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Centre for Ecology & Hydrology

Centre for
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NATURAL ENVIRONMENT RESEARCH COUNCIL

Formerly the Institutes of Hydrology, Terrestrial Ecology, Freshwater Ecology, and Virology and Environmental Microbiology

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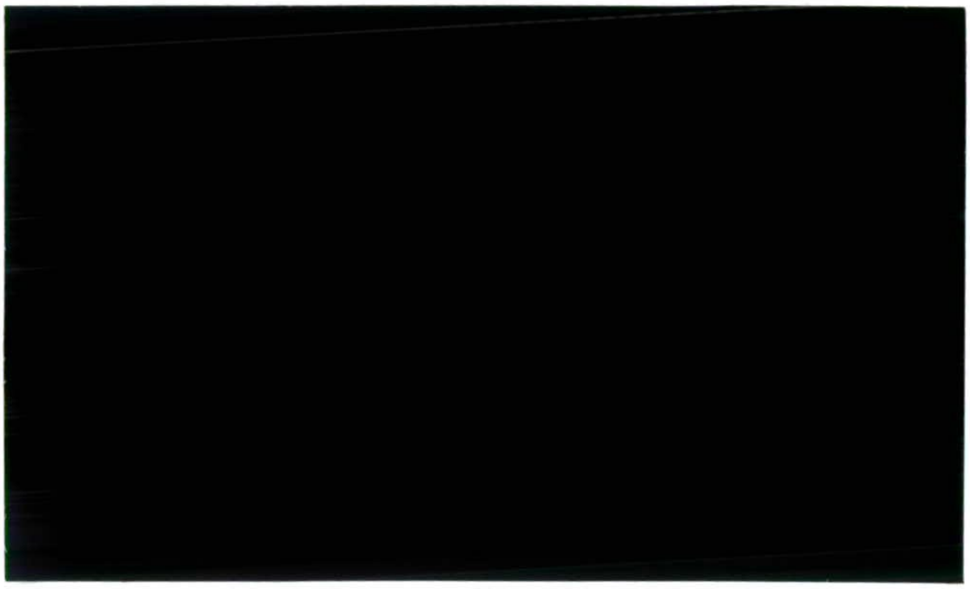

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- To advance the sciences of ecology, environmental microbiology (including virology) and hydrology through high-quality and internationally recognised research leading to a better understanding and quantification of the physical, chemical and biological processes relating to land and freshwater and living organisms within these environments
- To investigate, through monitoring and modelling, natural changes in the ecological, microbiological and hydrological environments, to assess both past and future changes, and to predict man's impact on these environments
- To secure, expand and provide ecologically and hydrologically relevant data to further scientific research and provide the basis for advice on environmental conservation and sustainable development to governments and industry
- To promote the use of the Centre's research facilities and data, to provide research training of the highest quality and to enhance the United Kingdom's research base, industrial competitiveness and quality of life.

Derivation and Testing of the Water Poverty Index Phase 1.

Final Report May 2002

Volume 2- Technical Appendices I

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DFID Department For International Development

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Appendix 1

Data analysis

In this appendix, we are focusing mainly on analysing the results obtained by using the time approach and composite approach at micro and macro level. A description of the gap approach is also included.

In section 1.1 all the data used in each of the WPI approaches are listed. Section 1.2 is entirely dedicated to the composite approach; here it is possible to find a detailed description of all the variables used in the calculation of the composite index and an analysis of the results within each country. In section 1.3 the results from the time analysis approach are shown and analysed by comparing them with the composite approach results. Section 1.4 explores the gap approach, the way it could be calculated and analyses the similarity of this approach with the composite one. Section 1.5 introduces how the composite approach has been applied at macro level.

Appendix 1.1

Data used for the WPI Calculations

Structure of Index and Data Used

WPI Component	Data Used
Resources	• internal Freshwater Flows • external Inflows • population
Access	• % population with access to clean water • % population with access to sanitation • % population with access to irrigation adjusted by per capita water resources
Capacity	• ppp per capita income • under-five mortality rates • education enrolment rates • Gini coefficients of income distribution
Use	• domestic water use in litres per day • share of water use by industry and agriculture adjusted by the sector's share of GDP
Environment	indices of: • water quality • water stress • environmenal regulation and management • informational capacity • biodiversity based on threatened species

Macro Data requirements collected from national and international institutional sources (Where possible, collect for 1990 and 1995, and rates of change over decades)

Data Item	Source
1. Official population for pilot sites and local government management unit (Arusha)	1. National statistics office
2. Rate of pop growth over last decade	2. National statistics office
3. Population density, local, regional and national	3. Nat.stats office and World dev rept 2000/01
4. Infant mortality rate, local regional and national	4. National statistics office
5. Under 5s mortality rate , local regional and national	5. National statistics office/ World dev rept 2000/01
6. Per capita / per hh water consumption (may need to be estimated from larger scale data)	6. Municipal water authority
7. Total water abstractions for domestic supply	7. Local water authority
8. Total water abstractions for agricultural and industrial sectors	8. Local water authority
9. percentage of households in pilot sites and local municipal areas having water access within household	9. Local water authority
10. percentage of households abstracting water from protected sources	10. Local water authority/ World dev rept 2000/01
11. percentage of hh with access to improved water source	11. Local water authority/ World dev rept 2000/01
12. Percentage of households in pilot sites and local municipal areas with sewage connection	12. Local water authority/ World dev rept 2000/01
13. Percentage of households in pilot sites and local municipal areas with latrine provision	13. Local water authority
14. Estimation of sedimentation load in nearest major river (upper Pangani)	14. Arusha / Pangani water authority
15. percentage of municipalities where communities are represented by water user groups	15. National water authority (min of water and livestock)
16. Institutional maturity - political representation	16. World dev rept 2000/01?
17. Total area of cultivated land	17. National statistics office/ministry of agriculture
18. percentage of cultivated land under irrigation	18. National statistics office/ministry of agriculture/ World dev rept 2000/01
19. Rate of soil erosion	19. National statistics office/ministry of agriculture
20. Top five major crops as % of total agricultural output	20. National statistics office/ministry of agriculture
21. Top five major industries as % of total manufacturing output	21. National statistics office/international

	datasets
22. Total area covered by wetlands, as percentage of total national area	22. Local Env. Ministry
23. Number of threatened invertebrate species	23. Local or international env groups and NGO sources
24. Number of threatened fish species	24. Local or international env groups and NGO sources
25. Incidence of floods / droughts in the last 10 years	25. Local or international env groups and NGO sources, local environment ministry
26. Energy use per capita by region	26. Local or international env groups and NGO sources, local environment ministry
27. data on hh water use from previous surveys (incl. gender distributions)	27. Uof DES
28. hh time spent on water collection	28. Uof DES
29. GDP per capita by region, and percentage value added by sector	29. World dev rept 2000/01
30. consumption of energy per capita	30. World dev rept 2000/01
31. percentage of total expenditure on goods and services	31. World dev rept 2000/01
32. Number of radios per 1000 of population	32. World dev rept 2000/01
33. Food productivity index	33. World dev rept 2000/01
34. Net enrolment ratio in primary and secondary education	34. World dev rept 2000/01
35. Access to improved water supply, rural and urban % of pop	35. World dev rept 2000/01
36. Nationally protected areas, % of total area	36. World dev rept 2000/01
37. Food production index	37. World dev rept 2000/01
38. Paved roads, % of total	38. World dev rept 2000/01
39. Gini coefficient	39. World dev rept 2000/01
40. percentage of total income held by lowest 10% income group	40. World dev rept 2000/01
41. Adult literacy rate (% of total pop)	41. World dev rept 2000/01
42. % pop below national poverty line	42. World dev rept 2000/01
43. % pop below $1 per day	43. World dev rept 2000/01
44. prevalence of child malnutrition (% malnourished under 5s)	44. World dev rept 2000/01
45. Official development assistance as percent of GNP	45. World dev rept 2000/01
46. External debt as percent of present value GNP	46. World dev rept 2000/01

Sources of data for national level WPI components

WPI component	
Resource	World Resources Institute, 2000 Table FW.1, and Gleick, 2000. Shiklomanov (1997) has compiled a comparison of water resources data for a selected, but large, range of countries from different sources, including the WRI, Gleick and his own State Hydrological Institute. The original WRI data has been adjusted to take account of the variation in estimates of water resources by taking the modal estimate. The most striking discrepancy was in the case of Peru, which WRI says has 1746 billion cubic metres of internal freshwater flows (69,000 per capita), while all other estimates have at 40 billion cubic metres (1,600 per capita). The World Bank's Development Indicators also quote the former number and the WRI as the source, although earlier years of the WRI's data have the latter estimate. **Population:** World Resources Institute, 2000 Tables HD.1 and SCI.1 and HDR, 2001
Access	World Resources Institute, 2000 Table HD.3, and HDR 1999 Irrigation - World Resources Institute, 2000 Table AF.2. and Gleick 2000 (irrigation) with cropland areas from *World Resources Institute (2000) 2000-01* Table SCI.1.
Capacity	GDP - HDR 2001 Under-5 mortality - World Resources Institute, 2000 Tables HD.2 and SCI.1 (7) Education - HDR 2001
Use	Gleick, 2000 and World Resources Institute, 2000 World Bank, 2001
Environment	World Economic Forum, Yale Center for Environmental Law and Policy, and Center for International Earth Science Information Network, Columbia University, *2001 Environmental Sustainability Index* (http://www.ciesin.columbia.edu/indicators/ESI), January 2001.
Other	HDI- HDR 2001; Health : HDR 1999

Appendix 1.2
Calculation of the Composite Index approach at micro level

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1.2.1 Introduction

The structure of the composite approach is based on the approach used in the *Human Development Index* (HDI). Various elements measured in different unit are aggregated together by first scoring them and then adding them using a weighting system as follows:

$$WPI = w_r R + w_a A + w_c C + w_u U + w_e E$$

with the condition that

$$w_r + w_a + w_c + w_u + w_e = 1$$

where *R*, *A*, *C*, *U* and *E* stand for:

R = water resource availability
A = access to water
C = capacity
U = water use
E = environment

These are the criteria that have been identified to represent the level of poverty that is water related. As each of these criteria are measured by a different unit, in order to aggregate them, they have to be converted to an index score ranging from 0 to 100. The score derived for each component has been calculated in a way that the higher is the value the better it is, so that the higher the WPI is the better a village isin terms of water and poverty level.

The weight given to the elements w_i, represents the relative importance given to each of the them. The weightings have to be chosen in a way that their sum is always equal to 1, this has the effect of creating a trade off between the criteria.

The WPI, obtained using the composite approach, has been calculated both at macro (see section **1.4**) and micro level. This section is looking entirely of how it has been applied at the micro level. The data used to calculate WPI at the micro level are mainly derived from the surveys that have been carried out in four villages for each of the three countries chosen to test the WPI. The three countries were: South Africa, Tanzania and Sri Lanka. If a component was believed to be essential in explaining the water poverty level, but the data were not contained in the survey, data derived from national statistics were used instead.

Each of the 5 WPI components listed above has been obtained by aggregating a set of sub components by again using the composite approach. In other words, each of the five components forming the WPI is itself an index. In the following sections, we describe how each sub index has been derived.

1.2.2 How the various components have been calculated

The first step to create the WPI is to convert all the components' values into a score system. As the score system selected goes from 0 to 100, two extreme values for each component need to be selected: a) the highest value of the set (or a round up of the highest value) will be converted to 100 (if the higher the component, the better off the household; ie: %of access to protected water) or 0 (if the higher the component, the worse off the household; ie: total time); and b) the lowest of the set (or a round down of the lowest value) will be converted to 0 (if the higher the component, the better off the household; ie: %of access to protected water) or 100 (if the higher the component, the worst off the household; ie: total time).

All the components and subcomponents are described one by one in the sections below; next to each explanation there will also be the associated values obtained from the household surveys, the score values and the ends points to derive the scores.

It is important to say that the development and calculation of the WPI is still at an initial stage. We are aware of the fact that many improvements can be made in later iteration of the WPI structure.

1.2.3 R – Resource

This component shows the water availability indicator values that have been calculated by using the following three factors:

- Water amounts (in litres/capita/day)
- Reliability and/or variability of the water supply
- Quality of the water

The indicators values range from 0 to 10, as follows:

0 Effectively zero usable water
1 Very poor
2-9 Intermediate levels from poor to very good
10 Excellent

For a full detailed explanation of how the water availability indicator has been calculated please see Appendix 3.

South Africa	score
Ethembeni	5
KwaLatha	2
Wembezi informal	5
Wembezi formal	5

The end points for this set of values have been chosen to be:

10	*scores 100*
0	*scores 0*

Resource

Score
50
20
50
50

Tanzania	score
Nkoaranga	3
Samaria	2
Majengo	1
Kijenge	2

The end points for this set of values have been chosen to be:

10 *scores 100*
0 *scores 0*

Resource Score
30
20
10
20

Sri Lanka	score
Agarauda	2
Awarakotuwa	1
Tharawaththa	2
Tissawa	2

The end points for this set of values have been chosen to be:

10 *scores 100*
0 *scores 0*

Resource Score
20
10
20
20

1.2.4 A – Access

This component tries to capture the level of access to water that a population is able to get. Access has been obtained aggregating the following 7 components:

- *Total time*
- *Gender*
- *Sanitation*
- *Irrigation potential*
- *No conflicts*
- *% pipe in house*
- *% access to protected water*

The values for the seven components of access and the associated scores are shown below.

Total time (minutes/day)

This component is the average time spent collecting water (minutes/day) by households in the village, this includes the time to get to the source and queuing. This component has been calculated using two types of data:

a) for those households that have got a pipe in the house, it has been assumed that they spend a nominal 2 minutes to collect water; and

b) for those that have not got a pipe in house and therefore need to travel to collect water, we have used data from the household survey. For those households, the total time has been obtained by multiplying together "the average time spent in each trip" by an individual of the household and the "total number of people" from each household carrying water during the day.

From this, a villages average time to collect water has been calculated by averaging the village households' total time. The village average total time was calculated both for the dry and wet seasons.

The tables on the left list the average time spent collecting water in each village, the table on the right shows the score that each time value has been converted to. In the middle are shown the two end points used to convert the values on the left table into the scores shown in the right table.

As a village is better off if its households do not spend too much time and effort in collecting water, the highest value (the top value) for time will obtain score 0 and the lowest value (the bottom value) the score 100.

Given the large variation in time spent collecting water across the three countries, selecting the largest value in the three countries (Samaria in Tanzania) as the value obtaining the score 0 would squeeze the rest of the other values around 100 (as these are quite far away from the Samaria result) without being able to discriminate very much among them. To avoid this, different end points for each country have been selected. However this will make the countries incomparable. For each country subset the highest score (100) will be given to zero minutes and the lowest score (0) to the 5% round up of the highest of the dry and wet season time values.

The data below refers to the total time spent to collect water during the dry season. The same end points have been used for the wet season.

South Africa	Minutes/day
Ethembeni	154.5
KwaLatha	295.9
Wembezi informal	142.1
Wembezi formal	2.5

The end points for this set of values have been chosen to be:

0 minutes *scores 100*
315 minutes *scores 0*

Total Time

Score
63
30
66
99

In South Africa KwaLatha is the village whose households spend on, average, the most time in collecting water. Wembezi (formal) spends less time overall in collecting water because there is a higher percentage of people with a pipe in the house.

Tanzania	Minutes/day
Nkoaranga	120.3
Samaria	595.3
Majengo	172.6
Kijenge	57.0

The end points for this set of values have been chosen to be:

0 minutes *scores 100*
625 minutes *scores 0*

Total Time

Score
81
5
72
91

Households in Samaria spend on average 10 hours getting water to the village. Kijenge is instead the one better off in terms of collection time. As in Wembezi (formal), Kijenge has got more infrastructure in place.

Sri Lanka	Minutes/day
Agarauda	28.8
Awarakotuwa	119.5
Tharawaththa	127.8
Tissawa	42.7

The end points for this set of values have been chosen to be:

0 minutes *scores 100*
134 minutes *scores 0*

Total Time

Score
79
11
5
68

Unlike South Africa and Tanzania where the village with lowest total time score is a rural one, in Sri Lanka both the urban villages have the lowest time score. Infact, in Sri Lanka the urban areas are very densely populated and do not have a very good infrastructure.

Gender

This component shows how many out of the total number of people from each household carrying water during the day are men. This component has been included into access to show the gender discrimination in carrying water. If the percentage is low it means that women and children are mainly carrying water. Up to a certain level (50%) the higher the percentage of men carrying water the better it is, after that the score reduces.

South Africa	Men %
Ethembeni	7%
KwaLatha	4%
Wembezi informal	16%
Wembezi formal	33%

The end points for this set of values have been chosen to be:

50 % *scores 100*
0% *scores 0*

Gender

Score
14
8
32
67

KwaLatha has scored the lowest value. This means that the majority of people in KwaLatha collecting water for the household are women and children.

Tanzania	%
Nkoaranga	11%
Samaria	19%
Majengo	1%
Kijenge	10%

The end points for this set of values have been chosen to be:

50 % *scores 100*
0% *scores 0*

% men

Score
23
38
1
19

In Majengo women are mostly collecting water, however the average time spent collecting water is much lower than in Samaria and Nkoaranga. So, in Majengo there are proportionally more women involved in the collection of water than in Samaria but the effort required to collect the water is much less. One possible reason why there are more women in Majengo collecting water, is that in Majengo there is the highest percentage of households earning a salary, and very often it is the man who has the job so women are left with the task of collecting water.

Sri Lanka	Minutes/day
Agarauda	28%
Awarakotuwa	36%
Tharawaththa	10%
Tissawa	33%

The end points for this set of values have been chosen to be:

50 % *scores 100*
0% *scores 0*

% men

Score
55
72
20
65

In both South Africa and Sri Lanka the villages that have to spend more time in collecting water are in general the poorest ones (as it will be seen in the capacity component), and also experiencing more gender discrimination; where instead the villages that have a better capacity components are also the once experiencing less gender discrimination.

In Tanzania it is a bit different probably because in Samaria there is such a great shortage of water that men also need to be involved in the collection of water to be sure to have the minimum of water per capita.

Sanitation

This is the percentage of household with access to sanitation. This is the only data in access that has not been derived from the household survey. Information from available regional or national statistics was used instead. More precisely, the Sri Lanka data were obtained from the National Water Supply and Drainage Board; the Tanzania data respectively from Ameuru District council and Arusha Urban Water Supply Authority; and South Africa data from Statistics South Africa.

South Africa	%
Ethembeni	32
KwaLatha	32
Wembezi informal	68
Wembezi formal	68

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Sanitation

Score
32
32
68
68

In South Africa the urban villages have a better infrastructure both in terms of water supply and sanitation.

Tanzania	%
Nkoaranga	4
Samaria	0
Majengo	4
Kijenge	4

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Sanitation

Score
4
0
4
4

In Tanzania the situation seems quite homogenous across the urban and rural areas, with the exception of Samaria that does not have any sanitation infrastructure.

Sri Lanka	%
Agarauda	70
Awarakotuwa	50
Tharawaththa	40
Tissawa	75

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Sanitation

Score
70
50
40
75

In Sri Lanka, the urban villages not only spend more time collecting water but they also have a worse sanitation system than the rural area, unlike South Africa where the sanitation is better in the urban area.

Irrigation potential

This is the proportion of households cultivating land that had at least one loss of crops due to drought in the last five years. This component captures the level of access to water for crops in terms of irrigation and rainfall. If there is good irrigation and/or good rainfall the probability of loosing the crops from drought is lower. The more crops they have lost the worse off they are, consequently the score is set in a way that the higher the percentage of households with loss of crops the lower the score for that village. It was decided to give no score to the urban villages obtaining 0% for the irrigation potential component. In fact, for the urban villages 0% irrigation potential did not mean that there are no households irrigating land who had experienced loss of crops in the last 5 years but instead it meant that households do not cultivate at all.

South Africa	% loss of crops
Ethembeni	77%
KwaLatha	87%
Wembezi informal	84%
Wembezi formal	0%

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

Irrigation potential

Score
23
13
16

Tanzania	% loss of crops
Nkoaranga	80%
Samaria	95%
Majengo	
Kijenge	0%

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

Irrigation potential

Score
20
5

Sri Lanka	% loss of crops
Agarauda	90%
Awarakotuwa	
Tharawaththa	
Tissawa	77%

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

Irrigation potential

Score
10
23

No Conflicts

This is the percentage of household in a village stating that there are not conflicts over the access to water. In the household survey it was asked if there were conflicts over water, in fact the data in the table on the left shows the percentage of household experiencing conflicts. As we want the WPI to be high when the village is better off, we had to convert the conflict component into a no-conflict component, this was done by giving to 0% the maximum score (100) and 100% the minimum score (0). The table on the right shows the no-conflicts score.

South Africa	% Conflicts
Ethembeni	
KwaLatha	
Wembezi informal	
Wembezi formal	

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

No conflicts

Score

No data were provided for South Africa, this was due to the tense political atmosphere in that area at the time when the survey was carried out.

Tanzania	% Conflicts
Nkoaranga	27%
Samaria	71%
Majengo	54%
Kijenge	17%

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

No conflicts

Score
73
29
46
83

Samaria and Majengo are the two villages with more conflicts, this could be due to both not enough water per household and because they have to spend a lot of time in collecting water. In fact both Samaria and Majengo score the lowest values for the component *time* and *litre per capita per day*.

Sri Lanka	% Conflicts
Agarauda	61%
Awarakotuwa	98%
Tharawaththa	99%
Tissawa	56%

The end points for this set of values have been chosen to be:

0 % *scores 100*
100% *scores 0*

No conflicts

Score
39
2
1
44

As it has been already said, the two urban villages in Sri Lanka are quite densely populated and with poor infrastructure, this explains why these two villages experience so many conflicts over water. In fact they are also the villages with the lowest litre per capita per day.

% pipe in house

This component represents percentage of households in the village with tap in the house or communal yard. Having a pipe in the house (or near by) makes a household considerably better off, as its members need to spend less time in collecting water. These data were obtained from the household surveys.

South Africa	%
Ethembeni	0%
KwaLatha	1%
Wembezi informal	12%
Wembezi formal	99%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% pipe

Score
0
1
12
99

As we have seen for sanitation the urban villages in South Africa have got a better infrastructure than the rural ones.

Tanzania	%
Nkoaranga	24%
Samaria	0%
Majengo	25%
Kijenge	30%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% pipe

Score
24
0
25
30

In Tanzania the situation seems quite homogenous across the urban and rural areas, with the exception of Samaria that does not have any pipe installed in the village.

Sri Lanka	%
Agarauda	0%
Awarakotuwa	0%
Tharawaththa	0%
Tissawa	0%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% pipe

Score
0
0
0
0

None of the households in the four Sri Lanka villages had a pipe in the house.

% access to protected water

Percentage of households in the village with access to water source that are protected. In this case, protected simply means supplies where attempts are made to prevent pollution of water source by animals and other contaminants. These data were obtained from the household surveys.

South Africa	%
Ethembeni	87
KwaLatha	18
Wembezi informal	99
Wembezi formal	100

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% protected

Score
87
18
99
100

The households in KwaLatha are those spending more time in collecting water and a large percentage of them does not have access to protected water (they use water from a pond). As a consequence KwaLatha has got many people suffering from diarrhoea (see no-diarrhoea component).

Tanzania	%
Nkoaranga	51
Samaria	69
Majengo	47
Kijenge	97

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% protected

Score
51
69
47
97

The situation in Samaria is quite different, where many households travel long distances to get water, but the water they collect is of very good quality. In fact, in Samaria not many people suffer from diarrhoea.

Sri Lanka	%
Agarauda	15
Awarakotuwa	77
Tharawaththa	93
Tissawa	56

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% protected

Score
15
77
93
56

In the two urban villages the water used by the households comes more often from a protected source than in the two rural villages. As a consequence these two villages have the lowest percentage of households suffering from diarrhoea.

Access final score

The *access* component has been obtained by aggregating the score of the seven sub-components described above and then by dividing the sum by the number of components that have got a value (for example, the access component of Wembezi (formal) has been divided by 5). In this way, we are assuming that the subcomponents have got the same weights (equal to 1). If instead it is decided that, for example, the total time spent collecting water is more important than the other components, a higher weight should be given to it. If, for example, we double the weight given to *time* and the total sum of the weights is equal to one, then for every increase in one unit score of *time*, two units of another factor must be given up.

$$A = w_{tt}TT + w_{m}M + w_{s}S + w_{ip}IP + w_{nc}NC + w_{p}P + w_{ps}PS$$

where
A = access
TT = total time
M = % men
S = sanitation
IP = irrigation potential
NC = no-conflicts
P = % of pipes in house
PP = % protected source

W_i ($0 < W_i < 1$) are subject to the condition: $\sum_i w_i = 1$

They are obtained as follows:

$w_i = \frac{d_i}{\sum_i d_i}$ where d_i is the weight given in decimals to the component i and $\sum d_i$ is the sum of all weights in decimals of all the components.

If all the components receive equal weight: $d_i = 1$, then w_i is equal to: $w_i = \frac{1}{7} = 0.143$

in this case it is assumed that all the components have got a value.

If, for example, TT obtain $d_{TT}=2$ and the others d_i only 1 (and all components have got a value), then w_{TT} is $w_{TT} = \frac{2}{8} = 0.25$ and the other components receive weight equal to

$w_i = \frac{1}{8} = 0.125$

The following tables show the results for each country for the *access* component assuming equal weights across the sub-components.

South Africa

Villages	Total time	% men	sanitation	Irrigation potential	No conflict	% of pipes in house	% protected source	Access
Ethembeni	63	14	32	23		0	87	**37**
KwaLatha	30	8	32	13		1	18	**17**
Wembezi inf	66	32	68	16		12	99	**49**
Wembezi for	99	67	68			99	100	**87**

In South Africa the rural villages have a worse access than the urban villages. The reasons that could explain this are mainly two: 1) in South Africa more infrastructure investments have been spent in the urban area; and 2) many of the villages in the rural areas have been forced to settle in specific areas often with poor access to water.
KwaLatha scores the lowest Access, where instead Wembezi formal scores the highest value for Access. This reflects what can be observed about the sites.

Tanzania

Villages	Total time	% men	sanitation	Irrigation potential	No conflict	% of pipes in house	% protected source	Access
Nkoaranga	81	23	4	20	73	24	51	**39**
Samaria	5	38	0	5	29	0	69	**21**
Majengo	72	1	4		46	25	47	**33**
Kijenge	91	19	4		83	30	97	**54**

In terms of *Access* Samaria is the worst community and Kijenge provides better results. Unlike South Africa there is not a clear cut between the urban and rural villages. Nkoaranga (rural village) has, in fact, better access than Majengo (urban village), as Majengo spends more time collecting water and has got more people competing over water than Nkoaranga.

Sri Lanka

Villages	Total time	% men	sanitation	Irrigation potential	No conflict	% of pipes in house	% protected source	Access
Agarauda	79	55	70	10	39	0	15	**38**
Awarakotuwa	11	72	50		2	0	77	**35**
Tharawaththa	5	20	40		1	0	93	**27**
Tissawa	68	65	75	23	44	0	56	**47**

The access score for the four villages in Sri Lanka do not vary as much as in Tanzania and South Africa. This is because the four villages in Sri Lanka have been selected on poverty criteria, where instead in Tanzania and in South Africa the four villages are not all among the poorer villages.

Contrary to South Africa, in Sri Lanka the villages in the rural areas have a better access to water than the villages in the urban areas. In Sri Lanka there has not been political constraints, as in South Africa, about where to locate a village, the driver to decide where to settle a village has been a good access to water. Where instead the driver for people deciding to move to the city is to find a job, with the consequence that many people compete for a low level of water provision.

1.2.5 C – Capacity

The reasons why the capacity component has been included in the WPI calculation are as follows:

1. It shows if a country/village has got the potential to overcome an inefficiency in water availability/access by investing in infrastructure to get water from somewhere else (transfers from other villages, desalination plants ..). This applies especially at macro level, as the investments required to put in place such infrastructure can be usually raised only at macro level and not at village level.

2. It shows when water unavailability or lack of access has not been a constraint for economic development. There are countries that despite a low level of water availablty have been able to develop a good economy and villages gain a good level of wealth. What is more difficult to know from the index it is if the lack of water has been a constraint for economic development, because many other factors could be the cause of the lack of development.

3. It shows the loss of welfare due to lack of water or access to good quality water. The more time people spend collecting water, the less time they spend in cultivating land and going to school. The less the amount of good quality water they can access the higher the risk of diarrhoea and diseases and therefore, the less time they can spend in carrying out economic activities.

4. It shows how much their economy/income is based on water resources and therefore their dependency on water use. For example, the higher is the proportion of household income coming from the production of bricks, the higher is the dependency on water availability as brick production requires significant quantities of water.

The capacity component constists of six subcomponents:

- *% people educated*
- *No Diarrhoea*
- *CoLand & %*
- *Wealth*
- *Income independency*
- *% of people with wage and pensions*

% people educated

Percentage of households in the village with at least one member of the household matriculated. Source: household survey.

South Africa	%
Ethembeni	57%
KwaLatha	31%
Wembezi informal	38%
Wembezi formal	61%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% educated

Score
57
31
38
61

Tanzania	%
Nkoaranga	43%
Samaria	5%
Majengo	40%
Kijenge	51%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% educated

Score
43
5
40
51

Sri Lanka	%
Agarauda	67%
Awarakotuwa	61%
Tharawaththa	52%
Tissawa	67%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% educated

Score
67
61
52
67

It is very interesting to observe that within each country the villages have the same ranking order if either the *% educated* scores or the *total time* scores are used. This validates our intuition which suggests that the more time spent collecting water, the less time is invested in education.

No Diarrhoea

This is the percentage of households in the village stating that over last year they have not experienced diarrhoea. This component is correlated with the *% protected sources* component. Infact the villages within each country have almost the same order position if either we use *no diarrhoea* or *% protected sources* component.
Source of the data: household survey.

The reliability of questions of this nature is not very good due to the fact that the respondent does not always know if other households members have diarrhoea or not; and also there are many different definitions of diarrhoea. Never the less the answer to this question does provide some insights into the level of household heath.

South Africa	%
Ethembeni	59
KwaLatha	44
Wembezi informal	90
Wembezi formal	89

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

No Diarrhoea

Score
59
44
90
89

No Diarrhoea

Tanzania	%
Nkoaranga	67
Samaria	74
Majengo	52
Kijenge	85

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Score
67
74
52
85

No Diarrhoea

Sri Lanka	%
Agarauda	52
Awarakotuwa	70
Tharawaththa	52
Tissawa	42

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Score
52
70
52
42

Land size and distribution (CoLand & %)

This component was included in the capacity group because it shows the capacity of a village to generate income. This component tries to capture the average amount of land cultivated and the proportion of households in the village that have got land. It has been obtained by simply multiplying the average size of land cultivated at village level by the percentage of households cultivating land, the results are shown in the second column on the left. As the agriculture in the three countries is done at a different scale, different end points have been chosen for each country. The highest score has been given to the value that is 20% higher than the highest values in the countries' subset.

CoLand & %

South Africa	m^2
Ethembeni	637
KwaLatha	301
Wembezi informal	28
Wembezi formal	

The end points for this set of values have been chosen to be:

764 m^2 *scores 100*
0 m^2 *scores 0*

Score
83
39
4

Overall Ethembeni is better off than KwaLatha, as the average land size cultivated by the households and proportion of households cultivating land in Ethembeni is larger than in KwaLatha.

CoLand & %

Tanzania	m^2
Nkoaranga	86
Samaria	68
Majengo	
Kijenge	

The end points for this set of values have been chosen to be:

103 m^2 *scores 100*
0 m^2 *scores 0*

Score
83
66

The average land size cultivated by the households in Samaria is slightly larger than in Nkoaranga but not enough to compensate for the fact that the proportion of households cultivating land in Nkoaranga is twice that in Samaria. As a result Nkoaranga is the village that is better off as there are more people able to support themselves through subsistence agriculture. The reason why there are so few people cultivating land in Samaria, is that they have to spend long time collecting water and there is not suitable water available for cultivation near the village.

Sri Lanka	m^2
Agarauda	9,560
Awarakotuwa	
Tharawaththa	
Tissawa	2,387

The end points for this set of values have been chosen to be:

11,507 m^2 *scores 100*
0 m^2 *scores 0*

CoLand & % Score
83
21

Overall Agarauda is better off than Tissawa, as the average land size cultivated by the households and proportion of households cultivating land in Agarauda is larger than in Tissawa.

Wealth

An approximation of the level of wealth for each household was obtained by aggregating the value of the durables belonging to the household. The number and the types of durables owned by the households were provided by the household survey, where the value of these durables was approximated by their local prices. Different end points were selected for each country. The highest score has been given to the value that is 20% higher than the highest values in the countries' subset.

South Africa	rands
Ethembeni	17,028
KwaLatha	23,420
Wembezi informal	22,781
Wembezi formal	35,756

The end points for this set of values have been chosen to be:

42,908 rands *scores 100*
0 rands *scores 0*

Wealth Score
40
55
53
83

Households in Wembezi (formal) own more valuable durables than the rest of households in the other villages.

Tanzania	Tan. shillings
Nkoaranga	546,365
Samaria	488,163
Majengo	617,467
Kijenge	480,969

The end points for this set of values have been chosen to be:

740,960 Tan. shillings *scores 100*
0 Tan. shillings *scores 0*

Wealth Score
74
66
83
65

Samaria together with Kijenge are the poorest ones. Majengo is not only the village with households owning more durables but it is also the village with a higher proportion of households earning a salary.

Sri Lanka	Sri Lanka rupee
Agarauda	73,490
Awarakotuwa	295,892
Tharawaththa	36,359
Tissawa	66,807

The end points for this set of values have been chosen to be:

355,070 SL rupee *scores 100*
0 SL rupee *scores 0*

Wealth Score
21
83
10
19

Tharawaththa is definitively the poorest one and Awarakotuwa is the richest one. Awarakotuwa is also the village with the highest proportion of households earning a salary.

For more information on the distribution of wealth across the households within villages, see appendix 2.3.

Income independency

Households were asked to answer this question: "How much of your household income comes from selling crops or products you have made?"

As water is required to produce crops and make products, such as bricks, we can say that the higher is the proportion of income coming from selling crops and hand made products the more the household income is dependent on water availability. If the water available to the households, whose income derives mainly from selling crops and bricks, was reduced they will be affected much more than those receiving a pension. However we have to distinguish between urban and rural villages; as rural villages are more probable to cultivate crops and consequently to sell them, they are going to be more dependent on water than urban ones. Therefore it is better to compare the rural among them and the urban among them.

As we want the WPI to be high when the village is better off, we had to convert the *income dependency* component into an *income independency* component, this was done by giving to 0% the maximum score (100) and to 100% the minimum score (0).

South Africa	Dependency %
Ethembeni	
KwaLatha	
Wembezi informal	
Wembezi formal	

Independency Income Score

No data were available for South Africa. This was due, in part, to deep suspicion by households about giving any king of data which would reflect their income.

Tanzania	Dependency %
Nkoaranga	54
Samaria	64
Majengo	12
Kijenge	2

The end points for this set of values have been chosen to be:

0 % *scores 100*
100 % *scores 0*

Independency Income Score
46
36
88
98

In Tanzania the rural villages depend more on water than the urban villages, as in the rural areas there are not many jobs the majority of the alternative income comes from selling crops and making hand craft.

Samaria is the village that economically depends most on water and it is also the one with lowest access score. By improving the access it would be possible to reduce the stress on its form of income.

Sri Lanka	Dependency %
Agarauda	20
Awarakotuwa	0
Tharawaththa	40
Tissawa	30

The end points for this set of values have been chosen to be:

0% *scores 100*
100% *scores 0*

Independency Income Score
80
100
64
75

Unlike Tanzania the village that depend more on water is not a rural one but an urban one. As Tharawaththa is not cultivating any land it means that its alternative form of income is primarily derived from selling products they make (bricks, handicraft) and/or occasionally work. Similar to Samaria, Tharawaththa is the village with the worst access and it is also the village more economically dependent on water.

% of people with wage/ pensions and other sources of income

This component estimates the income that a household receives. From the household survey we know:

a) the percentage of households in a village that have got at least one of its members earning a salary or receiving a pension; and
b) the percentage of households in the village that sell crops, hand craft or occasionally works.

These two types of income are quite different, the first one is a more secure income as it is a constant entry for the household; where instead the second one is a quite variable one and not so secure. For that reason a weighted average of the two percentages was done by giving a weight of 5 to the income a) and weight 1 to income b).

South Africa	%
Ethembeni	
KwaLatha	
Wembezi informal	
Wembezi formal	

% Wages & pensions Score

No information was available for South Africa from the household survey. This was due to deep suspicion by households about any kind of data which would reflect their income.

Tanzania	%
Nkoaranga	48%
Samaria	28%
Majengo	50%
Kijenge	40%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% Wages & pensions Score
48
28
50
40

In Samaria only a few households rely on a wage or pension as form of income. So it is not only in Samaria that on average a big proportion of household income comes from the selling of crops and hand craft but also the majority of the households are in this situation.

Sri Lanka	%
Agarauda	82%
Awarakotuwa	75%
Tharawaththa	68%
Tissawa	86%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

% Wages & pensions Score
82
75
68
86

For Tharawaththa what has been said for Samaria applies.

Capacity final score

The component capacity has been obtained by aggregating the score of the six sub-components described above and then by dividing the sum by the number of components that have got a value (for example, Wembezi (formal) has been divided by 3). The following tables show the results for the capacity component assuming equal weights across the sub-components for each country.

South Africa

Villages	% people educated	No Diarrhoea	CoLand & %	wealth	Income Independency	% of people with wage/pen +other	**Capacity**
Ethembeni	57	59	83	40			**60**
KwaLatha	31	44	39	55			**42**
Wembezi inf.	38	90	4	53			**46**
Wembezi for.	61	89		83			**78**

In South Africa KwaLatha has got the lowest capacity score, this is mainly due to the fact that there is a large proportion of people not educated and suffering from diarrhoea. In this case capacity represents the loss of welfare due to lack of water and/or limited access to water. Wembezi formal is clearly the better off one.

Tanzania

Villages	% people educated	No Diarrhoea	CoLand & %	wealth	Income Independency	% of people with wage/pen +other	Capacity
Nkoaranga	43	67	83	74	46	44	**59**
Samaria	5	74	66	66	36	22	**45**
Majengo	40	52		83	88	52	**63**
Kijenge	51	85		65	98	44	**68**

Samaria is the village with the lowest capacity score, it has, infact, a very low number of people educated and the main form of household's income is water dependent. The capacity scores for the other villages are quite similar, so there is not a clear dominant one. In fact, despite having the lowest wealth score, Kijenge is scoring the highest capacity value.

Sri Lanka

Villages	% people educated	No Diarrhoea	CoLand & %	wealth	Income Independency	% of people with wage/pen +other	Capacity
Agarauda	67	52	83	21	80	86	**65**
Awarakotuwa	61	70		83	100	83	**80**
Tharawaththa	52	52		10	64	75	**51**
Tissawa	67	42	21	19	75	88	**52**

Tharawaththa is the worst off one in term of capacity. Even though Tissawa has got a final capacity score quite close to the Tharawaththa one, in reality its score would be higher if we did not include in the calculation the score of the CoLand&% component, as 21 is lower that the average score of the other five subcomponents. We need to be aware of the fact that the final scores for the rural and urban villages are made up of a different number of subcomponents.

1.2.6 U – Use

This component intends to show the level of use of water per type of use. This is created by using four sub-components:

- *Domestic use*
- *Industrial use*
- *Agriculture use*
- *Livestock*

Up to a certain level, a high usage is good and a low usage is bad, as below this level the basic human needs such as washing, drinking, cleaning, the subsistence farming and economic activities have been limited. Where instead after that level a high use is bad and a low use is good, as the water now has been inefficiently used. Where it is reasonably easy to determine the optimum domestic amount of water per capita per day. It is more difficult to set the optimum amount of water per hectare per day, as this depends on the type of crops, climate and soil. The same is true for industrial use. We have assumed that all villages were below the optimal amount of water, so the higher was their use the better it was. It could be argued that the developing countries are actually the ones that use the less up to date irrigation techniques and industrial technologies. This argument applies especially at macro level but less at household level.

Domestic use

The average amount of water used in a day by each member of the household (litre per capita per day). This component has been obtained using two types of data:

1) Litre per capita per day collected by the household. Source: household survey.

2) Litre per capita per day provided by the local authority to those households having a pipe in house/yard. Source: local water authorities.

The first component has been calculated by dividing the total amount of water collected in a household by the size of that household.

The village average amount of water used in a day is obtained by averaging together the two components above.

100 litre/capita/day has been chosen as a top value, up to this level, the larger is the amount of water used the better is the situation of the household. After 100 litre/capita/day the additional amount of water used is seen as inefficient and is score reducing. In our case none of the villages has a l/c/d larger that 100.

South Africa	l/c/d
Ethembeni	17
KwaLatha	20
Wembezi informal	20
Wembezi formal	29

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Domestic use

Score
17
20
20
29

One possible reason why KwaLatha L/C/D is higher than Ethembeni, is that in KwaLatha a larger number of trips to collect water is done using motor vehicles, which means a larger quantity of water can be carried per trip.

Tanzania	l/c/d
Nkoaranga	36
Samaria	24
Majengo	30
Kijenge	57

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Domestic use

Score
36
24
30
57

In Samaria the households not only spend more time collecting water but also they have got the smallest amount of water per capita per day.

Sri Lanka	l/c/d
Agarauda	46
Awarakotuwa	40
Tharawaththa	32
Tissawa	46

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Domestic use

Score
46
40
32
46

As in Samaria the households in Tharawaththa not only spend more time collectting water but they also have got the smallest amount of water per capita per day.

Industrial use

As a proxy of the industrial use the percentage of people that use water for purposes other than drinking, washing, bathing, cleaning and cooking, has been used. In fact they use water for purposes such as: farming, brick production, building, making beer, watering the garden, watering flowers and washing the car. The underlying assumption is that the lower is the percentage of households using water for other purposes than drinking and washing, the less water they have got to spare for other activities. However, this assumption is truer in the rural area than in the urban one, as in the urban area there are fewer households using water for producing bricks, for example, not because they do not have enough water to spare but rather because they have enough income to buy bricks instead of producing them. Instead, in the rural area more households rely on alternative forms of income (as we have seen in the *independency income* component), so they use more water to produce items that they can sell or use ,such as bricks.

South Africa	%
Ethembeni	56
KwaLatha	42
Wembezi informal	48
Wembezi formal	47

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Industrial use

Score
56
42
48
47

In Ethembeni there are more households using water for other uses than drinking and washing, as they have got more water to spare. Wembezi formal is using just slightly less water that Wembezi informal, but it is not because they do not have water to spare but because they do not need to produce products such as bricks as they have money to buy them.

Tanzania	%
Nkoaranga	91
Samaria	39
Majengo	11
Kijenge	8

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Industrial use

Score
91
39
11
8

Samaria is using definitively less water than Nkoaranga, as its households have not got water to spare. Kijenge seems to be slightly better off than Majengo.

Industrial use

Sri Lanka	%
Agarauda	76
Awarakotuwa	2
Tharawaththa	0
Tissawa	89

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

Score
76
2
0
89

Both the urban sites seem not to have enough water to spare for uses that are not washing, drinking or cleaning. It is explainable why Awarakotuwa is not using water for other purposes, as households in this village have got enough income to buy, for example bricks on the market rather then producing themselves. What is strange is that in Tharawaththa no household uses water for other purposes when elsewhere they state part of their income comes from making bricks. It is probable misinterpretation of the question may have occurred, or it could be that the water they collect queuing at the pipe is used only for drinking and washing, where instead the water used for making bricks is coming from rainfall storage or is collected at the river. There is a water quality difference, if the people are asked if they use water collected for drinking and washing for other purposes they would answer no, because they see this water as good quality; to make bricks they can use water of less quality and they collect it from another source; and the collections are seen as different.

Agriculture use

This component has been obtained by simply multiplying the average size of land cultivated at village level by the percentage of households stating that they irrigate their land. the results are shown in the second column on the left. Different end points have been chosen for each country to reflect the different scale at which the agriculture is carried out in those countries. The highest score has been given to the value that is 20% higher than the highest values in each country's subset. This component should be essentially used to discriminate between rural villages in terms of water use for irrigation. We are assuming that the amount of water used in these villages is below optimal, so the higher is water use for irrigation the better off they are.

Irrigation is not relevant for urban villages as they do not cultivate land, with exception of wembezi (informal) that is peri-urban. For this reason. if an urban village scores zero, it does not mean that there are no farmers that irrigate but that there are not farmers at all. so a zero score is completely ignored.

The *agriculture use* component is different from the *Land (CoLand&%)* component, as the first represents how much irrigation is carried out in a village whilst the second represents how much land is owned by households in each village and by how many of them.

Agriculture use

South Africa	m^2
Ethembeni	614
KwaLatha	216
Wembezi informal	18
Wembezi formal	0

The end points for this set of values have been chosen to be:

737 m^2 *scores 100*
0 m^2 *scores 0*

Score
83
29
2

KwaLatha scores a lower agriculture use value than Ethembeni, as less water is available for them both in terms of availability and access. Wenbezi (informal) is scoring less than 5 so it is ignored in the final calculation.

Tanzania	m^2
Nkoaranga	10
Samaria	0
Majengo	
Kijenge	

The end points for this set of values have been chosen to be:

12 m^2 *scores 100*
0 m^2 *scores 0*

Agriculture use

Score
83
0

Samaria does not have any water to spare for agriculture. Households in Samaria are more involved in pastoralism

Sri Lanka	m^2
Agarauda	8452
Awarakotuwa	
Tharawaththa	
Tissawa	1467

The end points for this set of values have been chosen to be:

10,142 m^2 *scores 100*
0 m^2 *scores 0*

Agriculture use

Score
83
14

Tissawa irrigates less than Agarauda. In fact, in Agarauda there are more people irrigating and the average land size irrigated is three times the area cultivated by the households in Tissawa.

Livestock

This component quantifies the amount of water used by livestock. This amount has been calculated by using data from the household survey (number of cattle and goats owned by household) and data from the literature (King) (amount of water required per type of livestock). From this work, it has been estimated that a cow uses on average 25 litre per day and a goat 5 litre per day. This information has been applied across all the three countries. The average number of cattle and goats owned by households in a village has been calculated by considering all the households including those not owning any livestock.

This component is mainly relevant for rural villages and so it should be essentially used to discriminate among rural areas. As in South Africa we knew only if a household had cattle or not, we had to extrapolate the number of cattle from another source. From the statistics for Kwa Zulu Natal we found the average number of cattle per capita, we multiplied this by the household size to obtain the number of cattle, which was then used to produce the water requirement estimate.

South Africa	Litre/day
Ethembeni	10
KwaLatha	7
Wembezi informal	2
Wembezi formal	

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Livestock

Score
10
7
2

The scores in the table above show that KwaLatha has got less cattle than Ethembeni, but what we do not know is if this is due only to the fact that they do not have enough water or if there are other factors affecting their choice.

Tanzania	Litre/day
Nkoaranga	51
Samaria	87
Majengo	4
Kijenge	1

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Livestock

Score
51
87
4
1

Despite the poor access to water, Samaria is better off in terms of livestock than Nkoaranga. In this case the access to water has not been a constraint for Samaria's households to have a cattle. They take the livestock to the water sources where instead Nkoaranga's households give their livestock part of the water they have collected. As Samaria does not have enough water near by, the households have opted towards pastoralism rather than the cultivation of land (as it easier to bring to the water source the animal than the land!)

Sri Lanka	Litre/day
Agarauda	94
Awarakotuwa	
Tharawaththa	
Tissawa	50

The end points for this set of values have been chosen to be:

100 *scores 100*
0 *scores 0*

Livestock

Score
94
50

No data where provided for the urban villages, as this question was not relevant for them. Agarauda is the rural village that has got more livestock.

Use final score

The component use has been obtained by aggregating the score of the four sub-components described above and then by dividing the sum by the number of subcomponents that have got a value (for example, Wembezi (formal) has been divided by 2). The following tables show the results for the use component assuming equal weights across the sub-components for each country. The comparison should be done between rural and urban separately, for this component, as it includes agriculture use and livestock that are activity especially relevant for rural areas.

South Africa

Villages	Domestic use	Industrial use	Agricultural use	Livestock
Ethembeni	17	56	83	10
KwaLatha	20	42	29	7
Wembezi infor.	20	48	2	2
Wembezi form.	29	47		

Use
41
25
18
38

As the final *use* score shows, KwaLatha is much worse than Ethembeni in terms of use. Instead on the urban side Wembezi (informal) is the village scoring the lowest value. Access and use are often positively correlated, in fact KwaLatha is the village with the lowest access and use compared to Ethembeni; the same is for Wembezi (informal) in comparison with Wembezi (formal).

Tanzania

Villages	Domestic use	Industrial use	Agricultural use	Livestock	Use
Nkoaranga	36	91	83	51	**65**
Samaria	24	39	0	87	**38**
Majengo	30	11		4	**15**
Kijenge	57	8		1	**22**

Among the rural villages Samaria is the worst one both in terms of use and access. And Majengo is the worst urban village both in terms of use and access.

Sri Lanka

Villages	Domestic use	Industrial use	Agricultural use	Livestock	Use
Agarauda	46	76	83	94	**75**
Awarakotuwa	40	2			**21**
Tharawaththa	32	0			**16**
Tissawa	46	89	14	50	**50**

Tharawaththa is the urban village with the lowest use and access score. Tissawa score less than Agarauda in terms of use.

1.2.7 E – Environment

This component should tell us what is the requirement for water for the environment, and consequently the state of the environment. As it is not yet possible to come up with an estimate of the quantity of water needed by the environment, and because no data was available on the real state of the environment, we had to opt for data that were somehow a surrogate for that.

The component environment has been created by initially including the following household survey data:

- *No Erosion (question: is there erosion on your land?)*
- *No LC (question: how many times have you lost crops due to droughts in the last 5 years)*
- *Recreation and wildlife (question: do you use wildlife plants and animals? Do you use rivers for recreation?)*

However, given the unreliable quality of the data for the recreation and wildlife component, it was decided to remove it from the final calculation.

At this initial stage, the environment component is relying only on "no erosion" and "no CL" and these are provided mainly by those who live in rural areas, the environment component shows the state of the environment mainly for the rural areas and not for the urban areas. This is a disadvantage and more work needs to be done to improve this component of the WPI including improved environment data. In appendix 9.5 Acreman and King present a possible way the environment component could be incorporated into the WPI.

No Erosion

Percentage of households in the village stating that there is no erosion on their land. With this component we are trying to capture the fact that if there is erosion it suggests that the general state of the environment in that area is degraded. The households that have answered to this question are mainly the households living in the rural areas as they are in more direct contact with the land and are more aware of the impacts that erosion has on their land. For this reason it would be better to compare the urban and rural villages separately.

South Africa	%
Ethembeni	2%
KwaLatha	12%
Wembezi informal	7%
Wembezi formal	

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

No Erosion

Score
2
12
7

KwaLatha seems to experience a better state of the environment in terms of erosion with respect to Ethembeni. None of the households leaving in Wembezi (formal) seem to be aware of the level of erosion in their area.

Tanzania	%
Nkoaranga	63%
Samaria	76%
Majengo	98%
Kijenge	

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

No Erosion

Score
63
76
98

A smaller proportion of households in Samaria seem to experience erosion on their land with respect to Nkoaranga's households. No data were available for Kijenge.

Sri Lanka	%
Agarauda	18%
Awarakotuwa	28%
Tharawaththa	42%
Tissawa	13%

The end points for this set of values have been chosen to be:

100 % *scores 100*
0% *scores 0*

No Erosion

Score
18
28
42
13

Agarauda's households experience slightly less erosion than the households in Tissawa.

No Loss of Crops (No LC)

This component is looking at the average number of times a village has suffered from loss of crops in the last 5 years. It is implicitly assumed that if the crops are lost through lack of water, the area not cultivated is also under water stress. For the urban areas there is no information as they do not cultivate and consequently they do not experience loss of crops.

South Africa	Number
Ethembeni	2.3
KwaLatha	2.7
Wembezi informal	1.4
Wembezi formal	

The end points for this set of values have been chosen to be:

5 *scores 0*
0 *scores 100*

No LC Score
54
46
71

KwaLatha's households experience more loss of crops than the households in Ethembeni. This is probably due to the fact that Ethembeni can rely on irrigation much more than KwaLatha. KwaLatha does not have much water to spare for irrigation. No data were available for Wembezi (formal), almost any of the households living in this village are involved in agricultural activities. Wembezi (informal) is semi-urban and the average size of the land cultivated is quite small, so it is easier for the households to water their plants in case of emergency with respect to the households living in the rural areas whose average land size is ten times larger.

Tanzania	%
Nkoaranga	1.2
Samaria	3.2
Majengo	
Kijenge	

The end points for this set of values have been chosen to be:

5 *scores 0*
0 *scores 100*

No LC Score
76
37

No data were available for the urban villages, as they are not involved in agricultural activities. Samaria is definitively the rural village that is suffering more from the water stress. They do not have water available for irrigation, so making them much more vulnerable to drastic droughts.

Sri Lanka	%
Agarauda	2.5
Awarakotuwa	
Tharawaththa	
Tissawa	1.8

The end points for this set of values have been chosen to be:

5 *scores 0*
0 *scores 100*

No LC Score
50
64

Tissawa experiences on average less crop losses than Agarauda, this is may be due to the fact that the households in Agarauda own on average three times more land than the households in Tissawa, making them more probable to loose crops than the Tissawa households.

Environment final score

The component environment has been obtained by aggregating the score of the sub-components described above and then by dividing the sum by the number of subcomponents that have got a value (for example, Wembezi (formal) has no environment component). The following tables show the results for the environment component assuming equal weights across the sub-components for each country.

As we have already said, the way this component has been calculated, is biased towards the rural villages. The environment component of urban villages is empty or constituted of only one subcomponent and so less reliable. For this reason it is better to compare the rural and urban scores separately.

South Africa

Villages	No erosion	No LC
Ethembeni	2	54
KwaLatha	12	46
Wembezi infor	7	71
Wembezi form		

Environment
28
29
39

Wembezi (formal) does not have the environment component. KwaLatha and Ethembeni score a very similar value.

Tanzania

Villages	No erosion	No LC
Nkoaranga	63	76
Samaria	76	37
Majengo	98	
Kijenge		

Environment
70
56
98

Samaria is clearly the rural village that lives in a more difficult environment than Nkoaranga.

Sri Lanka

Villages	No erosion	No LC
Agarauda	18	50
Awarakotuwa	28	
Tharawaththa	42	
Tissawa	13	64

Environment
34
28
42
38

As in South Africa the two rural villages score a very similar value. The two urban villages rely only on the *no-erosion* sub-component to create their environment component.

1.2.8 WPI

The WPI has been calculated by aggregating the score of the five components and then by dividing them by the number of components that have got a value (for example. KwaLatha is divided by 5 as it has got all the five components. where instead Kijenge is divided by 4 as it is missing the environment component). For the moment it has been given equal weight to all the five components. However in the way the WPI has been calculated, by aggregating first the subcomponents to obtain the five components and then aggregating the five components to obtain the WPI, it implicitly gives different weights to the subcomponents, even if equal weight was used to aggregate them. This is because the number of subcomponents used to obtain each of the five components is different. *Access* is constituted of seven subcomponents where instead *Use* by only four. The more subcomponents are used in a component, the less weight is given to each of them (in comparison to the subcomponents used in the other components) in the final WPI calculation. The consequence is that a percentage change in the score of any of the access component would have less impact on the final WPI value than the same percentage change in any of the use subcomponents. If the five components were constituted by the same number of subcomponents, each of subcomponents would be equally weighted.

A way to avoid this is to first divide each of the subcomponents by the total number of subcomponents, then aggregate them to obtain the five components, and then aggregate the five components to obtain the WPI. In this case the component with more subcomponents is going to be larger than the other ones but this is not a problem, as we are not trying to compare across the five components but to compare components across villages.

To explore this difference in methodologies the WPI has been calculated for each country using both the approaches. The WPI obtained using the first methodology (with the implicit weightings) will be referred to as the *unbalanced WPI*, while the score obtained using the second method, will be referred to as the *balanced WPI*.
The balanced WPI can be expressed as follows:

$$WPI = \sum_{i=1}^{N} w_i subC_i = \sum_{i=1}^{N_1} w_i A_i + \sum_{N_1+1}^{N_2} w_i C_i + \sum_{N_2+1}^{N_3} w_i U_i + \sum_{N_3+1}^{N_4} w_i E_i$$

where

$subC_i$ are the all the subcomponents used in *Access*, *Capacity*, *Use* and *Environment* components;
A_i are the subcomponents used in the *Access* component;
C_i are the subcomponents used in the *Capacity* component;
U_i are the subcomponents used in the *Use* component;
E_i are the subcomponents used in the *Environment* component.
N is the total number of subcomponent used to create the WPI that have got a value; in our case the maximum number is 21; however for Wembezi (formal) N is equal to 12 as few of its subcomponents have not a value.
N_1 is the total number of subcomponent used to obtain the Access component;
N_2 is the total number of subcomponent used to obtain the Capacity component;
N_3 is the total number of subcomponent used to obtain the Use component;
N_4 is the total number of subcomponent used to obtain the Environment component.
w_i are the weight associated with each subcomponent. They are subject to the following constraint:

$$\sum_{i=1}^{N} w_i = 1$$

The weights can be expressed as follows:

$$w_i = \frac{d_i}{\sum_{i=1}^{N} d_i}$$

where

d_i can be any decimal number ranging from 1 to $+\infty$. In our case we have assumed equal weights across all the subcomponents by setting d_i equal to 1, and consequently w_i equal to 1/21 (in the case all the subcomponents have got a value).

In both the approaches if one component does not have a value, the WPI is calculated averaging only the remaining components/subcomponents. For example, Wembezi (formal) has got only the four components' values, so to obtain the unbalanced WPI the components are first aggregated and then divided by four. Where instead KwaLatha has got all the five components' values, so to obtain the unbalanced WPI the components are first aggregated and then divided by five.

As a consequence, despite the Wembezi (formal) and KwaLatha components are all equally weighted, the actual weight given to each of the four Wembezi (formal) components (1/4) is higher than the weight given to KwaLatha's five components (1/5). In addition, if KwaLatha's environment (the Wembezi (formal) missing component) score is lower than the average of the other four components scores, the inclusion of this score in the KwaLatha WPI calculation will be reduced the final WPI score in relation to the Wembezi (formal) one. In conclusion, despite KwaLatha has got more data for the environment, it is actually penalised with respect the villages not having data for the environment component.

Values for the unbalances and balanced WPI are shown in the tables below separately for the rural and urban villages. It can be observed that the ranking within the urban and urban does not change if we use the *balanced* approach instead of the *unbalanced* one.

SOUTH AFRICA

Rural villages

Village name	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Ethembeni	50	37	60	41	28	43
KwaLatha	20	17	42	25	29	[illegible]

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Ethembeni	3	12	13	9	3	40
KwaLatha	1	6	9	5	3	25

For both the methodologies KwaLatha scores the lowest WPI value. All the KwaLatha's five component scores are much less than the Ethembeni once, with the exception of environment that are similar.

Urban villages

Village name	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Wembezi infor	50	49	46	18	39	40
Wembezi form	50	87	78	38		63

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Wembezi infor	3	15	10	4	4	37
Wembezi form	4	33	20	6		63

Wembezi (formal) is definitively less water poor than Wembezi (informal). The *Access*, *Capacity* and *Use* components for Wembezi (informal) are much lower than the Wembezi (formal) once.

TANZANIA

Rural villages

Village name	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Nkoaranga	30	39	59	65	70	53
Samaria	20	21	45	38	56	36

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Nkoaranga	30	38	64	57	70	52
Samaria	20	20	49	38	56	37

Samaria is the rural village scoring the lowest value for all the five components. Its score is the lowest also in comparison the urban villages.

Urban villages

Villages	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Majengo	20	33	63	15	98	44
Kijenge	20	54	68	22		41

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Majengo	20	31	58	15	98	42
Kijenge	20	53	61	22		39

The difference between Majengo and Kijenge is not so wide. If the environment was not included in the Majengo final score, Kijenge would be the better off. This is because, for exception of the *Resource* component (that are equal) the *Access*, *Capacity* and *Use* score an higher value in Kijenge than in Majengo, but because the Environment score for Majengo is so much higher than the average of its other four scores that it compensates for the fact that Kijengo performs better in the other three components.

SRI LANKA

Rural villages

Village name	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Agarauda	20	38	65	75	34	46
Tissawa	20	47	52	50	38	42

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Agarauda	20	39	63	75	34	46
Tissawa	20	48	47	50	38	41

Tissawa scores a higher score than the Agarauda one, despite Tissawa has got only Capacity and Use better than Agarauda.

Urban villages

Villages	Resources	Access	Capacity	Use	Environment	WPI unbalanced
Tharawaththa	20	27	51	16	42	31
Awarakotuwa	10	35	80	21	28	35

Village name	Resources	Access	Capacity	Use	Environment	WPI balanced
Tharawaththa	20	31	45	16	42	31
Awarakotuwa	10	39	70	21	28	34

Tharawaththa scores the lowest unbalances and balanced WPI scores across the Sri Lanka villages. With exception of the environment component all the other components of Tharawaththa scores the lowest value among the other villages.

In conclusion we can say that the balanced approach is the better one, as it allows a more transparent and equitable assignation of weights to each of the subcomponents. However, in our examples the ranking within the urban and rural villages is the same independently from which approach is used.

Once the WPI has been used to identify the key area or issue to be developed, the way to intervene has to be chosen. The cost effectiveness approach is used to select the scheme able to reduce water poverty in the most effective way.

This paper has outlined a methodology by which a comprehensive and holistic indicator linking water and welfare has been developed. While there still remains the potential to improve this with future work and better data, the WPI outlined here does provide a means by which comparisons can be made at community level. This provides a standardised, transparent framework on which decisions can be made to promote more equitable and sustainable outcomes.

Appendix 1.3

Time- analysis approach

1.3.1 Introduction

One possible way to construct the WPI is to use a time-analysis approach, where time is used as a numeraire for the purpose of assessing water poverty. With this method, the WPI determines the time required to gain access to a particular quantity of water. The index is calculated as follows:

$$WPI = \frac{T}{V} \quad \left(m \cdot l^{-1}\right)$$

where T is the total time (in minutes) spent per household in a day to collect volume V of water (in litres). The more time a household spend in collecting a given volume of water the higher its opportunity costs.

This index can be used to measure how a particular water scheme could reduce the household's opportunity costs (by reducing the time spent in collecting water, the members of the household responsible for collecting water will have more time to look after children, do home work, grow vegetables etc.). However, if this index is used to compare villages or countries, an implicit important assumption is made: opportunity costs in different villages and countries are the same. As this often is not the case, a measure of the opportunity costs should be estimated. The minimum salary (£/hr) could be used as an approximation of the opportunity costs. However, at this stage the WPI will be calculated using only Time and Volume of water. An estimation of opportunity costs will be done in a second stage. It will be interesting to compare the results from the WPI (time approach) with and without opportunity costs, to see if there is any change in the ranking of villages/country.

1.3.2 Methodology

The WPI has been calculated using household data from the surveys carried out in South Africa, Sri Lanka and Tanzania. In this case the WPI is constructed using a bottom up approach. The data that have been used from the survey are the following:

- Time (in minutes) takes to collect water from the main source, including the queuing time respectively in the wet and dry season.
- Volume of Water (litres) collected in each trip respectively by women, men and children in the household.
- Number of women, men and children gathering water respectively in trip one, two and three of the day.

These data are used to calculate:

a) the total time spent by a household collecting water in a day; and

b) b) the total volume of water available for a household in a day.

Total time spent by the household in a day to collect water is calculated by multiplying time spent per person collecting water by the total number of people collecting water in the three trips.

The total volume of water obtained summing together the total amount of water transported by women, men and children. The total amount of water transported by women is calculated by multiplying the volume of water collected in each trip by a woman by the total number of women carrying water in a day. The same type of calculation is applied for men and children.

As we want to know the average time and volume of water at village level, we cannot disregard the households with a pipe in the house. For the latter we have assumed that the average time spent per head collecting water is 2 minutes and the average volume of water per head has been provided by local water authorities.

For the households with a pipe it is not necessary to calculate the total time and volume of water as the time and volume per head are the same across the members of the household, and if we divide total time by total volume the household size would disappear from the ratio:

$$\frac{total\_time}{total\_volume} = \frac{time / head * n^{o} heads}{volume / head * n^{o} heads} = \frac{time / head}{volume / head}$$

where *n° heads* is the household size.

The time-volume index (minutes/litre) is calculated simply by dividing the total time (minutes/day) by the total volume of water (litre/day)[1]. This index tells us how many minutes a household has to spend collecting each litre of water. The higher the index the worse off is the household.

Table 1.3 shows the time index value for each of the villages across the three countries. The first set of the table refers to the wet season where instead the second part to the dry season.

In South Africa the village that spends more time per litre of water collected is KwaLatha both in the dry and wet season, while Wembezi (formal) is the village that spends the least time per litre of water collected. Wembezi (informal) is relatively worst off than Ethembeni in the wet season, but its score in the dry season improves relatively to Ethembeni. This could be due to the fact that a higher proportion of households in Wembezi (informal) have got a pipe in their house than in Ethembeni, so if in Ethembeni the near by river dries up its households have to travel longer distance to find another water source.

In Tanzania, Samaria is definitively the village that suffers more for the lack of good access to water sources. In facts its households have to travel very long distance to get to the water sources spending on average 5 hours to collect water. Its situation gets even worse in the dry season. Kijenge is the village that is better off in terms of time spent collecting water. Whilst in the wet season Nkoaranga spends a relatively small time collecting water, in the dry season its time is doubled. In Nkoaranga the water supplied become very unreliable in the dry season so households have to collect water from water sources such rivers and streams.

[1] Or the time per head by the volume per head in case the household has got a pipe in the house.

Unlike South Africa and Tanzania where the village that scores the lowest value with the time approach is rural, in Sri Lanka the worst off village is urban. Actually both the urban villages are the worst ones. During the dry season the situation becomes even more dramatic in the urban areas, their average time more than doubles. Also the rural villages, especially Tissawa, spend much more time collecting water in the dry season than in the wet. Overall Sri Lanka experiences a big difference in terms of water availability in the dry and wet season, much more than the other two countries.

The last column in the table 1.3.1 lists the average time spent to collect one litre of water across the four villages of each country. Tanzania is the country that on average has to travel and queue longer to get some water in the wet season. In the dry season the ranking changes and Sri Lanka is now in the last position.

Table 1.3.1 – Time-volume index in the three countries

Season	Country	Village name	Sample size	HH with pipe	% HH without pipe	Average Total Time (min/day)	Average total volume (litre/day)	Average T/V (min/litre)	Country average T/V
Wet Season	South Africa	Ethembeni	124	0	100%	149	127	**1.20**	**1.2**
		KwaLatha	133	1	99%	300	121	**2.28**	
		Wembezi (informal)	220	26	88%	142	98	**1.23**	
		Wembezi (formal)	148	146	1%	3	80	**0.03**	
	Tanzania	Nkoaranga	120	35	71%	52	124	**0.44**	**1.7**
		Samaria	119	1	99%	537	123	**5.02**	
		Majengo	125	29	77%	127	108	**1.21**	
		Kijenge	118	51	57%	32	112	**0.25**	
	Sri Lanka	Agarauda	66	0	100%	106	185	**0.72**	**1.2**
		Awarakotuwa	121	0	100%	149	145	**1.15**	
		Tharawaththa	83	0	100%	230	136	**2.13**	
		Tissawa	144	0	100%	95	182	**0.64**	
Dry season	South Africa	Ethembeni	124	0	100%	155	127	**1.23**	**1.2**
		KwaLatha	133	1	99%	296	121	**2.24**	
		Wembezi (informal)	220	26	88%	142	98	**1.23**	
		Wembezi (formal)	148	146	1%	3	80	**0.03**	
	Tanzania	Nkoaranga	120	29	76%	120	124	**1.15**	**2.2**
		Samaria	119	1	99%	590	123	**5.53**	
		Majengo	125	27	78%	178	108	**1.69**	
		Kijenge	118	49	58%	50	112	**0.37**	
	Sri Lanka	Agarauda	66	0	100%	131	185	**0.89**	**2.5**
		Awarakotuwa	121	0	100%	458	145	**3.52**	
		Tharawaththa	83	0	100%	467	136	**4.23**	
		Tissawa	144	0	100%	176	182	**1.24**	

The table 1.3.2 compares the ranking position obtained using respectively the time approach, the composite approach with implicit weights (the WPI unbalanced) and the composite approach with equal weights (the WPI balanced).

We have coloured in red the ranking position when all the three approaches have ranked a village in the same position. The colour blue has been chosen to indicate that only two approaches have ranked a village in the same way. Black is when the ranking are all different across the three approaches.

Table 1.3.2 – Comparison of time and composite ranking

Wet Season

	Village name	Time approach rank	WPI unbalance rank	WPI balance rank
South Africa	Ethembeni	2	2	2
	KwaLatha	4	4	4
	Wembezi (informal)	3	3	3
	Wembezi (formal)	1	1	1
Tanzania	Nkoaranga	2	1	1
	Samaria	4	4	4
	Majengo	3	2	3
	Kijenge	1	3	2
Sri Lanka	Agarauda	1	1	1
	Awarakotuwa	3	3	2
	Tharawaththa	4	4	4
	Tissawa	2	2	3

Dry Season

	Village name	Time approach rank	WPI unbalance rank	WPI balance rank
South Africa	Ethembeni	3	2	2
	KwaLatha	4	4	4
	Wembezi (informal)	2	3	3
	Wembezi (formal)	1	1	1
Tanzania	Nkoaranga	2	1	1
	Samaria	4	4	4
	Majengo	3	2	3
	Kijenge	1	3	2
Sri Lanka	Agarauda	1	1	1
	Awarakotuwa	3	3	3
	Tharawaththa	4	4	4
	Tissawa	2	2	2

It is interesting to observe that all the three approaches rank villages in exactly the same way in South Africa in the wet season and Sri Lanka's villages in the wet season. In addition the three approaches are always able to identify the same worst off village in each country and season. In Tanzania it seems that the three approaches' ranking match much less.

1.3.3 Conclusions

The time analysis approach is quite simple to calculate and the only data required to compute it are, the time spent to collect water and the volume collected. The simplicity of this approach is an advantage in comparison to the composite approach. The later, in fact, requires more data and the computation of it is more complex.

In addition to its simplicity the time approach has few advantages with respect to the composite approach. First of all, it makes easier comparison of villages across country. In fact, to calculate the time approach it is not required to set any ends points whereas for the composite approach you need two end points to be able to convert a component into a score. In addition, as the time approach uses only two variables, there is less risk that a village is missing data for one of the variables (see section 1.2). Finally, no weightings are required in the time formula, avoiding the difficulty of setting them.

While the time method is apparently very simple, it does have a number of weaknesses:

- It is not able to represent the level of health of the environment and of the household;
- No consideration is done on the capacity level: in other words on the potentiality that a household/village has to reduce the time spent collecting water in the future;
- No information is provided on the actual amount of water available in the area;

By including information on the environment, capacity, health and water availability, the composite approach overcomes the weakness imbedded in the time approach.

Table 1.3.2 shows very clearly that there is a strong correlation between the time approach and the two composite approaches. So why should we collect more data to compute the composite approach if we can obtain the same answer by collecting only two set of data? The answer is that we want to know:

A) in what to invest to reduce the water poverty and to which extent; we know that we have to invest into improving water access but at which extent, it could be that after having improved access up to a certain level it is more effective to improve sanitation; as the composite approach is including both time and sanitation, it allows us to see how a combined intervention on them can reduce water poverty;

B) the impacts that a reduction of time spent collecting water could have on, for example, the environment and households wealth: the composite approach allows us to take that into account.

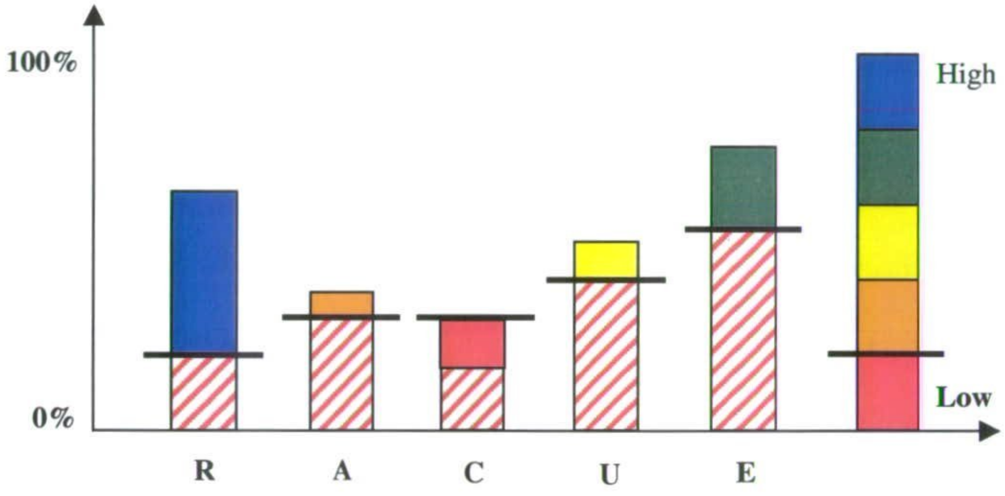
Overall the Time analysisapproach is a good approximation of the state of a village in terms of water poverty but for a more sustainable and holistic intervention towards water poverty alleviation the composite approach is the favoured one.

