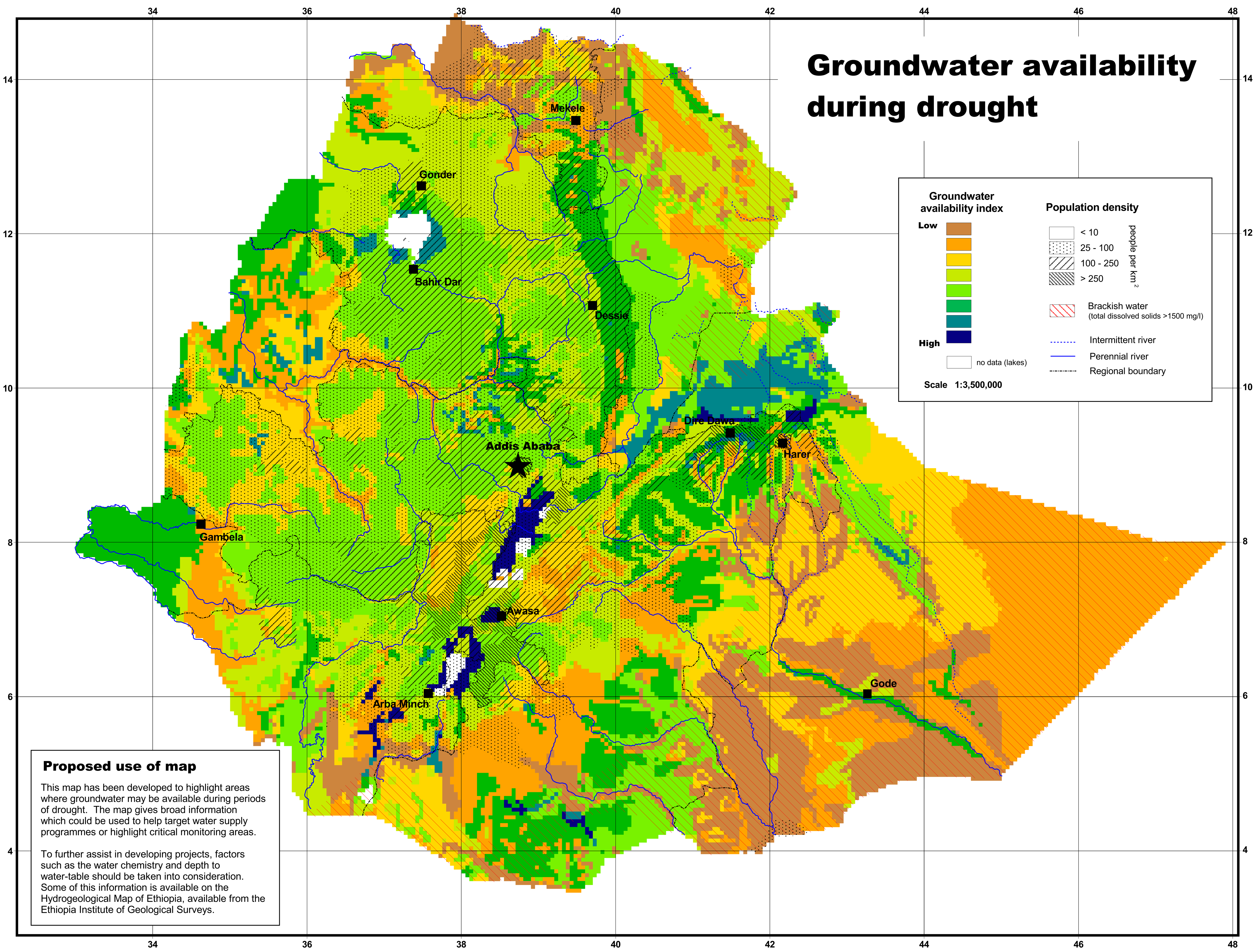
Ethiopia: Water Security and Drought

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

odi

DFID Department for International Development



Proposed use of map

This map has been developed to highlight areas where groundwater may be available during periods of drought. The map gives broad information which could be used to help target water supply programmes or highlight critical monitoring areas.

To further assist in developing projects, factors such as the water chemistry and depth to water-table should be taken into consideration. Some of this information is available on the Hydrogeological Map of Ethiopia, available from the Ethiopia Institute of Geological Surveys.

