COMMUNITY WATER SUPPLY AND SANITATION PROJECT
MINISTRY OF HOUSING, CONSTRUCTION & PUBLIC UTILITIES
Democratic Socialist Republic of Sri Lanka

REPORT ON SYSTEMATIC LEARNING

February 1993 to September 1994

THE DEMAND for WATER SUPPLY IMPROVEMENTS

SERVICE LEVELS, HEALTH BENEFITS and COST CONTRIBUTIONS

Prepared by

IDSS International Development Support Services Pty. Ltd of Australia
in association with TEAMS Pvt. Ltd. of Sri Lanka

THE DEMAND for WATER SUPPLY IMPROVEMENTS
SERVICE LEVELS, HEALTH BENEFITS and COST CONTRIBUTIONS
September 1994

Table of Contents

1. OBJECTIVES, FINDINGS and RECOMMENDATIONS

This report has been prepared as a synthesis of applied research, on a variety of issues, identified during discussions between CWSPU, the TSC and IDA Missions, which was carried out over the period February 1993 to August 1994. The main objectives, findings and recommendations are summarised below :-

1.1 Systematic Learning

Purpose ; To value the consumption benefits of improved water supplies and provide a rational basis for :-

- Preparation of the CWSSP expansion phase
- Economic analysis to determine optimum service levels and
- Informed community decision making

Findings ; The main findings are summarised below :-

- People with improved access use much the same time to collect more water i.e. they value the benefits of increased consumption over time savings.
- Increased consumption is associated with significant health benefits (Appendix E)
- The conventional approach to economic analysis and project preparation values time savings benefits only.
- The valuation of consumption benefits, proposed herein, highlights the benefits of improved service levels particularly piped schemes and yard taps. This is illustrated below :-

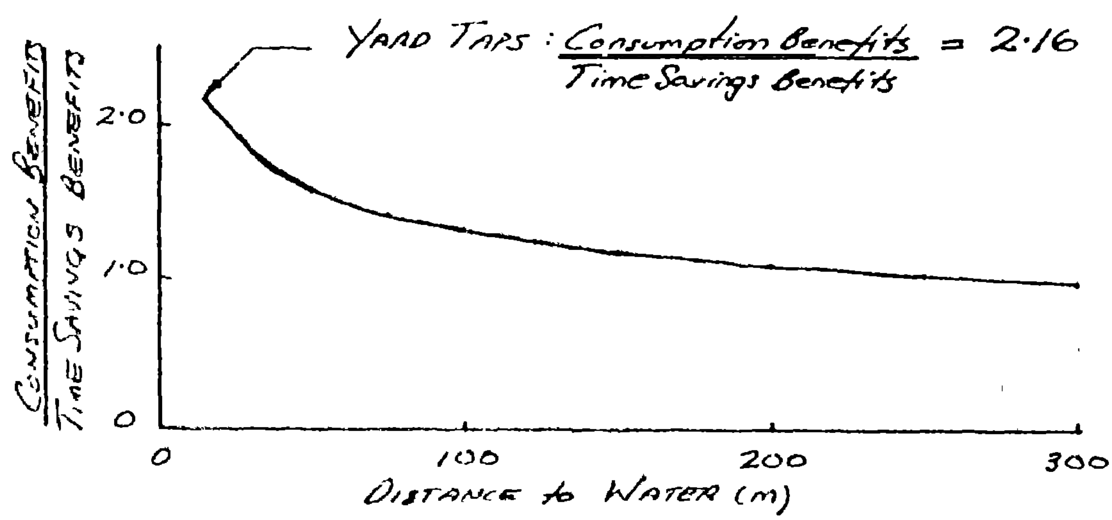


Figure 1: Water Supply Benefits and Access to Water

- The revised approach still undervalues health benefits as it does not account for the reduced risk of epidemics associated with improved access to water i e fewer users of a waterpoint.

Recommendations ; The valuation of consumption benefits, proposed herein, offers an improved basis for project preparation compared with the conventional approach which values time savings benefits only. The revised approach to economic analysis results in the following optimum service levels :-

Table 1 : Optimum Service Levels and Economic Performance

Scheme and Facility	Optimum Service Levels			CWSPU Contribution (Rs/HH)	Economic Indicators	
	Coverage (HH's/ WP)	Access Rmax (m)	Consumption (lcd)		NPB (Rs/HH)	BCR (Ratio)
Piped, Yard Taps	1	15	64	6,500	67,237	6.7
Piped, Standposts	4	100	45	4,900	22,457	3.8
Shallow Wells	5	110	43	4,900	19,499	3.4
Piped, Standposts	4	100	30	4,900	12,424	2.6
Tubewells	12	170	35	4,900	(694)	0 9

LEGEND: NPB = nett present benefit and BCR = benefit cost ratio

- The above service levels should be adopted for the preparation of the CWSSP expansion phase if not immediately.
- The choice amongst the above service levels depends on the available water resources.
- The benefits of piped schemes and yard taps are so superior tha GOSL would be justified in increasing the CWSPU cost contribution to Rs. 6,500 per household to encourage widerspread adoption of this solution wherever water resources permit.
- Where water supplies are limited the installation of piped schemes and standposts is economically justified even if consumption is restricted to 30 lcd. Experience however suggests these schemes would present the CBO with a significant management challange which should be dicussed with the community before their adoption eg. with the community before their adoption eg. recent SRTS experience (see Appendix D) Table 1 indicates shallow wells are a preferable solution where conditions permit.

1.2 DESIGN CRITERIA FOR PIPED SCHEMES

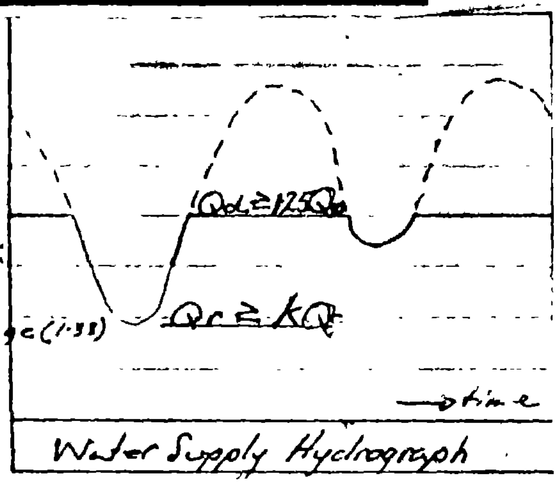
Purpose ; To increase the range of options and service levels available to local communities and to establish appropriate design criteria for yard tap schemes in particular (IDA 1993b and 1994 and RWSG 1993 a and b)

Findings ; Consumption varies with access to water yard taps are associated with the optimum level of consumption to maximise health benefits.

Recommendations ; The following design criteria are proposed :-

Table 2 : Summary of Proposed Design Criteria				
Facility	**Water Supply**	**Consumption qc (lcd)**	**Maximum Coverage qr (lcd)**	**Minimum Design Discharge qd (lcd)**
Yard Tap	Adequate	60	80	100
Standpost	Adequate	45	60	75
Standpost	Limiting	30	40	50

Qr = reliable discharge or
= safe yield (lps)
Qc = consumption (lps)
= KNqc where
N = maximum coverage or
= population served and
K = allowance for leakage and wastage (1.3
qc = unit consumption (lcd) (1.33)
Qd = design discharge (lps)
qd = unit design discharge (lcd)



2. DATA AVAILABILITY

Water Consumption and usage were surveyed in rural areas of Matale District (Danida 1991). The results are presented in Table 1 and show a strong association between access and consumption.

Water consumption and collection times were surveyed during preparation of CWSSP (Cowater 1991). The results are summarised in Table 2. They show :-

- Strong association between access and collection time but
- No association between access and consumption i.e. consumption in constant regardless of the distance to the source. There are two possible explanations :-

Sampling Errors i.e. the time taken to collect water and walk to the source and back can be estimated more reliably than the volume of water collected. Experience indicates villagers have trouble estimating volumes especially in litres.

Small Sample Size ; the classification of acceptable sources doesn't distinguish between access and water quality considerations. The vast majority of sources, including all unprotected wells, were therefore classified as unacceptable. Furthermore they were then lumped together and no attempt was made to distinguish differences in water consumption and collection times on the basis of access as was done for the much smaller sample of acceptable sources.

The following data sources were therefore adopted as a basis for analysis which revealed a remarkable degree of consistency between them :-

- Consumption & Use — Danida 1991
- Collection Times — Cowater 1991

Table I : Study of Water Usage in Rural Areas of Matale (Danida 1991)

Table 1a; Factors Affecting Consumption from Standposts				
Parameter	**Unit**	**Scheme**		
		Ukuwela	**Halangoda**	**Haywood 1)**
Consumption	lcd	19.0	18.5	39
Use of other water sources	Y/N	Y	Y	N
Standposts	No	5	8	4
Families Served	HHs	118	65	18
Service Level - No. of users	HHs/SP	24	8	4 1/2
Max. distance	m	350	270	200
Reliability of supply	R/U	U	U	R

Note: 1 Haywood consumption adjusted to exclude 3 HH's with recorded consumption in excess of 100lcd

Table 1b; Standpost Consumption and Distance to Water	
Distance to Water (m)	Consumption (lcd)
0 - 50	26.0
51 - 100	17.2
101 - 150	18.8
151 - 200	17.6
201 - 250	12.7
251 - 300	13.2
301 - 350	7.9
351 - 400	0.0

Note 1. Average for Ukuwela, Halangoda and Haywood.

Table 1c; Water Use for Various Purposes			
Parameter	Households Using for Purpose (%)		
	Ukuwela	Halangoda	Haywood
Cooking	98	89	94
Drinking	100	95	100
Bathing	16	8	28
Washing	15	15	56
Others	14	13	6

Table 2 : CWSSP Household and Village Surveys (Cowater 1991)

SUMMARY of DATA on ACCESS and COLLECTION TIMES (min/l)						
SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE				UNACCEPTABLE SOURCE 1)
		0 - 15	15 - 150	50 - 150	150 - 250	
SHALLOW WELLS	3.62	0 59	0.98	1 31	3.08	1 63
	1.06	0 66	0 90	1 02	1.17	1.38
	0 52	0.83	1 03	1.21	0 90	1 40
	0.27	0 42	0.92	1.31	1.80	2.09
	Weight Av.	0 626	0.954	1.212	1.585	1 570
PIPED 2)	1 74	0.62	NA 3)	1.22	1.13	1.64
	1 53	0 57		1.20	2 02	1.57
	0 54	0 38		0 81	1.80	1 59
	Weight Av	0.520		1 094	1.802	1 589
ALL	Weight Av.	0.573	0.931	1.183	1.637	1.582

Source: Recalculated from Cowater 1991

Notes:
1) Includes many sources closer than 250m but adjudged unacceptable on the basis of quality considerations eg unprotected shallow wells
2) The 1 53 HH/Ha data relates to pumped schemes ; other data are for gravity schemes.
3) The 15 - 150m class interval was used for piped schemes

SUMMARY of DATA on ACCESS and WATER CONSUMPTION (lcd)						
SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE				UNACCEPTABLE SOURCE
		0 - 15	15 - 150	50 - 150	150 - 250	
SHALLOW WELLS	3.62	27 7	30 6	32 1	13 0	22 5
	1.06	23 6	28 0	23 6	20 4	24 2
	0.52	27 6	29 4	27.9	28 0	23 5
	0 27	24.1	24.4	24.6	26 8	21.0
	Weight Av.	25 8	28.3	27.1	23.5	23.0
PIPED	1 74	20 2	NA	20 4	41.4	22.1
	1 53	23 6		24.6	24 5	22 4
	0.54	22 1		17 8	18.0	22.1
	Weight Av.	22 2		21.2	22 3	22 3

3. UNIT COLLECTION TIMES (MIN/L)

The following equations were derived previously and explain 99% of the variation in collection times (CWSPU 1993)

Eq1a $t = 0.3450R^{0.281}$

Eq1b $t_{av} = 0.3025R_{max}^{0.281}$

Eq1c $t_s = 1.582 - 0.3025R_{max}^{0.281}$ where :-

t = household collection time (min/l)

t_{av} = average collection time (min/l)

t_s = time savings (improved access) (min/l)

R = distance to water (m)

The above equation indicates that all dwellings presently have water available within $R_{max} = (1.582/0.3025)^{1/0\ 281} = 360m$

4. WATER CONSUMPTION RATES (LCD)

4.1 Access and Consumption

The consumption of water was affected by the unreliability of supply to the Ukuwela and Halangoda schemes (Table 1a). Estimates of unrestricted consumption at Haywood are presented in Table 3 below.

Table 3 : Standpost Consumption and Access to Water

Distance (m)	Consumption (lcd) 3 Schemes	Distance (m)	Average Consumption (lcd)	
			3 Schemes	Haywood
0 - 50	26.0	0 - 50	26.0	55.0
51 - 100	17.2	0 - 100	19.4	41.1
101 - 150	18.8	0 - 150	19.1	40.4
151 - 200	17.6	0 - 200	18.4	39.0
201 - 250	12.7	0 - 250	16.4	34.6
251 - 300	13.2	0 - 300	15.4	32.6
301 - 350	7.9	0 - 350	13.4	28.4
351 - 400	0.0	0 - 400	10.3	21.7

Source : Table 1b (Danida 1991)

Note 1: Example for distance = 0 to 200m
3 Schemes : Q = (26 0 + 17.2 x 3 + 18 8 x 5 + 17 6 x 7)16 = 18.4
Haywood : Q = 39.0 measured for Rmax = 200m (Table 1)
Ratio Haywood/3 Schemes = 39 0/18.4 = 2.1.

The following equation explain 97% of the variation in consumption and is illustrated below :-

Eq2a $Q = 131.0R^{-0\ 266}$ for $R \leq 300m$

Eq2b $Q_{av} = 151.1R_{max}^{-0\ 266}$ for $R_{max} \leq 300m$

Eq 2c $Q_{av} = 65.72 - 0.109\ R_{max}$ for $R_{max} \geq 300m$

where Q = household consumption (lcd)

Q_{av} = average consumption (lcd)

R = distance to water (m)

2 |

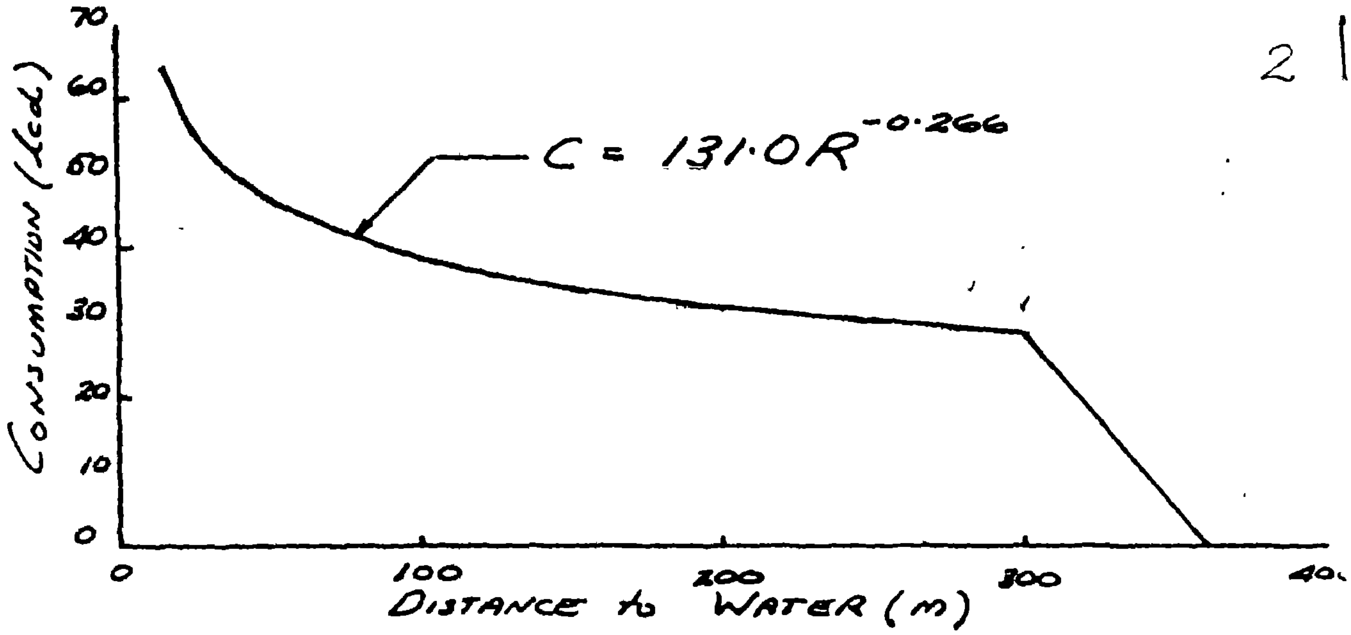


Figure 2 : Access to Water (m) and Consumption (lcd)

4.2 Present Consumption

The two sources of data were then compared. The comparison revealed a remarkable degree of consistency as illustrated below :-

- **Cowater 1991 found present consumption to be 23.0 lcd**
  This corresponds to a maximum distance to water of 360m i.e :-
  from Eq 1c for ts = 0 = 1.582 - 0.3025 $R_{max}^{0.281}$ --> R_{max} = 360m

- **Danida 1991 ; present consumption is estimated below**
  Qav = 65.72 - 0.109 x 360 = 26.5 lcd
  which represents good agreement with the actual value reported above.

4.3 Consumption and Water Use

The Haywood scheme approached CWSSP target service levels i.e 4 standposts serving 18 households (4 1/2 HHs/SP) with water available to all households within 200m. (Table 1a) Nevertheless the data indicates that only 28 and 56% of households use water for bathing and washing respectively. (Table 1c) The data can be used to estimate consumption if all households used water for bathing and washing :-

Q = a + bB + cW where
Q = Consumption of water (lcd)
B = Proportion of households using water for bathing
W = Proportion of households using water for washing

From Table 1 c (ignoring the small amounts used for other purposes)

$$19.0 = a + 0.16b + 0.15c \text{ for Ukuwela}$$
$$18.5 = a + 0.08b + 0.15c \text{ for Halangoda and}$$
$$39.0 = a + 0.28b + 0.56c \text{ for Haywood}$$

$$\mathbf{Q = 11 + 6B + 47W}$$

The result is consistent with the accepted minimum usage for cooking and drinking i.e. $Q = 11$ lcd when $B = W = 0$. It also indicates that consumption of 64 lcd is associated with the full adoption of beneficial hygiene practices i.e $Q=64$ when $B = W = 100\%$.

4.4 Service Levels and Consumption

Table 4 presents the results of using Equation 2 to estimate the consumption associated with different service levels.

Table 4 : Service Level and Consumption of Water

Agency	Service Level		Consumption (lcd) 1)
	Facility	Access (m)	
CWSPU	Yard Taps	15	64
CWSPU	Standposts	100	44
CWSPU	Shallow wells	100	44
CWSPU	Shallow wells	110	43
SRTS	Standposts	150	40
CWSPU	Tubewells	170	35
NWSDB	Standposts	250	35

Notes: 1. Yard taps Eq 2a, other facilities Eq 2b. Consumption from tubewells reduced by 10% to allow for manual pumping

Table 4 indicates that the target consumption of 64lcd, associated with full adoption of beneficial hygiene practices, is only attained if piped supplies and yard taps can be provided.

5. TOTAL COLLECTION TIMES (min/HH/day)

The time spent collecting water may be estimated by combining Equations 1 and 2 :-

Eq 3a T = tQ = $45.2 R^{0.015}$ for R ≤ 300m and
Eq 3b Tav = $45.7 R_{max}^{0.015}$ for R ≤ 300m where
T = total household collection time (mcd)
Tav = total average collection time (mcd)
t = unit household collection time (min/litre)
Q = household consumption of water (lcd) and
R = distance to water (m)

Consumption and collection times are summarised below for different levels of service.

