

MIT OpenCourseWare
<http://ocw.mit.edu>

11.479J / 1.851J Water and Sanitation Infrastructure in Developing Countries
Spring 2007

For information about citing these materials or our Terms of Use, visit: <http://ocw.mit.edu/terms>.

Steps in Water and Sanitation Planning

- Problem Identification
- Organize Community Participation & Support
- Set Objectives
- Collect Data
- Formulate Alternatives
- Choose Best Method
- Develop Detailed Plan
- Build the System
- Operate and Maintain
- Monitor and Evaluate

Problem Identification

- Current water source is unacceptable, if:
 - Water Quality is bad;
 - Water Quantity is insufficient;
 - Inaccessible Water Source
 - Unreliable Water Source
- Water Quality is measured by laboratory or field testing, but oftentimes, this is difficult, so...
- Surveys...

Types of Surveys

- “Sanitary” Surveys (water/sanitation/hygiene)
- Infrastructure Survey
- Epidemiological Surveys
 - Prospective and Retrospective Cohort Surveys
 - Cross-Sectional Surveys (snapshot in time);
 - Longitudinal ecologic surveys (on-going surveillance over many years)
- Willingness-to-Pay Surveys (aka “Contingent Valuation”)
- Focus Groups
- Example: Batey1, Dominican Republic

Batey – Dominican Republic



Batey, DR





Batey 1 Water Tower



Aquaduct

Community Participation and Support

- A successful program must include a plan for community support
- 3 ways to gain community support:
 - Promotion
 - Community involvement (community appraisal, user groups, mapping)
 - Training in O&M

Can you think of other ways?

Data Collection

- Population statistics
- Rainfall
- Environmental data
- Mapping
 - Community Mapping / Community Appraisal
 - GIS Mapping
- Community's development history
- Community resources
- Culture and customs

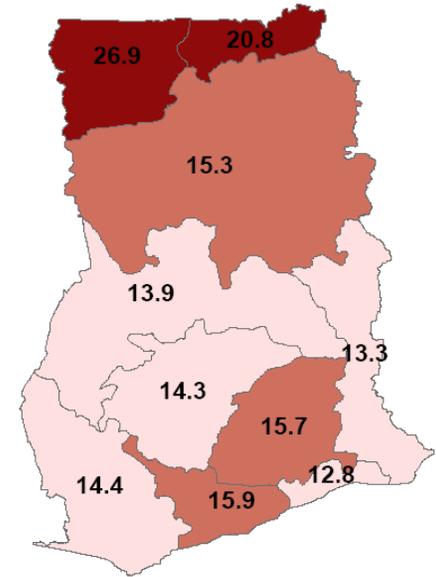
- <http://www.scn.org/ip/cds/cmp/modules/par-par.htm>