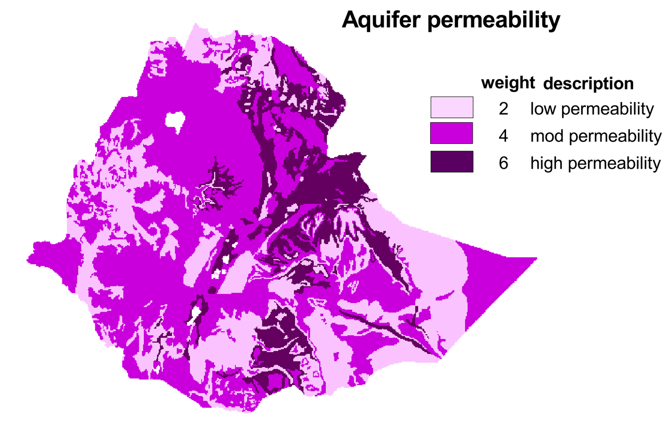
Constructing the map

The map showing groundwater availability during drought for Ethiopia was constructed by combining three factors:

(1) rock permeability (derived from the hydrogeology map)
(2) the ability of the rock to store water (from the hydrogeology map)
(3) recharge to the groundwater (estimated from rainfall data).

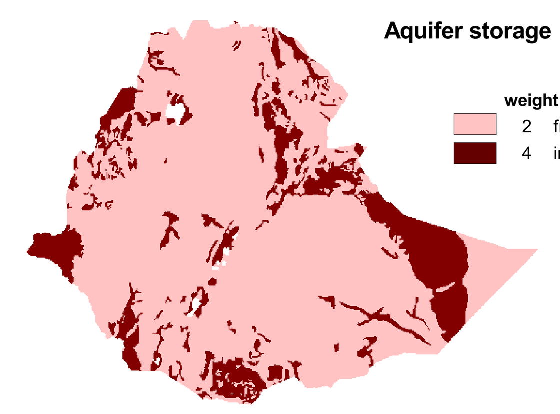
Areas of high permeability, high storage and high recharge have most groundwater available during drought (see box on "Groundwater and drought"). Rock permeability and groundwater storage factors have been derived from the published hydrogeology map for Ethiopia. Hydrogeology maps divide geology into three separate classes of permeability: high, moderate and low. These were given a weight of 6, 4 and 2 respectively.

Aquifer permeability



On hydrogeological maps, rocks are also divided into those with inter--granular flow and those with either fractured or karstic flow. Intergranular aquifers store water in pore spaces and have a large storage capacity. Fractured or karstic aquifers store groundwater only in fractures and therefore have much lower storage capacity. Intergranular aquifers were given a weight of 4 and fractured/karstic aquifers a weight of 2.

Aquifer storage

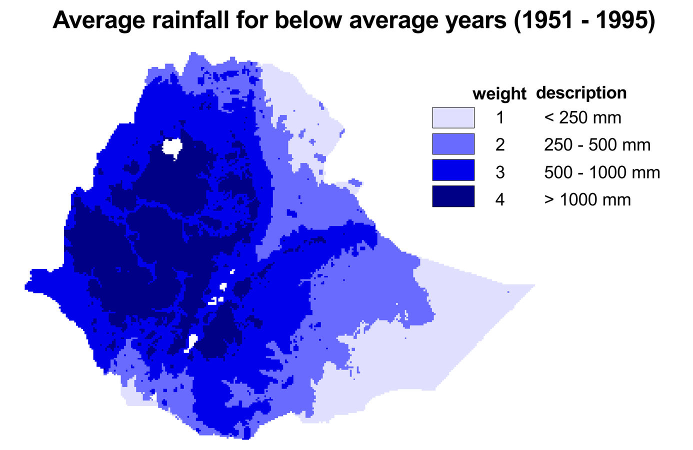


Recharge to the aquifer has been estimated from rainfall data for Ethiopia. To build a sophistocated recharge model demands much data and calibration which is beyond the scope of this project. Using solely rainfall data is a simplification, but the broad classifications used in making the maps make any errors less significant.

Rainfall data were taken from a 3 minute monthly climate grid for Africa for 1951 - 1995, constructed by New and Hulme (1997). To take into account rainfall variability, the coefficient of variability was calculated along with the annual average for each grid cell. The average annual rainfall for below average years (R) was then calculated using the formula:

R = mean x (1 - co of var) = mean - standard deviation.

Average rainfall for below average years (1951 - 1995)



Weighting and colours for final map

mean below average rainfall (1951-95)				
> 1000 mm	14	12	10	8
500 - 1000 mm	13	11	9	7
250 - 500 mm	12	10	8	6
< 250 mm	11	9	7	5
permeability, storage →	H, H	H, L M, H	M, L L, H	L, L

H - High
M - Moderate
L - Low

The final map showing groundwater availability during drought was then constructed by adding the various weights together. The matrix (left) shows the possible combinations of physical charactersitics that make up each weight, and the colour scheme used on the final map. The weights for each characteristic were chosen to reflect the relative importance of each of the factors in controlling groundwater availability during drought.