Table 5 : Consumption, Collection Times and Service Levels

Service Level		Consumption (Lcd)	Collection Time	
Facility	Access Rmax (m)		Unit (min/lcd)	Total (min/HH/d)
Yard Taps	15	64	0.73	47
Standposts	100	44	1.11	49
Standposts	250	35	1.43	50

Table 5 indicates that housholds with improved access use much the same time to collect more water.

6. VALUATION OF COSTS AND BENEFITS

6.1 Cost Estimates

Piped Schemes ; Experience to date suggest that communities select the best level of service available to them for the CWSPU cost contribution of Rs. 4,900 per household eg. where the source is close to the village they opt for yard taps instead of standposts and visa versa. Furthermore this seems to be resulting in a mix of about 2/3 standposts and 1/3 yard tap schemes.

This indicates the present level of funding is about right and only a small increase would be required to promote widespread installation of yard taps wherever sufficient water is available. Cost estimates are summarised below :-

Table 6: Cost Estimates for Piped Schemes			
Description of Item	**Standposts**	**Yard Taps**	
	Present	**Present**	**Proposed**
Present CWSPU cost contribution	4,900	4,900	4,900
Increased design discharge	none	none	1,600
Sub-total CWSPU cost contribution	4,900	4,900	6,500
Value of unskilled village labour	2,450	2,450	3,250
Provision of individual connections 1)	none	5,000	5,000
Sub-total community contribution	2,450	6,450	8,250
Life cycle O&M (allow 10%)	650	1,150	1,450
TOTAL ECONOMIC COST	**8,000**	**12,500**	**16,200**

Note : 1 The previous cost estimate of Rs. 5,000 per household for the provision of individual connections (Cowater 1991) sounds excessive and should be checked However it provides a suitably conservative basis for assessing the benefits of yard tap schemes.

Shallow Wells; The CWSPU cost contribution of Rs. 4,900 per household was justified (CWSPU 1993) on the basis of the target community contribution of 20% (IBRD 1992). The value of unskilled labour is now found to amount to about 33%. This represents an effective increase in the capital cost of wells. Furthermore experience indicates the actual cost of shallow wells is even greater (by about 25% ?) and the target coverage of 4HHs/SW can't be achieved. These effects are illustrated in Table 7.

Table 7 : Cost Estimates for Protected Shallow Wells				
Description of Item	**Unit**	**Original (CWSPU 1993)**	**Revised Estimates**	
			Labour	**Cost**
Coverage	HH's/SW	4	4	5
CWSPU Contribution	Rs/HH	4,900	4,900	4,900
Community Contribution	Rs/HH	1,225	2,450	2,450
CWSP Contribution	Rs/SW	19,000	19,600	24,500
Community Constribution	Rs/SW	4,900	9,800	12,250
Total Capital Cost	Rs/SW	24,500	29,400	36,750
Life Cycle O&M Cost (10%)	Rs/SW	2,500	2,600	3,250
TOTAL ECONOMIC COST	**Rs/SW**	**27,000**	**32,000**	**40,000**

The RWSE has agreed to review requirements and prepare practical cost-effective well designs for a range of situations. In the meantime the present analysis is based on economic well costs in the range Rs.32,000 to Rs.40,000.

Tubewells; The following cost estimates are available :

Table 8 : Cost Estimates for Tubewells equipped with Handpumps		
Description of Item	**NWSDB**	**Cowater 1991**
Well Drilling and Construction	30,000	
Supply and Installation of handpump	25,000	
Rig Depreciation	23,000	
GOSL Cost Contribution	78,000	
Community Contribution (Apron Construction)	6,500	
Total Capital Cost	84,500	91,800
Abortive Drilling (nominal allowance)	5,000	7,700
Life Cycle O&M Costs (Cowater 1991)	13,500	13,500
TOTAL ECONOMIC COST	**103,000**	**113,000**

Note : NWSDB values are actual charges which are likely to be subsidised

6.2 Valuation of Benefits

The analysis of the association between access to water and consumption, presented in Section 4 above, allows explicit recognition of the central issue of the tradeoff between increased consumption and decreased time savings.

The fact that households with improved access use much the same time to collect more water is strong evidence that they value the health benefits of increased consumption, up to 64 lcd, over time savings. It is reasonable to assume that the marginal benefit of increased consumption is equal to the value of time presently spent in collecting water i.e the benefits of consuming 23 lcd are equal to the cost of spending 1.582 min/l x 23 lcd = 36 mcd collecting water. This is a marked improvement on the previous approach which required an arbitary assumption regarding the value of Qav regardless of access. The two approaches are compared below for the normal situation i.e. shallow wells, tube wells and standposts with adequate water supplies. Standposts with limited water supplies and yard taps are considered in Sections 7.4.2. and 7.4.3 respectively.

Vts = 1,395 Qav (1.582 - 0.3025 $R_{max}^{0.281}$) from Eq. 1 and
Vct = 1,395 (1.582 x 151.1 $R_{max}^{-0.266}$ - 45.7 $R_{max}^{0.015}$) from Eqs 2&3
Vts = Previous estimate of the NPV of time savings benefits
Vct = Improved estimate of the NPV of consumption benefits less the cost of time spent collecting water.
Qav = consumption (previously assumed to be the average of present and target values i.e. (23+45)/2 = 34 lcd regardless of access).

The above equations are illustrated in Figure 3 and are both based on the following reasonable assumptions :-

- Inflation since 1991 = 10%
- Average family size = 5.5 persons/HH
- Opportunity cost of labour = 5 Rs/hr.
- Annual recurrent costs and benefits discounted at 10% over 20 years.

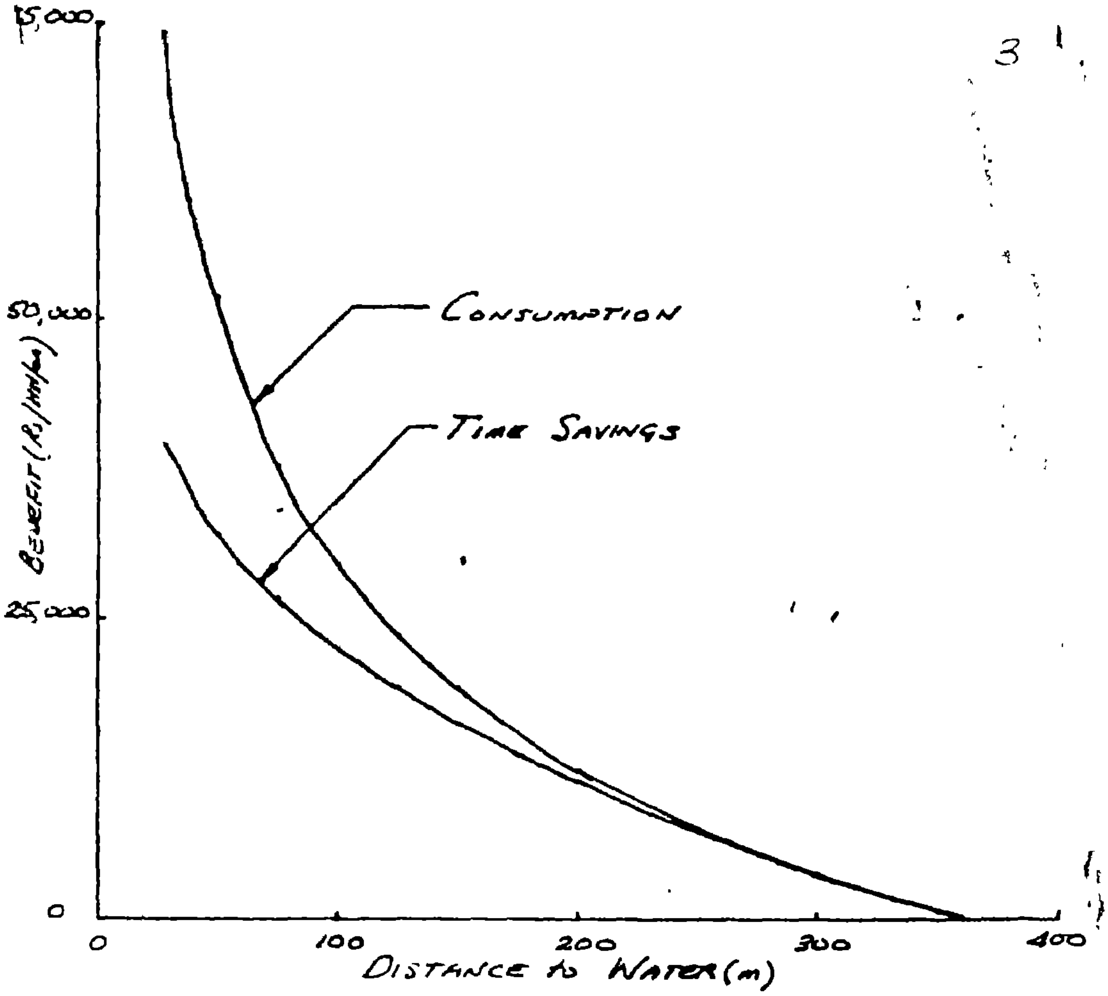


Figure 3 : Comparison of the Valuation of the Benefits of Improved Access

Table 3 indicates that the conventional valuation of time savings benefit substantially underestimates the benefits of increased consumption associated with improved access particularly the provision of yard taps.

.. OPTIMUM SERVICE LEVELS

..1 Economic Performance Criteria

Previous analysis (Cowater 1991 and CWSPU 1993) sought to maximise the value of nett present benefits (NPB). The present analysis compares the NPB with the benefit cost ratio (BCR).

7.2 Protected Shallow Wells

$NPB = 1{,}395\,(239.0R_{max}^{-0.266} - 45.7R_{max}^{0.015}) - 4{,}000CD^{-1}R_{max}^{-2}$

which is a maximum when d(NPB)/dR = 0 i.e.

when $1{,}395\,(63.6R^{-1.266} + 0.686R^{-0.985}) = 8{,}000CD^{-1}R^{-3}$

or when $R_{max} = \left(\frac{8{,}000CD^{-1}}{1{,}395 \times 63.6}\right)^{1/1.734}$ approximately

$BCR = 1{,}395D\,(239.0R_{max}^{1.734} - 45.7R_{max}^{2.015})/4{,}000C$

which is a maximum when d(BCR)/dR = 0 i.e.

when $R_{max} = \left(\frac{239.0 \times 1.734}{45.7 \times 2.015}\right)^{1/0.281} = 211m$

i.e. the maximum BCR is independent of both the cost of the well C and the village density D

Table 9 : Optimum Service Levels for Shallow Wells

Criteria	Well Cost C (Rs)	Village Density D (HH/Ha)	Service Level		Economic Indicators		CWSPU Cost (Rs/HH)
			Access Rmax(m)	Coverage (HHs/SW)	NPB (Rs/HH)	BCR (ratio)	
NPBmax	32,000	1.70	71	2.1	24,387	2.6	9,333
	40,000	3.62	53	2.5	32,563	3.1	9,800
	40,000	1.70	81	2.8	21,149	2.5	8,750
	40,000	0.27	233	3.7	(1,890)	0.8	6,622
BCRmax	32,000	1.70	211	19	9,528	6.6	1,032
	40,000	3.62	211	40	10,226	11.3	613
	40,000	1.70	211	19	9,105	5.3	1,289
	40,000	0.27	211	3	(2,091)	0.8	8,167
CWSPU	32,000	1.70	97	4	22,457	3.8	4,900
	40,000	3.62	74	5	30,036	4.7	4,900
	40,000	1.70	108	5	19,499	3.4	4,900
	40,000	0.27	272	5	(2,299)	0.7	4,900
	40,000	0.27	250	4	(1,980)	0.8	5,800

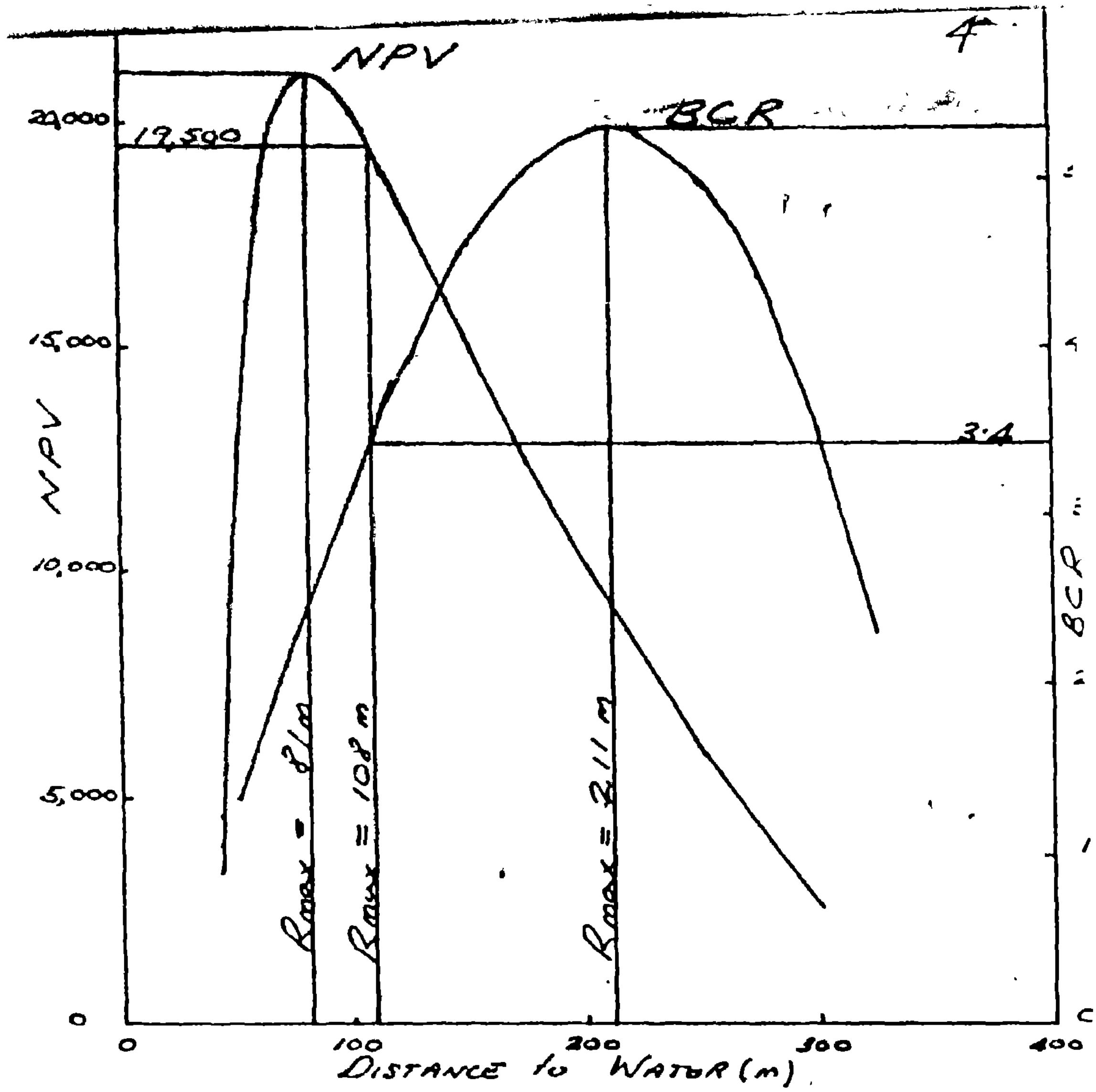


Figure 4 : NPB, BCR and Service Levels for Shallow Wells

C = Rs. 40,000 and D = 1.70 HH/Ha

Table 9 and Figure 4 indicate the current CWSPU cost contribution is economically sound. Coverage will however vary with average well cost but is expected to be between 4 and 5 households per shallow well. There is a good case to be made, on both equity and efficiency grounds, for increasing the CWSPU cost contribution wherever it can be demonstrated that target service levels (4 to 5 households per shallow well) don't allow water to be made available within 250m on average within the village i.e. where dwellings are very dispersed. These cases should be the subject of a special application to the NSC.

7.3 Tubewells equipped with Handpumps

The above analysis is repeated for tubewells to allow for :-

- Increased well costs and reduced coverage and
- The increased collection time (min/litre) associated with manual pumping (assumed to be 10%) which imples reduced consumption as experience indicates people use much the same time to collect water (min/HH/day) regardless of service level.

NPB = $1{,}395\,(217.3\,Rmax^{-0.266} - 45.7\,Rmax^{0.015}) - 4000C/DRmax^2$
which is a maximum when
$1{,}395\,(57.8\,R^{-1.266} + 0.686\,R^{-0.985}) = 8{,}000C/DR^3$
or when $Rmax = \left(\frac{8{,}000 \times CD^{-1}}{1{,}395 \times 57.8}\right)^{1/1.734}$ approximately

BCR = $1{,}395D\,(217.3\,Rmax^{-0.266} - 45.7\,Rmax^{0.015})/4{,}000C$
Which is a maximum when Rmax = 150m

Table 10: Optimum Service Levels for Tube Wells

Criteria	Well Cost C (Rs)	Village Density D (HH/Ha)	Service Levels		Economic Indicators		CWSPU Cost 1) (Rs/HH)
			Access Rmax (m)	Coverage (HH's/ TW)	NPB (Rs/HH)	BCR (ratio)	
NPBmax	103,000	1.70	147	9	454	1.04	5,989
	113,000	3.62	101	9	8,253	1.67	6,533
	113,000	1.70	155	10	(577)	0.95	5,880
	113,000	0.27	444	13	(18,447)	Negative	4,523
BCRmax	103,000	1.70	150	9 - 10	447	1.04	5,674
	113,000	3.62	150	20	5,668	2.02	2,940
	113,000	1.70	150	9 - 10	(599)	0.95	6,189
	113,000	0.27	150	1 - 2	(63,186)	0.15	39,200
CWSPU	103,000	1.70	161	11	304	1.03	4,900
	113,000	3.62	115	12	7,905	1.84	4,900
	113,000	1.70	168	12	(694)	0.93	4,900
	113,000	0.27	422	12	(18,487)	Negative	4,900
	113,000	0.27	250	4	(26,253)	0.02	14,700

Note: 1 CWSPU cost does not include rig depreciation

The results presented in Table 10 indicate that the benefits of providing tubewells equipped with handpumps are marginal at best.

However CWSPU and local communities both consider tubewells the solution of last resort and coverage will be restricted to less than 20%. Thus the overall economic viability of CWSSP is ensures and the continued provision of tube wells is justified to ensure an equitable level of service where no other options are available. Table 10 shows that the target service level of 12 households per tubewell is economically sound (in that it minimizes losses) and results in a CWSPU cost contribution similar to that adopted for shallow wells and standposts.

7.4 Piped Schemes

The above analysis optimised access to shallow wells and tubewells where the relationship between unit costs (Rs/HH) and coverage (HH's/WP) is known. This is not possible for piped schemes. However there are no significant benefits in providing standposts instead of shallow wells. Thus the same expenditure is justified by provision of the same access to facilities. Experience indicates that standpost schemes (4 HH's/SP) can frequently be provided at a CWSPU cost contribution of Rs. 4,900.per household. Different facilities and levels of service are compared below.