Appendix 1.4

Gap approach

An alternative method of calculating the Water Poverty Index is the Gap Approach.
In this method, the WPI is measured by the difference between the *predetermined* standard (the area below the black horizontal line) and the actual measured value (the histogram area, including the area below and above the horizontal line) on a variety of criteria. Here the WPI gap measure is shown by the full coloured area, see figure below. Different colours have been used to represent the level of distance from the *predetermined* standard, red represents the fact that the actual measured value is below the *predetermined* standard, blue represents that the current value is far above the *predetermined* standard and quite close to the optimal level.

Figure 1.4 – Gap approach



By using the same criteria identified in the composite approach, with the gap approach we can assess of by how much water availability, access to water, capacity, use and environment health deviate from their pre-determined standard.

In this approach, each of these components are assigned a standard value, which may be quantitative (scientifically defined) or qualitative, (identified through participation). This standard or target value reflects that level which would exist if the resources were managed in a sustainable way.

Such a methodology, the comparison of the actual current empirical situation (as identified from data), with this pre-set standard, is already used as a measure of poverty.

There are two ways the gap approach can be calculated:

1. each criteria and its predetermined standard are translated into a score, as has been done for the composite approaches (see section 1.2). The difference between the criteria and standards score are then used to calculate the Gap WPI. As with the composite index approach, different weights could be assigned to the various differences.

three approaches are always able to identify the same worst off village in each country and season. In Tanzania it seems that the three approaches' ranking match much less.

1.3.3 Conclusions

The time analysis approach is quite simple to calculate and the only data required to compute it are, the time spent to collect water and the volume collected. The simplicity of this approach is an advantage in comparison to the composite approach. The later, in fact, requires more data and the computation of it is more complex.

In addition to its simplicity the time approach has few advantages with respect to the composite approach. First of all, it makes easier comparison of villages across country. In fact, to calculate the time approach it is not required to set any ends points whereas for the composite approach you need two end points to be able to convert a component into a score. In addition, as the time approach uses only two variables, there is less risk that a village is missing data for one of the variables (see section 1.2). Finally, no weightings are required in the time formula, avoiding the difficulty of setting them.

While the time method is apparently very simple, it does have a number of weaknesses:

- It is not able to represent the level of health of the environment and of the household;
- No consideration is done on the capacity level; in other words on the potentiality that a household/village has to reduce the time spent collecting water in the future;
- No information is provided on the actual amount of water available in the area;

By including information on the environment, capacity, health and water availability, the composite approach overcomes the weakness imbedded in the time approach.

Table 1.3.2 shows very clearly that there is a strong correlation between the time approach and the two composite approaches. So why should we collect more data to compute the composite approach if we can obtain the same answer by collecting only two set of data? The answer is that we want to know:

A) in what to invest to reduce the water poverty and to which extent; we know that we have to invest into improving water access but at which extent, it could be that after having improved access up to a certain level it is more effective to improve sanitation; as the composite approach is including both time and sanitation, it allows us to see how a combined intervention on them can reduce water poverty;

B) the impacts that a reduction of time spent collecting water could have on, for example, the environment and households wealth; the composite approach allows us to take that into account.

Overall the Time analysisapproach is a good approximation of the state of a village in terms of water poverty but for a more sustainable and holistic intervention towards water poverty alleviation the composite approach is the favoured one.

Weaknesses: 1) difficulty to identify the threshold level and the ends points (or the optimum level for the second gap approach); 2) difficult to design a weighting system able to reflect the trade off among the various criteria.

Strengths: it provides a holistic picture of the reasons why there is water poverty in a village/country.

At this stage the gap approach has not been yet calculated using the household data, however we are hoping to complete it in phase 2 and to compare further the gap approach with the composite one.

Appendix 1.5

The Water Poverty Index: a National Approach[1]

Peter Lawrence[2], Jeremy Meigh[3], Caroline Sullivan[3]

1 Introduction

Indicators of performance are an important part of the process of evaluating achievement. They have also become an important management tool giving direction to managerial policy and the allocation of resources. They have also become an important political tool, allowing both professionals and the lay public, the possibility of making judgements about the effectiveness of government policy. Performance indicators have also come under academic scrutiny with questions being raised as to the degree to which a set of numbers should be allowed to drive policy. Nonetheless these indicators do offer a relative measure of achievement which can serve to direct policy towards the improvement of performance.

This paper reports on the results of the first phase of research project into the feasibility of a Water Poverty Index. The purpose of the Water Poverty Index is to express an interdisciplinary measure which links household welfare with water availability and indicates the degree to which water scarcity impacts on human populations. Such an index makes it possible to rank countries and communities within countries taking into account both physical and socio-economic factors associated with water scarcity. This enables national and international organisations concerned with water provision and management to monitor both the resources available and the socio-economic factors which impact on access and use of those resources.

Most international indices are derived from available national aggregate data. This paper uses the conceptual framework developed over the first phase of the project to show how it can be used to construct an index for international comparisons based on aggregate national data. The ultimate objective of the project is to show how the results of small participatory local surveys can be used to build up a weighted national index which can replace or complement an index based on aggregate national data. Pilot surveys have been successfully carried out to examine the feasibility of developing a 'bottom-up' monitoring tool and the results of this work will be reported in a separate paper.

[1] Our thanks to very helpful inputs from William Cosgrove, Richard Connor and many others at various meetings and workshops too numerous to list here. Discussions with Rivkka Kfir and her colleagues at the Water Research Commission, Pretoria, and Barbara Schreiner at DWAF Pretoria specifically led to indicators on water quality, governance and distribution being found and added to the index. Many others also made important contributions to the thinking behind this work, in particular the team members of the research project 'The development and testing of the Water Poverty Index'. This paper is an output of that research project funded by the Department for International Development (DFID), UK Knowledge and Research contract number C24. The views expressed here do not necessarily represent those of DFID.

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2 Conceptual Framework

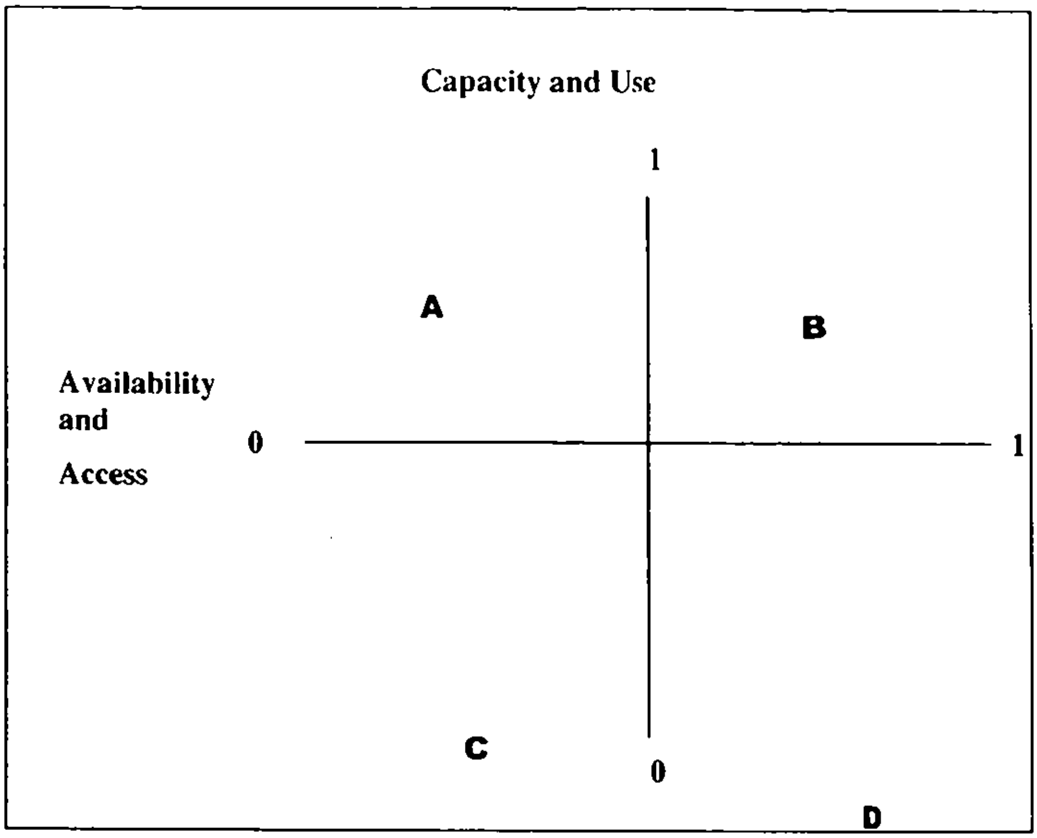
The idea of a WPI is to combine measures of water availability and access with measures of people's capacity to access water. People can be 'water poor' in the sense of not having sufficient water for their basic needs because it is not available. They may have to walk a long way to get it or even if they have access to water nearby, supplies may be limited for various reasons. People can also be 'water poor' because they are 'income poor'; although water is available, they cannot afford to pay for it. The South African Minister of Water Affairs and Forestry noted how he began life as a Minister,

...... with the shock of finding, in a village with a text book community water project, a young woman with her baby on her back, digging for water in a river bed, metres from the safe supply that we had provided. She was doing this because she had to choose between buying food or buying water. (Kasrils, 2000)

It is this kind of water poverty that the WPI constructed here is trying to capture alongside the more traditional definition of this condition. There is a strong link between 'water poverty', and 'income poverty' (Sullivan, forthcoming, 2002). A lack of adequate and reliable water supplies lead to low levels of output and health as well as a low capacity to enjoy adequate water supply because of its user cost. The underlying conceptual framework of the index therefore needs to encompass water availability, access to water, capacity for sustaining access, the use of water and the environmental factors which impact on water quality and the ecology which water sustains. Availability of water means the water resources, both surface and groundwater which can be drawn upon by communities and countries. Access means not simply safe water for drinking and cooking, but water for irrigating crops or for non-agricultural use. Capacity in the sense of income to allow purchase of improved water, and education and health which interact with income and indicate a capacity to lobby for and manage a water supply. Use means domestic, agricultural and non-agricultural use. Environmental factors which are likely to impact on regulation will affect capacity. The conceptual framework for the index can be illustrated in the four quadrant diagram in Figure 2. Quadrant A indicates a country or community which scores relatively highly on capacity and use, but has a low score on availability and access. Quadrant B show relatively high scores on both sets of factors. Quadrant C indicates both water and income poverty, while quadrant D covers relatively low capacity and use but high availability and access[4].

[4] The authors owe this quadrant approach to the participants at the WPI workshop in Arusha,Tanzania in May 2001, and especially to J. Delli Proscoli. See also Sullivan, 2002.

Figure 2 A WPI quadrant or matrix approach



Indicators are usually presented in the form of an index derived from a range of available data. The resulting measure enables a judgement of performance relative to previous time periods, or to the performance of others. The consumer price index tracks the prices of a typical basket of goods for one country or region over time and is usually published monthly. Indices of industrial output track the output of a representative sample of industrial products over time. The terms of trade indices track the relative prices of imports and exports over time. The Human Development and Human Poverty Indices evaluate countries' performance relatively to each other.

All indices, however well established are not without problems. The consumer price index (CPI), established in the late nineteenth century, is based on the prices of a representative basket of goods. However, this basket of goods changes over time as new products come onto the market and other products disappear. The importance of individual items in the basket may change over time both because of changing consumption habits with rising income, and because of changes in relative prices. These problems are partly overcome by regular changes of base year and changes in the weights given to each item in the basket. However, although an imperfect representation of price changes in the long run, the single number CPI is widely used to deflate nominal Gross Domestic Product (GDP) in order to estimate real output growth over time, the traditional way of judging a country's rate of development.

Using GDP as a measure of levels of development and rates of growth of real GDP as a measure of progress was considered to be an unsatisfactory way to compare levels of development because it said nothing about the quality of that development. Increases in output might not necessarily mean that there were improvements in health or education or that the benefits of increased output were spread throughout the population. The search for more representative indicators led to the development of the Human Development Index (HDI).

The HDI is an average of three separate indicators: life expectancy at birth, educational attainment and GDP per capita at purchasing power parity (PPP) values. The educational attainment index comprises an index of adult literacy and of primary, secondary and tertiary educational enrolment in which adult literacy is given a two-thirds weighting and school enrolment one-third. The life expectancy index is constructed by taking the ratio of the differences between the actual value for the country concerned and a fixed minimum (25 years), and a fixed maximum (85 years) and the fixed minimum. So a country with a life expectancy of 50 years would have an index of 50-25/85-25 = 0.417, while one with a life expectancy of 70 years would have an index of 0.75. Measures of educational attainment are straight percentages. The PPP measure of GDP per capita is adjusted by taking using log values in order to reduce the effect of very high incomes which are not necessary to attain a reasonable standard of living. The individual indices which make up the HDI are also published, so that it is possible to see what is driving any changes which take place.

The HDI gives a measure of social and economic progress which goes beyond the national income measures by which countries are usually compared. They encapsulate more than one measure of progress, averaged into a single number. The advantage of a single index is that it provides a measure which is uncomplicated and can clearly set one country's performance against that of others with which comparisons may wish to be made. Such comparisons will depend on the particular purposes of making them. Poor countries may wish to compare their position relatively to rich countries, neighbouring countries may wish to show how much progress they are making relatively to each other in order to convince their citizens that their governments are doing a good job. Failure to progress may push laggard regimes into making greater efforts, and may assist international organisations in pushing these regimes to progress. Publishing the component parts of the composite index can show where progress needs to be prioritised.

Nevertheless, the HDI, though now well-established, has been criticised on several grounds. Srinivasan (1994) is representative and has four main criticisms relevant to the present discussion. First, he argues (p.237) that 'income was never even the primary, let alone the sole, measure of development', as claimed by the first Human Development Report (UNDP, 1990). He notes that data on such measures as life expectancy at birth and infant mortality were used as measures of development from as early as the 1950s and that, for example, another single number index of 'international human suffering' already existed. Secondly, he takes issue with the conceptual framework underlying the HDI. The HDR distinguishes between the 'formation of human capabilities and the use people make of their acquired capabilities' (p.239). Countries can be compared internationally by measures of their real income based on values which are locally specific. This is not the case with such measures as life expectancy or educational attainment whose 'relative values may not be the same across individuals, countries and socio-economic groups' (p 240). Thirdly, most of its components are highly correlated with each other thus reducing the usefulness of the separate sub-indices in adding more information to the PPP income measure.[5] Finally, the data is weak, outdated or incomplete for many countries and therefore involves a large number of estimates.

Srinivasan is right to point to the prior existence of quality of life indicators. Nonetheless, until recently, the World Development Report in its statistical appendices, ordered countries by GDP per capita, suggesting that this was at least the first statistic to be used in any assessment of development. The single number HDI was essentially an alternative way of making that primary assessment. As with GDP, any serious assessment of performance would still require looking at a range of indicators, both quantitative and qualitative. His other criticisms are also valid. However, these numbers are 'indicators' and not precise measures. Although different capabilities and uses might be valued differently across countries and groups of people within countries, the development objective has always been conceived in terms of a 'catching-up' process. So making comparisons in relative terms does encapsulate this concept of development. The correlations between the different variables are indeed, high. However, the rank orders of countries do change from PPP GDP to HDI, and so the 'league table' could be viewed as one of real income adjusted for the other indicators, which though highly correlated, are not perfectly correlated.

However imperfect a particular index, especially one which reduces a measure of development to a single number, the purpose is political rather than statistical. As Streeten (1994: 235) argues:

> ...such indices are useful in focusing attention and simplifying the problem. They have considerable political appeal. They have a stronger impact on the mind and draw public attention more powerfully than a long list of many indicators, combined with a qualitative discussion. They are eye-catching.

An International Water Poverty Index (WPI)

Using a methodology comparable to that of the Human Development Index, we have constructed an index which measure countries' position relatively to each other in the provision of water. In order to do this, we construct an index consisting of five major components, each with several sub-components. The main components are:

- Resources
- Access
- Capacity
- Use
- Environment

Resources

This index combines two separate indices: one of *internal water resources* and the second of *external water inflows*. Both are calculated on a log scale to reduce the distortion caused by high values. Water inflow amounts are reduced by 50% to increase the weight of internal water resources in the measure. This index is a basic indicator of water availability.

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[5] Ogwang (1996) on the basis of principal component analysis concludes that using life expectancy at birth as a single measure of human development would lose little information and give a simpler and lower-cost index.

Access

There are three components to this index:

- percentage of the population with access to safe water
- percentage of the population with access to sanitation
- an index which relates irrigated land, as a proportion of arable land, to internal water resources. This is calculated by taking the percentage of irrigated land relative to the internal water resource index and then calculating the index of the result. The idea behind this method of calculation is that countries with a high proportion of irrigated land relative to low internal available water resources are rated more highly than countries with a high proportion of irrigated land relatively to high available internal water resources.

This index tries to take into account basic water and sanitation needs for relatively poor agriculturally-based countries, recognising that water availability for growing food is as important as for domestic and human consumption.

Capacity

There are four components to this index.

- Log GDP per capita (PPP) (US$). This is the average income per head of population adjusted for the purchasing power of the currency. This is considered to be a much more accurate measure of the average standard of living across countries. These data are presented in log form in order to reduce the impact of very high values.
- under-5 mortality rate (per 1000 live births). This is a well-established health indicator.
- UNDP education index from the *Human Development Report* 2001.
- the Gini coefficient. This is a well known measure of inequality based on the Lorenz curve which gives the distribution of income across the population.[6] It acts here as a proxy for the distribution of resources, including water. Where the Gini coefficient is not reported the Capacity index is based only on the first three sub-indices.

This index tries to capture those socio-economic variables which can impact on access to water or are a reflection of water access and quality. Introducing the Gini coefficient here is an attempt to proxy for unequal distribution of water resources.

Use

This index has three components:

- domestic water use per capita (m^3/cap/yr). This index takes 50 litres per person per day as a reasonable target for developing countries.[7] We then construct a two-way index such that countries at 50 litres =1. Countries below the minimum have an index calculated such that the lower the value the more they are below the

[6] Hicks (1997) constructs an 'inequality adjusted HDI which, for 20 countries, adjusts each of the component indices by a Gini coefficient for that indicator. He finds that there are 'losses on the HDI index score of up to 57%, and changes in rank go up to 3 negatively and 4 positively.

[7] see Gleick (1996) for a detailed rationale for adopting this standard

minimum. Countries above the minimum have a lower value on the index the higher they are above 50 litres. This gives some measure of 'excessive' use.

- industrial water use per capita (m^3/cap/yr). Here the proportion of water used by industry is related to the proportion of GDP derived from industry. Countries whose proportion of industrial water use is higher than their proportion of industrial GDP are indexed lower than those whose proportion of GDP from industry is higher than their proportion of water use by industry. This gives a rough measure of water use efficiency.
- agricultural water use per capita (m^3/cap/yr). The index is calculated in the same way as for industrial water use.

Environment

This index is calculated on the basis of an average of five component indices. These are:

- an index of *water quality* based on measures of
  - dissolved oxygen concentration,
  - phosphorus concentration,
  - suspended solids
  - electrical conductivity;
- an index of *water stress* based on indices of
  - fertilizer consumption per hectare of arable land,
  - pesticide use per hectare of crop land,
  - industrial organic pollutants per available fresh water
  - the percentage of country's territory under severe water stress;
- an index of *regulation and management capacity* based on measures of
  - environmental regulatory stringency,
  - environmental regulatory innovation,
  - percent of land area under protected status
  - the number of sectoral EIA guidelines;
- an index of *informational capacity* based on measures of availability of sustainable development information at the national level, environmental strategies and action plans, and the percentage of ESI variables missing from public global data sets;
- an index of *biodiversity* based on the percentage of threatened mammals and birds.

This index tries to capture a number of environmental indicators which reflect on water provision and management and which are included in the Environmental Sustainability Index (see bibliography). These indicators not only cover water quality and stress, but also the degree to which water and the environment generally, and related information, are given importance in a country's strategic and regulatory framework.

Table 1 provides a summary of the structure of the index and the data used to build it. The indices show a country's relative position. The basic calculation involves the following formula:

$x_i - x_{min} / x_{max} - x_{min}$

where x_i, x_{max} and x_{min} are the original values for country i, the highest value country, and the lowest value country respectively. The index for any one indicator lies between 0 and 1. The maximum and minimum values are usually adjusted so as to avoid values of or 1. Any remaining values above 1 or below zero are fixed at 1 and 0, respectively. Within each of the five components, sub-component indices are averaged to get the zero component index. Each of the five component indices is multiplied by 20 and then added together to get the final index score.

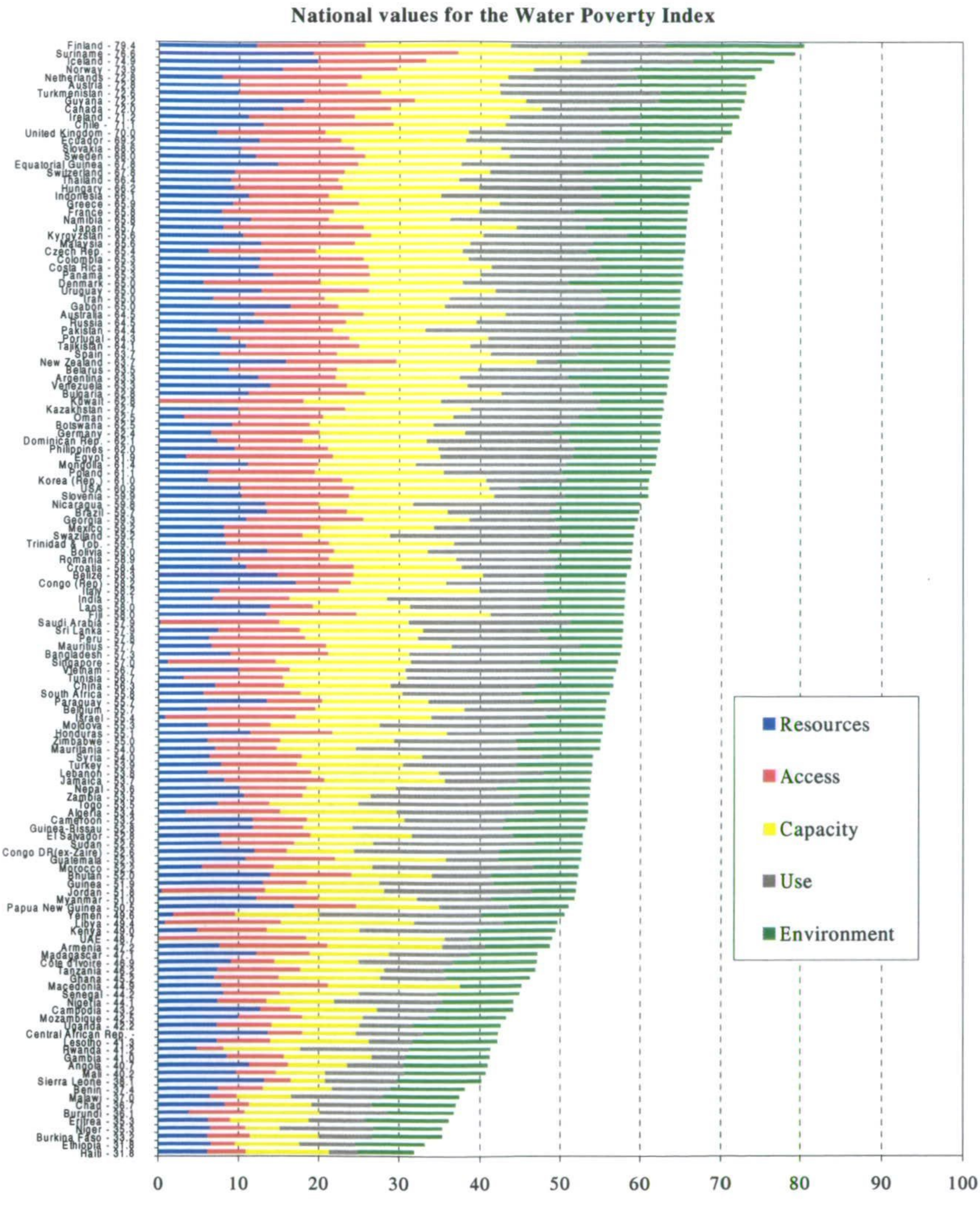
Table 1: Structure of Index and Data Used

WPI Component	**Data Used**
Resources	• internal Freshwater Flows • external Inflows • population
Access	• % population with access to clean water • % population with access to sanitation • % population with access to irrigation adjusted by per capita water resources
Capacity	• ppp per capita income • under-five mortality rates • education enrolment rates • Gini coefficients of income distribution
Use	• domestic water use in litres per day • share of water use by industry and agriculture adjusted by the sector's share of GDP
Environment	indices of: • water quality • water stress • environmenal regulation and management • informational capacity • biodiversity based on threatened species

Analysis

The resulting Water Poverty Index is presented in rank score order with the highest scoring country first (see Figure 1 and Appendix: Table 1). The results show few surprises. Of the 140 countries with relatively complete data, most of the countries in the top half are either developed or richer developing. There are a few notable exceptions: Guyana scores highly on resources and use to get into eighth position, while Belgium is 87th in the list, having scored low on resources and on environment.

Figure 1



The US and New Zealand, though they score relatively highly on Environment score very low on use. South Africa, low on the resources index is relatively high on the other sub-indices reflecting its progressive policies on access and management. The index as presented does suggest areas of current future policy concentration with the overall performance. Data is also provided in Appendix: Table 1 on the Falkenmark index measure: that is, water resources per capita per year. The correlation between the Falkenmark index of water stress and our Water Poverty Index is only 0.32 which suggests that the WPI does add to the information available in assessing progress towards sustainable water provision[8].

Table 2 below shows the correlation matrix for the five indices and the WPI. There is very little correlation between the different sub-indices, with the exception of access and capacity. Although intuitively, a strong association between these two indicators is to be expected, we might have expected a stronger negative correlation between resources and use and a strong negative association between resources and environment. It would appear that strong scores on access and capacity are associated with strong scores on the index, although the correlations are still relatively low. In this respect, the index avoids one of the main criticisms levied at the HDI.

Table 2: Correlation Matrix: sub-indices and WPI

	Resources	Access	Capacity	Use	Environ-ment	HDI
Resources						
Access	-0.14					
Capacity	-0.04	0.80				
Use	-0.08	0.16	0.09			
Environment	0.33	0.20	0.32	-0.10		
HDI	0.04	0.81	0.94	0.09	0.36	
WPI	0.36	0.71	0.74	0.49	0.49	0.77

The usual cautions need to be made here. First the data and the results based on them are, as always, to be used with care. Coverage is not 100 per cent and so some key measures are missing for some countries. This may affect their position in the ranking, although not by very much, since there are 17 components to the five sub-indices and some of these are themselves an average of two or more measures.

There is some implicit weighting in the overall index in that each sub-index has a different number of component indices, but there is no attempt to weight the five sub-indices other than equally. It could be argued that less weight should be given to resources and more to use, access and environment in that resources are given and it is their management and distribution that is most important. The index so far developed

[8] The Falkenmark water stress index measures per capita water availability and considers that a per capita water availability of between 1000 and 1600m^3 indicates water stress, 500 -1000m^3 indicates chronic water scarcity, while a percapita water availability below 500 m^3 indicates a country or region beyond the 'water barrier' of manageable capability (Falkenmark, 1989)

does allow for different weights. However, the information is in the components rather than the final single number, and as with the Human Development Index, it is likely that a straight average is as useful as a weighted one.

Conclusions

This water poverty index is a first pass at trying to establish an international measure comparing performance in the water sector across countries. It does seem to give some sensible results but it does not pretend to be definitive nor offer an accurate measure of the situation. No one single figure or set of figures could do this, especially when they are meant to be representative of the progress or otherwise of a whole country. This is, however a start. There are other data that could have been included, if available, the most important of which is some relative measure of investment in water. Several more countries could have been included if data had been available.

Similar criticisms to those made of the HDI can be made of this index, with the exception that most of the sub-indices are not correlated with each other. The data itself needs more investigation, since there are sometimes large differences between reputable estimates of the same variable, as in the case of water resources (see Appendix 2). Finally, the data does combine components that can be priced and ones that cannot be given a comparative value. However, it is argued that what this index is essentially doing is providing a measure of water availability and access that is adjusted by socio-economic and environmental factors and in showing the components of the index is making clear which apples are combined with which pears.

The index produced here is intended to focus attention at international level on improving water management performance across the world, and as Streeten wrote of the HDI it is also intended to 'contribute to a muscle therapy that helps us to avoid analytical cramps' (Streeten, 1994:235).

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Appendix 1

Table 1: The Water Poverty Index and Sub-Indices Compared with Falkenmark and the Human Development Index

Country	Resources	Access	Capacity	Use	Environ-ment	Water Poverty	Falken mark	HDI
Algeria	3.4	11.7	14.5	17.0	6.7	53.5	0.5	0.69
Angola	11.3	4.9	7.4	7.0	10.4	41.0	14.3	0.42
Argentina	12.4	9.7	15.3	13.5	12.6	63.5	26.8	0.84
Armenia	7.6	13.5	14.2	5.3	8.1	48.7	3.0	0.75
Australia	11.9	13.7	17.6	8.6	13.2	65.0	18.2	0.94
Austria	10.1	13.4	18.8	14.8	15.7	72.8	10.2	0.92
Bangladesh	9.0	12.2	10.1	17.3	9.1	57.7	9.4	0.47
Belarus	8.8	13.5	17.5	15.6	8.4	63.7	5.7	0.78
Belgium	6.0	13.6	18.5	12.3	5.4	55.7	1.6	0.94
Belize	14.9	9.5	15.9	7.7	10.4	58.4	66.4	0.78
Benin	7.5	5.6	8.7	7.2	9.2	38.1	3.7	0.42
Bhutan	14.0	10.2	9.9	7.2	11.0	52.2	44.7	0.48
Bolivia	13.6	8.3	11.6	15.1	10.5	59.1	37.9	0.65
Botswana	9.1	9.7	15.4	17.0	11.3	62.5	9.1	0.58
Brazil	13.5	10.1	12.5	12.7	11.1	59.8	40.9	0.75
Bulgaria	11.2	14.5	16.9	11.3	9.3	63.3	24.9	0.77
Burkina Faso	6.1	5.3	8.6	6.7	8.6	35.3	1.5	0.32
Burundi	3.8	6.9	9.4	8.4	8.1	36.7	0.5	0.31
Cambodia	12.8	3.7	10.8	7.2	9.5	44.1	42.6	0.54
Cameroon	11.8	6.7	12.1	12.4	10.4	53.4	17.8	0.51
Canada	15.5	13.5	18.7	8.4	16.1	72.2	89.6	0.94
Central African Rep.	13.6	4.4	6.7	8.2	9.3	42.2	39.0	0.37
Chad	8.3	3.1	7.8	7.5	10.4	37.0	5.6	0.36
Chile	13.1	16.2	13.8	15.6	12.5	71.2	30.8	0.83
China	7.1	8.6	13.2	18.1	9.7	56.7	2.2	0.72
Colombia	12.6	12.9	12.9	15.9	11.0	65.4	25.3	0.77
Congo (Rep)	17.1	6.9	11.8	12.1	10.4	58.3	282.7	0.50
Congo DR(ex-Zaire)	12.0	4.1	8.4	17.8	10.4	52.6	19.7	0.43
Costa Rica	12.5	13.7	15.2	13.8	10.2	65.3	23.6	0.82

Country	Resources	Access	Capacity	Use	Environment	Water Poverty	Falken mark	HDI
Côte d'Ivoire	9.0	5.5	10.6	11.6	10.4	47.1	5.3	0.43
Croatia	11.0	13.4	13.3	11.6	9.6	58.9	16.0	0.80
Czech Rep.	6.2	13.4	18.2	15.6	12.2	65.6	1.6	0.84
Denmark	5.5	14.7	17.6	13.2	14.3	65.3	1.1	0.92
Dominican Rep.	7.3	10.7	15.4	17.7	11.3	62.4	2.5	0.72
Ecuador	12.6	10.1	15.4	20.0	11.9	70.0	24.8	0.73
Egypt	3.4	18.3	13.3	16.4	10.4	62.0	0.9	0.64
El Salvador	7.6	11.4	12.6	12.4	8.7	52.8	2.8	0.70
Equatorial Guinea	14.8	10.0	12.7	20.0	10.4	68.0	66.2	0.61
Eritrea	6.2	2.8	9.8	7.0	10.4	36.1	2.3	0.42
Ethiopia	6.6	3.1	8.0	7.0	8.6	33.2	1.8	0.32
Fiji	13.4	11.3	16.5	7.9	8.9	58.0	35.0	0.76
Finland	12.2	13.5	18.0	19.3	17.4	80.5	21.3	0.93
France	7.9	13.9	18.0	11.9	14.2	65.9	3.2	0.92
Gabon	16.5	5.9	13.2	20.0	9.4	65.0	133.8	0.62
Gambia	8.6	7.1	10.9	4.2	10.4	41.2	6.1	0.40
Georgia	11.0	14.6	13.1	10.7	10.4	59.7	12.7	0.74
Germany	6.5	13.6	18.0	10.8	13.5	62.5	2.2	0.92
Ghana	6.9	8.1	12.7	8.2	10.4	46.2	2.6	0.54
Greece	9.3	15.7	17.4	14.5	9.3	66.1	6.5	0.88
Guatemala	10.9	11.1	13.8	6.4	10.4	52.6	11.8	0.63
Guinea	13.1	5.5	9.0	14.0	10.4	52.0	30.4	0.40
Guinea-Bissau	11.8	6.3	6.1	18.6	10.4	53.2	22.3	0.34
Guyana	18.1	13.7	14.0	16.4	10.4	72.6	279.9	0.70
Haiti	6.1	4.8	10.5	3.4	7.0	31.8	1.5	0.47
Honduras	11.4	10.3	14.2	10.8	8.6	55.3	14.8	0.63
Hungary	9.5	13.5	16.9	14.1	12.4	66.4	12.0	0.83
Iceland	19.9	13.4	19.2	14.0	10.0	76.6	605.0	0.93
India	6.8	9.6	12.1	20.0	9.7	58.2	2.1	0.57
Indonesia	11.2	10.0	13.9	20.0	11.0	66.2	13.4	0.68
Iran	6.8	13.9	15.5	19.8	9.1	65.0	2.0	0.71

Ireland	11.2	13.3	19.1	16.5	11.9	72.0	13.9	0.92
Israel	0.8	16.3	16.8	14.2	7.5	55.7	0.2	0.89
Italy	7.7	14.9	17.4	8.4	9.9	58.2	2.9	0.91
Jamaica	8.2	12.5	15.0	9.0	9.2	53.8	3.6	0.74
Japan	8.1	17.5	18.9	8.5	12.8	65.8	3.4	0.93
Jordan	0.4	12.9	14.9	18.2	5.5	51.9	0.1	0.71
Kazakhstan	10.0	13.3	15.6	15.8	8.2	62.8	8.9	0.74
Kenya	4.9	8.7	11.5	14.6	9.7	49.4	1.0	0.51
Korea (Rep.)	6.1	16.9	17.7	10.0	10.4	61.1	1.5	0.88
Kuwait	0.0	18.1	17.1	19.8	7.9	62.8	0.0	0.82
Kyrgyzstan	10.5	16.0	13.8	18.2	7.2	65.7	9.9	0.71
Laos	13.9	5.4	12.0	16.4	10.4	58.1	51.8	0.48
Lebanon	6.1	13.0	15.8	13.0	6.0	53.9	1.5	0.76
Lesotho	7.3	6.7	12.3	5.4	10.4	42.1	2.4	0.54
Libya	0.8	14.5	16.5	11.0	6.8	49.6	0.1	0.77
Macedonia	7.9	13.3	16.2	0.0	7.7	45.2	6.8	0.77
Madagascar	12.2	6.7	9.8	10.0	8.4	47.2	21.1	0.46
Malawi	6.4	3.5	6.7	11.4	9.4	37.4	1.7	0.40
Malaysia	12.7	11.7	14.3	15.3	11.5	65.6	26.1	0.77
Mali	9.8	4.9	6.2	9.8	10.0	40.7	8.9	0.38
Mauritania	7.1	7.7	9.8	20.0	10.4	55.0	4.3	0.44
Mauritius	6.6	14.3	15.5	16.0	5.3	57.8	1.8	0.77
Mexico	8.1	12.1	14.1	15.6	9.5	59.3	3.5	0.79
Moldova	6.1	7.9	13.6	18.5	9.3	55.4	2.7	0.70
Mongolia	11.1	8.8	12.0	18.7	11.2	61.9	13.1	0.57
Morocco	5.4	9.1	12.3	20.0	5.5	52.3	1.1	0.60
Mozambique	10.0	8.0	7.5	8.1	9.6	43.2	11.0	0.32
Myanmar	12.2	7.9	12.1	9.3	10.4	51.8	22.1	0.55
Namibia	11.4	9.7	15.0	19.3	10.4	65.8	26.4	0.60
Nepal	10.2	8.3	11.2	12.4	11.7	53.7	8.8	0.48
Netherlands	7.9	17.3	18.2	16.1	14.3	73.9	5.8	0.93
New Zealand	15.9	13.7	17.4	2.6	14.1	63.7	102.8	0.91
Nicaragua	13.4	6.7	11.6	17.8	10.5	59.9	34.5	0.64
Niger	6.4	4.4	4.4	11.6	8.5	35.3	3.0	0.27

Country	Resources	Access	Capacity	Use	Environment	Water Poverty	Falkenmark	HDI
Nigeria	7.4	6.1	8.5	13.4	8.8	44.2	2.8	0.46
Norway	15.5	14.3	17.0	12.5	15.7	74.9	88.0	0.94
Oman	3.1	17.4	16.2	15.6	10.4	62.7	0.4	0.75
Pakistan	7.3	14.4	11.5	20.0	11.3	64.5	3.0	0.50
Panama	14.3	12.1	13.6	14.5	10.8	65.3	51.6	0.78
Papua New Guinea	17.0	7.7	10.3	8.6	7.5	51.0	166.6	0.53
Paraguay	13.5	6.9	13.2	13.1	9.1	55.8	57.1	0.74
Peru	6.3	12.1	13.9	16.2	9.5	57.9	1.6	0.74
Philippines	9.5	11.7	13.6	17.0	10.3	62.1	6.3	0.75
Poland	6.2	13.3	16.0	14.7	11.2	61.4	1.6	0.83
Portugal	9.0	14.8	17.1	10.3	13.2	64.4	6.7	0.87
Romania	9.2	12.1	15.8	12.6	9.4	59.0	9.3	0.77
Russia	13.0	10.3	16.1	12.4	12.7	64.5	30.6	0.78
Rwanda	4.8	3.3	9.7	13.5	10.0	41.3	0.8	0.40
Saudi Arabia	0.2	14.9	16.1	20.0	6.8	58.0	0.1	0.75
Senegal	8.2	7.0	9.9	9.7	10.2	44.9	4.4	0.42
Sierra Leone	13.3	3.3	4.3	8.9	10.4	40.2	33.0	0.26
Singapore	1.2	13.4	16.8	16.1	9.8	57.3	0.2	0.88
Slovakia	10.3	14.1	18.1	13.2	13.5	69.2	15.4	0.83
Slovenia	10.4	13.4	17.9	8.8	10.4	60.9	9.3	0.87
South Africa	5.6	12.1	12.7	14.7	11.1	56.3	1.2	0.70
Spain	7.6	14.6	19.0	11.0	11.8	64.1	2.8	0.91
Sri Lanka	7.5	10.1	15.3	14.5	10.5	57.9	2.7	0.74
Sudan	7.9	9.1	9.8	20.0	5.9	52.8	5.2	0.44
Suriname	19.4	17.9	16.2	15.6	10.4	79.4	479.6	0.76
Swaziland	8.2	9.8	10.8	20.0	10.4	59.2	5.0	0.58
Sweden	12.1	13.6	17.9	10.4	14.6	68.6	20.0	0.94
Switzerland	9.5	13.7	18.0	11.7	15.0	67.8	7.2	0.92
Syria	6.3	11.6	14.9	14.8	6.4	54.0	2.8	0.70
Tajikistan	10.9	14.1	13.7	15.3	10.4	64.3	12.9	0.66
Tanzania	7.4	10.4	10.4	7.4	11.4	46.9	2.7	0.44
Thailand	9.0	13.5	15.0	19.6	10.8	67.8	6.7	0.76

Togo	7.4	6.5	11.1	19.3	9.3	53.5	2.6	0.49
Trinidad and Tobago	8.4	12.9	15.4	15.8	6.7	59.2	3.9	0.80
Tunisia	3.2	12.4	15.3	19.4	6.5	56.7	0.4	0.71
Turkey	7.8	9.5	13.1	14.0	9.5	54.0	3.1	0.74
Turkmenistan	10.0	17.7	14.7	20.0	10.4	72.8	15.8	0.73
Uganda	7.3	6.9	10.9	6.5	10.8	42.5	3.0	0.44
United Arab Emirates	0.0	18.5	17.1	2.9	10.4	49.0	0.1	0.81
United Kingdom	7.3	13.5	17.8	16.5	16.0	71.1	2.5	0.92
Uruguay	12.8	13.4	15.6	13.2	9.9	65.0	37.2	0.83
USA	10.3	14.1	16.7	3.8	16.2	61.0	8.9	0.93
Venezuela	14.0	9.5	14.9	14.0	10.9	63.3	54.5	0.77
Vietnam	10.0	6.4	14.4	18.2	8.0	57.0	11.2	0.68
Yemen	1.9	7.7	10.5	20.0	10.4	50.5	0.2	0.47
Zambia	10.7	7.3	8.5	18.2	8.9	53.6	12.7	0.43
Zimbabwe	6.1	9.1	14.2	15.0	10.7	55.1	1.7	0.55

Appendix 2: Sources of the Data

Population

World Resources Institute, 2000 Tables HD.1 and SCI.1 and HDR, 2001

Resources

World Resources Institute, 2000 Table FW.1, and Gleick, 2000. Shiklomanov (1997) has compiled a comparison of water resources data for a selected, but large, range of countries from different sources, including the WRI, Gleick and his own State Hydrological Institute. The original WRI data has been adjusted to take account of the variation in estimates of water resources by taking the modal estimate. The most striking discrepancy was in the case of Peru, which WRI says has 1746 billion cubic metres of internal freshwater flows (69,000 per capita), while all other estimates have at 40 billion cubic metres (1,600 per capita). The World Bank's Development Indicators also quote the former number and the WRI as the source, although earlier years of the WRI's data have the latter estimate.

Access

World Resources Institute, 2000 Table HD.3, and HDR 1999

Irrigation - World Resources Institute, 2000 Table AF.2. and Gleick 2000 (irrigation) with cropland areas from *World Resources Institute (2000) 2000-01* Table SCI.1.

Capacity

GDP - HDR 2001

Under-5 mortality - World Resources Institute, 2000 Tables HD.2 and SCI.1

(7)

Education - HDR 2001

Use

Gleick, 2000 and World Resources Institute, 2000

World Bank, 2001

Environment

World Economic Forum, Yale Center for Environmental Law and Policy, and Center for International Earth Science Information Network, Columbia University, *2001 Environmental Sustainability Index* (http://www.ciesin.columbia.edu/indicators/ESI), January 2001.

Appendix 2.1
Pilot Country and Site Characteristics
Tim Fediw, CEH Wallingford

2.1.1: Republic of **South Africa**

South Africa occupies 1,219,080 square kilometres at the southernmost tip of the African continent, stretching from the Limpopo River in the North to Cape Agulhas in the South. The eastern coastline runs along the Indian Ocean, while the South Atlantic Ocean lies on the west coast. South Africa borders Namibia, Botswana and Zimbabwe to the north, while Mozambique and Swaziland border on the North-East. The capital city is Pretoria, located in the north, although the legislative centre is Cape Town in the south. Terrain consists of a vast interior plateau rimmed by rugged hills and a narrow coastal plain.

Climate is mostly semi-arid, with subtropical areas along the east coast. Prolonged droughts often occur. Main natural resources include; gold, chromium, coal, iron ore, nickel, uranium, gem diamonds, vanadium, salt and natural gas. One of the biggest environmental issues facing South Africa at present is the threat of growth in water usage exceeding supply.

Key statistics are presented below:

Table 1: South Africa- Key Statistics:

Population	43.84m (2000)
Population Growth	2% per year (1996-2000)
Currency	RAND (R6.91:U.S$1, 2000 average)
GDP	R867bn (US$125bn, at exchange rate, 2000)
Per Capita GDP	R19,790 (US$2,864 at exchange rate, 2000)
GDP Growth	2.5% (average 1996-2000)
Inflation	6.7% (average 1996-2000)
Unemployment Rate	30% (estimate, 2000)

South Africa has one of the most unequal distributions of income in the world. At one end of the scale are the affluent classes who enjoy a standard of living comparable with the most developed countries in the world, whilst at the other end, many are living in extreme poverty associated with developing countries. Economic activity is primarily led by minerals and energy, around which much manufacturing industries are based. Exports are also mineral led.

Agriculture does not contribute significantly to GDP, with the most important crop being maize. Arable land accounts for 10% of land use, with permanent crops accounting for 1% and permanent pastures 67%. Services, notably an advanced financial sector, retail and tourism, are the most important contributors to GDP, although informal services are the main source of employment.

The spread of HIV/AIDS has led to reduced life expectancy in South Africa. The latest estimate places the average life expectancy for males at 47.64 years and females slightly longer at 48.56 years[1] The prevalence rate of HIV/AIDS has been estimated as approximately 20% of the adult population. It is estimated that 81.8% of the population are literate.

South Africa gained its independence from the UK in 1910. It became a full democracy in 1994, with the African National Congress (ANC) in power, who won a second term of office, under Thabo Mbeki, in 1999. Policy issues have tended to reflect contradictions between the needs to address social inequalities and the need for economic growth.

South Africa is a federal state divided into 9 provinces, of which the pilot sites lie in that of KwaZulu/Natal, located in the East of the country. KwaZulu/Natal has an area of 92180 square km which accounts for 7.6% of the total country. The region has a population of 8 505 340 (21.1% of total population) and a population density of 92.3 per square km .

The two cities of KwaZulu/Natal are Durban and Pietermaritzburg. Durban offers an atmosphere that is a blend Western, African and Eastern cultures. It is also one of the most popular holiday destinations and divides the KwaZulu/Natal coastline into the south coast and north coast, both of which offer numerous holiday resorts. In addition to the warm waters of the Indian Ocean, KwaZulu/Natal is also home to many game resorts and reserves in the majestic Drakensberg mountains. [2]..

The pilot study sites are in the Thukela basin within KwaZulu-Natal. The peri-urban areas are two separate sections of Wembezi township, which lies about 10 km west of the town of Estcourt. The rural sites are two communities within the general area known as Keate's Drift, about 75 km east of Wembezi. Table 2 gives some details of the populations and households surveyed.

Table 2: Communities surveyed – South Africa

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Wembezi A	Peri-urban	30,000 (total for Wembezi)	148	818
Wembezi C	Peri-urban		220	1329
Ethembeni	Rural	3280	124	1227
KwaLatha	Rural	1256	133	972

The Thukela basin has an area of 29,000 km^2. It rises in the Drakensberg mountains at altitudes of over 3000 m and flows eastwards to reach the Indian Ocean about 85 km north of the city of Durban. Mean annual rainfall varies from around 2000 mm in the Drakensberg to as little as 550 mm in the drier central regions. Most of the rain falls from December to February, and there is relatively high inter-annual variability of rainfall. Wembezi is in the western part of the basin at an altitude of about 1400 m,

[1] (2001) http://www.cia.gov
[2] http://www.exinet.co.za/sa_regn.html

and with annual rainfall of about 800 mm. Keate's Drift is in the lower central part of the basin which is also the driest (altitude about 700 m, annual rainfall about 550 mm). The basin has high levels of potential evaporation, which, combined with the strong seasonality and inter-annual variability of the rainfall, lead to the area being classified as generally semi-arid.

The basin's natural land cover is mainly grassland and savanna. However, it has been highly modified by human use, leading to a complex patchwork of uses which include mining, urbanisation, commercial and subsistence agriculture, irrigation and impoundments, as well as substantial areas of degraded grassland, thickets and bushveld.

The river flows in the basin are strongly seasonal, with very low winter flows (June-August) and high summer flows (November-February). The streamflow is dominated by storm flows, indicative of the episodic and intense nature of the rainfall, which often occurs as thunderstorms. Flow variability from year to year is also high for any given month. There is also evidence that high and low flow years tend to come in clusters. The water resources of the basin are relatively highly developed, and the basin is a major source of water for areas outside its boundary. Overall, a total of more than 600 million m^3 of the Thukela's annual resource of 4000 million m^3 are transferred out of the basin. However, the location of these major abstractions is such that they do not have a significant impact on the sites being examined in this study.

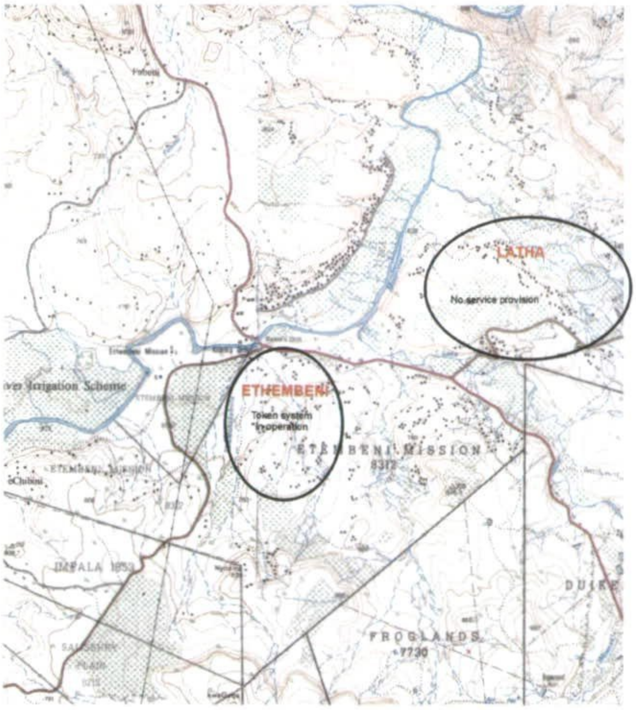


Figure 1 shows the topography and natural features of the Keate's Drift area in more detail. It can be seen that, although the communities are close to a fairly large river, steep slopes intervene, making access to the river difficult. The smaller streams closer to the houses are very much more ephemeral in their flow.

Figure 1 Locations and topography – Ethembeni and KwaLatha, South Africa

The study areas are underlain by rocks of the Estcourt Formation, a part of the Adelaide Subgroup, which is in turn part of the Beaufort Group of the Karoo Supergroup. These rocks consist predominantly of feldspathic mudstones, siltstones, shales and subordinate sandstones, and are of Permian to Triassic age. Generally speaking, the rocks are fine grained, very well cemented and hard and dense, and in consequence can possess little primary porosity or intergranular permeability. Groundwater storage and movement frequently occurs within and through fractures, as well as in the rock matrix. Borehole yields are therefore often dependent on the number, size and degree of interconnection of fractures encountered. Initial high yields may decline substantially due to the depletion of aquifer storage by abstraction. Recharge to certain fracture systems may be limited where these are overlain by less permeable rocks, or where interconnection between fracture systems is low.

Dolerite intrusions in the form of dykes or sills are common in Karoo rocks. These frequently outcrop to form ridges or other topographical features, or can be located as soil or vegetation changes or as lineaments on aerial photographs. Magnetometer geophysical surveys are used to locate dolerite bodies. Dolerite is normally regarded as an aquiclude; however the contact zone between a dolerite intrusion and the surrounding Karoo country rock forms a "chilled" and fractured zone which often has a relatively high permeability. The fractured dolerite can act to collect water from the surrounding less permeable country rock, and from the more porous weathered dolerite at the surface, and transmit it relatively rapidly to a well intake. For this reason the edges of dolerite intrusions are commonly targeted by groundwater drillers working in the argillaceous rocks of the Karoo Basin. Yields from such systems frequently decline with time as the limited storage in the fractures in the dolerite is soon exhausted by over-pumping. The formation of clays on fault planes or contacts may also prevent significant fracture permeability from developing.

2.1.2: Democratic Socialist Republic of **Sri Lanka**

Sri Lanka is an island in the Indian Ocean, south of India, in Southern Asia and occupies an area of 65,610 square kilometres. The capital city of Colombo, lies on the east coast, although Sri Jayewardenepura Kotte acts as the legislative capital. Terrain is mostly low with flat to rolling plain dotted with small hills at elevations of less than 500 m. The topography is dominated by the highland massif in the central southern part of the country, which rises to a maximum altitude of a little over 2500m. From here the land slopes down to sea level in all directions. The highland area covers a fairly small part of the country, and most of it is lowland or rolling plains.

Climate is tropical monsoon, which brings the occasional risk of cyclone and tornadoes. There is a strong pattern of spatial variation in rainfall. The wettest areas are found in the central mountains and on their western slopes, with annual totals exceeding 5000 mm at some stations. The south-western corner of the island is generally wet, with much of it receiving more than 3000 mm. The rest of the central part of the country has annual rainfall in the range 1500-2000 mm, while both the north and the extreme south are markedly drier, with rainfall typically 1000-1500 mm. Main natural resources in Sri Lanka are limestone, graphite, mineral sands, gems, phosphates, clay and hydropower. Current environmental issues include deforestation, soil erosion, freshwater pollution and air pollution in Colombo.

Key statistics are presented below:

Table 3: Sri Lanka- Key Statistics

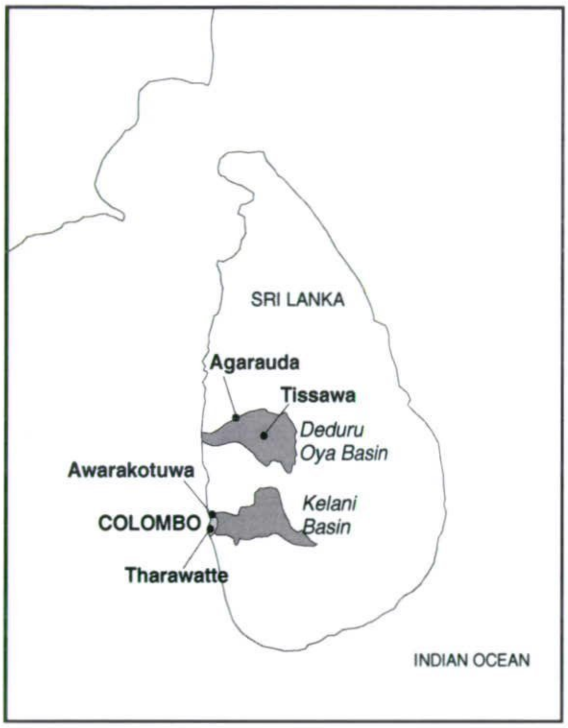
Population	19m (2000)
Population Growth	0.87% (2000)
Currency	Sri Lankan Rupee (LKR)
GDP	1,245,041 LKR xM (2001)
Per Capita GDP	65,528 LKR (Current Prices 2001)
GDP Growth	5.3% (2000 estimate)
Inflation	6.7% (2001 estimate)
Unemployment Rate	8.8% (1999 estimate)

Sri Lanka is suffering due to an ethnic war between the Sinhalese majority and Tamil separatists, which began in the mid eighties. Many Tamil civilians have fled the island or are living in refugee camps, predominantly in India.

Main export commodities are textiles, tea, diamonds, coconut products and petroleum products. Main agricultural products include; rice, sugarcane, grain , tea, rubber and beef. . Main industries in Sri Lanka are; the processing of rubber, tea, coconuts and other agricultural commodities, clothing, cement, petroleum refining, textiles and tobacco.

Approximately 14% of land is used for arable farming, whilst forests and woodland account for 32%, permanent pastures 7% and permanent crops 15%. Sri Lanka's most dynamic sectors are food processing, textiles, food & beverage, telecommunications, banking and insurance. Recent hostilities have thwarted the growth of the tourism sector.

Life expectancy is comparatively high in Sri Lanka at 69.58 years for males and 74.73 for females. This compares to 75.13 and 80.66 respectively for the UK. Prevalence of HIV/AIDS in Sri Lanka is low at only 0.07% of the adult population, whilst literacy is estimated at 90.2%



Sri Lanka, then called Ceylon, gained Independence from the UK in 1948. The People's Alliance, with C.B Kumaratunga as president was re-elected for a six year term in 1999.

The country is a federal state, divided into 8 provinces. The pilot study sites are the urban site of Tharawaththa (or Tarawatta), Colombo, Western Province, peri-urban Awarakotuwa, Gampaha, Western Province and two rural communities of Agarauda and Tissawa both in the Deduru Oya basin approximately 100 km to the north of Colombo, Kurunegala District, North Western Province. The North Western Province covers an area of 7,888 square kilometres, whilst the Western Province covers an area of 3,684 square kilometres. .The locations are shown in Figure 2, and some brief details of the populations and households surveyed are given in Table 4.

Figure 2 *Map of the study area – Sri Lanka*

Table 4 Communities surveyed – Sri Lanka

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Tharawatte	Urban	460	83	347
Awarakotuwa	Peri-urban	520	121	501
Agarauda	Rural	350	66	282
Tissawa	Rural	720	144	589

The country has been classified into three broad agro-ecological zones, defined on the basis of agricultural land use, climate, topography and soils. The wet zone is the south-western corner, roughly corresponding to the very wet area mentioned above; a band surrounding this is the intermediate zone, while the dry zone is the remaining northern, eastern and southern areas, covering more than half of the country. Based on various sources (Atlas of Sri Lanka, Department of Meteorology map and raingauge data), the mean annual rainfall at the four study sites is estimated as approximately:

Tharawatte 2700 mm, Awarakotuwa 2600 mm, Agarauda 1400 mm, and Tissawa 1700 mm.

There are two main periods of heavy rainfall each year – the south-west monsoon from May to September, which is the period of highest rainfall, and the north-east monsoon from December to February. The remaining inter-monsoon periods can still produce appreciable amounts of rainfall, especially in the very wet south-western area.

The natural vegetation of most of Sri Lanka was originally a wide range of forest types. The present land use is a complex mosaic. An assessment by Forest Department in 1993 showed 24% of the land area remaining under closed canopy natural forest, and another 7% of sparse forests. Through intense irrigation strategies, farmers in Sri Lanka are able to produce two rice crops a year.

All the drainage basins in Sri Lanka flow outwards radially from the central massif. The two of direct interest for the present study are the Kelani Ganga and the Deduru Oya (Figure 5.1). The Kelani Ganga covers 2292 km^2; it flows from the central mountains due west to reach the ocean just to the north of Colombo city centre. It includes some of the wettest areas in the country, and land use is mainly plantations and some forest. There are a number of large reservoirs in the upper parts of the basin and the river provides the water supplies for Colombo City.

The two rural sites lie in the dry zone in the Deduru Oya basin, which also flows westwards, and has an area of 2647 km^2. It is a drier area than the Kelani, but still has annual rainfall of more then 1500 mm over most of the basin. The land use is mostly coconut plantation and paddy fields. Scattered over the whole area are more than 3200 small shallow reservoirs (known locally as "tanks") which are used to provide the irrigation water for the paddy fields and other cultivation.

The four study sites are all located on metamorphic basement rocks, mainly proterozoic gneisses and paragneisses of the Wanni Complex. In places this basement is covered by variable thicknesses of quaternary alluvium, sands or gravels. (The study area at Tissawa is covered by 2-3 m of alluvial deposits, for example.) The exact composition of the basement rocks varies between the different sites, although hydrogeologically they behave in a similar fashion.

The fresh metamorphic basement rocks have a very low permeability and porosity, but weathering processes typically produce a regolith[3] rich in clay minerals. The regolith may range in thickness from thin or absent up to several tens of metres thick. The regolith is characterised by a low permeability but a relatively high porosity. Beneath the regolith a more permeable zone of decomposed (sometimes fractured) metamorphic rock can provide a conduit for groundwater, with transmissivities many times higher than the regolith, but with low groundwater storage potential. Fractures in this zone may develop as a result of weathering, or may be associated with tectonism and lineaments in the gneiss. The regolith and fractured zones together can constitute an aquifer, with storage of groundwater provided by the regolith and

[3] A surface layer of loose or weathered material, which in this case has developed more or less in situ.

movement of groundwater towards a well intake supported by the zone at the bottom of the regolith.

2.1.3: United Republic of **Tanzania**

Tanzania occupies an area of 945,087 square kilometres in Eastern Africa, bordering the Indian Ocean, between Kenya and Mozambique. Uganda, Rwanda and Burundi border to the north-west, with the Congo, Zambia and Malawi to the south-west .The capital city, Dar es Salaam, lies on the east coast, although legislative offices have been transferred to Dodoma which is planned as the new national capital.[4] Terrain consists of plains along the coast, a central plateau and highlands in the north and south.

Climate varies from tropical along the coast to temperate in the highlands. Weather patterns have given rise to flooding on the central plateau and periods of drought. Main natural resources consist of; hydropower, tin, phosphates, iron ore coal, diamonds, gemstones, gold, natural gas and nickel. Current environmental issues include; soil degradation, deforestation, desertification and threats to marine habitats.

Key statistics for Tanzania are presented below:

Table 5: Tanzania- Key Statistics

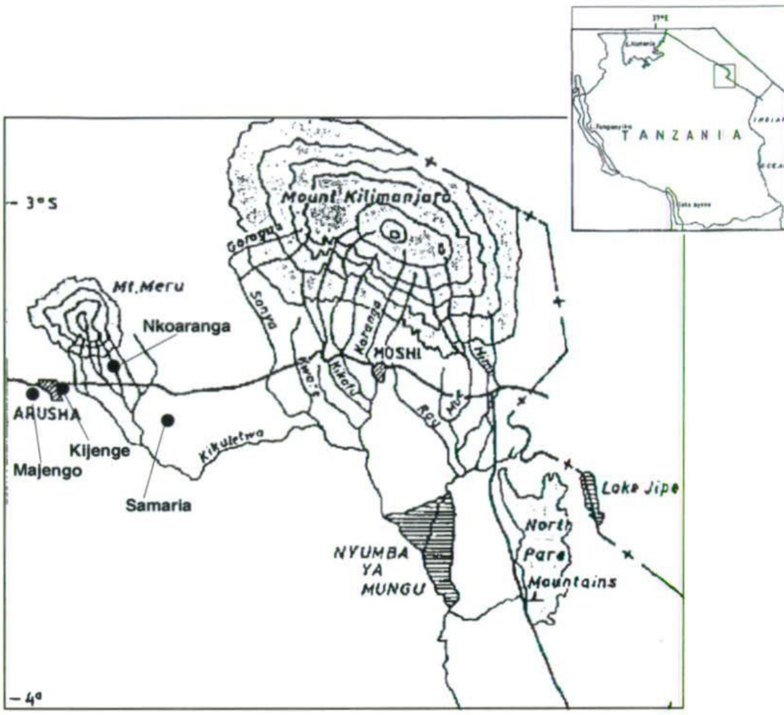
Population	36,232,074 (2001)
Population Growth	2.61% (2001 est.)
Currency	Tanzanian Shilling-TZS (803.34:$1U.S Dec 2000)
GDP	6,872,580 TZS xM (2000)
Per Capita GDP	215,446 TZS (2000)
GDP Growth	5.2% (2000 est)
Inflation	6% (2000 est)
Unemployment Rate	NA

Tanzania is one of the poorest countries in the world and has an economy that is heavily reliant on agriculture. Agriculture accounts for about half of GDP, provides 85% of exports and employs 90% of the workforce. Topography and climatic conditions, however, limit cultivated crops to only 4% of the land area. Main industries in Tanzania include, primarily agricultural processing, diamond and gold mining, oil refining, shoes, cement, textiles, wood products and fertiliser. Arable crops account for 3% of land use, permanent pastures 40%, permanent crops 1% and forest and woodlands 38%.

Life expectancy in Tanzania has been estimated at 51.04 years for males and 52.95 years for females. This reduced life expectancy reflects the fact that HIV/AIDS is prevalent in approximately 8% of the adult population and results in about 140,000 deaths per year. Approximately 68% of the population in Tanzania are literate.

Tanzania was formed in 1964 following the independence of Tanganyika and Zanzibar from the UK. Benjamin W Mkapa is current president and head of state. He was elected for a five year term in October 2000 as leader of the Chama Cha

Mapinduzi (CCM), revolutionary party. The government amended the Permanent Constitution, to bring about a multi-party system, in 1992. More than a dozen new parties have been registered, but none of them pose a real challenge to the political power of the CCM.



Tanzania is divided into 25 administrative regions, and the pilot sites lie in that of Arusha, located in the north east of the country. Arusha covers an area of 82,306 square kilometres and has a population of approximately 1.6 million. The general location of the area and the main features are shown in Figure 3.

Figure 3: Map of the study area – Tanzania

Two of the communities are peri-urban areas on the edge of Arusha, and the other two are in rural areas. Some details of the populations and households surveyed are given in Table 6.

Table 6: Communities surveyed – Tanzania

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Majengo	Peri-urban	-	125	748
Kijenge	Peri-urban	-	118	530
Nkoaranga	Rural	3197	120	671
Samaria	Rural	3722	119	650

All the sites lie close to and south of Mt. Meru, the dominant geographical feature of the area. At 4565 m high it is the fifth highest mountain in Africa. Only 70 km to the east lies Kilimanjaro, the highest mountain in Africa (5895 m). These two mountains dominate the area because they stand alone on a plateau (typical altitude 1000-1200 m), rather than forming part of a mountain range.

The two mountains are also very significant influences on the climate of the area, attracting heavy rainfall, with much less falling on the surrounding plateau. Mean annual rainfall in the study area ranges from considerably less than 1000 mm in parts of the plains to more than 2100 mm in the higher areas of Mt. Meru, with annual amounts changing rapidly over small distances. However, there is conflicting information on the annual rainfall for the study sites. Based on the map given in the Arusha Region Water Master Plan (ARWMP, 2000), mean annual rainfall can be estimated as: Nkoaranga 1650 mm; Samaria 1200 mm; Majengo 1550 mm; and Kijenge 1800 mm. But the much smaller scale Tanzania Mean Annual Rainfall map (no date) indicates roughly 1000-1200 mm for all sites, except for Samaria which is 600-700 mm. These values seem perhaps more realistic in relation to the vegetation of the area.

The general climate type is a tropical monsoon climate with two rainy seasons, typically lasting from March to June and October to December. The average monthly rainfall patterns for six stations close to the study area are shown in Figure 4.

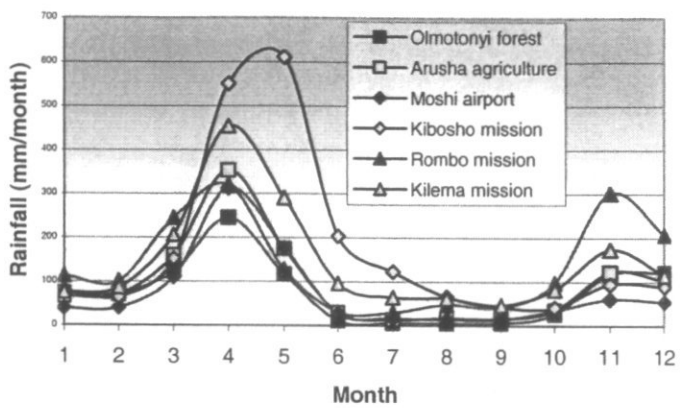


Figure 4: Monthly rainfall patterns in the upper Pangani basin (after Mkhandi and Ngana, 2001)

The vegetation of the area varies widely. The higher slopes of Mount Meru are covered in forest. Nkoaranga which lies on the lower slopes of Mount Meru was probably originally forest, but this is now mostly cultivated (coffee, bananas, maize, etc), with a few large forest trees remaining. Arusha is in a somewhat drier area with less dense natural tree cover, while Samaria is very different with the vegetation being defined as "dry open grassland" (Tanzania Vegetation Cover Types map, 1984). There is little cultivation here, with livestock rearing being the main economic activity.

The study area is in the uppermost part of the Pangani basin (total basin area 42,000 km^2). The Pangani river flows approximately south-east, reaching the sea near the city of Tanga. The northern boundary of the basin is mountainous, with Mount Meru and Kilimanjaro in the west and several other ranges further to the east. These mountains generate most of the runoff. The main water resources development in the basin is the Nyumba ya Mungu dam which is used for power generation. There is one hydropower plant here and two more downstream of it. The other large-scale water use is irrigation. Most of the irrigated areas are upstream of the dam, leading to conflicts between the two uses. The study area is upstream of these major water uses and they do not impact on it significantly.

The study sites are underlain by volcanic rocks (basalts, trachytes and pyroclastics) of Neogene age, which overlie Precambrian age crystalline Basement Complex rocks. Hydrogeologically, the volcanic rocks range from low yielding (<0.5 l/s) to fairly productive (>1 l/s, <4 l/s), with typical yields of about 1 l/s. A significant number of dry boreholes have been drilled in the Arusha area. Hand pumps are the most common way of extracting water from low-yielding boreholes. Groundwater flow occurs along secondary bedding planes and fissures, and as intergranular flow in agglomerates and vesicular basalts. It is likely that the local geology and hence groundwater potential is very variable.

Traditionally, shallow or perched groundwater associated with river beds or depressions (dambos) has been exploited using hand-dug wells. These wells may be subject to failure in the dry season. Laterite horizons and sands above black clay-rich soils (mbugas) are developed in some places, which can also provide a local source of shallow groundwater. Springs are common, particularly in the uplands, and supply numerous gravity fed water schemes. Due to the variable nature of the strata, and the discontinuities inherent in bedding planes and fissure systems, borehole success rates are variable, and expert hydrogeological advice is needed to develop these. Geophysical exploration methods such as EM34 ground conductivity measurements and Vertical Electrical Sounding have been used in the past to increase the likelihood of borehole success.

Borehole depths in the volcanic rocks are typically between 90 m and 120 m deep, although some boreholes and wells are much shallower. Boreholes in these rocks are usually drilled using air flush rotary drilling methods, using down the hole hammer or rock roller bits. These methods require relatively sophisticated equipment and are expensive. Cheaper to operate cable-tool percussion and hand auger methods may also be suitable in certain circumstances. Shallow large diameter wells can be dug by hand in appropriate locations such as river beds.

Groundwater in the Arusha area is frequently alkaline and of sodium-calcium-bicarbonate type. Fluoride concentrations greater than the World Health Organisation guideline maximum value of 1.5 mg/l are found in a considerable number of groundwater sources in this area, particularly those associated with the volcanic rocks. Excessive fluoride concentrations in drinking water can cause serious disease. Other inorganic constituents such as boron may occasionally be above recommended limits. High salinity, particularly associated with lacustrine sediments in the rift sequences, is found occasionally and is often correlated with high fluoride concentrations. Deeper wells may be more susceptible to high fluoride concentrations, as the water is likely to have been in the aquifer longer and more time will have been available for fluoride dissolution. High fluoride concentrations often correlate with low calcium concentrations, but it is difficult to predict fluoride concentrations before drilling. Shallow wells in the weathered zone that intercept relatively younger groundwater may circumvent the fluoride problem. Seasonal variations in water chemistry have been noted.

References

The statistics in this report have been drawn from a variety of sources and, where available, reports produced by the governments of individual countries have been used. Figures quoted are merely a guide, and may vary to some extent between different sources. Sources include the following:

Central Intelligence Agency (CIA) of America; *World Fact Book, 2001,* http://www.cia.gov/cia/publications/factbook/index.html

The Economist: http://www.economist.com/

National Bureau of Statistics, Tanzania; http://www.tanzania.go.tz/statistics.html

Statistical Abstract of the Democratic Republic of Sri Lanka 2000: http://www.statistics.gov.lk/Abstract/chapters/200contents.htm#c03

Statistics South Africa; http://www.statssa.gov.za/default1.asp

The World Bank, Poverty Net: http://www.worldbank.org/poverty/index.htm

The topography, climate, vegetation, hydrological features and hydrogeology of individual sites contained in this report are largely drawn from; Meigh, J & Cobbing ,J (2002) *"Water Poverty Index – Phase I, Assessment of Water Availability for the Pilot Study Sites"*. This report can be found in Appendix 3.