GIS & Data Mapping

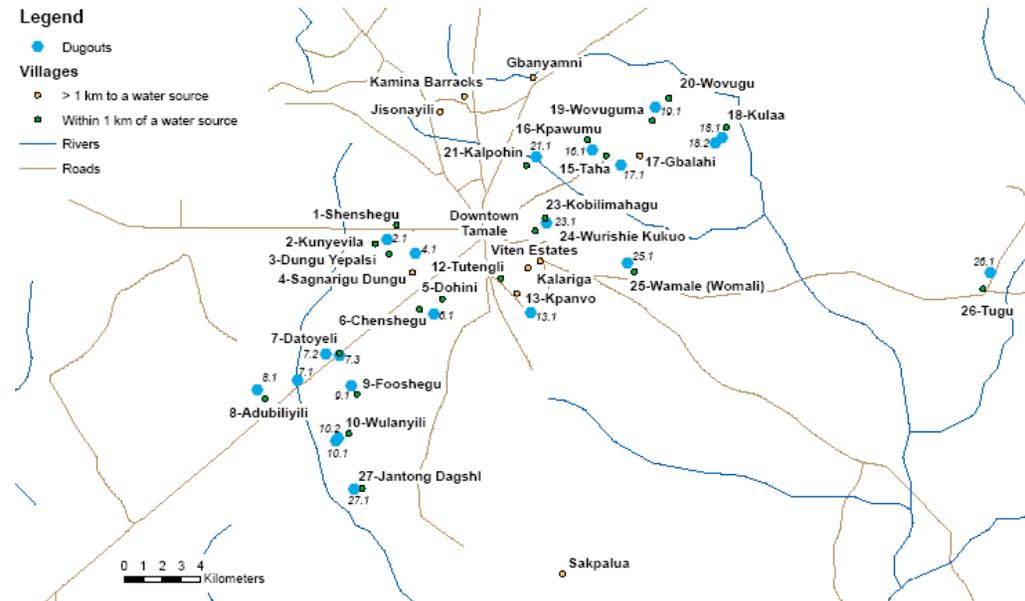
—

Diarrhea in Northern Region Ghana

Percentage of Children Under 5 Years of Age With Diarrhoea



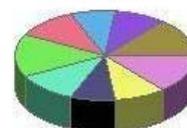
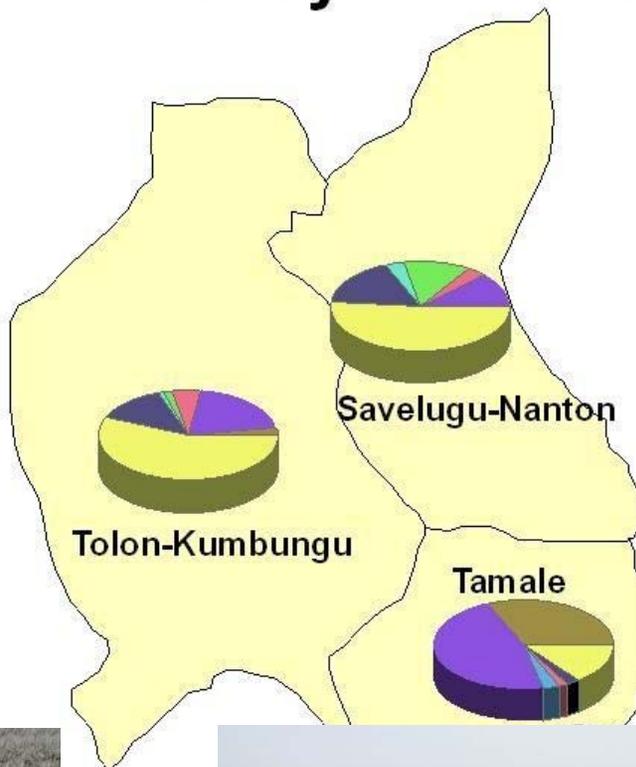
Villages and Water Sources Within the Pure Home Water Operating Area



(Map: Jenny VanCalcor, 2006)