Table 11: NPB, BCR and Facilities for Piped Schemes

Facility	Beneficial Consumption Q (lcd)	Economic Indicators			
		Costs (Rs/HH)	Benefits (Rs/HH)	NPB (Rs/HH)	BCR (ratio)
Yard Taps	60	12,500	75,218	62,718	6.0
Yard Taps	60	16,200	75,218	59,018	4 6
Yard Taps	45	16,200	42,115	25,915	2.6
Standposts	39	8,000	27,479	19,479	3.4
Standposts	30	8,000	13,137	13,137	2.6

Notes:
1. Standpost benefits (45 lcd) from Table 9 (4 HH's/SW)
2. YT benefits = 1,395 x 64 x (1.582 - 0.3025 x $15^{0.281}$)
3. SP benefits = 1,395 x 30 x (1,582 - 0.3025 x $97^{0.281}$) for 30 lcd

Interpretation of Table 11 leads to the following conclusions :-

- The optimal service level for piped schemes depends on water availability.
- The provision of yard taps is optimal wherever sufficient water is available
- The benefits of yard taps are extremely robust and GOSL would be justified in increasing the CWSPU cost contribution to encourage their widerspread adoption wherever suitable. CWSPU cost contribution of Rs. 6,500 per household is recommended for yard tap schemes.
- Where water supplies are extremely limited time savings benefits justify the provision of improved access (4 HH's/SP or Rmax = 100m) even where consumption is restricted to 30 lcd.

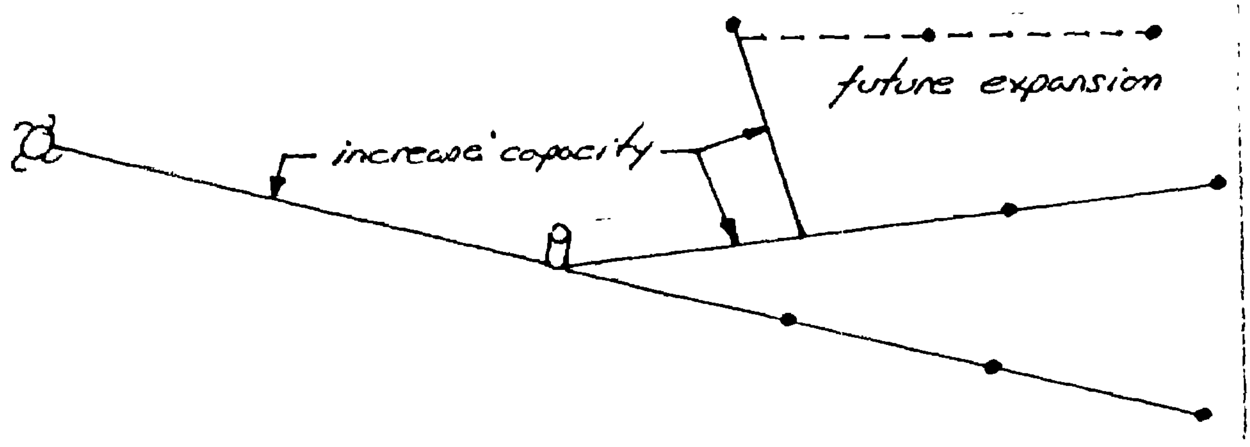
8. DESIGN CRITERIA FOR PIPED SCHEMES

8.1 DESIGN POPULATION AND SCHEME EXPANSION

Experience to date indicates the available water supplies are frequently limited and communities are justified in deciding to supply the existing population without provision for scheme expansion. Therefore, the following valves of consumption and design dischage do not include an allowance for population growth as is conventional.

The following methods are appropriate where water supplies are adequate to allow for future expansion :-

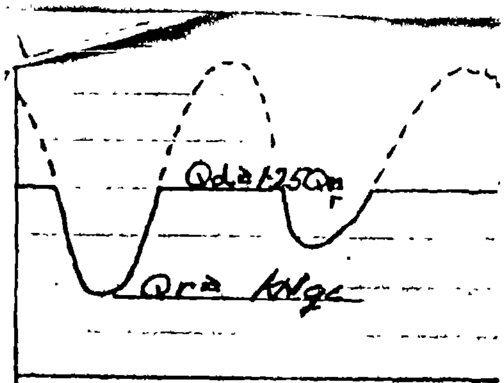
- Increase the capacity of the entire system by a fixed amount eg. 30%. This is the conventional approach.
- Identify the likely area of future expansion and increase the capacity of the system serving this area only as illustrated below. This method is to be preferred as it makes explicit the allowance for future expansion.



8.2 WATER SUPPLY SCHEME COVERAGE

The yield of a water source varies throughout the year and from year to year as illustrated opposite.

The following method is proposed to determine the maximum scheme coverage where the water supply is limiting.



Water Supply Hydrograph

$$N \leq Qr/kqc$$

Where

N	=	scheme coverage (persons) either now or after future expansion
Qr	=	safe yield or reliable discharge (lps) i.e. the minimum flow anticipated over the life of the scheme and
qc	=	per capita consumption (lcd) which varies with access to water
k	=	factor to allow for leakage and wastage.

The value of k is estimated below.

Agency	Rmax (m)	qc (lcd) 1)	Design (lcd)	k
WHO	250	35	45	1.29
SRTS	150	40	50	1.25
CWSPU	100	45	ADOPT	1.33

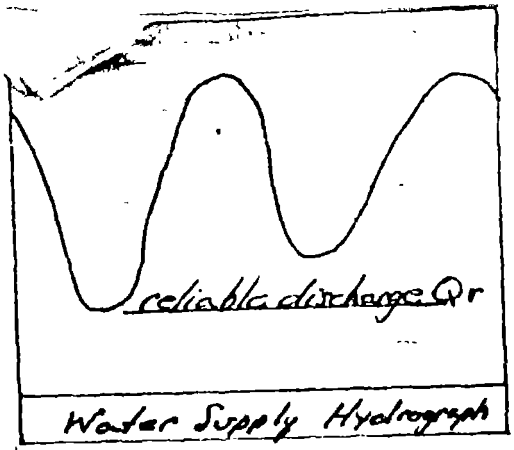
Source: WHO = Jordan 1980 and SRTS = Appendix D

Notes: Consumption $qc = 151.1\ Rmax^{-0.266}$

CWSPU has experienced some difficulty in estimating the reliable discharge (Qr) and existing procedures need to be improved perhaps by deriving unit hydrographs for each zone.

It should also be noted that the above method puts some pressure on the CBO to distribute water equitably during the dry system.

8.3 THE SYSTEM DELIVERY CAPACITY



It is also proposed that the system should be designed to deliver more than the reliable discharge Qr as illustrated opposite where :-

Qd = design discharge (lps)

This has two advantages which are summarised below :-

- Allows for some inequity in water distribution and consumption during the wet season and
- Fully utilizes the available water and allows for some use for other purposes eg. vegetable gardens.

It is proposed that the design discharge should be at least 25% greater than the reliable discharge. This leads to the design criteria summarised below :-

Table 13 : Summary of Proposed Design Criteria

Facility	Water Supply	Consumption qc (lcd)	Max. Coverage qr (lcd)	Min. Design Disc. qd (lcd)
Yard Tap	Adequate	60	80	100
Standpost	Adequate	45	60	75
Standpost	Adequate	30	40	50

REFERENCES

Cowater 1991 Community Water Supply and Sanitation Project
Priority Investment Plans; Badulla, Ratnapura and Matara
Volume 2;

CARE 1993 Community Self Financing Water and Sanitation Systems Project
A study of the Sustainability of CARE Assisted
Water Supply and Sanitation Projects 1979-1991
CARE International Indonesia.

Danida 1991 Support to the Rural Water Supply and Sanitation Sector
in Malate, Polonnaruwa and Anuradhapura Districts

Study of Water Usage in Rural Areas of Matale.

IBRD 1992 Community Water Supply and Sanitation Project
World Bank ; Staff Appraisal Report.

IDA 1993a Community Water Supply and Sanitation Project
Aide Memoire; First Supervision Mission,February 1993.

IDA 1993b Community Water Supply and Sanitation Project
Aide Memoire : Second Supervision Mission, July 1993

IDA 1994 Community Water Supply and Sanitation Project Aide Memoire; Third Supervision Mission,March 1994.

IRC 1991 On Site Sanitation: Building on Local Practice.
International Water and Sanitation Centre.

Jordan 1980 A Handbook of Gravity Flow Water Systems
Intermediate Technology Development Group.

RWSG 1993 a Community Water Supply and Sanitation Project
Back-to-Office Report; 1st Interim Mission, Oct 1993.
UNDP/WB Water and Sanitation Group for South Asia.

RWSG 1993 b Community Water Supply and Sanitation Project
Back to Office Report, 2nd Interim Mission, December 1993
UNDP/WB Water and Sanitation Group for South Asia.

RWSG 1994 Discussion Paper for the Preparation of a Proposal to Establish Structural Learning within the Community Water Supply and Sanitation Project in Sri Lanka.
UNDP/WB Water and Sanitation Group for South Asia.

APPENDICES

A. Systematic Learning Workshop ; Summary of Procedings

B. Optimum Service Level and the Base Case

C. Improved Access and Consumption of Water

D. Preliminary Evaluation of 16 SRTS Piped Gravity Schemes

E. Conceptual Framework for Hygiene Education
based on a Review of Health Impact Evaluations

F. Draft Proposal for a Well Polution Study

Appendix A

SYSTEMATIC LEARNING WORKSHOP

Interim Mission 23 and 24 June 1994

Summary of Proceedings

Participants : Interim Mission : Mr. K.M. Minnatullah
Ms. Sunitha Chakravarty
CWSPU : Director, DDCD and MES (CSP)
TSC : MTSC, MES and HES

1. PURPOSE OF THE WORKSHOP

The workshop was seen as an opportunity to discuss the strengthening of the CWSPU M&E system or the setting up of a "Learning, Documentation and Dissemination Unit" with full-time research officer to maintain the analytical rigor and to co-ordinate systematic data collection, recording, analysis, feedback, documentation and dissemination.

The feasibility of computerizing the entire system was also to be discussed(Interim Mission Discussion Paper).

2. REVIEW OF THE DISCUSSION PAPER

2.1 What is Systematic Learning ?

Systematic Learning was defined as a continuous process of applied research to test the hypotheses on which the SAR was based and document the key lessons learned as a basis for refined project and program design.

It was agreed that a flexible learning framework is required if the key lessons are to emerge. The term structured learning is too indicative of a mechanical process. CWSPU were, however, concerned by the following proposals :-

- "Computerization of the entire process " which is indicative of a mechanical process and
- Qualitative monitoring, as an alternative to structured learning, lacks the key ingredients of learning discussed below i.e. analysis and particularly interpretation.

Systematic learning seems to best describe the intended process. Several distinct activities, with different potentials for computerization, were recognized and are summarised below.

Proposed Framework for Systematic Learning		
Activity		Potential for Computerization
1.	Quantitative Monitoring	YES MIS database essential
2.	Qualitative Monitoring	YES document files desirable
3.	Analysis	Y/N potential for some but not all
4.	Interpretation	NO the computer can't think !

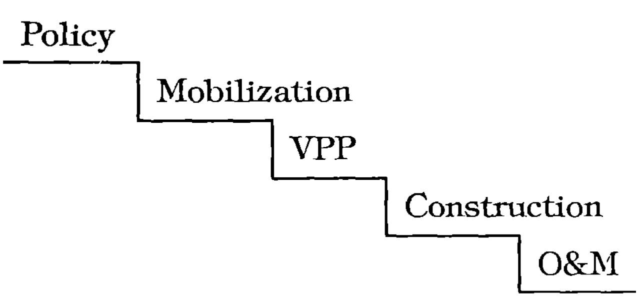
Interpretation of Experience is considered the key ingredient of structured learning and requires a combination of :-

- Rigorous analylitical ability (qualitative and quantitative data) and
- Practical familiarity with CWSPU procedures and processes and preferably direct implementation experience.

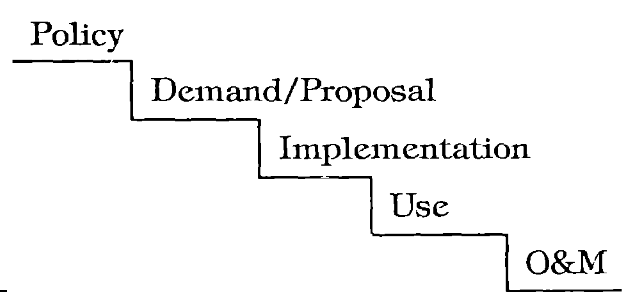
Interpretation is likely to identify a number of key issues which require applied research and analysis which is beyond the realm of routine monitoring and evaluation.

2.2 Variables for Project Sustainability

CWSPU proposed a revised conceptual framework to emphasis the critical role of community mobilization in engendering a sense of ownership and ensuring sustained operation and maintenance.



Preferred by CWSPU



Proposed by Interim Mission

3. PRESENT STATUS OF CWSSP

3.1 Quantitative Monitoring (MIS)

It was agreed that the management information system (MIS) is operational within CWSPU but needs to be consolidated.(See Figure 1).

- The present system of **monitoring project progress** during the development phase was endorsed by the Interim Mission.
- The same needs to be elucidated for the construction and consolidation phases.
- The computer database needs to be developed to allow aggregation of project data and facilitate **program progress monitoring** i.e. for the various rounds of SSIP and LSIP in each of the three districts.

3.2 Qualitative Monitoring

CWSPU and PO staff have a system of monthly progress review meetings for each of the main programs in each district. The minutes of these meetings provide a continuous record of implementation problems encountered and the measures taken to resolve them. The minutes of these meetings should be compiled into a comprehensive computer file which should then be updated monthly.

3.3 Program Development

The Interim Mission acknowledged that systematic learning has been taking place within CWSPU and is reflected in successive refinements of contractual arrangements, processes and procedures etc developed to support the programs implemented to date ; Pilot Projects, SSIP Round1 and LSIP Round 1. Program development is recorded in various documents including :-

- Support services agreements
- Minutes of consultative workshops with PO's
- Training material and procedures manuals.
- Quarterly progress reports and
- Internal discussion papers etc.

4. ESTABLISHMENT OF SYSTEMATIC LEARNING WITHIN CWSPU

4.1 **Resource Requirements ;** It was recognized that the present full time staff of the CWSPU and TSC are fully committed to the development and documentation of procedures and practices and facilitation of the various implementation programs. Additional resources will be required to develop and operationalize a system of systematic learning.

4.2 **Proposed Consultancy ;** CWSPU was requested to prepare a proposal and action plan to develop and operationalize a system of systematic learning using additional consulting inputs. The draft action plan, attached as Figure 1, was subsequently endorsed by the Interim Mission.

4.3 **Draft Terms of Reference ;** The consensus was that the intent of the Discussion Paper is clear and that it provides adequate orientation to develop a proposal and implementation plan for the establishment of a Systematic Learning System within CWSPU.

4.4 **Phased Implementation ;** It was decided to implement the consultancy in phases to allow for :-

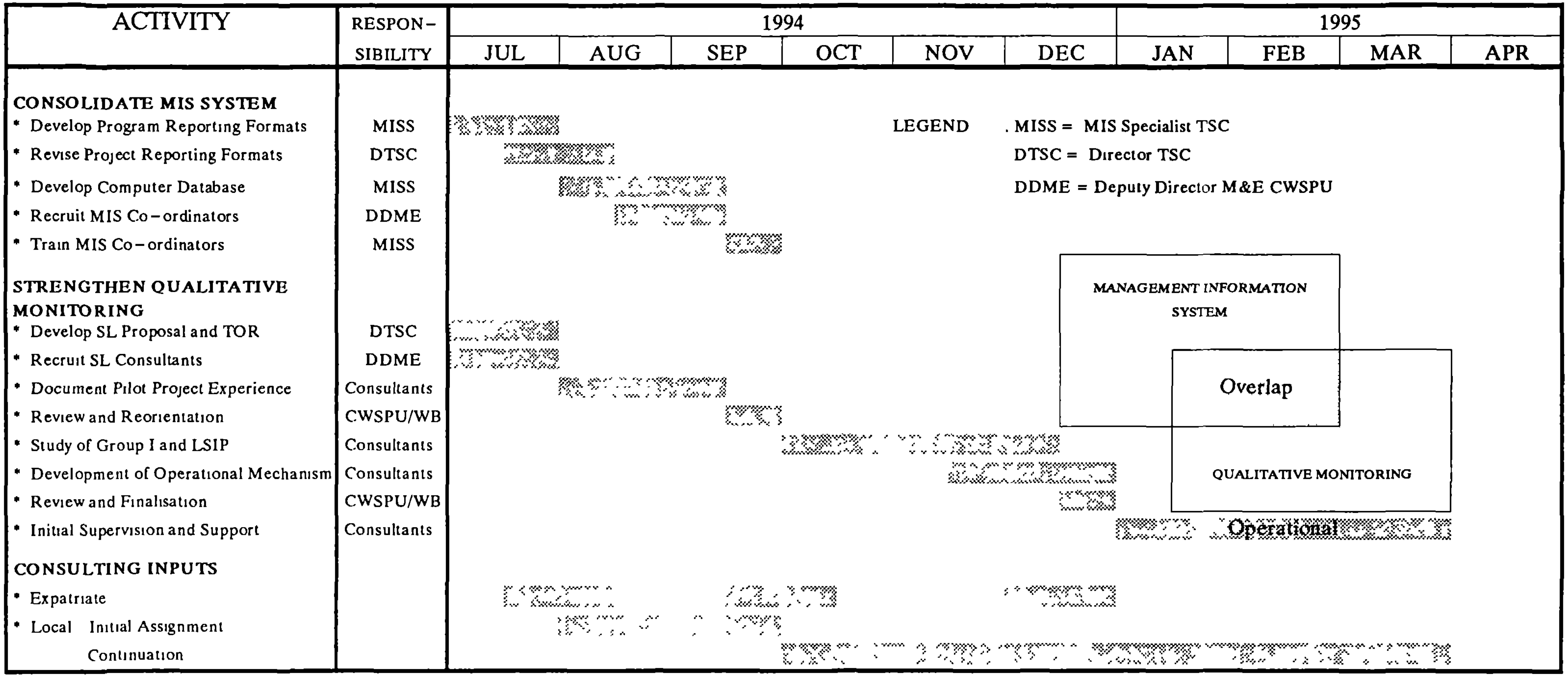
- Regular opportunity for reorientation in the light of feedback from the stakeholders eg. the next IDA Mission due in late September 1994 and
- The different requirements for systematic learning viz :-
  - Present programs involving a desk study of existing documents supplemented by interviews with key CWSPU and PO Staff and CBO members and
  - Future programs requiring an operational system to provide a continuous record of program development and innovation.