Appendix 2.2
Illustration of Key Variables in the Pilot Sites

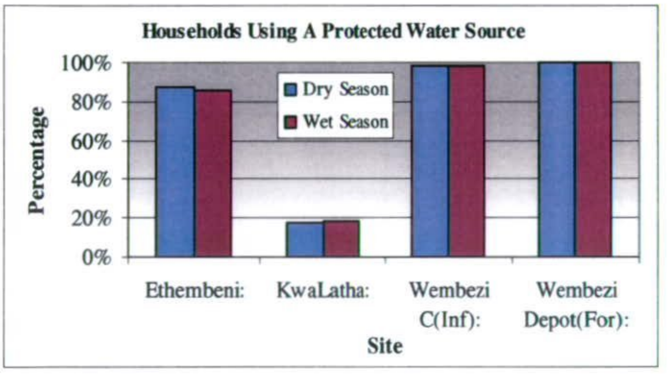
Tim Fediw, CEH Wallingford

2.2.1: South Africa

These data relate to the four study sites of Ethembeni, KwaLatha (or Latha), Wembezi section C community (or Wembezi informal) and Wembezi Depot Community (or Wembezi formal). The sample surveyed in each site and its perceived characteristics are shown in the table below. The following graphs provide the opportunity to compare responses to selected questions at the different study sites.

	Ethembeni	KwaLatha	Wembezi (informal)	Wembezi (formal)	Total
Site Location	*Rural*		*Peri Urban*		
Perceived Level of Water Provision	*High*	*Low*	*Low*	*High*	
Adults	747	534	790	559	2071
Children	480	438	539	259	1457
Total	1227	972	1329	818	3528
Households surveyed	**124**	**133**	**220**	**148**	**625**

Figure 1



Water Source (Figures 1, 2)

In KwaLatha, the rural site with low water provision, only 18% of respondents said that they used a protected water source. The 87% of people in Ethembeni claiming they use a protected water supply reflects the fact that, although this is a rural community, water provision is quite good with a large and reasonably comprehensive pay-for-water scheme in operation, using treated, protected water.

The almost 100% use of protected supplies in Wembezi C & Depot, reflect good standpipe provision and piped in-household supplies respectively.

The rural communities make greater use of rainwater as shown in Figure 2. The presence of good water supplies in the peri-urban areas is likely to diminish the need for households to collect water.

Figure2

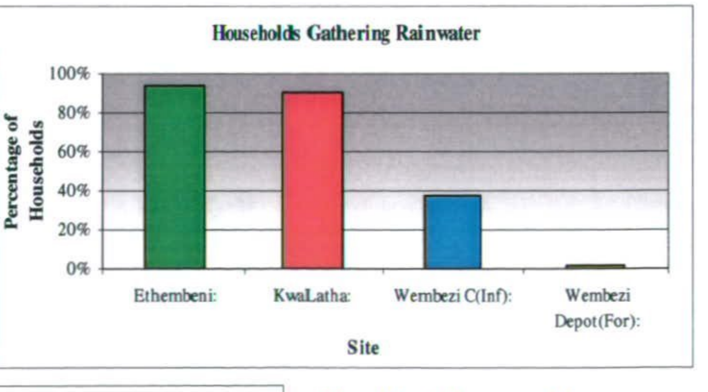
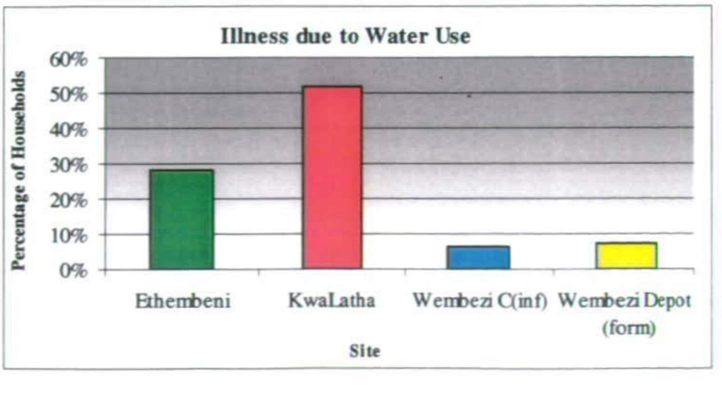


Figure 3:



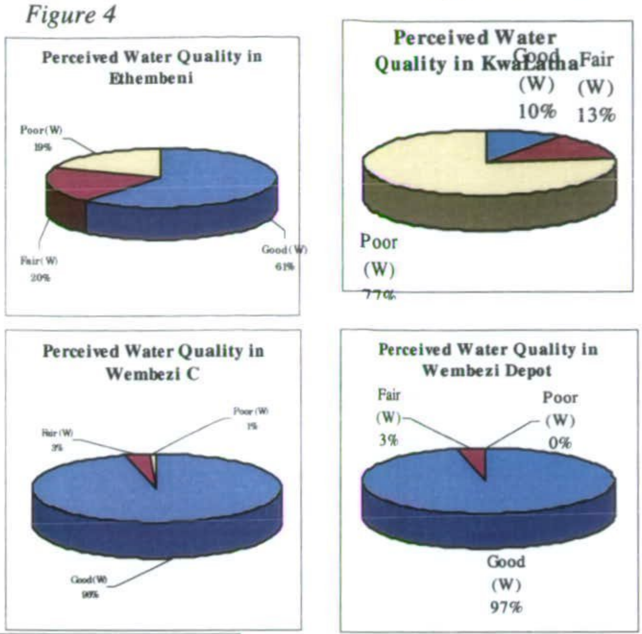
Health (Figure 3)

In KwaLatha, where unprotected supplies such as ponds and riverbeds are used, 51% of households believe they suffer illness from water use. In contrast, the Wembezi sites show that only around 9% of householders become ill.

Water Quality (Figure 4)

The variation in water quality is revealed when households are asked directly about the quality of the water. 77% of Households in KwaLatha said water quality was poor, whereas in Wembezi Depot 97% said it was good.

Figure 4



Supply Reliability (Figure 5)

Despite its poor quality, respondents in KwaLatha generally found that the water supply was reliable. 57% believed their supply was very reliable contrasted with only 23% in Wembezi Depot. People's expectations of water quality may have influenced these responses.

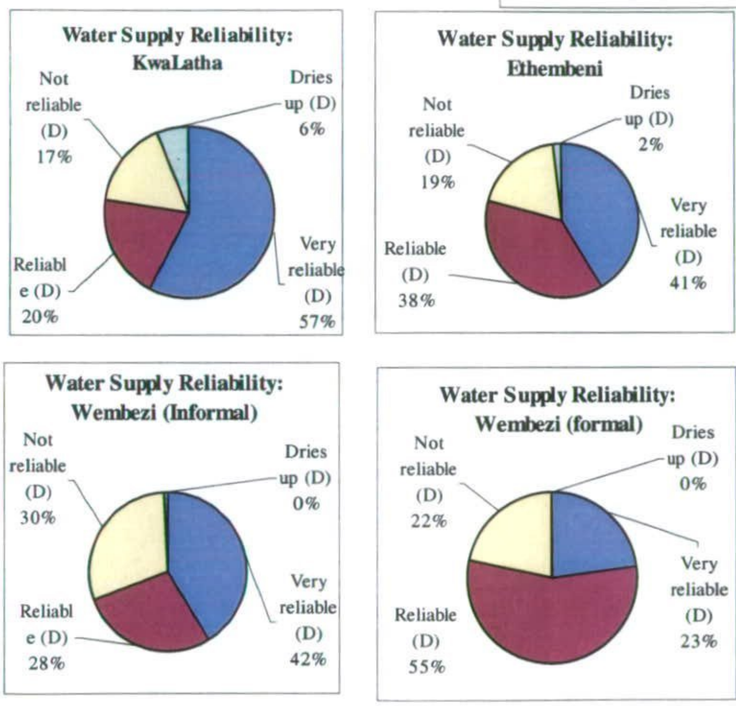


Figure 5

Time Spent Collecting Water (Figure 6)

Where water supplies are remote, valuable time can be spent collecting water which, if a closer supply was available, could otherwise be spent engaged in an activity that is economically beneficial to the household.

Rural communities spend longer collecting their water; on average, a trip to the water source takes almost double the time in KwaLatha than it does in Wembezi C.

Times spent collecting water in Wembezi Depot is minimal due to the existence of piped household supplies. A nominal 2 minutes for each collection from a piped household supply was allowed in this calculation.

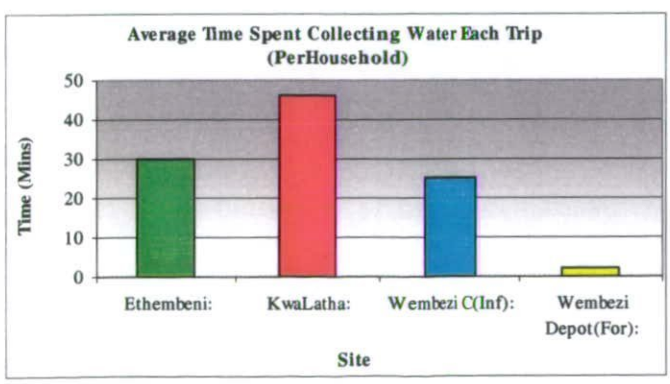
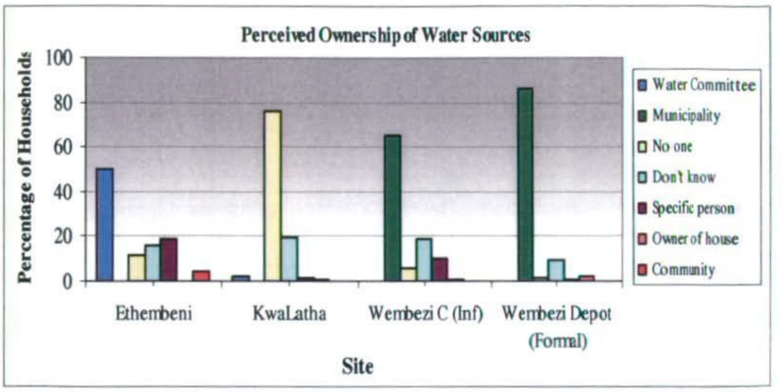


Figure 6:

Figure 7:

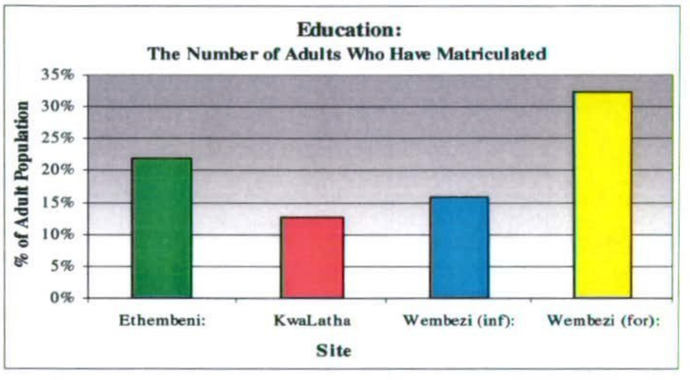


Ownership and Management of Water Sources (Figure 7)

In Wembezi C and Wembezi Depot, where water quality is perceived as good by 96% and 97% of the sample respectively, the majority of water sources are provided by the municipality.

The high figure responding with "water committee" as the main owner in Ethembeni reflects the presence of a formally structured and managed water services system in this area.

Figure 8:



Education (Figure 8)

Levels of education are high for the peri-urban, well supplied settlement of Wembezi Depot and low for the rural, poorly supplied settlement of KwaLatha

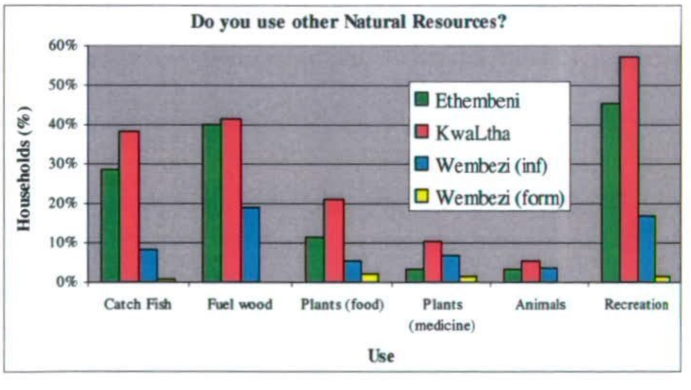


Figure 9

Natural Resources (Figure 9)

The rural sites make greater use of natural resources, no doubt due to their proximity to them. KwaLatha residents make the greatest use of natural resources in all cases.

2.2.2: Tanzania

The structure of the survey carried out in Tanzania was almost identical to that carried out in South Africa. Data are therefore available on the same categories with the addition of some basic information relating to income and collection of water. The data relates to the four study sites of Nkoaranga, Samaria, Majengo and Kijenge. The sample surveyed in each site and its perceived characteristics are shown in the table below. The following graphs provide the opportunity to compare responses to selected questions at the different study sites.

Table 1:

	Nkoaranga	Samaria	Majengo	Kijenge	Total
Site Location	Rural		Peri Urban		
Perceived Level of Water Provision	High	Low	High	Low	
Adults	343	301	390	311	**1345**
Children	328	352	358	221	**1259**
Total	671	653	748	532	**2604**
Households surveyed	**120**	**119**	**125**	**118**	**482**

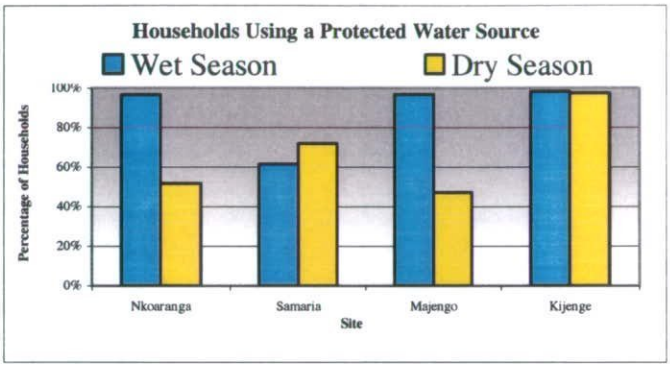


Figure 1

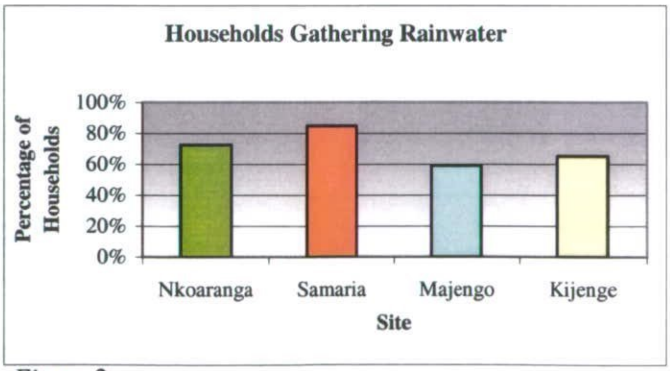


Figure 2

Water Source (Figures 1, 2)

Figure 1 shows that during the wet season, use of protected water sources is generally higher. The near 100% use of protected water sources during both seasons in Kijenge reflects the fact that 58% of households have a water source within the household, whilst a further 39% normally gain their water from a public pipe.

As with South Africa, rural communities are found to gather more rainwater than peri-urban ones, although unlike South Africa, peri-urban communities are significantly involved in the collection of rainwater.

Health (Figure 3)

Illness due to water use is quite high in Nkoaranga at 23% despite water provision being good compared to the other rural site of Samaria. The high level of illness in Majengo (26%) is a reflection of the poor reliability of piped supplies and a noted presence of water-borne disease in this area. Illness in Kijenge is less than 7% which may be a reflection of the piped municipality supplied sources that exist here.

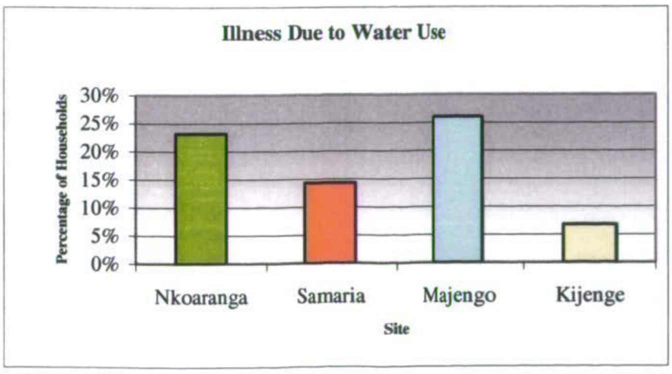


Figure 3

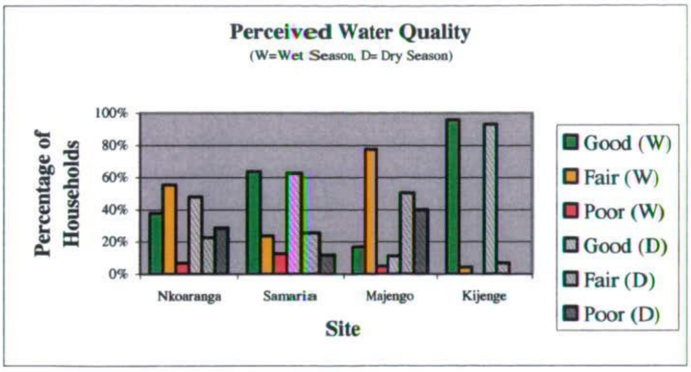


Figure 4

Water Quality (Figure 4)

Over 95% percent of households in Kijenge declared that it was "good" in both wet and dry seasons. This compares to Majengo where less than 15% said it was good with most households answering that it was "fair". Problems with water quality, in the dry season especially, are evident at this site from the fact that during the dry season 4.8% of households said that quality was "poor" but in the dry season this rose to 40%.

Reliability (Figure 5)

When it came to water supply reliability there was, again, a larger difference between wet and dry seasons.

Although supplies were deemed "reliable" by 60% percent of households in Kijenge for both seasons, there is a noticeable increase in those answering "not reliable" in the dry season.

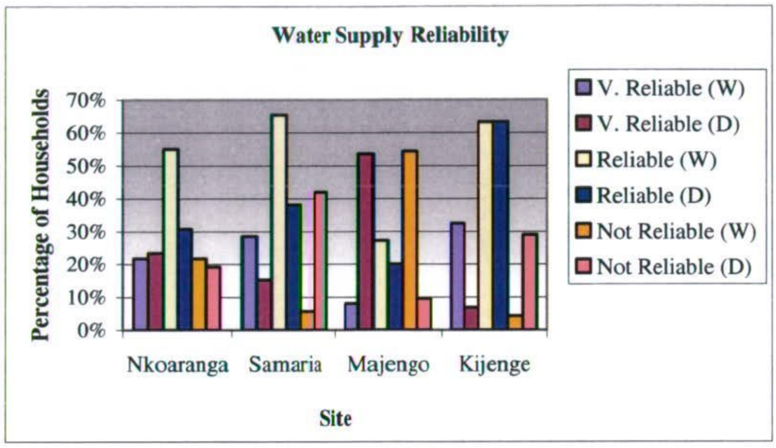


Figure 5

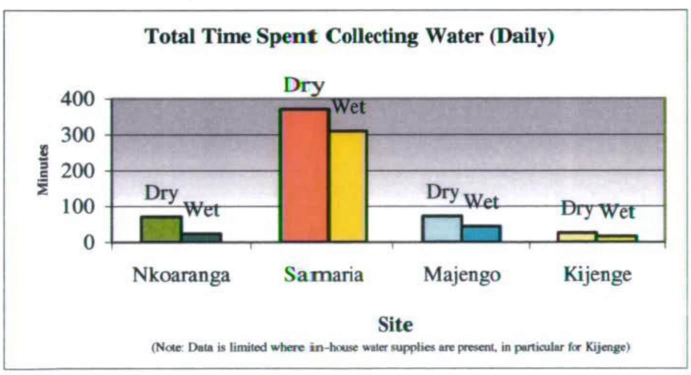


Figure 6

Time Spent Collecting Water (Figure 6)

The large distance to the main water source is reflected in the time that households in Samaria spend collecting water.

On average, all sites record longer times in the dry season, which may be put down to certain sources becoming unreliable. The short times spend collecting water in Kijenge reflect the high use of piped supplies.

Ownership and Management of Water Sources (Figures 7, 8, 9)

This graph does not include those households who had a water source within the household, therefore, in Kijenge where 58% have a household supply as their main source, there is little comment on ownership of water resources. Typically, in the rural areas, a large proportion of households report that water sources are either community owned or un-owned.

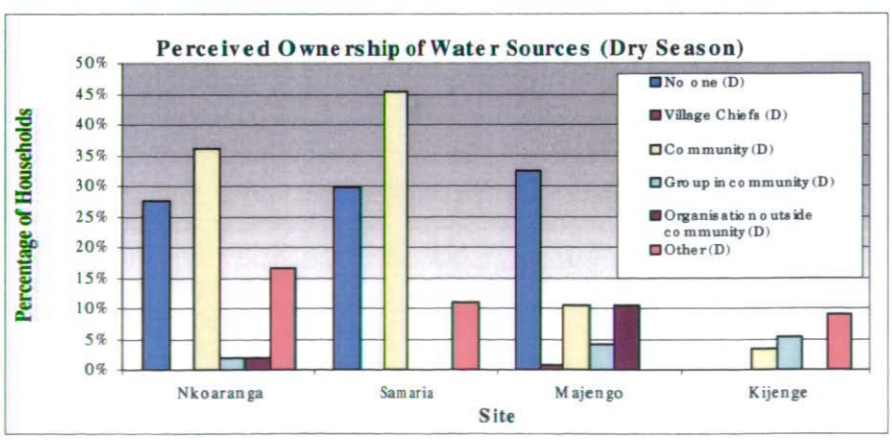


Figure 7

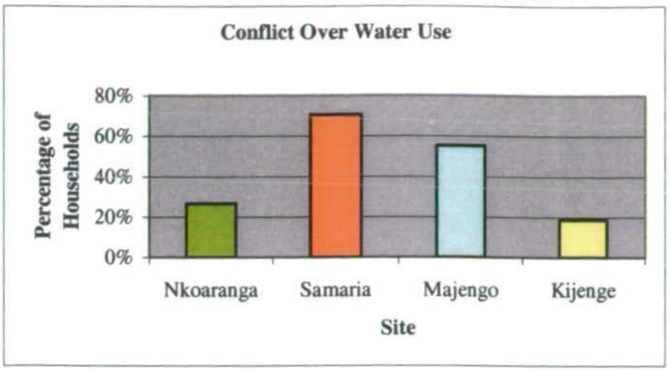


Figure 8

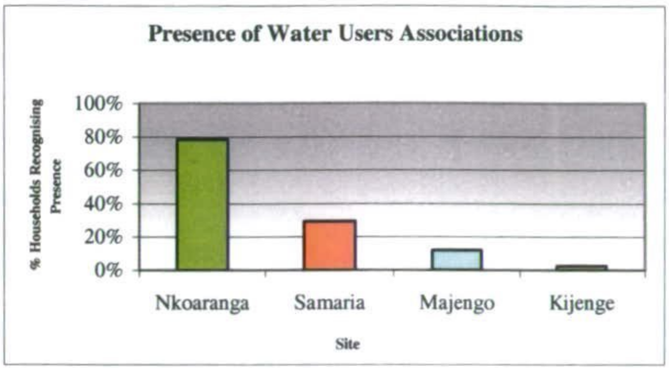


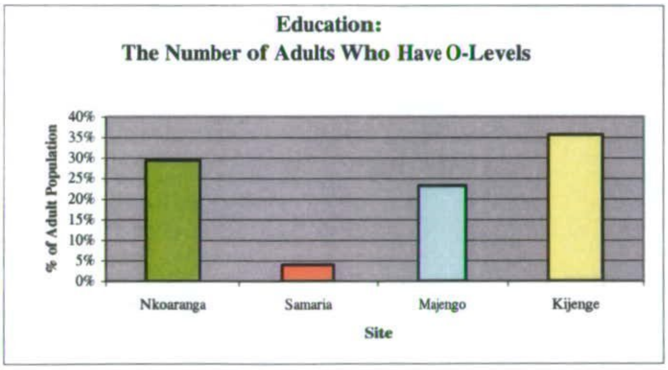
Figure 9

Nkoaranga has a well organised and active water committee, run by women, which is reflected by the fact that 78% of households recognise a water users' association. Furthermore, almost 80% of these households in Nkoaranga reported that the association was effective.

Figure 10, shows conflict over water use. When compared to Figure 9, it appears that there is a direct correlation between whether or not an association exists and whether there is conflict over water use.

Education (Figure 10)

Arguably, levels of education provide a good indicator of economic well- being. Samaria, the rural poorly provisioned site reports that only 4% of adults have O-levels. This contrasts to the well provisioned, peri-urban site of Kijenge where 35.7% of adults have o-levels



2.2.3: Sri Lanka

The survey carried out in Sri Lanka was similar in most respects to those carried out in South Africa and Tanzania. Some differences were evident, in particular the details collected relating to ownership and main use of water resources. Main water sources were given relating to different uses of water rather than a single main use and ownership of water resources was given by resource type rather than by main source. Whilst the data relating to main water sources provided some useful additional information, the data on ownership made it rather ambiguous to identify who owned the main source.

The data collected relate to the four study sites of Tissawa, Agarauda, Tharawaththa and Awarakotuwa. The sample surveyed in each site and its perceived characteristics are shown in the table below . The following graphs provide the opportunity to compare responses to selected questions at the different study sites.

Table 1:

	Tissawa	Agarauda	Tharawaththa	Awarakotuwa	Total
Site Location	Rural		Urban	Peri-Urban	
Perceived Level of Water Provision	Low	Low	Low	Low	
Adults	470	200	245	351	1266
Children	119	82	102	150	453
Total	589	282	347	501	1719
Households surveyed	144	66	83	121	414

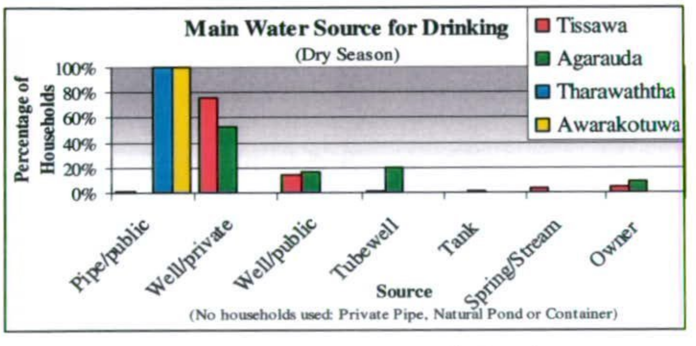


Figure 1

Water Source (Figures 1, 2, 3)

Main water sources for drinking and bathing are shown below.

In Awarakotuwa, the peri-urban site, there was 100% usage of public pipes, for all water uses in both seasons. Although more than 70% of households here collect rainwater, no use for it was declared.

In Tissawa, one of the rural sites, there was large usage of private wells, with 75% using it for drinking and 63% using it for washing and cleaning. For bathing, most households use the stream in the dry season.

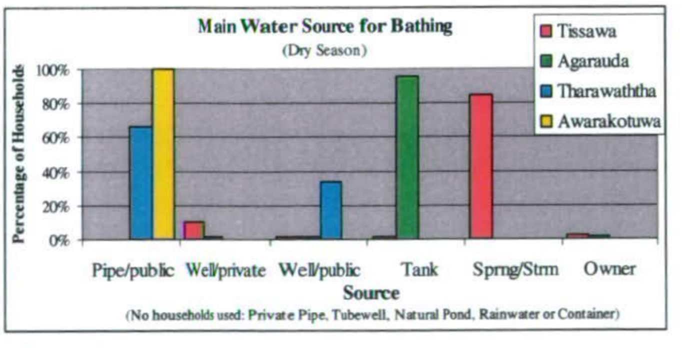


Figure 2

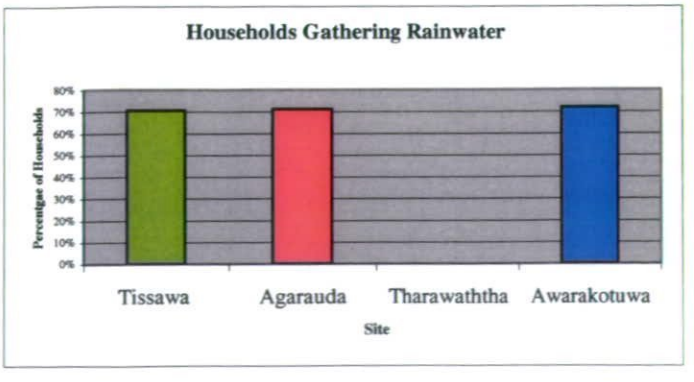


Figure 3

Many households in Tissawa, Agarauda and Awarakotuwa gather rainwater, as shown.

Health (Figure 4)

Illness due to water use is far higher in all four sites than in any of the sites in either South Africa or Tanzania. Predictably, the lowest incidence of illness through water use occurs in Awarakotuwa where there is 100% reliance on public pipes, however 67% of households still report that illness occurs. In each of the three other sites, it is found that at least ¾ of households suffer illness.

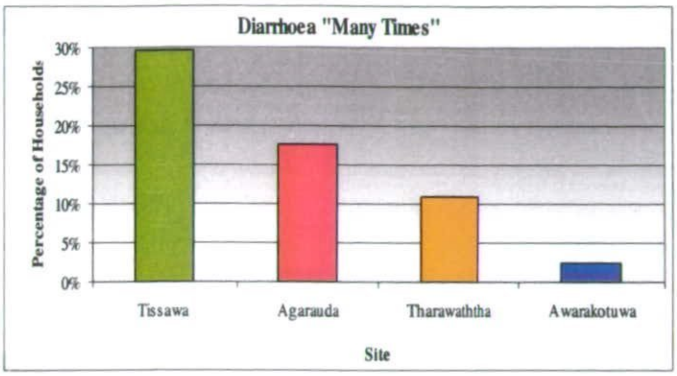


Figure 4

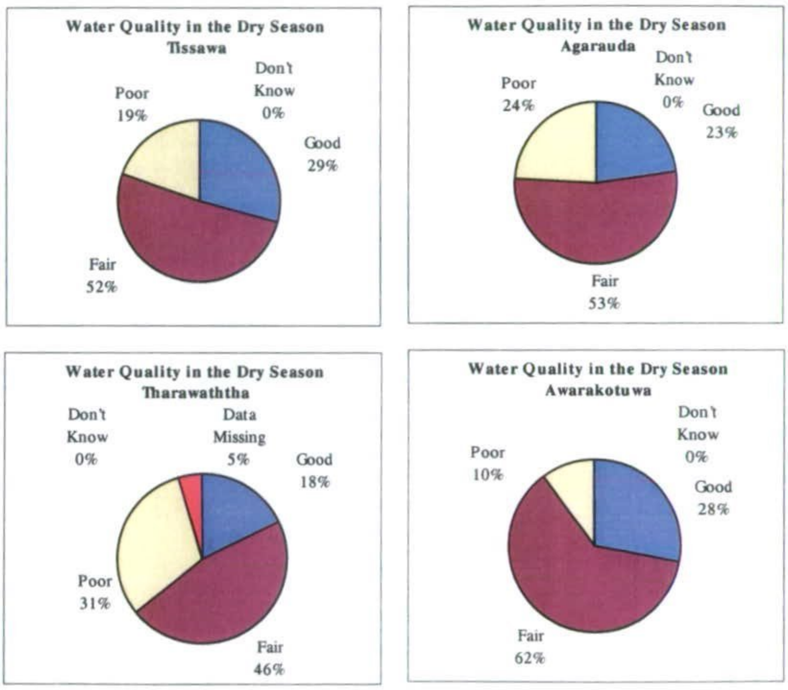


Figure 5

Quality (Figure 5)

The survey did not reveal great differences of perceived water quality between the sites in the wet season, however, the answers given may have been affected by the respondents expectation of quality. In all sites the number declaring quality as "good" was close to 50% of households, with very few answering "poor". In all sites, these figures showed a large change in the dry season with more households answering that water quality was "fair".

Supply Reliability (Figure 6)

Whilst these results may again be affected by varying expectations between the sites, it is clear that, although Awarakotuwa has the benefit of public pipes, in the dry season this supply is clearly unreliable as 100% of households answered that this was the case. However, during the wet season, the supply reliability appears acceptable as more than 80% of

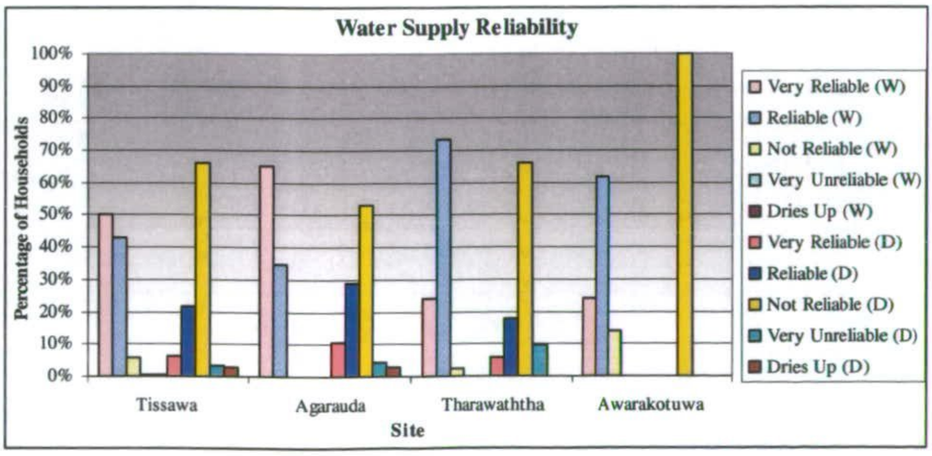


Figure 6

households reply that supply is at least reliable. Similar trends are evident in the other three sites but with a more diverse range of responses.

Time Spent Collecting Water (Figure 7)

In contrast to the surveys carried out in South Africa and Tanzania, it is found that in Sri Lanka, urban households tend to spend longer collecting their water. Collection times in the wet season are much lower, which is likely due to the improved reliability of the sources at this time.

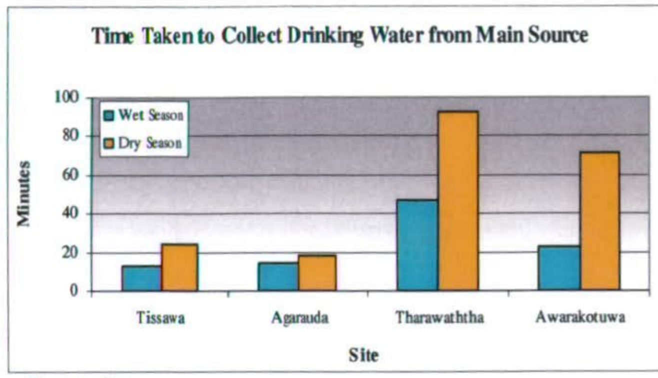


Figure 7

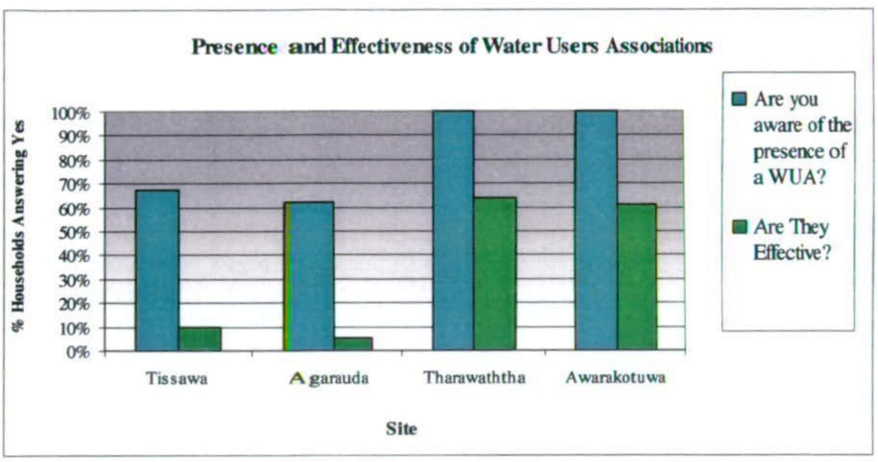


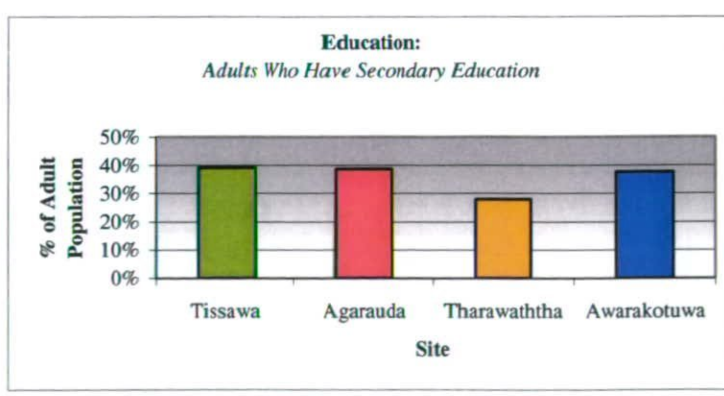
Figure 8

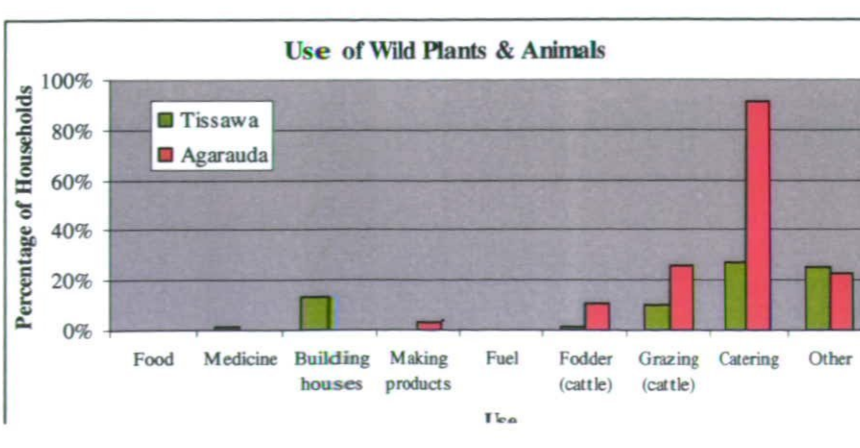
Ownership and Management of Water Sources (Figure 8)

Water Users' Associations (WUAs) are much more prevalent in the urban areas and are much more effective than those in rural areas.

Education (Figure 9)

In terms of levels of education, Tharawaththa stands out as being worse off than the other three sites. Only 28% of the adult population here has a secondary education, whereas in Tissawa, Agarauda and Awarakotuwa approximately 38% of adults do.





Natural Resources (Figure 10)

Data relating to use of natural resources was only available for the two sites of Tissawa and Agarauda.

Appendix 2.3
Approximations of Physical Asset Wealth & Wealth Distributions in the WPI Pilot Sites

Tim Fediw, CEH Wallingford

Introduction

Wealth and income are the two key measures used to rate households or individuals economic positions. Whilst income is a flow measure, wealth is a stock measure and measures the stock of assets that are owned by the household. Wealth not only includes physical assets but also includes financial assets such as savings stocks and shares. An analysis of wealth and where possible, income is therefore an essential component of any study of poverty, in order to ascertain how well off households are economically.

Whilst some data is available relating to income and wages in the three WPI pilot study countries, this data is somewhat limited and is not available at the individual community level. Additionally, the subsistence nature of many of the household, especially within the rural communities, means that any measure of money income may be a bad reflection of the economic well-being of the household.

As part of the survey work carried out, households were asked about their ownership of durable goods. This data is comprehensively available in all study sites and has therefore been used to estimate the physical asset wealth (PAW) of each household. Whilst this does not give a full reflection of total wealth of households, it does at least give show how physical assets are distributed and thus provide a basic indicator of wealth. This measure does not include any monetary assets that households have, or do not have as it was not possible to collect such data from a household survey. These estimates of physical asset wealth have been used to produce wealth distribution functions and Lorenz curves in order to show the nature of the distribution of wealth between households in each site.

Method

Using the data collected from the household surveys, it was possible to see each households holdings of a number of durable goods[13]. For each country, data relating to the approximate market price of each good was obtained and used to generate an asset wealth value for each household. Prices have not been discounted as the PAW values generated are intended to show wealth values relative to other communities, rather than give an accurate monetary value for total wealth.

For each country, a wealth distribution was created by dividing the range of wealth holdings into between 30-40 equal divisions[14], into which the households will fall

[13] Bicycle, Motor Vehicle, Washing Machine, Cooker, Television, Radio, Electric Fan, Power Supply, Gardening Tools and Fridge.
[14] Number of divisions vary between countries due to differing ranges.

depending on their level of PAW. In order to ensure that the lower end of distributions are not "squashed" by the small number of households with very large PAW, the final wealth category is a "more than" category, into which all such households will fall. The value at which this final category was set depended on the number of households with significantly higher than average PAW and accounted for no more than 5% of the sample size in any country.

A Lorenz curve was then generated for each site. Lorenz curves are normally employed to show the equality of distribution of income, however, in the absence of reliable income data, they can be used to show PAW in a similar way. The horizontal axis shows cumulative percentage of population, whilst the vertical axis shows the cumulative percentage of PAW that proportion of the population holds. The Lorenz curves for each study site are plotted against the line of perfect equality, which is a 45 degree line along which any given percentage of population will hold exactly the same percentage of PAW. thus, distribution of PAW is perfectly equal along this line. Inequality of distribution is therefore judged by the extent to which the plotted line deviates from the 45 degree line, the further away the plotted line, the greater is the inequality of distribution[15]. An example of a Lorenz curve is shown in figure 1.

The Gini Coefficient can also be generated, to show the inequality of distribution over the whole range of PAW. The coefficient is the ratio of the area between the Lorenz Curve and the 45 degree line, to the total area beneath the 45 degree line. Perfect equality would result in the Lorenz curve coinciding with the 45 degree line hence the ratio would be zero. Perfect inequality would result in a Gini Coefficient of one[16]. This is demonstrated below:

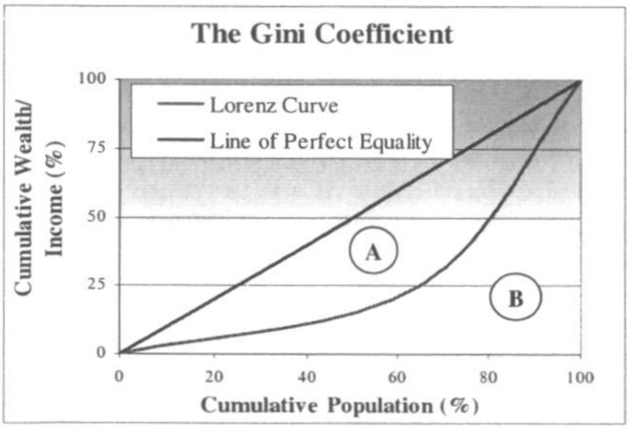


Figure 1

The Gini Coefficient = $\frac{A}{A+B}$

It should be noted however, that the Gini-Coefficient can only give an overall picture, it does not show where in the population the inequality occurs.

[15] Equality of distribution may vary between different points on the curve. It may be that distribution is reasonably equal among the top end of the population, but unequal at the lower end.

[16] Lambert (1993), p34.

Results

South Africa

The average wealth values for South Africa are shown below:

		PAW[9]	
	Community Type[10]	Average	Maximum
Ethembeni	RH	16891	77800
KwaLatha	RL	23420	245600
Wembezi (Inf)	UL	22678	77800
Wembezi (Form)	UH	35515	552300

Table 1

KwaLatha which has been identified as both an economically and water poor, rural community displays the second highest average household PAW. The reasons why this may be the case become more clear when the PAW distributions and Lorenz curves are examined. The PAW distribution for South Africa is shown in figure 2:

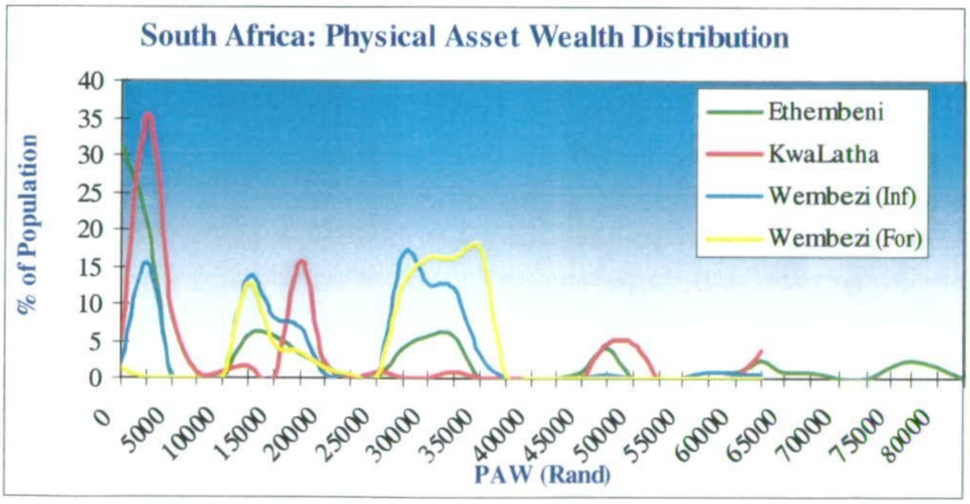


Figure 2

Despite the high average PAW, a large percentage of the population have a very low PAW holding around 2500 Rand, suggesting that the majority of this community is quite poor. The average PAW of households is pushed up by a smaller number of households who have a much higher PAW.

Ethembeni, a rural community, has the lowest average PAW of 16,891 Rand. This is reflected by the 31% of the population who have a PAW of zero and a further 21% who have less than 2500 Rand. Ethembeni does have 20 (16% of sample) more wealthy households, with PAW greater than 40,000 Rand.

[9] Minimum is zero in all cases.

[10] Where, R denotes Rural, U urban or peri urban, H high level of water provision and L low level of water provision.

Wembezi formal is recognised as the most prosperous of the four communities. This is reflected in the large peak in the PAW distribution that occurs at a much higher level of wealth around 35,000 Rand. Wembezi informal, a rural community, recognised as being not so prosperous as Wembezi formal, follows a similar distribution to Wembezi formal but with an additional peak lower down the wealth scale.

The presence of a number of households with PAW considerably higher than the average suggests that there may be some inequality in the wealth distribution. This is reflected in the Lorenz curves below:

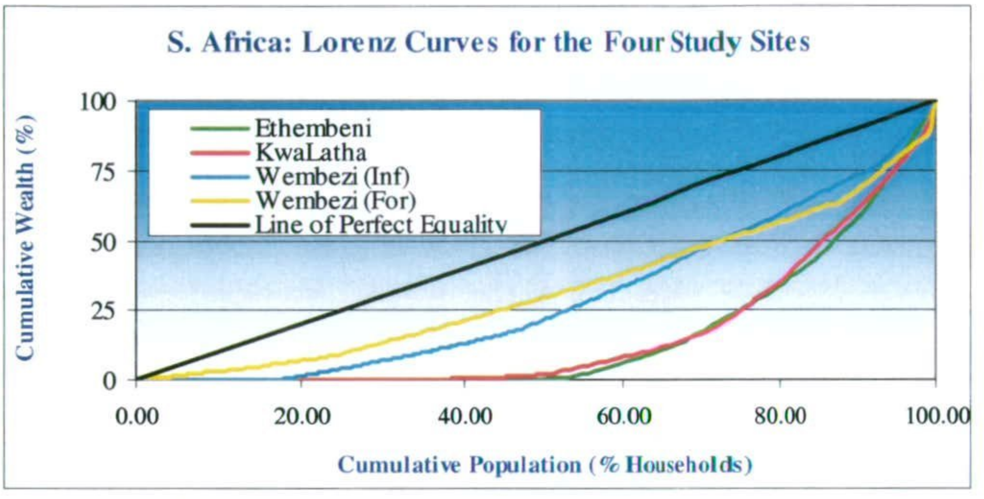


Figure 3

The Lorenz curves for both Ethembeni and KwaLatha are further from the 45 degree line suggesting that, based on the items measured, there is a greater inequality of PAW distribution in these two sites, compared to the other two. In KwaLatha, the first 60% of households only account for 8% of PAW, whilst the top 10% account for 40%. This compares to Wembezi formal where the first 60% account for 38% of PAW and the top 10% account for 30%. This shows that a considerable bias to the top end still exists in Wembezi formal.

This inequality is also borne out by the Gini Coefficients presented below:

	Gini Coefficient
Ethembeni	0.68
KwaLatha	0.67
Wembezi (informal)	0.40
Wembezi (formal)	0.35

Table 2

The high Gini Coefficient in Ethembeni and KwaLatha reflects the greater inequality in these sites, whilst the low coefficients in the urban Wembezi communities suggest that PAW is more evenly distributed here.

Tanzania

Average wealth values for Tanzania are shown in the table below:

		PAW[11]	
	Community Type[12]	Average	Maximum
Nkoaranga	RH	546365	6381450
Samaria	RL	488163	6381450
Majengo	UH	617467	6215283
Kijenge	UL	480638	6218833

Table 3

The two sites of Samaria and Kijenge that have been identified as having poor water provision both have low average PAW compared to the other two sites. Although Nkoaranga and Majengo, have greater average PAW values, the distribution below suggests that there are still many households with low wealth:

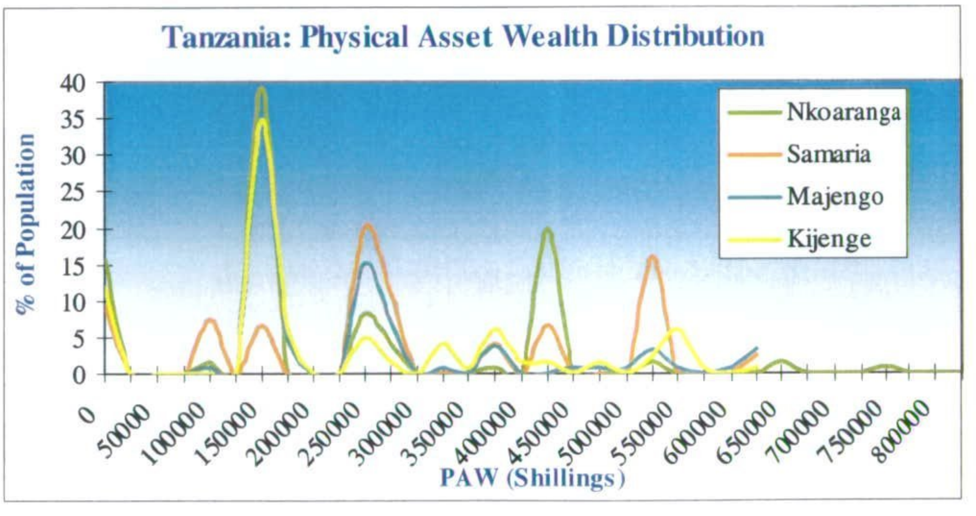


Figure 4

Large peaks around 150,000 Shillings for Nkoaranga, Kijenge and Majengo, show the less wealthy households. In Samaria, which has been identified as an economically and water poor community, PAW is distributed around a number of peaks, some of them higher up the wealth scale. This may be a reflection of the fact that a number of households in this community own cars due to their distance from a water source.

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[11] Minimum is zero in all cases.

[12] Where, R denotes Rural, U urban or peri urban, H high level of water provision and L low level of water provision.

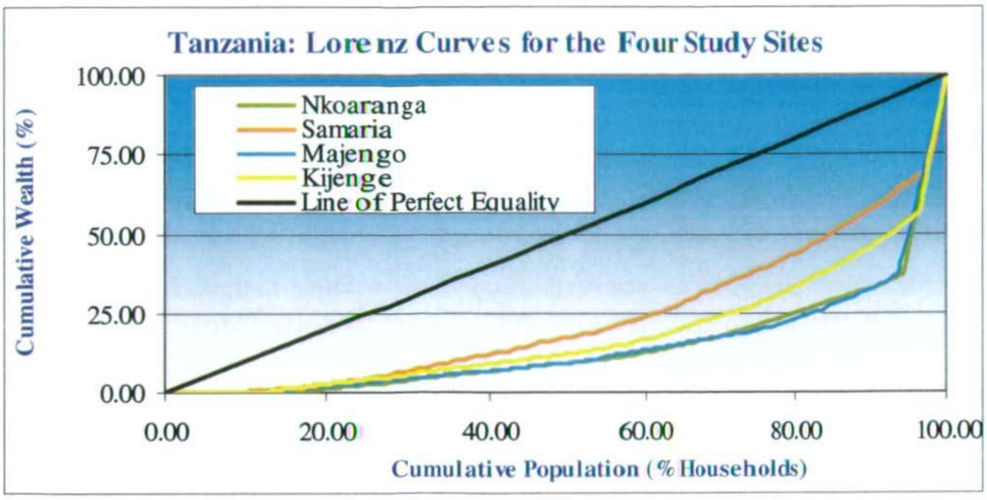

Figure 5

Looking at the Lorenz curves and noting that they do not say anything about total wealth of one site relative to any other, Samaria appears to have a more equal distribution of PAW as its curve falls closer to the 45 degree line. All four study sites show high concentrations of PAW amongst a few households at the top end of the scale. In Kijenge, the top 10% of the population account for over 50% of PAW, Majengo 66%, Nkoaranga 67% and Samaria 40%. So, despite Samaria and Kijenge having lower average PAW, they have a more equitable PAW at the top end of the scale. The Gini Coefficients represent this numerically, with Samaria having the lowest coefficient, suggesting that less inequality exists here.

	Gini Coefficient
Nkoaranga	0.71
Samaria	0.53
Majengo	0.71
Kijenge	0.63

Table 4

Sri Lanka

Average PAW for Sri Lankan communities are shown below;

		PAW[13]	
	Community Type[14]	Average	Maximum
Agarauda	RL	73490	411750
Awarakotuwa	UL	35853	331090
Tharawaththa	UL	36359	300600
Tissawa	RL	66807	576350

Table 5

[13] Minimum is zero in all cases.

[14] Where, R denotes Rural, U urban or peri urban, H high level of water provision and L low level of water provision.

The average PAW of the two urban communities of Awarakotuwa and Tharawaththa are found to be approximately half of those in the rural areas. PAW distributions are shown on the graph below:

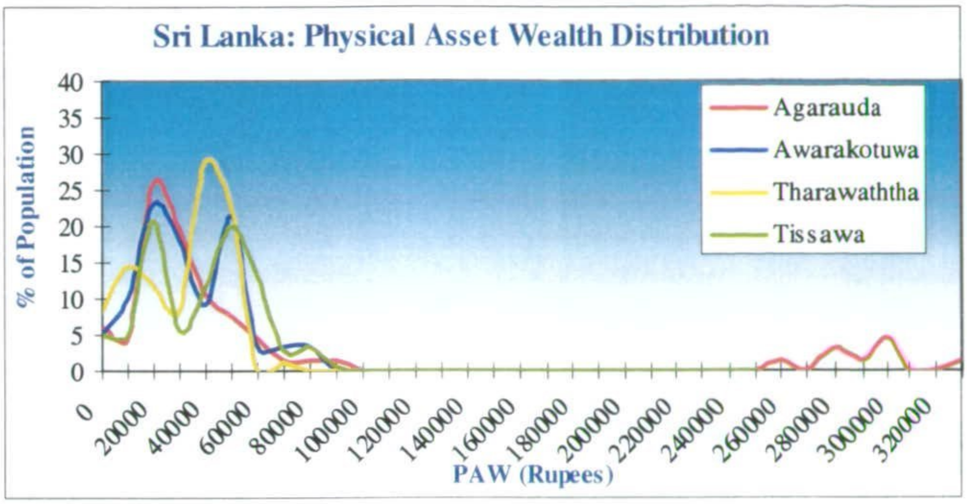

Figure 6

Most households in all four communities have PAW values below 100,000 Rupees, however, in the two rural communities of Agarauda and Tissawa, there are a small number of considerably more wealthy households. This could account for the higher average wealth in these communities. This is reflected by the Lorenz Curves below:

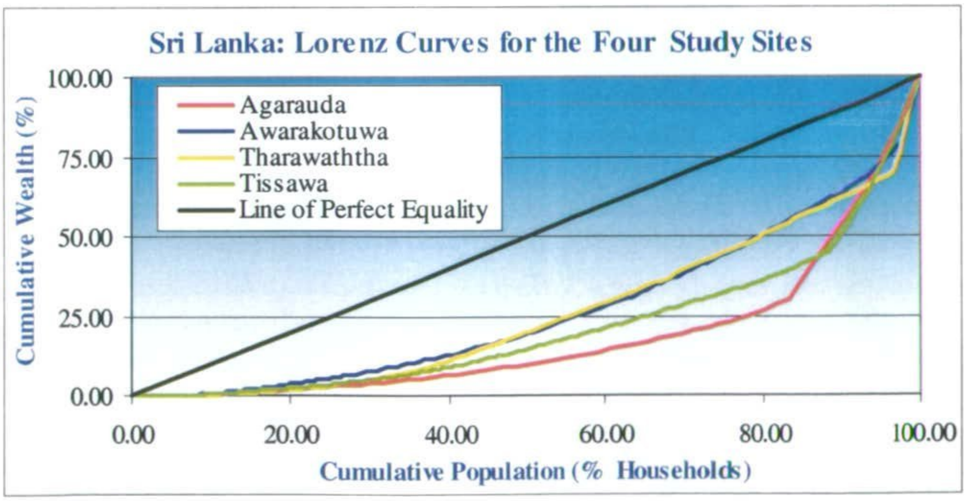

Figure 7

Both Agarauda and Tissawa have Lorenz curves further away from the 45 degree line, reflecting greater inequality of PAW at these sites. The curves though do converge at the top end of the population, leading to all sites having a similar distribution at this point. For Agarauda, the top 10% of the population hold 58% of wealth, Awarakotuwa 66%, Tharawaththa 63% and Tissawa 53%. A greater disparity occurs at the 85th percentile of the population where wealth ranges from 33% in Agarauda, to 57% in Tharawaththa. The Gini Coefficients are presented in table 6:

	Gini Coefficient
Agarauda	0.64
Awarakotuwa	0.47
Tharawaththa	0.48
Tissawa	0.57

Table 6

The Gini Coefficients reflect what is shown by the Lorenz curves. Agarauda, with the curve furthest from the 45 degree line has the highest Gini Coefficient with Awarakotuwa, the closest line having the smallest.

Limitations

These results show only an initial attempt to analyse the wealth and equality of wealth distribution in each study site. There are a number of problems that can be identified which if overcame would lead to an improved analysis.

There are a number of factors that contribute to wealth which are not part of PAW. Cattle and land cultivation are significant assets that contribute to wealth, especially in rural areas. Cattle were not included at this stage as it would have led to bias in wealth values towards the rural communities who own the majority of cattle. Cattle provide rural communities with an income, and, if cattle is to be included in any measure of wealth, an equivalent measure would need to be included to compensate urban communities. In some communities it was noted that households were reluctant to disclose how much cattle they own in a household survey, for fear of taxation. Whilst land is an important asset, in many rural communities, it is not clear whether more land cultivation implies greater wealth or is instead a function of family size and cultivated out of necessity.

The values or prices that were placed on goods may not accurately reflect the value of each commodity. In all cases, the market price for that particular good was used when in many cases the goods may have depreciated significantly from this. This is particularly relevant when it comes to motor cars as use of the market price may have led to the wealth of households owning a car being over stated. However, as it is not possible to appraise the individual value of each commodity for each household, the value has not been discounted.

This analysis was based on a limited number of household items which were thought to give a reflection of the wealth of households and it is by no means a comprehensive evaluation of true wealth. This limitation may have distorted the wealth distributions that were produced. Similarly, the wealth brackets that were used to divide up the wealth distribution may have distorted the curves produced. Nothing is said about household size in this analysis, although the measured variables are unlikely to be affected by household size. For example, one television will serve a household of eight equally as well as a household of three.

Conclusion

Although a number of possible drawbacks have been identified with this analysis, it does at least identify how some durable goods are distributed across the population and therefore gives an indication of how wealth may be distributed. In a number of cases, it is shown that average wealth may not be a good indication of typical wealth in a community, as a large percentage of the wealth may be concentrated in the hands of a small number of households. KwaLatha in South Africa provides a good example of this.

According to the Lorenz curves, in South Africa, the two rural communities of KwaLatha and Ethembeni had greater inequality of distribution compared to the rural ones. This is also the case in Sri Lanka, where greater inequality of distribution is found in Agarauda and Tissawa. In Tanzania, the two sites of Majengo (urban, good water provision) and Nkoaranga (rural, good water provision) have the greater inequality. Gini Coefficients tend to reflect what is shown by the Lorenz curves. Some interesting questions regarding distribution of wealth are raised by this and give scope for further investigation into whether inequality of distribution has consequences for effective water resources management.

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Appendix 2.4
Household Surveys

2.4.1: Household Survey Methodology Report

Dr. C. W. Hutton, Ms I. Steyl, Ms L. Tricklebank
(March 2002)

GeoData Institute.
University of Southampton

Generic Survey Team Development

It should be noted that many of the points made below will be secondary to the needs of a Census survey. Where WPI is to be carried out within a Census survey please adapt the following:

Once a country is selected for the WPI survey process, the identification of an appropriate country partner/agent is paramount (in future surveys it may well be that the in-country agent become the sole operator using specific guidelines and the finalised survey documentation). The funding agent will agree a pre-set budget within which the partner organisation must operate. The in-country partner should provide for the following:

- An appropriate survey team. This will normally consist of the following components
  - Eight surveyors - these people should consist of capable individuals, preferably with social survey experience (although there is provision for a training day and the survey is designed to be straightforward in its deployment). Survey teams could be drawn from University students, Government agency staff, constancy staff, NGO extension workers already employed in field etc.
  - Two in-field supervisors (responsible for 2 pairs of surveyors and Key Personnel Interviews).
  - Team leader - responsible for the budget and the overall running of the project in country.
  - Provision of a community representative drawn from the target communities for each survey pair.

- The survey team will need to be able to put in a full day's work for required number days in each surveyed community to which they are allocated.

- The surveyors will need to be reasonably presentable, drawn from the broad culture/ethnic group under survey and speak the language of those being surveyed fluently. As such they must be aware of security and social issues within the communities to be surveyed (see training day structure).

- A daily rate will need to be allocated to the surveyors from which all personnel expenses are drawn (rate must include the per day payment for lunch etc).

- All provision of accommodation, transport, access and materials (photocopies etc) are to be met within the allocated budget by the in-country partner.

- Arranging for appropriate permission to be gained from the target communities. Full protocol should be observed to ensure that target communities are consenting, well informed of the key communities as a result of these surveys. There is a suggestion that future WPI projects – Phase II – would benefit from "piggy-backing" on infrastructure development projects.

- This process should involve official and extensive contact with all relevant representatives/leaders within the communities. This may involve political sensitivity as there is often more than one strand to the primary institutional bodies within a community (traditional and government). This may not be an issue if the survey is conducted within a Census.

Identification Of Target Communities

In selecting communities for the WPI survey the following should be considered:

- The requirement to survey rural, peri-urban and urban environments. Where possible representative communities should be identified from within each of these settlement groups. Clearly each of the rural, peri-urban and urban settlement groups can be sub-divided, and where provision is made, can be sampled independently.

- Within each major settlement area, at LEAST two communities need to be surveyed. This allows for a comparison between relatively good provision and poor provision within a given settlement type/area. Thus, a community with adequate supply in an urban setting should be compared to an urban community (within close proximity where possible) with inadequate provision. This provides for:
  - Calibration of the survey approach;
  - Establishment of an evidently "achievable" upper water resource status for the settlement type.

- The survey should be carried out in a community that is considered typical or broadly representative of a water resource status and where suitable, contact and representation to community leaders has been established.

Broad Survey Approach

- Each community should have between 100 – 150 household surveys carried out where possible. There is no strict sampling regime within the surveys as absenteeism and occasions where there is no one suitable to interview produce an unavoidable bias to the data. Surveyors are simply instructed to gain a certain number of interviews from a designated globular area. In the derivation of broad indicators within a short period of time this is considered sufficient. A Census survey will be more comprehensive.

- Where possible communities should be selected where a 150 sample will cover a substantial area of the community, however this is generally not the case in peri-urban and urban environments.

- Each community selected should be divided into two adjacent areas covering some 75 houses each. A survey pair operates in each sector. The spread of data between the two groups should be such that it produces a single globular area of coverage.

Excessive focus on roads, rivers and other specific community influences should be avoided to minimise bias. Again if the survey is based upon a Census then WPI will fit into the required Census protocols.

- A local representative who is paid at a reasonable daily rate for work with the village should accompany each surveyor pair.

- All aspects of the survey should be carried out within 1 working day for 3 – 5 questions. The survey may also run with a census.

- Survey pairs then begin the task of approaching every house in their designated area. Houses can be returned to if no one suitable is available on a given day if necassary.

Surveyor Training

Prior to the survey a training day with the surveyors and supervisors is necessary. During this session the following must be established (this will be covered if associated with a Census)

- The purpose of the survey should be explained to the surveyors and open discussion encouraged.

- A complete read through of the questions with open discussion on the content, intention of the question and translation. Whilst it may not be possible to change the survey structure, notes can be taken by surveyors to assist in the field. Issues raised by the surveyors regarding relevance and approach should be noted for interpretation and development

- A structured introduction should be outlined for use by the surveyors. This should include:
  - Interviewers name;
  - The institute they are working for;
  - Their intention during the interview;
  - Establishing the presence of a suitable interviewee (female adult involved in water resource management);
  - Establishing if the household member is willing to participate in the survey
  - Thanking the household member

- Health and safety in the field must be discussed:
  - Staying in pairs and having a cell phone if possible;
  - Clear understanding of pick-up times;
  - Clear points of contact with the supervisor;
  - Provision of food and water;
  - The need to avoid discussion on politics, or issues which might result in arguments or conflict should be emphasised;
  - The option to simply halt the interview if conflict were to arise;
  - The option to leave a community should the surveyors feel at all intimidated

- Once a suitable respondent is identified the following should be kept in mind by surveyors:
  - ➢ Ask the questions clearly as written, repeat if necessary. If there is still some misunderstanding re-structure question as little as possible and repeat;
  - ➢ Do not anticipate or prompt responses from people. Be patient where required;
  - ➢ Let people settle on an answer – do not simply write the fist thing said.

- ➢ Do not appear to judge and answer in any way. Remain neutral, whatever is said;
- ➢ Be polite and maintain reasonable eye contact throughout;

Specific Considerations for more Detailed Survey Structure - e.g WPI Pilot Surveys

- Access and information relating to catchment and community management at secondary institutional level - this should include organising interviews with government/consultantancies responsible for:
  - operation and maintenance of water provision infra-structure;
  - development of policy pertaining to water resource management;
  - Research carried out within or concerning the target communities.

- A local representative who is paid at a reasonable daily rate for work with the village should accompany each surveyor pair.

- (For more detailed surveys more time is needed for water point mapping and familiarisation - The first morning of the survey involves both survey pairs and the supervisor walking the complete survey area to identify, agree upon a code and generate a GPS position for all water points within the community. This is irrespective of the status or nature of the water point. Water tanks for catching rainwater at households should be ignore during reconnaissance survey. Codes are given on the survey sheet (see training day). This allows for a common classification and reference to water points, which might be shared between survey areas.

- A GPS position is taken for each household interviewed if required.

- Household surveys can be initially analysed from viewing the data and from interviewing the surveyors. From this analysis a list of relevant contextual questions can be derived for "Key Personnel" interviews. This interview should be semi-structured in nature and consist of some 10 broad areas that can be discussed with members of water committees, doctors, teachers etc. and the conclusions noted. This approach allows for cross-confirmation in regards to the H/H interviews as well as allowing further questioning of issues that arise. It was found during the development of key person surveys that, on a number of occasions, members of the water committee were unaware of fundamental issues relating to water resource management within their own community. Greater background information was gathered through informal interview approaches.

- Survey time at the house may be as much as 25 minutes

- Developing codes for houses and water points:
  - ➢ Houses are simply named in order according to the area code. The area code is A, B, C, D etc. for each survey allocated to a survey pair. A community is divided in two and two pairs are surveying each community (which can be divided for arguments sake into A & B). The boundaries for each survey pair should be clearly demarcated to avoid households being approached twice by different survey pairs. The first house surveyed in area A will be A1. Area codes are unique to the community and should not be repeated in other areas of the country to avoid confusion.
  - ➢ Water points are identified during the initial community reconnaissance with the survey teams. There classification (as on the survey sheet) is agreed upon and an order of recording noted. e.g. the first borehole identified and a GPS reading taken will be 5/1.

Data Input in the field environment(base camp etc)

- In regards to the ongoing checking and inputting of data it has been the experience of the Pilot phases of WPI that:
    - Minor errors and inconsistencies are only identified by individuals with *extensive* experience of the outputs of the survey sheet or actual experience of supervised inputting of the data (casual familiarity with the survey sheet by sending in advance is not sufficient). The supervisors will have only as much experience of the survey as the surveyors and can not reasonably be expected to carry out the detailed checking for internal inconsistencies.
    - If data is to be input in country without an experienced supervision continuously available (e.g. at a local University) then a detailed check of the data must be made by an experienced team member (5-10 minutes on each sheet) prior to the data input.
    - It should be noted that it is not possible for the 1 or 2 available experienced WPI team members to check the output of 10 field members each evening in detail. A sampling approach is advised.

  If the project should hope to carry out a survey entirely from within a country with only remote assistance in future, then the following will be necessary:

    - A comprehensive training course for data checking/data input. It would not be sufficient to simply send the survey sheet and inputs in advance as it is only when checking real data that suitable experience is gained.
    - The survey could be simplified (see phase II recommendations) to minimise potential errors
    - The survey will be adjusted in the light of the Tanzanian experience to minimise ambiguities and potential for misinterpretation etc.

- There is a requirement for the individuals inputting the data to have direct, regular contact with the field surveyors throughout the fieldwork to prevent the propagation of errors and clarify points. This should be done on a nightly basis and not left to field supervisors who are not actually inputting the data.

- There might be some benefit in setting an upper limit on the number of surveys carried out in by a survey pair. Whilst surveyors were undoubtedly consciences and worked very hard in both South Africa and Tanzania there was evidence some minor errors occurring, possibly through tiredness/rushing. Additionally this would prevent a large number of survey sheets having been completed in the field before data input and detailed checking can begin.

- The use of semi-structured interviews with key persons has proven to be highly valuable. The questions are derived by the data managers during the input of the data. In this way the key person interviews can be used to answer specific questions arising from the database. In both the rural and urban areas the following community representatives were interviewed
    - Teachers (both primary and secondary)
    - Members of the clergy

- Health clinic workers and doctors
- Ward officers and water committee personnel

The semi-structured interviews were carried out by a Tanzanian team member and members of the GeoData team. The presence of the GeoData Institute members was not deemed necessary but was of value to determine the validity of this approach. A full report on the interviews will be sent to the UK shortly.

2.4.2: Example of Household Survey Questionnaire (Tanzania)

WATER POVERTY INDEX
INFORMATION TO BE COLLECTED FROM HOUSEHOLD RESPONDENT

GENERAL INFORMATION

Surveyor: .... **Time take** .... **Date:** ....

Location (GPS Position): .... **House code** ....

Name of respondent .... **Position in h/h** ....

City/Village .... **District:** .... **Province/State:** ....

Gender of Adult respondent who gathers water:

Male ☐ **Female** ☐

1.1 How many adults and children normally live in your household?

Adults		Children	

2.1 Gathered Water Supply in Household

2.1.1 What is your main source of gathered water for your household in the **DRY SEASON**?

Dry Season ☐ GPS ☐

Protected/Unprotected ☐ Public/Private ☐

What is your main source of gathered water for your household in the **WET SEASON**?

Wet Season	☐	GPS	☐
Protected/Unprotected	☐	Public/Private	☐

Choose one of the following sources:

1.	Pipe (Private)	**2.**	Pipe (Public)	**3.**	Household source	**4.**	Borehole (Private)
5.	Borehole (Public)	**6.**	Well (Private)	**7.**	Well (Public)	**8.**	Small dam
9.	Tank (container)	**10.**	Natural pond	**11.**	Spring	**12.**	Stream
13.	River	**14.**	Gov. Water Truck	**15.**	Water vendor	**16.**	Rainwater

17. Other (specify): ....

If you pay for water from your main source, do you feel it is affordable for your household? (direct payment only – not maintenance etc)

Yes		**No**	

2.1.2 Does your household use water at a source away from the household (washing, laundry, cleaning food, etc)? (*Can be the same as main source*)

DRY SEASON	☐	GPS	☐
Protected/Unprotected	☐	Public/Private	☐
WET SEASON	☐	GPS	☐
Protected/Unprotected	☐	Public/Private	☐

If the respondent has not mentioned use of a river/stream

Do you ever use the river/stream for collecting or using water?