Types of Water Sources Used by Households



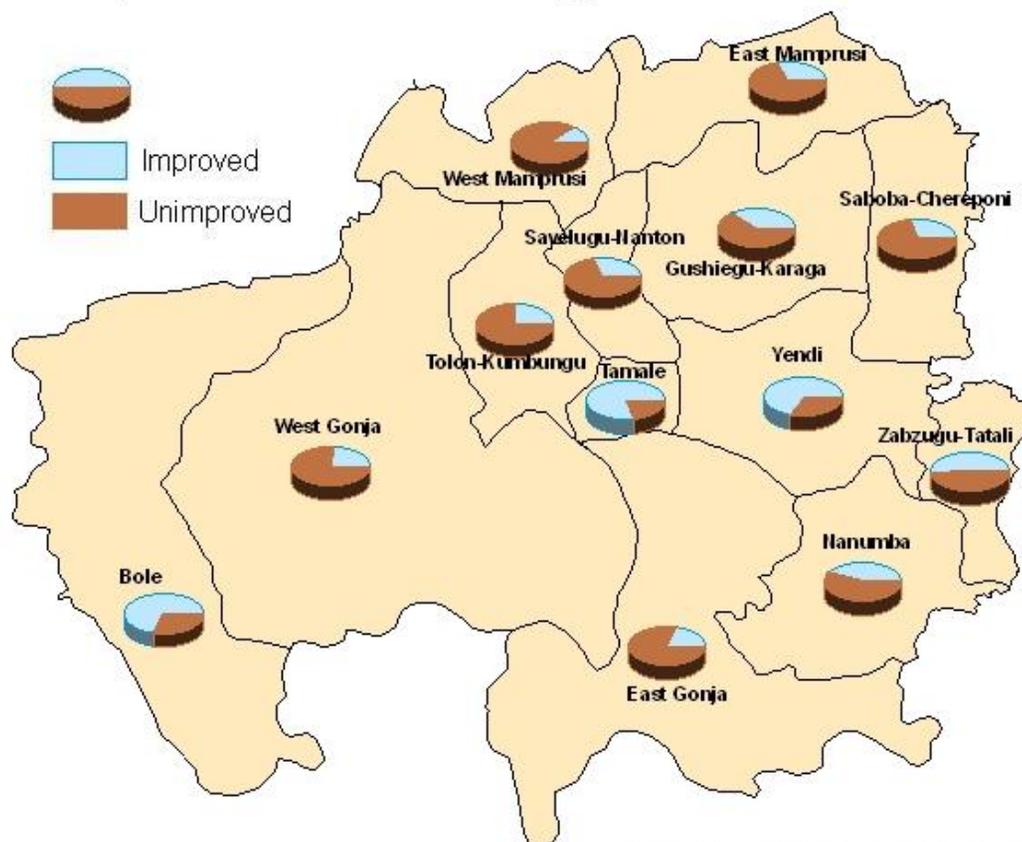
- Pipe Inside the Home
- Pipe Outside the Home
- Tanker
- Well
- Borehole
- Spring or Rain Water
- Stream
- Dugout
- Other