The following phases were envisaged by the workshop participants :-

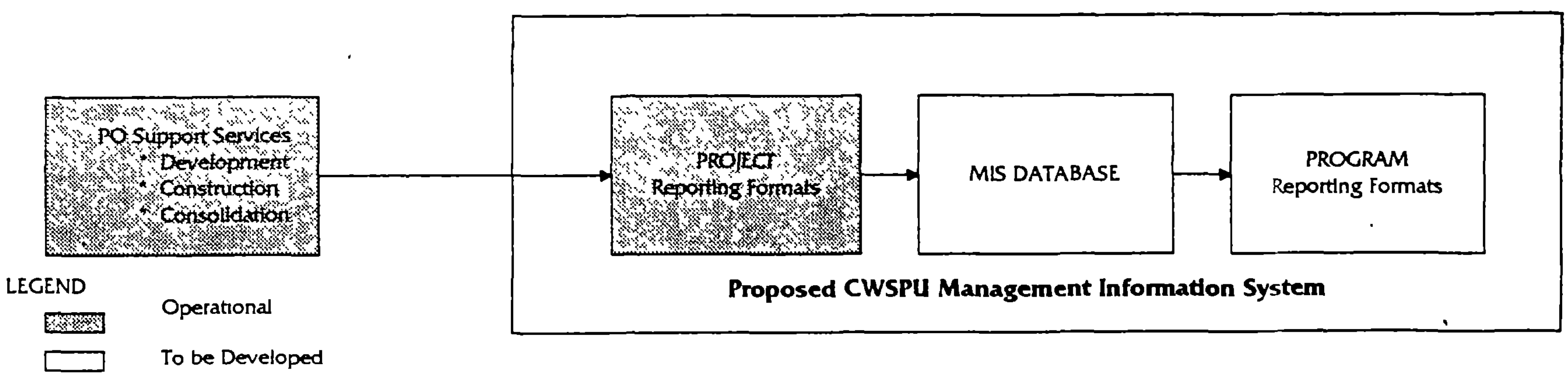
1. Development of detailed TOR based on the discussion paper and preparation requirements for a follow-up project (SAR 1992)
2. Documentation of the Pilot Project experience.
3. Documentation of SSIP and LSIP Round 1 experience and development of an operational mechanism and
4. Operational system to document subsequent program development and innovation.

sds/mtsc/slw1 sop/July 20, 1994

PROPOSED IMPLEMENATION PLAN for Consolidation of the CWSPU Management Information System and Strengthening of the System for Qualitative Monitoring



CONSOLIDATION of the CWSPU MANAGEMENT INFORMATION SYSTEM (MIS)



Appendix B

OPTIMUM SERVICE LEVEL and the BASE CASE

1. Introduction

2. Conclusions

3. Cost Estimates

4. Water Collection
   4.1 Individual Households
   4.2 Waterpoints
   4.3 Time Savings

5. Valuation of Time Savings
   5.1 Water Consumption
   5.2 Opportunity Cost of Labour
   5.3 Inflation Since 1991

6. Impact of Improved Service Levels
   6.1 Nett Present Benefits
   6.2 Programme Costs and Coverage

OPTIMUM SERVICE LEVEL and the BASE CASE

1. INTRODUCTION

The original benefit cost analysis to determine the optimum accessability service level for shallow wells *(Cowater 1991)* has been reviewed and updated. The following factors influence the optimum service level and are reviewed below :-

- Capital and recurrent costs
- Water collection time savings
- Water consumption increases
- The value of time savings and
- Inflation since 1991

2. CONCLUSIONS

The results of the original and revised analysis are compared below :-

OPTIMUM ACCESS to WATER POINTS			
PARAMETER	UNIT	OPTIMUM SERVICE LEVEL	
		Original	Improved
Maximum Distance	m	188	100
Household Served	HH's	15	4
Capital Cost	Rs/HH	1,500	6,125
CWSSP Contribution	Rs/HH	1,200	4,900
Net Present Benefit	Rs/HH	6,400	16,430

The following improved level of service is now proposed. It is based on reasonable assumptions concerning the valuation of time savings benefits.

- Access to waterpoints 4 HH's/WP and
- Maximum distance to water 100m

The proposal involves additional costs and substantially increased benefits. The most likely scenrario involves a 10% increase in the CWSSP programme budget or a corresponding decrease in programme coverage.It is based on the following assumptions :-

- Average scheme costs equal to 75% of the maximum CWSPU cost contribution plus an allowance of 33% for construction overheads and
- The most likely technology mix comrising 75% piped gravity schemes and 25% shallow wells.

3. COST ESTIMATES

Average well costs are summarised below. The recurrent cost is the nett present value of annual costs discounted at 10% over 20 years (Cowater 1991)

Capital Cost i.e. Construction	Rs. 22,444
Recurrent Cost i.e. O & M	Rs. 2,300
TOTAL Cost per Well say	Rs. 24,700

Unit costs may be estimated from the following formula which assumes a uniform distribution of population around a waterpoint. It also allows for some overlap in coverage between adjacent waterpoints i.e. the service area is not a full circle but is taken as $2.5R^2$

$$C = \frac{24{,}700}{F} = \frac{24{,}700 \times 10{,}000}{2.5\,R^2 \times 1.70} = 58.12 \times 10^6\,R^2$$

C	=	unit well cost	(Rs/HH)
F	=	families served	(HH)
R	=	maximum distance to water and(m)	
1.70	=	average population desity (Cowater 1991)	(HH/Ha)

4. WATER COLLECTION

4.1 Individual Households

The original analysis of water collection data (Cowater 1991) suffers from the following deficiencies :-

- Inspection of the example presented as Annex 1 shows a simple arithmetic error has been made in extending the basis data i.e. the calculation of total volume collected accounts for the number of collectors per household but the total collection time does not. i.e. the average collection time for 0 - 15m is simply (3.4+3.5)/11.6= 0.6 and not 0.3 min/litre as presented in the 12th column (Annex 1).

- The analysis of time savings does not account for the population distribution around the water point i.e. for a uniform population density only about 25% of households have access to water within half the maximum distance.

The revised estimates of water collection times, for individual households, are presented in the following table. Disaggregated data on waiting and trevelling times is presented as Annex 2.

The previous analysis underestimated the time savings benefits of high service levels and vis versa. This is illustrated in the figure presented in section 4.3 below.

SUMMARY of DATA on WATER COLLECTION TIMES (min/l)						
SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE SOURCE(m)				UNACCEPTABLE SOURCE 1)
		0-15	15-150	50-150	150-250	
SHALLOW WELLS	3.62	0.59	0.98	1.31	3.08	1.63
	1.06	0 66	0.90	1 02	1 17	1 38
	0.52	0.83	1.03	1.21	0.90	1.40
	0.27	0.42	0.92	1.31	1.80	2.09
	Weight Av.	0.626	0.954	1.212	1.585	1.570
PIPED 2)	1.74	0.62	NA 3)	1.22	1.13	1.64
	1.53	0.57		1.20	2.02	1.57
	0.54	0.38		0.81	1.80	1.59
	Weight Av.	0.520		1.094	1.802	1.589
ALL	Weight Av.	0.573	0.931	1.183	1.637	1.582

Source: Recalculated from Cowater 1991

Notes
1) Includes many sources closer than 250m but adjudged unacceptable on the basis of quality considerations eg.unprotected shallow wells
2) The 1.53 HH/Ha data relates to pumped schemes, other data are for gravity schemes
3) The 15 - 150m class interval was used for piped schemes

WATER COLLECTION TIMES for INDIVIDUAL HOUSEHOLDS			
INTERVAL D (m)	AVERAGE T* (min/l)	INTERVAL D (m)	AVERAGE T* (min/l)
0 - 15	0.573	0 - 15	0.573
15 - 50	0.931	0 - 50	0.8236
50 - 150	1.183	0 - 150	1.0632
150 - 250	1.637	0 - 250	1.29272
VARIABLE	FORMULA	EQUATION	
		Linear	Exponential
T*	A/D 1)	$a + {}^1/_2 bD$	$(a/b+1)D^b$
A	$\int_0^R T\, dD$	$aR + {}^1/_2 bD^2$	$(a/b+1)D^{b+1}$
T	basic eqn.	$a + bD$	aD^b

Note 1 From regression analysus

4.1 Individual Households (Ctd.)

Regression analysis results in the following equations :-

$T = 0.6060 + 0.005715\ D$ and
$T = 0.34497\ D^{0.28065}$ where
T = water collection time (min/l) and
D = distance to water (m)

The exponential equation and distance to water explain 99% of the variation in water collection times for individual households. The corresponding value for the linear equation is 96% which is not statistically significant at the 1 % level.

4.2 Waterpoints

The above equations need to be modified to account for the distribution of population around a waterpoint i.e. for a uniform population density only about 25% of people have access to water within half the maximum distance.

AVERAGE WATER COLLECTION TIMES from a WATERPOINT			
VARIABLE	FORMULA	EQUATION	
		Linear	Exponential
T	D = R 1)	$a + bR$	aR^b
V	$\int_0^R \pi R^2 dT$	$\frac{1}{3}\pi bR^3$	$\frac{\pi abR^{b+2}}{b+2}$
Tav	T-V/A	$a + \frac{2}{3}bR$	$\frac{2aR^b}{(b+2)}$

Note 1. From table above

The modified equations are summarised below :-

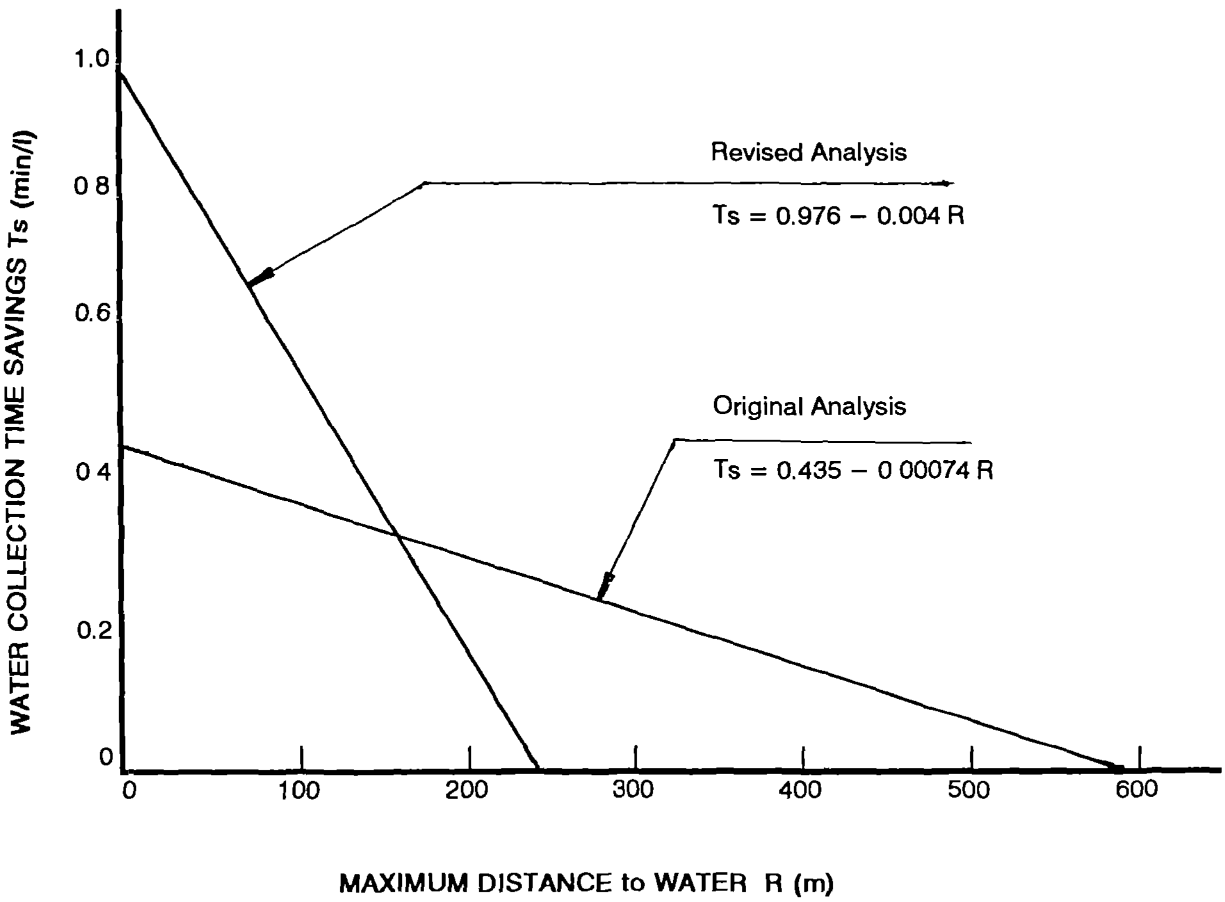
$Tav = 0.6060 + 0.003810\ R$ and
$Tav = 0.302519\ R^{0.28065}$ where
Tav = average collection time (min/l) and
R = maximum distance to water (m)

4.3 Time Savings

Time Savings (Ts) are calculated simply as the difference between water collection times for unacceptable sources (see table above) and the improved level of service :-

$$Ts = 0.976 - 0.003810 R$$
$$Ts = 1.582 - 0.302519 R^{0.28065}$$

The difference between the results of the previous and present analysis is illustrated below.



COMPARISON of WATER COLLECTION TIME SAVINGS

5. VALUATION of TIME SAVINGS

Vs = 5.5 x 7.58 x (365/60) Cw Cl Ts
= 253.6 Cw Cl Ts
= nett present benefit of time savings (Rs/HH)
Ts = average time savings (min/l)
Cw = water consumption (lcd)
Cl = opportunity cost of labour (Rs/hr)
5.5 = average family size (No/HH)
7.58 = present valve discounting at 10% over 20 years.

5.1 Water Consumption

The CWSSP is designed to increase consumption to 45 lcd (World Bank 1992). This is consistant with modern practice to maximize the health impact of water supply schemes. Health benefits are, however, difficult to quantify. The above analysis implies health benefits compensate for the additional collection time associated with increased consumption. Present water consumption data are summarised below.

SUMMARY of DATA on PRESENT WATER CONSUMPTION (lcd)

SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE SOURCE (m)				UNACCEPTABLE SOURCE
		0 - 15	15 - 50	50 - 150	150 -250	
SHALLOW WELLS	3.62	27.7	30.6	32.1	13.0	22.5
	1.06	23.6	28.0	23.6	20.4	24.2
	0.52	27.6	29.4	27.9	28.0	23.5
	0.27	24.1	24.4	24.6	26.8	21.0
	Weighted Av.	25.8	28.3	27.1	23.5	23.0
PIPED	1.74	20.2	NA	20.4	41.4	22.1
	1.53	23.6		24.6	24.5	22.4
	0.54	22.1		17.8	18.0	22.1
	Weighted Av.	22.2		21.2	22.3	22.3

5.2 Opportunity Cost of Labour

ORIGINAL VALUATION of TIME SAVINGS			
USE of TIME SAVED	**PROPOTION** %	**VALUE** (Rs/hr)	**WEIGHTED** (Rs/hr)
Income Earning	43	5.0	2.15
Housework	42	2.5	1.05
Leisure Activities	15	zero	zero
TOTAL	100		3.2

Source: Cowater 1991

It has been argued elsewhere that value judgements are in appropriate and all time saved should be valued at the real wage rate of Rs. 5.0 per hour (Coffley 1992)

5.3 Inflation Since 1991

The analysis might also account for the significant iflation, in the cost of materials etc, since 1991.

6. IMPACT of IMPROVED SERVICE LEVELS

6.1 Nett Present Benefits (B)

$$B = \text{Present Value of (Benefits - Costs)}$$

$$= 253.6\ Cw\ Cl\ (0.976 - 0.003810\ R) - 58.12 \times 10^6\ R^{-2}$$

$$= 253.6\ Cw\ Cl\ (1.582 - 0.3025\ R^{0.28065}) - 58.12 \times 10^6\ R^{-2}$$

The NPB is maximised where dB/dR = 0 i.e when :-

$$R = \left(\frac{2 \times 58.12 \times 10^6}{253.6 \times 0.003810\ Cw\ Cl} \right)^{1/3}$$

$= 493.7\ (Cw\ Cl)^{-1/3}$ linear

$= 895.2\ (Cw\ Cl)^{-1/2.28065}$ exponential

The effect of a range of reasonable assumptions regarding the valuation of time savings benfits is reviewed below :-

VALUATION of BENEFITS				OPTIMUM SERVICE LEVEL				
Water Consumption (lcd)	Value of Time Sav. (Rs/hr)	Inflation since 1991 (%)	Time Sav. Distance Relationship	Maximum Distance (m)	Families Served (HHs)	Capital Cost (Rs/HH)	CWSSP Contribution (Rs/HH)	Maximum NPB (Rs/HH)
23	**3.2**	**0**	**original 1)**	**188**	**15**	**1,500**	**1,200**	**6,400**
23	3.2	0	exponential	137	8	2,800	2,240	3,969
23	5.0	0	exponential	108	5	4,500	3,600	8,327
34	5.0	0	exponential	97	4	5,600	4,480	14,935
34	**5.0**	**10**	**exponential**	**97**	**4**	**6,125**	**4,900**	**16,429**
34	5.0	25	exponential	97	4	7,000	5,600	18,669
34	5.0	0	exponential	84	3	7,500	6,000	20,044
45	5.0	0	linear	84	3	7,500	6,000	22,173
45	5.0	25	exponential	84	3	9,375	7,500	27,716

Note Source of original relationship Cowater 1991

The following improved level of service is now proposed. It involves additional costs and sustantially increased benefits.

- Access to waterpoints 4 HH's
- Maximum distance to water 100m

6.2 Programme Costs and Coverage

AVERAGE UNIT SCHEME COSTS (Rs/HH)						
COST COMPONENT	ORIGINAL PROGRAMME				IMPROVED	
	Piped	Wells	HP Wells	Tube Wells	Piped	Wells
Max. Direct Cost	6,000	800	2,270	3,100	4,900	2,300
Construction Overheads 1)	2,000	270	760	1,000	1,600	750
Max. Scheme Cost	8,000	1,070	3,030	4,100	6,500	3,050
Av. Scheme Cost 2)	6,000	800	2,270	3,100	4,900	2,300

Sources : World Bank 1992 and present analysis

Note: 1. Overheads at 33% of direct costs.

2 Average scheme costs at 75% of maximum costs

ESTIMATED CWSSP PROGRAMME COSTS (MRs)					
TECHNOLOGY	ORIGINAL PROGRAMME		TECHNOLOGY MIX i.e Proportion of Piped Schemes		
	Coverage (HH's)	Cost (MRs)	100	75	50
Piped Gravity	31,200	187.1	541.0	405.7	270.5
Shallow Wells	52,800	42.1	-	63.5	127.0
Handpump Wells	1,900	4.3	-	-	-
Tube Wells	24,500	75.8	-	-	-
Pumped i.e. Small Towns	13,700	163.9	163.9	163.9	163.9
BUDGET REQUIRED	124,100	473.2	704.9	633.1	561.4
BUDGET AVAILABLE		582.4	582.4	582.4	582.4

Source World Bank 1992

The above table shows that the most likely scenario, where piped schemes comprise 75% of the total would require a 10% increase in the programme budget or a corresponding decrease in programme coverage.