To give an overall impression of the demand for groundwater and the population at risk during drought, the population density was overlain as a stipple on the map. This information was taken from the 1995 census and also the Environmental Systems Research Institute world data set (ESRI 1996).

The methodology and weights used here could easily be applied to other areas. The data sets used to construct the map are also widely available. Hydrogeology maps are made to an international standard (IAH 1995) and are available for most countries. The rainfall data set is available for all Africa, and likewise some rough estimates of population are also available. The weighting system has been developed primarily for Ethiopia and may need to be modified and tested before applying elsewhere.

Groundwater and drought

Groundwater (water stored below the ground in aquifers) provides the only affordable means of meeting the dispersed demand of rural communities. One of the key advantages of groundwater is its reliability, particularly during drought. After surface rivers and streams have dried up, groundwater can still be accessed through wells, springs and boreholes.

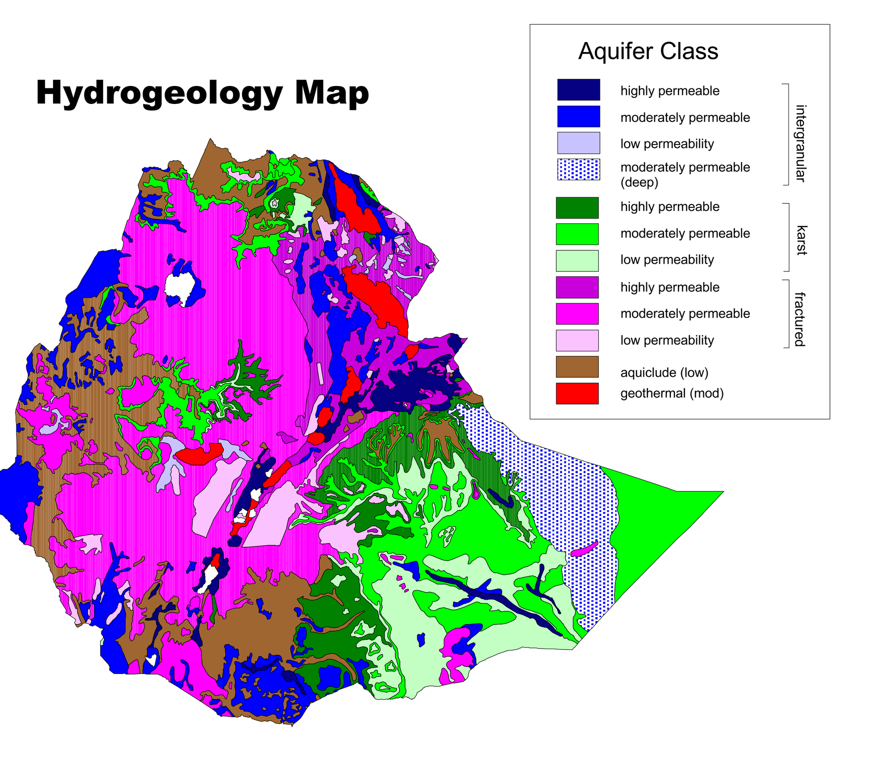
Research in Malawi, Ghana, South Africa and Ethiopia (Calow et al. 1997, Robins et al.1997, Calow et al. 2000) has shown that water security during drought is dependent on three main factors: groundwater availability (as volume stored in the aquifer), access to groundwater (via springs, wells or boreholes) and demand for groundwater during drought (dependent on livelihood strategies and the failure of other sources). The main map above addresses the first of these issues - groundwater availability during drought.

Two main factors control the amount of groundwater available during drought: rock type (geology) and rainfall (aquifer recharge).

Geology

Groundwater is stored within pore spaces and fractures in rocks. Where the pores and fractures are interconnected, groundwater can flow easily and the rocks are said to be permeable. Rocks which contain significant groundwater are called aquifers. Hydrogeologists classify rocks according to permeability to produce hydrogeology maps (see right). To ensure ground-water availability during drought, the ease with which groundwater flows through the rocks (permeability) and the volume of water stored within the rocks are both important. Since the volumes of water required by dispersed rural communties are low, groundwater storage is probably less important than permeability.