Yes		**No**	

2.1.3 Do you ever have to spend extra money to gather water (hire car to collect water, buy water from a vendor, pay someone to collect water for you)?

Yes		No	

2.1.4 Do you gather rainwater at your house?

Yes		No	

2.1.5 How long (in minutes) does it usually take to collect water from your main source, during a single trip including queuing time? (*This can include multiple journeys within a single trip*)

Wet Season		Dry Season	

2.1.6 What methods of transport does your household use to transport water from your main source to your home?

Transport Type	Wet season	Dry season
Head/Hand		
Livestock		
Wheelbarrow		
Motor vehicle		
Cart		
Other		

2.1.7 What is the quality of the water you gather from your main source in the dry and wet season?

Water Quality	Wet season	Dry season
Good		
Fair		
Poor		

2.1.8 Do you treat your water (allow to settle, chemical treatment, boil the water)?

Yes		No	

2.1.9 How much water is usually carried by a single woman, a single man and a single child in your household on **EACH TIME your household gathers water**? (*Include multiple journeys as one trip*)

Woman		Man		Child	

2.1.10 How many trips to gather water does you household usually make a day?

2.1.11 How many people gather water on the **FIRST** trip of the day?

Women		**Men**		**Children**	

2.1.12 How many people gather water on the **SECOND** trip of the day?

Women		**Men**		**Children**	

2.1.13 How many people gather water on the **THIRD** trip of the day

Women		**Men**		**Children**	

2.1.14 Of the water gathered at your household, do you use water for purposes other than drinking, washing, bathing, cleaning and cooking?

Yes		**No**	

If YES, name the activity ……………………………………………………………………

2.2 Ownership and maintenance of water sources

2.2.1 Who is responsible for maintaining your main water source?

……………………………………………………………………..

2.2.2 Who owns the main source of water you use?

Water supply reliability	Wet Season	Dry Season
No one		
The village Chiefs		
All the community		
A group of people within the community		
Organisation outside the community		
Other		

2.2.3 If you have to pay for the maintenance of your water supply, is it affordable to your household?

Yes		No	

2.3 Reliability of water supply

2.3.1 How reliable is your main water supply?

Water supply reliability	Wet Season	Dry Season
Very reliable		
Reliable		
Not reliable		
Sometimes dries up completely		

2.3.2 How reliable is the water source you use source away from the household(washing,laundry, cleaning food etc).

Water supply reliability	Wet Season	Dry Season
Very reliable		
Reliable		
Not reliable		
Sometimes dries up completely		

2.3.3 How many times have you had a poor crop yield through drought over the last 5 years?

[ ] ***(SF for Stop Farming due to drought)***

3. *CAPACITY*

3.1 School

3.1.1 How many adults in your household have matriculated from school?

[ ]

3.2 Water Management Organisations (*default to No*)

3.2.1 Are you aware of the presence of a formal water users association / committee in your community?

Yes		No	

3.2.2 If YES, is the committee effective at managing your household water supply?

Yes		No	

3.2.3 Are you aware of organisations outside your community responsible for water supply?

Yes		No	

3.2.4 Has any member of your household participated in water use and/or hygiene related training programmes?

Yes		No	

3.2.5 Are there conflicts over water in your community?

Many times		Occasionally		Never	

3.3 Household Health

3.3.1 How many times, over the last year, has anyone in your household had diarrhoea or been ill due to contaminated water?

Many times		Occasionally		Never	

3.3.2 Do you think that your household has suffered illness due to a lack of water for washing and cleaning

Yes		No	

3.4 Agriculture

3.4.1 How much land does your household cultivate (m^2)?

3.4.2 Do you irrigate your crops?

Yes		**No**	

3.4.3 What is more important for growing your crops?

Rainwater		**Irrigation**		**Do not know**	

3.4.4 How many cattle does your household own? ☐

Is there adequate water for your cattle in the dry season?

Yes		**No**	

3.4.5 How many goats does your household own? ☐

Is there adequate water for your goats in the dry season?

Yes		**No**	

3.4.6 Is there erosion on your land?

Erosion	
None	
Some	
A lot	
Do not know	

3.6 Information about the Home

3.6.1 How many of the following durable products are used in your household? (*Give numbers of each*)

Bicycle		**Motor Vehicle**		**Washing machine**	
Cooker		**Television**		**Radio**	
Electric fan		**Power supply**		**Gardening tools**	
Fridge		**Others_1 (specify)**		**Others_2 (specify)**	

3.6.2 How many members of your household earn a regular wage or have a pension?

☐

3.6.3 Does your household sell food you have grown, products you have made or occasionally work to make money

Yes		No	

3.6.3 How much of your household income comes from selling food or products you have made?

[ ] (all, ¾, ½, ¼, less than ¼)

4. Ecological products (Availability)

Use of Wild Plants and Animals

4.1.1 Do you use the river for anything else other than water?

For cattle		Catching fish		Fuel wood	
Plants		Animals		Recreation	

4.1.2 Are there plants or animals that you used to use from the river area that you cannot find anymore?

Yes		No	

4.1.3 Do you sell any products you gather from the river?

Yes		No	

2.4.3: Examining the Potential for Using a Shortened Survey Instrument

Craig Hutton, GeoData Institute, Southampton

Developing indicators from the survey questions

Indicators are selected data that is gathered to represent a complex system or series of systems where it is unfeasible or impractical to measure the system in its entirety. A simple ranking system has been developed to assist in the task of identifying the most relevant indicators/questions for WPI. This should be of particular relevance should the WPI surveys become **part of a census approach** where only a limited number of questions would be feasible. Such an approach will allow a far wider coverage of communities than a larger survey.

When developing indicators it is essential to remember that an indicator question should be:

- Easily gathered
- Can be measured repeatedly with time
- Has near linear relationship with the true measurement of interest (in this case water poverty).
- The exact relationship between the indicator and the system does not have to be fully understood (e.g. we may find that overall water poverty appears to be mirrored by economic status without fully understanding the relationship between them

It should also be noted that there are a number of limitations to the development of a small number of indicators to define water poverty:

- Initial questions were developed after a great deal of discussion by experts in a wide range of fields, however, it is inevitable that there will be an element of judgement in the initial selection. This issue was minimised by having a large number of initial questions from which the most suitable questions could be identified.
- The ranking system below is not statistically rigorous, as we have carried out work in only 8 communities in 2 countries (South Africa and Tanzania). It does, however, offer a broad direction for future research and testing. It should be noted that NO causative relationships can be deduced from the rankings and until further studies are carried out the rankings are simply a guide.
- In this case, all questions were given an equal weighting.

Reducing the number of questions

The following steps were carried out to reduce the 25-30 minute survey structure down to a few key questions that can be included in a census or extensive survey work:

1) *Questions that were considered potentially ambiguous were removed.* This includes questions which could lead to poverty ranking either rising or falling based upon a single response. For example, whilst it is clearly a valuable contribution to livelihood to utilise water for economic purposes, it does not follow that those who do not are in some way poorer. The more formal peri-urban communities studied were the most economically productive but had little or no utilisation of water as an economic resource. This could be due to the fact that these people were able to find employment in local commercial centres and thus had no need to use water in this way. Had they been ranked for there low use of water in an economic context they would have scored a misleading 10.

2) *Questions giving rise to potential bias are removed.* Such an example is volumetric water collection data. Whilst such data is highly relevant to water poverty, it may not be

possible to collect volumetric data from those with a supply within their household. Where in-house water supplies are extensive, community poverty ranking may become biased by the few people who do not have a household supply.

3) *The ease with which the relevant information can be obtained by a reasonably trained census surveyor. is evaluated.* Where possible simple yes/no answers can be translated into %. Questions on volumetric water collection can require an extensive series of questions in order to deduce the volumes and might therefore not be suited to a census or time limited approach to WPI.

Field Methodology for the generation of indicators from the detailed WPI surveys

Once all the survey questions from the initial survey have been put through the above process of elimination, it was found that 11 questions remained. The following approach attempts to rank these questions in order of value as indicators.

1) For each question asked a graph is plotted of the ranked response (1-10) for each community. These graphs are presented further below. Where a question is a yes/no question a % response gives a 1- 10 ranking. Questions with quantitative answers are plotted with 1 representing the lowest poverty values and 10 the highest (see table of questions for details). Communities are plotted next to each other for comparison.

2) Within each community the rankings of all the questions are added together (equally weighted at this stage) and divided by the number of questions to derive a single WPI value for each community, based upon the response to all 11 questions. This WPI value is plotted together to compare communities.

3) Individual question trends are compared with the overall WPI trend to see which single question is most reflective of the combined response to 11 questions

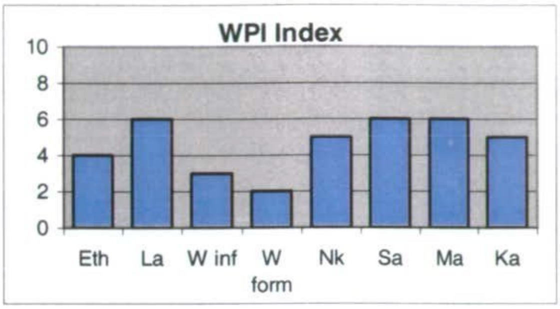
Ranking of WPI Questions asked in pilot studies

The following questions are those that resulted from the above process of question elimination, ranking and comparison with the WPI plot. These data were found to be easily gathered and relatively unambiguous in their relation to water poverty.

1. Total **time** for water journey in the dry season (including queuing) *(Ranking based upon 1 ranking point /10 minutes - max of 10)*
2. **Household size:** (1-3 = 1 3-6 = 2 etc.)
3. **Education:** % of household that have no individuals that have matriculated from school (*Ranking based upon % not having matric.*)Average household size (assumption is larger is poorer) *(Ranking is based upon 1-3 people =1 3-6 people = 2 etc up to 10)*
4. **Reliability:** % households reporting an unreliable main supply in the dry season (=)
5. **Water related illness:** % household who perceive that water has been responsible for family illness
6. **Participation:** % of households reporting that they have been involved in a training regarding water hygiene or water use (=)
7. **Wealth:** Average number of specified products within a *household (ranking based upon subtracting number of products x2 from 10)*
8. **Protected/Unprotected main water supply:** The % of households who utilise a main source of water that is protected from animal and general exposure
9. **Diarrhoea:** % households reporting suffering from Diarrhoea many times in the last year
10. **Quality:** % of household reporting poor perceived water quality
11. **Organisation:** % households reporting awareness of an organisation (community/external) that is responsible for the main water supply they use

Recommendation for a census survey.

If the WPI project could have 3 questions added to a census then it would seem sensible to pick the first 3 questions from the above list. However, it is normal for a census to ask about education and household size anyway. Thus it might actually be possible to add 3 water based questions and use the education and household size questions directly from the survey. The 2 plots below indicate that by asking only 3 water questions (2 from census data) virtually the same result as gathering 11 questions can be found.



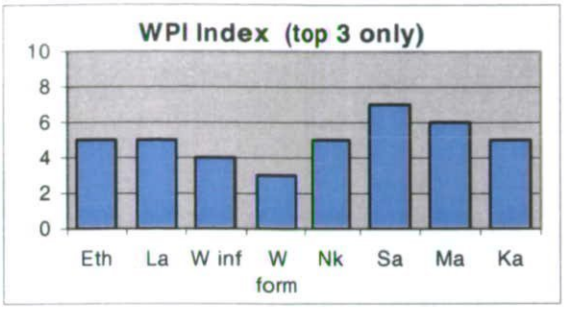


Figure 1 Comparison of WPI (normalised) derived from 11 questions and WPI derived from top 3 Questions. (Variations are in part due to using integers only in the ranking)

Social Capacity

It is important that we include in our survey a question regarding Social Capacity. This is essential to allow us to develop a context to water poverty. The data gathered in a census will be utilised by planners and others who will need to be aware if there is already a community context in which development can occur within a community. If a community has high water poverty but has a community water organisation then this would be a suitable target for development of water resources. Where a similar community exists without a community based water organisation it would be prudent to develop community participation first before embarking on a water resource development program. Thus the following question should always be associated with WPI surveys at a community level:

"Do you feel that there is effective community/institutional management of your main water supply"? (yes/no)

Comparative plots

(Cumulative differential value is the total graph variation from the WPI index)
The following abbreviations have been used:

Ethembeni (SA)	Eth
Latha (SA)	La
Wembezi (informal) (SA)	W inf
Wembezi (formal) (SA)	W form
Nkoaranga (T)	Nk
Samaria (T)	Sa
Majengo (T)	Ma
Kijenge (T)	Ka

The results obtained for a selection of questions are presented overleaf and can be compared with the combined result of all selected questions as presented in figure 1.

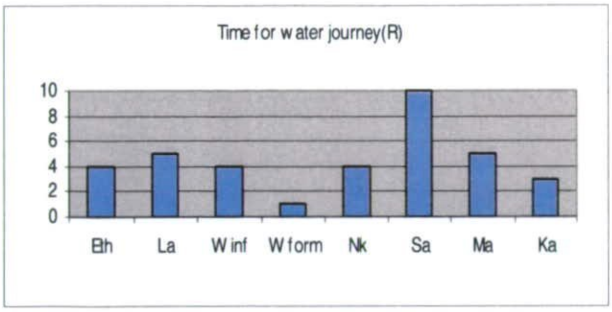


Figure 2

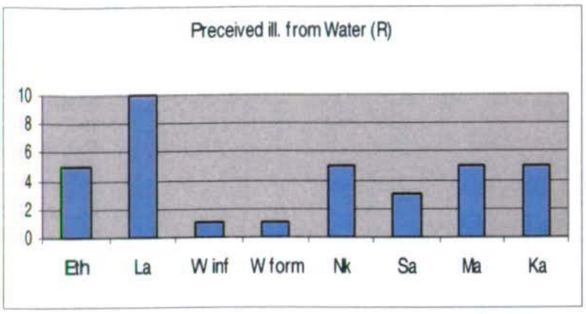


Figure 3

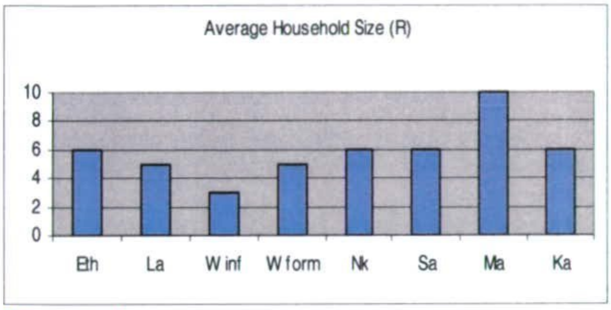


Figure 4

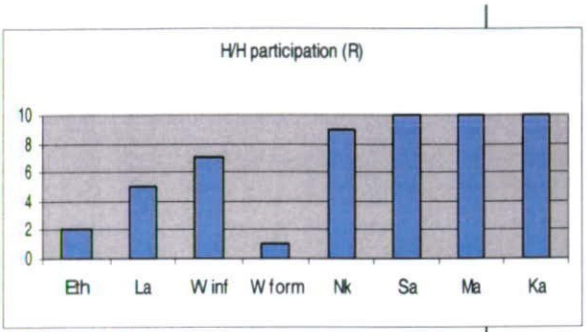


Figure 5

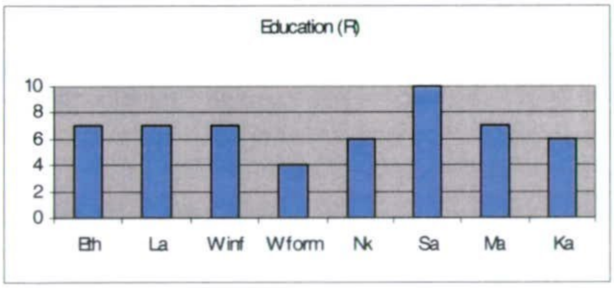


Figure 6

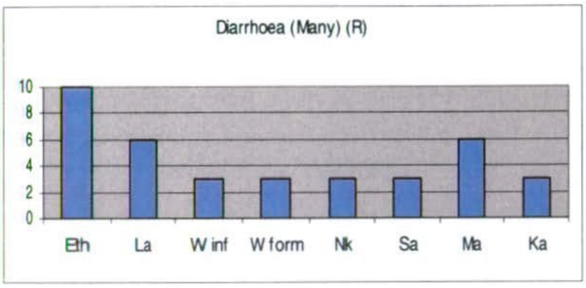


Figure 7

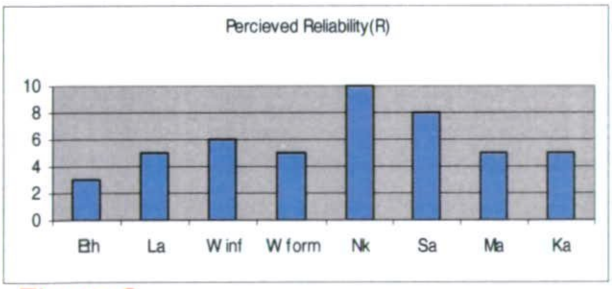


Figure 8

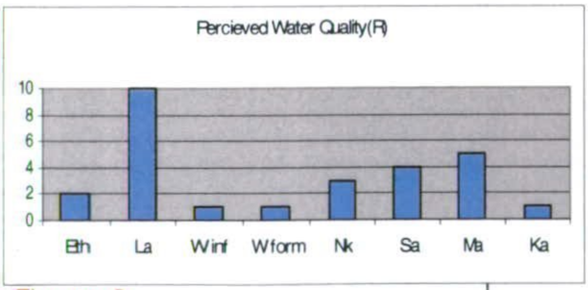


Figure 9

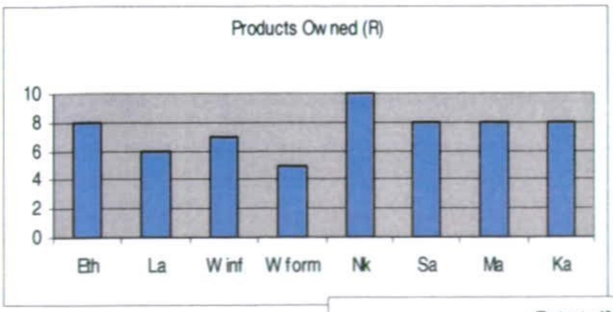


Figure 10

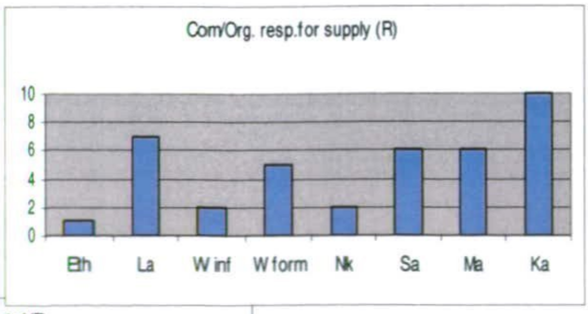
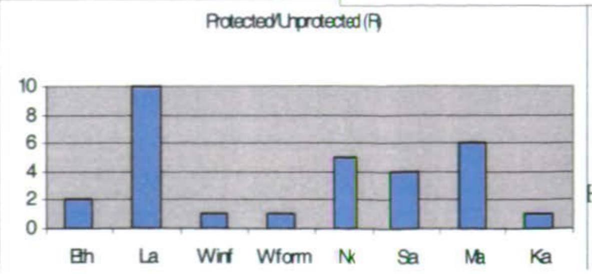


Figure 11



2.4.4: Possible Short Form Questionnaire

Water Poverty Index

Short Form Questionnaire

INFORMATION TO BE COLLECTED FROM HOUSEHOLD RESPONDENT

GENERAL INFORMATION

Surveyor: ……………. **Time taken:** ……….. **Date:** …….……………

Location (GPS Position): ……………………………. **House code** ……………

Name of respondent ……………………… **Position in h/h** ………..

City/Village ………………… **District:** …………… **Province/State:** ………

Gender of Adult respondent who gathers water:
Male ☐ **Female** ☐

1 How many adults and children normally live in your household?

Adults		Children	

2. What is your main source of gathered water for your household in the **DRY SEASON**?

Dry Season ☐ GPS ☐

Protected/Unprotected ☐ Public/Private ☐

Choose one of the following sources:

1.	Pipe (Private)	2.	Pipe (Public)	3.	Household source	4.	Borehole (Private)
5.	Borehole (Public)	6.	Well (Private)	7.	Well (Public)	8.	Small dam
9.	Tank (container)	10.	Natural pond	11.	Spring	12.	Stream
13.	River	14.	Gov. Water Truck	15.	Water vendor	16.	Rainwater

3. If you pay for water from your main source, do you feel it is affordable for your household? (direct payment only – not maintenance etc)

Yes		No	

4. How long (in minutes) does it usually take to collect water from your main source, during a single trip including queuing time, during the dry season? (*This can include multiple journeys within a single trip*)

Dry Season	

5. What is the quality of the water you gather from your main source in the dry season?

Water Quality	**Good**	**Fair**	**Poor**

6. How reliable is your main water supply in the dry season?

Water supply reliability	**Dry Season**
Very reliable	
Reliable	
Not reliable	
Sometimes dries up completely	

7. How many adults in your household have matriculated from school?

8. Are you aware of the presence of a formal water users association / committee in your community?

Yes		**No**	

9. Are you aware of organisations outside your community responsible for water supply?

Yes		**No**	

10. Has any member of your household participated in water use and/or hygiene related training programmes?

Yes		**No**	

11. How many times, over the last year, has anyone in your household had diarrhoea or been ill due to contaminated water?

Many times		**Occasionally**		**Never**	

12. How many of the following durable products are used in your household? (*Give numbers of each*)

Bicycle		**Motor Vehicle**		**Washing machine**	
Cooker		**Television**		**Radio**	
Electric fan		**Power supply**		**Gardening tools**	
Fridge		**Others_1 (specify)**		**Others_2 (specify)**	

2.4.5: Comparing the Composite Index Approach with a WPI Constructed from a Shortened Survey Instrument

Tim Fediw, CEH Wallingford

The WPI values generated by Giacomello and Sullivan (Appendix 1.2), using the composite index approach can be contrasted with a WPI that is created using a more limited data set such as would be produced by employing the *short form questionnaire* presented in appendix 2.4.4. The shortened survey water poverty index (SSWPI) values have been generated using the same principles and scoring techniques as the composite approach, however, due to the limited data, a single value has been created by averaging the score generated by each question, rather than using the five categories discussed in appendix 1.2.

In appendix 2.4.3 Hutton suggests which questions are most relevant for a shortened survey instrument. The results obtained from these suggested questions have been used to generate the SSWPI, however, in this instance, household size has been omitted. Whilst household size was found to have some correlation with water poverty, it remains unclear as to how household size should be scored as it is difficult to determine what the optimum household size is[23]. Incidence of Diarrhoea has also been omitted due to its similarity with "water related illness". The following components constitute the SSWPI[24]:

- **Time** taken to collect water in the dry season (including queuing)
- **Education:** Number of adults who have matriculated
- **Reliability:** % households reporting an unreliable main supply in the dry season
- **Water related illness:** % households who perceive that water has been responsible for family illness
- **Participation:** % of households reporting that they have been involved in a training regarding water hygiene or water use
- **Wealth:** Based on ownership and market value of certain consumer durables.
- **Protected/Unprotected main water supply:** The % of households who utilise a main source of water that is protected from animal and general exposure (dry season)
- **Quality:** % of household reporting poor perceived water quality (dry season)
- **Organisation:** % households reporting awareness of an organisation (community/external) that is responsible for the main water supply they use

[23] Whilst a larger household is generally associated with greater levels of poverty, extremely small households may lack capacity and therefore be at a disadvantage. The implications of household size will also differ greatly between urban and rural areas.

[24] Details of how scores are created for each of these are found in appendix 1.2

Using data from each of these questions, the following values were generated for the 12 study sites:

		Time	Education	Reliability	Illness	Participation	Wealth	Protected Supply	Quality	Organisation	SSWPI
S Africa	Ethembeni	65	57	19	72	15	34	87	19	85	**50**
	KwaLatha	28	31	17	48	45	47	18	76	42	**39**
	Wembezi (inf)	62	38	29	94	36	46	99	1	18	**47**
	Wembezi (for)	90	61	21	93	3	72	99	0	51	**54**
Tanzania	Nkoaranga	88	43	19	79	14	78	51	28	79	**53**
	Samaria	10	5	37	86	5	70	69	12	45	**37**
	Majengo	72	40	10	75	6	88	47	38	41	**46**
	Kijenge	91	51	29	93	3	69	97	0	18	**50**
Sri Lanka	Agarauda	87	67	53	23	79	18	85	24	83	**58**
	Awarakotuwa	78	61	0	33	36	74	21	10	98	**46**
	Tharawaththa	65	52	66	23	55	9	6	31	98	**45**
	Tissawa	86	67	66	24	63	17	43	19	79	**52**

Table 1

These values, and the relevant ranking they produce for each community, can be compared with those produced by the composite index approach. It should be noted that, due to the different end points used in constructing the range of scores, it is not appropriate to compare values between countries.

		SSWPI		Composite WPI	
		Value	Rank	Rank	Value
South Africa	Ethembeni	50	2	3	38
	KwaLatha	39	4	4	23
	Wembezi (informal)	47	3	2	38
	Wembezi (formal)	54	1	1	62
Tanzania	Nkoaranga	53	1	1	49
	Samaria	37	4	4	33
	Majengo	46	3	3	35
	Kijenge	50	2	2	43
Sri Lanka	Agarauda	58	1	1	47
	Awarakotuwa	46	3	3	37
	Tharawaththa	45	4	4	30
	Tissawa	52	2	2	42

Table 2

As shown, very similar results are obtained by using the SSWPI as those created by the micro level composite index approach, suggesting that a shortened survey instrument may indeed be a valuable method of collecting data at the micro level. However, it must be borne in mind that this comparison is based on three countries only. The similarities shown may have arisen through a certain amount of chance and it may not be the case that they will hold in other countries.

Although not entirely appropriate, due to the different end points used in score calculation, a Spearman's Rank Correlation Coefficient has been calculated for the twelve sites. A coefficient of 0.942 is generated, which is found to be significant at the 95% confidence level. Correlating the scores rather than the ranks produces a correlation coefficient of 0.83. An X-Y scatter of the WPI values are shown below:

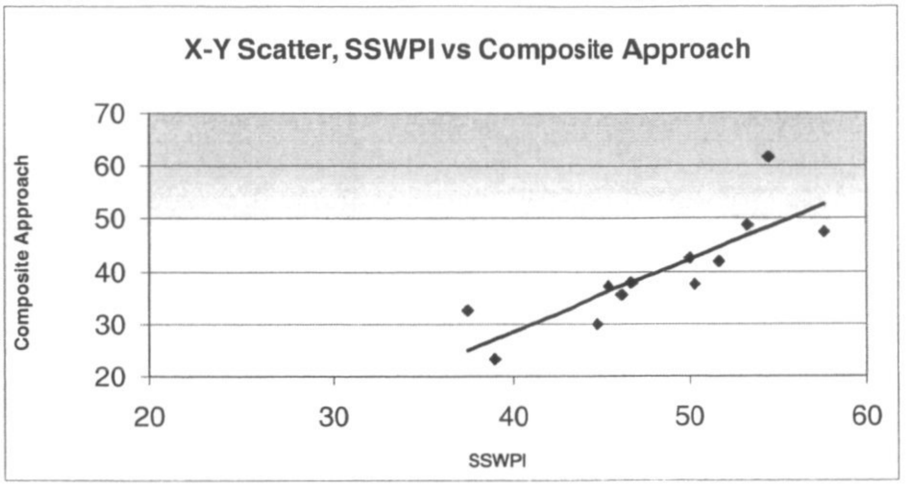


Figure 1

A reasonable correlation is shown, which at least shows that using the *short form questionnaire,* does not lead to a massive distortion of WPI values, although at the same time it should be remembered that in different countries this may not be the case.

Using the *short form questionnaire* may therefore provide a way of collecting data efficiently and allow local level WPI values to be calculated without employing a lengthier questionnaire. Further trial of the *short form questionnaire* alongside the full length questionnaire in different countries would help to identify whether the limited questions provide a good indication of water poverty in all cases. The *short form questionnaire* by its very nature, collects less information, so it will be inevitable that its description of water poverty will not be so comprehensive as that generated by employing the composite approach, but could provide an option that is easily calculated by policy makers at the local scale.

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Appendix 3
Assessment of Water Availability for the Pilot Study Sites

Jeremy Meigh, CEH Wallingford

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1. Introduction

1.1 Objectives of this report

Phase I of the Water Poverty Index (WPI) project is a development and testing phase in which data have been collected from four sites in each of three countries: Tanzania, South Africa and Sri Lanka. The methodology has been developed and it is applied at each of these pilot study sites in order to test it.

There are number of components making up the WPI, defined as: availability, access, capacity, use and environment. The last four of these are discussed elsewhere; the present report deals only with the availability component. The objective of the report is:

- to determine an appropriate general methodology for the assessment of water availability in the context of the WPI, and
- to apply the methodology at the pilot study sites and provide the results of the assessment for each site.

In order to do this, it is first necessary to define water availability and to determine what indicators should be used for it; this is discussed in Sections 1.2 and 1.3, immediately following. Then, in Section 2, the methodology which is used to determine availability is defined. The remainder of the report then provides the details of the work out for each study site, and presents the results of the assessments.

1.2 Definition of water availability

In order to provide a realistic definition for use in the development of the Water Poverty Index, water availability can best treated in two separate ways:

- **Primary natural endowment (or primary availability).** This is the quantity of water that is naturally available at or near the location of interest. By naturally we mean the situation which would have occurred before any significant human interventions or alterations to the streamflow regime or the groundwater aquifers. Thus, the effects of dams, diversions, water transfers or pollution are disregarded in making these estimates. Where substantial impacts on the natural regime from changes in land use or vegetation cover can be identified, it should, if feasible, be attempted to estimate the natural situation before the changes. When there is deep groundwater at the study site it should be included in the natural availability even if there are no boreholes, because it still represents a potential resource.

- **Actual availability (or potential supply).** This is similar to the natural endowment, but the impacts of human intervention *are* taken into account. Human interventions can be of two types:

  - o Direct interventions which affect flow quantity, seasonal regime or quality. The existing water resources infrastructure needs to be taken into account. There are many possible types of intervention. The most straightforward type, and the one that needs to be considered most often, is the water supply system which people actually use to get their water. whether a complex distribution system covering a whole city, or a small-scale system of a pipe and tank supplying a small village. Other examples might include a dam which diverts water for irrigation upstream, or a diversion for industrial use which returns polluted waters. Both these would decrease the availability compared to the natural endowment. Examples which increase the availability include transfers by pipe or canal from a distant catchment to the location. Groundwater is only considered as far as there are boreholes in place to supply the water, or a transfer system from a distant aquifer.

- Changes to the catchment which can affect flows in a similar manner also need to be considered. These could be changes in land use or vegetation cover (*eg.*, forestry, cropping types, overgrazing, etc). In many cases, such changes within the recent past will be relatively minor and the changes in water availability will not be significant. In others very substantial changes may have taken place and substantial impacts may have occurred. Where there is sufficient information, such impacts should be included in assessing the actual availability. However, in many cases the availability of data and the methodologies needed to assess these impacts are likely to be lacking and any assessment may have to be mostly descriptive.

Clearly, it is the actual availability which is most relevant in evaluating the WPI since it relates to the water that people are actually able to use. Nevertheless, the primary or natural availability is also of interest. It provides a context for the actual availability, describing the setting in which the assessment is being made, whether generally water abundant or water poor. It also gives some idea of the potential availability, indicating what might be available if the ideal infrastructure was in place and functioning correctly. This definition of water availability has considerable overlap with the evaluation of people's access to water which is another component of the WPI process. However, the distinction is that water availability relates to the natural environment and water resources infrastructure, while access relates to people's ability to obtain that water to satisfy their needs, taking into account factors such as time and distance to collect water, rights of access and costs.

In assessing the availability of water it is implicit that its variability (seasonality and inter-annual) or reliability as well as its quality must be taken into account at time scales appropriate to the location and types of water use being considered. (The change in availability over time, as distinct to the variability, is also an issue, but this would be measured by change in the indicators from repeated assessments). With regard to water quality, different degrees of physical, chemical and biological contamination are important depending on the intended use of the water. For the WPI, the focus is on drinking water although other uses are also considered, so availability is considered to be limited when the quality does not meet international or other drinking water standards. The assessment must also be at the appropriate scale. It is not clear how far outside the village, community or city area resources should be considered to be part of the natural availability. This cannot be specified in a general way, but will have to be decided in each case on an ad-hoc basis.

1.3 Indicators of water availability

As a first step, three separate aspects of water availability are examined. These are, for *both primary and actual* availability:

- Amount of water, expressed as per capita quantities (eg., litres/capita/day) for each source (both surface and ground water), or for the most important source where one is dominant.

- A measure of the variability or reliability. For the natural system (primary availability) it is the natural variability, both seasonal and inter-annual, that is most relevant, while for actual availability it is more the reliability of the relevant systems that need to be examined.

- A measure of water quality; generally only whether or not it is fit for drinking and washing is considered (fitness for other purposes is not included).

These three values can then be reduced to a single indicator for primary availability, and one for actual availability:

- An indicator on a scale of 0 to 10 which gives a combined assessment of the three factors: amount, variability/reliability, and quality of the water. A procedure by which this can be done is described in Section 2.3. While this single indicator gives an overall result for availability, the information relating to the three separate aspects is still valuable, and should be retained so that it can be seen what is included within the final result.

The indicators will generally express the present situation (that is, at the time of making the estimates). For instance, present population figures would be used in estimating per capita quantities. However, it would also be possible to use this approach to examine possible future values of the indicators by considering scenarios of climate change in combination with projected populations for 10, 20 years ahead, etc.

2. General Methodology

2.1 Surface water

This methodology attempts to define, in a very general way, the approach which was applied in the assessment of surface water availability in the context of the development phase of the WPI. That is, for a situation where detailed household surveys have been carried out for individual communities. For implementation of the WPI over larger areas and at different scales, a range of other approaches are appropriate, and the possible methodologies for this are discussed elsewhere.

This section outlines the general approach; details of the particular methodologies actually applied for each country and community studied, are discussed with the results in Sections 3 to 5 below.

A combination of elements are needed for the assessment of surface water availability. These include:

- Collection and analysis of data at the regional level,
- Discussion and collection of information from district or local water resources officials,
- Field surveys, both at the community and the household level,
- Field inspection of sites and catchments,
- Rainfall-runoff and water resources modelling or approximate estimation.

The approach to be used in a particular situation and the accuracy of the results will depend on the data availability and the amount of previous work, including modelling, that has been done in the area. Broadly speaking, much of the methodology will be the same whatever the data availability, but in situations which are richer in data and have been well studied, much more detailed modelling will be possible, and more accurate results may be obtained. When this is the case, results can be expressed numerically, either based on direct observations or on sophisticated modelling. For situations which are data poor a combination of more simplistic modelling with regional data and estimation, household/community surveys and field observation, is needed. Then it may be that only qualitative indicators can be determined, expressed on a scale from "good" to "poor", for instance. The work is carried out always bearing in mind that the results should be assessments of both the primary (or natural) water availability and the actual availability, as discussed earlier.

The following are the principal steps in the procedure:

Collection and analysis of data at the regional level

The first step is to collect relevant information that may be available at the national level, or even internationally (from web sites, etc), and carry out a preliminary analysis:

- Obtain topographic maps at suitable scales and other maps as available (land use/vegetation, soils, etc; both present and past data on land use if available).

- Identify the location of the community in relation to the natural systems (catchments and aquifers) and decide what are the potential water sources. Determine the relevant catchment areas.
- Obtain monthly (or daily), long-term rainfall and river flow records for the study catchments (if available) and immediately adjoining areas. River flows anywhere in the same basin may be useful even if far downstream. In a data poor situation additional records of rainfall and river flows (mean annual rainfall and flows, or monthly series, and catchment areas) from a wider area that has broadly similar hydrological characteristics should also be obtained.
- Obtain information on national or other studies which identify typical rainfall-runoff relationships, model types and parameters for the study region.
- Obtain any relevant information on water quality in the study area.
- Depending on level of previous work, some analysis will be needed. For data poor areas this might be the development of a simple relationship between mean annual rainfall and runoff, for instance.
- As the indicators of availability are to be expressed in per capita terms, information on the population served by the sources will be needed. In some cases the water sources may not serve only the community being studied, so data on the total population served by source will be needed. For instance, if we are looking at a community in a city which is served by a large-scale water transfer, then the total population of the part of the city being served by this transfer is needed to calculate the per capita availability.

Discussion and collection of information from district or local water resources officials

A range of information that may not be available at the national level should be collected at the district or local level. Some of this may be qualitative rather than quantitative, and should cover:

- Water sources used, quantities and variability of the sources, occurrence of droughts, whether or not the sources are used by others than the community being studied (and if so, quantities relating to this use).
- Details of the water resources infrastructure: dams, transfers, wells and boreholes, operation procedures, amounts used, transferred and returned, losses in transfers and distribution, type of water use, reliability or effectiveness of the infrastructure.
- Information on land use and vegetation changes in the catchment which may have affected flows, and information on the impacts that have occurred as a result.
- Any measurements of water quality and qualitative information on impacts on water quality, eg., factories discharging upstream.

Field surveys

Much the same information as listed in the previous step should be collected, however this is at the community level rather than the view from outside and serves as a check on information obtained from other sources. Information may be collected from a few key informants in the community, and the relevant questions that have been included in the household surveys should be analysed from the perspective of assessment of availability:

- The information collected would be largely the same as at the previous step, to confirm the situation as far as possible.

- Identify and map all the sources actually used (not just the main source), and determine the numbers of households using each different source. These may differ between the dry season and the wet season.
- Questions in the household survey that cover issues of reliability of water supply, quality of the water, and health problems related to water should be analysed. These data provide information on people's perceptions, but can still be very useful.

Field inspection of sites and catchments

In some cases an inspection of the field sites and the catchments would need to be carried out by an experienced hydrologist or water resources specialist. This would serve to:

- Confirm the arrangements and state of the water supply infrastructure so that it can be realistically modelled and the impacts assessed.
- Assist in estimating runoff, variability/reliability and water quality by obtaining field details and impressions of the particular situation rather than the broad picture which will result from the previous activities. (This activity may not be needed in data rich situations where accurate modelling can be carried out).

Modelling or estimation

Activities will depend on the amounts of available data and modelling experience in the area, as discussed earlier:

- Data rich areas – carry out modelling to assess flows and variability and account for the impact of the water resources infrastructure and land use changes. To include variability, assess the quantity which is present in the driest month of the year with a 1 in 10 year return period, for example. This should be done separately for the individual sources, which are then summed. If the demand varies over the year, then the month when there is the least supply in relation to demand will have to be considered. If water quality (for a particular source) is not adequate, then this part of the supply is removed from the available quantity.
- Data poor areas – use simple regional relationships (for instance, between mean annual rainfall and runoff) to estimate flows, and adjust these based on the broad range of information collected and field experience. Estimate variability/reliability, water quality problems, and impacts of the infrastructure and land use changes in an approximate/qualitative manner.
- Some areas may have intermediate levels of information/previous experience, and in these cases a combination of approaches may be used to get the best estimates.
- The final step is to combine the results to produce the indicators of water availability as described in Section 2.3 (also taking into account the results of the groundwater analysis, discussed below).

2.2 Groundwater

The distinction between "primary availability" and "actual availability" (Section 1.2) is a convenient classification which can be applied equally to surface water and to groundwater. In the case of groundwater, primary availability is taken as referring to the potential resource in the aquifer, before drilling, borehole construction or any other actions have been taken to access or extract the water. The primary availability can be regarded as the development potential of an area as deduced by hydrogeologists. Primary groundwater availability is usually presented as a map or series of maps, on which such criteria as aquifer types and vulnerability are presented along with expected water quality and typical borehole yields. The maps are often accompanied by booklets or notes that explain or enhance the information.

The fact that there may be primary availability of groundwater does not mean that any water will in fact be available or accessible. Actual availability is taken as referring to the availability of groundwater via existing infrastructure, such as boreholes and associated reticulation systems. The actual availability of groundwater can be classified in exactly the same way as a surface water resource, on the basis of the yield of the source, the quality of the water and the reliability of the source. (Quality and seasonal reliability are likely to be higher than for an untreated surface water source, but the maintenance issues affecting boreholes should be included in the reliability assessment.)

Evaluating the "primary availability" of groundwater in a given area is a complex process which involves numerous considerations[25]. The emphasis in this section is on the problem of evaluating the primary availability of groundwater in any given area, but some consideration is also given to the evaluation of the actual availability. Much depends on the amount and quality of data collected from a series of monitored boreholes. Conditions are also liable to change with time, although data is often gained from boreholes only at the time of drilling[26]. Decisions made about the primary availability may however affect an earlier assessment of the actual availability, for instance in a case where recharge is thought to be in decline the reliability of an existing borehole might be called into question.

The question of scale is also important, since the primary groundwater availability for a relatively large area will change as hydrogeological conditions change across the area, and some sort of average will have to be taken to arrive at a single final figure for the whole area. Thus a "Fair" rating for water quality across a large area can mask the fact that some waters have very poor quality, whilst others are very good, and the rating refers to some compromise between them.

Unlike surface water such as rivers and dams, groundwater is hidden from view and cannot easily be seen. Only where groundwater issues from the ground as springs, or is pumped from the ground by boreholes, can it be appreciated (actual availability). This makes it inherently difficult for the layperson to assess the groundwater potential or resources for a particular area (primary availability), especially if that area has few springs or boreholes. There are in addition a myriad of controls on groundwater occurrence and quality, and conditions can vary dramatically over very small areas – for example from one side of a village to the other. Even in areas where a lot of hydrogeological research has been done, and where many boreholes have been drilled,

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[25] The number of existing boreholes or springs in an area is not necessarily a guide to the primary availability of groundwater.

[26] Successive borehole drilling campaigns can be thought of as analogous to producing a series of photographic snapshots of an area. The level of detail required should be considered when interpreting the data. Even if detailed information is gained from each borehole, this may give only a "hazy" picture of the entire area.

new boreholes may not match expectations. The presence of surface water is often not related to the occurrence of groundwater below the surface, and should not be seen as a guide to groundwater. Whilst the volume of groundwater in a given area is usually many times that of the surface water resource, the groundwater is normally much more difficult to access, and variations in it are much less apparent.

The most important factor influencing the groundwater potential for any area is the nature of the underlying rocks and sediments (geology). The geology determines whether surface water or rain can sink down into the ground (recharge), move within the aquifer, and be drawn out by means of a borehole. It is not enough that the rocks are able to hold or store quantities of water (porosity), the water must also be able to move within the rocks and towards a borehole intake (permeability). The quality of the groundwater, too, is usually strongly influenced by the nature of the aquifer rocks because minerals in the rocks tend to dissolve in the groundwater as it passes through. Whilst geology is normally the controlling factor in groundwater potential, there are some areas where rainfall – or more properly the amount of rainfall that infiltrates into the ground (recharge) – is the most important constraint on the groundwater potential. The depth to the groundwater (water table) is also important, as it affects both drilling and pumping costs[27]. Water quality, recharge and depth to the water table are also subject to seasonal or other variations, and these should be taken into account. Finally, some aquifers are particularly vulnerable to pollution, which needs to be taken into account in the planning process as it may affect the reliability of the resource. All these need to be taken into account in any area, and all are subject to often considerable areal variations. These key criteria or questions are summarised below[28]:

(a) Six key questions: groundwater primary availability

Geology: How permeable are the rocks below the study area? What is the basis of this permeability – i.e. does groundwater move through the rocks by means of fractures, by moving between grains, or by a combination of both? How does the permeability vary across the study area, and with depth beneath the area? Permeability will directly influence the amount of water that can be pumped from a well, and is a critical factor in deciding groundwater potential. Remember that the properties of rocks can vary greatly over relatively small areas, even when the rocks are all given the same name[29]. The permeability can be used to give a very rough figure for the amount of water (in litres per second) which could be obtained from a hypothetical borehole or well in the area.

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[27] This may be related to patterns of drainage base flow, possibly developed in the geological past when conditions were very different to the present.

[28] It is to be debated whether these questions can be answered satisfactorily by people or organisations without special training. Whilst a very rough hydrogeological assessment can be done relatively easily, so often in groundwater "the devil is in the detail", and seemingly small factors or changes (which are very easy to overlook) can have a major influence on the final position as regards people and their access to safe and reliable water supplies. There are numerous examples in the literature of hydrogeological water supply schemes whose outcome has been very different to what was expected due to such unforeseen "details". Thus the value of a rough assessment performed by a lay-person may be quite legitimately questioned.

[29] The effects of weathering and erosion, diagenesis, the development of duricrusts, faulting, fracturing etc. can all have a great effect on the hydraulic properties of rocks. The geology of an area is frequently subject to changes which may be relatively small but have nonetheless a large impact on the hydraulic properties of the rock.

Recharge: Is water able to move easily into the permeable rocks (aquifer), and will there be enough of it to support the envisaged groundwater development? The places where water enters the aquifer as recharge, either falling as rain or originating from rivers or lakes, may be distant from the area where groundwater is to be developed. If there is little or no recharge, then this will limit the life of a groundwater scheme, as only the water stored in the aquifer will be available – a situation referred to as "groundwater mining". It may be necessary to consider the effects of envisaged climate changes on recharge, and hence on the reliability of the groundwater resource when planning for the long term. Estimating recharge to aquifers accurately is notoriously complex, however in certain areas relatively simple working relationships that "lump" many parameters together may have been established that describe recharge over longer time periods.

Groundwater quality: Is the quality of groundwater likely to be poor, either because of inorganic contaminants such as fluoride or because of man-made wastes? Are there quality variations across the area? The uses to which the water will be put will to some extent determine what is acceptable quality and what is not. If only a few samples have been analysed, then these may not be representative of the whole area. Generally, groundwater quality is much better than untreated surface water, but it can have unacceptably high concentrations of natural pollutants such as fluoride, or be contaminated by surface activities in many ways. In some cases, the acts of drilling and pumping alone can change the groundwater chemistry and pollute the resource.

Depth to groundwater: How deep below the ground surface is the water found? (i.e. at what depth is the water table?) Very deep groundwater will incur higher costs in drilling, well construction and pumping. Water quality may also decline with depth, and very deep waters are frequently saline. If the water table is especially shallow, then this may make it particularly vulnerable to contamination by latrines, factories, etc.

Variability or reliability: This refers to the variation of the groundwater resource with time. In some cases groundwater reserves may fail during the annual dry season, for instance in cases where the aquifer is only able to store a small amount of water and must rely on being constantly recharged, or where the water table periodically drops below the level of well intakes. Cycles of drought should also be considered. Groundwater quality may change along with the variability in the amount of the resource.

Vulnerability: All aquifers are vulnerable to contamination to a certain extent. Some aquifers, which may meet all other criteria for groundwater development, may be at particular risk of contamination. This may be because potential sources of contamination such as intensive agriculture, certain factories, sewage systems etc. are found on or near the aquifer,. because water in the aquifer is particularly close to the ground surface, because the aquifer has fractures which would allow transport of contaminants to be too rapid for processes of natural attenuation to take effect, or a combination of these things. Vulnerability will need to be assessed with regard to the amount of water pumped, and the uses to which water will be put. For example, coastal aquifers may allow the ingress of sea water under certain pumping conditions, and other aquifers may allow contaminants to enter if the water table falls too far. Water for certain industrial purposes may not need to be of drinking water quality.

(b) Answering the questions

Answering these questions is critical to a reliable estimation of the groundwater resource for an area. Expert advice and assistance should be sought by the lay person in all cases, except where the most cursory assessment is required. There is a certain amount of interdependence between the questions, which should be borne in mind. For example, aquifer vulnerability may be determined by activities in the recharge area, which may be some distance from the area where groundwater development is to take place, or depth to groundwater may have some relation to water quality. Furthermore, the action of exploiting the groundwater can change the nature of the resource, for example by lowering the water table or increasing the vulnerability. The final groundwater scheme or well field should therefore be seen as a dynamic system.

Some areas have very little information available on either the geology or the hydrogeology, and require careful study and assessment to determine the hydrogeological potential, whilst other places have detailed information about the groundwater resources which has already been processed. The following suggestions are an outline of work that might be undertaken by a hydrogeologist involved in resource determination. These suggestions should be independent of the size of the area, although particularly large areas, or very detailed studies of small areas, will impose additional costs in terms of time and resources, and may well necessitate additional specialist assistance. Certain stages of the procedure might be more or less important or feasible, depending on the area. These suggestions will be variously accessible and useful depending on the area and on the training of the person carrying out the task, and on the quality of the data available.

Literature review or desk study

A good place to start any hydrogeological assessment is to gather together all relevant material on the hydrogeology, the geology, the groundwater resources and the water supplies, and use it to gain both a general impression of the area and if possible more detailed information. A literature review will perhaps not be as useful to the non-specialist, who will want to augment information gained at this stage with the interpretations and opinions of people working or living in the study area. Taken together, however, a good set of maps and reports on a particular area can provide the specialist with a fairly detailed idea of groundwater occurrence.

- Hydrogeological maps show the basic geology, and also interpret it from a hydrogeological point of view, often classifying areas in terms of groundwater potential and giving typical yields which might be expected if a borehole was drilled. Such maps frequently also have information such as groundwater quality, rainfall or recharge estimates, and existing boreholes and springs. A good hydrogeological map can often provide a very good overview of the groundwater resources in an area, but should not be used alone to site boreholes. Hydrogeological maps are only as good as the data used in their manufacture, and this should be fully understood and appreciated.
- Geological maps show the nature and extent of the geological strata, and must be interpreted to gain an understanding of possible aquifers. They are particularly useful when combined with topographical maps and with additional information about the basic hydrogeological properties of the rock units depicted. In terms of

groundwater, they are not as useful nor as easy to interpret as hydrogeological maps, but are much more widely available. Other maps such as aeromagnetic maps, satellite images and aerial photographs are variously useful, depending on the area and on the interpretive skills of the user.

- Reports and books on the local hydrogeology and on the number, type and depths of wells and boreholes can give a very detailed view of groundwater in an area, depending on the nature and depth of previous studies. Academic libraries, university departments, water companies, drillers and other contractors, and private consultants may have such information.

Consultation with relevant people

People or agencies involved in water supply, drilling, well construction and other groundwater related activities are a good source of specific information about a particular area. Such information has usually been gained through direct experience in the area, and can be very detailed. It is also often much easier for the non-specialist to consult with people rather than attempt to interpret literature in isolation. Government agencies, university experts, local hydrogeologists, drillers, NGO workers and consultants are all sources of information and advice. The identity of local or regional experts will differ according to the area. Questions to ask include:

- What types of rocks underlie the area, and what are their hydrogeological properties?
- How many people in the area use groundwater sources such as wells and boreholes for their water supply? If the answer is very few, then why is this?
- What are the main water supply problems in the area?
- Do wells and boreholes ever fail (dry up), and if so why is this? What actions do people take when this happens?
- Have there been any long-term changes in the amount, depth or quality of the groundwater?
- Are there any water quality problems which are known, either from organic or inorganic contaminants? What is the effect of these problems on water users?
- What is the rainfall for the area, and is anything known about the recharge of groundwater from the surface? The length and quality of rainfall records is an important consideration.
- What is the drilling success rate for boreholes in the area?
- How are boreholes sited, and what is the best way to find groundwater in the area?
- How deep are the boreholes normally?
- Are there any sources of potential contamination of groundwater in the area?
- Are there any other people with hydrogeological expertise in the area?

Field visit to the area

A field visit to an area will often give a good idea of the groundwater resources, especially when accompanied by local advisors or guides. A field visit is sometimes the only way to make a more detailed assessment of areas where very little hydrogeological work has been done in the past. Useful equipment to take includes a hammer, a camera, a GPS, a magnifying glass, a water EC and pH meter, a compass clinometer and a water level dipper. The GPS will enable all observations and sampling points to be plotted accurately on a map. A useful tool is a GIS system, which can be used to correlate data and plot maps. It is a good idea to plan the field visit in the dry season when reliance on groundwater or the pressure on the groundwater resource will be highest. Things to ask about or look out for include:

- Rock outcrops, which are often found in river valleys or road cuttings. Take samples, measurements and photographs of the rocks, and try to build up a picture of the regional geology.
- Note the positions of wells and boreholes, and ask local people about the quantity and quality of the groundwater. Test the borehole or well water for EC and pH, and if possible take chemical samples for later analysis.
- Locate and describe the topography of the area. Does it seem to relate to the location of groundwater sources?
- Locate and describe any surface water features which are visible, as these may interact with or be dependent upon groundwater.
- Note any potential sources of contamination, such as factories, pipelines, latrines, etc, depending on the scale of the area.
- If practical, geophysical investigations using appropriate equipment such as EM34 ground conductivity equipment can be carried out. This is often best done with reference to satellite images or topographical maps. Any planning of geophysical work should be matched to the geological or hydraulic features to be detected.

When information from all of these activities is combined, it should allow a more informed assessment of the groundwater resources of an area to be made. On its own, each source of data may be misleading, but taken together they can provide a useful initial assessment of groundwater potential. It is desirable that the answers to the key questions are summarised in a report which explains the basis for the decisions, and gives details of the data sources used. This will help to convey to decision makers the uncertainties inherent in many of the characteristics, and thereby facilitate better planning.

Amount of groundwater per capita

To complete the assessment, it is necessary to estimate the amount of groundwater available per capita. For this, it is necessary to consider the number of "typical" boreholes (boreholes that yield a typical amount for a given place) that could be installed per unit area. A figure for the amount of water reaching the aquifer, or recharge, is thus needed, which would balance the outflow of water from the system via the boreholes. The following equation allows the recharge area (the smallest area of land which each borehole needs to support its discharge) for each borehole to be calculated:

$$\text{Annual Yield } (m^3/yr) = \text{Annual Recharge } (m/yr) \cdot \text{Recharge Area } (m^2)$$

Once the recharge area for one borehole is known, the number of boreholes that the area of interest could support can be calculated, and this divided into the number of people living in the area gives the number of people per borehole. The amount in litres per capita per day is then obtained:

Amount (l/c/d) = (no. of boreholes in area . typical yield in l/day) / no. of people in the area.

2.3 Using the data to create the availability indicator values

Once the assessments have been carried out for both surface and groundwater, the indicator values for water availability can be estimated. Assessment of water availability is based on information relating to three factors:

- Water amounts (in litres/capita/day)
- Reliability and/or variability of the water supply
- Quality of the water

This section deals with how the information could be combined to produce a final estimate of water availability for a particular site. The result will be an indicator which can have a value from 0 to 10, as follows:

0 Effectively zero usable water
1 Very poor
2-9 Intermediate levels from poor to very good
10 Excellent

The same general approach applies to the assessment of both the primary natural endowment (or primary availability) and the actual availability, although there are some differences in the procedure at various stages. Normally, these procedures should be carried out separately for surface water and for groundwater. This is necessary because the reliability and quality components are usually different for the different sources. The methodology is broadly the same for each. Then, the final step is to combine the indicators for surface and for groundwater to produce overall water availability indicators.

Water amount

In some cases per capita water amounts can be assessed rigorously. But in many cases this may not be possible, and a more subjective element has to be brought into the assessment. Then Table 2.1 can be used to obtain rough equivalence between the two types of assessment.

The values used here are based on the following considerations. The water amounts proposed are solely domestic requirements; they exclude use for industry, agriculture and municipal activities. Domestic water use in developed countries is typically in excess of 100 l/c/d; for instance Gleick (1996) quotes figures of 104 l/c/d for the Netherlands and 215 for Sweden. Consumption in this USA is much higher than this: for instance, the same source shows average use is about 250-300 l/c/d, while in California it is 531. Shiklomanov (1997) suggests that 150-250 litres per day are required to satisfy all personal requirements, while Falkenmark and Lundqvist (1997) use a figure of 100 l/c/d as "a level which in the long term would allow a decent and realistic quality of life". In line with this, we accept the value of 100 litres per day as a reasonable level of consumption at the top end of the scale[30]. Much higher

[30] A further consideration in looking at water requirements for vital human needs is water for food production. In the Statement of Understanding which accompanies the UN Convention on the Law of the Non-navigational Uses of International Watercourses, it is stated "In detemining 'vital human needs', special attention is to be paid to providing sufficient water to sustain human life, including both drinking water and water required for production of food in order to prevent starvation." (United Nations, 1997). This definition explicitly includes water for food production which would require much larger quantities for water. However, in most cases, this water is provided directly from rainfall, and

consumption (as in California for instance) would seem to include much wasteful and excessive use. Looking at national average estimates for domestic use, current figures indicate that 81 countries fall below this baseline value of 100 l/c/d, ranging from 3 l/c/d in Gambia to 98 in Syria. And, of these, 62 are below 50 l/c/d (Gleick, 2000). Gleick notes "There are, of course, problems with the data. Average water-use figures by country are known to be unreliable or old. ... Some of the countries ... are relatively well endowed with water and it is likely that domestic water use is higher, perhaps substantially higher, than reported." This particularly applies to the very low consumption values. However, the figures still give a useful context. It must also always be remember that the values are *averages*, and there will be wide variation within individual countries. The equivalent figures for the study countries (from the same source) are: Tanzania 8, Sri Lanka 27 and South Africa 134 l/c/d.

Table 2.1 *Per capita water amounts and equivalent qualitative assessments*

Amount (l/c/d)	Qualitative assessment of amount
>100	Excellent
50-100	Very good
25-50	Good
10-25	Fair
5-10	Poor
2-5	Very poor
Negligible	Negligible

Looking at what might be called basic needs for water, a commonly used value is 25 l/c/d, recommended by the UN International Drinking Water Supply and Sanitation Decade. Targets in the range 20 to 40 l/c/d have been set by the World Bank, World Health Organization and US Agency for International Development (Gleick, 2000). These figures only include consideration of water for drinking and sanitation. Gleick (1996), based on a consideration of needs also for bathing and cooking, has proposed a figure of 50 l/c/d as an overall basic water requirement, independent of climate, technology and culture, and which "should now be considered a fundamental human right". In constructing Table 2.1, the value of 50-100 l/c/d has been taken as "very good", while 25-50 l/c/d is defined as "good". Smaller amounts than 25 l/c/d are increasingly unsatisfactory, with lowest levels of less than 5 litres per day being insufficient to support life. (Gleick gives various estimates of solely drinking water needs in the range 2-5 litres per day).

Reliability/Variability

Given the initial assessment of the amount of water (whether quantitative or qualitative), an assessment of the reliability or variability of the supply needs to be made. Where this can be done fairly rigorously, the reliability categories are defined as below.

thus it is a very different consideration to that conventionally included under domestic water supply, and it is not included in this analysis.

Key to reliability/variability categories

Very good	Supply available at least 98% of the time
Good	Supply available from 95 to 98% of the time
Fair	Supply available from 80 to 95% of the time
Poor	Supply available from 50 to 80% of the time
Very poor	Supply available less than 50% of the time

Note that the terms variability and reliability are both used here. Variability is normally taken to apply to the amount of variation in a natural system (eg., river flow), while reliability more usually applies to man-made systems (eg., the proportion of time that a water supply system actually supplies water). Since for the WPI, both natural and man-made (or actual) aspects of availability need to be assessed, both terms are used. The variability of the natural system is used when assessing the primary availability, while the reliability of the water supply is used when assessing the actual availability. Where questions on the reliability of the water supply has been included in a household survey, they can also be used to indicate the reliability category for actual availability. This cannot be done in a totally quantitative manner since people's responses to the questions will depend on their expectations of reliability (and possibly several other factors). The survey data are not objective evaluations, but nevertheless provide a useful guide, especially when no other information is available.

There are a number of complications in determining the appropriate choice of reliability classification. First, the different assessment methods for water amount need to be consider. This might have been done in a number of different ways, depending on the availability of relevant data, and these have different implications for the selection of the reliability category:

- Assessment using modelling or long series of observed data. In this case the reliability can be calculated at the same time as determining the amount of water, by (for instance) calculating the monthly flow that is exceeded in 9 out of every 10 years, or by determining the reliable yield of a reservoir. In this case the reliability category can be set according to the actual evaluation of reliability/variability as specified above.
- Sometimes, there will be a less sophisticated, but still quantitative, assessment of amount. For instance, it might only be possible to estimate the mean flow. Then, a qualitative assessment of reliability will be need to be applied.
- In the third case, both the amount and the reliability might have to be assessed qualitatively.

Furthermore, the possibility of rationing should be considered. A water supply system may not be able to supply the full design quantity at all times. When there is a shortfall in supply at the source, the amount supplied to particular consumers may be restricted for certain periods of time. This is a different condition to an unreliable system (which would be one where the shortages are uncontrolled), but for the purposes of this exercise it can be treated in the same way. Thus, if rationing is used in an otherwise reliable system, depending on the amount and severity of rationing, it may be appropriate to reduce the reliability level by one or two steps, for instance from "Good" to "Fair".

Water quality

The next step is to consider the assessment of water quality. Depending on to what level of detail the water quality is known, the quality should be assigned into categories as follows:

Key to water quality categories

Very good	No known health risks, meets WHO standards
Good	Minor doubts about quality, may only meet local or temporary standards or may have one or two determinants which exceed limits but which are not thought to present health risks. Water not tested, but general believed to be of good quality.
Fair	More significant doubts about quality, slight health risk
Poor	Moderate health risk
Very poor	Serious health risk

In a similar manner to the reliability assessment, where questions on the water quality of the supply, or on health issues related to water quality, have been included in a household survey, these can also be used to indicate the water quality category for actual availability. Again, this cannot be done in a totally quantitative manner since people's responses to the questions will depend on their expectations, and the answers to the health questions might also be influenced by sanitation facilities or other factors.

The use of the water quality factor depends on whether the assessment is of the primary availability or the actual availability. For the first, the water quality being considered is that which is affected only by natural factors. If, for instance, there is industrial or sewage pollution affecting the source, these are man-made factors, and are disregarded at this stage. Normally, only natural factors, such as how the mineral composition of the rocks affect water quality, would be considered. However, when considering actual availability, all relevant factors must be considered to obtain estimates of the quality of water which people are actually using.

Combining amount, reliability and quality

Having classified the amount of water, the reliability/variability and the water quality, as discussed above, the components are combined to produce indicators of availability. For this study the indicator used are values in the range 0 to 10, and they were determined using Table 2.2. An indicator of 10 shows that the amount of water was in the highest category and that both reliability and quality were also classified at the top of their scales. Conversely, an indicator of zero is used for negligible amounts, whatever the reliability and quality. The values shown between these two extremes provide a reasonable and consistent procedure to assign the indicators for other combinations. But, it is clear that these are subjective assignments, and the values cannot be objectively justified. Because of this, the opinions of number of water resources specialists were sought. It was found that the opinions did not vary very widely, and they were averaged and then rounded to produce the final result shown in Table 2.2. This table should be treated as only a preliminary solution to the problem. The approach needs to be tested over a wide range of conditions, which may reveal that it needs to be adapted.

Table 2.2 *Water availability indicator values for combinations of amount, reliability and quality*

Amount (l/c/d)	Reliability/ Variability	Water Quality: Very good	Good	Fair	Poor	Very poor
>100	Very good	10	8	5	3	1
"	Good	8	7	5	3	1
"	Fair	7	6	4	2	0
"	Poor	4	3	2	1	0
"	Very poor	2	1	1	0	0
50-100	Very good	9	7	5	3	1
"	Good	7	6	4	2	1
"	Fair	5	4	3	2	0
"	Poor	3	2	1	1	0
"	Very poor	1	1	1	0	0
25-50	Very good	7	5	3	2	1
"	Good	5	4	3	2	0
"	Fair	4	3	2	1	0
"	Poor	2	2	1	1	0
"	Very poor	1	1	0	0	0
10-25	Very good	4	4	2	1	0
"	Good	3	3	2	1	0
"	Fair	2	2	1	1	0
"	Poor	2	1	1	0	0
"	Very poor	1	0	0	0	0
5-10	Very good	3	2	1	1	0
"	Good	2	2	1	1	0
"	Fair	2	1	1	1	0
"	Poor	1	1	1	0	0
"	Very poor	0	0	0	0	0
2-5	Very good	2	1	1	0	0
"	Good	1	1	0	0	0
"	Fair	1	1	0	0	0
"	Poor	1	0	0	0	0
"	Very poor	0	0	0	0	0
negligible	Any	0	0	0	0	0

Combining surface and groundwater indicators

The above combination procedure should be carried out separately for primary availability and actual availability. Also, as noted earlier, it is usually necessary to carry to the whole procedure separately for both surface and groundwater sources, since reliability and quality are usually different for the different sources. It is then necessary to produce a final result for overall water availability from the combined sources. In many cases, one or the other of the sources will be very much dominant. When this is the case, the indicator value for the dominant source is used as the overall value, and the other source is neglected. Where the results are more or less comparable, then it is necessary to consider whether they can be treated additively. The larger indicator value is taken, whether it is surface water or groundwater. Then, the smaller value is considered in the light of Table 2.2. If is judged that the combined sources give a significantly increased availability compared to the highest rated single source, then the indicator value can be raised one or more steps in the scale. To take a specific example: Suppose surface water is dominant, with an amount of 50-100 l/c/d, "fair" reliability, and "good" water quality; the indicator would be 4. If small amounts of groundwater were also available such that the total amount still remained in the range 50-100 l/c/d, the quality of the groundwater was "good" or better and its reliability "very good", then it would be reasonable to raise the overall reliability category from "fair" to "good". The quality category is not changed as the lower quality of surface water is a limiting factor. Then, the overall indicator value would be increased to give 6 as the final result.

3. Assessment of Availability – Tanzania

3.1 General situation of the study sites

Locations

The pilot study sites were four communities close to Arusha in the northern part of Tanzania. The general location of the area and the main features are shown in Figure 3.1. The four communities are shown in more detail in Figure 3.2, which indicates the locations of the households surveyed and the main water sources used by those households.

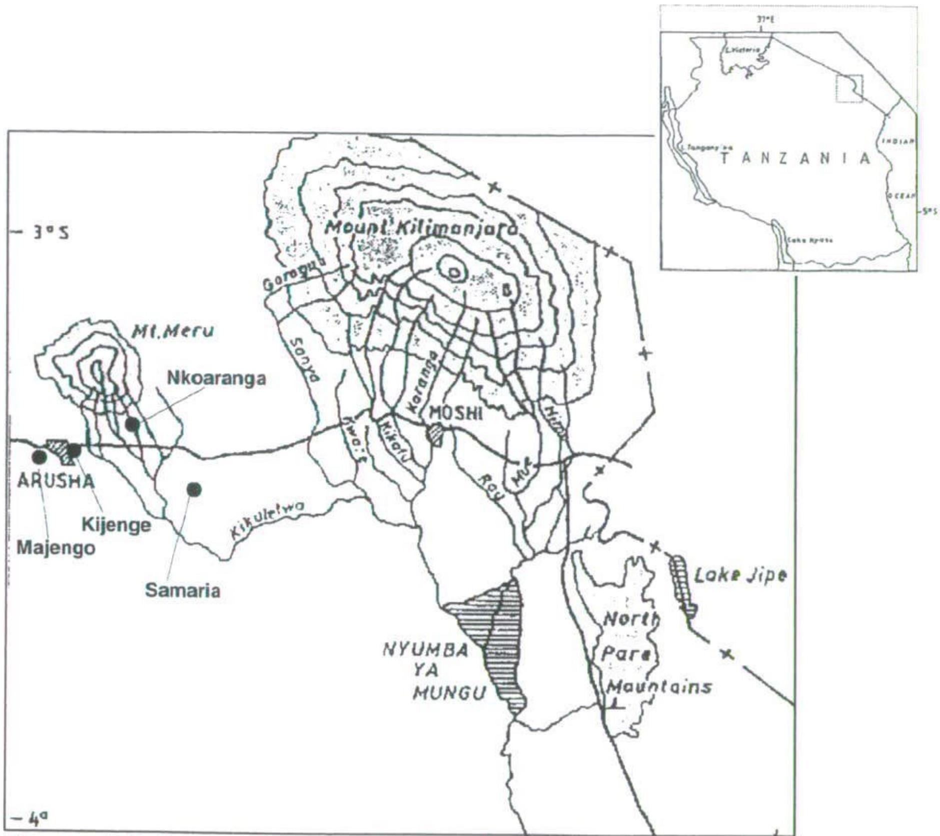

Figure 3.1 *Map of the study area – Tanzania*

Two of the communities are peri-urban areas on the edge of Arusha, and the other two are in rural areas. Some details of the populations and households surveyed are given in Table 3.1.

Table 3.1 *Communities surveyed – Tanzania*

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Majengo	Peri-urban	-	125	748
Kijenge	Peri-urban	-	118	530
Nkoaranga	Rural	3197	120	671
Samaria	Rural	3722	119	650

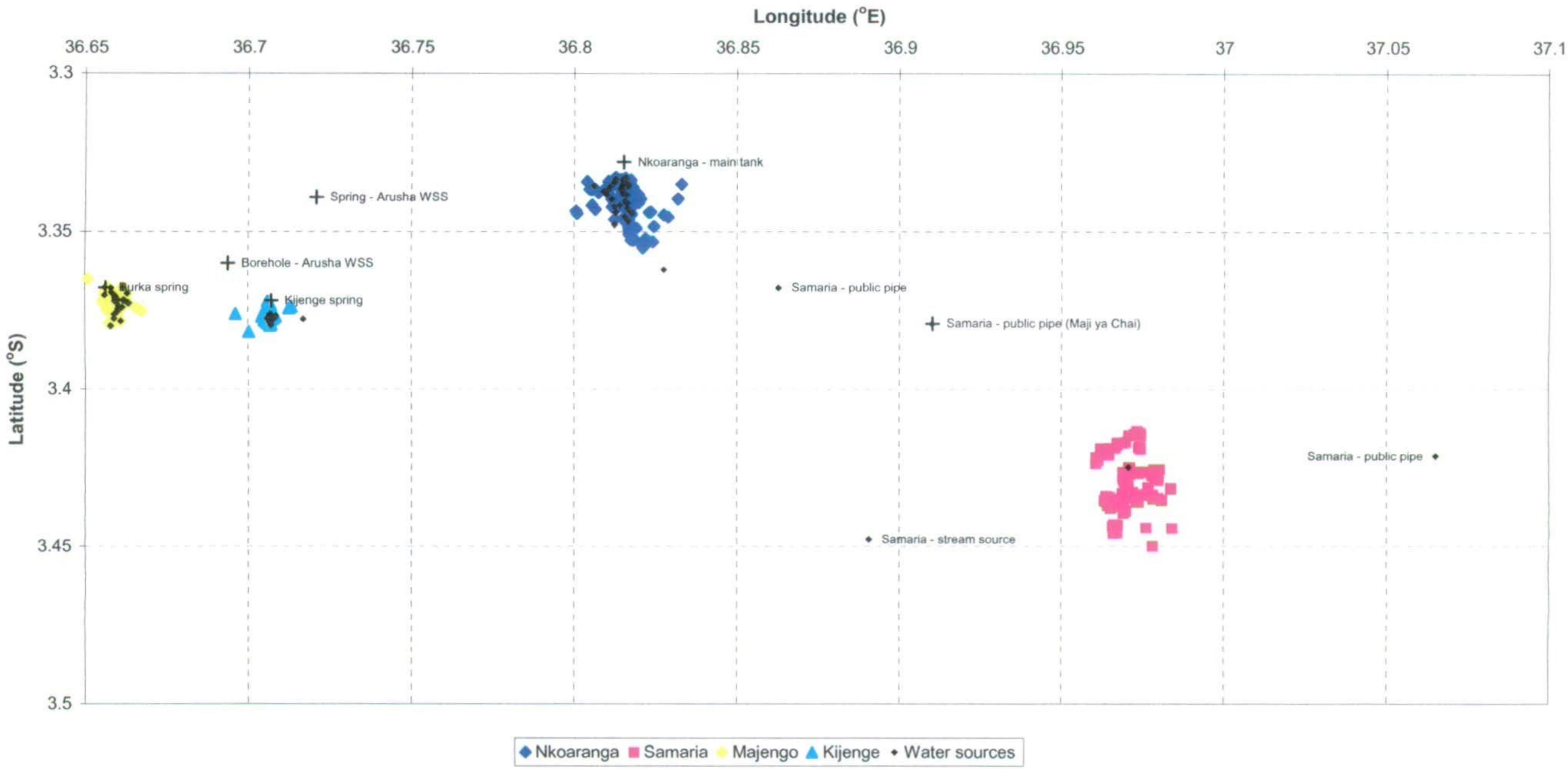

Figure 3.2 *Location of pilot study communities and water sources used – Tanzania*

Topography, climate and vegetation
All the sites lie close to and south of Mt. Meru, the dominant geographical feature of the area. At 4565 m high it is the fifth highest mountain in Africa. Only 70 km to the east lies Kilimanjaro, the highest mountain in Africa (5895 m). These two mountains dominate the area because they stand alone on a plateau (typical altitude 1000-1200 m), rather than forming part of a mountain range.