ANNEX 1 : Example of Previous Extension of Water Collection Data

ANNEX 1 : Example of Previous Extension of Water Collection Data

Well Water Collection Data - Population Density 3.62 HH/Ha

15 Meter Time Savings

Distance	Volume/Trip	Time/Trip	Wait/Trip	# of Trips	# Collectors/HH	Total Volume	HH Size	Expected Wage	Sample Size	Total Time	Time/Litre	Incremental Volu	TSO	TSI	TTS	GTS
0 - 15	11.6	3.4	3.5	7.4	2.0	167.6	6.2	11.1	22.0	51.0	0.3	37.5	116.4	13.0	129.4	77.2
16 - 50	12.9	6.5	6.1	7.0	2.0	176.6	5.9	5.4	20.0	88.1	0.5					
51 - 150	15.2	12.0	7.9	9.5	1.2	177.8	5.4	4.8	13.0	188.3	1.1					
161 - 250	10.5	26.1	6.2	5.2	1.5	81.5	6.3	5.0	4.0	166.8	2.0					
Unnacep able	12.7	13.1	7.6	6.2	1.6	125.0	5.6	5.0	336.0	127.8	1.0					
UNAC A	12.8	12.8	7.5	6.3	1.6	30.1	5.6	5.0	93.3	128.2	1.0	0.0	0.0	0.0	0.01	0.0

50 Meter Time Savings

Distance	Volume/Trip	Time/Trip	Wait/Trip	# of Trips	# Collectors,HH	Total Volume	HH Size	Expected Wage	Sample Size	Total Time	Time/Litre	Incremental Volu	TSO	TSI	TTS	GTS
0 - 15	11.6	3.4	3.5	7.4	2.0	167.6	6.2	11.1	22.0	51.0	0.3					
16 - 50	12.9	6.5	6.1	7.0	2.0	176.6	6.9	5.4	20.0	88.1	0.5					
ACC B	12.3	4.9	4.7	7.2	2.0	171.9	6.1	6.4	21.0	68.7	0.4	4.4	108.3	14.0	122.3	61.6
51 - 150	15.2	12.0	7.9	9.5	1.2	177.8	5.4	4.8	13.0	188.3	1.1					
151 - 250	10.5	26.1	6.2	5.2	1.5	81.5	6.3	5.0	4.0	166.8	2.0					
Unnaceptable	12.7	13.1	7.6	5.2	1.6	126.0	5.6	5.0	336.0	127.8	1.0					
UNAC B	12.8	13.2	7.6	5.3	1.6	127.4	5.6	5.0	117.7	130.5	1.0	0.0	0.0	0.0	0.0	0.0

ACC = the acceptable distance weighted average UNAC = the unacceptable distance and source type weighted average

TSO = time saved on the original volume of water TSI = time saved on the incremental volume of water

TTS = total time saved inclusive of volume, GTS = gross time saved exclusive of volume

ANNEX 2 : Waiting and Travelling Times for Water Collection

WAITING TIMES for WATER COLLECTION (min/l)						
SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE SOURCE (m)				UNACCEPTABLE SOURCES
		0 - 15	15 - 50	50 -150	150-250	
SHALLOW WELLS	3.62	0.30	0.47	0.52	0.59	0.60
	1.06	0.36	0 37	0.30	0.35	0.46
	0.52	0.38	0.44	0.51	0.35	0.49
	0.27	0.19	0.37	0.33	0.42	0.59
	Weighted Av.	0.31	0.41	0.42	0.40	0.53
PIPED	1.74	0.44		0.73	0.17	0.61
	1.53	0.38		0.84	1.27	0.53
	0.54	0.21		0.44	0.82	0.50
	Weighted Av.	0.34		0.69	0.89	0.54
TOTAL	Weighted Av.	0.32	0.51	0.52	0.52	0.54

Source: Recalculated from Cowater 1991

TRAVELLING TIMES for WATER COLLECTION (min/l)						
SCHEME TYPE	DENSITY (HH/Ha)	DISTANCE TO ACCEPTABLE SOURCE (m)				UNACCEPTABLE SOURCES
		0 - 15	15 - 50	50 -150	150-250	
SHALLOW WELLS	3.62	0.29	0.50	0.79	2.49	1.03
	1.06	0.30	0.53	0.72	0.82	0.92
	0.52	0.46	0.59	0.69	0.55	0.91
	0.27	0.23	0.55	0.98	1.38	1.50
	Weighted Av.	0.32	0.54	0.79	1.18	1.04
PIPED	1.74	0.18		0.49	0.96	1.03
	1.53	0.19		0.36	0.75	1.04
	0.54	0.17		0.37	0 98	1.10
	Weighted Av.	0.18		0.41	0.91	1.05
TOTAL	Weighted Av.	0.25	0.44	0.65	1.12	1.04

Source . Recalculated from Cowater 1991

sds/osl bc:

OPTIMUM SERVICE LEVEL and the BASE CASE

Attachement : Optimum Service Level for Tubewells ; 23 Sept. 93

Ecomnomic Tubewell Costs

☐	Capital Cost	RP 91,800	Cowater
☐	Well Construction	Rp 30,000	
☐	Handpump	Rp 25,000	
☐	Rig Depreciation	Rp 23,000	
☐	Apron Construction	Rp 6,500	
☐	Total Capital Cost	Rp 84,500	NWSDB
☐	Maintenance Cost (NPV)	Rp 13,500	Cowater
	ECONOMIC COST	Rp 98,000	

Nett Present Benefits

$$B = 253.6\ Cw\ Cl\ (0.976 - 0.003810R) - 230.6 \times 10^6\ R^{-2}$$

$$R = \left(\frac{2 \times 230.6 \times 10^6}{253.6 \times 0.003810\ CwCl} \right)^{1/3} \quad \text{for maximum B}$$

$$R = 141\ m$$

Parameter		Unit	Time Savings Realationship		
			Linear	**Recommended**	Exponential
Max. Distance to Water		m	141	**150**	172
Families Served		HH's/TW	8	**10**	12
Contributions :	CWSPU	Rs/HH	6,900	**5,500**	4,600
	Rig. Dep.	Rs/HH	2,900	**2,300**	1,900
	CBO's	Rs/HH	800	**650**	500
Total Capital Cost		Rs/HH	10,600	**8,450**	7,000
Nett Present Benefit		Rs/HH	7,300	**6,200**	5,100

sds/opsl

Appendix C

IMPROVED ACCESS to and CONSUMPTION of WATER

Draft Discussion Paper : MARCH 1994

Current CWSPU design criteria have been adopted from the Staff Appraisal Report (IBRD 1992) which specifies :-

- Average Daily Design Demand for :-
    - Standposts 45 lcd
    - Individual Connections 140 lcd
- Population Growth Factor (1.7% over 15 years) 30%
- Allowance for Leakage and Wastage 50%
- Peak Factor for Distribution Systems 2.5

CWSPU understand the Mission now propose :-

- Individual connections offer additional health benefits and should be promoted in preference to standposts wherever they can be provided cost-effectively and
- The design demand for individual connections should be reduced to make them more readily available to rural communities.

CWSPU concur and seek the Missions advice regarding appropriate design criteria. The key issues are reviewed below :-

1 The Benefits of Individual Connections

Consumption of 45 lcd is the current international standard based on WHO studies (Jordan 1984). This presumably allows for improved personal and domestic hygiene, particularly handwashing and flushing of toilets, to optimise health benefits. The Mission is requested to provide copies of the original WHO studies and details of the Banks experience.

Household surveys, conducted during the preparation of CWSSP, indicated that water is presently available within 240m (on average) and that this result in consumption of only 23 lcd regardless of the type of source or its proximity to the dwelling (Cowater 1991).

However another study of a local scheme, with a reliable supply of water and comparable service levels (4 standposts serving 18 households with water available to all households within 200m), indicated the following variation in consumption (Danida 1991) :-

- 45 lcd where water is available within 50m and
- 30 lcd where water is available beyond 50m

This indicates that the provision of standposts for every four households (i.e 4 HH/Standpost), which make water available within 100m (on average), will achieve a substantial increase in consumption. However the target consumption of 45 lcd is only likely to be achieved, by all households, if service levels are further increased viz :-

$H = DA$ and $A = 2.5\ R^2/10{,}000$ where :-

H = the number of dwellings served by a waterpoint (HH)

D = population density = 1.70 HH/Ha on average (Cowater 1991)

A = waterpoint catchment area (Ha)
R = maximum distance to water
= 50m to ensure consumption of 45 lcd (Danida 1991)
∴ H = 1.70 x 2.5 x 50 ^{2}/10,000 = 1.06 HH's/waterpoint.

This implies that the provision of yard taps (i.e 1 HH/standpost) is required to achieve the target consumption of 45 lcd for all households. Furthermore the provision of individual connections is likely to have a direct impact on the incidence of diarrhoea by reducing the risk of epidemics eg. children using private wells have been found to suffer 64% less diarrhoea than those using communal wells (Bradley and Karunadasa 1989)

2 Design Discharge for Yard Taps

People with individual connections tend to consume more water than people who have to carry it from the source to the dwelling. Local studies indicate the following values for individual house connections :-

Consumption from Individual Connections	
Type of Individual Connection	Consumption (lcd) 1)
• Multiple tap house connections	131
• Single yard taps supplying household storage tanks not equipped with float values	144

Source Danida 1991
Note 1 Adjusted consumption increased by 1/0 875 as unreliable supply caused 25% of households to use alternative sources throughout the year for an assumed 50% of their consumption

This indicates that 140 lcd is an appropriate value to the design of multiple tap house connections. However the "natural" consumption from yard taps appears to be intermediate between standposts and multiple tap house connections

3 Other Design Criteria

The other design criteria which affect system capacity and hence cost are reviewed below.

- **Population Growth Factor** ; In the spirit of community ownership the CBO should be allowed to decide whether or not to provide for future population growth.
- **Leakage and Wastage** ; The current average daily demand values quoted above are based on NWSDB design criteria which "include unaccounted water, wastage and leakage and any further additional allowances are unwarrented". Confirmation is sought as to whether the target consumption of 45 lcd also includes a reasonable allowance for leakage and wastage which amounted to only 13% in a local system with adequate service levels and reliable supply (Danida 1991)
- **Peak Factors** ; Peak demand is clearly related to the service level provided, SRTS design the system for 0.1 l/sec/standpost and assume all standposts operate simultaneously. This is logical where more than about 10 households are served by a single standpost but is too conservative for higher levels of service. Study of a local standpost system, with similar levels of service (4 standposts serving 18 families), found the peak factor to be 2.85 (Danida 1991). The peak demand for yard tap systems is likely higher again. On the other hand it seems reasonable to expect households to draw water out of peak hours to satisfy other than basic needs i.e. peak demand should be restricted to that for standpost systems.

4 Appropriate Service Levels

It is now proposed that communities should be enabled to make informed decisions regarding the level of service appropriate to their needs and resources within the limits specified below. The upper limit of design discharge should recognize the following factors :-

- **Consumption above 45 lcd** presumably has an amenity value to the individual but not an economic health benefit.
- **Increased System Capacity** causes higher costs and tends to reduce coverage. Preliminary analysis indicated yard tap systems designed for 120 lcd cost about 50% more than standpost systems designed for 45 lcd.
- **Increased Water Requirements** reduce coverage where limited water is available.

The lower limit of design discharge should recognize that :-

- **Consumption Inequities** are inevitable i.e. people in privileged locations will tend to consume more than others even where the overall water supply is limited. The provision of yard taps tends to exacerbate such inequalities by facilitating increased consumption. The inclusion of regulating devices can mitigate, but rarely eliminate, inequalities. Therefore the design of yard tap systems should allow for some consumption in excess of the target level (45 lcd) to ensure fledgling CBO's don't become embroiled in conflict resolution.

Proposed Design Discharge Limits

Design Criteria	Unit	Standposts		Yard Taps	
		Min	Max	Min	Max
Average Daily Demand	lcd	45	45	70	105
Population Growth Factor	%	0	35	0	35
Leakage and Wastage	%	15	15	0	0
Peak Factor	%	3.0	3.0	NA	NA
Design Discharge: Av:	lcd	50	70	70	140
Peak	lcd	150	210	150	210

5 Location of Storage Tanks

Storage tanks may be relocated to the downstream end of the distribution system rather than further upstream as is conventional eg :-

- Standposts could be equipped with cistern or
    - Yard taps could discharge to individual household storage tanks equipped with float values to minimise wastage.

The additional cost of providing multiple small storage tanks would be offset by the saving in the cost of the distribution system which would be designed for the average demand rather than the peak rate. CWSPU are preparing cost-effective designs for individual storage tanks and cost comparisons of alternatives.

sds/mtsc/m22/March 22, 1994,10 40am

Appendix D

PRELIMINARY EVALUATION OF 16 SRTS PIPED GRAVITY SCHEMES

AUGUST 1994

Preliminary Evaluation of 16 SRTS Piped Gravity Schemes

This preliminary evaluation is based on a rapid review of 16 completed questionnaires. The results are summarised in the Table 1.

1. SUMMARY OF FINDINGS

The preliminary findings reviewed below are significant and warrent detailed analysis and interpretation on completion of the survey and availability of results for all 250 schemes.

1.1 Sustainability ; Coverage generally increased after completion of schemes in Kandy and Nuwara Eliya (one anomaly remains to be explained) Schemes in Matara, however, displays a consistent decrease in coverage (average 30%!).

1.2 Causes of Decreased Coverage ; The regional differences noted above are quite apparent and are likely associated with differences in water resource endowments i.e. water is abundant in Kandy and Nuwara Eliya but less so in Matara. The reporting of problems and constraints also displays regional differences which are consistent with the above interpretation. In particular it seems systems in Matara are consistently constrained by :-

- Shortages of water at the source particularly during the dry season and
- System delivery capacity (design discharge) i.e. indications are that many schemes have been designed to deliver 1.24 x 30 = 37.2 lcd which is inadequate to meet present demand let alone allow for future expansion as intended.

2. RECOMMENDATIONS

2.1 Procedures to Estimate Safe Yield need to be improved. The development of regional unit hydrographs and improved to techniques integrate indigenous knowledge of water resources should be considered as an alternative to prolonged flow measurements.

2.2 Design Discharge and Safe Yield ; SRTS schemes are designed for :-

Safe Yield = Design Demand = System Capacity

The absolute minimum requirement is 52 lcd to meet present demand. This should only be increased to allow for future expansion where sufficient water is available i.e. safe yield is adequate.

Table 1 : Sustainability of SRTS Piped Gravity Water Supply Schemes

Scheme	Age	Design Discharge	Sustainability			Reported Causes of Reduced Coverage																	
			Coverage (HHs)			Water Supply					System Capacity					Social Conflicts							Add HCs.
No	(years)	(lcd)	Design	Present	Change (%)	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	6	Total (No)	
3/17	0		60	69	+15		✓	✓							✓		✓	✓			✓	6	0
3/37			14	18	+29			✓	✓				✓		✓		✓	✓	✓	✓	✓	9	0
7/18	4		240	198	-18								✓				✓	✓				3	0
7/27	2		42	46	+10									✓	✓			✓			✓	4	0
7/30	2		31	40	+29					✓					✓			✓		✓		4	0
Sub-total			**387**	**371**	**-4**	**0**	**1**	**2**	**1**	**1**	**0**	**0**	**2**	**1**	**4**	**0**	**3**	**5**	**1**	**2**	**3**	**26**	**0**
5/01	13			15			✓	✓		✓	✓				✓	✓		✓	✓	✓	✓	10	3
5/03	10		66	31	-53		✓	✓		✓	✓			✓		✓	✓	✓	✓	✓	✓	11	5
5/05	7			21		✓		✓			✓				✓							4	0
5/06	8		32	24	-25		✓	✓			✓	✓	✓	✓				✓		✓	✓	9	0
5/08	7		63	42	-33	✓	✓	✓			✓		✓					✓		✓	✓	8	0
5/09	9		40	28	-30						✓				✓			✓	✓	✓	✓	6	3
5/10			72	46	-36	✓		✓			✓		✓	✓	✓			✓		✓	✓	9	0
5/11	6		44	33	-25	✓	✓	✓	✓	✓			✓	✓	✓			✓		✓	✓	11	3
5/14	4		126	90	-29		✓	✓			✓		✓	✓				✓			✓	7	0
5/15	4		63	55	-13	✓	✓	✓			✓		✓	✓				✓				7	0
5/18	2		50	42	-16	Says No Change in Coverage ?																	0
Sub-total			**556**	**391**	**-30**	**5**	**7**	**9**	**1**	**3**	**9**	**1**	**6**	**6**	**5**	**2**	**1**	**9**	**3**	**7**	**8**	**82**	**14**
TOTAL			**943**	**762**	**-19**	**5**	**8**	**11**	**2**	**4**	**9**	**1**	**8**	**7**	**9**	**2**	**4**	**14**	**4**	**7**	**11**	**108**	**14**

3. SUSTAINABILITY

3.1 Kandy and Nuwara Eliya

The five schemes in Kandy and Nuwara Eliya report an average decrease in coverage of 4%.

The results are however dominated by a single large scheme (No7/18) where coverage is reported to have decreased by 18%. This is an apparent anomaly which warrents follow-up study based on PRA as indications are that a lack of social cohesion resulted in reduced coverage. Indicators include :-

- The evaluator observed there is sufficient water (for extended coverage ?) but much is being wasted or used for cultivation.
- The scheme was extended twice ; once by SRTS, during implementation to supply a satellite village and later by the caretaker without benefit of technical advice.
- This was the only one of the 16 schemes to report a major breakdown (leaking storage tanks costing Rs. 19,500 to repair). Reporting of this fact is curious as it was funded by SRTS (not the community !) and seems to have been remedial works prior to commissioning.

The remaining four schemes report a consistent increase in coverage averaging 18%.

3.2 Matara

Schemes in Matara displays a consistent decrease in coverage averaging 30%. This is substantial and must be cause for concern. A single scheme (No 5/03) warrents further consideration as it reported an exceptional reduction in coverage from 66 to 31 households associated with five illicit private connections.

4. CAUSES OF REDUCED COVERAGE

4.1 Regional Water Resources

Regional differences in sustainability (change in coverage after completion) appear to be associated with different water resource endowments as illustrated below.

Table 2 : Regional Differences in Sustainability and Water Resources

Region	Change in Coverage (%)	Water Resources
Kandy and N'Eliya	plus 18	Abundant
Matara	minus 30 !	Moderate
Badulla	to be verified	Moderate to Scarse

4.2 Reported Problems and Conflicts

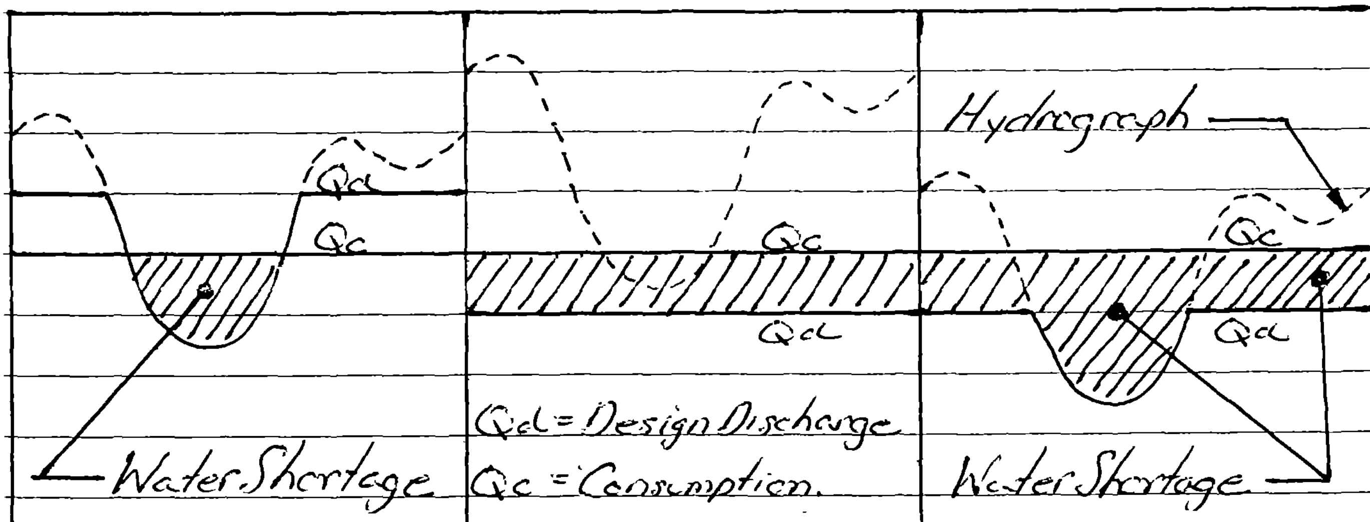
The reporting of problems and constraints also displays regional differences which are summarised below.

Table 3: Regional Differences in Sustainability and Water Resources

Problem or Constraint	Frequency of Reporting (%)	
	Kandy+N'Eliya	Matara
Water Source Problems	**10**	**50**
Dry Season Shortages	40	90
Declining Yields	20	70
General Shortages	none	50
Other Problems	20	20
System Capacity Problems	**14**	**54**
Delivery Limitations	none	90
Other Problems	17 1/2	45
Social Conflicts	**23 1/3**	**50**
Consumption Inequalities	100	90
Lack of Maintenance	60	80
Lack of Organization	40	70
Private Connections	20	30
Expansion Pressures	30	15

In Kandy and Nuwara Eliya social conflicts are reported more frequently than water supply or system capacity limitations. All five schemes reported consumption disputes. Evidently consumption inequalities exist, and cause conflicts, even where overall water supplies are adequate.

In Matara, on the other hand, water shortages at the source, system delivery capacity limitations and social conflicts are all reported with equal frequency. Evidently water availability to consumers is a widespread constraint. The relationship between safe yield, system capacity and water shortages to consumers is illustrated in Figure 1 while the reported frequency of occurrence and resulting reductions in coverage are presented in Table 4.