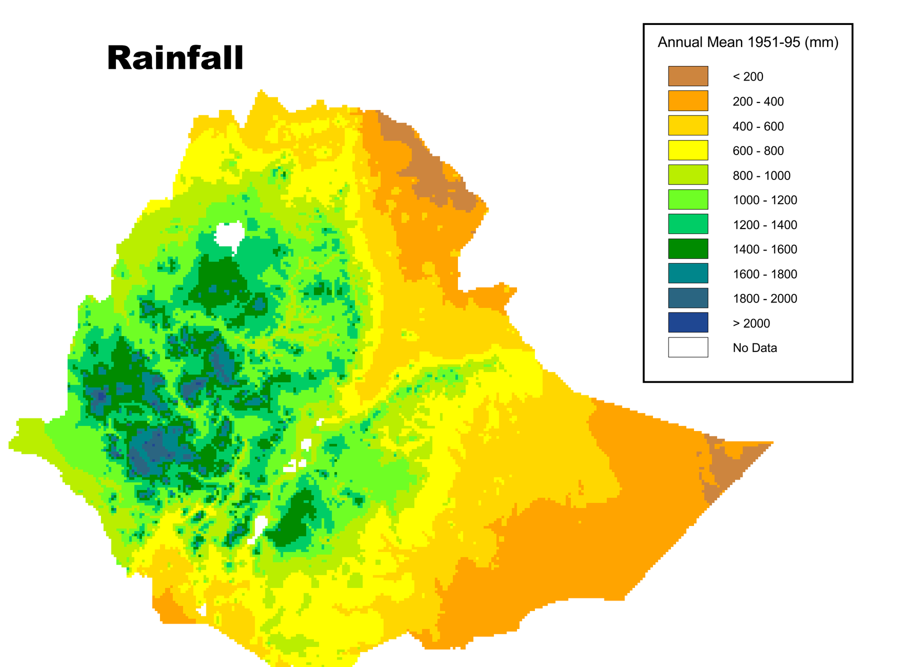
Hydrogeology Map



Recharge to groundwater

Recharge to groundwater is also important in controlling the availability of groundwater during drought. Recharge to groundwater usually occurs annually and depends on a number of factors, including: total annual rainfall; distribution and intensity of rainfall events; connection to streams and rivers; soil type; and land use. Aquifers react slowly to changes in rainfall and long term average rainfall is more important in controlling recharge to aquifers than short term variations. Therefore groundwater sources can bridge surface water deficits. The average annual rainfall for Ethiopia is shown to the right.

Rainfall



Access to groundwater and patterns of demand

Accessing available groundwater resources during drought is often more of a problem than the absolute availability of groundwater. Once surface streams have dried up, people are reliant on whatever groundwater sources are present. Where these are few in number, the demands placed on individual water points may lead to mechanical failure or reductions in yield. In some circumstances the groundwater source, though not the aquifer, may dry up altogether. The result may be severe water stress as consumption declines, and people and animals are forced to use the same deteriorating sources.

Household livelihoods may be impacted in other ways too. For example, income generation as well as direct consumption may suffer if the watering of livestock and small scale irrigation are affected. Similarly, time spent finding and collecting water may carry a high opportunity cost because of lost production, income, and food gatheriing through reduced labour time, as well as missed eduction for children.

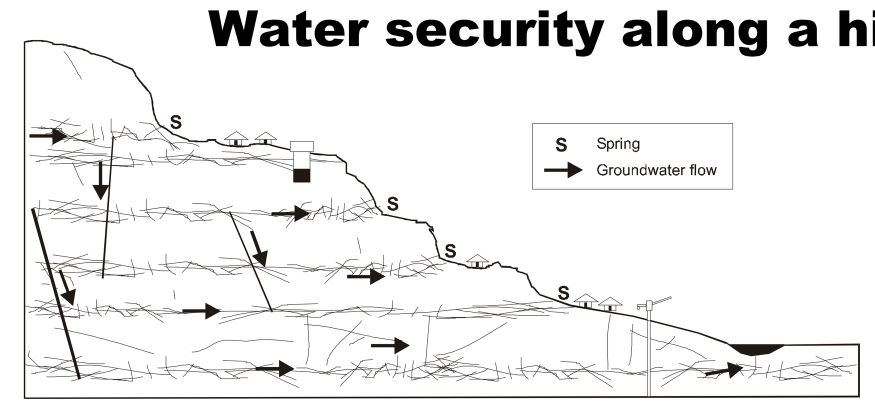
Links with policy and practice

PROGRAMME DEVELOPMENT. Maps could be used to target water supply programmes to areas which are vulnerable to drought, but which contain reliable sources of groundwater. Maps could also be used to highlight areas where the monitoring of water availability and access is important, perhaps through widening the scope of existing food security assessments. Regional maps could be used to identify water insecure woredas, but cannot be developed at present because of insufficient data.