The two mountains are also very significant influences on the climate of the area, attracting heavy rainfall, with much less falling on the surrounding plateau. Mean annual rainfall in the study area ranges from considerably less than 1000 mm in parts of the plains to more than 2100 mm in the higher areas of Mt. Meru, with annual amounts changing rapidly over small distances. However, there is conflicting information on the annual rainfall for the study sites. Based on the map given in the Arusha Region Water Master Plan (ARWMP, 2000), mean annual rainfall can be estimated as: Nkoaranga 1650 mm; Samaria 1200 mm; Majengo 1550 mm; and Kijenge 1800 mm. But the much smaller scale Tanzania Mean Annual Rainfall map (no date) indicates roughly 1000-1200 mm for all sites, except for Samaria which is 600-700 mm. These values seem perhaps more realistic in relation to the vegetation of the area.

The general climate type is a tropical monsoon climate with two rainy seasons, typically lasting from March to June and October to December. The average monthly rainfall patterns for six stations close to the study area are shown in Figure 3.3.

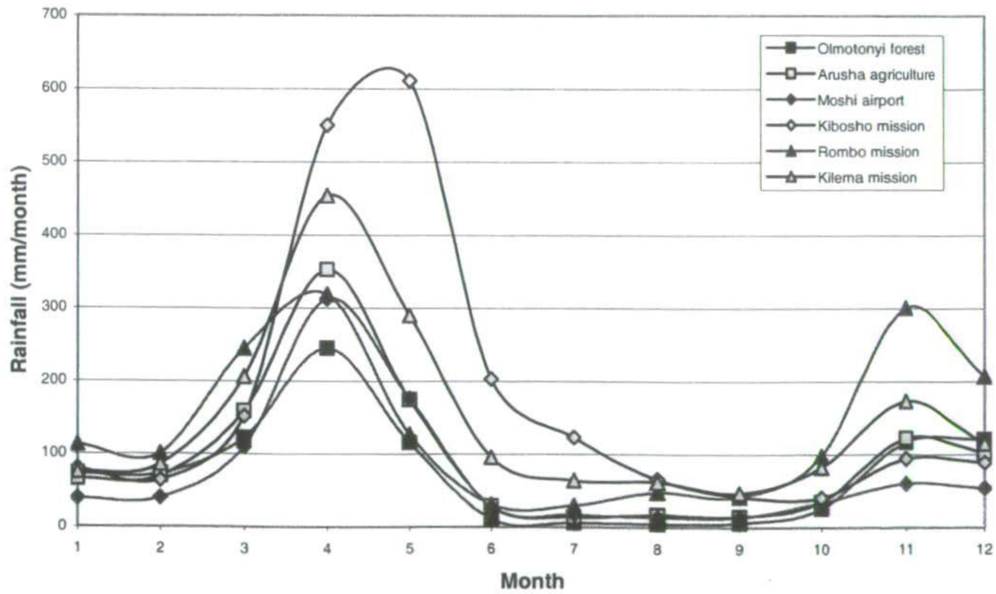

Figure 3.3 *Monthly rainfall patterns in the upper Pangani basin (after Mkhandi and Ngana, 2001)*

The vegetation of the area varies widely. The higher slopes of Mount Meru are covered in forest. Nkoaranga which lies on the lower slopes of Mount Meru was probably originally forest, but this is now mostly cultivated (coffee, bananas, maize, etc), with a few large forest trees remaining. Arusha is in a somewhat drier area with less dense natural tree cover, while Samaria is very different with the vegetation being defined as "dry open grassland" (Tanzania

Vegetation Cover Types map, 1984). There is little cultivation here, with livestock rearing being the main economic activity.

Hydrological features

The study area is in the uppermost part of the Pangani basin (total basin area 42,000 km^2). The Pangani river flows approximately south-east, reaching the sea near the city of Tanga. The northern boundary of the basin is mountainous, with Mount Meru and Kilimanjaro in the west and several other ranges further to the east. These mountains generate most of the runoff. The main water resources development in the basin is the Nyumba ya Mungu dam which is used for power generation. There is one hydropower plant here and two more downstream of it. The other large-scale water use is irrigation. Most of the irrigated areas are upstream of the dam, leading to conflicts between the two uses. The study area is upstream of these major water uses and they do not impact on it significantly.

Hydrogeology

The study sites are underlain by volcanic rocks (basalts, trachytes and pyroclastics) of Neogene age, which overlie Precambrian age crystalline Basement Complex rocks. Hydrogeologically, the volcanic rocks range from low yielding (<0.5 l/s) to fairly productive (>1 l/s, <4 l/s), with typical yields of about 1 l/s. A significant number of dry boreholes have been drilled in the Arusha area. Hand pumps are the most common way of extracting water from low-yielding boreholes. Groundwater flow occurs along secondary bedding planes and fissures, and as intergranular flow in agglomerates and vesicular basalts. It is likely that the local geology and hence groundwater potential is very variable.

Traditionally, shallow or perched groundwater associated with river beds or depressions (dambos) has been exploited using hand-dug wells. These wells may be subject to failure in the dry season. Laterite horizons and sands above black clay-rich soils (mbugas) are developed in some places, which can also provide a local source of shallow groundwater. Springs are common, particularly in the uplands, and supply numerous gravity fed water schemes. Due to the variable nature of the strata, and the discontinuities inherent in bedding planes and fissure systems, borehole success rates are variable, and expert hydrogeological advice is needed to develop these. Geophysical exploration methods such as EM34 ground conductivity measurements and Vertical Electrical Sounding have been used in the past to increase the likelihood of borehole success.

Borehole depths in the volcanic rocks are typically between 90 m and 120 m deep, although some boreholes and wells are much shallower. Boreholes in these rocks are usually drilled using air flush rotary drilling methods, using down the hole hammer or rock roller bits. These methods require relatively sophisticated equipment and are expensive. Cheaper to operate cable-tool percussion and hand auger methods may also be suitable in certain circumstances. Shallow large diameter wells can be dug by hand in appropriate locations such as river beds.

Groundwater in the Arusha area is frequently alkaline and of sodium-calcium-bicarbonate type. Fluoride concentrations greater than the World Health Organisation guideline maximum value of 1.5 mg/l are found in a considerable number of groundwater sources in this area, particularly those associated with the volcanic rocks. Excessive fluoride concentrations in drinking water can cause serious disease. Other inorganic constituents such as boron may occasionally be above recommended limits. High salinity, particularly associated with lacustrine sediments in the rift sequences, is found occasionally and is often correlated with high fluoride concentrations. Deeper wells may be more susceptible to high fluoride concentrations, as the water is likely to have been in the aquifer longer and more time will have been available for fluoride dissolution. High fluoride concentrations often correlate with low calcium concentrations, but it is difficult to predict fluoride concentrations before drilling. Shallow wells in the weathered-zone that intercept relatively younger groundwater may circumvent the fluoride problem. Seasonal variations in water chemistry have been noted.

3.2 Data assembly

Hydrology and water resources

All the sites are supplied from springs (or streams close to the springs) or from boreholes. Data on the actual amounts of water supplied from these sources or on the capacities of the water supply systems was obtained from the relevant authorities, the Arusha Urban Water Supply and Sewerage Authority (AUWSSA) for the peri-urban sites, and Arumeru District Council for the rural communities. The details are given with the assessments for each site below.

The natural or primary sources of water that are most relevant are the streams and springs. Data on the flows from these are sparse. Most spring flows have been measured only intermittently and many of the records are quite far in the past. Details of the data collected are given in Table 3.2; they were obtained from the hydrology office at AUWSSA and from ARWMP (2000). The standard flow gauging stations (ie., those with continuous records of daily flow) that are nearest to the study sites are not so relevant as the spring flow data because they include substantial additional catchments. For the two nearest stations, short periods of record are available, and the details are also listed in the table, although these data were not used directly in the analysis.

Table 3.2 *Flow data availability – Tanzania*

Station name (and code)	Station type	Approx. location Lat.	Long.	Relevant to	Data availability
Burka at (or above) Arusha-Dodoma (or Babati) road (1DE1A)	Spot gaugings	36°39'E	3°22'S	Majengo	90 measurements 1940-95, but mostly 1961-76
Kijenge at Old road bridge (1DE4 or 9)	Spot gaugings	36°42'E	3°23'S	Kijenge	132 measurements 1949-77
Mbembe spring (various locations)	Spot gaugings	36°48'E	3°19'S	Nkoaranga	8 measurements 1959-98
Usa spring (Tuvaila)	Spot gaugings	-	-	Samaria	Single measurement 1995
Various locations	Spot gauging	-	-	-	Single measurements available for numerous springs
Nduruma below new road (1DD20A)	Daily flows	36°45'E	3°22'S	-	January 1978 to March 1981
Kikuletwa at Karangai (1DD55)	Daily flows	36°51'E	3°26'S	-	February 1977 to December 1981

Hydrolgeology

The hydrogeological and topographical maps of Tanzania were used to give a rough indication of groundwater availability for the study area. Other data sources included the Arusha region water master plan and papers from the 21st and 23rd WEDC conferences. Further data on groundwater availability and quality, and on drilling methods, was provided by British Geological Survey staff members with project experience in Tanzania and in similar hydrogeological environments elsewhere.

Relevant data from the household surveys

The detailed household surveys that were carried out in the study communities provide much information which is helpful for the assessment of water availability. Table 3.3 lists the different water sources used by the households in both the dry and the wet seasons. These are the main sources that are used. A very small proportion of households were also using sources away from the house for such activities as washing and laundry, but these do not alter the pattern shown in the table.

Table 3.3 *Water sources used – Tanzania (from household surveys)*

Source type	Dry season No. h/holds	%	Wet Season No. h/holds	%
Majengo				
Pipe (private)	1	0.8	9	7.2
Pipe (public)	10	8.0	70	56
Household source	14	11	33	26
Borehole (public)	27	22	10	8
Well (private)	1	0.8	0	0
Well (public)	2	1.6	0	0
Tank (container)	1	0.8	0	0
Natural pond	34	27	2	1.6
Stream	35	28	1	0.8
Kijenge				
Pipe (private)	1	0.8	3	2.5
Pipe (public)	46	39	47	40
Household source	68	58	66	56
River	3	2.5	2	1.7
Nkoaranga				
Pipe (private)	3	2.5	9	7.5
Pipe (public)	31	26	69	58
Household source	23	19	39	33
Natural pond	18	15	0	0
Stream/River	44	37	3	2.5
Samaria				
Pipe (private)	12	10	8	6.8
Pipe (public)	72	61	61	52
Household source	0	0	1	0.8
Borehole (public)	1	0.8	1	0.8
Stream	34	29	30	25
Rainwater	0	0	17	14

Further information on people's perception of the reliability of the water supply and some indicators of the water quality are given in Table 3.4. The water quality information includes not only the response to a direct question on perception of quality, but also whether or not water is treated[31] after it has been collected, and perception of health problems related to water quality.

Table 3.4 *Reliability, water quality and health information – Tanzania (from household surveys)*

[31] Treatment may be chemical, boiling, or simply allowing the water to settle.

		Majengo Dry season	Majengo Wet season	Kijenge Dry season	Kijenge Wet season	Nkoaranga Dry season	Nkoaranga Wet season	Samaria Dry season	Samaria Wet season
Reliability	Very reliable	55	7.5	7.0	33	24	22	15	29
	Reliable	19	27	64	64	31	56	38	65
	Not reliable	10	55	29	2.6	19	22	42	5.8
	Dries up	16	11	0	0.9	26	0.8	5.7	0
Water Quality	Good	11	17	93	96	48	38	63	64
	Fair	50	78	6.8	4.3	23	56	25	24
	Poor	39	4.8	0	0	29	6.7	12	13
Treating water at house		86		81		75		48	
Diarrhoea	Many times	14		2.6		3.3		2.6	
	Occasionally	33		12		30		21	
	Never	53		86		67		77	
Illness due to water		26		6.8		23		14	

All values are percentages of households.

These data may not provide objective evaluations since people's expectations of reliability and water quality may not be consistent, and their perceptions of whether it is good or bad may vary considerably from place to place. In addition, the health data are likely to be affected by other factors, especially the provision of effective sanitation. Nevertheless, these data do provide useful indications, especially when no other information is available, or to supplement other more rigorous data.

3.3 Particular methodology

Generally speaking, the methodology used follows that discussed in Section 2. But, the particular characteristic of all the sites in Tanzanian are that the water systems are supplied by springs. Spring flows are not readily susceptible to standard kinds of hydrological analysis (eg., regression analysis to relate mean flows to catchment areas and mean rainfall) since they are likely be more dependent on underlying geological factors than on surface features. Therefore this type of analysis has not been adopted; rather, estimates of water quantities have been based on the available measurements, the records of the water supply authorities and a number of assumptions about the design of the systems. This has been combined with the supplementary information from the household surveys to provide the overall assessments. For groundwater, the key questions discussed previously (Section 2.2) are considered, in order to arrive at the assessment.

3.4 Water supply systems and water availability assessments

(a) Surface water – peri-urban areas

Arusha water supply system
The peri-urban communities (Majengo and Kijenge) are on the fringes of Arusha, and the main water supply for both is part of the overall Arusha water supply system, operated by the Arusha Urban Water Supply and Sewerage Authority (AUWSSA). The system provides piped supplies to the whole urban and peri-urban area. The main water sources are a set of 13 boreholes and 2 well protected spring systems (where flows from several smaller springs are combined and chlorinated) on the lower slopes of Mount Meru, immediately to the north of

the city. There are two more boreholes in the city itself. Additionally, there is one more spring in the city which is used to supply industrial areas, but this is a separate system. The spring yields are variable, with substantially higher flow during and shortly after the wet season. The system is operated to minimise use of the boreholes since these have high pumping costs. Maximum use of the springs is made in the wet season, with increasing use of the boreholes as needed during the dry season. Currently (November 2001) the demand for the whole of Arusha is 42,000 m^3/day. Under typical conditions, the combined sources can produce 44,000 m^3/day during the wet season, and 35,000 m^3/day in the dry season. Thus, there is normally a shortfall in availability in the dry season, but this can increase substantially in dry years. In order to overcome these problems in the short term, the supply is rationed, with certain areas of the city being switched off for some of the time, in rotation.

Water from all the sources is mixed and treated before being supplied. Because the sources are all groundwater or very well protected springs the quality of the raw water is generally good. In particular bacteriological quality is excellent, with zero coliforms in the raw water. Chlorination is mainly needed to protect against seepage of polluted water into the system in the distribution network. The only significant water quality problem is high fluoride levels. Fluoride is naturally occurring, as a result of the particular geological of the Arusha area. Exceptionally high levels have been found to lead to serious disease (skeletal fluorosis) in some parts of Tanzania. The fluoride level in Arusha water is about 4.5 mg/l; this is well above the WHO recommended standards of 1.5 mg/l, but within the Tanzanian temporary standard of 8 mg/l. This standard has been set in recognition of the fact that fluoride is a widespread problem across the country and that it is not practicable to meet the WHO recommendation in the short term. It is believed that this level will not be likely to have severe health implications. In order to move towards overcoming the problem, as well as meeting the present shortfall in supply, it is proposed that new water sources should be surface water sources, which, when mixed with the existing groundwater, will reduce the fluoride concentration.

Primary availability – Majengo

For the natural situation, the available water source relevant to Majengo is the Burka spring or river, which is just on the edge of the community. Spot measurements of the flow have been made near the point where the stream crosses the Arusha-Dodoma road; a total of 90 measurements are available, mostly from 1961 to 1976, with a very few earlier (1940-41) and two later (1994-95) (Table 3.2). For a few years the measurements were taken at approximately monthly intervals, but otherwise they are very irregular. These data can be used to give a rough estimate of the natural water availability in Majengo. On the reasonable assumption that the measurements represent a random series, they have been used to create an approximate flow duration curve (Figure 3.4). This curve relates the flow to the percentage of time that it is exceeded. Taking the flow that is exceeded 95% of the time as a suitable indication of the reliable flow gives a values of about 60 l/s. This analysis is based on old flow data, so the question of whether or not it is representative of the current situation arises. An examination of trends in rainfall in upper Pangani basin has been carried out by Mkhandi and Ngana (2001). For the period from the 1930s to 1990, they found that five stations showed a slight decline in annual rainfall, while only one showed an upward trend. However, the changes are small, and it is also the opinion of the local hydrological office that the old data remain representative. For an approximate analysis such as this, it is considered that they are adequate.

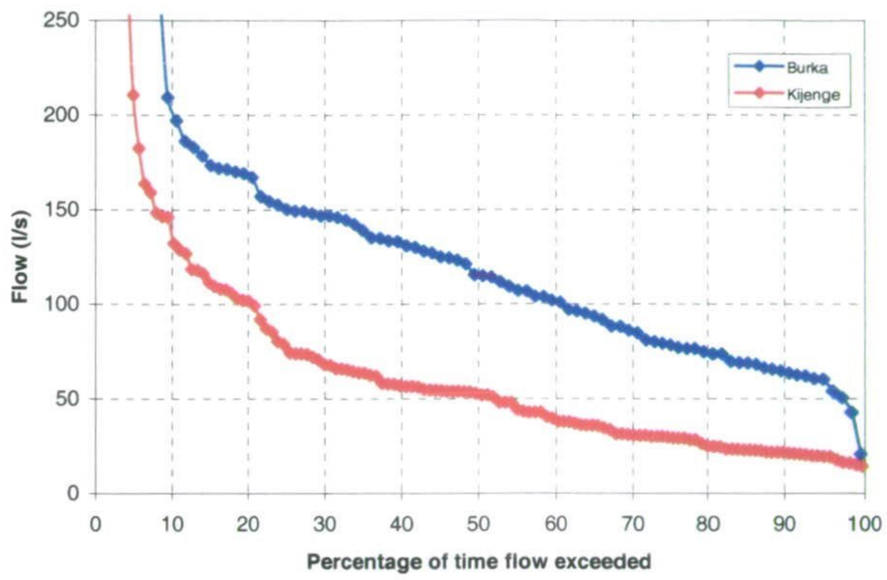

Figure 3.4 *Approximate flow duration curves for Burka and Kijenge rivers*

No population estimates specifically for Majengo seem to be available. Population data from the 1988 census (Bureau of Statistics, 1991) are only given to the level of ward, of which Majengo is a subdivision. If we assume the population is a high value of 10,000 and we also assume that the flow in the Burka river could be used to supply Majengo only, the per capita amount is 520 l/c/d. This figure should be reduced substantially because the same source is also needed to supply several other communities, but the per capita amount would still remain more than 100 l/c/d. This is a low flow estimate with approximately 95% reliability, so the variability can be classified as "Good". There are no data from testing, but the natural quality of the water is expected to be good, except for the problem of high levels of fluoride which are common over much of the Arusha area. Because of this the water quality classification is taken to be "Fair". This gives a result of **5** for the assessment of primary availability.

Primary availability – Kijenge
For the natural situation, the available water source relevant to Kijenge is the Kijenge river which flows through the community. Spot measurements of the flow have been made near the old road bridge; a total of 132 measurements are available, mostly from 1949 to 1977 (Table 3.2). An approximate flow duration curve was estimated from these data in the same way as for the Burka river (Figure 3.4). In this case the flow that is exceeded 95% is about 19 l/s. As for Majengo, we have no population values for Kijenge specifically. But, if again, a high value of 10,000 is used, and we assume that this flow is used to supply Kijenge only, the per capita amount is 164 l/c/d. This figure should perhaps be reduced because the same source may also be needed to supply other communities, but the per capita amount would probably remain more than 100 l/c/d. This is a low flow estimate with approximately 95% reliability, so the variability can be classified as "Good". The water quality situation is also the same as for Majengo, with a classification of "Fair", giving a result of **5** for the assessment of primary availability.

Actual availability – Majengo

The main source of supply is the AUWSSA system that covers the whole of Arusha, but there are particular problems in Majengo because it is at a very similar altitude to the treatment plant and receives very little water by gravity. Pumping is required, but it seems to be insufficient to meet demand and suffers from an unreliable electricity supply. To try to overcome the problem an additional borehole was opened closer to Majengo, but this has also suffered from unreliable electricity. The result is that Majengo suffers from a shortfall in supply and rationing much more than other parts of the city, especially in the dry season. Table 3.3 confirms that the AUWSSA system is the main supplier, with the majority of households obtaining their water from public standpipes or from house connections. (Note that households listed as using "public borehole" are in fact supplied by the general Arusha system. On a site visit, we were informed that some private boreholes are also in use, but no specific information on these seemed to be available). Table 3.3 also shows that the proportion of households using surface water sources (ponds and streams) increases from just over 2% in the wet season to 55% in the dry season. The main additional source is the Burka spring or along the stream downstream from here. The spring is tapped close to its source and it is piped from there to supply a number of villages in Arumeru district. It is not fully protected, and although there are no water quality data, AUWSSA consider that the quality is poor as there is a high risk of contamination by livestock and pollutants between the spring itself and the points where people collect water.

In order to assess the actual water availability in Majengo, only the supply from the AUWSSA system is considered. As noted, the Burka stream provides substantial part of the communities water in the dry season, but the availability from this is treated as zero because of the pollution problems. Based on the available data (only one year July 2000 to June 2001), lowest water production is 26,400 m^3/day (November 2000). This is well below the typical dry season production level of 35,000 m^3/day noted above. Assuming that the November 2000 value represents a reasonable estimate of the minimum production in a drought year, this is taken to represent the reliable low flow. 73% of the production is supplied to consumers (domestic and kiosks) according to AUWSSA figures for 2000-01. The losses in the system between production and supply are not known. A nominal figure of 20% is assumed. This means that the reliable minimum supply for the whole of Arusha is 15,400 m^3/day.

The 1988 census gives a population for the whole of Arusha as 134,553. To allow for population growth, an increase rate of 7.17% per year was taken from HABITAT (1996). This is the urban growth figure for the whole of Tanzania for the period 1975-2000, and it is known that Arusha has been a fast expanding town, so this figure seems reasonable. The population in 2001 is then estimated as 331,000, giving a per capita amount of 47 l/c/d. However, the Majengo area suffers from heavy rationing, and reliability is low because of the high altitude relative to the treatment works and electricity failures. For the wet season the household survey figures (Table 3.4) show that the general perception is of poor reliability, with 66% considering it "not reliable" or that it "dries up". It is notable that in the dry season people generally consider the supply to be much more reliable than the wet season (55% say "very reliable", 19% "reliable"), when the reverse situation might have been expected. These findings appear to be because the piped supply is in fact unreliable all year round, whereas the spring our river sources, although less convenient, do have a reliable flow. Overall, the reliability classification is taken as "Poor". Considering the high fluoride levels, the quality of the piped supply is assessed as "Fair", the same as for the natural condition. Note that this applies to the piped water only, the unprotected surface water sources having been disregarded for the assessment. Table 3.4 shows that Majengo was perceived as having the worst water quality out of the four sites. The health impacts were also highest, with 47% of respondents saying they had had diarrhoea "many times" or "occasionally", and 26% of households saying that they has suffered from illness due to the water. This seems to be a result of the fact that a substantial proportion of the population is forced to use the unsafe surface water sources in the dry season. The resulting assessment of actual availability is **1**.

Actual availability – Kijenge

Actual water availability in Kijenge is derived from the AUWSSA system, with very slight supplementation from the Kijenge river (used by only about 2% of households in both the dry and the wet seasons). The great majority of households obtain their water from public standpipes or from house connections throughout the year, and there is a much higher rate of house connection than elsewhere. Availability deriving from use of the river is treated as zero because of the very low use and the potential pollution problems which are likely to result from use of a source flowing through a densely settled area. Only the supply from the AUWSSA system is taken into account. Considering only the per capita amount of water, the situation is the same as for Majengo; that is 47 l/c/d. However, in other respects, the situation is very different. The great majority of households have a reliable supply from the piped system throughout the year. The whole Arusha system suffers from some degree of rationing in the dry season and there are some shortages because of this, but Kijenge appears to be no worse than the general situation across the city. The household survey shows that 71% consider the supply "reliable" or "very reliable" in the dry season, and 97% in the wet season. Because of this, the reliability classification is treated as "Fair". Considering the high fluoride levels, the quality of the piped supply is assessed as "Fair". This applies to the piped water only, the unprotected surface water sources having been disregarded for the assessment. The household data show that Kijenge was perceived as having the best water quality out of the four sites, with 93 to 96% (depending on season) assessing the quality as "good", less than 3% of respondents saying they had had diarrhoea "many times", and only 7% of households saying they thought they has suffered from illness due to the water. The resulting assessment of actual availability is **2**.

(b) Surface water – Nkoaranga

Primary availability

For the natural situation, the available water sources are the two streams flowing through the village. One of these is the Mbembe spring, which lies a little higher up the slopes of Mount Meru. There are no data for the streams, except for a very few spot measurements for the Mbembe river. However they appear to have been made at a variety of different locations, or on different branches, and do not seem to give any picture of the reliable flow which would be relevant to Nkoaranga. The assessment of actual availability (see below) based on the size and inflows to the storage tank used in the village supply system, indicate that the minimum Mbembe spring flows are about 2.5 l/s, and the other stream is a roughly comparable size. Using the population figures and annual growth rates (2.16%) given in ARWMP (2000), the population of Nkoaranga is estimated as 3197 in 2001. Based just on the Mbembe stream, and assuming that the flows are available for Nkoaranga village only, the per capita amount is 68 l/c/d. With the two streams, it must be considerably more than this, and it is likely to be more than 100 l/c/d. This is a low flow estimate, but the proportion of time that it is exceeded is not known. However, it seems reasonable to assume that the variability is similar to the Arusha sites since all the sources are springs on Mount Meru; thus the variability classification is assigned as "Good". No data on the natural water quality are available, but as elsewhere, there is the likelihood of relatively high fluoride levels, so a classification of "Fair" is assumed, giving a result of **5** for the assessment of primary availability.

Actual availability
Both the rural communities are in Arumeru District, and the Arumeru District Council is responsible for water supply. Nkoaranga has a piped water supply system which is supplied from Mbembe spring. The spring is tapped at source (well protected) and piped to a main storage tank from which the water is fed to the village and part of a neighbouring village by gravity mains to standpipes and some house connections (Table 3.3). Some of the water is also used for livestock, they are kept in the village in relatively small numbers, but are not allowed to graze freely. The water is not treated, and there are no data on water quality, but as it comes from a protected spring it is expected to be good. However the authorities recommend boiling the water; this is presumably a precaution to protect against contamination in the distribution system or after collection, and does not indicate that quality is generally poor. The protected sources are almost always used in the wet season (more than 97% of households), but a high proportion of the population (52%) uses natural ponds or streams in the dry season. This is a clear indication that although the supply system is considered to work reasonably well, it is not always reliable or has a shortage of capacity at times when the spring flows are low. This is supported by the households survey data (Table 3.4) which shows that the proportion of the population saying the water supply is "not reliable" or "dries up" increases from 23% in the wet season to 46% in the dry season.

As before, the actual water availability is assessed from the water supply system only, and the supplementary surface water sources are disregarded because of the likely contamination. There are no useable data on the flows into the system. However, the main storage tank was inspected on a site visit in November 2001. The capacity was estimated to be 50,000 gallons (227 m^3), and, on information from Arumeru District Council that the original design of the tank should have been such that its capacity is 50% of the reliable daily flow, the reliable flow can be estimated as about 450 m^3/day. An approximate measurement of the inflow to the tank was also made during the visit; this was 2.5 l/s (216 m^3/day). The short rains expected in October to December had almost totally failed, and it was thought that this is roughly the lowest flow that is likely to occur. Therefore, the value of 216 m^3/day was assumed to be a reasonable estimate of the reliable low flow. The population of Nkoaranga in 2001 is estimated to be 3197, but the water supply system also serves 70 households in the neighbouring village of Nshupu. Assuming these have the same average number of people per household as found in the survey in Nkoaranga, this gives a total population using the system as 3588. This gives a per capita amount of 60 l/c/d. The basis of this assessment is that it is thought to be the reliable low flow. However, because about half the village needs to use other sources in the dry season, the reliability is taken to be "Fair". Considering the high fluoride levels and the lack of any treatment system, the quality of the piped supply is assessed as only "Fair". The people's assessment is generally that the quality is fair rather than good (considerably better than Majengo, but much worse than Kijenge). The health data are also relatively poor, with 33% having diarrhoea "many times" or "occasionally", and 23% of households saying that they has suffered from illness due to the water. As in the case of Majengo, this seems to be a result of the fact that a substantial proportion of the population is forced to use the unsafe surface water sources in the dry season. The resulting assessment of actual availability is **3**.

(c) Surface water – Samaria

Primary availability
The situation in Samaria is very different from the other three sites. Rather than lying on the well-watered slopes of Mount Meru, it is in the relatively dry plains area where natural sources of water are scarce. There are very few streams in the immediate area of the village and these only flow intermittently. Thus there are no natural surface water sources readily available. Groundwater has been considered a possibility, and a shallow well has already been developed. However, the local people report that this water has very high fluoride levels; they cannot drink the water and it is not even used for washing clothes as they fall apart after only one month. On this basis – amount of water negligible or very small, with very high variability and sources often drying up, and water quality that is unusable – the primary availability classification is set at **0**.

Actual availability
When looking at actual availability, the situation is more complex. There has been a piped supply to the village in the past, but this is completely non-functional (ARWMP, 2000). Also, a new system is being planned, but this is not yet in place and it is not known when it may be expected.

In contrast to the other study sites, few of the sources actually used are in or close to the village. This can be clearly seen on the map (Figure 3.2). The only source in the village itself is rainwater collection (used by 14% of households), but this is only in the wet season. Except for this, the patterns of water use are very similar throughout the year. The majority of people obtain their water from public supply systems, travelling considerable distances to use systems that were originally intended to serve only their immediately surrounding areas. For the dry season, the household data (Table 3.3) show that 71% (84 households) are using such systems. The main one is at Maji ya Chai (9 km in a direct line) used by 49 households, while 10 use the system at Usa River (14 km) and 24 use the International Airport (10 km). The remaining households (34 in dry season, 30 in wet season) use an unprotected stream as their source, 9 km away in a direct line. Of course the actual distances travelled are longer than these.

Looking in more detail at the majority source, the public system at Maji ya Chai, this is a similar type to the one at Nkoaranga. The source is a protected spring on the slopes of Mount Meru. This is Usa spring (also known as Tuvaila spring, or sometimes Nkoanekoli spring). The water is brought via the Tuvaila pipeline for about 10 km to the storage tank at Maji ya Chai, via at least one other tank. The Maji ya Chai tank was inspected on a site visit in November 2001, and the capacity was estimated to be 30,000 gallons (136 m^3). Following the same procedure discussed for Nkoaranga, the reliable daily flow is expected to be twice this, that is about 270 m^3/day. However, because of the other tank, the overall capacity of the system should be larger. Other estimates are much higher than this. ARWMP (2000) gives the capacity of the pipeline as 1080 m^3/day, while a recent project report on water supply to Samaria, available at the Arumeru District Council office, gives the yield of Usa springs as 19,500 m^3/day. This last value is very high, and is likely to include other springs which are not tapped for this system. The value of 1080 m^3/day was taken as the most likely estimate of the reliable yield of the Tuvaila pipeline system. The pipeline is believed to be heavily overloaded, with many private unofficial abstractions. Besides Samaria, it is thought that six other villages (Kikatiti, Maji ya Chai, Imbabeni, Kitefu, Kwa Ugoro, Maroroni) use the system as their main supply.

Based on the recent project report at Arumeru office, the population of Samaria for 2001 is estimated to be 3722. The total population in all the villages supplied by the pipeline is around 25,300 (averaging the different estimates which vary slightly). This gives a per capita amount of 43 l/c/d. Although some of the people in Samaria are using other public sources of a similar type, the overall amount can still reasonably be taken to lie in the range 25-50 l/c/d. The household data show that the systems are moderately reliable; 94% consider the supply "reliable" or "very reliable" in the wet season, decreasing to 53% in the dry season. Although people do not appear to have to change sources to a great extent between the dry and wet seasons, it is clear that the reliability is not great, and it is classified as "Fair". Considering water quality, the main sources are protected, but there is no treatment and they are likely to be affected by the generally raised fluoride levels. The household data indicate quality is reasonably good with 63-64% assessing it as "good", and better health data than any of the other sites except Kijenge. This is likely to be because a smaller proportion of the population are making use of the unprotected surface sources than in either Majengo or Nkoaranga. However, because of the fluoride problems, the water quality classification is "Fair", giving a resulting classification of actual availability as **2**.

This analysis has omitted consideration of the unprotected surface water source, but as before, although it appears to be available throughout the year, because of likely health risks related to its use, it is appropriate to disregard it. We have also omitted consideration of the factor that nearly all the sources used are far from the village, requiring people to spend a large portion of their time fetching water. This factor is of course highly relevant, however in the definition of actual availability being used here, it is not taken into account. Rather it is included in the "Access" element of the WPI.

(d) Groundwater – all sites

Primary availability
Hydrogeological conditions are similar at all four sites, so they are treated together. The primary availability of groundwater depends on the amount of effective recharge reaching the aquifer, as well as the number of people living in each area under consideration. No data has been found for recharge in this part of Tanzania. The populations of the rural locations of Nkoaranga and Samaria are listed as 3197 and 3722 people respectively, whilst the populations of the peri-urban areas of Majengo and Kijenge are not recorded but have been assumed to be 10000 people each. Recharge of less than 5 mm per annum considered over an area delineated by an arbitrary 5 km radius of each site would provide water supplies of at least 100 l/c/d to each of the locations. 5 mm per annum is probably a conservative figure for recharge, as rainfall in this part of Tanzania is relatively high. 75 boreholes each yielding about 0.5 l/s for eight hours each per day would be required to abstract the water from each area.

Looked at another way, a more realistic figure for recharge of 20 mm per annum over an area of 5 km radius would supply populations of more than 40000 people with more than 100 l/c/d. Whilst recharge is a complex topic, affected by variations in geology, slope, soils, topography and vegetation, it has been assumed that each of the four sites in Tanzania has a primary resource of groundwater sufficient to provide each person with at least 100 litres per day.

The reliability of boreholes in the four areas has been assumed to be "Good", as properly sited and constructed boreholes in these areas should yield 0.5 l/s for eight hours per day more or less indefinitely. Once again however, reliability of a source is often dependent on the local geology, and the presence of impermeable strata, faults or other factors that may affect reliability is always possible.

Concentrations of fluoride in excess of both World Health Organisation and Tanzanian drinking water limits are recorded from many sources in the Arusha area. This problem is particularly associated with volcanic sediments, but is also found in lacustrine sediments. High fluoride concentrations tend to occur in discrete areas, dependent on the geology, groundwater chemistry and groundwater movement at the depth of the well intake, and not enough is known about the distribution of the fluoride problem over the study area to make a distinction between the four sites in question.

High salinity is a common problem in the Arusha region, particularly in the dry season, and again not enough data is available to specify exactly where this problem occurs. Groundwater in the Arusha region may also have high concentrations of certain metals.

In view of the groundwater quality problems that have been documented for the area, and considering the difficulty in pinpointing these problems, primary groundwater quality for each of the four sites has been assessed equally as "Poor". This is lower than the surface water classification because fluoride levels tend to be higher in boreholes.

The above assessments result in a score for primary groundwater availability of 3 for each of the sites. This score is low only because of the quality problems – primarily fluoride – as the other factors (reliability and amount per capita) would support a much higher score.

Actual availability
The two urban areas depend to a large extent on water piped from springs and boreholes on the slopes of Mount Meru, which are blended together, and it is therefore not possible to assess the actual groundwater availability individually for each site. The discussion in section (a) above has already dealt with actual availability from the combined surface/groundwater system in Arusha, and no further analysis is necessary. For the rural areas only surface water sources are used (with the exception of a single borehole recorded in the household survey, which is possibly an error), so again no groundwater analysis is needed.

3.5 Summary and results for overall availability

Table 3.5 summarises the findings discussed above for the primary water availability assessment at each site from both surface water and groundwater. Table 3.6 gives the same results for the actual water availability assessments.

Table 3.5 *Summary of primary water availability assessments – Tanzania*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Majengo	Surface	>100 l/c/d	Good	Fair	5
	Ground	>100 l/c/d	Good	Poor	3
Kijenge	Surface	>100 l/c/d	Good	Fair	5
	Ground	>100 l/c/d	Good	Poor	3
Nkoaranga	Surface	>100 l/c/d	Good	Fair	5
	Ground	>100 l/c/d	Good	Poor	3
Samaria	Surface	Negligible	Not relevant	Not relevant	0
	Ground	>100 l/c/d	Good	Poor	3

Table 3.6 *Summary of actual water availability assessments – Tanzania*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Majengo	Both	25-50 l/c/d (surface/groundwater – combined assessment)	Poor	Fair	1
Kijenge	Both	25-50 l/c/d (surface/groundwater – combined assessment)	Fair	Fair	2
Nkoaranga	Surface	50-100 l/c/d	Fair	Fair	3
	Ground	Not relevant – only surface water used			n/a
Samaria	Surface	25-50 l/c/d	Fair	Fair	2
	Ground	Not relevant – only surface water used			n/a

To provide the overall water availability classifications, the results for surface water and groundwater are combined as follows (Table 3.7):

Primary availability
All sites except Samaria – the result is **5**. This is based on surface water only, as although good amounts of groundwater are believed to be potentially available, the quality is likely to be lower due to the high fluoride concentrations. Thus the groundwater does not significantly add to the natural water availability.

Samaria – the result is 3. This is the reverse situation. There is negligible surface water, so the result is based on the natural groundwater availability.

Actual availability
Majengo and Kijenge – the results are **1** and **2** respectively. The water actually used comes from a combined surface and groundwater system, discussed earlier.

Nkoaranga and Samaria – the results are **3** and **2** respectively. No groundwater is actually used, so the overall results are based on the surface water supply systems.

Table 3.7 *Overall water availability assessments – Tanzania*

Community	Water availability indicator	
	Primary	Actual
Majengo	5	1
Kijenge	5	2
Nkoaranga	5	3
Samaria	3	2

Overall, it can be seen that, in although water is reasonable abundant in this part of Tanzania in the natural situation (with the exception of Samaria), the results for actual availability at all of the sites is low or very low. The principal factors causing this outcome are the naturally occurring high levels of fluoride which affects all the sites, combined with water supply systems which have inadequate capacity and are unreliable, especially in the dry season. The delivery of water to the people in these communities is not good. It might be expected that Samaria would stand out as significantly worse than the other communities because of the long distances that the people there have to travel to fetch water. However, this aspect is accounted for in the "Access" component of the WPI, and, in terms of the actual availability of water it is not relevant. Thus, the result for Samaria is broadly similar to the other communities studied.

4. Assessment of Availability - South Africa

The situation in South Africa is different to the other two countries, especially as regards surface water, because of the greater levels of data availability and the extensive experience in water resources modelling that is available in the country. All four pilot study sites lie in the Thukela basin, and this a particularly well studied catchment. A special study of surface water resources of the basin has been carried out as part of the project by the University of Natal, and this is attached as a separate report (Annex __). As well as the modelling results, the University of Natal report provides much background material on the basin. Most of the information and results on surface water in this section is summarised from that report, and the reader should refer it for more details.

4.1 General situation of the study sites

Locations

The pilot study sites are in the Thukela basin in KwaZulu-Natal province. The peri-urban areas are two separate sections of Wembezi township, which lies about 10 km west of the town of Estcourt. The rural sites are two communities within the general area known as Keate's Drift, about 75 km east of Wembezi. The four communities are shown in Figures 4.1 and 4.2, which indicate the locations of the households surveyed and the main water sources used by those households. Table 4.1 gives some details of the populations and households surveyed.

Table 4.1 *Communities surveyed – South Africa*

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Wembezi A	Peri-urban	30,000 (total	148	818
Wembezi C	Peri-urban	for Wembezi)	220	1329
Ethembeni	Rural	3280	124	1227
KwaLatha	Rural	1256	133	972

Topography, climate, vegetation and hydrological features

The Thukela basin has an area of 29,000 km^2. It rises in the Drakensberg mountains at altitudes of over 3000 m and flows eastwards to reach the Indian Ocean about 85 km north of the city of Durban. Mean annual rainfall varies from around 2000 mm in the Drakensberg to as little as 550 mm in the drier central regions. Most of the rain falls from December to February, and there is relatively high inter-annual variability of rainfall. Wembezi is in the western part of the basin at an altitude of about 1400 m, and with annual rainfall of about 800 mm. Keate's Drift is in the lower central part of the basin which is also the driest (altitude about 700 m, annual rainfall about 550 mm). The basin has high levels of potential evaporation, which, combined with the strong seasonality and inter-annual variability of the rainfall, lead to the area being classified as generally semi-arid.

The basin's natural land cover is mainly grassland and savanna. However, it has been highly modified by human use, leading to a complex patchwork of uses which include mining, urbanisation, commercial and subsistence agriculture, irrigation and impoundments, as well as substantial areas of degraded grassland, thickets and bushveld.

The river flows in the basin are strongly seasonal, with very low winter flows (June-August) and high summer flows (November-February). The streamflow is dominated by storm flows, indicative of the episodic and intense nature of the rainfall, which often occurs as thunderstorms. Flow variability from year to year is also high for any given month. There is also evidence that high and low flow years tend to come in clusters. The water resources of the basin are relatively highly developed, and the basin is a major source of water for areas outside its boundary. Overall, a total of more than 600 million m^3 of the Thukela's annual resource of 4000 million m^3 are transferred out of the basin. However, the location of these major abstractions is such that they do not have a significant impact on the sites being examined in this study.

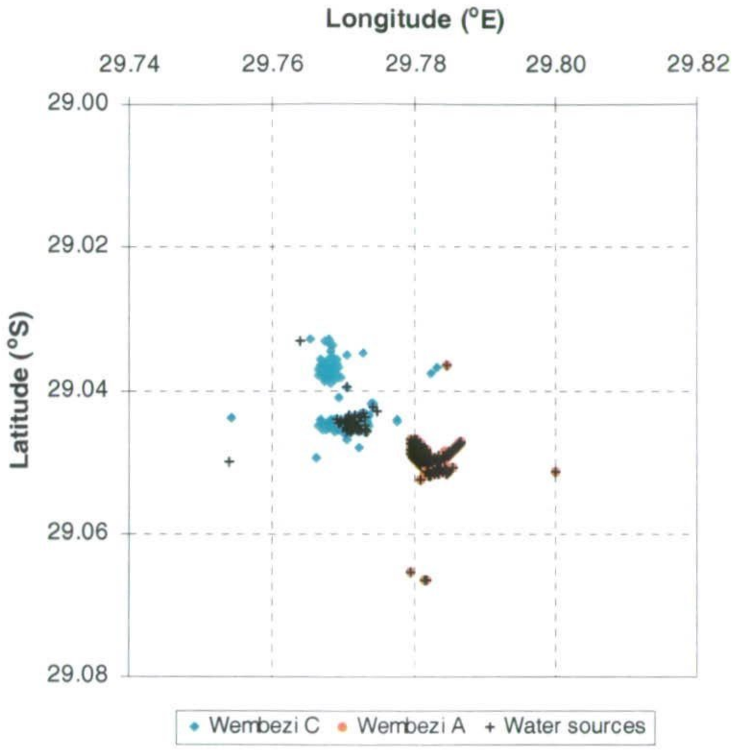

Figure 4.1 *Locations of households and water sources (main sources, dry season) – Wembezi, South Africa*

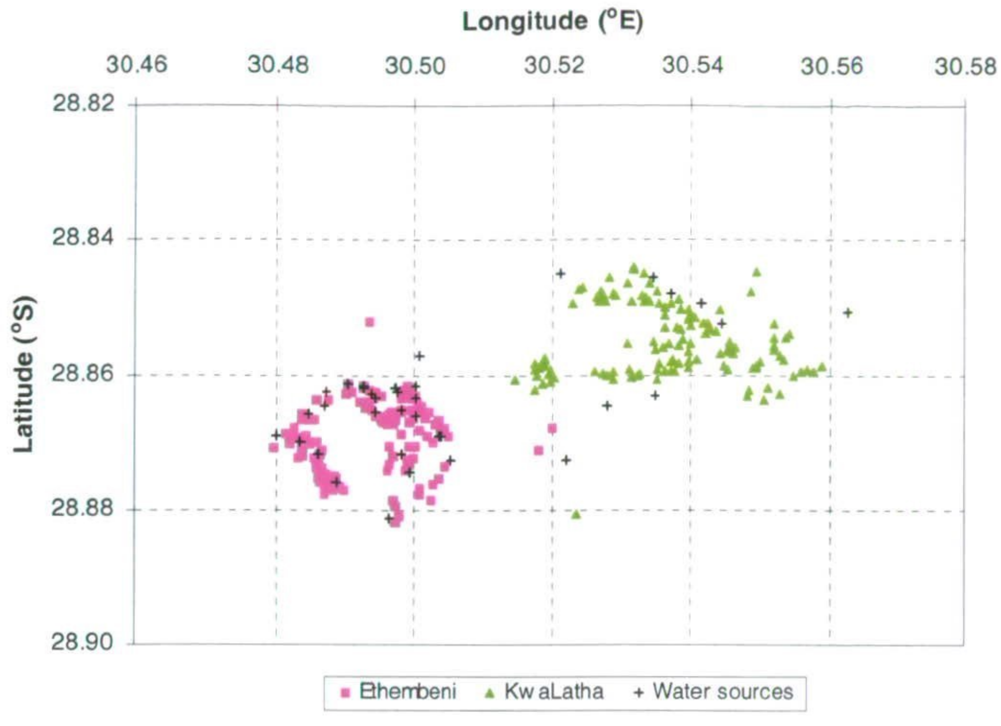

Figure 4.2 *Locations of households and water sources (main sources, dry season) – Ethembeni and KwaLatha, South Africa*

Figure 4.3 shows the topography and natural features of the Keate's Drift area in more detail. It can be seen that, although the communities are close to a fairly large river, steep slopes intervene, making access to the river difficult. The smaller streams closer to the houses are very much more ephemeral in their flow.

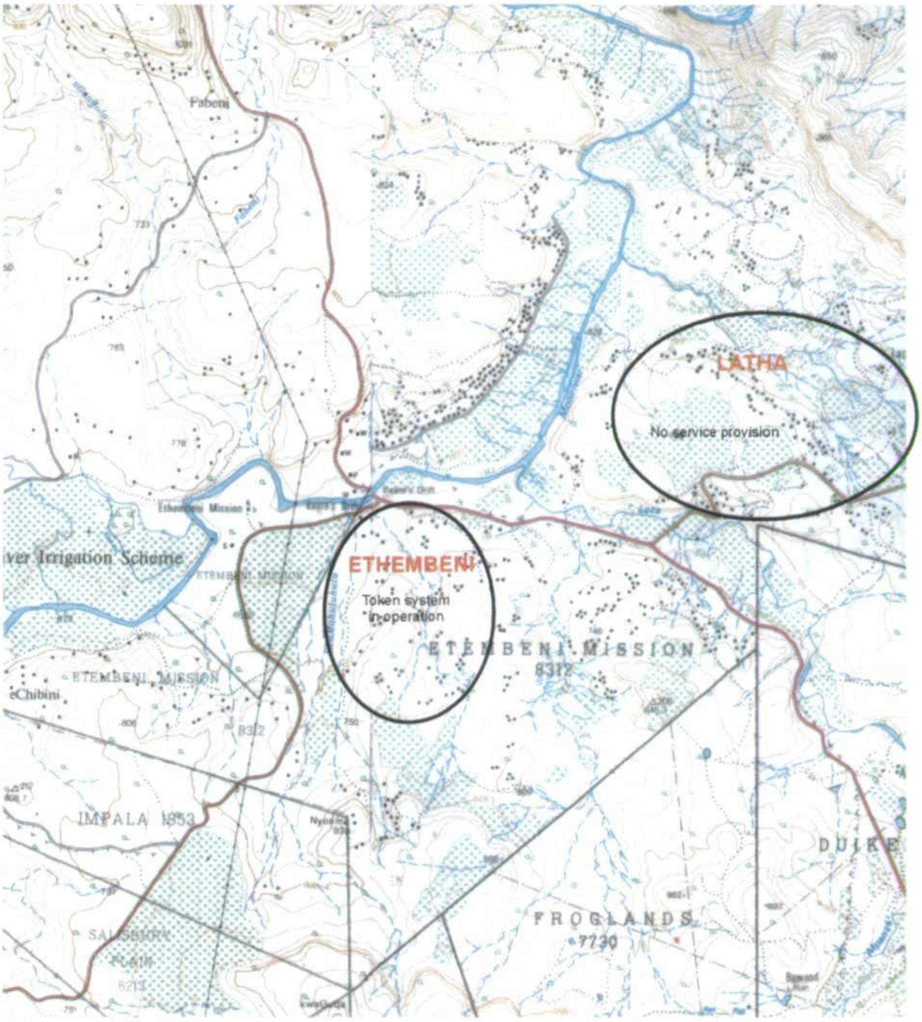

Figure 4.3 *Locations and topography – Ethembeni and KwaLatha, South Africa*

Hydrogeology

The study areas are underlain by rocks of the Estcourt Formation, a part of the Adelaide Subgroup, which is in turn part of the Beaufort Group of the Karoo Supergroup. These rocks consist predominantly of feldspathic mudstones, siltstones, shales and subordinate sandstones, and are of Permian to Triassic age. Generally speaking, the rocks are fine grained, very well cemented and hard and dense, and in consequence can possess little primary porosity or intergranular permeability. Groundwater storage and movement frequently occurs within and through fractures, as well as in the rock matrix. Borehole yields are therefore often dependent on the number, size and degree of interconnection of fractures encountered. Initial high yields may decline substantially due to the depletion of aquifer storage by abstraction. Recharge to certain fracture systems may be limited where these are overlain by less permeable rocks, or where interconnection between fracture systems is low.

Dolerite intrusions in the form of dykes or sills are common in Karoo rocks. These frequently outcrop to form ridges or other topographical features, or can be located as soil or vegetation changes or as lineaments on aerial photographs. Magnetometer geophysical surveys are used to locate dolerite bodies. Dolerite is normally regarded as an aquiclude; however the contact zone between a dolerite intrusion and the surrounding Karoo country rock forms a "chilled" and fractured zone which often has a relatively high permeability. The fractured dolerite can act to collect water from the surrounding less permeable country rock, and from the more porous weathered dolerite at the surface, and transmit it relatively rapidly to a well intake. For this reason the edges of dolerite intrusions are commonly targeted by groundwater drillers working in the argillaceous rocks of the Karoo Basin. Yields from such systems frequently decline with time as the limited storage in the fractures in the dolerite is soon exhausted by over-pumping. The formation of clays on fault planes or contacts may also prevent significant fracture permeability from developing.

4.2 Data assembly

Hydrology and water resources

All the communities, except KwaLatha, have water supply systems. Information on the amounts of water supplied by these systems and on the water quality and reliability were supplied by the relevant authorities, Estcourt Municipality for Wembezi, and AquAmanzi for the rural areas. The details are given with the assessments for each site below. Other information on the surface water resources is taken from the University of Natal report.

Hydrogeology

Sources for the hydrogeology included the publications listed in the references, and the 1:500 000 and 1:250 000 scale hydrogeology maps of the region published by the Department of Water Affairs and Forestry. Information from hydrogeologists at the British Geological Survey with experience of working in the Karoo sediments was also used. This general information was supplemented by the household surveys, and by records of chemical analyses carried out on surface and groundwater sources in the area.

Relevant data from the household surveys

The detailed household surveys that were carried out in the study communities provide much information which is helpful for the assessment of water availability. Table 4.2 lists the different water sources used by the households. They include both the main sources as well as secondary or other sources away from the house which may be used for such activities as washing and laundry. The table shows only data for the dry season; information was also collected on sources used in the wet season, but the results are practically identical and so they are not presented.

Table 4.2 *Water sources used in dry season – South Africa (from household surveys)*

Source type	Main source		Other source	
	No. h/holds	%	No. h/holds	%
Wembezi A				
Pipe (private)	148	100	-	-
Wembezi C				
Pipe (private)	26	12	0	0
Pipe (public)	191	87	78	35
Natural pond	0	0	4	1.8
Spring	0	0	3	1.4
Stream	3	1.4	19	8.6
n/a	-	-	116	53
Ethembeni				
Pipe (private)	1	0.8	0	0
Pipe (public)	79	64	12	9.7
Borehole (public)	25	20	34	27
Tank	3	2.4	0	0
Spring	1	0.8	2	1.6

River	14	11	38	31
n/a	-	-	38	31
KwaLatha				
Household source	1	0.8	0	0
Borehole (public)	22	17	21	16
Natural pond	81	61	23	17
River	29	22	50	38
n/a	-	-	39	29

Further information on people's perception of the reliability of the water supply and some indicators of the water quality are given in Table 4.3. The water quality information includes not only the response to a direct question on perception of quality, but also whether or not water is treated[32] after it has been collected, and perception of health problems related to water quality.

Table 4.3 *Reliability, water quality and health information – South Africa (from household surveys)*

		Wembezi A		**Wembezi C**		**Ethembeni**		**KwaLatha**	
		Dry season	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**
Gathering rainwater		2.0		38		94		90	
Reliability	Very reliable	23	24	41	41	41	45	58	61
	Reliable	55	55	28	28	38	41	20	33
	Not reliable	22	22	30	31	19	15	17	5.3
	Dries up	0	0	0	0.5	1.6	0	6.1	0.8
Water Quality	Good	97	97	96	96	60	61	11	9.9
	Fair	3.4	3.4	3.3	3.3	20	20	13	13
	Poor	0	0	0.9	0.9	20	19	77	77
Treating water at house		2.0		2.4		35		83	
Diarrhoea	Many times	0		0.5		23		14	
	Occasionally	9.6		8.3		19		42	
	Never	90		91		59		44	
Illness due to water		7.5		6.5		29		52	

All values are percentages of households.

These data may not provide objective evaluations since people's expectations of reliability and water quality may not be consistent, and their perceptions of whether it is good or bad may vary considerably from place to place. In addition, the health data are likely to be affected by other factors, especially the provision of effective sanitation. Nevertheless, these data do provide useful indications, especially when no other information is available, or to supplement other more rigorous data.

4.3 Particular methodology

For surface water, the methodology follows that discussed in Section 2. Because in this case, detailed hydrological modelling results are available for the sites of interests, these have been used to provide accurate results, at least as far as relates to the primary water availability. For the actual availability, the estimates have been based mainly on the information from the water supply authorities. This has been combined with the supplementary information from

[32] Treatment may be chemical, boiling, or simply allowing the water to settle.

the household surveys to provide the overall assessments. For groundwater, the key questions discussed previously (Section 2.2) are considered, in order to arrive at the assessment.

4.4 Water supply systems and water availability assessments

(a) Surface water – Wembezi A and C

Since these two sites are very close together and receive water from the same source, they are treated as a unit and have the same results for water availability.

Primary availability
The township lies on a small stream which has a catchment area of 196 km^2. The stream has a mean annual flow of 0.59 m^3/s, and in the driest month (June) the mean flow is only 0.08 m^3/s. The low flow for the driest months (May-July) which has a 1 in 10 year (or 90%) reliability is zero. Thus the amount classification is "Negligible". In this case the variability and the water quality are not relevant, and the result for primary availability is **0**.

Actual availability
The main water supply for Wembezi is the Wagendrift Dam which lies on the Bushman's River south of the Township. It is a large dam with a capacity of about 2700 million m^3. Water is supplied to Wembezi via a 300 mm diameter pipeline which is 10.1 km long. The average supply in this pipe is 35,000 m^3 per month, and it supplies a total population of about 30,000 people in Wembezi itself, plus an additional 2000 elsewhere. There must be some losses between the pipeline and distribution to individual taps but they have not been quantified. Making the reasonable assumption that losses are 20%, and using the total population supplied of 32,000, the per capita amount is 29 l/c/d.

No specific information is available on the reliability of the system or on the water quality, but as it is a formal water supply system which is believed to be well run, both can be assumed to be good. These figures are supported by the data from the household surveys (Table 4.3). In terms of reliability, both communities rate it fairly high, with only 22% (Wembezi A) and 30% (C) saying it is not reliable, and the remainder saying it is reliable or very reliable. These figures indicate that reliability is perhaps a little lower than would be expected with the best domestic water supply standards (which would be rated "Very good"), and on this basis the reliability category has been downgraded to "Good". The survey figures show that 96-97% rate the water quality as good, and rates of diarrhoea and illness are also low. It is therefore assumed that the quality category can be taken as "Very good". The resulting actual availability classification is **5**.

Wembezi A is formalised housing area with yard taps in each property, while Wembezi C is more informal housing; there are no house connections, but communal standpipes about 150 m are available. From the point of view of the water availability assessment this makes no difference and both communities can be rated the same. In Wembezi A only the formal supply system is ever used, but in Wembezi C a small amount of use is made of other sources (Table 4.2). For three households (1.4%) the stream, rather than the public supply, is the main source, and a small number of households also use ponds or streams as their secondary source. As these numbers are small, they have not been considered to make any significant difference to the assessment results.

(b) Surface water – rural areas

Primary availability
Both the communities are close to the Mooi River, and this can be treated as the primary surface water source in each case. There are a number of ephemeral streams closer to the houses, but they would only contribute a significant supply in the wet season and would provide no year-round supply. The river has a catchment area of 2880 km^2. The mean annual flow is 10.1 m^3/s, and in the driest month (July) the mean flow is 1.3 m^3/s. The low flow for the driest month (July) which has a 1 in 10 year (or 90%) reliability is 0.11 m^3/s. The population figure used for water supply in the Keate's Drift area is 11,848 (see below), and assuming that all this flow could be used by this population, the per capita amount is 800 l/c/d. Clearly there will be other demands on this relatively large resource, but it is reasonable to assume that the amount will remain in the highest category of >100 l/c/d.

Since the amount value relates to a low flow assessment at the 1 in 10 year level, the appropriate variability category is "Fair" (equivalent to 80-95% reliability). Analysis of a single water sample from the Mooi River in 1996, shows that the water quality meets international standards, except that the faecal coliform count is high. This is an indication of upstream sewage pollution, but there is no reason to assume that the natural water quality is less than adequate. Therefore a category of "Good" is assigned. The resulting primary availability classification is **6** for both communities.

Actual availability – Ethembeni
The main source of water supply is a piped system in which water is pumped from the Mooi River, passed through a treatment works, and then supplied to standpipes scattered around the community. People collect water from the standpipes using pre-paid tokens. Information from the operation and maintenance reports of the water supply agency (AquAmanzi) indicates that the population served is 2191. The business plan for improved water supply in the area (AquAmanzi, 2001) gives the population in Ethembeni as 3280. Thus, about 67% of the population are served by the existing piped system. Our household survey supports this, indicating 64% served by the piped system. The system (pipeline and treatment works) has a capacity of 480 m^3/day, which ignoring losses, gives a per capita amount of 219 l/c/d. After accounting for reasonable losses, the amount must remain in the highest category of >100 l/c/d.

Some of the population use other sources. The main ones are groundwater (20%) which is discussed further below, and the river (11%). The river is capable of supplying an abundant quantity of water (see under KwaLatha), so this does not change the amount assessment significantly. In addition, a high proportion of households gather rainwater to supplement supplies.

The reliability of the piped system seems to be generally good. AquAmanzi report that "most problems ... have been the result of vandalism. The rural location of Ethembeni is not conducive to efficient repair work being carried out, as it takes time for maintenance teams to hear of the problem and get there before frustration levels of the consumers are high. The District Municipality has requested that the communal pre-paid meters be replaced by house connections ... in order to create a sense of ownership, thereby reducing vandalism. Despite incidents of vandalism, consumers are generally content with the reliability of the scheme. The water office seems to be well run and convenient to most people." The household surveys show similar levels of satisfaction to Wembezi A, with 79-86% (depending on season) saying that it is reliable or very reliable. On this basis, the reliability category is assigned as "Good".

A sample from the Mooi river indicates that the raw water quality is good except for the high level of faecal coliforms (see above). The water actually supplied is treated, so it would be expected to meet all standards. No analysis has been done, but AquAmanzi report "operations records show that based on consumer's satisfaction with appearance, taste and odour of a sample drawn daily at a selected point, there have been zero days of 'quality unsatisfactory'." The household surveys indicate a relatively poor situation, with 40% saying water quality is fair or poor and 42% of households suffering from diarrhoea many times or occasionally. This might seem to contradict the situation as reported by AquAmanzi, but it must be remembered that a proportion of households use unprotected surface sources, and in addition people tend to limit their use of the treated water because of the cost. Overall, balancing the use from different sources, a quality category of "Fair" is assigned. The resulting actual availability classification is **5**.

Actual availability – KwaLatha

At KwaLatha there is no formal water supply system; people collect water either from boreholes (17%), or from ponds and rivers (83%). These surface water sources could include a variety of small streams and ponds which might have very variable and uncertain availability. However, the main Mooi river can be considered as the main source, and since there is no infrastructure, the actual availability can be considered to be the same as the primary availability assessed above. The low flow for the driest month with a 1 in 10 year reliability is 0.11 m^3/s. The AquAmanzi business plan for improved water supply in the general Keate's Drift area quotes a population of 11,848 for the whole area (of which 1256 is in KwaLatha). As above, using this total population gives a per capita amount of 800 l/c/d, and taking into account that there will be other demands on this relatively large resource, the amount still remains in the highest category of >100 l/c/d. It should also be noted that these flow figures, which are from the University of Natal report, assume that the catchment is in its natural condition. In fact, the catchment has been highly modified, but even with the these probable alterations to the low regime, it is judged that the actual availability remains in the same category of >100 l/c/d.

Since this amount value relates to a low flow assessment at the 1 in 10 year level, the appropriate variability category is "Fair" (equivalent to 80-95% reliability). As noted earlier the single sample from the river had high levels of faecal coliform, and the household data indicate a worse situation than at Ethembeni, with 77% saying water quality is poor, 56% of households suffering from diarrhoea many times or occasionally, and 83% treating water at the house. Generally, a problem of cholera is known in the area, and the quality rating was assigned as "Poor". The resulting actual availability classification is **2**.

(c) Groundwater – all sites

Primary availability

Records for boreholes in this area suggest that the probability of drilling a successful borehole is 40-60%. (A successful borehole is defined as one which yields >0.1 l/s upon completion, about the minimum yield necessary for the installation of a hand pump). Long term sustainability (over a period of years) is however likely to be lower, and may be as little as 50% of the success rate on drilling. The median yield of successful boreholes in this area is between 0.5 and 2 l/s. Where present, groundwater tends to be less than 30 metres below ground level, and the recommended depth of drilling is less than 20 metres below the water table, as the fractures and weathered horizons tend to be restricted principally to this zone directly below groundwater level.

Groundwater quality in the area is generally good, with low to moderate dissolved mineral content. More than 60 % of water samples analysed are of the $(Ca,Mg)(HCO_3)_2$ type. Waters are often slightly alkaline. It is thought that the principal contaminants in the area are likely to be of anthropogenic origin, particularly where the water table is shallow and/or fracture systems in the rock permit the rapid transport of contaminants to borehole intakes without allowing time for natural attenuation. Boreholes should be completed with suitable sanitary seals, and should be not be situated near latrines, rubbish dumps or other sources of potential contamination. (Anthropogenic contamination would not alter primary groundwater quality however.)

Drilling costs in the hard Karoo rocks and the dolerite are likely to be high, with rotary percussion being the most practical drilling method. This should be added to the relatively high probability of drilling a dry or unsuccessful borehole when considering costs. Expert assistance in the form of geophysical and geological surveys is recommended in order to minimise the risk of dry boreholes, and the cost of such assistance may be considerable. Borehole construction should be within accepted limits, particularly where narrow borehole diameters have been selected, in order to minimise the potential for later pump failure.

In summary, boreholes in this area are most likely to support only a hand pump, and are likely to be unsuitable for irrigation or industrial applications. Initial high yields may decline with time, affecting borehole reliability. A successful borehole should be able to provide the domestic water requirements of about 200 people. The cost of siting, drilling and completion is likely to be relatively high. Water quality should be good and potable, although there is some risk of anthropogenic contamination which can be minimised by careful construction and siting. Dolerite dykes, faults or other geological features may provide the best drilling targets, and as such the borehole site may not be ideally located for the purposes of convenience.

The geology has been assessed for all of the study sites together, since not enough is known about any changes in potential which might exist between the separate sites. When considering the amount of groundwater available per capita, it is first necessary to consider the number of "typical" boreholes that could be installed per unit area. A figure for the amount of water reaching the aquifer, or recharge, is thus needed, which would balance the outflow of water from the system via the boreholes. An estimate of average annual recharge of 10 mm has been made, after consulting Bredenkamp et al (1995) who summarise work on the Karoo System[33]. (This is probably a conservative figure, Magda (1995:42) quotes figures for recharge of 14-15 mm for the vicinity of the study areas, or about 2% of rainfall.) As has been mentioned, recharge is a controversial topic, and is very difficult to estimate accurately. The true figure may be significantly different to this one. Furthermore, the following calculation assumes that the aquifer is homogeneous in its hydraulic properties, and that recharge infiltrates the ground evenly. The heterogeneous nature of the rocks in question, in particular the effect of dolerite dykes, fracture systems and similar structures, mean that the calculation must incorporate significant error. It is possible that under certain circumstances

[33] Figures of 21.3 mm pa and 12.3 mm pa were quoted for Karoo Sediments at De Wetsdorp and De Aar respectively. The more conservative figure of 10 mm pa has been adopted for convenience of use.

that the calculation will bear very little relation to reality at all, for instance in the case of a fractured dyke which could greatly increase well yields. Nonetheless, the calculation can provide some idea of the primary groundwater availability, and proceeds as follows. A typical well yield is regarded as 0.5 l/s (although a significant number of boreholes in this area yield more than 1 l/s, a number of boreholes are dry or very low yielding, and for this reason the lower amount per source figure was chosen). On the assumption that the well is pumped for 8 hours per day, the annual yield is 5256 m^3/yr. Using the recharge figure given above of 10 mm/yr, means that approximately 0.5 km^2 of land is needed to support each well in a sustainable manner. If we also assume an arbitrary 5 km radius around a community is applicable for the availability of groundwater, this means that a theoretical maximum of 149 wells (each yielding 0.5 l/s) is possible, having a total yield of 2151 m^3/day. Using the populations given above of 30,000 for Wembezi and 11.848 for Keate's Drift, gives per capita amounts of 72 and 182 l/c/d respectively.

The reliability of the all the sources is assumed to be "Fair" (i.e. available 80 to 95% of the time). Boreholes would be expected to deliver the relatively low pumping rates of 0.5 l/s more or less continuously when first drilled. However failure after three or four years may take place due to low permeability horizons in the geology which may place limits on the amount of recharge reaching the borehole and slowly cause the borehole to fail. In this area severe droughts may also cause rare incidences of groundwater depletion and borehole failure. (Note that as an assessment of primary availability, this assumes that no mechanical failures will occur, and that boreholes are constructed to adequate depth to withstand normal dry-season water level fluctuations.)

The water quality is regarded as "Good" as there are no known geochemical elements that are hazardous to human health in the groundwater, although no comprehensive water quality survey has been carried out.

The resulting primary availability classifications are Wembezi (both sites): **4**, and Keate's Drift (both sites): **6**.

Actual availability – Wembezi
No groundwater sources are actually used, so this is not relevant.

Actual availability – rural sites
The following figures for actual availability are based on what is known about the existing infrastructure for accessing groundwater in the four study areas. This is based on the assumptions made for the primary availability assessment, together with information from the household surveys, since little detailed information was available from the actual boreholes used. It must be emphasised that the actual availability of groundwater may well bear little relation to the primary availability, dependent as it is on wells, boreholes or springs, together with suitable reticulation, by means of which the people can access the water.

At Ethembeni and KwaLatha only 20% and 17% respectively of households were found to use groundwater as their main source. Available amounts are uncertain and have been assumed to be a minimum of 5-10 l/c/d in the absence of any other data, but based on the fact that one well at KwaLatha and two wells at Ethembeni yielding 0.5 l/s would provide at least this amount per capita amount if pumped for eight hours per day. Reliability has been judged as "Good" (in view of possible effects of unusual drought). Water quality has been judged as "Fair", rather than "Good" since a number of people report illness due to water, although it is not clear whether those reporting illness due to water are the ones who use groundwater as a source and this may therefore be a conservative quality classification. It is possible that boreholes in the area are contaminated by human activities, although this is more likely to occur with unprotected surface water sources. This gives a resulting classification for actual availability at Ethembeni and KwaLatha of **1**.

4.5 Summary and results for overall availability

Tables 4.4 summarises the findings discussed above for the primary water availability assessment at each site from both surface water and groundwater. Table 4.5 gives the same results for the actual water availability assessments.

Table 4.4 *Summary of primary water availability assessments – South Africa*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Wembezi A	Surface	Negligible	Not relevant	Not relevant	**0**
	Ground	50-100 l/c/d	Fair	Good	**4**
Wembezi C	Surface	Negligible	Not relevant	Not relevant	**0**
	Ground	50-100 l/c/d	Fair	Good	**4**
Ethembeni	Surface	>100 l/c/d	Fair	Good	**6**
	Ground	>100 l/c/d	Fair	Good	**6**
KwaLatha	Surface	>100 l/c/d	Fair	Good	**6**
	Ground	>100 l/c/d	Fair	Good	**6**

Table 4.5 *Summary of actual water availability assessments – South Africa*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Wembezi A	Surface	25-50 l/c/d	Good	Very good	**5**
	Ground	Not relevant – only surface water used			**n/a**
Wembezi C	Surface	25-50 l/c/d	Good	Very good	**5**
	Ground	Not relevant – only surface water used			**n/a**
Ethembeni	Surface	>100 l/c/d	Good	Fair	**5**
	Ground	5-10 l/c/d	Good	Fair	**1**
KwaLatha	Surface	>100 l/c/d	Fair	Poor	**2**
	Ground	5-10 l/c/d	Good	Fair	**1**

To provide the overall water availability classifications, the results for surface water and groundwater are combined as follows (Table 4.6):

Primary availability

Wembezi A and C – the result is **4** for both sites. This is based on groundwater only, since no surface water was found to be naturally available.

Ethembeni and KwaLatha – the result is **6** for both sites. Surface water is relatively abundant and has a classification of 6, and there is also a reasonable potential for groundwater, classified as 6. Overall surface water is dominant. As the amount of water is already in the highest category, and it is not judged that the addition of groundwater would increase the reliability or quality significantly, the overall classification has been kept at 6.

Actual availability

Wembezi A and C – the result is 5 for both sites. No groundwater is actually used, so the overall result is based on surface water which is supplied from the Wagendrift dam.

Ethembeni – the result is 5. About 80% of households are supplied from surface sources (the majority from the formal piped system). Groundwater is little used, and its actual availability is uncertain, but thought to be considerably less than surface water. Therefore the overall classification is taken to be the same as the surface water one.

KwaLatha – the result is 2. About 83% of households are supplied from surface sources (although there is no formal piped system). Again, groundwater is little used, and its actual availability is uncertain, but thought to be considerably less than surface water. Therefore the overall classification is taken to be the same as the surface water one.

Table 4.6 *Overall water availability assessments – South Africa*

Community	Water availability indicator	
	Primary	Actual
Wembezi A	4	5
Wembezi C	4	5
Ethembeni	6	5
KwaLatha	6	2

The final assessment of actual availability is the same at all sites except KwaLatha. For Wembezi this is essentially a result of the relatively small quantities of water that are available from the water supply system (25-50 l/c/d). The other factors (reliability and quality) are good, and given a higher amount of water per capita would have indicated a substantially higher result. In Ethembeni, the water supply system is capable of providing good quantities (>100 l/c/d), which would lead to a high score, but not all the population have access to this supply. Instead, some people have to use the polluted river water, leading to only a medium overall result for this community. In KwaLatha the amount of water is again high, but as this is obtained from polluted surface water sources, the resulting actual availability assessment is much lower than at the other sites.

5. Assessment of Availability – Sri Lanka

5.1 General situation of the study sites

Locations

The pilot study sites were two urban or peri-urban areas in the capital Colombo, and two rural communities in the Deduru Oya basin approximately 100 km to the north of Colombo. The locations are shown in Figure 5.1, and some brief details of the populations and households surveyed are given in Table 5.1.