Statistical Service
Ghana, 2006



Percentage Use of Improved and Unimproved Drinking Water Sources

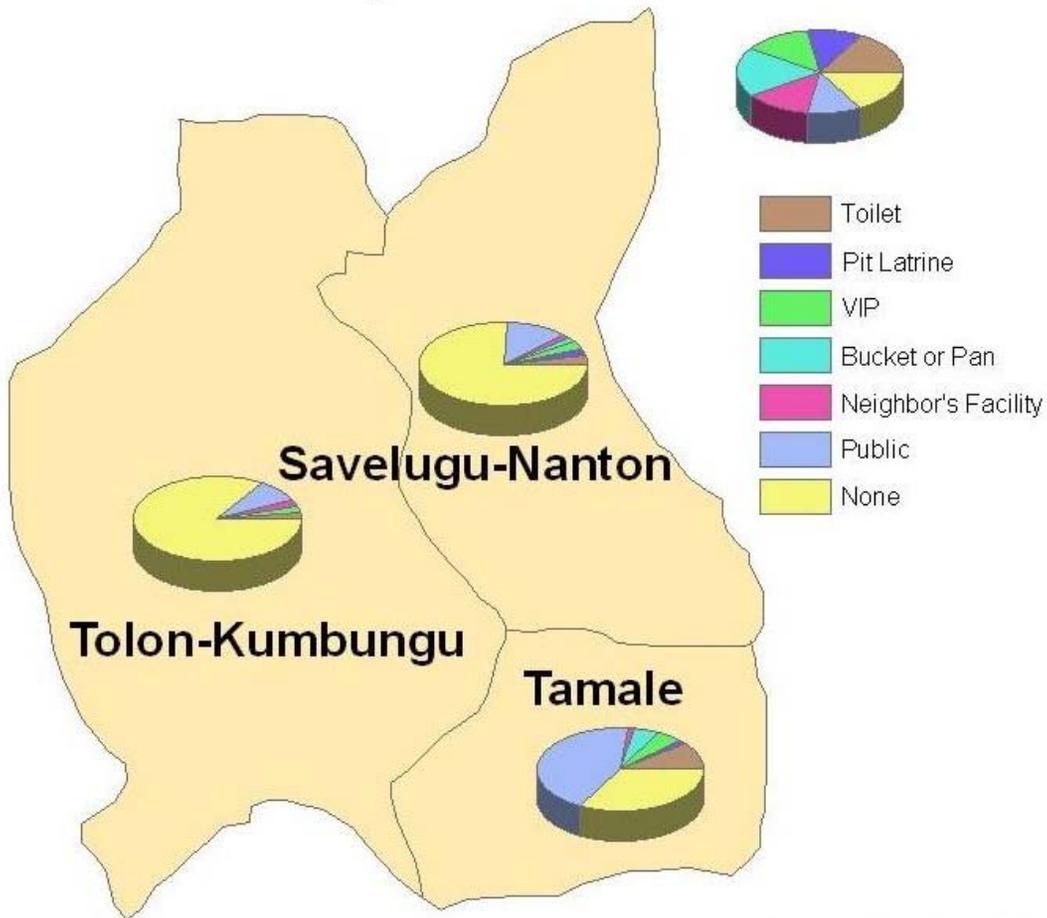


Data: Ghana Statistical Service, 2003
Map: J. VanCalcar, 2006

- Improved Sources
 - Boreholes
 - Household connection
 - Public standpipe
 - Rainwater harvesting
 - Protected Springs and dug wells
- Unimproved Sources
 - All surface water sources
 - Unprotected dug wells and spring
 - Tanker trucks
 - Vendor water

1 million out of 1.8 million people in the Northern Region are currently using an unimproved source