Safe Yield Limitation (Dry Season Shortages)	System Capacity Limitations (Continuous Shortages)	Simultaneous Limitations (Continuous shortages ; Worst During the Dry Season)

Figure 1: Safe Yield, System Capacity and Water Shortages

Limitation	Reporting Frequency (%)	Average Reduction in Coverage (%)
Safe Yield of Source	10	25
System Delivery Capacity	10	30
Both Safe Yield and Delivery Capacity	80	32

Table 4: Reported Frequency of Limitations and Reduced Coverage

Table 4 indicates that safe yield and delivery capacity limitations are equally important in restricting water availability to consumers.

4.3 Safe Yield or Reliable Discharge

The above analysis indicates that water supply limitations are pervasive in Matara. Furthermore while 40% of schemes report shortages only during the dry season a further 50% report general shortages as well. This indicates extreme water supply limitations which, however, are not reflected in differences in the reduction of coverage. There are two explanations of water supply limitations (CWSPU has experienced both problems) :-

- Consistent overestimation of safe yield and
- Community pressure for extended coverage with limited water supplies.

4.4 System Delivery Capacity

The above analysis also indicates that continuous shortages of water to consumers are pervasive in Matara but not in Kandy or Nuwara Eliya. There are several possible explanations :-

- General water supply limitations at the source, discussed above, which implies consistent gross overestimation of safe yield
- Overestimation of the hydraulic capacity of pipelines. SRTS design criteria specify ks = 0.01 mm whereas the hydraulic chart used for design appears to employ ks = 0.10mm (Helvetas 1992) The more conservative value is recommended by CWSPU. This explanation is therefore discounted subject to confirmation of the actual value of ks used in design and
- Insufficient delivery capacity (design discharge) to meet present demand.

SRTS employ the following design criteria and reject the scheme if the safe yield of the source is less than the lower value of future demand (Helvetas 1992) :-

- Future Demand = 1.24 x 55 = 55.8 lcd normally or
  where water is scarse= 1.24 x 30 = 37.2 lcd minimum
- Design Discharge = Future Demand (as above)

There are two alternative methods of estimating present demand which are compared below :-

Method 1 : Based on the Results of the SRTS Survey particularly the changes in coverage presented in Table 2 above. It requires the reasonable assumption, which should be verified, that schemes in Kandy and Nuwara Eliya were designed to deliver 55.8 lcd while most schemes in Matara were designed for 37.2 lcd in response to water scarcity.

Table 5 : Estimate of Present Demand based on SRTS Survey

Region	Design Discharge (lcd)	Actual Coverage vs Planned (%)	Present Demand (lcd)
Kandy and N'Eliya	55.8	1.18	47.3
Matara	37.2	0.70	53.1
Average Value of Present Demand			**50.2**

Method 2 : Based on the Results of Recent CWSPU Research

- Consumption = 151.1 $R_{max}^{-0.266}$ (lcd) where
- Water is available to all households served by a standpost within Rmax which is about 150m for the level of service provided by SRTS (8 to 10 per standpost)
- An allowance of 20% is adequate for normal leakage and wastage (Danida 1991 and IRC 1983)
- **Demand = 1.20 x 151.1 x 150 $^{-0.266}$ = 47.8 lcd**

Thus the two results are consistent and indicate that the lower SRTS design discharge of 37.2 lcd is inadequate to meet present demand let alone allow for future expansion as intended. What then should be adopted as the minimum value of design discharge ? The current WHO standard is 45 lcd (Jordan 1981) which is presumed to relate to the current target of making water available, to all users of a standpost, within 250m (NWSD and IRC 1983). This value needs to be revised to allow for increased consumption from the improved level of service :-

Minimum Design Discharge = 45 (150/250) $^{-0.266}$ = 52 lcd

4.5 Community Organization and Social Conflicts

Thus it would appear that community development and organization are not a constraint and the (slightly !) increased incidence of social conflict in Matara reflects the water supply limitations discussed above. There us however an apparent need to enable communities to make more informed choices from amongst a range of practical options and to appreciate the management implications of each option.

4.5.1 Consumption Inequalities appear to cause social tensions whether water supplies are limiting or not. Some consumption inequalities are unavoidable (because consumption is related to access) unless yard taps can be provided.

4.5.2 Private Connections appear to be a response to water shortages rather than their cause :-

- None were reported in Kandy and Nuwara Eliya where water is sufficiently abundant to supply them and
- 40% of schemes in Matara reported unplanned private connections amounting to about 7% of the design population in each case. Only one of these schemes, however, was associated with an exceptional reduction in coverage (53%) which warrents further consideration.

4.5.3 Maintenance Requirements were obviously not a constraint as none of the schemes required a major repair, costing more than Rs. 1,000, after commissioning of the works (see Section 3.1)

5. Further Analysis and Interpretation

The preliminary findings reviewed above are significant and warrent further detailed analysis and interpretation on completion of the survey and availability of results for all 250 schemes.

In particular it will be interesting to see if the results for Badulla show a further reduction in coverage compared with Matara. In interpreting this information it would be useful to know the design discharge for each scheme i.e. 55.8 lcd or 37.2 lcd ?

In addition CWSPU seek the following minor clarifications of terminology

- Water Supply Facilities (Question 1.02) the meaning of the ration reported under yard taps is unclear as is the interpretation of the difference between yard taps and house connections. CWSPU use the following terminology :-
    - Standposts serve multiple households
    - Yard Taps involve individual connections and a single tap in the yard
    - House Connections involve single or multiple taps in the home.
- Extensions and Reduced Coverage ; The summary presented under Question 1.02 often doesn't tally with reporting under Question 4 and 5 which attempt to measure the key issue of sustainability. eg. for scheme No 5/18 Q 1.02 indicates coverage reduced from 50 to 42 HH's but Q5 reports no reduction and identifies no problems or disputes. CWSPU recognize the following extensions :-
    - Extension of Coverage (Q 4a) to serve additional households either with existing facilities or through provision of additional standposts and
    - Improvement of Service Levels (Q 4b) through the provision of individual connections either sanctioned or illicit.

Appendix E

Draft

Discussion Paper

Conceptual Framework for Hygiene Education
based on a
Review of Health Impact Evaluations

February 1992

Table of Contents

February 1992

Conceptual Framework for Hygiene Education

1. Findings and Recommendations

The results of the Kurunegala Study have been reinterpreted and found to be consistent with the findings of international health impact evaluations. The main conclusions are summarized below where water supply and sanitation interventions are listed in the likely order of their impact on diarrhoea morbidity in children.

The Impact of water Supply and Sanitation Interventions

Sanitation and Water Consumption have the Greatest Impact

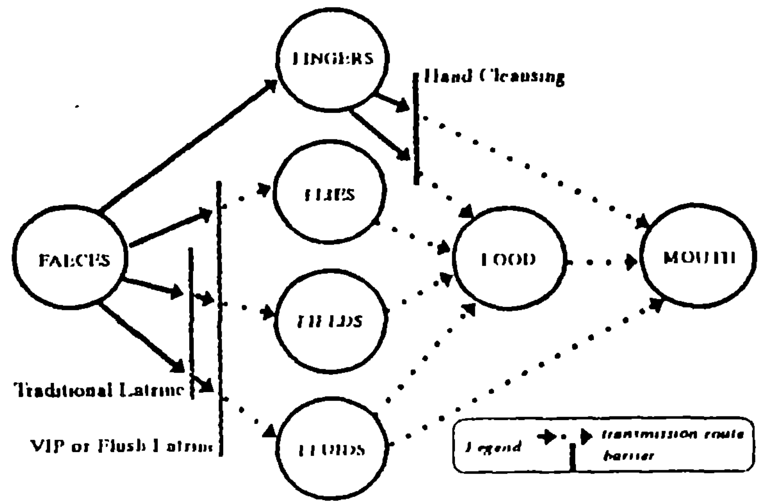
- Provision of improved access to water, fewer users of a waterpoint and preferably individual connections, to promote increased consumption and reduce the risk of water borne epidemics.
- Provision of sufficient water and its use for :-
  - cleaning and flushing water seal latrines and
  - handwashing with soap after defecation or handling childrens faeces and before food preparation, feeding, eating or collecting water
- Provision of sanitary latrines and safe disposal of faeces particularly of young children and babies and of people with diarrhoea.

Improved Water Sources may also have an Impact

- The impact of improved water sources (protected shallow wells, piped supplies and tubewells equipped with handpumps vs traditional unprotected sources) increases as other interventions become effective and environmental contamination and diarrhoea rates are reduced.
- Improved hygiene practices at the waterpoint, i.e. during collection, are also likely to be effective and CBO's should be encouraged to sterilize sources in the event of waterborne epidemics.

Other Water Quality Interventions have No Discernable Impact i.e.

- Improved household storage of water and
- Boiling of drinking water

<table>
<tr><th colspan="4">Proposed Conceptual Framework for Hygiene Education</th></tr>
<tr><th>Project Phase + Purpose</th><th>Sanitation Interventions</th><th>Improved Access and Consumption</th><th>Improved Water Sources & Quality</th></tr>
<tr><td>Mobilization; to create awareness of both the benefits of, and stimulate demand for, water supply and sanitation improvements</td><td colspan="2">
</td><td>Faecal - Oral
Transmission
Routes and Barriers</td></tr>
<tr><td>Participatory Planning; to assist communities in the selection and location of appropriate water supply and sanitation facilities</td><td>o Promote the benefits of water seal latrines where water is plentiful and
o VIP latrines where it is not
o Latrines to be located >30m from wells</td><td>o Promote the benefits of improved access, fewer users of a waterpoint and of individual connections (yard taps) in particular
o Promote the benefits of schemes designed to supply at least 45 lcd and review management implications where availability is limiting.</td><td>o Promote the benefits of improved water sources and the need to protect them from contamination.</td></tr>
<tr><td>Construction; to promote appropriate hygiene practices and reduce diarrhoea morbidity amongst children.</td><td>o Promote the sanitary disposal of faeces, particularly of young children and babies, and of people with diarrhoea.</td><td>o Promote widespread adoption of:-
  o Cleaning and flushing of latrines
  o Handwashing with soap after defecation or handling childrens faeces and before food preparation feeding, eating or collecting water</td><td>o Establish an early warning system for diarrhoea epidemics.
o Encourage CBO's to sterilize water sources during epidemics
o Promote improved hygiene practices at the waterpoint</td></tr>
<tr><td>Consolidation</td><td colspan="3">Reinforcement of Hygiene Practices : Activities to be Defined.</td></tr>
</table>

2. Purpose and Method

Partner Organizations have requested a more focused and clearly defined HE program to facilitate community mobilization (LSIP regional progress review meetings 28 Jan to Feb 1994) This paper has been prepared to provide a basis for the discussion and agreement of a conceptual framework prior to a three month assignment by the Hygiene Education Specialist (1 March to 31 May).

In addition the NSC meeting of 15 Feb 1994 agreed that the draft HE Policy paper should be reformulated in the light of the detailed comments provided by Mr. K.A.H. Ranaweera the Secretary to the Minister of Housing.

The discussion paper was prepared following review and interpretation of Health Impact Evaluations (HIE's) available in the literature. These aim to quantity the associations between water and sanitation improvements and associated hygiene practices and the health of the rural population particularly the incidence of diarrhoea (morbidity) amongst children. The following sources of information were considered. Each offers a different perspective.

- **Review of International HIE's** (Esrey et al 1990 and 1991) has been described as the definitive comparison of the health impact of different WSS interventions (Simpson 1992). It is based on a review of 144 international studies of which 84 were concerned with diarrhoea morbidity. The findings of six more recent studies were found to be consistent (Sandiford and Gorter 1992)
- **The Central Java Cross-Sectional Study** (Wibowo and Tisdell 1993) used multiple regression techniques to investigate the interaction between safe water supply and sanitation coverage over an extensive area.
- **The Kurunegala Case-Control Study** (Mertens et al 1990 and 1991) warrants particular scrutiny because :-
  - o It is the only comprehensive study conducted recently in Sri Lanka.
  - o The authors reached the following main conclusions which conflict with the consistent findings of the international studies cited above :-
  - **The Impact of Improved Water Sources on Diarrhoea Morbidity**
    The provision of improved water sources (protected shallow wells, piped supplies and particularly tube wells equipped with hand pumps), rather than unprotected traditional sources, is likely to bring about a substantial reduction in childhood diarrhoea morbidity (Mertens et al 1990 c)
    Water Consumption, Sanitation and Diarrhoea Morbidity
    Little evidence of confounding of the above association between diarrhoea and water source was observed (Mertens et al 1990 c) and
    Water Supply and Sanitation Interventions and Anthropometric Status
    No convincing evidence was found of a rational association between the anthropometric status of children and water supply, sanitation and hygiene practices even though such data are though to be indicators of both chronic undernutrition and diarrhoea (Mertens 1990 d)
  - o The reported conclusion appears to have had considerable influence on WSS policy in Sri Lanka. One local NGO, prominent in the WSS sector, promotes the widespread availability at safe drinking water. The paramount importance of water quality interventions seems to be the basic premise underlying project preparation for CWSSP (Cowater 1989) and is reflected in the current hygiene education policy paper.

3. Methodological Difficulties of HIE's

Policy makers require an understanding of how the various water and sanitation interventions interact to improve health eg to develop a conceptual framework for hygiene education or set priories for applied research.

Unfortunately HIE's suffer from a number of methodological difficulties (Esrey et al 1990). In particular there are multiple causes of health problems many of which are ultimately associated with poverty. Poorer households are less likely, for example to boil drinking water, wash with soap or dispose of childrens faeces. Diarrhoea morbidity is likely, therefore, to be more highly correlated with indicators of poverty than with any individual hygiene practice even though poverty is obviously not a direct cause of diarrhoea. There are two basic approaches to HIE's:-

Case - Control Studies don't resolve the basic dilemma (Sandiford and Gorter 1992) but are more prevalent, They evaluate the health status of individuals in relation to their access to water and sanitation facilities and hygiene practices. The problem is that this usually involves a limited number of interventions and simple binary variables eg. :-

- Health Status — sick or not sick
- Access to facilities — yes or no
- Hygiene practices — do or don't

The resulting statistical models have limited explanatory power as they can only evaluate the impact of one intervention at a time (n - 1 =1) while controlling confounding variables.

Cross-Sectional Studies recognize that water supply interventions often serve entire communities. They employ multiple regression analysis to develop health production functions similar to those used by the agricultural and hydrological sciences. These have the potential to quantify for each intervention, alone or in combination, its health impact and statistical significance. The method involves continuous variables eg. the proportion of the community suffering a particular health problem or with access to WSS facilities etc.

Unfortunately these studies are rare. The problem is that each WSS project or community represents a single data point. Consistent data are rarely available for an extensive area and the many variables of interest.

4. Review of International HIE's (Esrey 1990 and Esrey et al 1991)

The results of 84 international HIE's were reviewed. The median reduction for total child mortality was 60%. Based on the 6 better studies, the median reduction in total child mortality was 55% with a range of 20 to 82%.

When all relevant studies were considered, the median reduction in general diarrhoea morbidity was 22% but the reduction based on the better studies was 26% with a range of 0 to 68%. It is worth noting that some studies showed no significant reduction. The results for specific interventions are summarized below

Summary of the Results of Health Impact Evaluations of WSS Interventions

WSS Intervention	Health Impact 1)		Diarrhoea Morbidity Impact			
	Total Studies (No)	Positive Impact (%)	All Studies		Rigorous Studies 2)	
			Sample (No)	Reduction (%)	Sample (No)	Reduction (%)
Water & Sanitation	11	64	7	20	2	30
Sanitation 3)	30	70	11	22	5	36
Water Supply 4)	43	56	22	16	2	17
Water Quality	16	63	7	17	4	15
Water Quantity	15	93	7	27	5	20
Hygiene	6	100	6	33	6	33
TOTAL	121	68	60	22	24	26

Source: Esrey et al 1990 and 1991

Notes.
1. The health impacts reported were diarrhoea morbidity and mortality and nutritional status. 84 studies were reviewed i e some reported on more than one intervention or impact
2. Rigorous studies are those that meet specific methodological criteria (Esrey et al 1990) The better studies and those conducted in the past few years have both a higher proportion showing a positive impact (100% for sanitation and water quantity interventions) and a higher reduction in disease which may reflect better studies or better projects or both
3. Of the studies that compared the relative importance of water and sanitation most reported that sanitation had the greatest impact on child health based on mortality, growth and morbidity indicators.
4. These studies have been grouped together because it is difficult to know if the impact was due to quality, quantity or both. However in the studies reporting a health benefit the water was piped into or near the home whereas in those studies reporting no benefit the improved water supplies were protected wells, (1) tube wells (1) and standposts (5).

Studies tend to report the reduction due to a single combination of interventions. Thus the median reductions reported above are not strictly comparable as they are based on different study samples. Some results are also counter-intuitive eg. the median reduction due to sanitation alone is greater than the reduction due to the combination of water and sanitation interventions. This reflects the variability of the estimated reductions. The results however, support the following conclusions.(Esrey et al 1990):-

- Safe excreta disposal and proper use of water for personal and domestic hygiene appear to be more important than drinking water quality in achieving broad health impact. (particularly in highly contaminated environments where diarrhoea rates are high)
- Access to water supply should be as close to the home as possible- to foster the

use of more water for hygiene practices and

- Hygiene education is necessary to encourage people to use more water for personal and domestic hygiene.

The above review was extended during the project preparation for CWSSP when a further six international studies were identified (Sandiford and Groter 1992) The emphasis was on the impact of water quality interventions. The results are reviewed below.

Recent Studies Examining the Health Impact of Water Quality

Country	Type of Improvement	Comparison	Observed Impact
China	Quality & quantity	Deep well tap water in house or yard vs surface water at 10-40m	Reduction of 38% in diarrhoea incidence, 73% in hepatitis, 88% in El Tor cholera and 0% in *Shigella*
Bangladesh	Sanitation, water quantity, and water quality	Intervention area with handpumps, latrines and hygiene education vs control areas	25% reduction in incidence of diarrhoea. No impact on nutritional status
	Quality only	Exclusive wet season use of handpump water	Not significant
Egypt	Quality	Tap water versus well water for drinking	Nil
Malaysia	Quality	Absence vs presence of faecal coliforms in water source	Insignificant 23% reduction in diarrhoea
		Absence vs presence of faecal coliforms in drinking water	Insignificant 31% reduction in diarrhoea
Nicaragua	Quality	Piped water versus protected wells versus unprotected wells	Nil
Nigeria	Quality	Boreholes versus traditional sources	Reduced incidence of dracunculiasis. Nil effect on diarrhoea.

Source Sandiford and Gorter 1992

The above studies indicate minimal health benefits even though they generally involved major water quality improvements to achieve faecal coliform (FC) counts close to zero. The review also noted that water quality intervention more likely to have a positive health impact through reducing contaminations from very high levels (eg. several thousand FC) to moderate levels (around 100 FC) than from moderate to low levels. Furthermore such improvements are more likely to be effective where many families share a water source than where the source is used by just one or two families. This implies that water consumption and access considerations subsume the benefits of water quality improvements particularly moderate ones.

5. The Central Java Cross- Sectional Study (Wibowo and Tisdell 1993)

The following equation was found to explain 75% of the variation in diarrhoea morbidity within 194 Subdistricts in Central Java.

$D = 938.5\, W^{-1} + 101.5 S^{-1}$ where
D = Diarrhoea morbidity (%)
W = Safe water coverage (%)
S = Sanitation coverage (%)

Data on other variables which might be expected to influence diarrhoea morbidity, were either unvariable or unreliable. The particial regression coefficients are however significant at the 2.5% and 0.5% levels respectively. The greater variability associated with water supply interventions may reflect their relative complexity eg. involving both quality and quantity considerations.

The impact of improved water supplies is nearly five (5) times that of sanitation (1% increases in present coverage reduce diarrhoea by 1.51% and 0.34% respectively) This subsumes any cost advantage increased sanitation coverage may enjoy. The potential benefits of full coverage are summarized below and compared with those reported in case-control studies.