Figure 5.1 *Map of the study area – Sri Lanka*

Table 5.1 *Communities surveyed – Sri Lanka*

Community	Type	Estimated population in 2001	No. households surveyed	Total no. people in the surveyed households
Tharawatte	Urban	460	83	347
Awarakotuwa	Peri-urban	520	121	501
Agarauda	Rural	350	66	282
Tissawa	Rural	720	144	589

Topography, climate and vegetation

Sri Lanka is a relatively small island with a land area of approximately 65,600 km^2, stretching about 430 km from north to south and 230 km from east to west. The topography is dominated by the highland massif in the central southern part of the country which rises to a maximum altitude of a little over 2500 m. From here the land slopes down to sea level in all directions. The highland area covers a fairly small part of the country, and most of it is lowland or rolling plains dotted with small hills at elevations of less than 500 m.

The climate is a tropical monsoon type, with a marked seasonal rhythm of rainfall. There is a strong pattern of spatial variation in rainfall. The wettest areas are found in the central mountains and on their western slopes, with annual totals exceeding 5000 mm at some stations. The south-western corner of the island is generally wet, with much of it receiving more than 3000 mm. The rest of the central part of the country has annual rainfall in the range 1500-2000 mm, while both the north and the extreme south are markedly drier, with rainfall typically 1000-1500 mm. The country has been classified into three broad agro-ecological zones, defined on the basis of agricultural land use, climate, topography and soils. The wet zone is the south-western corner, roughly corresponding to the very wet area mentioned above; a band surrounding this is the intermediate zone, while the dry zone is the remaining northern, eastern and southern areas, covering more than half of the country. Based on various sources (Atlas of Sri Lanka, Department of Meteorology map and raingauge data), the mean annual rainfall at the four study sites is estimated as approximately: Tharawatte 2700 mm, Awarakotuwa 2600 mm, Agarauda 1400 mm, and Tissawa 1700 mm.

There are two main periods of heavy rainfall each year – the south-west monsoon from May to September, which is the period of highest rainfall, and the north-east monsoon from December to February. The remaining inter-monsoon periods can still produce appreciable amounts of rainfall, especially in the very wet south-western area.

The natural vegetation of most of Sri Lanka was originally a wide range of forest types. The present land use is a complex mosaic. An assessment by Forest Department in 1993 showed 24% of the land area remaining under closed canopy natural forest, and another 7% of sparse forests. Other major land use types include plantations (mainly rubber, coconut and tea), rice cultivation in paddy fields, other cultivation and urbanised areas.

Hydrological features

All the drainage basins in Sri Lanka flow outwards radially from the central massif. The two of direct interest for the present study are the Kelani Ganga and the Deduru Oya (Figure 5.1). The Kelani Ganga covers 2292 km^2; it flows from the central mountains due west to reach the ocean just to the north of Colombo city centre. It includes some of the wettest areas in the country, and land use is mainly plantations and some forest. There are a number of large reservoirs in the upper parts of the basin.

The two rural sites lie in the Deduru Oya basin, which also flows westwards, and has an area of 2647 km^2. It is a drier area than the Kelani, but still has annual rainfall of more then 1500 mm over most of the basin. The land use is mostly coconut plantation and paddy fields. Scattered over the whole area are more than 3200 small shallow reservoirs (known locally as "tanks") which are used to provide the irrigation water for the paddy fields and other cultivation.

Hydrogeology

The four study sites are all located on metamorphic basement rocks, mainly proterozoic gneisses and paragneisses of the Wanni Complex. In places this basement is covered by variable thicknesses of quaternary alluvium, sands or gravels. (The study area at Tissawa is covered by 2-3 m of alluvial deposits, for example.) The exact composition of the basement rocks varies between the different sites, although hydrogeologically they behave in a similar fashion.

The fresh metamorphic basement rocks have a very low permeability and porosity, but weathering processes typically produce a regolith[26] rich in clay minerals. The regolith may range in thickness from thin or absent up to several tens of metres thick. The regolith is characterised by a low permeability but a relatively high porosity. Beneath the regolith a more permeable zone of decomposed (sometimes fractured) metamorphic rock can provide a conduit for groundwater, with transmissivities many times higher than the regolith, but with low groundwater storage potential. Fractures in this zone may develop as a result of weathering, or may be associated with tectonism and lineaments in the gneiss. The regolith and fractured zones together can constitute an aquifer, with storage of groundwater provided by the regolith and movement of groundwater towards a well intake supported by the zone at the bottom of the regolith.

5.2 Data assembly

Hydrology and water resources

Data on the formal water supply system in Colombo were supplied by the National Water Supply & Drainage Board. In the rural areas, there are no surface based water supply systems, but data on the irrigation tanks were obtained from the Department of Agrarian Services. River flow data were obtained from the Irrigation Department as monthly values; details of the stations most relevant to the analysis are listed in Table 5.2. Water quality data were collected from a number of surface water locations near the rural sites specially for this study.

Table 5.2 *River flow data availability – Sri Lanka*

Station name	Station no.	Approx. location Lat.	Long.	Catchment area (km^2)	Relevant to	Period of data
Kelani Ganga at Nagalam Street	0101	6°57'30"N	79°52'30"E	2085	Urban sites	1924/25–1959/60
Kelani Ganga at Kaduwela	0111	6°56'05"N	79°59'05"E	1884	Urban sites	1960/61–1966/67
Kelani Ganga at Hanwella	0114	6°54'35"N	80°04'45"E	1782	Urban sites	1972/73–1985/86
Kolamuna Oya at Hettipola	9901	7°36'30"N	80°05'35"E	233	Rural sites	1944/45–1982/83
Deduru Oya at Batalagoda	9902	7°31'00"N	80°28'00"E	210	Rural sites	1945/46–1946/47
Kospothu Oya at Alawala Anicut	9903	7°28'20"N	80°27'10"E	102	Rural sites	1945/46–1962/63
Deduru Oya at Chilaw	9904	7°36'00"N	79°48'58"E	2611	Rural sites	1948/49–1978/79
Deduru Oya at Moragaswewa	9907	7°41'45"N	79°59'50"E	2002	Rural sites	1978/79–1985/86

Hydrogeology

Data on the boreholes in the rural areas, including well logs, sketch diagrams and some water quality information, were supplied by the National Water Supply & Drainage Board. No hydrogeological maps were available, however geological and topographical maps provided basic data. Hydrogeologists at the British Geological Survey with experience of long-term groundwater assessment in Sri Lanka provided literature and data, including information on drilling methods. The most useful data sources are listed in the references.

[26] A surface layer of loose or weathered material, which in this case has developed more or less in situ.

Relevant data from the household surveys

Figures 5.2 to 5.4 show the locations of the households surveyed and the water sources used in the dry season (except for Tharawatte which is not shown as it is a very compact urban area). In Sri Lanka, as opposed to the other two countries, information was collected on the sources of water for a range of different uses. In the urban areas these were drinking/food preparation, washing/cleaning, and bathing. In the rural areas they also included agriculture, livestock, and cottage industry, and water used directly at source was identified as well. This information is summarised in terms of the percentages of households using the various sources for the different purposes, in both the wet and dry seasons, in Tables 5.3 and 5.4. In the case of piped supplies, wells and tubewells, the tables also show whether the sources are protected or unprotected. For shallow wells, this indicates whether or not animals are prevented from getting access to the water. Pipes and tubewells are usually recorded as protected, but they are unprotected if the water is first allowed to enter an open tank and is then scooped up from there. The other types of source are always assumed to be unprotected.

Returning to the maps in Figures 5.2 to 5.4, the sources used in the wet season are not mapped as the patterns are broadly similar. Also, the maps show only some of the uses for the rural areas. However, what can be clearly identified is that people are predominantly using the groundwater sources (wells and tubewells or boreholes) for drinking, food preparation and cleaning. On the other hand, surface water sources (tanks and rivers) are generally used for bathing, agriculture and other activities, and this water is used at source rather than being transported.

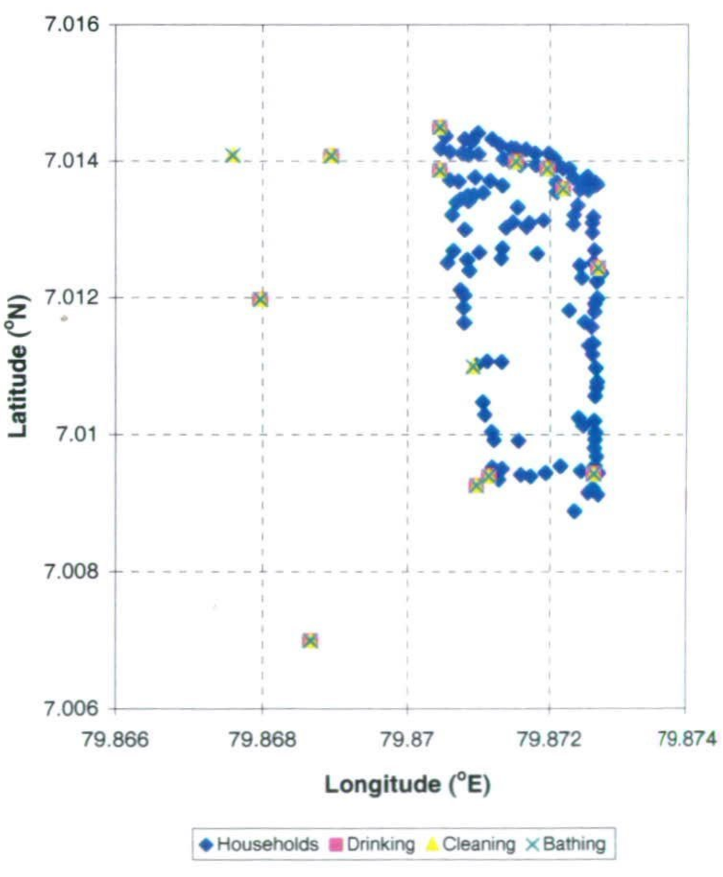

Figure 5.2 *Locations of households and water sources (dry season) – Awarakotuwa, Sri Lanka*

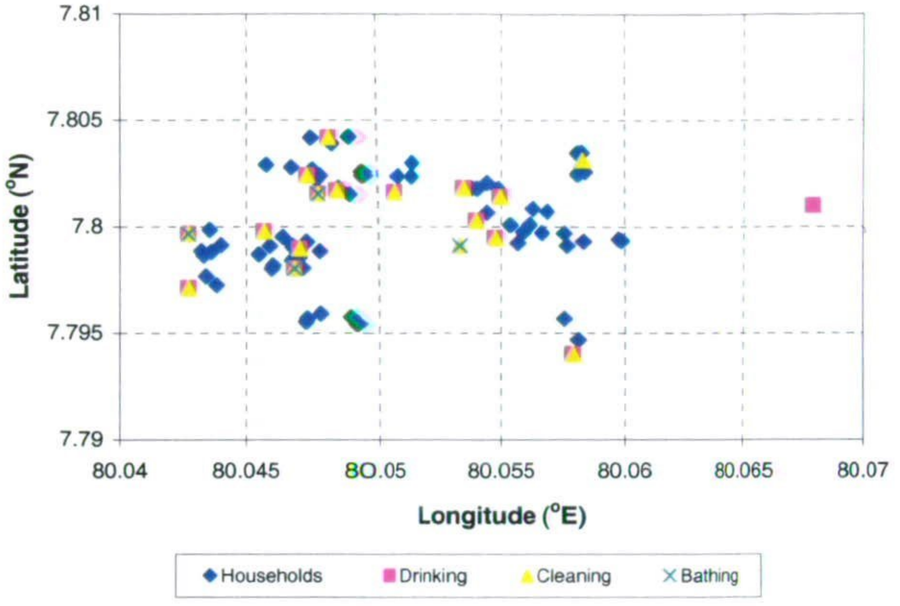

Figure 5.3 *Locations of households and water sources (dry season) – Agarauda, Sri Lanka*

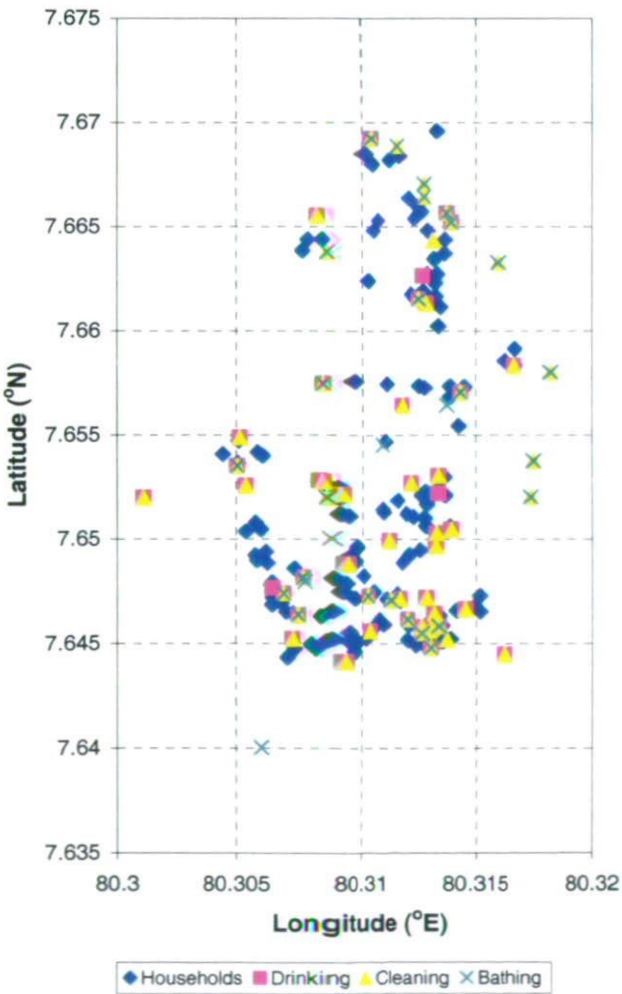

Figure 5.4 *Locations of households and water sources (dry season) – Tissawa, Sri Lanka*

Table 5.3 *Water sources used at urban sites – Sri Lanka (from household surveys)*

Source type		Drinking/ Food prep.		Washing/ Cleaning		Bathing	
		Dry	Wet	Dry	Wet	Dry	Wet
Tharawatte							
Pipe (public)	P	6	6	43	39	61	29
"	U	94	94	0	0	5	5
Well (public)	P	0	0	27	31	11	43
"	U	0	0	31	31	23	23
Awarakotuwa							
Pipe (public)	P	21	24	11	13	11	13
"	U	79	76	89	87	89	87

All values are percentages of households. P – protected source, U – unprotected source

Table 5.4 *Water sources used at rural sites – Sri Lanka (from household surveys)*

Source type		Drink-ing		Food prep-aratio		Wash/ Clean-ing		Bathing		Agric-ulture		Live-stock		Cottage industry		Water used at source	
		D	W	D	W	D	W	D	W	D	W	D	W	D	W	D	W
Agarauda																	
Well	P	67	64	44	42	35	27	5	2	0	0	0	0	3	2	22	20
"	U	12	9	11	17	32	24	0	2	2	0	0	0	2	2	8	12
Tubewell	P	20	23	12	9	12	11	0	0	0	0	2	3	0	0	6	5
"	U	2	2	2	5	2	2	0	0	0	2	0	2	0	0	8	8
Tank		0	3	32	27	20	35	96	97	61	74	42	38	24	27	58	56
Stream		0	0	0	0	0	2	0	0	2	0	0	0	0	0	0	0
Rainwater		0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0
n/a		0	0	0	0	0	0	0	0	36	21	56	58	71	70	0	0
Tissawa																	
Well	P	43	69	42	65	45	69	8	29	1	4	14	17	5	7	29	30
"	U	52	26	50	27	35	16	6	6	2	1	17	3	4	3	31	38
Tubewell	P	0	0	0	1	1	1	0	0	0	0	1	0	0	1	0	0
"	U	1	0	1	1	5	1	0	1	0	0	0	0	0	0	1	1
Tank		0	0	0	0	0	1	1	14	29	35	6	22	3	16	19	17
Nat. pond		0	0	0	0	13	0	0	1	0	1	1	2	0	2	1	0
Stream		3	3	7	4	0	10	85	49	4	6	24	9	10	3	15	12
Rainwater		0	2	0	2	0	1	0	1	1	16	0	5	0	3	5	3
n/a		0	0	0	0	0	0	0	0	62	39	38	42	79	66	0	0

All values are percentages of households. P – protected, U – unprotected source. D – dry, W – Wet season

Further information on people's perception of the reliability of the water supply and some indicators of the water quality are given in Table 5.5. The water quality information includes not only the response to a direct question on perception of quality, but also whether or not water is treated[35] after it has been collected, and perception of health problems related to water quality.

Table 5.5 *Reliability, water quality and health information – Sri Lanka (from household surveys)*

		Tharawatte		Awarakotuwa		Agarauda		Tissawa	
		Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season
Gathering rainwater		0		72		71		70	
Reliability	Very reliable	6.0	24	0	25	11	66	6.5	49
	Reliable	18	74	0	62	29	34	19	45
	Not reliable	66	2.4	100	14	53	0	68	5.8
	Very unreli.	9.6	0	0	0	4.5	0	2.9	0
	Dries up	0	0	0	0	3.0	0	2.9	0.7
Water Quality	Good	19	47	28	46	23	46	25	48
	Fair	49	52	62	44	53	43	54	44
	Poor	33	1 2	10	10	24	10	21	7.9
Treating water at house		0		11		79		71	
Diarrhoea	Many times	11		2.5		18		30	
	Occasionally	37		27		31		28	
	Never	52		70		52		43	
Illness due to water		77		66		77		76	
Illness due to lack water for washing/cleaning		79		73		54		58	

All values are percentages of households

These data may not provide objective evaluations since people's expectations of reliability and water quality may not be consistent, and their perceptions of whether it is good or bad may vary considerably from place to place. In addition, the health data are likely to be affected by other factors, especially the provision of effective sanitation. Nevertheless, these data do provide useful indications, especially when no other information is available, or to supplement other more rigorous data.

5.3 Particular methodology

Generally speaking, the methodology used follows that discussed in Section 2. For the urban areas the analysis is dependent on the data supplied by the water supply authorities on the urban water supply system, combined with information from the household surveys. For the rural areas, the surface water analysis uses an evaluation of the available river flow data in the basin to derive an approximate technique for estimation at other sites, combined with standard methods employed by the Irrigation Department to estimate the yields of small catchments. For groundwater, the key questions discussed previously (Section 2.2) are considered, in order to arrive at the assessment.

5.4 Water supply systems and water availability assessments

(a) Surface water – urban areas

[35] Treatment may be chemical, boiling, or simply allowing the water to settle.

The two urban or peri-urban sites are both part of the Greater Colombo area and can be treated together, both in terms of the natural availability of water and of the water supply systems that are actually in use.

Primary availability

The two communities are in low-lying areas close to the sea. Awarakotuwa is an informal settlement in what is essentially a marsh close to the sea. The water here is brackish. Tharawatte is a densely-settled urban area, but again, the nearest small streams seem to be connected to marshy areas which are affected by their proximity to the sea. Because of this it seems more appropriate to treat the nearest main river, the Kelani Ganga, as the source for the primary water availability in both cases.

Observed monthly flow data are available for the Kelani Ganga close to Colombo (Table 5.2). Based on the most downstream, and also nearest location (Kelani Ganga at Nagalam Street), which has 36 years of record, the mean flow is 176 m^3/s. For February, the driest month on average, the mean is 99 m^3/s, and the monthly flow which is exceeded in 19 out of 20 years can be approximately estimated as 47 m^3/s. This basin can be considered to be relevant for supply to the whole of the Greater Colombo area, which has a population of 2.72 million (2001 census). This gives the per capita amount as 1490 l/c/d. The observed flow values may be affected by upstream reservoirs, although these do not control a large portion of the catchment; thus the natural flows may be somewhat different, but the likely impact would be small. It should also be noted that the analysis is based on old data (1924-60). However, the stations with more recent data that are a little further upstream do not seem to indicate any substantial change in the pattern of flows in more recent years.

The quantity of water available in the basin is large. At a reliability of 95% it is much greater than the highest category of amount of >100 l/c/d/. The length of data record is such that estimation of the amount available at 98% reliability is not so straightforward, but it is reasonable to assume that this would also be well above 100 l/c/d. On this basis, the reliability classification can be assigned as "Very good".

Currently there is a high level of pollution in the lower Kelani Ganga, derived from sewage and industrial waste. For examining the primary availability, however, it is the natural water quality which is relevant. There is no reason to assume it is less than adequate, and as it has not been tested, a quality classification of "Good" is assigned. The resulting classification for primary water availability is 8 for both communities.

Actual availability

The primary source of water for the whole of the Greater Colombo area is the city water supply system, mainly based on the Kelani Ganga. Water is pumped from the river at Ambatale, 14 km from the mouth, and water is also piped separately from two reservoirs (Kalatuwawa and Labugama) which are on small tributaries in the southern part of the basin. The water is treated at a number of plants and distributed across the whole area. For water supply purposes the area is divided into four parts. For this study, the sections of interest are Colombo City (CC) for Tharawatte, and Towns North of Colombo (TNC) for Awarakotuwa. Data are available on the monthly amounts of water supplied to each of these areas. Using figures for 1999, 2000 and 2001, and using population figures from the 2001 census, we can estimate the typical average water consumption as:

- CC: water supplied = 4.84 million m^3, population = 1.157 million, water per capita = 135 l/c/d
- TNC: water supplied = 1.60 million m^3, population = 0.282 million, water per capita = 183 l/c/d

These figures are based on the total water supplied in a number of categories. Thus, they take account of losses, but they may also be some water consumed illegally which is not accounted for. This would tend to reduce the average per capita amounts. In TNC about 50% of the water is bulk supplies to the industrial zone, and if this is discounted the average per capita amount is reduced to about 90 l/c/d.

So far the figures refer to average quantities supplied over large areas. However, in the two study sites the situation is very different from the average. Tharawatte is a small enclave of squatter dwellings in an expensive city area (such enclaves are referred to as tenement gardens). Because of the high value of the land, the people have not been granted land tenure, even though the settlement is of long standing. This means that there are only limited or no rights of access to water, electricity and schooling, and drainage is also inadequate leading to flooding in the wet season. The water and sanitation facilities (for about 460 people) are two public taps, two toilets and a single shallow well divided into separate areas for men and women. For drinking and food preparation only the piped supply is used, while households use a mixture of the piped supply and the well for cleaning and bathing. The reliability of the piped supply is reasonably good, but because there are only two taps, people nearly always have to queue. In the dry season pressure is low, and then the richer or more influential people tend to get priority, leading to longer queuing times for the poorer. The well is shallow and tends to almost dry up in the dry season, making it difficult to get much water.

Awarakotuwa is also an informal settlement although it differs in that the houses are much more widely spaced. The area is marshy and very prone to flooding; on inspection it does not appear to be at all a suitable area for habitation. Although the settlement has been allowed, again the people do not have land tenure, and there is no official connection to the water supply system. Nevertheless, there is a system which takes water to standpipes scattered around the community. It was constructed by the people themselves with money collected from each household. Awarakotuwa is at the "downstream" end of the city water supply system, and as more and more other areas have been connected the pressure has reduced. The situation is such that now hardly any water reaches the settlement except during the night when other users or not using much. People have to wait until between midnight and 6 am, and then queue to get water. Alternatively, they sometimes travel to other areas where there is better supply, and transport the water from there. The community is surrounded by canals which used to be used as bathing points; people do not do so now because the canals are polluted by sand extraction activities. Rainwater is collected from roofs by many households providing a small supplement for 3-6 months of the year, depending on the rains. Other than this, people are totally reliant on the very inadequate piped system.

There are no data on the actual quantities of water that is reaching these two communities. Clearly it is less than the average quantities available over large areas that were quoted earlier. It can also be seen that, since the supply is so limited, the amount that is available can hardly be significantly more than the amounts that people are actually using. Data from the household surveys can be used to estimate the per capita use of gathered water (see Annex _). This gives 32 l/c/d for Tharawatte and 40 l/c/d for Awarakotuwa. In Tharawatte there is some additional availability from the shallow well, but for both sites it is estimated that the real availability is only slightly larger than these figures, and considerably less than the average figures given earlier. For both sites the per capita amounts are taken to be in the category 25-50 l/c/d.

Looking at the reliability figures from the household surveys for the dry season, which is the critical time, it is clear that people are not getting a reliable supply (Tharawatte: 66% not reliable, 10% very unreliable; Awarakotuwa 100% not reliable), although it does not actually dry up completely. The reliability classification is therefore assigned as "Poor".

Most of the water used, at least for drinking and food preparation, is from the piped supply. This is treated water which would be expected to be a good quality. However, the household data reveal a generally low level of satisfaction with the water quality and fairly high incidence of water-related illness: Tharawatte 82% say quality is fair or poor (dry season), 48% suffer from diarrhoea many times or occasionally; Awarakotuwa 72% say quality is fair or poor, 30% suffer from diarrhoea many times or occasionally. Although the figures for Tharawatte are somewhat worse (perhaps reflecting the higher use of unprotected drinking water from the piped supply, or the worse sanitation facilities), for both sites a water quality classification of "Poor" is assigned. The resulting actual availability classification is **1** in each case.

(b) Surface water – rural sites

Primary availability
Both the study sites are in the Deduru Oya basin. In order to estimate the primary availability, the available river flow data for the basin were assembled (Table 5.2), and the key quantities for these sites – the mean annual runoff and the mean annual rainfall for the catchment corresponding to each gauged location – were determined as presented in Table 5.6. The flow values are given in terms of runoff depth in millimetres to standardise them with respect to catchment area.

Table 5.6 *Mean annual rainfall and runoff in the Deduru Oya basin*

Catchment code	Period of data:		Mean annual:	
	All years	Complete years	Rainfall (mm)	Runoff (mm)
9901	27	21	1930	486
9902	2	2	1850	449
9903	18	8	2000	977
9904	31	23	1680	435
9907	8	6	1660	678

A plot of mean annual rainfall versus mean annual rainfall (Figure 5.5) can be used to provide an approximate means of estimating the runoff for ungauged sites. There are several factors which mean that estimates based on this plot are preliminary. First, data are only available for very few catchments, and the range of catchment sizes is limited; either from about 100 to 200 km^2, or greater than 2000 km^2. Second, some of the flow stations have very short records, and they do not cover the same period of time. (The fitted line shown in the figure has been adjusted to take account of the very short records). Third, as noted earlier the Deduru Oya basin has a large number of small reservoirs or tanks, and several canals (anicuts) divert water within the basin. The tanks are always on small headwater tributaries, and the area controlled by each is small. But, overall they must have a substantial impact on flows. It would be a major data collection and modelling task to make a systematic evaluation of this factor, and this is not feasible within the scope of the present study. Instead, the observed flow data have been used as they stand. It must be accepted that this does not give a true representation of the natural water availability, but it does give an idea of the status of the catchment as it presently exists, and this is reasonable bearing in mind that some of the tanks have been established for a very long period.

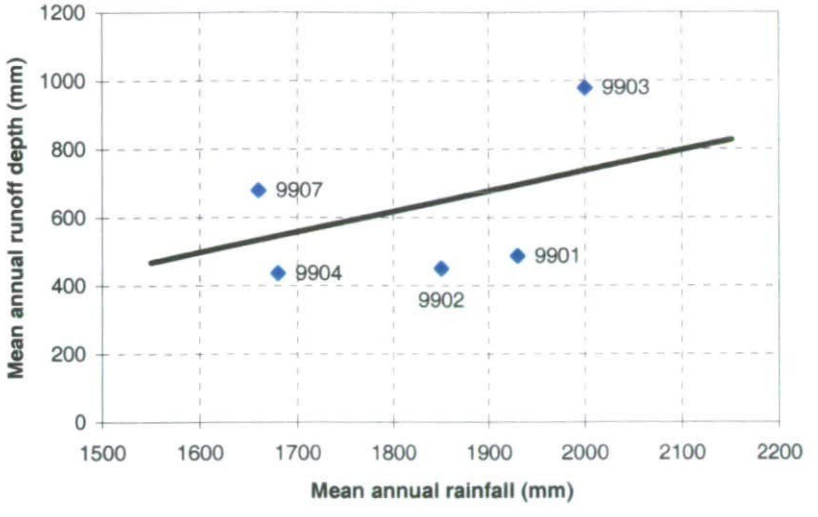

Figure 5.5 *Mean annual rainfall and runoff in the Deduru Oya basin*

For Tissawa, the village lies beside the main Deduru Oya river with a catchment area of 590 km^2. The mean annual catchment rainfall is 1900 mm, and from Figure 5.5 this gives an estimated mean annual runoff of 677 mm. At Agarauda there is no main river, and in fact no stream near the village can be identified on the 1:50,000 scale map. A notional catchment area of 2 km^2 has been assumed. The annual rainfall is 1400 mm, and runoff is estimated at 379 mm.

In order to look at the variability of the runoff, the mean monthly flow patterns in the basin are plotted in Figure 5.6. This shows a strong seasonal pattern at all sites, with very low dry season flows.

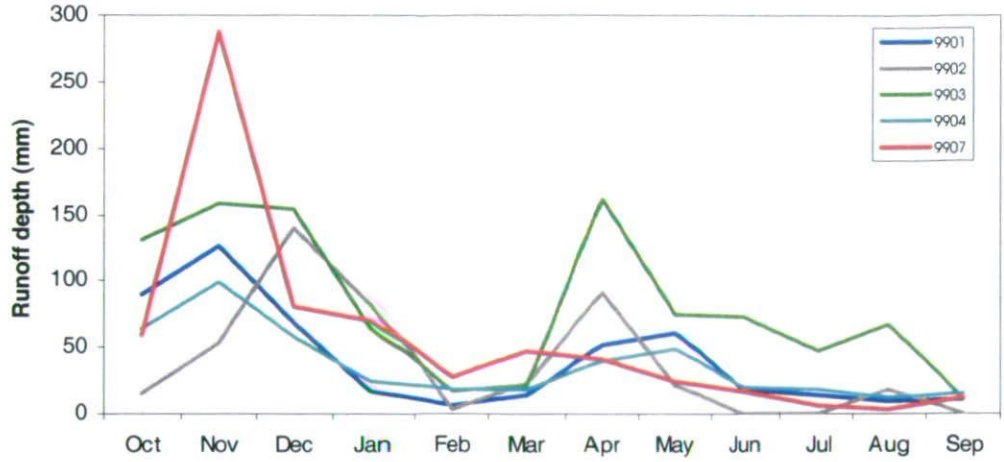

Figure 5.6 *Mean monthly runoff patterns in the Deduru Oya basin*

There are two stations for which the reliability of the low flows can be examined (at the other sites the periods of data are too short for this to be feasible). For station 9904 with a catchment area of 2611 km^2, the 1 in 10 year low runoff in the driest month (February) is approximately 8.5 mm, while for the smaller catchment, 9901 (area 233 km^2) it is zero. We can conclude that for the very small catchment of only one or two square kilometres at Agarauda, the reliable flow would also be zero. In the case of Tissawa, there is no directly comparable catchment with data. Gauge 9904 has low runoff of 8.5 mm and a mean of 435 mm. If the Tissawa catchment were directly comparable, the 1 in 10 year low runoff might be assumed to be 13 mm (compared to a mean of 677 mm). However, as the catchment area is substantially smaller than at 9904, it has been assumed that the low monthly runoff is half of this, that is 6.5 mm. In terms of quantity this gives 3.8 million m^3 per month. The population of Tissawa village itself is only 720, but this water availability would apply to a larger population. Taking the next larger administrative division (the D.S. Division of Wariyapola), the population from the 2001 census is 56,376, and assuming the water availability relates to this, the per capita amount is 2220 l/c/d. Even allowing for the very substantial uncertainties in this procedure, a figure of >100 l/c/d seems reasonable.

The above figure for water amount has been estimated for a 1 in 10 year exceedance (reliability of 90%). However, the amount is very large, and it is assumed that at higher reliabilities, the amount would still be more than 100 l/c/d. A reliability classification of "Good" (equivalent to 95-98%) has been assigned.

The natural water quality in the basin is not known, but some samples of surface water indicate that while actual quality is poor, the only naturally occurring problem is the high levels of iron. However, this does not present a health risk, and a classification of "Good" is assigned for the natural water quality. (See below for more details of water quality). The resulting primary availability classifications are then: Agarauda **0**, Tissawa **7**.

Actual availability – Agarauda

In Agarauda the only useable surface water supplies are from the tanks. All drinking water is taken from groundwater sources, while for food preparation and cleaning most households use the groundwater, but some take it from the tanks. For other purposes (bathing, agriculture, livestock and cottage industries) only the tanks are used, with a very few exceptions. Some basic information on the tanks was obtained from the Department of Agrarian Services databook (2000). The two for which data were recorded in Agarauda are:

- Ihala Agarauda Wewa: dam length 1600 ft, command area 10.1 ha, gross catchment area 0.52 km^2, net catchment area (excluding upstream irrigation schemes) 0.26 km^2.
- Pahala Agarauda Wewa: dam length 1000 ft, command area 9.7 ha, gross catchment area 0.52 km^2, net catchment area (excluding upstream irrigation schemes) 0.26 km^2.

The basic purpose of the tanks is to provide irrigation water for paddy rice cultivation, and the irrigation requirement dominates in terms of quantity. The tanks help to regulate the flow for cultivation in the main rice growing season (the Maha season, October to March), and are usually used to grow other crops in the drier season (Yala, April to September). Following standard Irrigation Department techniques for small catchments (Ponrajah, 1984), combined annual yield of the two very small catchments supplying the village is estimated as 135,000 m^3. Over the stated command area of 19.8 ha this would provide only 680 mm per year. This seems barely enough for rice cultivation, although the rainfall input also needs to be taken into account. People report that there is a shortage of water for irrigation, and the last two years have been drought years in which reduced crops have been produced. A detailed analysis of cropping patterns and agricultural water needs would be needed to determine the adequacy of water availability for irrigation. Even if the data needed for this were available, it is beyond the scope of this study.

Examined in per capita terms, the amounts of surface water available are very large and certainly much more than 100 l/c/d. Therefore the highest classification of amount can be assigned. The reliability of supply for domestic purposes is high because water is available in the tanks all year round even in a drought year. However, we also need to take into account the apparent shortage of water for agricultural needs. Also, examining the household survey data, there is clear perception that reliability is not good, with 53% of households saying it is "not reliable" in the dry season. The reliability classification is taken to be "Poor".

Twelve samples of surface water quality were analysed for three locations in the basin, and these are assumed to be representative of the whole basin. Compared to WHO standards, there is a clear health risk with faecal coliforms present in many of the samples. In addition, colour, turbidity and iron levels are above the recommendations. Iron in particular is very high with some samples having 2-3 mg/l against recommended values of less than 0.3 mg/l. While this does not present a health risk, it means that the water has a poor taste and stains laundry. It is the coliform levels that are critical, and poor sanitation with the tanks accessible to livestock means that the quality classification is "Poor". This is confirmed by people's perception of quality from the household surveys and the high levels of water related illness revealed there (similar to the rates found in the urban study sites). The resulting actual availability classification is 1.

Actual availability – Tissawa

The situation is similar to Agarauda except that the river is also available and this is important especially for bathing and livestock. The tanks are still the main source of irrigation water. Information was only available for the main tank in Tissawa:

- Maha Wewa: dam length 1100 ft, command area 19.4 ha, gross catchment area 3.11 km^2, net catchment area (excluding upstream irrigation schemes) 1.04 km^2.

The annual yield of the catchment is estimated as 460,000 m^3, and over the command area of 19.4 ha this would provide a substantial 2370 mm per year. This is a much better situation than Agarauda, but people still report a shortage of water for agriculture.

In this case the river is also part of the actual availability, so based on the analysis above for primary availability, we can take the amount to be >100 l/c/d. The large amount available from the tanks does not alter this. When considering reliability, the classification for primary availability was "Good", however people's perception of reliability is that it is somewhat worse than in Agarauda, so it seems necessary to assign a value of "Poor" as in that case.

The water quality is assumed to be the same as in Agarauda, that is "Poor", and this is supported by very similar data in the household survey. The resulting actual availability classification is again 1.

(c) Groundwater – all sites

The yield of a well or borehole is dependent on the number and interconnectedness of fractures (if present), as well as on the thickness and nature of the regolith. Where the bottom of the regolith has insufficient permeability, the yield of the hole will depend to a greater extent on the open area of saturated regolith in the hole. In this case yields will decline as the water table falls because the saturated thickness of the regolith decreases. Due to the varied nature of the regolith, it is possible that boreholes in close proximity may have greatly different yields. Borehole yields may also decline with time if storage in isolated fracture systems or weathered zones at the bottom of the regolith is exhausted.

An examination of yield data for boreholes at Agarauda and Tissawa show average yields of 0.9 and 0.8 l/s respectively. The records state that these yields are sustainable for at least ten hours of pumping per day. It has been assumed that properly sited and constructed wells or boreholes in the regolith aquifer in Sri Lanka are capable of yielding at least 0.5 l/s for eight hours per day given no constraint on recharge.

Well and borehole construction

Hand-dug wells and boreholes are both used to abstract groundwater in the study areas. Hand-dug wells have diameters ranging up to ten metres, and are excavated through the regolith to the fractured zone at the top of the basement. Explosives are sometimes used to break up solid basement rock. Horizontal adits may be installed to increase yields by using a small drilling rig inside the well. These wells are time consuming and laborious to construct, but require relatively little equipment.

Boreholes are usually drilled using rotary down the hole hammer techniques. Fifteen centimetre (six inch) casing is usually installed to support the top of the regolith, and drilling proceeds through the casing into the fractured or weathered basal part of the regolith at a diameter of about twelve centimetres (five inches). The hole is usually left open beneath the casing. Boreholes are usually 30 to 50 metres deep, although depths of up to 80 metres are recorded in both the Agarauda and Tissawa areas. Borehole siting is improved using geophysical methods such as resistivity to detect fractures in the basement as well as thick weathered zones. Both the siting and the drilling of boreholes is relatively expensive.

Groundwater quality

Groundwater quality is broadly similar in both shallow and deep wells. High concentrations of total dissolved solids (frequently > 1000 mg/l) and high hardness (> 400 mg/l as $CaCO_3$) characterise many of these waters. The waters are frequently slightly acidic, which may allow the mobilisation of metals such as aluminium, although alkaline waters are also found. Fluoride concentrations greater than the World Health Organisation guideline maximum value of 1.5 mg/l are a fairly common occurrence. The concentration of dissolved species such as fluoride depends on the residence time of the groundwater in the aquifer, the nature of the host rocks and other geochemical factors. It can be difficult to predict the fluoride concentration in groundwater before drilling a well, and concentrations may differ markedly between wells that are relatively close together. High levels of iron are also relatively common in many parts of the country.

There is evidence of contamination of shallow and deep regolith groundwater in Sri Lanka by human and agricultural sources, characterised by elevated concentrations of ammonium, nitrate, chloride, phosphate and other dissolved species. Pit latrines and polluted rivers and canals are examples of sources of such contamination. In Colombo only 60% of households have sewers, with the balance making use of septic tanks or pit latrines. Sewers may also leak or discharge to surface waters without prior treatment. Risk assessments will depend on local sources and aquifer characteristics, since contaminants in the regolith aquifer are unlikely to be transported over large distances.

Recharge

Recharge to the regolith aquifers in Sri Lanka depends on factors including topography, plant cover, rainfall factors and actual evapo-transpiration. Recharge has been estimated as being as high as 40% of rainfall in those areas with uniform and deep soils, and a deep water table (Engineering Consultants; 1999). In other areas recharge is lower, between 1% and 10% of rainfall. Irrigation returns contribute significantly to recharge in many parts of Sri Lanka. For the purposes of this study, it has been assumed that recharge is at least 15 mm per annum in all of the study areas.

Primary availability of groundwater

Available amounts of groundwater per capita will depend on the number of people per unit area taken into account for each study area. If the populations used are those given for each study area, and a five kilometre radius around each area is taken as constituting the boundary of the groundwater resource, then even the low estimate of recharge of 15 mm per annum will supply each person with more than 100 litres per day. However, it is unlikely in the two rural areas and impossible in the two urban areas that the populations being considered will have sole claim to the groundwater existing beneath an area as large as this. More realistic areas of 500 m radius in the two urban study areas and 1000 m radius in the two rural study areas have been chosen when considering the primary or potential groundwater resource. (The primary availability of groundwater is sensitive to this parameter, and more exact estimates would need accurate measurements of the recharge area "available" to each community.)

Tharawatte and Awarakotuwa: Recharge has been assumed to be an average of 30 mm per annum at these two urban study sites, given the relatively flat topography and the presence of standing water close to both sites. This recharge would provide both populations (460 and 520 people respectively) with a primary groundwater resource of about 140 and 120 litres per person per day (l/c/day) respectively. Five wells, each yielding 0.5 l/s over an eight hour day, would be needed per area of 500 m radius to supply this water.

Agarauda and Tissawa: If a recharge area of radius 1000 m is considered for each of the study areas, then even with recharge as low as 10 mm per annum, available amounts for the stated populations are 246 and 120 l/c/day respectively. Six wells, each yielding 0.5 l/s over an eight hour day, would be needed per area of 1000 m radius to supply this water.

Reliability of groundwater supplies has been taken to be "Very good" for all of the areas. Probable recharge amounts of at least 15 mm per annum imply that properly spaced, sited and constructed wells (possibly large diameter with adits) should yield 0.5 l/s for 98% of the time or higher (i.e. susceptible to a one-in-fifty year drought). Once again, a more detailed study (of local geological and recharge factors) could lead to this assessment being downgraded.

Groundwater quality has been taken to be "Good" in all of the four study areas. None of the available analyses of water from the four study areas showed fluoride concentrations in excess of WHO guidelines. High salinity (total dissolved solids) and hardness might be expected at the sites and although this is not desirable, available analyses show that these are not in excess of permissible Sri Lankan standards. More specific analyses of groundwater from the study areas, including a range of trace constituents, could however lead to the primary quality assessment being downgraded. It is possible that brackish surface waters at Awarakotuwa may cause the shallow groundwater at that site to be too saline to drink.

These assessments lead to a primary groundwater availability figure of **8** for each of the four study areas.

Actual availability of groundwater

Awarakotuwa: No groundwater facilities exist at this site, so the assessment is not relevant.

Tharawatte: One large diameter well exists at Tharawatte, serving a population of 460 people. If it is assumed that this well yields 1 l/s for 8 hours per day, this gives an amount of just over 60 l/c/day. Quality is assumed to be "Poor" since this is an urban area with known anthropogenic pollution of groundwater, and the household surveys show that the water is not used for drinking or food preparation by the community. Reliability of the resource is assumed to be "Fair", since the effects of other abstractions together with possible mechanical failure of the well must be considered. The site is therefore awarded an actual availability figure of **2**.

Agarauda and Tissawa: Large numbers of shallow and deep wells and boreholes exist in the vicinity of these two study areas, and there is evidence that groundwater is used extensively for both domestic and agricultural purposes. It is difficult to estimate the exact amounts available, in the absence of data regarding well locations. It has been assumed that the amount available at Tissawa is >100 l/c/day, since water from either wells or boreholes is used for almost all drinking and food preparation purposes, and most washing and cleaning. At Agarauda, roughly 30% of water for food preparation, washing and cleaning is drawn from tanks. It is therefore assumed that actual availability of groundwater is lower at this study site. A value of 50-100 l/c/day has been assigned, although it is realised that the greater proportion of tank water used may be a reflection of the convenient positions of tanks in the area rather than the lack of groundwater[36].

Water quality at both sites has been classed as "Poor", in recognition of the fact that more than 70% of households at Agarauda and Tissawa report illness due to water (almost all water drunk is groundwater, most of it from "protected" sources). 30% of households in Tissawa and 18% of households in Agarauda reported frequent occurrences of illness. It is most likely that this illness is due to microbiological contamination, probably from pit latrines and waste-water soakaways.

Most respondents to the surveys in Agarauda and Tissawa (66% and 100% respectively) report that their water supply is "not reliable" during the dry season, although this refers to all water sources. Tanks and other surface water sources might be expected to dry up during the dry season, but groundwater sources should persist. The reliability of groundwater at both sites has been classed as "Fair" in reflection of the household survey results. This is better than the category of "Poor" assigned to the surface water sources on the basis that groundwater is inherently less variable.

This leads to a rating for actual groundwater availability at both rural sites of **2**. Note that this low rating is due primarily to information gained from the household surveys, which report that both water quality and reliability are poor.

5.5 Summary and results for overall availability

Table 5.7 summarises the findings discussed above for the primary water availability assessment at each site from both surface water and groundwater. Table 5.8 gives the same results for the actual water availability assessments.

Table 5.7 *Summary of primary water availability assessments – Sri Lanka*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Tharawatte	Surface	>100 l/c/d	Very good	Good	8
	Ground	>100 l/c/d	Very good	Good	8
Awarakotuwa	Surface	>100 l/c/d	Very good	Good	8
	Ground	>100 l/c/d	Very good	Good	8
Agarauda	Surface	Negligible	Not relevant	Not relevant	0
	Ground	>100 l/c/d	Very good	Good	8
Tissawa	Surface	>100 l/c/d	Good	Good	7
	Ground	>100 l/c/d	Very good	Good	8

Table 5.8 *Summary of actual water availability assessments – Sri Lanka*

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
Tharawatte	Surface	25-50 l/c/d	Poor	Poor	1
	Ground	50-100 l/c/d	Fair	Poor	2
Awarakotuwa	Surface	25-50 l/c/d	Poor	Poor	1

[36] Average yields for boreholes in the Agarauda and Tissawa areas are 0.9 and 0.8 l/s respectively, meaning that a single well pumped for eight hours per day would supply 100 l/c/day to about 240 people. Only two such wells at Agarauda and three at Tissawa would therefore be sufficient to supply the populations with this "maximum" amount. The amount stated for Agarauda should therefore be regarded as conservative.

Community	Source	Water amount	Variability / Reliability	Water Quality	Water availability indicator
	Ground	Not relevant – only surface water used			n/a
Agarauda	Surface	>100 l/c/d	Poor	Poor	1
	Ground	50-100 l/c/d	Fair	Poor	2
Tissawa	Surface	>100 l/c/d	Poor	Poor	1
	Ground	>100 l/c/d	Fair	Poor	2

To provide the overall water availability classifications, the results for surface water and groundwater are combined as follows (Table 5.9):

Primary availability
All sites – the result is **8**. For the urban areas there a good quantities of both surface and groundwater and the classifications are similar for both. Since the doubts about water quality are what limits the availability, this remains the same for the combined assessment. For the rural areas, groundwater availability is better than surface water, and this has taken to indicate the overall result.

Actual availability
Tharawatte – the result is **2**. Both surface and groundwater are used, with groundwater having the slightly higher rating. The poor availability of surface water is not thought to be sufficient to raise this.

Awarakotuwa – the result is 1. No groundwater is actually used, so this is based on the surface water supply system.

Agarauda and Tissawa – the result is **2** for both sites. Groundwater is considered to be more reliable and has a higher rating so this is used. Although surface water is abundant its low reliability and poor quality do not add to the availability significantly.

Table 5.9 *Overall water availability assessments – Sri Lanka*

Community	Water availability indicator Primary	Actual
Tharawatte	8	2
Awarakotuwa	8	1
Agarauda	8	2
Tissawa	8	2

Overall, the results for Sri Lanka show a striking contrast between the high primary availability and the very low actual availability. Generally water is abundant, but the systems which get it to people are inadequate and water quality is universally poor. The two urban study sites are disadvantaged communities who do not get adequate recognition of their needs from the supply authorities. In the rural sites, the water quality problem is dominant with serious pollution from livestock and human sewage likely to be the main factors.

6. Sources of Information and Acknowledgements

The sources of information used in the assessment of availability (although not all are specifically referenced in text) were:

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Topographic maps, scales 1:250,000 and 1:50,000, Survey Department, Sri Lanka.

Acknowledgements
For assistance in carrying out this work and for supplying the information requested, we are extremely grateful to the following who provided generously of their time and knowledge:

Tanzania – Staff of the Arusha Urban Water Supply and Sewerage Authority, Arumeru District Council, and the University of Dar es Salaam.

South Africa – Staff of Estcourt Municipality and AquAmanzi.

Sri Lanka – Staff of the National Water Supply & Drainage Board, International Water Management Institute, and the University of Moratuwa.

Appendix 4
Integration of Socio-Economic and Environmental Data within GIS for the Water Poverty Index

Dermot O'Regan, CEH Wallingford

Introduction

The effective analysis and management of human and natural resources requires a comprehensive and accurate information base to reduce uncertainty and enhance decision-making. The ability to integrate social, economic and biophysical data enables managers and policy makers to formulate effective strategic development tools. Data on the social, economic and environmental aspects of regional development are collected at different scales, in different formats, and for different purposes. This creates technical difficulties in integrating these data sources. Recent advances in geographic information systems (GIS), however, have made it possible to integrate data from disparate sources into a common system for display, analysis and mapping. A GIS can be defined as a computer system capable of integrating, storing, analyzing and displaying geographically referenced information, i.e. data identified according to their locations. Using GIS, a spatially distributed database provides the basis from which the Water Poverty Index can be calculated at different management scales – community level, basin level and national level.

Data Integration for the Water Poverty Index

Water Poverty Index team members in each of the study countries – in Sri Lanka, Tanzania and South Africa – have been developing GIS databases for the integration of basemaps, community and water point data, and ancillary data at relevant scales for the study sites. Digital basemaps from the national to the community scale have been integrated with ancillary data such as catchments, transport networks, land use and vegetation cover. These 'layers' of background information can then be combined with the collected community and related water point data as in Figure 1.

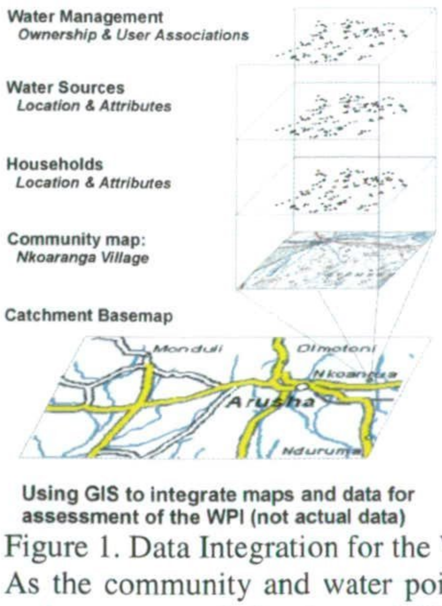


Figure 1. Data Integration for the Water Poverty Index

As the community and water point data were collected at each site, the location of each was recorded using a GPS receiver. GPS refers to the 'Global Positioning

System', a network of 24 satellites which enable the user to determine their position on Earth accurately. This reading can be read directly by the GIS and the location of the community or water point represented by a point referenced to the same projection as the basemap, and so its location displayed accurately. The Water Poverty Index survey teams have collected data at over 1400 locations in the three countries. This information, the 'attributes' of the location, is entered into the GIS database and thus has a spatial dimension, and this information is then said to be 'geo-referenced'.

The following figures show examples of the GIS mapping resulting from the integration of data from each of the study countries. Analyses carried out so far include establishing the distances household members travel to collect water and the distribution of and variation in concentrations of 'wet' and 'dry' water points.

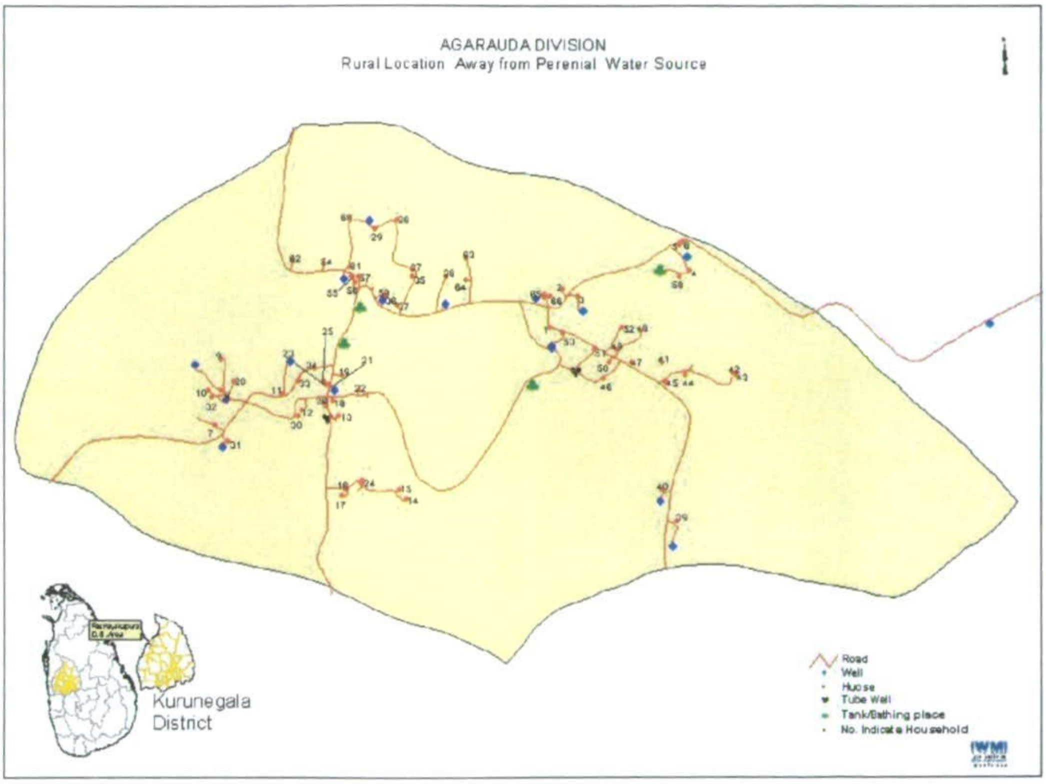


Figure 2. GIS mapping from Sri Lanka study sites
(Source: Bandula Senaviratna, IWMI, Sri Lanka)

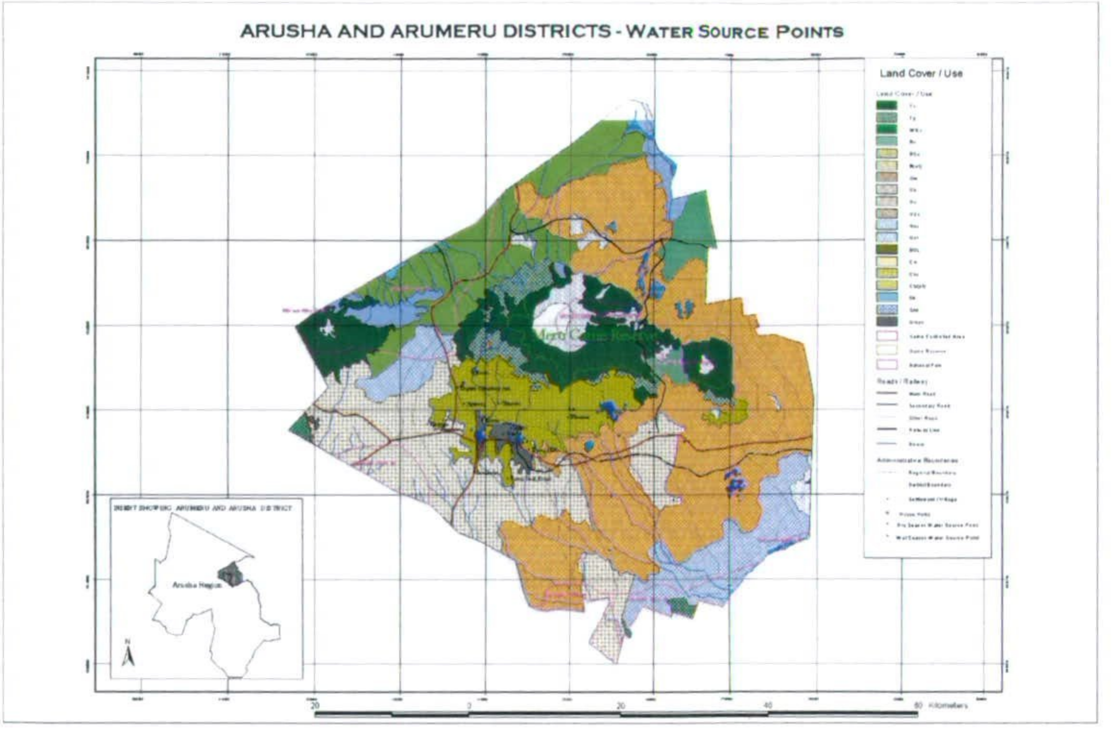


Figure 3. GIS mapping from Tanzania study sites
(Source: Prof N. F. Madulu, University of Dar es Salaam, Tanzania)

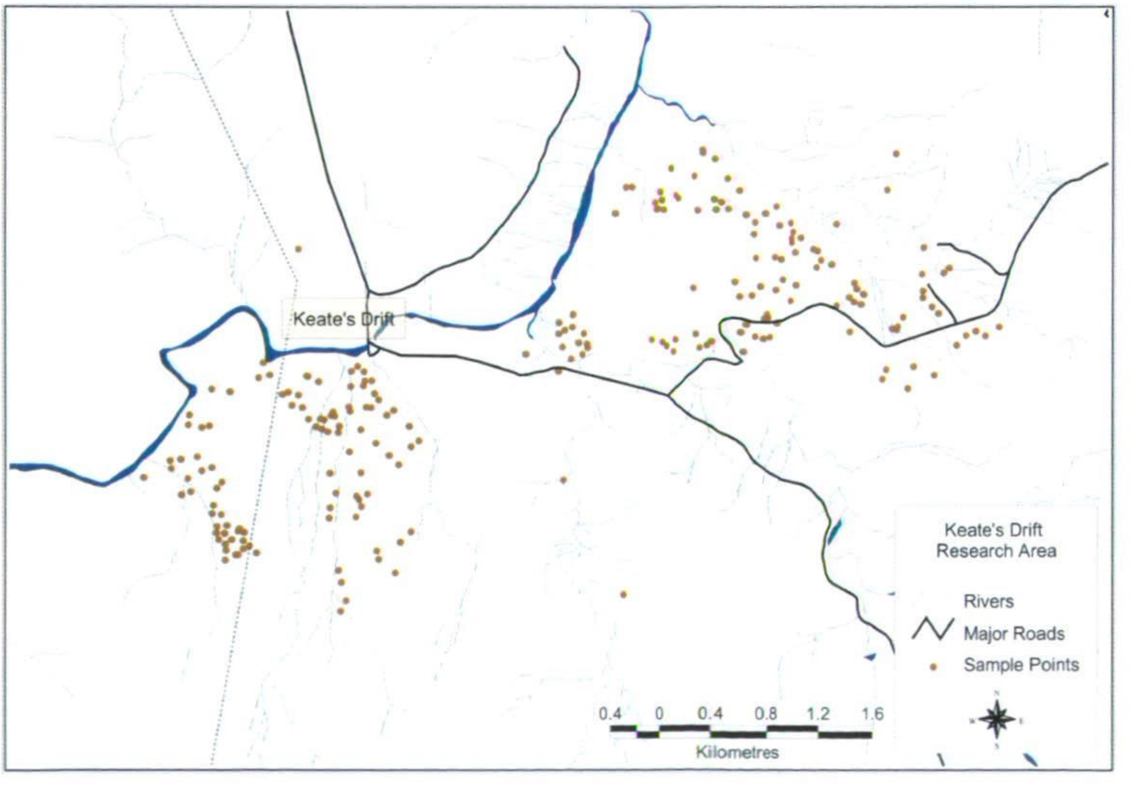


Figure 4. GIS mapping from South Africa study sites
(Source: Mark Horan, University of Natal, South Africa)

Conclusion

The work of the Water Poverty Index teams in Sri Lanka, Tanzania and South Africa has illustrated that GIS is a useful technical tool in integrating social and environmental data. A comprehensive and accurate information base has been developed for the derivation of the Water Poverty Index. The rich spatial datasets so far established in Sri Lanka, Tanzania and South Africa provide the potential for extensive spatial analysis and database querying with the aim of applied problem solving. Further analysis and understanding of the data remain challenges for the next phase of the project.

Application of the GIS approach to data integration and analysis gives a new perspective on the processes and change taking place in natural and human environments. The use of geographical information systems in the development of indicators and decision-support tools such as the Water Poverty Index helps to solve real-world problems and further the establishment of the sustainable livelihoods needed to address the problem of poverty.

Appendix 5
The WPI Consultation Process

Consultation process in developing the tool
The project was designed to rely heavily on an extensive consultation process which allowed a wide range of stakeholders to participate in many different ways. This was planned as a means of developing some sense of 'ownership' of the WPI by a wide range of groups. The first part of this process took place in a the conceptualisation workshop in Arusha, in May 2001, and then followed up by a second conceptualisation meeting in Wallingford in December 2001. These are described below.

Appendix 5.1
The Arusha conceptualisation workshop, May 2001 in Tanzania.

5.1.1. Conceptualisation Meeting Participants

Prof. Yadon Kohi,	Director General, Commission of Science and Technology, Tanzania.
Mr. Steven Mlote	COSTECH, Tanzania
Dr. Caroline Sullivan Wallingford,UK	Head of Water Policy & Management, CEH,
Dr. Bill Cosgrove UNESCO.	Ecoconsult, Canada and World Water Council,
Prof. Tony Allen	London School of Oriental and African Studies, UK
Mr. Siyan Malomo	Commonwealth Science Council, London.
Dr. Jerry Delli Priscoli	US Army Corps of Engineers, USA
Prof. Ndalahwa F. Madulu	University of Dar es Salam, Tanzania
Dr. Madar Samad	International Water Management Institute, Sri Lanka.
Prof. Roland Schulze	University of Natal, South Africa.
Dr. Peter Lawrence	University of Keele, UK
Mr. Roger Calow	British Geological Survey, UK
Dr. Craig Hutton	Geodata Center, University of Southampton, UK
Dr. Jeremy Meigh	Center for Ecology and Hydrology, Wallingford.UK
Mr. Ian Smout	Water and Environmental Health, Loughborough, UK
Dr. Mike Acreman	Center for Ecology and Hydrology, Wallingford.UK
Ms. Sue Milner	Natural Resources Institute, UK.
Dr. Jackie King	University of Cape Town, South Africa
Ms Emma Tate	Center for Ecology and Hydrology, Wallingford. UK

Mr. A. Aconaay	Regional Water Engineer, Arusha, Tanzania
Mr. Mohd. B Loisenget	Arumeru District Water Engineer, Arusha, Tanzania
Mr. Joshua Mgeyekwa	Arusha Urban Water Supply & Sewerage Authority, Tanzania
Mr.Asil A. Munisi	Managing Director, Arusha Urban Water Supply & Sewerage Authority

External reviewers not able to attend but who sent contributions, and who will review the workshop outputs and contribute further to the WPI development process.

Dr. Peter Gleick, Pacific Institute, USA

Dr. Athar Hussain, London School of Economics

Mr. Alan Hall, Global Water Partnership

Professor Stephen Foster, British Geological Survey

5.1.2. Conceptualisation Meeting Agenda

Water Poverty Index Conceptualisation Meeting,

Arusha, Tanzania, May 2001

Agenda

For inspiration, a quote ….

'If you can develop a practical and representative index that can be utilised at regional/district or lower levels then this may be a useful monitoring tool for measuring progress of Tanzania's Poverty Reduction Strategy'. **George Macdonald DFID Tanzania, May 2001**

Sunday 20th May

Arrivals, reading and preparation day. (Comprehensive reading materials and references provided by CEH Wallingford)

7.30 Welcome Dinner.

Monday 21st May.

Session 1.

9 am Opening remarks
Prof. Yadon Kohi, Director General, Tanzanian Commission of Science and Technology.

Introduction to the WPI
Dr. Caroline Sullivan, Head of Water Policy and Management, Centre for Ecology and Hydrology, Wallingford, UK

Which Water Are We Indexing And Which Poverty?
Prof. Tony Allan, SOAS, University of London

Conflicts In Water Resource Use In Developing Countries: The Case of Tanzania
Steven D M Mlote (Reg. Eng [T]) Tanzania Commission for Science and Technology

The Use Of Index Numbers: An Economist's Perspective

Dr. Peter Lawrence, Dept. of Economics, University of Keele, UK

Some practical issues and solutions from Yemen and Gujarat

Bill Cosgrove, President, Ecoconsult Inc. (Canada). (Vice President, World Water Council)

Some thoughts from absent friends..... a virtual contribution from Peter Gleick Director
Pacific Institute for Studies in Development, Environment, and Security, and from the Global Water Partnership. Presented by Dr. Caroline Sullivan

Coffee

Session 2

Social Deprivation and the Water Poverty Index

Dr. Siyan Malomo Commonwealth Science Council, London.

A perspective on groundwater

Roger Calow, British Geological Survey, UK

Environmental water allocation

Dr. Mike Acreman, Head of Hydro-Ecology and Wetlands, Centre for Ecology and Hydrology, Wallingford, UK

Sustainable use of water: managing the donor aquatic ecosystems

Dr Jackie King Institution: SouthernWaters Consulting, University of Cape Town, South Africa.

Physical evaluation of water resources for the WPI

Dr. Jeremy Meigh, Centre for Ecology and Hydrology, Wallingford. UK

Seasonal Variations In Water Availability And Demand

Ian Smout, Acting Director, Water Engineering and Development Centre, Loughborough University, UK

Getting the WatSan data - and the choices implicit in the WPI
Sandy Cairncross, Professor of Environmental Health, London School of Hygiene and Tropical Medicine. **Note:** *Professor Cairncross was unable to attend due to visa problems, and this presentation was given by Ian Smout, his colleague from WELL.*

1-2 Lunch

2 pm Session 3 Review of field sites

Water needs in Tanzania

Prof. Ndalahwa F. Madulu , University of Dar es Salam, Tanzania.

The Thukela Catchment : Biophysical Background Towards a WPI.
Roland E. Schulze, Professor of Hydrology, University of Natal,

The Sri Lankan Case Study: Salient Characteristics of Field Study Locations.
Dr. Madar Samad, International Water Management Institute, Colombo, Sri Lanka.

Field Survey Structure: Key Issues For Discussion

Dr. Craig Hutton, GeoData Institute, University of Southampton

3pm **Tea**

3.20 pm **Session 4**

Small group discussion and consensus-building - Determining possible WPI structures

4.45pm Presentations to the plenary

Close 5.30 pm.

7.30 pm Evening cocktail and buffet.

TUESDAY 22nd May

8 am Departure to field sites.

Picnic lunch en route

3 pm return to Arusha in time for tea.

3.30 – 5.30 appropriate structures for calculating the WPI. (small workgroup discussion)

7pm **Dinner**

WEDNESDAY 23rd May

9 am	Plenary debate on *suggested structures* from Tuesday workgroups
10.30	Tea
11am	Small group discussion and consensus building on *structure selection*
1pm	lunch
2- 5 pm	Structure selection report-back; plenary debate and identification of WPI frameworks
5- 6pm	Farewell drink for departing members
8 pm	Dinner

THURSDAY 24TH MAY

9am	Working breakfast
10-12.30	Write-up session 1.
12.30	Lunch
2-4 pm	Write-up session 2.
8pm	**Closing Dinner**

FRIDAY 25TH MAY **Departures**

5.1.3: Summary of WPI conceptualisation meeting, Arusha, May 2001

Objective of the project:

'To develop an evaluation tool for assessing poverty in relation to water resource availability'.
Or, as Professor Kohi said, *'How will we measure the not-enoughness?'*

1. Outcome of discussions about the development of the WPI:

The discussion is summarised under four headings:

- Uses of the WPI;
- Derivation of the WPI;
- Format of the WPI;
- Specific components of the WPI.

1.1 Uses of the WPI:

- By water resources/services managers as a performance indicator related to efficiency;
- For benchmarking utilities;
- For IWRM;
- For intervention;
- For both higher decision-makers and at community level for prioritisation;
- As a benchmark for change, to look at trajectories and see how situations are developing, and thus as a measure of progress. Higher level users might need to know how to get from one situation to another, and what options are available to do so;
- At the national level as a comparison tool;
- For management of the community;
- Used above community level to identify need for intervening wherever capacity or availability is low, then at community level could elaborate on the problem in more detail;
- This is a monitoring tool, not to provide a solution to what that tool indicates. It is up to policy makers to respond to the results.

1.2 Derivation of the WPI:

Must be applied at different levels (an all encompassing index is confusing). Four levels are suggested: Community (as a tool to push them upwards), Funding agency (measurement of development), District (as measure of performance), Ministry (as measure of performance). These should all be consistent and commensurate. Apply/derive the index from the bottom up (community level first). Quality not quantity of community surveys; Periodically check if sensible indicators are being measured – revisit the indicators;

Apply WPI to the worst case scenario, seasonally, or annually. Availability must be assessed in a dry season of a dry year (the critical situation). Maybe annual to start with, then seasonal (like an employment index - seasonally adjusted WPI); May be possible for communities to carry this process out themselves, and then they themselves could do something with the index.

Need targets rather than simply a position on a scale, and trajectories of change in the matrix. Poverty felt at household level – index should capture this, not aggregate so much that this is lost. Need an effort to see how people see good and bad life and where water fits into their wider priorities. Asking community about water problems will miss wider socio-economic problems.

1.3 Format of the WPI:

A framework to be consistently used, with components the same but the way they're derived depending on the scale at which they are used (cf. Retail Price Index). Overall framework should be the same for all situations to give it generic value. Could incorporate the Montreal meeting ideas.

To be used at various levels – thus a matrix would be applicable (e.g. capacity (physical, behavioural, social) versus availability); Should not be static. Indices are static snap shots. Could have a series of snap shots to monitor change; Measures of current situation (status - access) and potential situation (process - capacity) – these should not be confused.

Could use a matrix as a starting point, then continue with more detailed indices; Set a framework which is refined when the community itself says what is important - Develop the framework as the information arrives, then finalise the format later. Need participatory development of indicators. Need a limited number of indicators to put together in the matrix (consider what is important and use a points system for rating them); Must see that what is relevant at local level is same at higher level – must be the same at all scales.

Shapes/diagrams give a good instant picture of water status, better than scores. Can alter their shape to show trajectories of change. Matrix of 'Availability and Access' versus 'Capacity and Use', or have a column for each of the four categories. Use a big matrix box to get the broad picture and the small sub-boxes to get detail. 'Adequacy' incorporates the idea of access, and could be an axis. Could call it 'Access' for high level application, and 'Adequacy' for application at community level.

Agreed four categories, but use simple words: Access; Availability; Capacity; Use;
Index could be gap between C-U and Av-Ac, *e.g.*: (C-U) + (Av - Ac) = WPI;
Index could be represented as an arrow in the matrix. Could use a Geographical Information System (GIS) to represent the index visually, to highlight areas of stress.

Need to be able to use existing data and supplement these with surveys.

1.4 Specific components of the WPI:

At community level should have a measure of need as well as capacity and availability - perhaps using *perceived* need, or 'Adequacy' instead of 'Availability and need', and could use a triangle of perceptions of water availability (society-economy-environment) whereby different perceptions are compared. Need to look at the capacity for sharing resources, and a livelihoods component;

State of the environment is a key issue -- have an element to account for environmental degradation (this is difficult to measure as perceptions vary widely).

Need to incorporate the 'hard' version of environment (that which is central to the community's life support systems) into the index instead of a vague, woolly idea.

Must include ecology; consider alternative sources used throughout the year at various times; Must build-in environmental/ecological integrity to consider sustainability.

Need an indicator of vulnerability/security/risk of system. Could be ecological or environmental risk, but static measurement is not sufficient: just monitors the decline. However, measuring something that incorporates risk incorporates an awareness of that decline – may not pick it up in time otherwise and thus would not be able to act on it. Need that safeguard, as environmental degradation is usually a long-term phenomenon. Must incorporate an element of risk into a static indicator.

Need to look at allocation to different types of use. If aggregation of indicators is used, need indicators that can be sensibly aggregated into a new one.

Appendix 5.2
Second conceptualisation meeting, Wallingford, December 10, 2001

This meeting was held to provide the opportunity for discussion of the project progress, and to provide the chance to develop the ideas further, after the test-bed data had been collected.