PROJECT DEVELOPMENT. An understanding of water security at a local level, and of the factors that influence it, is needed to respond effectively to community 'demand' for projects. For example in areas of high water demand, where few other options for water supply exist, it may make more sense to install several lower yielding handpumps rather than a single deep borehole which may fail under stress.

DROUGHT PLANNING. A broader approach to drought mitigation, focusing on food and water security (and the links between them), could be developed. Water security analysis could be combined with existing vulnerability/profiling exercises (which focus on food security) to gain a clearer picture of livelihood security, and of the interventions required to support it. For example, in protecting the assets of households in the early stages of drought, or rebuilding them in the aftermath of a bad year, the key variable may be access to water, both in increasing labour availability and in protecting and increasing livestock production. This may indicate the need for targeted water supply interventions, coordinated and carefully sequenced with food security/asset rebuilding efforts, rather than just food or water interventions alone.

Water security along a highland-lowland transect



	Dega (mountain)	Weyna Dega (intermontain)	Kolla (plain)
Availability	Small resource base but high recharge	Moderate resource base but less recharge than Dega. More surface water (fed by groundwater)	Large resource base but low rainfall Fewer surface sources (all groundwater fed)
Access	High: multiple access mainly springs	Moderate: multiple access through springs wells and boreholes (often widely spaced)	Low: few boreholes no springs
Demand	Low - mainly household consumption	High demand from people and livestock (most populated)	Human population less dense, but greater demand from livestock

The water security of households is influenced by the availability of water, the ability to access this water, and patterns of water demand. The diagram on the left shows how the relative importance of these factors varies along a highland-lowland transect in the Amhara region of Ethiopia. The transect falls within a single geological unit.

The availability of water for different uses depends on resource characteristics such as storage and reliability. In highland areas groundwater resources are limited since the aquifers are small, although recharge is high and streams more numerous. Water security is generally higher however, as springs are more numerous and demand (from people and livestock) is relatively low. In lowland areas the aquifer is larger, but water security is undermined by limited (and poor quality) surface water, restricted access to the aquifer via boreholes, and greater demands. Boreholes are also subject to mechanical failure. Large increases in demand can put stresses on individual groundwater sources, but are unlikely to affect the resource as a whole.

While a general trend in highland-lowland water security emerges, significant local variation also occurs. For example, access to water at the household level is also influenced by access to labour and animals for water carrying, money for water purchase and social capital for securing customary water rights.

This map is an output from a project (R7125) funded by the UK Department for International Development (DFID) for the benefit of developing countries. The views expressed are not necessarily those of DFID.

The help of Save the Children Fund (UK) and the Amhara Region Water Bureau is gratefully acknowledged; particularly contributions from Ben Foot & Wendy Fenton (SCF) and Ato Fekadu Debalkie & Ato Shumet Kebede (Amhara Region Water Bureau).

Authors:
A M MacDonald, R C Calow, A L Nicol, B Hope and N S Robins.

Bibliographic reference:
MacDonald A M, Calow, R C, Nicol A L, Hope B and Robins N S, 2001. Ethiopia: water security and drought. British Geological Survey Technical Report WC/01/02

The following material has been used in the development of the map:

Calow R C, MacDonald A M and Nicol A L 2000. Planning for groundwater drought in Africa: towards a systematic approach for assessing water security in Ethiopia. British Geological Survey Technical Report WC/00/13.

Calow R C and others 1997. Groundwater management in drought prone areas of Africa. Water Resources Development, 13, 241-261.

ESRI 1996. ArcAtlas: Our Earth. Environmental Systems Research Institute, USA.

Ethiopian Institute of Geological Surveys 1988. Hydrogeological Map of Ethiopia. Ethiopian Institute of Geological Surveys.

International Association of Hydrogeologists 1995. Hydrogeological maps: a guide and standard legend. International Contributions to Hydrogeology Vol 17, Verlag Heinz Heise, Hannover.

New M and Hulme M 1997. Construction of 3 minute latitude/longitude monthly climate surfaces over Africa for the period 1951-1995. Climate Research Unit, University of East Anglia, Norwich.

Robins N S and others 1997. Final report: groundwater management in drought prone areas of Africa. British Geological Survey Technical Report WC/97/57.

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

British Geological Survey, Keyworth,
Nottingham, NG12 5GG, United Kingdom
telephone: +44 (0) 131 667 1000
email: enquiries@bgs.ac.uk
website: www.bgs.ac.uk