Health Impact of WSS Interventions 1)

Study Type	Intervention		
	Water	Sanitation	Combined
Cross-Sectional 2)	38	8	46
Case-Control rigorous studies 3)	17	36	30
Case-Control all studies	16	22	20

Notes:
1. Reduction in prevalence of diarrhoea morbidity
2. Central Java, Indonesia (Wibowo and Tisdell 1993)
3. Median valve for rigorous studies from a review of 84 International studies (Esrey et al 1990 and 1991)

6. The Kurunegala Case-Control Study

(Mertens 1989 and Mertens et al 1990)

6.1 Purpose and Methodology

The study was conducted between January 1987 and March 1988 and involved case-control studies of the impact of WSS interventions on diarrhoea morbidity and anthropometric status of children as well as household surveys of a community comparison group and microbiological analysis of water samples and faecal specimens. The relevant results are presented in several complementary papers.

The study was conducted in support of the GTZ Rural Water and Sanitation Project. This project promoted the provision of wells, particularly tube wells, and was justified in terms of the health benefits of providing safe drinking water rather than increased consumption or the time savings benefits associated with improved access to water (Kumarasiri 1994). The study concentrates on water quality issues and the findings reflect these concerns viz:-

Summary of the Main Published Conclusions of the Kurunegala Study
• **The Impact of Improved Water Sources on Diarrhoea Morbidity** The provision of improved water sources (protected shallow wells, piped supplies and particularly tube wells equipped with hand pumps), rather than unprotected traditional sources, is likely to bring about a substantial reduction in childhood diarrhoea morbidity (Mertens et al 1990 c) • **Water Consumption, Sanitation and Diarrhoea Morbidity** Little evidence of confounding of the above association between diarrhoea and water source was observed (Mertens et al 1990 c) and • **Water Supply and Sanitation Interventions and Anthropometric Status** No convincing evidence was found of a rational association between the anthropometric status of children and water supply, sanitation and hygiene practices even though such data are thought to be indicators of both chronic undernutrition and diarrhoea (Mertens 1990 d)

The above conclusions conflict with the consistent findings of international studies (Sections 4 and 5 above) and were therefore subject to particular scrutiny. Health indicators and their present status were first considered briefly (Section 6.2). The published results were then re-interpreted to evaluate the justifications for the above conclusions.

Drought conditions prevailed during the conduct of fieldwork. Monthly rainfall was consistently below the mean and many traditional sources dried up. This is likely to have suppressed the impact of water quality interventions and the benefits of using improved sources in particular. On the other hand the benefits of using improved sources appear to have been overestimated as illustrated below :-

Relative Rate of Diarrhoea : Improved vs Unprotected Sources				
Type of Source	**Sample size**			**incidence I (%)**
	Cases	**Controls**	**Total**	
Improved	1,561	3,065	4,626	34
Unprotected	808	1,029	1,837	44
Relative Rate (I improved/ I unprotected)				0.77

Logically the incidence of diarrhoea is the number of cases divided by the total sample and the relative rate is simply the incidence amongst children using improved sources divided by that associated with unprotected sources. Of the Children in hospital 44% of those using unprotected sources had diarrhoea compared with only 34% amongst those using improved sources. Thus the relative rate is 77% less diarrhoea compared with those using unprotected sources.

The authors note that "the cross-product estimates the relative rate of disease among exposed and unexposed rather than the odds ratio (Rodrigues and Kirkwood 1990)" However the adds ratio is the same as the cross-product of cases and controls (Fingeleton 1984) and it seems likely that the cross-product referred to is that between cases and the total sample viz:-

$$(1{,}561 \times 1{,}029) / (3{,}065 \times 808) = 0.65$$
$$(1{,}561 \times 1{,}837) / (4{,}626 \times 808) = 0.77$$

The latter interpretation agrees with the simple rational explanation. The original authors, however, adopted the adds ratio and are likely to have overestimated the health benefits of WSS interventions as a consequence.

The relative rates of diarrhoea morbidity reported herein have been adjusted using the above simple rational explanation. This was not possible for the relative rates of wasting as the original paper (Mertens 1990 d) contained insufficient information.

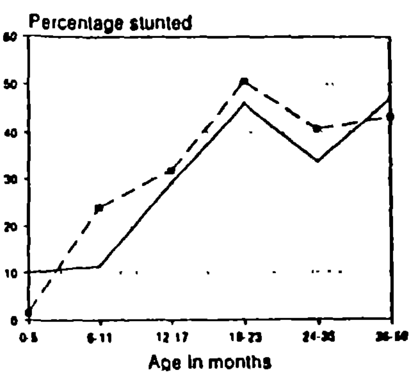
6.2 Health Indicators and Present Status

Health impact evaluations should be based upon an understanding of the health problems suffered by the rural population particularly children. Mertens estimated the incidence of diarrhoea to be of the order of two (2) episodes per child per year based on an assumed average duration of 3 days per episode and the measured two-week diarrhoea prevalence of 7.9% which confirmed the results of the nationwide DHS study conducted in 1987. This is higher than the country median of 1.0 episodes per child per year reported by WHO in 1987. This hardly seems to represent the prevalence of chronic diarrhoea. Nevertheless further corroboration and bases for comparison are being sought.

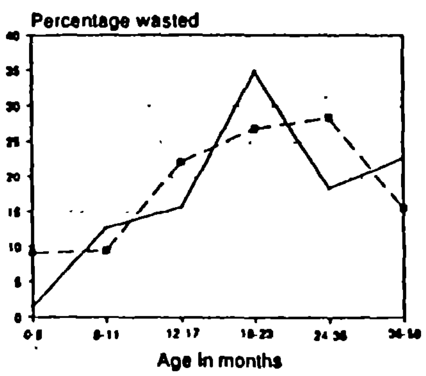
Indicators of Nutritional Status of Children		
Z Score	Indicator of Undernutrition	
	Description	Type
Height-for-Age Weight-for-Height	Stunting Wasting	Chronic Acute

The Z score is described as a standard WHO technique to compare the local population with an international reference population. The Z score measures the number of standard deviations from the median while stunting and wasting are defined as two or more standard deviations below the median. The nutritional status of children is summarized below. The illustrations shows that the prevalence of stunting increases with age up to about 2 years while wasting may persist a little longer at least in girls.

Summary of the Nutritional Status of Children				
Parameter	Z Scores			Prevalence of Stunting/ Washing (%)
	Mean	Range	SD	
Height-for-Age Weight-for-height	-1.44 -1.13	-5.77 to +2.95 -5.17 to +2.67	1.33 0.99	34.2 19.3



STUNTING



WASTING

The study found that 34.2% of children are stunted and 19 3% are wasted. There is considerable evidence to support this horrorfying conclusion (Daily News 1992, Gamage 1994 and IBRD 1991) and it appears that most rural children simply arn't getting enough to eat

Height-for-Age (stunting) is typically taken as an indicator of chronic undernutrition while weight-for-height (wasting) is considered an indicator of current undernutrition The implication is that weight-for-height is the preferred indicator of the impact of WSS interventions as wasting tends to increase following an episode of diarrhoea. Furthermore weight-for-height is a continuous variable and has more explanatory power than wasting which is a simple binary variable.

6.3 Impact on Diarrhoea

Reinterpretation of the published results of the Kurunegala Study is constrained by the focus on the impact of improved water sources (piped suppliers, protected shallow wells and particularly tube wells equipped with handpumps) compared with unprotected sources.

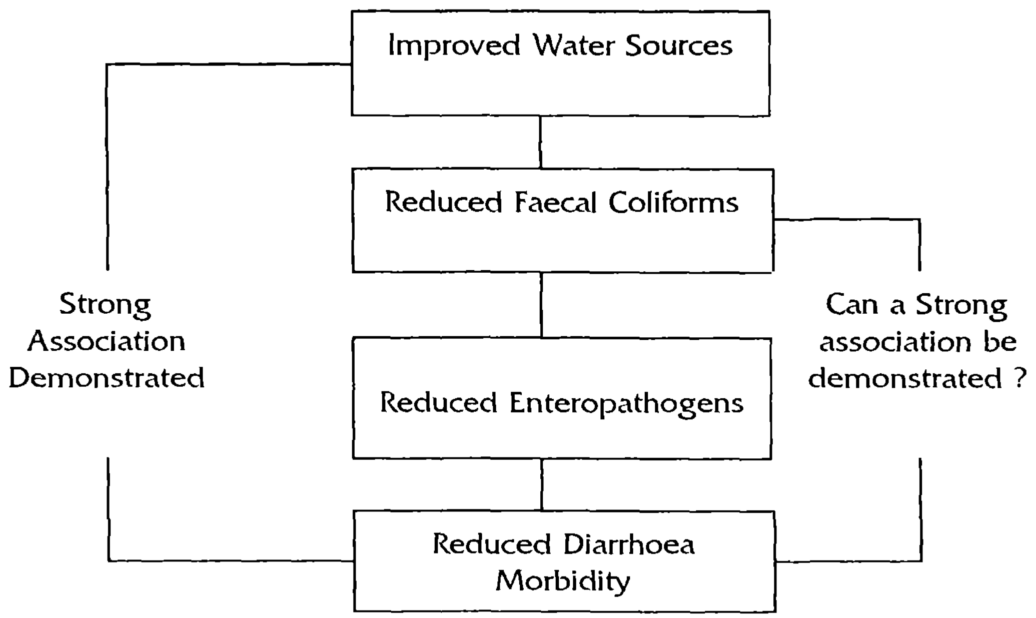
6.3.1 Improved Water Sources

The Relative Rate of Diarrhoea Morbidity associated with Improved Sources

Variable	Unit	Source of Water 1)				
		TW	PS	PW	IS	US
Relative Rate of Diarrhoea	Unit	**0.68**	**0.77**	**0.77**	**0.77**	**1.00**
95% C I upper limit	Unit	0.86	0.96	0 85	0.84	NA
lower limit	Unit	0.51	0.58	0.69	0.69	NA
Sample Size	No	281	287	4,058	4,626	1,837
Contamination Source	(%)	52	77	95	90	98
Mean FC (+ves only)	FC count	96	62	93	92	203
Mean FC (all samples)	FC count	50	48	88	83	199

Sources. Mertens et al 1990 c (diarrhoea) and Mertens et al 1990 b (water quality)
Note 1 TW = tube well equipped with handpump , PS = piped supplies ,
PW = protected well , IS = improved sources , US = unprotected sources
2 The relative rates are all significant at the 99 9% probability level

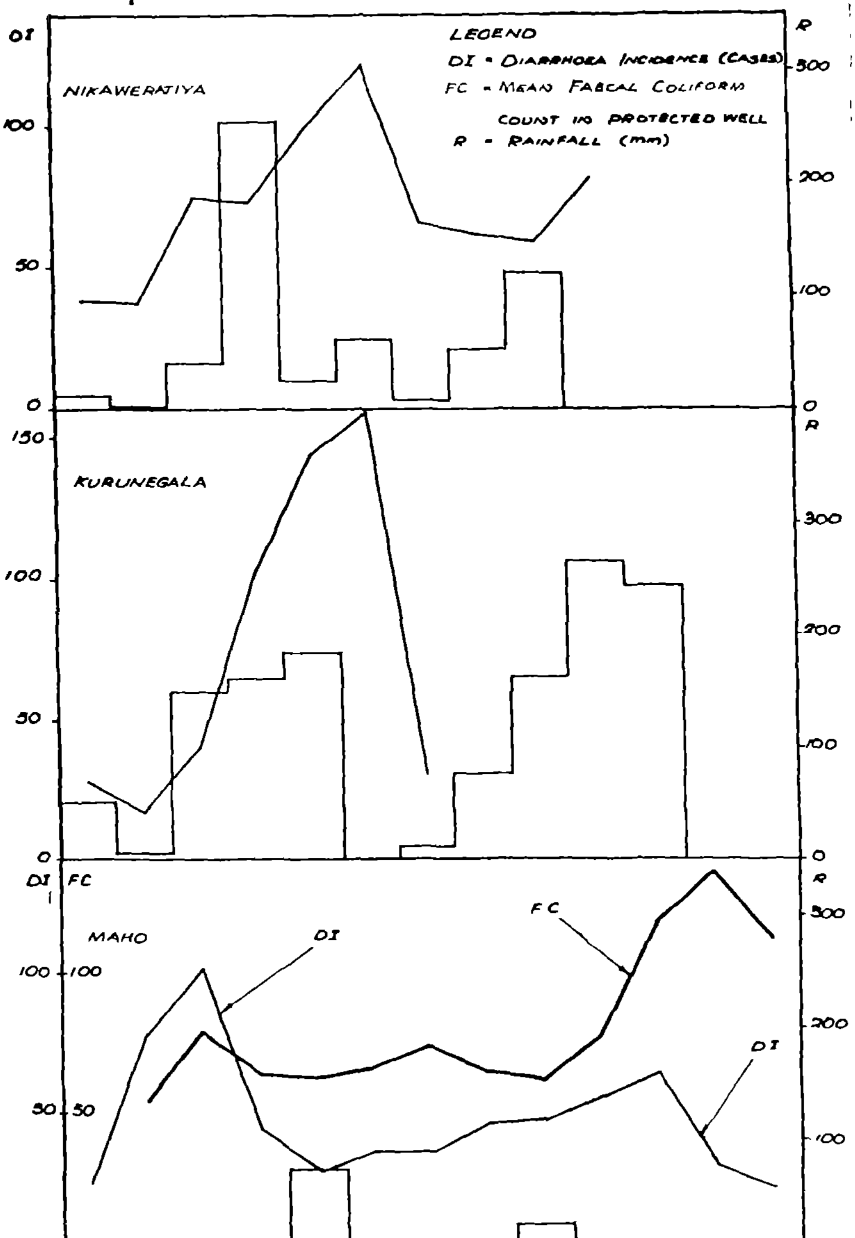
Children using tubewells equipped with handpumps suffer 32% less (i e. a relative rate of 0.68) diarrhoea compared with children using unprotected sources and a reduction of 23% is associated with the use of other improved sources i.e. standposts and protected wells. Mertens et al concluded that the incidence of childhood diarrhoea could be reduced by these amounts simply by achieving full coverage of improved sources. The type of water source is, however, only an indicator of faecal contamination which is itself an indicator of the enteropathogens which cause diarrhoea viz. :-



The Impact of Improved Water Sources on Diarrhoea Morbidity

6.3.2 Contamination of Water Sources

The assumed causal relationship between improved water sources and diarrhoea morbidity should be reflected in a strong association between source contamination and diarrhoea (the presence of enteropathogens was not measured directly). The association is explored below :-



The Seasonality of Diarrhoea and its Association with Contamination

The above figure shows that the incidence of diarrhoea is markedly seasonal. Diarrhoea increases when it rains. The figure also shows the monthly variation in contamination for Maho which is indicative of the general trend in all five areas. (Mertens et al 1990b) No association between contamination and diarrhoea is apparent i.e. contrary to intuitive expectation contamination is not seasonal.

The Association between Contamination of Protected Wells and Diarrhoea Morbidity 1)													
Variable	Unit	F	M	A	M	J	J	A	S	O	N	D	J
Incidence of Diarrhoea	cases	78	102	44	29	36	36	46	47	56	64	31	23
Mean FC (all samples)	FC	54	79	64	63	66	74	65	62	77	118	136	112

Source Figures in Mertens et al 1990a (diarrhoea) and Mertens 1990b (contamination)
Note 1. In Maho from February 1987 to January 1988 inclusive

Contamination of protected wells in Maho explained only 20% of the variation in diarrhoea and there is no significant association between the two variables.

The Impact of Improved Water Sources in different Areas						
Variable	Unit	Area of Recruitment				
		W	N	K	M	A
Relative Rate of Diarrhoea	Unit	**0.19**	**0.87**	**0.89**	**0.93**	**1.01**
95% CI upper limit	Unit	0 26	1 10	1.10	1.11	1.45
lower limit	Unit	0.13	0.72	0.68	0 75	0.57
Sample Size	No	269	274	289	415	131
Relative Polution of Sources	Unit	0.51	0 53	0.41	0.62	0 21

Sources Mertens et al 1990c (diarrhoea) and Mertens et al 1990b (water quality)
Note. 1 W = Wariyapola . N = Nikaweratiya, K = Kurunegala
M = Maho and A = Ambanpola hospitals
2 The relative rates of diarrhoea are all significant at the 99 9% probability level

Clearly there are substantial differences between the five areas :-

- Children using improved sources in Wariyapola suffer 81% less (relative rate of 0.19) diarrhoea compared with those using unimproved sources. Children in Ambanpola, however, suffer much the same rate of diarrhoea whether they use improved sources or not.
- Unimproved sources are more poluted particularly in Ambanpola where mean FC counts are nearly five times (relative rate of 0.21) those for improved sources.
- Contrary to intuitive expectations there is a negative association between the relative rates of diarrhoea and polution of sources. If unimproved sources are more poluted children using them tend to suffer less diarrhoea compared with improved sources eg. in Ambanpola compared with Wariyapola.

Reinterpretation of the Impact of Improved Water Sources

- The general association between improved water sources and reduced diarrhoea morbidity is spurious and has no practical significance as it is not confirmed by a positive association between source contamination and the incidence of diarrhoea in children.
- Surface runoff is not causing significant polution of shallow wells as FC counts don't peak during the wet season.

The issue of what then causes the very large differences in the relative rates of diarrhoea between the five areas is considered in the following section.

6.3.3 Environmental Contamination and Rates of Diarrhoea

The Impact of Improved Water Sources In different Areas						
Variable	**Unit**	**Area of Recruitment 1)**				
		W	**N**	**K**	**M**	**A**
Relative Rate of Diarrhoea	Unit	**0.19**	**0.87**	**0.89**	**0.93**	**1.10**
Incidence of Diarrhoea	%	27 0	34 4	45 6	35 6	59.5
Mean FC count (all samples)	FC	91	126	98	126	277

Sources Mertens et al 1990c (diarrhoea) and Mertens et al 1990b (water quality)
Note 1 W = Wariyapola , N = Nikaweratiya, K = Kurunegala
M = Maho and A = Ambanpola hospitals

The impact of improved sources appears to be very different in Wariyapola compared with the other four areas :-

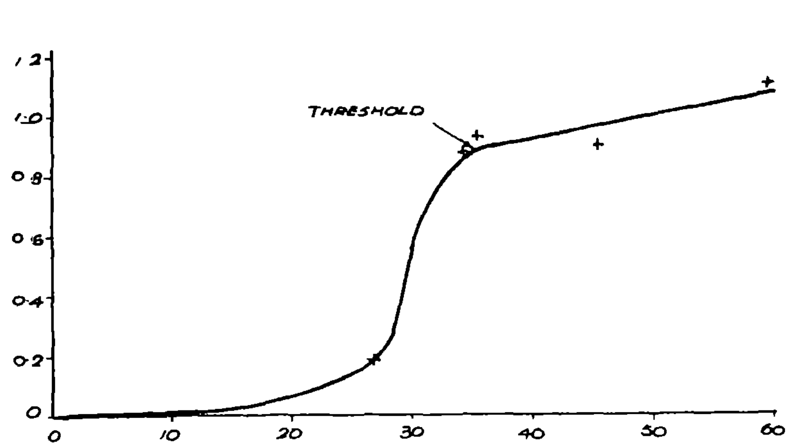
- The most significant simple correlation is with the incidence of diarrhoea which explains 76% of the variation in the relative rate of diarrhoea between the five areas and is significant at the 90% probability level.

- This is however inadequate to explain the very large impact of improved sources in Wariyapola as simple linear regression would predict a relative rate of only 0.51% (27% incidence) compared with the actual value of 0.19 (which is itself significant at the 99.9% probability level)

- The most significant simple correlation within the other four areas, is with the mean faecal coliform count for all samples which explains 97% of the variation in the relative rate of diarrhoea and is significant at the 99% probability level.