5.2.1. List of participants

Dr Mike Acreman	CEH Wallingford
Dr Bill Cosgrove	Ecoconsult
Mr Roger Calow	British Geological Survey
Mr Tim Fediw	CEH Wallingford
Dr John Gash	CEH Wallingford
Ms. Anna Maria Giacomello	CEH Wallingford
Dr Peter Gleick	Pacific Institute for Dev't, Environment, & Security
Mr Alan Hall	HR Wallingford Ltd
Dr Caroline Hunt	London Sch. of Hygiene & Tropical Medicine
Dr Athar Hussain	London School of Economics
Dr Craig Hutton	GeoData Institute, University of Southampton
Dr Peter Lawrence	Keele University
Dr Jeremy Meigh	CEH Wallingford
Ms. Sue Milner	Natural Resources Institute
Mr Steven Mlote	Costech, Tanzania
Dr Madar Samad	International Water Management Institute
Professor Roland Schulze	University of Natal
Ms. Ilsa Steyl	GeoData Institute, University of Southampton
Dr Caroline Sullivan	CEH Wallingford
Ms. Emma Tate	CEH Wallingford

5.2.2. Agenda

Derivation and Testing of the Water Poverty Index Phase 1

Interim Meeting

Monday 10th December 2001, CEH Wallingford

Agenda

10.00	Arrive. **Tea and Coffee**	
10.30	Welcome and Introduction	**Dr Caroline Sullivan**
10.40	Short Presentations, as follows:	

- *Linking Poverty with Water* — **Dr Athar Hussain**
- *Developing Indicators: Experiences from the Joint Monitoring Programme* — **Dr Caroline Hunt**

- *A Brief Look at Results from the WPI Surveys* — **Mr Tim Fediw**
- *WPI Structures to be Tested* — **Dr Caroline Sullivan**
- *Identifying Variables for Use in WPI Structures* — **Ms. A.M. Giacomello**
- *The hydroclimatic context of the WPI survey in the Thukela region.* — **Professor Roland Schulze**

12.00	Group Discussion Sessions
13.00	**Lunch**
14.00	Group Discussion Sessions
15.00	**Tea and Coffee**
15.30	Feedback from Group Discussions
16.00	Task Allocations: • *Data Analysis* • *Testing of Methods* • *Development of Training Materials* • *Running of Workshops* • *Report Writing*
17.0	End of Meeting

5.2.3: Notes on short presentations

Athar Hussain
Notion of capability – what do you expect of people in their everyday life situation?
In development if an index, there is a trade-off between simplicity and detail. Need to think: for whom? For what purpose? Doesn't need to be a catch-all index – be aware of the index's limitations – the elements of the index will be influenced by our own experience.
May need to give different weightings to different elements of the index for different applications (e.g. urban, rural) where priorities are different. Virtual water is an option for richer countries with good foreign exchange. Can also move agricultural production to more water-abundant areas of the country.
Don't assume that the poor cannot pay; they're often paying lots already - the poor often pay much more for electricity than the rich – this may well be the same for water. Need to think about availability of complementary inputs, as well as of the resource itself (e.g. ability to buy a water purification system for the household is often the difference between the rich and poor).
How to account for the costs involved in gaining access? Economists reduce everything to monetary values – depends heavily on base assumptions. Some uses

have priority over others. Don't assume that different uses of water are nterchangeable (e.g. water quality issues).
Consider lexicographic ordering: certain needs have absolute priority over others. In a composite index, start with basic needs with high priority (e.g. physiological uses).
Water stress limits the choice available to people.
Water pricing is a key issue; start with the assumption that water has a price, then look at equity, and how to design a tariff to enable poor people have access to sufficient water. Index should help us in designing improved water supply schemes.
A technique might be to apply a draft index, look at the policy implications, then refine the index. Need to do a reality check – does our perception match those of the people being interviewed? Perhaps consider the negative aspects of improved water supply, for example.

Caroline Hunt
Joint Monitoring Programme of WHO/Unicef – supply country-level water supply and sanitation coverage data every five years to the UN system.
Methods:
Questionnaire to governments – asked them to circulate it
Collection of existing population-based coverage data
Entry and review of data in country files
Discussion with governments through national WHO and Unicef representatives.
Uses:
Advocacy for the sector
National and regional progress and status
A proxy for poverty
A proxy for health impact (no longer using the term 'safe')

JMP lessons for the WPI:
Water availability doesn't equal use
Local data exist in large quantities
Ease of using existing data
Existing data can improve if used enough
Just how much don't the data tell us?
How accurate are they in what they do tell us?
Will externally generated data be used locally?

Group discussion sessions
Group 1
Jeremy:
Priorities until end of March. Test the 4 methodologies. Look at reducing no of questions. Go back to the locations and see if these reflect what people say (verification). Come up with different approaches to expand database to regional levels in the 3 countries, for the next phase. Using the approach of HDI data, Bill and Peter to work together. In testing the different ways of calculating the index, do we have the kinds of data we need for each of them? Try calculating the index using a simplified set of data.

Group 2

Caroline:

Need multi-level approach. National and local? Ultimately the two could come together in the future.

Aim for broad compatibility, not perfect nesting.

Ask Caroline about extra data availability.

Use and develop a standardised framework that could use locally adjustable weights, which must be transparently determined and explained.

Index should be used for countries that are comparable (incomplete ordering).

Focus on water at core of index, look at different agro-ecological zones to do this regionally.

Health – use infant mortality rate to 5 years old.

Anything written about formation of WPI should include a 'user manual' with caveats.

WWDR people are desperate for something relevant and decent for their publication – get something out quickly.

Alan: Locally adjusted weights – possibly set according to national priority areas?

Group 3

Peter L:

What can be done with the data collected so far? Need for statistical analysis to pick out likely indicators. Would it be a household index? Must appear useable. What we be physically trying to explain? Whether people have access to improved water sources? Time to collect water? Must follow through the different methodologies of the indices (matrix etc). How might weights be derived from a statistical analysis? Lots depends on the quality of the data. This would demonstrate how useful the tool is at a local level.

Mike: Is it a circular argument? E.g. multiple regression. What are we trying to regress against? Need an independent variable. Don't regression dependent things. Do analysis to pick out the most important variables, and then can drop the least important ones.

Caroline S: Lots of work has been done on household datasets from the UK, by someone who's coming to see whether any of their methodologies would be applicable for us. Pick up significant variables.

Alan: Get an idea of how water poor people are? Very difficult concept.

Caroline S: We need to see if there is a definite link between water and household welfare.

Alan: Useful to look at Asian Development Bank's new initiative to look at water and poverty. Link into it. Feb 7-9 2002.

Mike: Need to measure all the other things that make people poor, and then decide whether it's water related.

Athar: Interested in association, not necessarily to prove causes. Water poverty raises the problem of what it means. 'What is poverty?' is also a difficult question.

Alan: No generic definition of 'water poor'.

Sue: How does the dependency between water and poverty work? Which way round is it?

Alan: For this project we can make a definition suited to what we want, but we *must* define it.
Athar: Must be explicit. Time to collect water makes sense in a rural context, but not an urban context.

Group 4
Roland:
Four points-
Household versus national level. Both levels are needed. How to link the two? Iterative process.
How a WPI could be used as decision-support? Who are we supporting? Want the WPI to be used.
How are decisions made in terms of water development in the developing world? Where are the weak links? Can we improve the situation with a WPI? Where are the bottle necks?
Optimise the data sets we have. How can it be used and by whom? How can it improve bottom-up decision-making?
Mike: Model (e.g. regression) – could it be a useful thing? Could it be used as a predictor tool? Could it be used to focus effort on key areas?
Caroline S: Attendance by girls at school is reduced by lack of toilet facilities. Emphasis on linking water availability in schools to attendance levels. Highlights the interaction between different elements of life. Can use such a tool to improve this situation.
Roger: Tempting to assume there's a homogeneous set of decision-making people, but things are decentralising and becoming demand-led. Issue for how data on water and poverty could be used to improve decisions made at many levels to improve many things. Danger of handing the index over and letting them get on with it. Get so far and then go and see how decisions are currently being made and by whom, and identify the weak links, and iterate the development of the WPI.
Caroline S: Tool for prioritising. Great.
Mike: May need to get ecological data at a national level, because local level people won't understand what we're asking. How to bring in the ecological side of things? How to test a method where you haven't got anything to test against?
Caroline S: Test our methodology on the data we've collected. Should be able to predict something about the communities, and find correlations.
Sue: Perception issue. Some sites may not represent other sites in terms of ecology. IUCN looking at how Lucy Emerton's (?) work can be used.
Roland: Aim of Phase I report? Lots of ideas for Phase II.
Mike: See what South Africa is already doing with regard to data collection – they've lots of experience in ecological aspects.
Roland: Will see how local survey fits into bigger scheme.
Sue: See how GIS can be used as a training tool, and in decision-making. Enable policy makers to understand the problems.

Appendix 5.3
Dissemination/Consultation meetings with policy makers

As part of the consultation and dissemination process in Phase 1, a number of meetings were conducted in Tanzania and Sri Lanka by Dr. Caroline Sullivan and Dr. Jeremy Meigh, and in the Republic of South Africa, by Dr. Caroline Sullivan and Dr. Peter Lawrence. The purpose of these meetings was to discuss the Water Poverty Index water management tool with policy makers and other potential end users. This was designed to allow a two way dialogue to encourage a wide range on inputs into the process of the development of the WPI, and if possible, to develop some feeling of 'ownership' in those consulted. This is considered an important component of Phase 1 of the project, since if Phase 2 were to be continued, the process would involve a wide range of government departments, and their co-operation would be essential for success.

5.3.1: Consultation meetings held in South Africa, March 2002

Meetings were held in Pretoria, Johannesburg and Capetown with the following institutions and people:

Department of Water Affairs and Forestry
Dr. Paul Roberts, Deputy Director General, Water Resources
Barbara Schreiner, Chief Director, Water Use and Conservation.
Mr. Harrison Pienaar, Assistant Director, Stream Flow Reduction Allocations

The Water Research Commission of South Africa
Dr. Rivka Kfir,CEO, Executive Director
Dr. George Green, Deputy Executive Director
Dr. Stephen Mitchell, Research Manager, Ecosystems
Dr. Sizwe Mikhize, Research Manager, Social Issues

The Department of Environment and Tourism
Dr. J.R. Pretorius, Director, Environmental Information and Reporting

Local Governtment and Water Sector Education and Training Agency
Alastair Machin, Chief Executive Officer.
Nonlilanhla Dube, Manager, Water Sector

Working for Water Programme
Dr. Christo Marais, Research Manager

Statistics South Africa
Professor Akiiki Kahimbaara, Chief Director, National Statistics Systems, Pretoria
Virginia Motsoedi Marobe, Information Officer, Johannesburg

The Mvula Trust, (Water NGO)
Mr. Martin Rall, Executive Director

DFID South Africa

Jim McAlpine (phone discussion and literature delivered)

African Development Bank
Priscilla De Gasparis, (phone discussion and literature delivered)

Positive reactions and useful comments were forthcoming from all of those consulted, along with an indication that the WPI would be useful to South Africa and would compliment and add value to work already being carried out there.

5.3.2: Consultation meetings held in Tanzania, December 2001

President's Office Planning & Privatization
Mr. Charles O. Igogo, Poverty Monitoring Programme

Ministry of Science, Technology & Higher Education
Mr. Titus Mtelcka
Mr S. A. Matemu

Ministry of Education & Culture
Mr. Oliver P. J. Mhaiki

Ministry of Water and Livestock Development
Mr. Benedict P. Michael
Mr. Ismail A. G. Mwaka, Rural water Supply & sanitation Project,

Institute of Resource Assessment, University of Dar Es Salaam
Professor R. Mwalyosi

National Bureau of Statistics (N.B.S)
Mr. Abdulrahaman M. Kaimu
Mr. Cletus P. B. Mkai

Arumeru District Council.
Mr. Mohammed, Acting Director

Arusha Urban Water Supply and Sewerage Authority, Arusha.
Mr Asili A. Munisi
Mr. Joseph P. N. Mosha
Mr. Joshua Mgkewa

DFID Tanzania,
Mr. George I Macdonald
Education and social development advisors also consulted.

The information was very well received and it was repeatedly stated that the WPI would be useful to Tanzania in many ways.

5.3.3: Consultation meetings held in Sri Lanka, February 2002

Ministry Finance & Planning, Dept. of National Planning
Upali Dahanayake, Director (Economic Infrastructure)

Ministry of Finance & Planning, Dept. of Census & Statistics
D.B.P.S Vidyaratne, Director

Ministry of Irrigation & Water Management,
R. de. S. Ariyabandu, Director/ Policy Planning,
K.A Upali S. Imbulana, Director (Water Resources Development)

Department of Agrarian Development, District Office, Kurunagala.
P.M. Premathilake, Deputy Commissioner

Mahaweli Authority of Sri Lanka
Ranjinee Lanka Haturusinha, Director (Project Planning)

Ministry of Health
Dr. C.K. Shanmugarajah, Director (Primary Health Care)

National Water Supply & Drainage Board
K.L.L Premanath, Deputy General Manager
R.R.J.W. Serasinghe, Manager , Ground Water Section Studies
W.B.G Fernando, Assistant General Manager Non Revenue Water Section

University of Moratuwa Engineering Faculty
Professor Senerath, Professor. Civil Engineer

Central Environmental Authority
K.G.D. Bandarathilaka, Deputy Director

"Sevanatha", Water NGO, Colombo
K.A. Jayaratne, President

Ministry of Forestry & Environment, Environment Division,
Dr. B.M.S. Batagoda, Director (Environmental Economics)

Ministry of Housing & Plantation Infrastructure
Mr. L. Perera, Director of Planning

National Water Resources Authority
K.S.R. de Silva , Director General

National Institute of Education
Mr. Dayawansa, Primary Education Section

Almost without exception, all those consulted expressed keen interest in the work and said it would be very relevant and useful to improve water management in Sri Lanka

Appendix 5.4
Dissemination and Consultation Workshops in Pilot Countries

During April and May 2002, a workshop was held in each of the pilot countries. These were attended by representatives of a range of different institutions including government departments and NGOs. The workshops in Tanzania and Sri Lanka were designed as a dissemination and training exercise, while that in South Africa was designed as a consultation exercise, where the WPI methodology was presented, followed by discussion. Issues covered included determination of the standard for the gap approach, on which a Water Poverty Gap can be based, and how weights can be applied.

5.4.1 WPI Training and Dissemination Workshop, Tanzania.

a. Agenda

The Development and Testing of the Water Poverty Index

Consultation and Dissemination Workshop, Dar Es Salaam , April 2002

Day One

Welcome and opening remarks — Prof. Yadon Kohi, Director General, COSTECH

Session I: The purpose of the Water Poverty index

Some thoughts on Indices

Session II: *Poverty Eradication Strategies and the Need for Planning and Monitoring Indicators.* Mr. C. Tandari, Poverty Eradication Unit, Vice President's Office

Poverty monitoring and Evaluation Indicators for water supply and Sanitation. Ms. N. Lupimo of Policy and Planning, Ministry of Water and Livestock Development

Coffee/tea

Session III: Indices: what they do and how they are constructed.

Questionnaire Design: what questions to ask and why.

Sampling theory and practice, interviewing households

Lunch

Session IV: Estimating water resources for the Water Poverty Index

Tea/Coffee

Session V: Practical Exercises: constructing indices, using hydrological data.

Session VI: Feedback session

Day Two

Session I: Identifying appropriate variables and data for a location

Weighting variables

Session II: Practical Exercises: constructing a preliminary Water Poverty Index using data from pilot surveys and other sources

Coffee/tea

Session III: Developing the baseline criteria for the 'gap' approach

Lunch

Session IV: Using the Water Poverty Index – some cautionary comments

	Moving towards implementation of the Water Poverty Index
	Tea/coffee
Session V:	Feedback session
	Wrap-up session and closure

b. Workshop Attendees

Mr. Alex Kaaya	Ministry of Water & Livestock Development, Box. 35066, DSM
Mr. E. Karugendo	National Bureau of Statistics, DSM.
Prof. James Ngana	Institute of Resource Assessment- University of Dar es Salaam
Prof. N. F. Madulu	Institute of Resource Assessment- University of Dar es Salaam
Mr. Judicate Shoo	PST-Guardian, Dar es Salaam (Newspaper editor)
Mr. S. Mahole	Arusha Urban Water Supply and Sewage Authority, Box. 13600,
Mrs. C. Mchomba	Ministry of Water & Livestock Development, Box. 9153, DSM
Mr. C. Tandari	Vice President's Office, Box. 5380, DSM
Mr. E. Masawe	Water Resources Institute, Box. 35059, DSM
Mr. J. Mgaiwa	Water Resource Institute, Box. 35059, DSM
Mrs. R. Koya	Arusha Urban Water Supply and Sewage Authority,
Mr. N. Mtega	Maths. Dept. UDSM, Box. 35062
Mr. Alex Musilanga	Ministry of Water & Livestock Development, Box. 9153, DSM
Mr. W. Masanza	Ministry of Water & Livestock Development, Box. 9153, DSM
Mr. F. Ngamlagosi	Ministry of Water & Livestock Development, Box. 9153, DSM
Mr. R. Alfayo	Tanzania Commission for Science and Technology (COSTECH)
Mrs .Salha M. Kasim	Dar es Salaam Institute of Technology, Box. 2958, DSM
Ms. H. Gideon	Tanzania Commission for Science and Technology (COSTECH)
Mr. C. Yongolo	Tanzania Commission for Science and Technology (COSTECH)
Mr. D. Mafunda	Tanzania Commission for Science and Technology (COSTECH)
Mr. Mlote	Tanzania Commission for Science and Technology (COSTECH)
Mr. B. Thompson	PST- Guardian, Box. 16526 DSM (journalist)
Prof. Y. Kohi	Tanzania Commission for Science and Technology (COSTECH)
Dr. R. Kingamkono	Tanzania Commission for Science and Technology (COSTECH)
Dr Caroline Sullivan	CEH Wallingford, UK
Dr Jeremy Meigh	CEH Wallingford, UK

c. Opening address by Prof. Yadon Kohi

WORKSHOP ON DEVELOPMENT AND TESTING OF WATER POVERTY INDEX COSTECH BUILDING 22nd – 23rd APRIL 2002

OPENING SPEECH BY Prof. YADON M. KOHI DIRECTOR GENERAL COSTECH

Distinguished Chairperson

Distinguished Guests from UK (Dr. Caroline Sullivan and Dr. Jeremy Meigh)

Distinguished workshop participants

Ladies and Gentlemen:

May I first of all take this opportunity to welcome Dr. Caroline Sulivan and Dr. Jeremy Meigh who have come all the way from UK. You are warmly welcome to Tanzania and particularly to Dar es Salaam "**THE HEAVEN OF PEACE**". KARIBUNI SANA.

It gives me a great pleasure to have the opportunity to raise a few remarks in this important workshop on **Development and Testing of Water Poverty Index.**

Chairperson: This is my second time to mark the opening of the workshop in Development and Testing of Water Poverty Index, the first time it was in Arusha in

May 2001, this workshop was a conceptualisation workshop on Development and Testing of Water Poverty Index. It is therefore my pleasure today to officiate a dissemination and consultation workshop on the same.

Chairperson; let me try to explain what is Water Poverty Index;

The Water Poverty Index is the interdisciplinary measure (indicator) which links household welfare with water availability/accessibility and indicates the degree to which water scarcity impacts on human populations. It is an indicator like Human Development Index (HDI), and is derived using the same methodology.

Chairperson; Then comes a question "Why do we need indices like Water Poverty Index?"

We need a Water Poverty Index to facilitate the following

- More equitable water allocations, basing on needs and availability
- Better understanding of links between water, human welfare and the ecosystem – This needs more integrated water management approach
- An assessment of progress towards development targets
- Prioritization in resource allocation and monitoring the effectiveness of development projects

The Index being developed is expected to be used for:

- Policy making
- Decision making for water project development at all levels (Village - District –National and Global)
- Forecast future trends in water management
- Water development planning, Monitoring and Evaluation to achieve poverty eradication strategies (vision 2025 for the case of Tanzania)

The Index will reflect the change in level of poverty, and therefore indicate whether we are progressing or becoming poorer.

Chairperson; The development of a Water Poverty Index should be seen as a contribution to an international process; as one element of the general international efforts both to raise consciousness about the importance of water issues, and to look at them in a more holistic and integrated manner. This is because Water Poverty Index will not only make a real contribution to ability of water managers to prioritise their expenditure in a transparent manner, but also enable them to effectively monitor development progress within their countries and eventually at global level.

With a Water Poverty Index, it will become possible for both government departments and NGOs to bring pressure to bear on those international and national institutions involved in the water sector, whose support may facilitate real changes in the currently inequitable use of water seen so widely across the world.

Chairperson; The Commission for Science and Technology, which is the focal point for Development and Testing of the Water Poverty Index, and the government of

United Republic of Tanzania, is keen and eager, to see the Water Poverty Index developed and adopted for planning and management processes.

Chairperson; May I take this opportunity to thank DFID for its financial support and the Centre for Ecology and Hydrology of Wallingford UK, for facilitating this project.
I wish you a very fruitful discussion.
With these few remarks, I would like to declare this workshop on Development and Testing of Water Poverty Index officially open.
Thank you for listening,

5.4.2 WPI Training and Dissemination Workshop, Sri Lanka

a. Agenda

The Development and Testing of the Water Poverty Index
Consultation and Dissemination Workshop, Colombo, April 2002

Day One

Welcome and opening remarks

Session I:	The purpose of the Water Poverty index Some thoughts on Indices Indices: what they do and how they are constructed.
Session II:	Questionnaire Design: what questions to ask and why. Sampling theory and practice, interviewing households
Session III:	Estimating water resources for the Water Poverty Index
Session IV:	Practical Exercises: constructing indices, identifying Water Poverty Index components, using hydrological data.
Session V:	Feedback session

Day Two

Session I:	Identifying appropriate variables and data for a location Weighting variables
Session II:	Developing the baseline criteria for the 'gap' approach
Session III:	Practical Exercises: constructing a preliminary Water Poverty Index using data from pilot surveys and other sources
Session IV:	Using the Water Poverty Index – some cautionary comments
Session V:	Feedback session

b. List of attendees

Mr. Upali Dahanayaka	Director (Economic Infrastructure), NPD
Mr. K.A. Upali S. Imbulana	Director (WRD), My. IWRM
Mr. Thilakarathna	Senior Statistician, Dept. of Census & Statistics
Mr. W.B.G. Fernando	Assistant General Manager (NRW), NWSDB
Mr. A.D.K.K. Wisayagunawardan	Engineer (NRW), NWSDB
Mr. Premathilaka	Dep Com. Dept. of Agricultural Development
Mr. Jagath Prema Kumara	NGO "Sevanatha", Urban Resources Center
Mr J.K.S. Pathirana	Chief Engineer (Planning), NWSDB
Mr. A.H. Gunapala	Chief Sociologist (RWS), NWSDB
Ms. Chandani Wijewardena	Deputy Director, National Planning Department
Mr. G.S.S. Jayaweera	Assistant Director (Project Planning), MASL
Mr. Pathiranage	Chief Engineer (Planning & Designs), NWSDB

Prof. D.C.H Senerath	Engineering Faculty, University of Morotuwa
Mr. A.H. Jayaweera	Director, NWRA
Mr. K.L.L. Premanath	Deputy General Manager NWSDB
Dr Caroline Sullivan	Centre for Ecology & Hydrology UK
Dr. Jeremy Meigh	Centre for Ecology & Hydrology UK
Mr A Wijerathne	Technical Officer,Dept of Agrarian Development, Kurunegala
Mr Senivirathne	Asst Commissioner,Dept of Agrarian Development, Kurunegala
Mr. D. Senivirathne	Water Supply Section, NWS&DB, Ratmalana

5.4.3 WPI Dissemination Workshop, South Africa

a. Agenda

The Development and Testing of the Water Poverty Index
Consultation Workshop, Pretoria, May 2nd, 2002

09H00 - 09H30	Introductions	
09H30 - 10H40	WPI purpose and structure Highlighting gaps and need for weighting	
10H40 - 11H00	Tea break	
11H00 - 12H30	Discussions:	Introducing weighting into WPI Developing a gap approach
12H30 - 13H15	Lunch	
13H15 - 14H45	Discussions:	Environmental components in WPI Practical difficulties in introducing WPI
14H45 - 15H00	Tea break	
15H00 - 16H00	**Discussions:**	**Institutional interest in WPI development for RSA**
16.30	Summing up of workshop and closure	

b. Attendees

The Development and Testing of the Water Poverty Index

Consultation meeting participants, Water Research Commission, South Africa,
March 2002

Water Research Commission

Dr. George Green, Deputy C.E.O.
Dr. Sizwe Mkhize, Social Themes programme leader,
Dr. Stephen Mitchell, Ecosystems programme leader

The Department of Environment and Tourism
Dr. Ester Koch, Environmental Information and Reporting,
The Department of Environment and Tourism, Republic of South Africa

The Mvula Trust, (Water NGO)
The Mvula Trust, Republic of South Africa

Rural Support Services, Eastern Cape

Lesley Steele

Department for Water Affairs and Forestry, South Africa
Mr. Harrison Pienaar

Local Government and Water Sector Education and Training Agency
Nonlilanhla Dube, Manager, Water Sector
Johannesburg, Republic of South Africa

University of Natal
Prof Roland Schulze
Mr. Dennis Dhlamini

CEH Wallingford

Dr. Caroline Sullivan
Dr. Jeremy Meigh

Appendix 5.4.4. An example of the certificate of appreciation distributed to workshop participants in Tanzania and Sri Lanka

The Development and Testing of the Water Poverty Index

We would like to thank

....

For their contribution to the
Water Poverty Index Workshop

Conducted by CEH Wallingford
as part of the DFID funded project on

The Development and Testing of the Water Poverty Index

Colombo, April 26th and 27th, 2002

Dr Caroline Sullivan csu@ceh.ac.uk

Dr Jeremy Meigh jrm@ceh.ac.uk

Centre for Ecology & Hydrology
NATURAL ENVIRONMENT RESEARCH COUNCIL

DFID Department for International Development

Appendix 6.1
WPI Management Primer

Please see separate document;

Evaluating Your Water

A Management Primer for the Water Poverty Index

Appendix 6.2
WPI Workbook and Workshop Materials

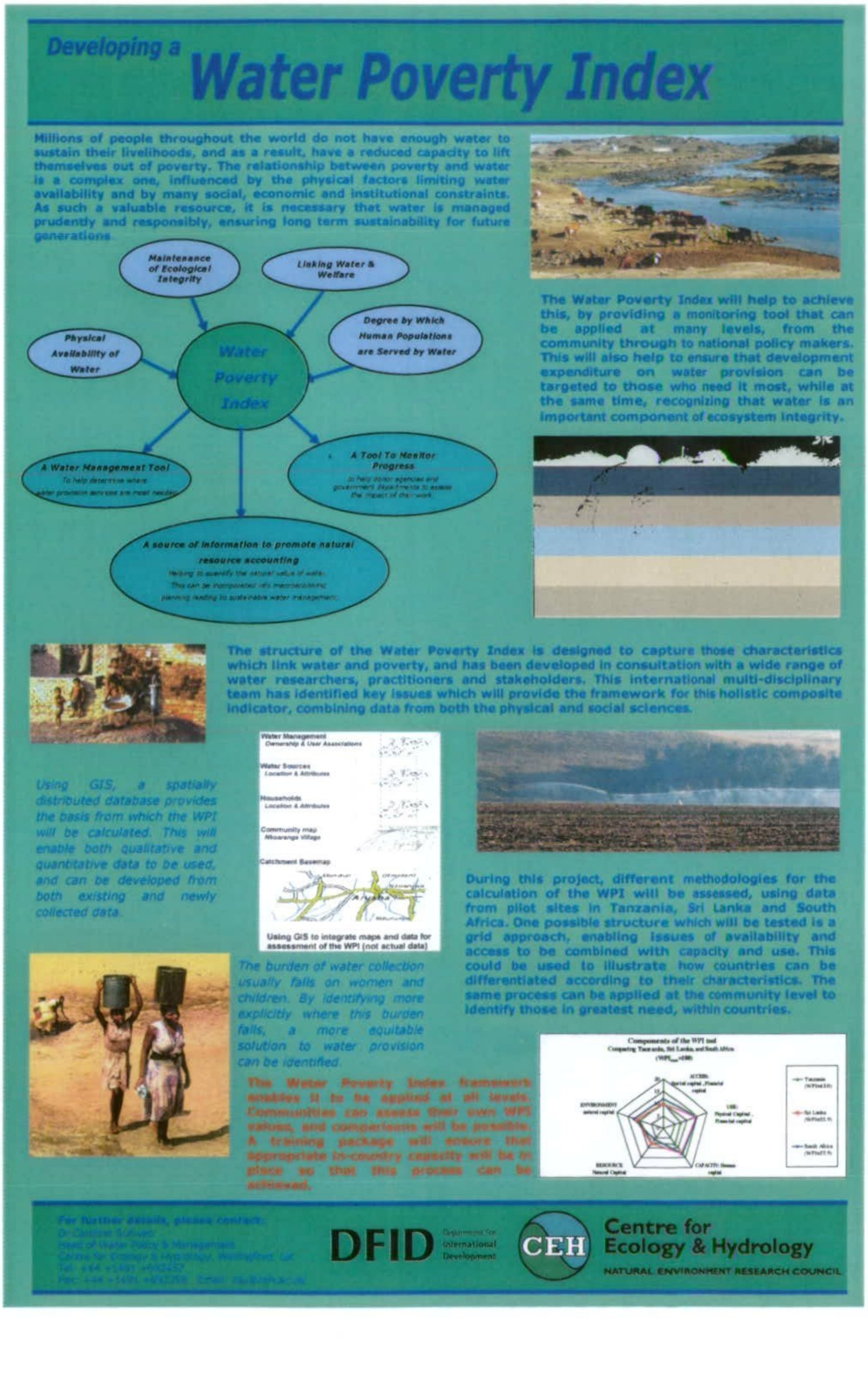
All workshop materials are contained in the separate document;

The Development and Testing of the Water Poverty Index

An Outline Set of Training Materials for Field Staff

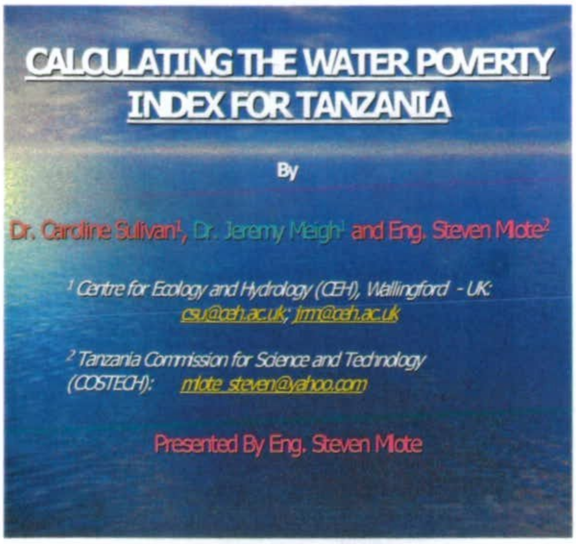
Appendix 6.3
Water Poverty Index Poster

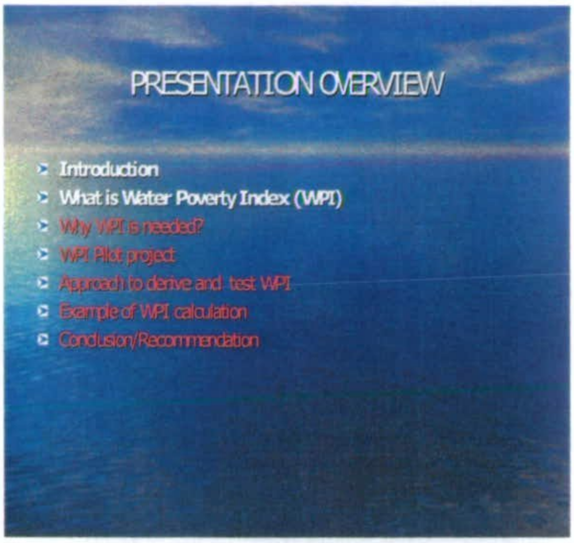
As used to promote the WPI at Dundee meeting and various workshops

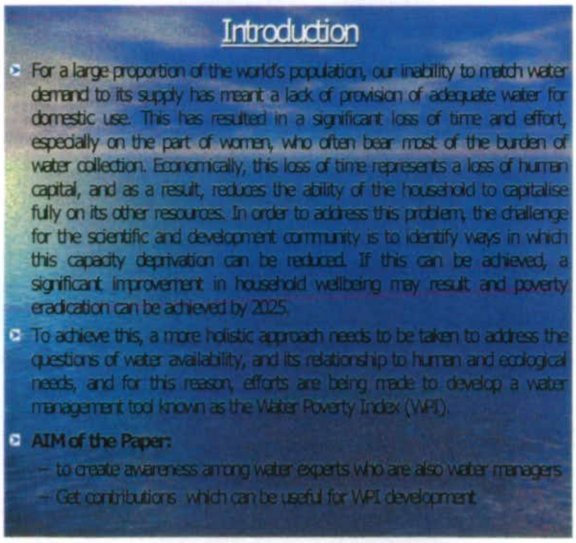


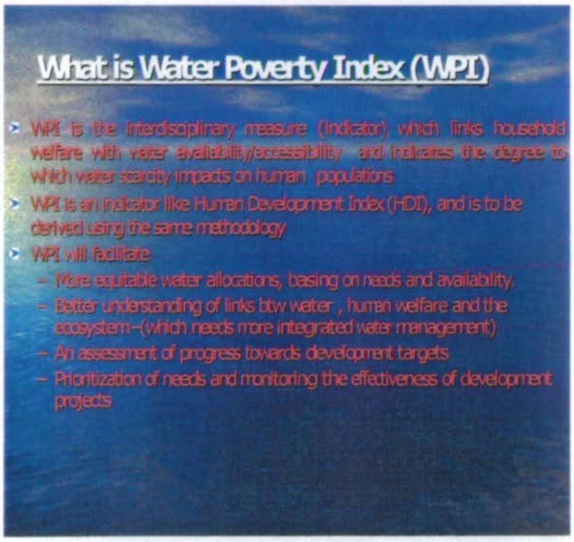
Appendix 6.4
Calculating the Water Poverty Index for Tanzania

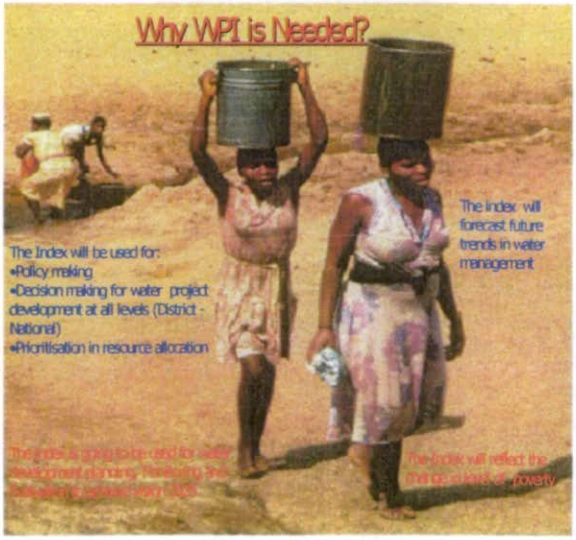
Presentation by Stephen Mlote (AWEC Conference, Jan 2002)

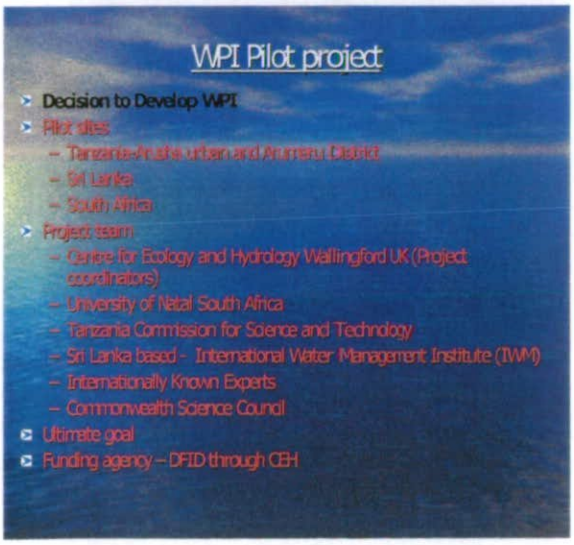












Current status of the project

- Conceptualisation process underlying the development of WPI is well advanced
- The pilot data has been collected from households in four sites in each of the three pilot countries (Tanzania, SA and Sri Lanka)
- The collected data is being complimented with existing data being collected from a variety of sources (i.e. hydrological, institutional, and infrastructure issues).
- The comprehensive collection of data will provide the basis for testing the methodologies/approaches

Building an Integrated data set

- Consistent approach
- Data contains
  - Socio-economic status
  - Specific water data relating to locations of communities and water points, family/household demographics, water source utilization and preferences, distance/time to source,volumes gathered along with water uses and gatherers age and gender.
  - GPS for all households and water points

Water Poverty Index - The Approach

1. Composite Index approach (Widely used)
2. Matrix Approach
3. Gap Approach
4. Time-analysis approach
5. Others?

Composite Index Approach

$$WPI = W_a \cdot A + W_a \cdot S + W_a \cdot (100 - T)$$

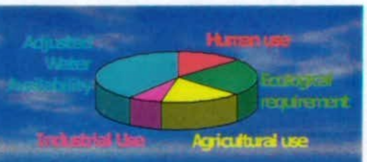
A = Adjusted Water availability (%)

S = % of population with access to safe water and sanitation.

T = Index representing time and effort taken to collect water.

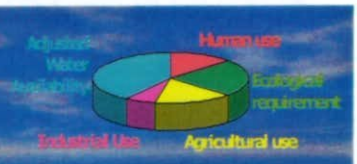
W_a, W_s and W_s = weights for each component

Variable A

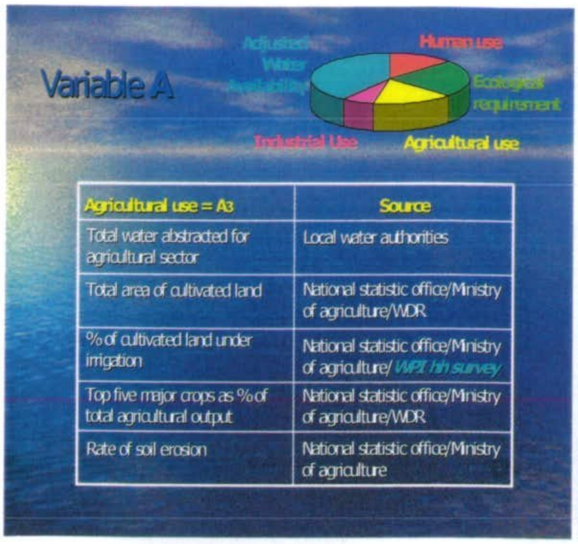


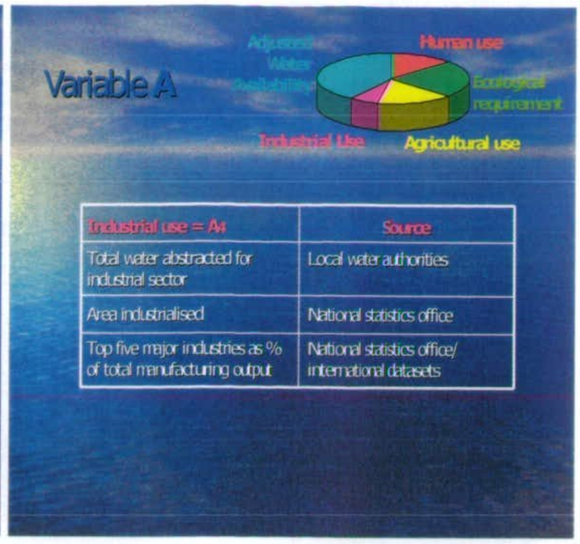
Human use = A1	Source
Average per capita consumption	*WPI household survey*
Population (in urban and in rural areas)	National statistics office and WDR 2000/01
Total water abstracted for domestic supply	Local water authority

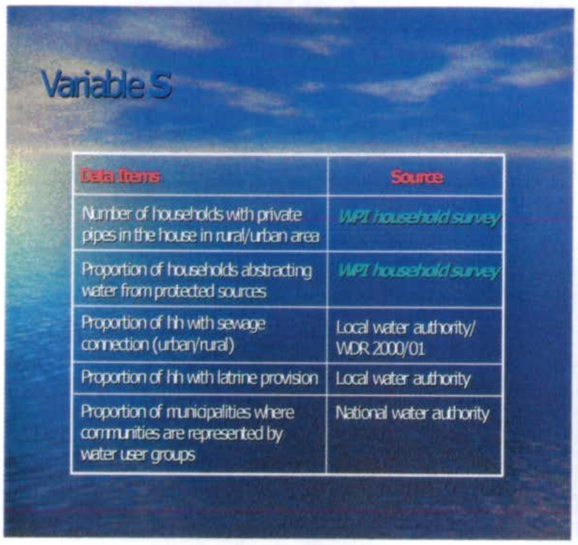
Variable A

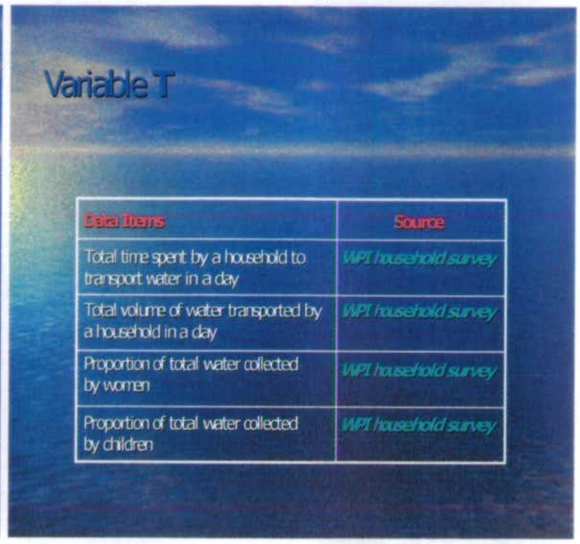


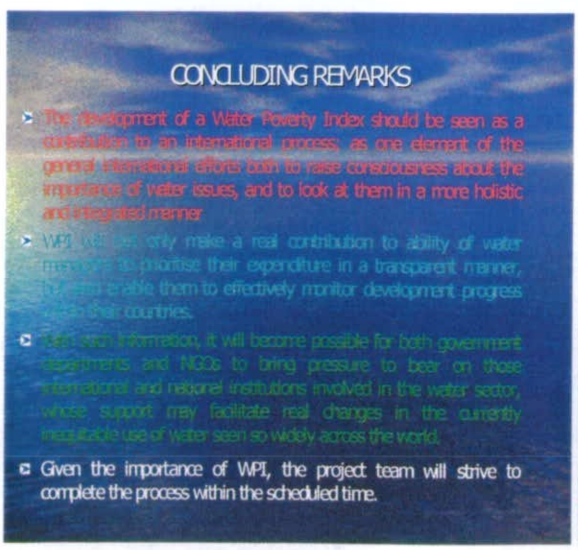
Ecological requirement = A2	Source
Number of Wetlands and their location	Local Env. Ministry
Number of parks and their location	Local Env. Ministry
National protected areas	WDR 2000/01
Ecological disasters related to water availability and water distribution (dams construction)	Local or international env. Groups and local Env. Ministry


Variable A
Adjusted Water Availability
Human use
Ecological requirement
Industrial Use
Agricultural use
Agricultural use = A3 | Source
Total water abstracted for agricultural sector | Local water authorities
Total area of cultivated land | National statistic office/Ministry of agriculture/WDR
% of cultivated land under irrigation | National statistic office/Ministry of agriculture/ WPI hh survey
Top five major crops as % of total agricultural output | National statistic office/Ministry of agriculture/WDR
Rate of soil erosion | National statistic office/Ministry of agriculture


Variable A
Adjusted Water Availability
Human use
Ecological requirement
Industrial Use
Agricultural use
Industrial use = A4 | Source
Total water abstracted for industrial sector | Local water authorities
Area industrialised | National statistics office
Top five major industries as % of total manufacturing output | National statistics office/ international datasets


Variable S
Data Items | Source
Number of households with private pipes in the house in rural/urban area | WPI household survey
Proportion of households abstracting water from protected sources | WPI household survey
Proportion of hh with sewage connection (urban/rural) | Local water authority/ WDR 2000/01
Proportion of hh with latrine provision | Local water authority
Proportion of municipalities where communities are represented by water user groups | National water authority


Variable T
Data Items | Source
Total time spent by a household to transport water in a day | WPI household survey
Total volume of water transported by a household in a day | WPI household survey
Proportion of total water collected by women | WPI household survey
Proportion of total water collected by children | WPI household survey


CONCLUDING REMARKS
The development of a Water Poverty Index should be seen as a contribution to an international process; as one element of the general international efforts both to raise consciousness about the importance of water issues, and to look at them in a more holistic and integrated manner
WPI will not only make a real contribution to ability of water managers to prioritise their expenditure in a transparent manner, but also enable them to effectively monitor development progress within their countries.
With such information, it will become possible for both government departments and NGOs to bring pressure to bear on those international and national institutions involved in the water sector, whose support may facilitate real changes in the currently inequitable use of water seen so widely across the world.
Given the importance of WPI, the project team will strive to complete the process within the scheduled time.


THANK YOU FOR YOUR ATTENTION

Appendix 6.5
Journal Papers

WD 1290
17 April 2002 Disk used
ARTICLE IN PRESS
No. of Pages 16, DTD = 4.3.1
SPS, Chennai

Pergamon
www.elsevier.com/locate/worlddev

World Development Vol. xx, No. x, pp. xxx–xxx, 2002

Printed in Great Britain
0305-750X/02/$ - see front matter

PII: S0305-750X(02)00035-9

Calculating a Water Poverty Index

CAROLINE SULLIVAN *
Head of Water Policy and management, Centre for Ecology and Hydrology, Wallingford, UK

Summary. — This paper provides discussion of ways in which an interdisciplinary approach can be taken to produce an integrated assessment of water stress and scarcity, linking physical estimates of water availability with socioeconomic variables that reflect poverty, i.e., a Water Poverty Index. It is known that poor households often suffer from poor water provision, and this results in a significant loss of time and effort, especially for women. By linking the physical and social sciences to address this issue, a more equitable solution for water allocation may be found. For the purpose of initiating discussion, a summary of different approaches to establishing a Water Poverty Index is discussed. © 2002 Published by Elsevier Science Ltd.

Key words — water, poverty, management tools, global, local, index

1. INTRODUCTION

Policies for development and environment are evolving as tools of behavioral change throughout the world, and it is now understood that an essential prerequisite to effective policy making is accurate monitoring backed up by rigorous interdisciplinary science. Water is essential for life, and an adequate water supply is a prerequisite for human and economic development. It has been recognized that human behavior can have an impact both on water, and on the global ecosystem, and that there is a need to regulate that behavior in order to stabilize and sustain our future (WCED, 1987). Global water resources are limited, and only through a more sustainable approach to water management, and more equitable and ecologically sensitive strategies of water allocation and use, can we hope to achieve the international development targets for poverty reduction that have been set for 2015 (DFID, 2000).

There is a considerable literature on the use of indicators (Anderson, 1991; DoE, 1996; Hammond, Adriaanse, Rodenburg, Bryant, & Woodward, 1995; Rennings & Wiggering, 1997; Rogers *et al.*, 1997; Salameh, 2000; Streeten, 1996; World Bank, 1998). While many of these allow policy makers and funding agencies to monitor progress for environmental change or poverty elimination, those of the Committee for Development Policy of the United Nations are particularly of use. None, however, recognizes the unique importance of water to all forms of life. Without adequate and efficient water supplies, i.e., where there is "water poverty," any measures to reduce income poverty are unlikely to be successful. In this paper, it is proposed that water poverty needs to be quantified in a universally accepted way, through the derivation of a "Water Poverty Index." This index will enable progress toward development targets to be monitored, and water projects to be better targeted to meet the needs of the current generation, while securing water availability for the needs of future generations, as recommended in the Brundtland Report (WCED, 1987).

Effective accounting processes are an important component of any management strategy. To date, however, economic accounting in general does not address the issue of natural capital utilization in an appropriate way (Cos-

* The funding for this work has been provided by the UK Department for International Development, contract number IUDDC24. The views here do not necessarily represent those of DFID. Contributions to the development of this paper have been made by the participants in the WPI workshop held in May 2001 in Arusha, Tanzania, including J. Meigh, P. Lawrence, W. Cosgrove, J. Delli Priscoli, A. Allan, R. Schulze, M. Samad, J. King, C. Hutton, M. Acreman, S. Milner, E. Tate, S. Mlote, R. Calow, I. Smout and S. Malomo. In addition, special thanks are due to John Gash for his stimulating contributions to the early stages of development of these ideas. Final revision accepted: 26 February 2002.

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tanza, Cumberland, Daly, Goodland, & Norgaard, 1997; Daly, 1999). While some work has been done recently to design auditing systems for water resources (Batchelor, Rama Mohan Rao, & James, 2000) and other researchers have addressed the issue of incorporating water accounts into national accounting systems (Friend, 1993; Lange, 1998) systems of accounting for water use, both at a macro- and micro-level, are yet to be fully developed.

At present, national and regional policy makers seldom consider the time spent by women in subsistence households, and indeed, within the structure of the United Nations System of National Accounts, women's housework is rarely included. In developing regions, the burden of domestic water provision most acutely falls on women and children (Curtis, 1986), and in some areas, as much as 25% of women's productive time can be spent on water collection. This represents a significant cost in terms of household human capital entitlements (Carney, 1998; Scoones, 1998) but little has been done to quantify these real household costs, and even less to account for them explicitly in economic analyses. The objective of developing a Water Poverty Index is to produce a holistic policy tool, drawing on both the physical and social sciences, and having application throughout the world. It is hoped that the development of such an index will enable decision makers to target crosscutting issues in an integrated way, by identifying and tracking the *physical*, *economic* and *social* drivers which link water and poverty.

(a) *The relationship between water use and economic development*

While global water resources may be finite, the same cannot be said of water demand. Growth in human populations is creating an increasing demand for water, and if, at the same time, if standards of living are to rise, water consumption per capita is also likely to rise. This means that water resource availability, or lack of it, is linked to economic and social progress, suggesting that development is likely to be influenced by how water resources are managed. At a national level, it can be seen that countries which have higher levels of income tend to have a higher level of water use, as can be demonstrated by the examples shown in Table 1.

Table 1. *Water use and national income*

	GDP per capita, US$ (1990)	Annual water withdrawals, per capita, M^3 (1970–87)		
		Domestic	Industrial and agricultural	Total
Tanzania	110	8	28	36
Sri Lanka	470	10	493	503
South Africa	2,530	65	339	404
United Kingdom	16,100	101	406	507
Sweden	23,660	172	307	479
United States	21,790	259	1,903	2,162

Source: World Bank (1992), *World Development Report*. Development and the Environment. Table 1 and 33.

(b) *Building better understanding of the links between water availability (supply) and water demand*

Demand management is one of the real challenges faced by policy makers today. On a global scale, water for agriculture is by far the most important use, with domestic water requirements being just a fraction of the total. Even taking the very arid countries in the Middle East, this pattern still tends to occur, as shown in Table 2. While there is some scope for better management of domestic water, there is little doubt that better water management in agriculture is likely to have the greatest impact on water resource availability.

The complexity of the problem of water resource allocation can be illustrated by looking more closely at three countries in this region. For example, in Jordan, rapid industrialization and population growth has led to water demand being on the verge of exceeding water

Table 2. *Distribution by sector of annual water withdrawals, selected states (%)*

Country	Domestic	Industry	Agriculture (irrigated and rainfed)
Egypt	7	5	88
Syria	7	10	83
UAE	11	9	80
Jordan	29	6	65
Saudi Arabia	45	8	47
WORLD	8	23	69

Source: World Resources Institute (1996).

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availability, and the high concentration of population around the capital city of Amman, has led to a significant rise in demand for domestic water (Allan & Karshenas, 1995), and in pumping water from regions hundreds of kilometers away. In Qatar, the almost total lack of rainfall means that agricultural development can be achieved only through the use of groundwater, and it is now known that the aquifer from which this is pumped, is likely to be depleted within 20–30 years. In addition, this groundwater is becoming heavily polluted by nitrates resulting from rapid urbanization and agricultural development (UNEP, 1987). Other typical pollution problems are demonstrated by the case of Syria, where inadequate sanitation and dumping of industrial wastes has led to significant ecological disruption in the Euphrates, Oronte and Barrada catchments (Biswas, 1994; Shuval, 1994). National water management problems are further confounded by overpumping of groundwater, giving rise to saltwater intrusion on the coastal plain. These and other issues highlight the importance of considering both ground and surface water when addressing the problem of water resource assessment, and in the development of the Water Poverty Index.

The patterns of water use illustrated in Tables 1 and 2 are found in most countries of the world, and as pressure on water resources increases, the need for new approaches to managing this use becomes more pressing. These could include the development of more efficient irrigation systems which minimize evaporative losses, more sustainable farming practices avoiding the production of "water thirsty" plants in semi-arid areas, dependence on fossil groundwater and other measures. Increased public awareness and the use of water pricing can promote less wastage of domestic and industrial water, and better systems of resource accounting will enable a reduction in the externalities associated with water use, both at a micro-economic and macro-economic level (CDP, 1989).

(c) *Water policy in the 21st century*

Following the debates at the second World Water Forum in The Hague in March 2000, it has become clear that despite improvements in water services in many places, there are still millions of people worldwide without access to sufficient water for domestic use. Possibly as much as half of the world's population lack adequate water for basic sanitation and hygiene. With a world water crisis of such epidemic proportions, it seems an immense task to manage water so that there is enough for people to drink, let alone for agricultural and industrial uses. It is clear that the time has come for more effective targeting of water provision. With limited resources, this targeting requires decisions to be made and priorities to be assessed so that water can be delivered to where it is most needed to meet the needs of human populations. The development of a Water Poverty Index is intended to help this process of identifying those areas and communities where water is most needed, enabling a more equitable distribution of water to be achieved.

Gleick (1993, 1997a,b, 2000) has examined many aspects of water resources and entitlements, especially with respect to global security, and indeed, as highlighted in a keynote speech at the Pugwash [1] conference in Cambridge (August 2000), the issue of poverty and its drivers is now attracting considerable attention from a security point of view. The widespread publication of global disparities in water accessibility in such meetings as the World Water Forum and the G8 ministerial conference in 1999 have also emphasized the need to address the problem of water management more effectively, both at a local and international scale. At a global level, the problems associated with future climate change also have serious implications for water availability (Strzepek, 2000; Strzepek, Yates, & ElQuosy, 1996).

(d) *The problem of poverty*

The literature on poverty is so vast as to be impossible to list. Some of the key issues on poverty which have been examined include work on gender (Rosenhouse, 1989), definitions of poverty in the context of development (CDP, 2000; Sen, 1995; UNDP, 2000; van der Gaag, 1988), poverty thresholds (Orshansky, 1969), poverty measurement (Desai, 1995; Lipton, 1988; World Bank, 1996a) poverty and welfare (World Bank, 1998) poverty and food (Malseed, 1990) poverty and politics (Uvin, 1994) poverty and health (WHO, 1992), poverty and vulnerability (CDP, 1999) and many more issues. While a lot of these issues may touch on the importance of water, very few attempts make the link explicitly between water and poverty, although the WHO/UNICEF Joint Monitoring Program does attempt to assess

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progress in the provision of clean water and sanitation.

(e) *How economists measure poverty*

Methods currently in use to assess poverty need to be considered in any attempt to link water resource assessments with poverty to form a Water Poverty Index. There are a number of approaches to this, including the *Poverty Line*, the *Headcount Index*, and the *Poverty Gap*. The Poverty Line is a consumption-based measure comprised of an element representing the minimum level of expenditure required for basic necessities, plus an extra amount for that required to participate in the everyday life of society. This varies considerably throughout the world, but for developing countries it is thought to range from \$275 to \$370 per capita per annum. This measure indicates that over one billion people fall below the poverty line, roughly one-third of the total population of developing countries. The Headcount Index expresses the number of poor, as defined by the poverty line, as a percentage of the total population. In a large country like China, a relatively low Headcount Index can actually mean very large number of people. The Poverty Gap is sometimes called the *Average Income Shortfall*, an assessment of the amount of money that would be necessary to bring every poor person up to the poverty line. This is expressed as the aggregate income shortfall of the poor, as a percentage of aggregate consumption.

All of these approaches are based on national income figures, and as averages, are not very representative of regional variations. As a result, they often fail to accurately represent the levels of poverty experienced in different communities. Importantly, measures of per capita income are recognized to be inadequate to represent human well-being. While money measures may provide some means of comparison of economic activity, they take no account of nonmonetary attributes of human well-being, nor of the value of women's household labor, nor indeed of depreciation of natural capital.

(f) *Water needs of the environment*

Since water is a key component of the natural capital entitlements of households (Scoones, 1998), and of healthy ecosystems, improved definition of water data, and its integration with economic accounting systems, is an important key to sustainability. This would need to be addressed in any holistic management tool, by including ecosystem water requirements as a component of the analytical framework used for the calculation of the Water Poverty Index. [2]

In the past, little attention has been given to the water needs of nature itself. Economic development has in most cases taken precedence, and numerous examples can be found where ecological disruption has resulted from water projects designed to increase agricultural or industrial production. These have occurred because knowledge of the complexities of ecosystems is limited, and values of the relevant environmental attributes have been ignored. Compounded by a scientific approach which has been specific rather than generic, to some extent at least, this has led to erroneous theories of growth economics. These theories, on which many development projects are founded, are based on understandings which:

- suggest that man-made and natural capital can infinitely be substituted, and
- ignore the constraints on production provided by the basic laws of thermodynamics (Daly, 1999).

Clearly, while man-made capital is generated from the depletion of natural resources (Daly, 1999), it can also be shown that certain natural resources cannot be reproduced by utilization of financial or physical capital. This refutes the concept of "*perfect substitutability of factors of production*" which is a basic assumption underlying the positions held even by eminent economists such as Beckerman (1995) and Simon and Khan (1984). Furthermore, the fact that money generated by exploitation of natural capital is accounted for in terms of "income streams" rather than "capital depletion," brings about an inevitable undervaluation of such resources, and consequent policy failure.

The physical existence of entropy, as explained by the laws of thermodynamics, means that even the most efficient production system must produce waste. This underlines the fact that the idea of infinite resource recycling and substitution is physically impossible. The failure of growth theories to take account of these real world conditions is one of the reasons why many water projects developed in the past have failed to live up to expectations, and why numerous examples exist of inequitable development outcomes.

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Highlighting the importance of taking more account of ecological and hydrological conditions, the Dublin Conference in 1991 (a preparatory meeting for UNCED, Rio, 1992), concluded that "since water sustains all life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems" (ICWE, 1992). At the UNCED Conference itself, it was agreed that "in developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems" (Agenda 21, Chapter 18, 18.8). In areas where water shortages already exist, this situation has sometimes been presented as a conflict between water for people and water for nature. This ignores the fact that the global ecosystem provides our life-support system, and as such, its integrity needs to be maintained, not merely for ecocentric reasons, but equally for anthropocentric ones, as it is the direct and indirect benefits of functioning ecosystems which maintain human life-support systems. Indeed, in many parts of the world, natural resources produced by healthy ecosystems provide livelihood support for millions of poor people, so a balance needs to be struck between allocating water for people's direct needs (for domestic use, industry, and agriculture) and for their indirect needs, through the numerous and as yet unquantified goods and services provided by functioning ecosystems (Acreman, 1998).

One example of how this has been incorporated into national water policy is illustrated by the new water law of South Africa, whose Principle 9 states that:

> The quantity, quality and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems.

This shows how the national government of South Africa has adopted a very proactive approach toward the principles of sustainable water management as outlined in Agenda 21, and as such, are farther advanced in this respect than most other countries of the world.

The question of identifying and quantifying the "demand" for water by functioning ecosystems is an important part of the research agenda for water management. Currently, there is no simple measure of ecosystem health in terms of effective hydrological functioning, and little is known about how much water different ecosystems need. In a recent study, a figure of 25% of available water was used as a proxy for this environmental demand (Seckler, 2000; Seckler, Amarasinghe, Molden, de Silva, & Barker, 1998). While such an approach recognizes the need to include environmental demand, it does not go far enough to examine the fact that different ecosystems will have different water requirements, and these will vary across the seasons.

On the other hand, different ecosystems perform different functions (Dickenson & Murphy, 1998), each having its own role to play in natural catchment processes. Almost all natural ecosystems can perform valuable hydrological functions, such as water purification, flood control, habitat provision and groundwater recharge, and many of these can help to reduce both water stress and poverty. Identification of the water requirements of different ecosystems is clearly an important prerequisite to the achievement of sustainable water management, and as such, must be placed high on the research agenda.

Today, in many cases, water poverty is increased by ecosystem degradation, and as a result, any index of water poverty should aim to include the status of ecosystems that help sustain levels of water availability. As a result, the newly established IUCN Commission on Ecosystem Management (among others) is trying to address this issue, and as an end user of this work, it is anticipated that eventually, the Water Poverty Index will incorporate a measure of ecological water demand, enabling development decisions to be made which explicitly take this constraint into account.

2. CONVENTIONAL ASSESSMENTS OF WATER RESOURCES

Since the 1970s, the need to assess water resource availability has been recognized. A number of attempts have been made since then to estimate water supplies, both globally and regionally, and just some of them are outlined here.

(a) *A comprehensive assessment of the freshwater resources of the world*

One of the most widely known assessments of global water resources is the work published in 1997 by the by the Stockholm Environment Institute (Shiklomanov *et al.*, 1997). The key concept in this approach is the assessment of total water resources at the country level in terms of the mean annual runoff. The runoff values were based on observed data from river flow measurement stations, supplemented by estimates based on meteorological data where river flow observations were lacking. The country values also include estimates of the water imported from, or exported to, other countries. Based on such assessments, country estimates of water resources and water stress expressed in terms of gross annual water resources per head of population are widely quoted. The essential point about these results is that the comparison of resources to demands is made only at the country level, and very little or no weight is put on other important issues such as spatial and temporal variability.

(b) *Other global water assessments*

Other work has addressed the issue of spatial and temporal variability. One example is the method used in the global water availability assessment (GWAVA) (Meigh, McKenzie, & Sene, 1999). In this work, the use of a grid approach has provided the means whereby physical assessments of water availability are adjusted to take some account of human factors. Two other water assessments following the grid approach will be discussed briefly in order to illustrate what has been achieved. Arnell and King (1998) used a 0.5 by 0.5 degree (i.e., 55×55 km^2) grid model to estimate global runoff. This approach is similar to that of GWAVA, except that only the local runoff within each grid cell is estimated, and key aspects of water resources systems such as cell linkages, abstractions, reservoirs, lakes and wetlands are not considered. The grid-cell results are aggregated to the country level, and the comparison of resources to demands is then carried out only at the country level.

A similar, but more sophisticated approach was taken in the WaterGAP model (Alcamo, Döll, Kaspar, & Siebert, 1997). This also uses the 55×55 km^2 size grid, with the grid cells grouped into 1162 catchments, providing almost total global coverage. Calculations are done at the grid-cell level but the results are aggregated to the catchment and country scale. As before, many of the key aspects of water resources systems are overlooked, but time variability is considered as the water availability is computed for average conditions over period of years.

One of the first studies which highlighted the importance of linking the physical assessments of water to the needs of human populations was that done by Falkenmark and Lindh (1974) and more recently, they, and others, have tried to take this approach further (Brouwer & Falkenmark, 1989; Falkenmark & Suprapto, 1992; Gleick, 1997a, 1997b; Postel, 1990, 1992; Raskin, Gleick, Kirshen, Pontius, & Strezepek, 1997; Seckler *et al.*, 1998). In an attempt to take a more holistic approach, Leif Ohlsson has tried to link the physical assessments of water with relevant social factors (Ohlsson, 1998). In this model, the physical measure is provided by the assessment of "available renewable water," and this is linked to "adaptive capacity" through the use of the UNDP Human Development Index to create what he refers to as the Social Water Stress/Scarcity Index. This is a significant step forward, paving the way for the development of a Water Poverty Index.

Another example of alternative indicators of water use that may be useful as components of a Water Poverty Index is that produced by the Water and Sanitation Collaborative Council, and referred to as the *basic water, sanitation and hygiene requirement* (Chattergee, Abrams, Cleick, & Lane, 1999). According to this work, the minimum requirement to meet these basic human needs is calculated at 40 l per capita, per day.

(c) *Water utilization intensity*

The concept of water utilization intensity has been used by the United Nations Food and Agriculture Organization to identify areas which are likely to be water stressed in the future (FAO, 1996). When this figure is over 100%, this means that aquifers are depleting faster than the recharge rate, or that pollution may be making some otherwise renewable supplies, unusable. In either case, water becomes a constraint on production, and more efficient means of using it becomes a vital issue. A number of countries in the Middle East already have a water utilization intensity of over 100%, and in the future, this number most probably will increase further.

While demonstrating some variation, these examples of water assessments all indicate the urgency of the need to develop more equitable and sustainable approaches to water management. Through a more accurate linkage of in-

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formation on water demand with that of supply, the development of a Water Poverty Index will be able to contribute to the resolution of potential conflicts over water shortages, or more importantly, their avoidance in the first place.

3. INDICATORS AND INDEX NUMBERS

The use of indices as policy tools began in the 1920s (Edgeworth, 1925; Fisher, 1922). An index number is a measure of a quantity relative to a base period. Indices are a statistical concept, providing an indirect way of measuring a given quantity or state, effectively a measure which allows for comparison over time. Key issues which have to be addressed in the construction of any index are:

choice of components,
sources of data,
choice of formula,
choice of base period.

Apart from these empirical issues, the main point of an index however is to quantify something which cannot be measured directly (e.g., how water stressed a household is) and to measure changes (e.g., the impacts of economic growth). The proposed Water Poverty Index fits this concept of an index which measures something indirectly, and which is made up of defined components.

A large number of indicators are widely used today (Adriaanse, 1993; World Bank, 1994, 1997; Yu, Dufournaud, & Rogers, 1995). Water indices mainly address availability and quality issues (Lohani & Mustapha, 1982), while indicators on poverty consider a whole range of social and economic variables. Over 50 indicators of sustainable development have been identified, and globally, indicators of all types are in use. Methods to develop indicators have been put forward (UNICEF, 1995; World Bank, 1996a, 1996b), and through a thorough literature review and consultation process, lessons learnt from these different approaches can be examined. On that basis, the most appropriate and effective index possible to assess the links between water and poverty can be developed, within the limitations of our current knowledge.

(a) *Acceptability and relevance*

One of the most important attributes of any management or policy tool is that of acceptability. In order for any tool such as the Water Poverty Index to become widely accepted, it is important that it is developed in collaboration with those who are likely to use it. To this end, it is important that a consultation process should be initiated, and this process should try to be as inclusive as possible, not only in terms of who is consulted where, but also in terms of the types of people or organizations involved in the conceptualization process.

(b) *The problem of scale*

Scale issues are a major challenge, as up-scaling and down-scaling can be subject to serious errors (Gibson, Ostrom, & Ahn, 2000; Schulze, 1999). In relation to the development of a Water Poverty Index in particular, consideration needs to be given to the problem of how far physical and socioeconomic information can be expressed at comparable scales to form a meaningful management tool. The water environment is naturally heterogeneous, with the physical availability of water varying even over very short distances. In an index addressing water poverty, the heterogeneity of water's physical availability will be compounded by heterogeneity in access to water within a community, or even in access within family groups. Indeed such variability is perhaps the essence of water poverty; since given sufficient financial resources, adequate water supplies can be provided almost anywhere, albeit by import or desalination.

The extent to which indices will accurately reflect actual variations will depend on the scales at which they are applied, and for policy purposes, policy objectives will determine the most appropriate and relevant scale. Within any community and household, substantial variations in access and availability to water resources can occur, but these may be obscured by indices which operate at inappropriate scales. These variations may be physical, for instance where portions of a community lie above the command level of an existing water distribution network, or economic, where water is available but a household cannot afford the cost of access or delivery. Indices can, however, be derived that seek to describe the extent of variability, for instance a measure of the percentage of a population with access to clean water and sanitation is an indicator of variability on whatever scale it is constructed.

Furthermore, an index at the national level may say nothing about regional variations in

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access, and regional indices may indicate nothing about the differences between rural and urban populations or between genders. One way to address this may be to use georeferenced datasets which allow the information for any one place to be linked with all other types of data for that place (Gurnell & Montgomery, 1999). This would mean that for any specific point on the globe (identified by its grid reference) detailed and accurate data from both the social and physical sciences could be linked in an integrated way. Within such a framework, it would become possible to produce a measure reflecting the degree of water stress felt by local communities, which at the same time can provide the foundation of a tool to be used for regional and national-scale water management problems. This concept is illustrated in Figure 1.

4. SOME APPROACHES TO CALCULATING A WATER POVERTY INDEX

As can be summarized from the above, a number of methods could be used to produce a Water Poverty Index. For such a tool to be widely accepted and adopted, it would need to be derived in a participatory and inclusive manner. Its calculation would need to be transparent, and it would need to be a tool which could be freely and easily used by all countries, at various scales. As such, its implementation would need to be preceded by a period of consultative conceptualization, followed by a period of pilot testing and capacity building. While this may be seen by some as a daunting challenge, it is clear that the potential of its achievement to bring forth a new era of

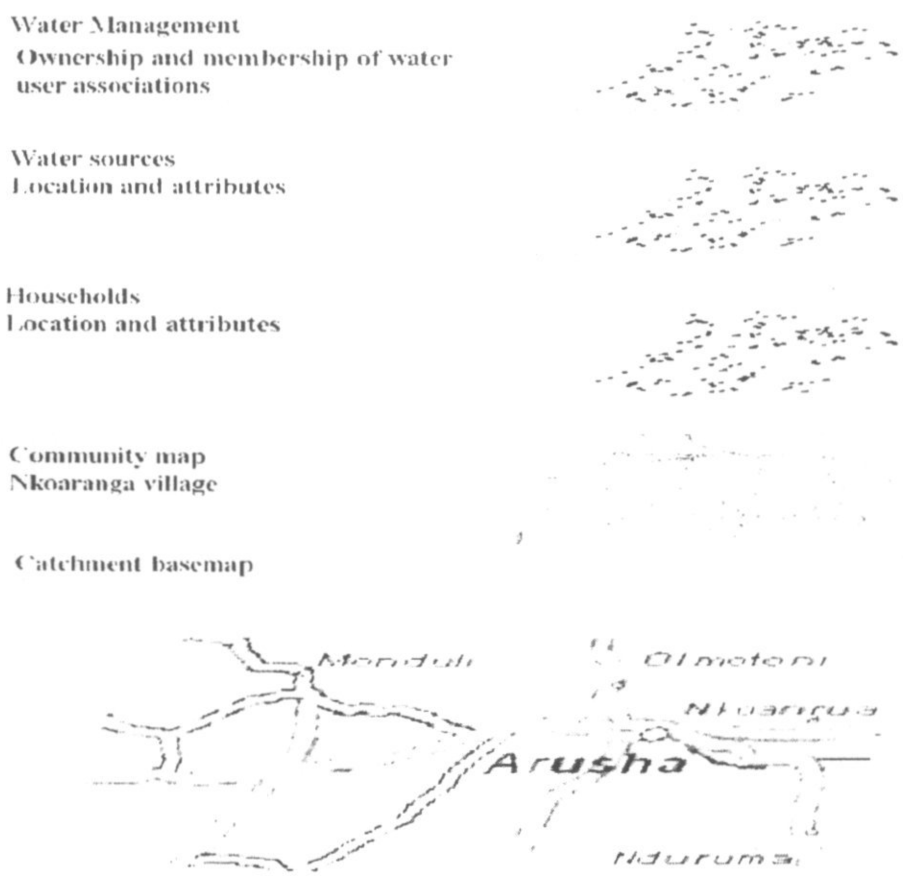

Figure 1. *Linking different types of data using GIS. Source: Sullivan, Meigh, and Mlote (2002).*

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accountability in water management and use makes the effort worthwhile.

In the conceptualization phase, the structure of the Water Poverty Index would be determined, possibly as a definition of a "water poverty line," perhaps as a calculation of "the water poverty gap," even as a GIS-based decision tool, or perhaps a combination of all of these. While this still is an issue which needs to be determined by consensus, some *suggestions* are provided here as to how the Water Poverty Index can be brought into being.

(a) *The conventional composite index approach*

In this approach, the index itself would be constructed from a series of variables which capture the essence of what is being measured. This can be done using national scale data (a top-down approach), or at a local level, using locally determined values and parameters (a bottom-up approach). Using the composite index approach, the WPI could comprise various elements, such as:

(i) water availability,
(ii) access to safe water,
(iii) clean sanitation, and
(iv) time taken to collect domestic water.

This would result in the WPI formula as follows:

$$\mathrm{WPI} = w_a A + w_s S + w_t(100 - T) \quad (1)$$

where

A: adjusted water availability (AWA) assessment as %. Calculated on the basis of ground and surface water availability related to ecological water requirements and a basic human requirement, plus all other domestic demands, as well as the demand from agriculture and industry. (The value of *A* should also recognize the seasonal variability of water availability.)

S: the population with access to safe water and sanitation (%).

T: the index (e.g., between 0 and 100) to represent time and effort taken to collect water for the household (e.g., from proportion of population having access in or near the home etc. This could be modified to take account of gender and child labor issues). (100 − *T* is the structure used to take account of the negative relationship between the time taken to get water, and the final level of the WPI).

—w_a, w_s and w_t are the weights given to each component of the index (so that $w_a + w_s + w_t = 1$).