This clearly suggests confirmation of the findings of international studies i.e. water quality improvements will only produce significant impacts once other interventions have reduced environmental contamination and rates of diarrhoea (Esrey et al 1990). This is illustrated below.

Relative Rate of Diarrhoea improved vs. unimproved sources



Incidence of Diarrhoea Morbidity (%)

Impact of Improved Water Sources and Rates of Diarrhoea

Stratified analysis of 19 'extraneous' variables found that the following confounded the association between improved water sources and diarrhoea morbidity :-

Confounding of the Impact of Improved Water Sources		
Simultaneous Logistic Regression 1)	**Test for Homogeneity 2)**	
	5 areas	**4 areas**
Age	58	61
Period of recruitment	87	22
Distance from home	65	82
Hospital of recruitment	99.9	12
Time of return trip to water source	51	96 *
Latrine Use	69	94 *
Method of childs excreta disposal	36	15

Note. 1. The designated variables were included in the preferred regression equation.
2 * Indicates statistical significance at or near the 95% probability level.

The above presentation confirms the different nature of the interrelationship between independent variables in Wariyapola compared with the other 4 areas.

While the results don't quantify the interaction of sanitation and water consumption interventions they indicate they are likely to have a significant impact in all areas other than Wariyapola. The lack of results from a seperate analysis prevents similar conclusions regarding the most likely determinants of diarrhoea morbidity.

6.3.4 Improved Access and Consumption of Water

The time taken for the return trip to the drinking water source appeared to modify the effect of the type of water source. People who took more than six minutes for the return trip gained greater benefit from using improved sourceS. i.e. they suffered less diarrhoea. This effect is significant at the 96% level and implies a benefit to increased consumption although no significant association was found between consumption and the distance to the source.

The number of households sharing a water source was not considered as a variable. Data from another case study in a rural village in Sri Lanka are however available and are summarized below.

Access to Water and Incidence of Diarrhoea (%)			
Type of Shallow Well	**Drinking Water**		**Reduction (%)**
	Unboiled	**Boiled**	
Shared	52.1	25.0	27.1
Seperate	18.8	14.3	4.5
Reduction (%)	33.3	10.7	37.8

Source . Fernando 1986 quoted in Bradley and Karunadasa 1989

The results indicate that the use of separate wells in associated with a 64% reduction in the incidence of diarrhoea (from 52.1 to 18.8%). It also indicates that boiling of drinking water is only marginally beneficial if families enjoy access to a separate source.

6.3.5 Sanitation Interventions

Sanitation Practices and Diarrhoea Morbidity in Children						
Sanitation Practice	Classification	Households			Relative Rate	Significance
		Cases	Controls	Total		
Latrine Ownership	Yes No	578 837	947 1357	1,525 2,194	0 99	No
Latrine Use	Yes No	578 837	947 1357	1,525 2,194	0 99	No
Disposal of Faeces	Yes No	97 2,232	301 3,503	398 5,735	0 63	>99 9%

Source Mertens 1989

Note 1 Clinic and community control data on the prevalence of the disposal of childrens faeces in a latrine or clay pot

The data for latrine ownership and use are identical. The data appear to refer to latrine ownership, rather than use as they indicate a negligible benefit whereas latrine use was found to be a significant confounder of the association between the use of improved water sources and diarrhoea morbidity.

There was however strong evidence of a simple association between the disposal of childrens excreta and diarrhoea morbidity. Children whose mothers dispose of their faeces in a sanitary manner suffer 37% less (relative rate 0.63) diarrhoea compared with children who defecate outside. The association is highly significant at better than the 99.9% probability level. This compares most favourably with the 10% reduction due to the use of improved sources in the four areas other than Wariyapola.

6.3.6 Hygiene Practices

There is considerable potential for improved hygiene practices particularly those associated with sanitation and water consumption interventions. viz :-

- Handwashing was practiced by only 16%, and soap used by only 11%, of respondents
- While 42% of respondents had latrines only 8% used them to dispose of childrens faeces.
- On the other hand 33% of respondents always boiled their drinking water and 39% sometimes did ; presumably in response to the risk of epidemics.

6.3.7 Other Water Quality Interventions

Water Collection ; The quality of groundwater available from tubewells was assessed by sampling after sterilizing the mouth of the handpump. Less than 5% of samples were found to be poluted and only one FC count in excess of 150 and two in excess of 50 were found compared with 52% sample polution and a mean FC count (positives only) of 96 when samples were collected normally. It seems some polution is taking place during collection but it is difficult to envisage why.

The Effect of Storage and Boiling on Water Quality							
Location	**Variable**	**Unit**	**Source of Water 1)**				
			TW	**PS**	**PW**	**IS**	**US**
Source	Poluted Samples	%	52	77	95	90	98
	mean FC (+ves only)	FC	96	62	93	92	203
	mean FC (all samples)	FC	50	48	88	83	199
Stored	Poluted Samples	%	83	88	94	93	94
	mean FC (+ves only)	FC	64	99	101	97	144
	mean FC (all samples)	FC	53	87	95	91	135
Boiled	Poluted Samples	%	42	53	53	52	54
	mean FC (+ves only)	FC	55	52	103	96	71
	mean FC (all samples)	FC	23	28	55	50	38

Note 1 TW = Tube well equipped with handpump
PS = Piped Supplies , PW = Protected Well
IS = Improved sources , US = unprotected sources

Water Storage; The above results indicate very little polution is taking place during storage. Furthermore there was no evidence of an association between FC counts in stored water and the disease status of children.

Boiling of Drinking Water ; The results indicate the reported boiling of drinking water is not very effective in reducing polution. There is no evidence of a direct link between the practice and the incidence of childhood diarrhoea.

6.4 Impact on Nutritional Status

Nutritional status is presented first because the analysis was more comprehensive and considered a number of WSS interventions whereas the investigation of diarrhoea morbidity concentrated on interventions which influence water quality. The results of the associations between WSS interventions and weight-for-height Z score and wasting are summarized below.

Impact of WSS Interventions on Weight-for-Height and Wasting

Exposure	Outcome	Wasting Odds Ratio		Mean Z Score		Significance 1)	
		Crude	Adjusted	Crude	Adjusted	Crude	Adjusted
Water Quantity							
Consumption	<10lcd	1.00	1.00	-1.07	-0.92	**0.002**	**0.02**
	10-20 lcd	1.06	0.84	-1.24	-1.03	0.34,3.28	0.46,1.54
	>20 lcd	0.71	0.99	-1.02	-0.85	0.39,1.28	0.66,1.48
Presence of Soap	yes	1.00	1.00	-1.14	-0.82	**0.99**	**0.19**
	no	1.18	1.52	-1.14	-1.04	0.67,2.08	0.58,3.95
Handwashing (Food Prep)	yes	1.00	1.00	-1.20	-1.03	**0.27**	**0.19**
	no	1 04	0.88	-1 12	-0.83	0.49,2.23	0 39,1.19
Sanitation							
Latrine Ownership	yes	1.00	1.00	-1 11	-0.90	**0.50**	**0.39**
	no	1 04	0 99	-1.15	-0 96	0.68,1.57	0 29,1 02
Disposal of Faeces	yes	1 00	1.00	-1.21	-0.90	**0.50**	**0.62**
	no	0.81	0 82	-1 13	-0.96	0.44,1.48	0.44,1.52
Water Quality							
Type of Source	piped	1.00	1.00	-1.40	-0.96	**0.22**	**0.39**
	handpump	0.84	1.73	-1 07	-0.90	0 00,1.97	0 29,10 3
	prot.well	0.52	1.10	-1.10	-0.88	0.09,2 90	0 20,5 92
	unimproved	0.67	1.29	-1 20	-0.99	0 06,7.10	0.23,7.12
Boiling of Water	always	1.00	1.00	-1.12	-1.04	**0.95**	**0.05**
	sometimes	0.90	0.71	-1 13	-0 87	0 62,1.31	0.47,1.05
	never	0.69	0.43	-1.15	-0 89	0.47,1 02	0 27,0.71

Notes 1 Statistical Significance eg of the association between consumption and nutritional status
0.002 = the probability of a general association between the intervention and
0 34,3 28 = the 95% confidence interval of the wasting odds ratio

There is a significant association between water consumption and both wasting and the mean Z score while the presence of soap shows considerable promise as a scondary explanatory variable

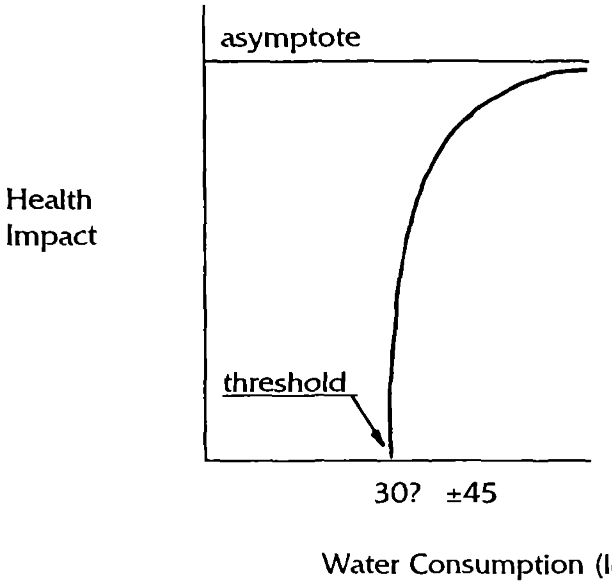
Statified analysis, of the association between each outcome and exposure of interest, were performed to control for possible confounding. The following cofounders were selected on the basis of the magnitude of the change in the odds ration ; age of the child, area and month of recruitment, fathers education and employment, mothers education and size of the families house.

Logistic regression (wasting) and analysis of variance (Z score) models were then constructed. The first pair of models used all the cofounders listed above and all the exposures of interest, except the method of disposing of the childs stools. Because the high cross-correlation is obvious the method of stool disposal replaced latrine ownership in the second pair of models. The estimates given above are those obtained from the first pair of models except for stool disposal which is taken from the second pair of models.

This raises the need for more systematic consideration of the cross-correlations between independent variables (why recognize the association between latrine ownership and disposal of stools and not that between handwashing and the presence of soap etc. ?) In particular the results presented above appear to represent the difference between samples, eg with and without latrines, with all other variables adjusted to provide a standard basis for comparison. This approach fails to take full advantage of the explanatory power of the stepwise multiple regression based on the analysis of variance (Haan 1977). This procedure consists of building the regression equation one step at a time by starting with the highest simple correlation and adding at each step the variable that explains the largest amount of the remaining unexplained variation (NB. not necessarily the next tested separately for significance. The procedure continues until all significant variables are included and all insignificant variables excluded. The original data was amendable to such analysis as the highest simple correlation is between weight-for-height Z score and water consumption which are both continuous variables. The other binary variables could be treated as dummy variables. Unfortunately the original data are not available to support such refined analysis.

6.4.1 Water Consumption and Hygiene Practices

The most significant simple correlation is between water consumption and the weight-for-height Z score which is highly significant at the 0.2% probability level and remains so (2%) after indiscriminate controlling for confounding variables. The association between water consumption and wasting is also significant (3% simple and 1% adjusted) These associations should however be treated with some caution as it is only consumption above a threshold (± 30 lcd ?) which is likely to be associated with improved hygiene and impact on health status. Only 44% of respondents used more than 20 lcd. Furthermore the relationship is unlikely to be linear but to show decreasing returns to consumption beyond the optimum 45 lcd established by WHO. This is illustrated below and makes the health impact of increased consumption difficult to quantify.



Conceptual Model of the Impact of Increased Consumption

The presence of soap in the house also shows promise as an explanatory variable as it is associated with less wasting and heavier children (mean z score) especially after controlling for confounding variables. Furthermore only handwashing before food preparation was considered and the use of soap for handwashing both after using the latrine and before eating and food preparation is likely to be a more powerful explanatory variable.

6.4.2 *Water Quality and Sanitation Interventions*

There is no evidence of a simple correlation between either the weight-for-height Z score or wasting and any water quality or sanitation intervention. However the possibility of a secondary association can't be ruled out without performing the type of stepwise analysis described above.

It should be noted that there is a significant negative association between health status and the boiling of water after controlling for confounding variables i.e people who drink boiled water appear to be more underweight and suffer more wasting not less of each as might be expected. The authors of the study observe that it is likely the association arose by chance (Mertens et al 1990d). There may however be a rational explanation if people who use poor quality water are more inclined to boil their drinking water and boiling is not entirely effective in eliminating pathogens. This may also improve the association between health impact and the type of water source.

sds/1/mtsc/cfhe1/ March 2, 1994

REFERENCES

Esrey, S.A. et al 1990 Health Benefits from Improvements in Water Supply & Sanitation: Survey and Analysis of the Literature on Selected Diseases. Water and Sanitation for Health Project Tech Report No. 66

Feachem, R.G. 1986 The Role of Water Supply and Sanitation in Reducing Mortality In China, CostaRica, Kerala State (India) and Sri Lanka London School of Hygiene and Tropical Medicine.

Kumarasiri, S. 1984 Personal Communication

Mertens, T.E. 1989 Health Impact Evaluation of Existing Water Supplies in the District of Kurunegala, Sri Lanka Department of Epidemiology and Population Sciences London School of Hygiene and Tropical Medicine.

Mertens, T.E. et al 1990 a Health Impact Evaluation of Improved Water Supplies and Hygiene Practices in Sri Lanka : Background and Methodology Trop. Med. Parasit 41 (1990) 77

Mertens, T.E. et al 1990 b Determinants of Water Quality, Availability and Use in Kurunegala, Sri Lanka op. cit.

Mertens, T.E. et al 1990 c Childhood Diarrhoea in Sri Lanka : A Case-Control Study of the Impact of Improved Water Sources op. c.t.

Mertens, T.E. et al 1990 d The Anthropometric Status of Children in Kurunegala Disitrct in Sri Lanka : its Relation to Water Supply, Sanitation and Hygiene Practices op. cit.

Mertens, T.E. et al 1990 e Microbiological Agents Asscociated with Childhood Diarrhoea in the Dry Zone of Sri Lanka op cit.

Sandiford, P. and Gorter, A. 1992 Polution of Protected Wells A Literature Review and Terms of Reference for Applied Research ; London Associates in Tropical Health prepared for Cowater International Inc.

Simpson L. 1992 Health, Baseline and Other Project Studies Review of Current Plans and Reccommendations Environmental Sanitation and Water Supply Project Indonesia

Wibowo, D. and Tisdell, C. 1993 Health, Safe Water and Sanitation A Cross- Sectional Health Production Function for Central Java, Indonesia ; Bulletin of WHO 71(2) 237 - 245

Appendix F

DRAFT PROPOSAL
for a
WELL POLUTION STUDY

25 May 1993

Table Of Contents

PROPOSED WELL POLUTION STUDY

25 May 1993

1. Background

Recent reports found protected wells, are as polluted with faecal coliforms as unprotected wells (Cowater 1991 and Haskoning 1991).

2. Hypotheses

The study is designed to test the following hypotheses.

2.1 Epidemiological Risk

Faecal coliforms (E-coli) analysis alone is an inadequate indicator of epidemiological risk as both cholera and typhoid are relatively fragile organisms whose sole reservoir is man. (Bradley 1977).

2.2 Shallow Well Polution Mechanisms

These are three mechanisms of polution of shallow wells each with different implication for CWSSP programme design. These are:-

- **Groundwater polution** particularly from latrines where contamination is limited to human wastes.
- **Surface water polution** from runoff following rainstorms which drains into open wells and is likely to be contaminated with both human and animal wastes. Anecdotal evidence suggests epidemics are also seasonal.
- **In-situ polution** associated with unhygienic water extraction practices eg. contamination of the bucket. Polution levels would be related to the number of users.

2.3 Groundwater Contamination Model

Groundwater contamination by latrine effluent is influenced by local hydrageological conditions and the number and location at latrines rather than a single factor. The model illustrated in Figure I is postulated.

2.4 *Simple Indicator of Groundwater Polution*

Not withstanding the above there is a need for a simple indicator to predict groundwater polution levels for planning purposes i.e. to locate wells relative to latrines and visa versa.

3. *Purpose and Methodology*

The proposed well study is intended to :-

- Determine the seasonal variation of well polution and the origin of faecal contamination i.e. human or animal.
- Evaluate the relative importance of the alternative three well polution mechanisms.
- Verify the accuracy of the proposed groundwater contamination model.
- Test the distance to the nearest latrine as an indicator of groundwater polution.

Measurement of the following variables is proposed to provide a basis for multiple regression analysis.

TABLE I : Variables to be Measured

PARAMETER		UNIT
Symbol	Description	
F_c	Faecal coliform (E-coli)	No/ 100mg
F_s	Faecal streptococci	No/ 100mg
S	Season i.e. wet or dry	W/D
P	Well protection	Y/N
U	Well use	HH
k	Hydraulic conductivity *	m/day
i	Hydraulic gradient *	m/m
h	Latrine height above WT *	m
n	Latrines upstream of latrine *	No
d_u	Distance to upstream latrine *	m
d_e	Distance to nearest latrine *	m

Note* : Groundwater polution model variables see Fig I.

4. *Well Sample Selection*

The Selection of wells requires careful consideration to ensure a representative sample. 24 shallow wells should be selected for study of which 12 should be adequately protected ad the others should have no effective protection from surface runoff. The sample chosen should have the following characteristics.

TABLE 2: Characteristics of Wells Sample

Distance to Latrine(m) 1)	Sample Size (No)		Well Users (HHs)2)	Sample Size (No)	
	Protected	Unprotected		Protected	Unprotected
0 - 10	3	3	1	3	3
10 - 20	3	3	2-4	3	3
20 - 30	3	3	5-8	3	3
30 - 50	3	3	9-15	3	3
TOTAL	12	12	**TOTAL**	12	12

Notes: 1. The simple distance to the nearest latrine is adequate.
2. Wet season well users.

Wells in the vicinity of concentrated sources of animal waste should be excluded from the sample.

5. *Measurement of Parameters*

5.1 *Human Faecal Polution*

Faecal Coliform (E-coli) analysis is the accepted test for recent faecal polution while concurrent testing for Faecal Streptocci allows calculation of the FC/FS ratio which is an indicator of the origin of polution i.e. human or animal. Because of their survival characteristics, however, faecal streptocci should not be used alone as an indicator of water quality (Millipore 1986) viz:-

TABLE 3: Interpretation of the FC/FS Ratio

FC/FS Ratio	INDICATIVE ORIGIN OF POLUTION
> 4.0	Polution derived from human wastes
2.0 - 4.0	Predominance of human wastes in mixed polution
1.0 - 2.0	Uncertain interpretation (sample nearer source)
0.7 - 1.0	Predominance of animal wastes in mixed polution
< 0.7	Polution derived from livestock or poultry

Source: Millipore 1986

FIELD TESTING and LAB VERIFICATION

5.2 Seasonal Variation

FREQUENCY of TESTING (WS and DS)

5.3 Well Protection

Wells should either be adequately protected or completely unprotected. Partially protected wells should be excluded from the sample. Adequate protection requires provision of the following effective measures:-

- Wellhead i.e. parapet wall and apron
- Lining of the upper well shaft and
- Drainage to divert surface runoff

APPENDIX A : REFERENCES

Bradley, D.J. 1977	*Health Aspects of Water Supplies in Tropical Countries in Water, Wastes and Health in Hot Climates* *Feachem, Mc Garry and Mara eds; Wiley.*
Cowater 1991	*Rural Water Supply* *District Development Plans* *Matara, Ratnapura and Badulla Districts* *Cowater International Inc.*
Haskoning 1991	*Rural Water Supply and Sanitation* *Sector Development Planning Project* *District Development Plans* *Kegalle, Kalutara and Monaragala Districts* *Royal Dutch Consulting Engineers and Architects*
Millipore 1986	*Water Microbiology; Laboratory and Field Practices* *Millipore Corporation.*