Since *A*, *S* and *T* are all defined to be between 1 and 100, and w_a, w_s, and w_t are between 0 and 1, to produce a WPI value of between 0 and 100, the formula needs to be modified as follows:

$$\mathrm{WPI} = \tfrac{1}{3}(w_a A + w_s S + w_t(100 - T)) \quad (2)$$

To use this method effectively, it would be necessary to define and identify the "base rate" on which to calibrate the index values, and to provide an explanation of what exactly the resultant scores meant. These would be important research questions in the development of the WPI.

The problem of incommensurability does not arise in this method as the index is composed of parts which can be compared as they are all expressed as a percentage (or index number). In addition, by using water access and time spent to collect water as a proxy for socioeconomic well-being (the two can be shown to be highly correlated), the problems associated with calculating monetary incomes, exchange rates, etc. can be avoided.

A numerical example: To illustrate, consider two different regions or countries:
Region A: The values *A*, *S* and *T* are 60, 20 and 30, and the weights w_a, w_s and w_t are 0.5, 0.25 and 0.25 respectively.
Referring to Eq. (2), $\mathrm{WPI} = \tfrac{1}{3}(w_a A + w_s S + w_t(100 - T))$, so

$$\begin{aligned}\mathrm{WPI}_A &= 1/3[(60 \times 0.5) + (20 \times 0.25) \\ &\quad + 0.25(100 - 30)] \\ &= 17.5 \text{ (index points)}\end{aligned} \quad (3)$$

In the example here, the time variable *T* is expressed as a percentage (perhaps a percentage of per capita available labor time).
Region B: The values *A*, *S* and *T* are 60, 12 and 40, and the weights w_a, w_s and w_t are 0.5, 0.25 and 0.25 respectively.
Referring to Eq. (2), $\mathrm{WPI} = \tfrac{1}{3}(w_a A + w_s S + w_t(100 - T))$, so

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$$\begin{aligned} WPI_B &= 1/3[(60 \times 0.5) + (12 \times 0.25) \\ &\quad + 0.25(100 - 40)] \\ &= 16 \text{ (index points)} \end{aligned} \qquad (4)$$

This comparison shows that although the physical assessment of water in the regions is the same, and weights (preferences) used are the same, in region B, fewer people have access to safe water, and more time is spent by people collecting water.

On the basis of such a calculation, it is possible to show that in region A, water poverty is less of a problem than in region B, although it is still a problem which needs to be addressed. Nevertheless, policy makers can see that in both regions A and B, their priority for future water management may be to increase the number of people who have access to safe water, and to reduce time spent on water collection. Quantifying the issues in this way should help to determine which area faces more pressing problems in water provision. The results of the exercise are summarized in Table 3.

Table 3. *WPI calculated using the composite index approach*[a]

	Water availability (%)	Access to water (%)	Index of time spent in water collection	WPI
Weights	0.5	0.25	0.25	
Region A	60	20	30	17.5
Region B	60	12	40	16

[a] In this method, the higher the value of WPI, the lower the degree of water stress; so Region B has a greater degree of water poverty than A.

(b) *An alternative approach—the gap method*

Another way to develop a WPI measure could be to consider the assessment of by how much water provision and use deviates from a predetermined standard. This standard could be an assessment made up of considerations of the following:

(i) ecosystem health,
(ii) community well-being,
(iii) human health,
(iv) economic welfare.

In this approach, each of these components are assigned a standard value, which may be quantitative (scientifically defined) or qualitative (identified through participation). This standard or target value reflects that level which would exist if the resources were managed in a sustainable way. The WPI is determined by comparing the actual current empirical situation (as identified from data), with this preset standard. [3] Such a methodology has already been used as a framework for estimating indicators of sustainability (Simon, 1999), and as a measure of poverty (Gillis, Perkins, Roemer, & Snodgrass, 1987); in the case of the WPI, some of the same principles apply. This approach is summarized in Table 4.

Table 4. *Calculation of the WPI based on the 'gap' method*

	Ecosystem health	Human health	Community well-being	Economic welfare
Predetermined standard	Could be based on biodiversity, waste assimilation, and resource depletion, and could include a measure of water availability. (Symbol EH)	Could be based on infant mortality rates, incidence of selected disease, and life expectancy. (Symbol HH)	Could be based on crime rates, marital breakdown, education, political participation. (Symbol CW)	Could be based on per capita incomes, income distribution, re-investment rates, unemployment, etc. (Symbol EW)
Actual empirical value	(Symbol AEH)	(Symbol AHH)	(Symbol ACW)	(Symbol AEW)
Water poverty gap	EH − AEH = eh	HH − AHH = hh	CW − ACW = cw	IW − AIW = iw
WPI	The final WPI will not be one single value, but an index made up of four values, each part of which may be expressed either quantitatively or qualitatively, depending on the data and indicators used.			

Note: Using this approach, water stress is highest when the water poverty gaps are largest; if the situation improves, the gap gets smaller.
Source: Sullivan (2001a).

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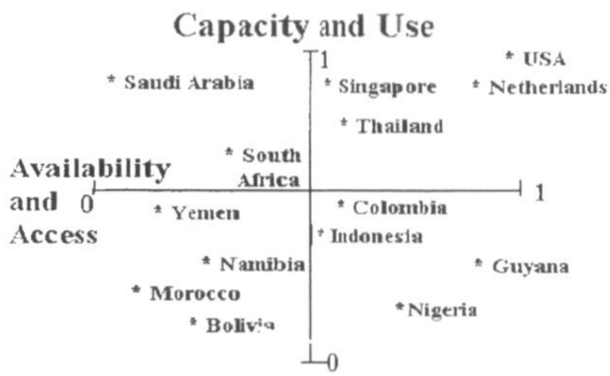

Figure 2. *Using a matrix approach to express the WPI. Source: Sullivan (2001a).*

(c) *A matrix approach*

In order to keep the WPI simple and easy to understand, the main characteristics of water stress and human welfare could be combined into a two-dimensional matrix. This would involve the identification of key indicators, representing a suite of appropriate characteristics, and these would then be combined on a suitable scale. It is possible that this could be developed from the analysis discussed in the composite index approach. With this method, the characteristics underlying the WPI could be expressed in a two-dimensional matrix, as shown in Figure 2. In this diagram, the (hypothetical) relative positions are shown of countries with different levels of water availability and access, and capacity and use.

(d) *A simple time-analysis approach*

Another possible way of addressing the methodology of constructing a WPI, is to use a time analysis approach, where time is used as a numeraire for the purpose of assessing water poverty. In this method, the WPI is determined by the time required (per capita) to gain access of a particular quantity of water. As such, the WPI would be as follows:

$$WPI = T/1000\ m^3 \quad (5)$$

Here T is the time required per person to collect a quantity of water (here, 1000 m^3).

In cases where the water is provided by infrastructure (e.g., in more developed areas) the value of the WPI would be equivalent to the wage-earning labor time required by residents to enable them to pay the appropriate fee for that level of water provision. In rural areas where infrastructure was less relevant, the figure T would be based on the actual measurement of time required by persons in that household or community, to collect the standard measurement unit (e.g., 1000 m^3). While this method is apparently very simple, it does have a number of weaknesses. The single figure simply reflects domestic issues, and fails to include ecosystem needs and commercial concerns; nor does it really address the water assessment issue in an interdisciplinary, holistic way. In addition, it does not fully address the supply side, although it does produce a measure which is universally easy to understand.

5. IMPLEMENTING THE WATER POVERTY INDEX

The above examples illustrate that the development of a Water Poverty Index is something which needs to be carefully thought out. It is obviously important to include issues such as physical water availability, water quality and ecological water demand in the WPI, along with social and economic measures of poverty, but it is essential to recognize the importance of institutional issues as they impact on water access, and to ensure that some measure of this is included in the structure of the WPI.

While considerable data on water availability and use exist in some countries (Gleick, 2000), comprehensive datasets are relatively rare. For those places where data are lacking, it is likely that some extension to existing in-country statistical capacity will be needed, to capture the necessary information to develop the Water

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Poverty Index. While some of this may relate to engineering and technical skills, most of this lack of capacity may be in lower and middle management and administration, and in the provision and analysis of data. To develop an effective national water management strategy, these gaps in local expertise need to be addressed.

For the Water Poverty Index to be consistent across countries, there is a need for international co-ordination, so that the surveys would ask the same sets of questions on water availability and access. In most cases this would require an adjustment to existing questionnaires. In countries where such surveys were not common, however, it would require establishing them on some regular basis (perhaps biennially, or every five years), inevitably having implications for resource allocation to statistical agencies. Some international effort in capacity building would be required in these cases, both in terms of assistance to conduct or extend initial surveys, and also for training to build up local capacity to continue the surveys without external support. As Selman puts it, "capacity building encompasses the variety of methods that assist local communities to participate in, or even take responsibility for decisions which affect their neighborhoods" (Selman, 1996, p. 29). If the Water Poverty Index were to become widely used, such initial implementation support would be essential, and from the outset, communities would be empowered with information relevant their own water management needs.

Training programs for capacity building would need to cover the following:

- designing household survey questionnaires and training interviewers,
- sampling methods,
- data inputting, processing and analysis,
- publication of findings.

Manuals of *Tools for Managers of New Surveys* are available from the World Bank's website. These, in conjunction with the standard literature on these issues, could form the basis of training courses, in those developing countries where needs assessment showed this was necessary to upgrade the skills of existing statistical agency staff and to train new staff to manage these surveys. There is potential for these to be designed as in-country or regional short courses, and to be supplemented by distance learning. In addition, "on the job" training as participants in the pilot studies or subsequent surveys is an effective way of transferring skills.

6. CONCLUSION

There has been a considerable amount of data collected about both water and poverty. One of the key features of the Water Poverty Index is that it will make use of some of these in a practical way. Examples of the type of socioeconomic datasets becoming available for numerous countries around the world is provided by the work of the World Bank's Large Scale Monitoring System (World Bank, 1996b), and the Joint Monitoring Program (WHO/UNICEF, 1997), which has generated considerable data relating to the links among sanitation, health and poverty. Other such datasets exist, and one of the objectives of this research is to add value to these by making use of some of it as a component in the calculation of the Water Poverty Index.

By geo-referencing the various WPI variables, the link can be made between macro-level hydrological data reflecting regional or catchment-level water availability, and micro-level data on household water stress. Using GIS technology (Gurnell & Montgomery, 1999), the WPI values can be used to develop estimates at different scales, assisting water managers in the difficult task of project prioritization. Over time, these geo-referenced databases can be enriched by additional data as they becomes available, and if the database is developed with an object-orientated structure (Coad & Yourdon, 1990), it will remain flexible and adaptable in the future. New attributes, such as better details on water quality, can be incorporated into the data structure, ensuring that the relevance of the WPI is sustained over time.

Effective water management requires an explicit link to be made between water availability and water demand. While improvements may continue to be made in the accuracy of water resource modeling, it is also important to acknowledge that much more needs to be known about patterns of water demand, and how these can be influenced to ensure more efficient use of any given resource. As in other areas of environmental policy, changing human behavior is often a prerequisite to the achievement of a more sustainable way of life, and in order to achieve this, much more needs to be known about the consumption behavior of those sec-

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tors of the economy which have the greatest impact on overall water demand. If such information can be collected in a participatory manner at the community level, local people will be empowered, both through a better understanding of their water needs, and of how to communicate this information to policy makers. By providing information about household welfare, and water stress at the household and community level, this locally generated data can form the core of the WPI.

To become an acceptable tool, the WPI should be calculated using an appropriate methodology, determined through consultation and participation. Scientific issues (such as linking data from different sources and scales) are likely to be resolved in the near future, and so in reality, the most important challenge is to develop the appropriate degree of political will and institutional acceptance which will allow the index to be used as an objective criterion addressing water poverty. Along with this acceptance, the necessary human capacity must be put in place to ensure that individual countries will be enabled to produce their own integrated assessments of water poverty. If this can be done, the development of the Water Poverty Index will deliver a comprehensive tool to help in water management at a variety of levels, and, in particular, make a direct contribution to the process of poverty elimination in poor countries.

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NOTES

1. These conferences, now in their 50th year, provide a forum for international discussion on key issues affecting global security. Natural resources, including water, are now considered to be part of this debate.

2. The final structure of the WPI framework will be most effectively developed through both collaboration between researchers, and in consultation with practitioners and stakeholders. This will ensure general acceptance of the WPI tool, and more widespread application of its use.

3. Some critics may suggest that determination of this standard is inherently subjective.

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International Water Resources Association
Water International, Volume 26, Number 4, Pages 471–480, December 2001

The Potential for Calculating a Meaningful Water Poverty Index

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Abstract: *One of the most significant failures in the development process has been our inability to match water demand to its supply. For a large portion of the world's population, this has meant a lack of provision of adequate water for domestic use, resulting in a significant loss of time and effort, especially on the part of women. While science can now provide us with detailed assessments of water resource availability, little to date has been done to link this to our knowledge of human resources and their geographical distributions. In order to manage these resources better, it is essential that they be addressed in a more holistic way. This paper provides a preliminary discussion of possible ways in which an interdisciplinary approach can be taken to produce a more holistic assessment of water stress, in such a way as to link physical estimates of water availability with the socio-economic drivers of poverty. To this end, some approaches to creating a Water Poverty Index are discussed, and it is hoped that this paper will generate interest and debate among a wide range of readers*

Keywords: *Proverty, water, indices, development targets*

Introduction

A large number of people in the world today live in conditions of extreme hardship, lacking adequate food and water resources to meet their basic needs. It is, of course, not correct to imply that there is any global shortage of water. Over 7,000 m^3 of freshwater per capita enters rivers and aquifers each year (World Bank, 1992), but the problem arises when this water does not arrive where and when it is needed. In recognition of the hardship suffered by so many people, and the need to address it, poverty alleviation has been identified as one of the key development targets set for 2015 (DFID, 2000), and this has consequently become an important part of the agenda for international donor agencies. Recognizing the role of water, several governments, including those from the United Kingdom, The Netherlands, and Japan have pledged to significantly increase their expenditure on development aid for water projects, with a view to achieving more equitable and sustainable strategies of water management.

The development of a better understanding of the relationship between the physical extent of water availability, its ease of abstraction and use, and the level of household and community welfare, will allow water policy makers to make more rational and equitable decisions about water allocation. Set in the context of the ecological constraints required by sustainability, and the possible effects of climate change, there are strong arguments for an interdisciplinary approach to address this complex problem. By identifying and tracking the physical, economic, and social drivers which link water and poverty, a Water Poverty Index (WPI) could enable decision-makers to target cross-cutting issues in a holistic way, as recommended at the Dublin Conference in 1991, where it was concluded that, "since water sustains all life, effective management of water resources demands a holistic approach, linking social and economic development with protection of natural ecosystems" (ICWE, 1992).

Water inequities most acutely influence the lives of women and children, and in developing regions, they bear most of the burden of domestic water provision (Curtis, 1986). In some areas, as much as 25 percent of women's productive time can be spent in water collection, and this clearly has a significant opportunity cost in terms of household human capital entitlements. At present, national and regional policy-makers seldom consider the time spent by women in subsistence households, and indeed, within the structure of the United Nations System of National Accounts (UNSO, 1993), women's housework is never included. By clarifying explicitly the water management needs of this group, women and children will become major beneficiaries of any work to develop a Water Poverty Index.

Empirical attempts to understand the causes of poverty date back to the pioneering work of Rowntree and others who studied poverty in English cities at the turn of the 20th century (Maxwell, 1999). Rowntree developed the first composite poverty standard based on nutritional requirements and designed for application at the household level. Now recognized as a widely variable concept, poverty has been defined in many ways, and many methods of assessing it have been developed. While debate still continues over the differences between the definitions of absolute and relative poverty, Sen (1985) argues that "there is an irreducible absolutist core in the idea of poverty. If there is starvation and hunger, then no matter what the relative picture looks like, there clearly is poverty." Taking this further, Townsend (1985) highlights the importance of social standards and values, and Rowson (2001) stresses the need for poverty measures to be much broader than that provided by a simple income-focused measure. In suggesting a solution to the controversies surrounding poverty semantics, O'Boyle (1999) argues that the terms "minimum living standard" and "income distribution standard" could be used to capture both the depth of income poverty within a society, and the breadth of the distribution of that poverty across the households within it.

As part of this holistic approach to understanding how to manage water, the ecological needs of the environment have to be addressed, otherwise the concept of sustainable water management is flawed. Global security itself may depend on this recognition of the environment as our life support system and the development of policies and tools that recognize this are essential. In Africa, Asia, and Latin America, some 70 percent of human populations currently live in fragile ecosystems, where significant disruption to ecological services could bring about what effectively would be irreversible consequences. This can already be seen globally in terms of increased rates of desertification, soil salinity, and deforestation, and in cases like the Aral Sea and certain countries of the Middle East (Allan and Karshenas, 1995), the impact of human activities has already disrupted the life support function of that system. Since the will to survive is an evolutionary driver for the human species, it is inevitable that as resource availability shrinks, conflicts about their use-over will arise, and indeed this can already be observed in many places. Gleick (2000) examined many aspects of water resources and entitlements, especially with respect to global security, and indeed, as highlighted in the keynote speeches at the Pugwash (these conferences, now in their 50th year, provide a forum for international discussion on key issues affecting global security. Natural resources, including water are now considered to be part of this debate) conference in Cambridge (August 2000), the issue of poverty and its drivers is now attracting considerable attention from a security point of view. The widespread publication of global disparities in water accessibility in such meetings as the 2nd World Water Forum and the associated ministerial conference have also emphasized the need to address the problem of water management more effectively, both at a local and international scale.

At the international level, the UN Sustainable Development Commission has called for better coordination and harmonization of indicator initiatives. The Director of the Statistical Division of DESA (Dept. of Economic and Social Affairs) has advised the Commission of the need for integrated and coordinated development indicators, and of the importance of adopting these both within the UN system, and in other relevant international and national institutions (UNDP, 2000). The development of a Water Poverty Index (WPI) will be a useful component within that agenda, and if developed in a participatory manner, can, like other indices, become a valuable tool in many countries.

The Purpose of the Water Poverty Index

The construction of the Water Poverty Index (WPI) will contribute to a more equitable allocation of water resources, by considering water issues from the perspectives of both the supply of water, and the demand for it, in order to identify who needs water, when, and where. A more comprehensive understanding of the factors which influence the relationship between ecosystems, water and poverty, and the time dependent nature of this relationship, will enable decision-makers to make better informed decisions about how financial resources can be used to most effectively and equitably deal with water allocation problems. In a number of countries, a body of appropriate data may already exist, and this can be extended by collecting a relatively small amount of supplementary household data (Sullivan, 2000). At present, this is being attempted in a number of pilot sites in South Africa, Sri Lanka, and Tanzania, and these sites will be used to test the possible frameworks for the construction of the WPI. It is hoped that in the longer term, this supplementary household data can be collected in any country, simply by adding a few key questions into existing household surveys carried out for national censuses, health surveys, etc. (Deaton, 1999). In this way, the WPI can become a dynamic index, reflecting changes over time, and enabling people and their governments to address more explicitly the links between household welfare and water stress.

Because of the complexity of the problem, and the need for transparency in the political process, it is suggested that the link between water and poverty cannot be reduced to a simple single number. Furthermore, seasonal variation in water availability is another issue which needs to be considered, as some areas may be much more subject to water stress (and the consequent impact on household welfare) during certain months of the year than others. Any index designed to identify this relationship must therefore be a composite one, made up of the numerous variables which can link the various key factors together. The purpose of the WPI is therefore to produce a set of performance indicators, which directs policy towards particular welfare goals, with respect to water provision. Since water is a key component of the natural capital entitlements of households, and of healthy ecosystems, improved definition of water data, and its integration, is an important key to sustainability. This can be addressed in a holistic management tool by including ecosystem water requirements as a component of the analytical framework used for the calculation of the Water Poverty Index. The final structure of the WPI framework will be most effectively developed through both collaboration between researchers, and in consultation with practitioners and stakeholders. This will ensure general acceptance of the WPI tool and more widespread application of its uses.

The Pre-requisites for a Water Poverty Index

In the early part of the 20th century, the most pressing problem faced by policy makers and economists was how to deal with rising rates of inflation, and huge levels of unemployment. At that time, the development of the Retail Price Index (RPI) allowed decision makers to monitor changes in price levels and enabled policies to be developed which addressed these serious problems more effectively. At the beginning of the 21st century, the problems facing policy makers are more often to do with resource allocation, and in many parts of the world water resources are those which are most under stress. As policy tools indices can be used to present complex sets of information in a simple way, being used by policy makers to inform policy choices, and by politicians as a measure of performance.

The use of indices as policy tools began in the 1920s (Fisher, 1922; Edgeworth, 1925), and since that time, the value of "the opinion of representative housewives" (Bowley, 1919) has been the foundation on which household survey data has been based. Edgeworth (1925) defined an index number as "a number adapted by its variations to indicate the increase or decrease of a magnitude not susceptible of accurate measurement." This is more than a simple ratio of two particular quantities, and later this definition was extended by adding the idea of time (Allen, 1964). This means that an index number is a measure of a quantity relative to a base period. Indices are a statistical concept, providing an indirect way of measuring a given quantity or state, effectively providing a measure that allows for comparison over time. Key issues that have to be addressed in the construction of any index are:

- choice of components
- sources of data
- choice of formula
- choice of base period

However, apart from these empirical issues, the main point of an index is to quantify something that cannot be measured directly (e.g., how water stressed a household is) and to measure changes, (e.g., the impacts of development progress). The proposed Water Poverty Index fits this concept of an index that measures something indirectly and that is made up of clearly defined components. The existence of an index, which captures water availability taking account of the distribution of availability across the population and through time, would allow for monitoring and comparisons of progress to be made and for pressure to be put on governments, which were not making progress. Furthermore, the advantage of a measure that was internationally accepted would make the index difficult to manipulate for domestic political purposes. In the creation of a Water Poverty Index, however, there are a number of issues that would need to be addressed.

The Need to Examine the Links between Water and Poverty

In spite of the vast literature that exists on the subject of poverty, little of it makes an explicit link between water and poverty, and little acknowledgement is given to the livelihood support provided by ecosystems and their associated services. While it is recognized that poor people often have to rely on such environmental goods and services for their everyday survival, their poverty, worsened due to population pressure, is often a driver of environmental degradation (Redclift, 1996; Pearce et al., 1990). As a core component of every ecosystem, water is the key to all forms of life, but at the same time, water use is an essential prerequisite to human activity, and its consumption tends to increase with economic development, as illustrated by the figures in Table 1.

This suggests that as economic development takes place and human populations rise, there may be increased competition for water resources, in spite of increases achieved in water use efficiency. While there is no doubt that demographic patterns are changing as a result of the impact of HIV Aids, the UN population program currently estimates (November 2001) that human populations will exceed nine billion by 2050. As a result, likely increases in demand for both water and food highlight the pressing need for more efficient tools of water management (Fallenmark, 1990). Today it is recognized that modern water management strategies must address water not only as an economic resource, but also as a basic human requirement, and a key component in the structure of our life support system. The emphasis placed on this latter issue was highlighted during the discussions at the Second World Water Forum in The Hague, in March 2000, when it became evident that, in spite of the fact that over half of the world's population lack adequate access to safe water and sanitation, there is nevertheless some conflict between the demands of "water for nature" and "water for food."

Addressing the Constraints Imposed by Sustainability

A commitment to sustainability in water management requires the incorporation of ecological issues with the more usual dimensions associated with resource management and poverty alleviation. Different ecosystems perform different functions (Dickenson and Murphy, 1989).

Table 1. Water Use and National Income Levels

	GDP Per Capita (US$)	Annual Water Withdrawals Per Capita (cubic meters)		
	1990	*1970–87* *Domestic*	*1970–1987* *Industrial and Agricultural*	*1970–1987* *Total*
Tanzania	110	8	28	36
Sri Lanka	470	10	493	503
South Africa	2,530	65	339	404
United Kingdom	16,100	101	406	507
Sweden	23,660	172	307	479
United States	21,790	259	1,903	2,162

Source: World Bank, World Development Report 1992: Development and the Environment, Tables 1 and 33

each having their own role to play in global ecological and hydrological processes. Natural ecosystems can perform valuable hydrological functions, many of which can help to reduce both water stress and poverty. These ecosystem functions would include water purification, habitat provision, waste assimilation, groundwater recharge, and the maintenance of seasonal water delivery. Consequently, an important prerequisite to the achievement of genuinely sustainable water management must therefore be the identification of the differing water requirements of these various types of ecosystems.

Currently, there is no simple measure of ecosystem health in terms of effective hydrological functioning, and little is known about how much water different ecosystems need. In a recent study carried out by IWMI, a figure of 25 perecent of available water was used as a proxy for this environmental demand (Seckler, 2000). While this approach emphasizes the need to include environmental demand, it does not go far enough to examine the fact that different ecosystems will have different water requirements and these of course will be subject to seasonal variations.

An example of one attempt to use such an interdisciplinary, holistic approach is provided by the Comparative Research Programme on Poverty (CROP) of the International Social Science Council. Based in Norway, this program is founded on the idea that the application of sound theories to reliable data will provide a basic tool for poverty reduction, and the concept of the WPI fits well with this principle. CROP is an example of the many international initiatives, which are currently being undertaken to address the problem of poverty, while examples of work being undertaken to address water-related issues include the WHO/UNICEF Joint Monitoring Programme. Attempts have been made to link physical assessments of water with 'human adaptive capacity' through the use of the UNDP Human Development Index, to create a Social Water Stress/Scarcity Index (Ohlsson, 1998). Another example of an interdisciplinary approach is the Collaborative Council's basic water, sanitation, and hygiene requirement (Chattergee et al., 1999), which defines the minimum requirement to meet basic human needs as 40 per capita per day. While this is by no means a high figure, in many parts of the world, millions of people do not have ready access to even this amount.

Other attempts to link water with socio-economic variables tend to involve large-scale models such as the LUC economic model, and Threshold 21 model produced by the Millennium Institute, and the Asian-Pacific Integrated Model. While these sophisticated models can be of great use to policy makers and planners and do incorporate both hydrological and economic parameters, there is, to date, no single model or technique which explicitly links poverty and water in an easily used policy tool. There is, however, one striking example of how commitment to sustainability and the Dublin principles have been incorporated into national water policy, as illustrated by the new water law of South Africa. Principle 9 of that country's national water policy states that: "the quantity, quality, and reliability of water required to maintain the ecological functions on which humans depend shall be reserved so that the human use of water does not individually or cumulatively compromise the long term sustainability of aquatic and associated ecosystems." This shows how the national government of South Africa is working towards the adoption of the principles of sustainable water management as outlined in Agenda 21, and as such, are in theory at least, farther advanced in this respect than most other countries of the world.

Building on Conventional Water Resource Assessments

One of the best-known water resource assessments is the work done by the Stockholm Environment Institute (Shiklomanov et al., 1997). The key concept in this approach is the assessment of total water resources at the country level, in terms of the mean annual runoff. The runoff values are based on observed data from river flow measurement stations, supplemented by estimates based on meteorological data where river flow observations are lacking. This work has provided the foundation of many other studies, and while it was of seminal importance, very little weight was put on important issues such as spatial and temporal variability. Recent work has attempted to address these issues, including the method used in the Global Water Availability Assessment (GWAVA) (Meigh et al., 1998). In this work, the use of a grid approach has provided the means whereby physical assessments of water availability are adjusted to take some account of human factors. Other similar attempts using the grid approach have been made, including the work of Arnell and King (1998), and the WaterGAP model (Alcamo et al., 1997). An excellent summary of these and other studies is provided by Gleick (2000) in his second assessment, "The World's Water 2000–2001," and indeed the comprehensive nature of his work is one factor which has prompted the United Nations to begin production of the forthcoming "World Water Development Report," to be launched at the 3rd World Water Forum in Japan in 2003.

Considering the importance of water use in agriculture, the concept of water utilization intensity has been used by the FAO to identify areas which are likely to be water stressed in the future (FAO, 1996). When this figure is over 100 percent, this means that aquifers are depleting faster than the recharge rate, or that pollution may be making some otherwise renewable supplies unusable. In either case, water becomes a constraint on production, and more efficient means of using it becomes a vital issue. A number of countries in the Middle East already have a water utilization intensity of over 100 percent, and in the future, this number is certain to increase.

While demonstrating some variability, these examples of water assessments all indicate an already existing degree of water stress, and the urgency of the need to develop more equitable and sustainable approaches to water management. The objective of developing a Water Poverty Index is to produce a holistic policy tool, drawing on both the physical and social sciences and having application throughout the world. Through a more accurate linkage of information on water demand with that of supply, the development of a Water Poverty Index will be able to contribute to the resolution of potential conflicts over water shortages, or more importantly, their avoidance in the first place.

The Possibility of Using Existing Datasets

The research and donor community already has access to considerable data on both water availability and on household well being. It is possible that much of the data requirements of a Water Poverty Index may already exist in some countries, and as such, the production of a WPI will be possible on the basis of this data. While there are numerous possible sources of water data, some of them include data from the World Bank, such as from the LSMS living standards measurement survey (household based surveys), the Water Demand research team papers, and other information such as "voices of the poor" (available from the World Bank website); The "Comprehensive Assessment" underlying data sets (170 countries); the WHO/UNICEF Joint Monitoring Programme; the IUCN commission on ecosystem management; aquatic ecosystem health (catchment scale data); numerous university and research center datasets such as from the GRDC, Koblenz, and the UEA Climate Center, Norwich; remotely sensed data (such as that provided by NOAA, etc.); the UN datasets such as from UNEP, UNDP, and the FAO; national ministries in many countries, which may have data from national censuses etc. on their websites, e.g., the Botswanan inventory or the South African Department of Water Affairs and Forestry database of all water projects and access to water; national mapping of groundwater, DEMs, etc., and a variety of data available from the OECD, the development banks, and NGOs.

While this list is not exhaustive, it does demonstrate the fact that considerable data relevant to water management has been collected. Some of it is available from searchable sites on the Internet (such as the IWMI website, FAOs Aquastat, and sites such as www.worldwater.org). Recognition must be made, however, of the fact that data sets are not perfect, gaps exist, and there are qualitative aspects that perhaps should have been included, but data has not been collected. This lack of consistency of data is one of the main problems faced by those wishing to make international comparisons, or by donor agencies attempting to evaluate development progress, and one of the objectives of any work to identify a Water Poverty Index is to try to develop a standardized framework which can be used as a foundation for future data collection relating to water and its uses. If this can be achieved, this framework can be adopted to provide a system of national and international comparability such as that attempted under the United Nations System of National Accounts.

Criteria to Consider when Developing a Water Poverty Index

To develop a Water Poverty Index (WPI), work will need to be done which will:

- Identify the causal variables that determine household welfare in relation to water availability.
- Determine a water poverty line (i.e., given the location, and hydrological and ecological constraints, what is the appropriate volume of water per capita which should be made available to households to facilitate basic human health and dignity?)
- Produce a set of indices which address:
- Welfare in relation to water availability and water quality (access, time and effort to get water, institutional constraints, etc.)

- Water management issues (hydrological and ecological constraints, storage and delivery, cost recovery, requirements for economic development, etc.).
- The extent of the location specific "Water Poverty Gap" (how far short of basic needs is the current situation).
- The potential to reduce that gap – an indicator of how well the appropriate authorities have addressed the objective of providing safe water supplies for all.

For this set of performance indicators to be most useful, they must:

- be constructed in a transparent manner,
- be easy to understand, and cheap to generate,
- be generated locally, and
- have the potential to be scaled-up to the regional and national level.

If the methodology of its development can be standardized (and accepted) for use in all countries (as with other indices), then this will mean that the WPI will be useful both for national planning, and in situations where international comparisons need to be made. In the future, as technological improvements help in the resolution and storage of data, the WPI can be refined and improved, but at present, by making a start in the process of developing such a holistic management tool, the development of the WPI will contribute to the process of more equitable and sustainable water management.

The Structure of the Water Poverty Index

There are a number of different approaches that can be taken to produce a Water Poverty Index. These will vary in complexity and may have different theoretical foundations. For such a tool to be widely accepted and adopted, it would need to be derived in a participatory and inclusive manner. Its calculation would need to be transparent, and it would need to be a tool that could be freely and easily used by all countries, at various scales. As such, its implementation would need to be preceded by a period of consultative conceptualization, followed by a period of pilot testing and capacity building. While this may be seen by some as a daunting challenge, it is clear that the potential of its achievement to bring forth a new era of accountability in water use, will make that effort worthwhile.

One of the first tasks, which would be required in the creation of a Water Poverty Index, would be the development of an integrated database of information relating both to water availability and to water demand. A major problem of combining data from the physical and social sciences and with time is one associated with scale (Schulze, 1999). Physical water assessments tend to use large scales, based on whole river catchments, or on grid squares, the best resolution of which is most usually 10 Km square, while data from the social sciences tends to be at the household or community level. There are four main scaling issues relating to attempts to integrate the social and physical sciences (Gibson et al., 2000). These are:

- how scale, extent, and resolution affect the identification of patterns,
- how different levels on a scale explain different social phenomena,
- how theoretical propositions about phenomena on one spatial, temporal, or quantitative level of a scale may be generalized to another level (up and down scaling), and
- how processes may be optimized at particular points or regions on a scale.

In addition to these difficulties of integrating data at different scales, there will also be a need to integrate data which may be both quantitative and qualitative, and one of the challenges in the development of a Water Poverty Index is to link all of these data types in a meaningful and understandable way.

The development of computer-based geographical information systems (GIS) does provide one way in which such an integrated database can be constructed (Gurnell and Montgomery, 1999), and the use of an object orientated approach to database construction can provide a foundation for future change (Coad and Yourdon, 1990). By ensuring that household and community information is identified by its grid reference, it can be linked exactly to the physical data relating to that location, thus minimizing the need to use averages which so often can be very misleading, hiding the heterogeneity of household water access resulting from physical or economic factors, or both. Once an integrated database is produced in this manner, it becomes more feasible to produce an integrated management tool that could have applicability for policy issues at the local, regional and global scales.

Attempts have been made by a number of UN agencies, and the World Resources Institute, to integrate existing survey data to generate poverty maps (Henninger, 1998). While this kind of top-down approach can generate broad coverage of specific information, it fails to capture the diversity that characterizes most countries today. If, however, a standardized set of household survey questions could be generated, to capture key issues relating to water stress and human welfare, the household data generated could reflect this heterogeneity, and allow it to be integrated into the policy process. This is what may be possible, if an appropriate framework for a Water Poverty Index can be devised. The specific structure of how this can be done would be best determined through a consultative process, drawing on a wide range of expertise, and representing a wide range of views. To facilitate the inclusion of this variety of data from different sources and of different scales, a geographical information system can be used, as shown in Figure 1.

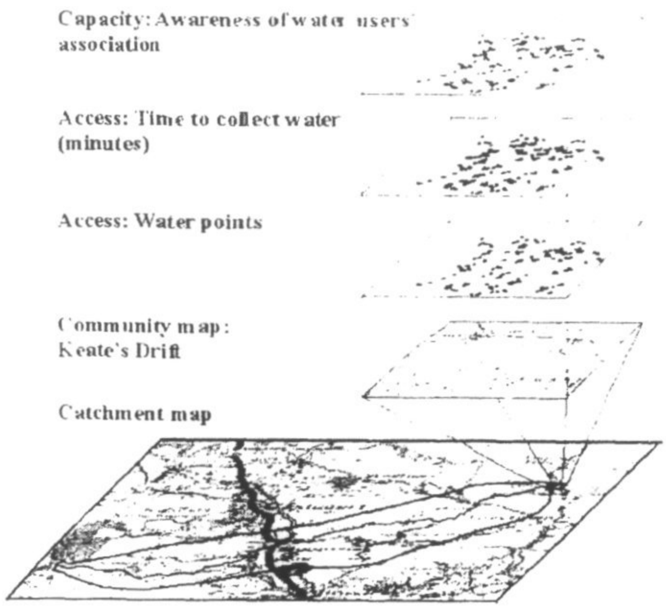


Figure 1. How layers of data can be linked by grid reference in a GIS. Using GIS to integrate data for assessment of the WPI (not actual data).

Some Possible Frameworks for the Development of the Water Poverty Index

There are a variety of different possible methods that could be used to develop a Water Poverty Index, but for comparison, three different approaches are presented here.

An Example of a Possible Water Poverty Index Using the Composite Index Approach

The Human Development Index has been an important tool by which the process of development has been re-evaluated to take account of factors other than simple assessments of economic growth in monetary terms. Incorporating life expectancy, educational attainment, and income levels adjusted for purchasing power, the HDI is a composite index, which enables more meaningful comparisons to be made both between countries and within countries over time. While some criticism has been made of this approach (Streeten, 1996), it is generally perceived as being an improvement in how development is measured. Along the same lines as the Human Development Index, the WPI could be a composite index, comprising various elements such as water availability, access to safe water and clean sanitation, and time and effort required collecting domestic water.

This would result in a formula for the Water Poverty Index as follows:

$$WPI = w_a A + w_s S + w_t (100 - T) \qquad (1)$$

where A is the Adjusted Water Availability assessment as percent (AWA) calculated on the basis of ground and surface water availability related to ecological water requirements and a basic human requirement, plus all other domestic demands, as well as the demand from agriculture and industry (The value of A should also recognize the seasonal variability of water availability); S is population with access to safe water and sanitation (percent); T is the index (e.g., between 0 and 100) to represent time and effort taken to collect water for the household (e.g., from proportion of population having access in or near the home, etc. This could be modified to take account of gender and child labour issues) $(100 - T)$ is the structure used to take account of the negative relationship between the time taken to get water and the final level of the WPI), w_a, w_s and w_t are the weights given to each component of the index (so that $w_a + w_s + w_t = 1$).

Since A, S, and T are all defined to be between 1 and 100, and w_a, w_s, and w_t are between 0 and 1, to produce a WPI value of between 0 and 100, the formula needs to be modified as follows:

$$WPI = \frac{1}{3}(w_a A + w_s S + w_t (100 - T)) \qquad (2)$$

To use this method effectively, it would be necessary to define and identify the "base rate" on which to calibrate the index values, and to provide an explanation of what exactly the resultant scores meant. The problem of incommensurability does not arise as the index is composed of parts that are all expressed as a percent (or index number). In addition, by using water access and time spent to collect water as a proxy for socio-economic well-being (the two can be shown to be highly correlated), the problems associated with calculating monetary incomes, exchange rates etc can be avoided.

A Numerical Example

As an illustration, consider two hypothetical regions:

Region A

The values A, S, and T (in the example here, the time variable T is expressed as a percentage — perhaps percent of per capita available labor time are 80, 50, and 30, and the weights w_a, w_s and w_t are 0.5, 0.25, and 0.25, respectively. Referring to Equation 2

$$WPI = \frac{1}{3}(w_a A + w_s S + w_t (100 - T)) \text{, so } WPI_A = 1/3[(80 \times 0.5) + (50 \times 0.25) + 0.25(100-30)] = 23.3 \text{ (index points)} \qquad (3)$$

Region B

The values A, S, and T are 80, 20, and 50, and the weights w_a, w_s and w_t are 0.5, 0.25, and 0.25, respectively. Referring to Equation 2

$$WPI = \frac{1}{3}(w_a A + w_s S + w_t(100 - T)), \text{ so } WPI =$$

$$1/3[(80 \times 0.5) + (20 \times 0.25) + 0.25(100-50)];$$

$$19.1 \text{ (index points)} \quad (4)$$

This comparison shows that although the physical assessment of water in the regions is the same, and weights (preferences) used are the same, in Region B, fewer people have access to safe water and more time is spent by people collecting water. On the basis of this calculation, it is possible to show that in region A, water poverty is less of a problem than in region B, although it is still a problem that needs to be addressed. Nevertheless, policy makers can see that in both Regions A and B, their priority for water management may be to increase the numbers of people who have access to safe water and to reduce time spent on water collection. Quantifying the issues in this way should help to determine which area faces more pressing problems in water provision. These results are summarized in Table 2.

Table 2. A Summary of the WPI Calculated using the Composite Index Approach

	Water Availability (%)	*Access to Water (%)*	*Index of Time spent in Water Collection*	*WPI*
Weights	0.5	0.25	0.25	
Region A	80	50	30	23.3
Region B	80	20	50	19.1

In this method, the higher the value of WPI, the lower the degree of water stress, so Region B has a greater degree of water poverty than A

An Alternative Approach - A Gap Method

Another way to develop a WPI measure could be consider the assessment of by how much water provision and use deviates from a pre-determined standard. This standard could be an assessment made up of considerations of the following:

- ecosystem health
- community well-being
- human health
- economic welfare

In this approach, each of these components are assigned a standard value, which may be quantitative (scientifically defined) or qualitative, (identified through participation). This standard or target value reflects that level which would exist if the resources were managed in a sustainable way. The WPI is determined by comparing the actual current empirical situation (as identified from data), with this pre-set standard. Such a methodology is already used as a framework for estimating indicators of sustainability (Simon, 1999), and as a measure of poverty (Collis et al., 1987), and in the case of the WPI, some of the same principles can be applied. This approach is summarized in Table 3.

Using the approach in Table 3, water stress is highest when the water poverty gaps are largest, and if the situation improves, the gap gets smaller. It must also be noted that the measure of Ecosystem Health should reflect some assessment of both the quantity and quality of water, as well as recognition of the fact that many ecosystems have already been modified by human activities, and as such, are no longer natural. As a result, the definition of EH will have to be based on local interpretations of what aspects of the ecosystem are important and need to be preserved.

Table 3 The Calculation of the WPI Based on the "Gap" Method

Ecosystem Health	*Human Health*	*Community Well-being*	*Economic Welfare*
Could be based on biodiversity waste assimilation, and resource depletion.	Could be based on infant mortality rates, incidence of selected disease and life expectancy	Could be based on crime rates, martial breakdown, education, political participation	Could be based per capita incomes, income distribution, reinvestment rates, unemployment, etc.
(Symbol EH)	(Symbol HH)	(Symbol CW)	(Symbol EW)
(Symbol AEH)	(Symbol AHH)	(Symbol ACW)	(Symbol AEW)
EH-AEH=ch	HH-AHH=hh	CW-ACW=cw	IW-AIW=iw

A Simple Time-analysis Approach

A third possible way of addressing the methodology of constructing a WPI is to use a time analysis approach, where time is used as a numeraire for the purpose of assessing water poverty. In this method, the WPI is determined by the time required (per capita) to gain access of a particular quantity of water. As such, the WPI would be as follows:

$$WPI = T/1000M^3 \quad (5)$$

Here, T= Time required per person to collect a quantity of water (1,000 M^3). In cases where the water was provided by infrastructure, the labor time required by residents to pay the appropriate fee for that quantity of water would be equivalent to the value of the WPI for them. While this method is apparently very simple, it does have a number of weaknesses: notably, the single figure simply reflects domestic issues, and, by failing to include ecosystem needs and commercial interests, it does not really address the water assessment issue in an interdisciplinary, holistic way. In this method, it is also difficult to evaluate the means by which water may be provided, or the relevance of issues such as access to irrigation water and its impact on food production, since it fails to address the supply side of water provision. On the other hand however, it does produce a measure which is relatively easy to calculate and universally easy to understand.

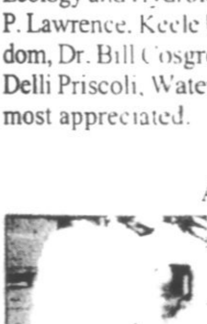
Conclusion

The appropriate methodology to calculate a WPI will be that which is determined through consultation and participation. While scientific issues (such as linking data at different scales, or identifying a meaningful value of ecosystem water demand) may have to be resolved in the process of deriving the WPI, the most important challenge is to develop the appropriate degree of political and institutional will. This will then allow technical difficulties (such as data variability etc) to be overcome, along with the necessary capacity building to ensure that individual countries will be enabled to produce their own integrated assessments of water and its impact on poverty. If this can be done, (and it is most likely to be an iterative process) the development of the Water Poverty Index will eventually deliver a comprehensive, ecologically sensitive tool to help in water management, and as a result make a direct contribution to the process of poverty elimination in poor countries by meeting the needs of the current generations, while at the same time securing water availability for the needs of future generations.

Acknowledgements

The funding for this work has been provided by the United Kingdom Department for International Development, contract number C24, but this paper does not necessarily reflect the views of DFID. Contributions to the development of the ideas in this paper have been made by a large number of people who have been involved in this work, but in particular, those of Dr. J. Meigh, Center for Ecology and Hydrology, Wallingford, United Kingdom, Dr. P. Lawrence, Keele University, Staffordshire, United Kingdom, Dr. Bill Cosgrove, Ecoconsult, Canada, and Dr. Jerry Delli Priscoli, Water Resources Group, USACE have been most appreciated.

About the Author



Dr. Caroline Sullivan is currently head of Water Policy and Management at the United Kingdom's Centre for Ecology and Hydrology. An environmental economist by profession, she has worked for over 20 years in developing countries, in Africa, Asia, and Latin America. Her main research interest is solving problems of environmental management by "making interdisciplinary as reality." Email:csu@ceh.ac.uk

Discussions open until June 1, 2002

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Appendix 6.6
World Water Development Report Contribution

The nature of the WPI makes it extremely relevant to the work being carried out to produce a World Water Development Report. This UN initiative is being coordinated by UNESCO, and they have confirmed that the WPI project has produced something which they feel is very appropriate for inclusion in the WWDR, and we are preparing some summary material for that purpose for inclusion in that document. Such material will focus on the composite approach, and will include something on both the micro and macro approaches. It is hoped that some of the controversial characteristics of the findings from the macro approach will provoke debate on the subject, and that the work will highlight the need for and value of improved and standardised water data.

The WWDR will be launched at the Kyoto World Water Forum, and it is hoped that some opportunity will be provided to present the WPI method and results to the wider international community at that time. If a Phase 2 of the project does come into effect, this will provide a means by which the methods presented here can be improved and refined in time for that meeting.

Appendix 6.7
Future Dissemination of the Water Poverty Index

Considerable interest in the WPI work has been generated during the life of the project and as a result, the dissemination process will be continuing after Phase 1 has been completed. Presentations on the work will be given at the following meetings:

1. Commonwealth Science Council coordinated one-day workshop to disseminate WPI to the International Community in London. June 2002.

2. Climate Change Workshop at Snowmass, Colorado, USA, August, 2002.

3. HELP meeting, Sweden, August 2002.

It is also likely that the work will be disseminated elsewhere, and in fact many people consulted in South Africa thought the work should be presented somehow at the Johannesburg summit, August 2002.

In addition, following the indicators workshop held for the World Water Development Report team, enquiries have been made by the representatives from the Bolivia, Thailand and Senegal case studies, and each of these groups would like to implement the WPI in their cases. While time will not permit this for the first volume, the possibility of extending those case studies through the application of the WPI, has been suggested for the second volume in 2005. .

The following documents give details of a future meeting to disseminate the WPI to members of the international community:

WORKSHOP TO PRESENT THE WATER POVERTY INDEX TO THE INTERNATIONAL COMMUNITY IN THE UK

Marlborough House, 26 June 2002

Invitation list

High Commissions – CSC London Contacts

Mr Frank Davis
Second Secretary
High Commission of the Bahamas

Mr Sikder Md Zahidur Rahman
Counsellor & Head of Chancery
Bangladesh High Commission

Mr Ricardo Browne
Minister Counsellor
Barbados High Commission

Ms Florence Molefe
Second Secretary
Botswana High Commission

Mrs Krtini Tahir
Second Secretary
Brunei Darussalam High Commission

Mr Martin Agbor Mbeng
Deputy High Commissioner
(Common-
wealth Liaison Officer)

Cameroon High Commission

Mr Christos Christys
Second Secretary
Cyprus High Commission

H E Mr George E Williams
High Commissioner
Dominica High Commission

Mr Anani Demuyakar
Minister Counsellor, Education
Ghana High Commission

HE Ms Ruth Elizabeth Rouse
High Commissioner
Grenada High Commission

Mrs Marion Herbert
First Secretary
High Commission for Guyana

His Excellency Shri Nareshwar Dayal
High Commissioner
High Commission of India

Mr Audley Rodriques
Deputy High Commissioner
Jamaican High Commission

Mrs Rebecca Nabutola
Counsellor
Kenya High Commission

Miss Teboho Mapetla
First Secretary
High Commission for the
Kingdom of Lesotho

Mrs Veronica Tasosa
First Secretary (Political)
Malawi High Commission

Mr Mohamad Muda
Second Secretary (Political)
Malaysian High Commission

Mr Jonathan Galea
Commonwealth Desk Officer
Malta High Commission

Mr J Isaack
Minister Counsellor
First Secretary
High Commission of Namibia

Commonwealth Desk Officer
New Zealand High Commission

Mr S O Omoigiade
Minister Counsellor
Nigeria High Commission

Mr Raja Ali Ajaz
Second Secretary, Political
High Commission for Pakistan

HE Sir Kina Bona KBE
High Commissioner
High Commission for Papua New
Guinea 14 Waterloo Place

Mrs Colletta Arouma
Counsellor
High Commission for St Lucia

H E Mr Bertrand Rassool
High Commissioner
Seychelles High Commission

Mr S B Daramy
Commonwealth Desk Officer
Sierra Leone High Commission

Miss Reita G Toussaint
First Secretary
Trinidad & Tobago High
Commission

Mr James Paterson
First Secretary
South Africa High Commission

Mr W Hettiarachchi
Minister (Political)
Sri Lanka High Commission

Mr Clement T Mabuza
Counsellor
Kingdom of Swaziland High Commission

Miss Reita G Toussaint
First Secretary
Trinidad & Tobago High Commission

Ms Elizabeth Kanyogonya
Minister Counsellor
Uganda High Commission

Mr Rajab H Gamalia
Deputy High Commissioner
Tanzania High Commission

Mr G P Alikipo
Deputy High Commissioner
Zambia High Commission

Mr N Mutizwa
First Secretary, Political
High Commission for the Republic of Zimbabwe

Members of the Diplomatic Science Club

Prof. Salvarore Aloj - Italian Embassy

Mrs Vera Balint – Hungarian Embassy

Dr Michel Bernier – French Embassy

Mr Martin Bloom –Emblem Technology parners

Mr Arthur Bourne – European Union of Science Journalists Associations

Dr Leonard Bovey -

Mr Wolgang Bruellant - Swiss Embassy

Mr James H. Chang – Tapei Rep. Office

Mr Han Peter Christophersen – Royal Norwegian Embassy

Mr Wlfgang Drautz German Embassy

Dr Alice Tidball – U S Embassy

Prof. Ming Yi Fan – Chinese Embassy

Prof. Arthur Finch – University of London

Dr Wayne Garrett – Australian High Commission

Mr Peter Healey – Science Policy Support Group

Prof. Phillip Hills – University of Manchester

Dr Frederick Hotchner - US Embassy

Mr Lee-Hwan Kim – Korean Embassy

Dr Marcel Kilmo - Embassy of the Slovak Republic

Mr Stanley Langer – The Royal Society of Chemistry

Ms. A Monika Lawacz - Embassy of the Republic of Poland

Dr Peter Lee – Office of Science and Technology

Dr Caroline Martin – Canadian High Commission

Mr Hiroshi Masuko – Embassy of Japan

Dr John Mckenzie – World Federation of Engineering Organisations

Prof. Samuel Okoye - Nigerian High Commission

Mr Miles Parker – Office of Science and Technology

Dr Edward Robson - Teaching Company Scheme

Dr George C Stirling - CLRC

Mr Arne Tonning - Royal Norwegian Embassy

Dr Peter Warren CBE – World Humanity Action Trust

Dr Nicholas Watts – University of North London

Dr Austin Woods – European Centre for Medium Range forecasting

Senior C Cunyong Xu – Chinese Embassy

Workshop to Present the Water Poverty Index to the International Community

Commonwealth Secretariat, Marlborough House Pall Mall, London

Wednesday 26th June 2002

Draft Agenda

09.00	Arrive. **Tea and Coffee**	
9.30	Introduction	**Siyan Malomo**
9.45	Welcome	**Mrs F Mugasha,** ***Deputy Secretary***
General		
10.00	Presentations	
	• *Overview – Water and Poverty*	**Caroline Sullivan**
	• *CSC Contribution*	**Siyan Malomo and Silencer Mapuranga**
	• *Developing the Water Poverty index*	**CEH**
	• *How to use the Water Poverty Index*	**CEH**
	• *Assistance required from governments*	**CEH and CSC**
12.00	Group Discussion Sessions	
13.00	**Lunch**	
14.00	Group Discussion Sessions	
15.00	**Tea and Coffee**	
15.30	Feedback from Group Discussions	
16.00	End of meeting	

Appendix 7
Feedback from the consultation process

7.1 Summary

The consultation process has been very successful and a very large number of people have been involved. The responses have been almost unanimously positive, and those consulted have repeatedly expressed the desire to see the WPI implemented in the future in their countries. A summary of some of the general feedback is given below, and copies of the appraisal sheets are attached to the main report documentation.

Appendix 7.2
Feedback Documentation

7.2.1 WPI Management Primer, Comments

Participants at WPI workshops in South Africa, Tanzania and Sri Lanka were asked to give feedback on a draft copy of the primer, by way of a simple form. Copies of these forms are attached[37].

In South Africa, 50% of respondents said that the primer was overall very useful. 20% said it was useful as a WPI reference and a reference in general and 20% said it was a useful general reference for water managers

In Tanzania, 20% of respondents said that the primer was overall very useful, with 60% saying it was useful as a WPI and general reference. 10% believed it to be beneficial as a reference for water managers.

36% of respondents in Sri Lanka found the primer very useful, Half of respondents thought it was useful as a general reference and 7%, as a reference for water managers.

[37] DFID copy only. If not attached, please see separate document *Derivation and Testing of the Water Poverty Index, Feedback from workshop participants.*

7.2.2 Comments on WPI Workshops

Participants at WPI workshops in Tanzania and Sri Lanka were asked to give feedback on the workshops, by way of a simple form. Copies of these forms are attached[38].

In Tanzania, 100% of respondents said that the workshops were interesting. Of those who commented, everyone believed the workshop was pitched at the right level.

77% of respondents in Sri Lanka found the workshops interesting, with only 1 respondent (8%) saying that they were too simple. Most respondents felt that the workshops were pitched at the right level.

[38] DFID copy only. If not attached, please see separate document *Derivation and Testing of the Water Poverty Index, Feedback from workshop participants.*

7.2.3: Short Report on Annual Water Experts Conference (AWEC)-Arusha, January 2002

Steven D. M. Mlote
Tanzania Commission for Science and Technology

Introduction

This report gives a brief summary of the AWEC workshop, which was held in Arusha from 21st to 25th January 2002. The theme of the workshop was "Water and Poverty Eradication".

The workshop was attended by about 300 water experts from the ministry of water and livestock development and experts from all corners of the country. Others in the workshop were Dr. Andy Bullock from World Water Assessment program (WWAP) focal point for Africa, Permanent secretaries from vice president's office, and Ministry of water and Livestock development. The guest of honour was the minister of water and livestock development hon. Edward Lowasa. During this workshop I presented a paper entitled "Calculating Water Poverty Index for Tanzania" which was written by Dr. Caroline Sullivan, Dr. Jeremy Meigh and Steven Mlote.

1: SPEECH BY THE MINISTER

The minister in his speech started by pointing out that African countries needs to improve their policies in order to improve poverty levels. Also he stressed that international communities and donors must allocate more aid to poor Africa. The minister noted that poor water supply and sanitation to the communities have detrimental impact to education (reduced school attendance), health and increased poverty.

The minister observed that in most cases the poor pay more for water than the rich. He sited examples that in Morogoro town, people getting water from kiosks pay more than those with house hold connections. In his words he said, " In this case the poor subsidize the rich- it is not proper it must be reversed".

The minister challenged the water experts to

- identify linkages between poverty eradication and water supply and sanitation and suggest interventions.
- Reverse the trend where the poor pay for the rich in terms of water supply

2: SPEECH BY THE PERMANENT SECRETARY – VICE PRESIDENT'S OFFICE

The permanent secretary – vice president's office is responsible for poverty eradication and environmental issues in the country. In his speech he pointed out that water was important to life because water is needed for;

- Food security
- Sanitation
- Ecosystem sustenance
- Income generation
- Health life for both human and animals

He challenged the water experts to find a sustainable way of providing water for the points above without affecting the environment (ecosystems).

He noted that, although water is a necessity for life, people should be prepared to pay the water service charges (conveyance and delivery costs).

The permanent secretary also noted that, the poor urban water supply and sanitation is not a scarcity crisis, rather it is a governance crisis. He pointed out that more than 50% of the water drawn at the intake is lost during conveyance through leakage, and it is a habit that industries do not recycle/reuse their water and do not treat waste water before they dispose of it. He stressed that fresh water bodies' degradation from cities and towns effluents was rather a governance crisis.

The permanent secretary concluded his speech by challenging the water experts to develop indicators of performance of both water supply and sanitation and poverty eradication. He also urged the water managers to allocate development resources equitably basing on needs and demands.

3: OTHER PAPERS

There were several other papers, which generally discussed water and poverty eradication.

The papers noted that there are two categories of poverty

- Income poverty: people earn much less than is required to enable them to acquire enough basic goods and services.
- Non-income poverty: people have a bit of money but have no access to good schooling or safe water

The papers also discussed the linkages between poverty and water supply and sanitation. The tables below show the linkages.

Table 1: Linkages between poverty and water supply and sanitation

	Poverty Dimension	Key effects
Lack of water supply and poor sanitation and	Health	Water and sanitation related illnesses Stunting from diarrhea and malnutrition Reduced life expectance

Table 2: Effect of water supply and sanitation intervention health

INTERVENTION (Input)	EFFECT (Output)	HEALTH (Outcome)
Increasing the quantity of water Improving the quality of water Providing means of safe excreta disposal	**Better Hygiene (hand washing, etc.)** Reduced ingestion of pathogens Reduced number of pathogens in the environment	**Reduced morbidity and mortality rates**

4: Paper on Water Poverty Index

The paper on calculating the water poverty index highlighted the following

- What is Water Poverty Index (WPI)
- Why WPI is needed?
- WPI Pilot project
- Approach to derive and test WPI
- Example of WPI calculation using different approaches

hygiene	Education	Reduced school attendance by children (especially girls), due to ill health, lack of available sanitation, and water collection duties (Time and effort to gather water)
	Gender and social inclusion	Burdens borne disproportionately by women, limiting their entry into cash economy.
	Income/consumption	High proportion of budget used on water Reduced income earnings potentials due to poor health, time spent on collecting water or lack of opportunity for businesses requiring water input High consumption risk due to seasonal or other factors

The majority of the w/s participants were impressed by the exercise of developing the WPI, they said this is going to be the only development and water management indicator/tool which considers many variables in its development, Most of them said they were looking forward to see it developed and would be glad to use it as a yard stick for human development as far as the water sector is concerned.

Generally those who got a chance to discuss it observed that the composite index approach is likely to produce a more realistic WPI because it uses several variables which are related to water availability and use, and considers water for ecological sustenance.

Most of the participants agreed that there was a need for adding a question in the national census that asks about distance and time spent to gather water. However, it was said to be rather late for this year's census because the census materials have already been taken to the regions and districts.

7.2.4: Letters of support for the WPI

DW 6/1

DEPARTMENT: WATER AFFAIRS AND FORESTRY

Dr Caroline Sullivan
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Barbara Schreiner
Senior Executive Manager:
Policy and Regulations
Private Bag X 313
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South Africa
Tel +27 12 336 8731 (Direct)
Email Bschreiner@dwaf.gov.za
Ref 10/4/1/7

26 April 2002

Dear Dr Sullivan

SUGGESTIONS FOR THE APPLICATION OF THE WATER POVERTY INDEX

There are a number of potential catchments in which your project could operate but I would suggest that you try and link up with existing processes. In this case the Department is piloting a project for the compulsory licensing of water use in catchments. This offers an opportunity to re-allocate water from those who have enough or too much, to those who have been historically excluded. The compulsory licensing process is vital for the Department to understand the inequalities within a catchment so that Previously Disadvantaged Communities are not excluded in future allocations.

The first pilot Compulsory Licensing Project is to be conducted in the Mhlathuze Catchment in Northern KwaZulu-Natal. One of the things we most need is an indication of the levels of poverty in this particular catchment before implementing any form of re-allocation. The catchment is fairly data rich, stakeholders in the catchment are well aware of water management issues and there is an active water management forum in the catchment. These factors make it an ideal catchment for piloting most processes. The catchment also has numerous inequalities: the irrigation sector takes the lion's share of the water followed by bulk industry; poor people who make up the bulk of the people in the catchment only receive a very small percentage of the allocated water.

The definition of poverty, with regard to water supply, was a topic of discussion at a workshop we have just held (24 April 2002) and I have asked my staff to e-mail to you any relevant outcomes on this aspect as recorded at the workshop.

Institutions and individuals, which may be relevant for you to consult with, regarding the application of the Water Poverty Index:

- Mr. Ashwin Seetal, Catchment Management KZN, and Mhlathuze Compulsory Licensing Pilot Project Leader 031 336 2743/2700 seetala@dwaf.kznl.gov.za
- Dr. Graham Jewitt, The School of Bio Resources Engineering and Environmental Hydrology, University of Natal, 033 260 5490 jewitt@aqua.ccwr.ac.za
- Mr. Andrew Pott, CPH Water, Consultancy working on Multiple Criteria Decision Analysis in the Mhlathuze Catchment, 033 347 3723, andrew@cphwater.com
- Mr. Japhet Ngubane, Economic, Environmental and Social Impact Assessment, Social Consultant Northern Kwazulu Natal, 082 772 2344, ecsia@saol.com
- Mr. Johan van Rooyen Department of Water Affairs and Forestry Pretoria, Water Resources Planing, 012 336 8814, javr@dwaf.gov.za
- Mr. Malcolm Watson, Department of Water Affairs and Forestry Pretoria, Water Situation and Assessment Model, 012 336 8359, ICE@dwaf.gov.za
- Ms Barbara van Koppen, Water, Poverty and Gender specialist, IWMI, Pretoria, 012 845 9109, b.vankoppen@cgiar.org

I trust that this will be of assistance to you.

Warm regards

DIRECTOR–GENERAL

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ජාතික ක්‍රමසම්පාදන දෙපාර්තමේන්තුව
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நிதி, திட்டமிடல் அமைச்சு
DEPARTMENT OF NATIONAL PLANNING
Ministry of Finance and Planning

මගේ අංකය / எனது இல / My No.: NP/EI/4/121
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මහලේකම් ගොඩනැගිල්ල, (පළමු මහල), කොළඹ 1
செயலகம் (1 ஆம் மாடி), கொழும்பு 01
The Secretariat (1st Floor)
Colombo 01

20.05.2002

Dr. Caroline Sullivan,
Head of Water Policy & Management,
Center for Ecology & Hydrology,
United Kingdom.

Dear Dr. Sullivan

Development and Testing of the Water Poverty Index

We would like to thank you first for the groundwork that you have done in Sri Lanka on the development of the above Index.

Our long-term goal is to provide access to safe water for all by 2010. In achieving that we consider that it is no longer adequate to deal only with technical solutions and hydrological directions. Therefore, we consider developing of such an Index that incorporates physical, social as well as economic factors and addresses different dimensions such as the shortage of water as well as the social and economic adaptive capacity is necessary and useful to Sri Lanka. At present a Concept Paper/ Project Paper for this is being prepared by the National Water Supply & Drainage Board identifying Hambantota District as a pilot area for the development of the Index. It is expected to request the necessary assistance thereafter.

We look forward again to your valuable cooperation. Thank you.

Yours sincerely,

Dr. (Mrs.) P. Alailima
Director General

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தேசிய நீர் வழங்கல் வடிகாலமைப்புச் சபை
National Water Supply & Drainage Board

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සාමාන්‍යාධිකාරී / முகாமையாளர் / General Manager — 636449
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මගේ අංකය / எனது இல. / My No. PD/ADB3/16J

ඔබේ අංකය / உமது இல. / Your No.

25th March 2002

Dr Caroline Sullivan
Head of Water Policy and Management
Centre for Ecology and Hydrology
Crowmarch Gifford, Wallingford
OX10 8BB England

Dear Dr Sullivan

<u>THE WATER POVERTY INDEX</u>

I have now had a chance to read the material you left for me on the subject of the Water Poverty Index. I found it useful and informative. As you suggested, I am writing to give you some feedback on this work. It seems to me to be something, which could be relevant here in Sri Lanka in a number of ways.

It is possible for example that we could use this tool to help us to determine the location of those areas next selected to be included in a number of water supply projects, which are going to be carried out with loans from the World Bank and the Asian Development Bank. This means that we can make better use of our loans and ensure that the money reaches those areas where it is most needed.

Another way the Water Poverty Index tool could be used is as a way of helping us to decide how to deal with the situation we are currently facing where a drought is forcing us to ration water supplies, especially in urban areas. Using this tool will help to identify those areas where a lack of basic water supplies will have a severe effect on poor people. Also we will be able to investigate how some re-distribution of water from other sectors in industry or agriculture can influence poor people in our country.

Many people are involved in water management in our country and many of them are young and less experienced than before. These people sometimes find it difficult to make decisions on how water should be allocated between different users, and this WPI can help with this by giving them a clear structure to follow. As we discussed, we will be happy to send a representative to the consultative workshop on the WPI that you are planning to hold here in April. I am sure that many others would like to attend to find out more about this interesting development.

MINISTRY OF URBAN DEVELOPMENT, PUBLIC UTILITIES, HOUSING AND SPORTS
"Water - Every Drop is Precious"

In many places in Sri Lanka, decisions about water management are not easy to resolve. We have complex conflicts over water, which have arisen due to ethnic, religious and other social differences, and may be the WPI can help to reduce these by making our decisions easier to justify on rational grounds. We also like the idea of including the school system in the collection of data from households, by involving children in discussions of water problems as part of their everyday school work.

In ADB assisted Third Water Supply & Sanitation Project in Sri Lanka, it is important to identify the Water Poverty Areas. The above project is implemented with the demand driven community centred approach. Therefore, community demand is given high priority when selecting subprojects. There are three batches in this project. Batch No.01 is almost complete. The criteria developed for Water Poverty Index can be used in other batches in implementation, in order to select the subprojects.

Therefore, we would be very much appreciated if you could inform us the status on the above activities regularly and involve us when preparing above.

Yours faithfully

K L L Premanath
Project Director
ADB Assisted Water Supply & Sanitation Projects
National Water Supply & Drainage Board

WATER RESEARCH COMMISSION

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Your Reference

Our Reference

10 April 2002

Dr Caroline Sullivan
Natural Environment Research Council
Maclean Building
Cromwarsh Gifford
Wallingford, Oxfordshire
OX 10 8BB, UK

Dear Caroline

Thank you for offering to send us a copy of the report on Phase I of the Water Poverty Index (WPI) Project.

The areas we would like to suggest for inclusion in the next phase of the project are:

Central Free State and
Eastern parts of the Eastern Cape

(recently classified by HSRC as poor regions in South Africa).

The other institutions whom you may consider involving are:

1 HSRC (Human Sciences Research Council) – Mike De Klerk : mdeklerk@hsrc.ac.za

2 RSS (Rural Support Services) – Lesley Steele : lesley@rss.org.za

3 IWMI (International Water Management Institute) – Doug Merrey : d.merrey@cgiar.org.

The WRC, once more, wishes to congratulate you on the excellent work you have done and to ensure you of our support and willingness to be involved in future initiatives.

Yours sincerely

George Green

GC Green
ACTING CHIEF EXECUTIVE OFFICER

INTERNET http://www.wrc.org.za

Please address all correspondence to the Chief Executive Officer

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UNIVERSITY OF MORATUWA
Department of Civil Engineering
Moratuwa, Sri Lanka

Tel: Head of Department - 645422
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Fax: 647622

Your Ref: *My Ref*

07.08.2000

CEH Wallingford (Attention: Dr. C. Sullivan)
Maclean Building, Wallingford, Oxon. OX10 8BB, UK

Dear Sir,

Water Poverty Index

Reference to the article on the above in "Water" of DFID.

We at this department are working on the poverty of farmers under the minor irrigation schemes of Sri Lanka. I feel that a development of an indicator such as the Poverty Index could be very relevant for our work.

Please be kind enough to send us information and material regarding your project which could be incorporated to our research work.

Yours sincerely,

Dr. N.T.S. Wijesekera,
Course Coordinator,
Environmental Water resources
Engineering and Management.

Appendix 7.2

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY

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Fax: (255 - 022) 275313
Telex: 41177 UTAFITI
In reply please quote:

Ali Hassan Mwinyi Roa
P.O.Box 4302
Dar es Salaam
Tanzania

Dear Dr. Caroline Sullivan

I am writing to you to recommend the job you are doing with your team to develop Water poverty Index using Tanzania as a pilot country.

I assure you that Tanzania will d efinitely need and use Water Poverty Index in its planning and decision making on priority setting regarding water development projects. In brief Tanzania will need Water Poverty Index to facilitate the following:

- More equitable water allocations, basing on needs and availability;
- Better understanding of links between water, human welfare and the ecosystem – This needs more integrated water management approach;
- An assessment of progress towards development targets;
- Prioritization in resource allocation and monitoring the effectiveness of development projects;

Therefore the Index being developed is expected to be used for:

- Policy making in the water sector;
- Decision making for water project development at all levels (Village - District –National and Global);
- Forecast future trends in water management and;
- Water development planning, Monitoring and Evaluation to achieve poverty eradication strategies (vision 2025 for the case of Tanzania)

The Index will reflect the change in level of poverty, and therefore indicate whether we are progressing or becoming poorer.

The pilot sites in Tanzania are based in Arusha, but we have the filling that the testing in phase II should extend to other regions to get more realistic results.

Lastly but not the least, I would like to thank DFID for funding the project and many other projects in Tanzania. I hope they will be able to continue funding till the Water Poverty Index gets developed and adopted by the international community.

Yours truly,

Dr. Rose Kingamkono
For Director General

TANZANIA COMMISSION FOR SCIENCE AND TECHNOLOGY

(COSTECH)

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Ali Hassan Mwinyi Road

P.O. Box 4302

Dar es Salaam

Ref. CST/SC.216/1225/2001 **14th December 2001**

Dear Dr. Caroline Sullivan

Re: APPRECIATION FOR YOUR KIND DONATION

On behalf of my institution and on my own behalf, I wish to extend my sincere thanks to you, Dr. John Gash and the Centre for Ecology and Hydrology (CEH) for the kind donation of Toshiba Laptop to me and my institution. This laptop will definitely increase my efficiency and ease my work on both my daily duties as a National research co-ordinator on environment, and on WPI issues.

As I am not getting proper words to thank you, Let me end by saying God bless you for your kindness. THANK YOU VERY MUCH.

Sincerely yours

Steven D. M. Mlote

Appendix 8
WPI Contract Deliverables

8.1 Deliverable Table

Contract Deliverables are shown below;

Deliverable	Completion
Reports to DFID and journal publications	✔
Communities at pilot sites enabled to assess their WPI values.	✔
WPI Component Report received by DFID by July 2001, with preliminary data on component inputs.	✔
WPI Framework Report received by DFID by July 2001	✔
Copy of documentation received by DFID by July 2001.	✔
Training workshops held in 3 pilot sites	✔
Data collected and compiled in GIS framework, and included in Phase 1 final report submitted to DFID by Jan, 2002.	✔
Community WPI values from pilot sites included in Phase 1 Final report delivered to DFID by Jan 2002.	✔
Contribution on WPI published in 1st WWDR	✔
Copy of policy briefing note and general WPI dissemination booklet delivered to DFID by Jan 2002	✔
Copy of training module included in Phase 1 final report delivered to DFID by Jan 2002	✔

8.2 Evaluation of deliverables

An evaluation of much of the work done during this phase of the project is given in the main report. All of the contracted deliverables have been completed and delivered. The capacity building materials produced have been tested, and in the next phase of the project, these will be modified according to the recommendations of those who have appraised them.

Many of those consulted thought that the primer document, 'Evaluating your water' was an excellent source of information and could be of much use to water managers generally, as well as being of use for the WPI. Many people commented on the fact that this booklet addressed the issues contained within Integrated Water Resource Management (IWRM), and that it should be widely distributed for this purpose also. It is planned to modify and improve this booklet with a view to being able to do this. There is also some scope for producing a book from the Final Technical Report documentation.

We have made great efforts to disseminate this work widely, to promote its uptake, and we feel that we have made some success in this, which is indicated by the letters of support we have received for the work. (See Appendix 7.2.4) It is very clear from these letters that the governments in the Pilot study countries are keen to take the work forward.

The Centre for Ecology and Hydrology has 600 staff, and well-equipped laboratories and field facilities at nine sites throughout the United Kingdom. The Centre's administrative headquarters is at Monks Wood in Cambridgeshire.

This report is an official document prepared under contract between the customer and the Natural Environment Research Council. It should not be quoted without the permission of both the Centre for Ecology and Hydrology and the customer.

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Further information about CEH is available on the World Wide Web at www.ceh.ac.uk

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