Types of Sanitation Facilities Used by Households



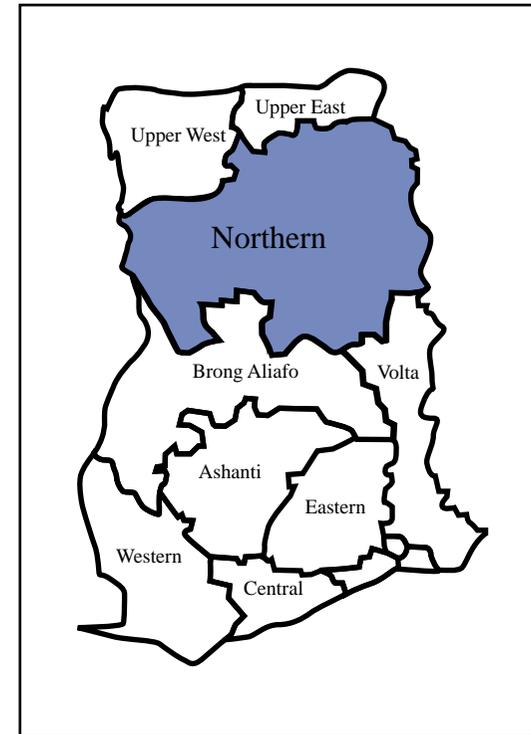
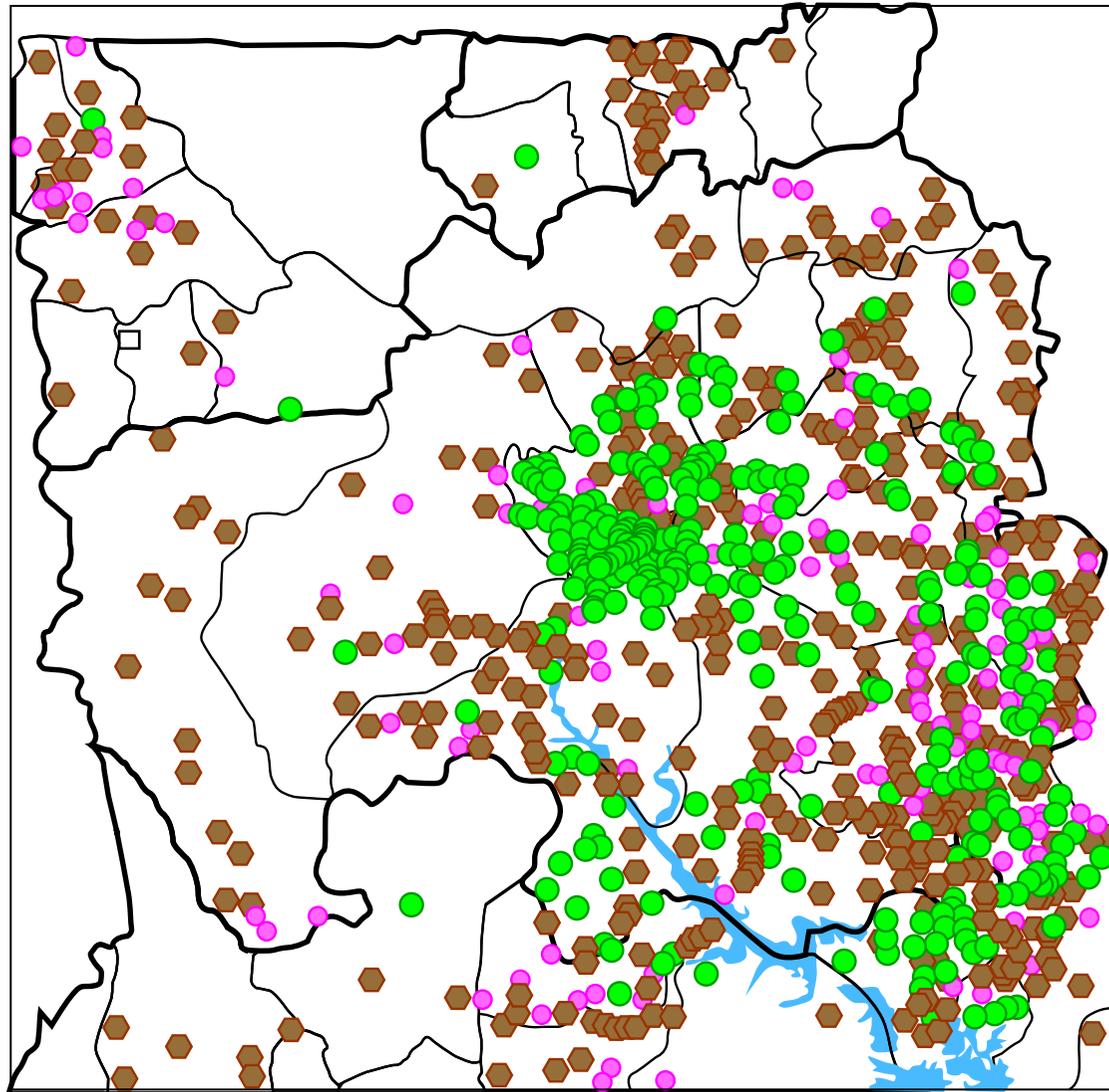
Data: Ghana Statistical Service, 2003
Map: J. VanCalcar, 2006



Latrine is the process of being built

Ghana Guinea Worm Eradication Program

Villages Reporting Endemic and Imported Cases in 2005



Legend : ● - Endemic Village ● - Imported Cases ⬡ - Villages □ - Districts

0 5 10 20 30 40
Kilometers

Set Alternatives



OR



OR



OR...?

Choose the Best Alternative

- **Question: What are some considerations (decision criteria) you might use to choose the best alternative?**

Choose the Best Alternative

- **Water supply characteristics (will it meet demand now? In 10 years?)**
- **Social acceptability – community's needs**
- **Health factors**
- **Economic factors- willingness to pay**
- **Institutional context**
- **Accessibility**
- **Other... What do you think...?**

Develop the Plan

- **Question: What should be in the plan?**

What's in the Plan?

- **Proposed System**
- **Costs**
- **Sources of Finance**
- **Implementation Schedule**
- **Plan for Construction and Sources of Materials**
- **Energy Requirements**
- **Environmental Impacts**
- **Social Impacts**
- **Operation and Maintenance Requirements**
- **Other?**

Monitor and Evaluate the System

- User Acceptance
- Water Quality
- Water Quantity
- Accessibility
- Reliability
- Proper Operation and Maintenance
- Financial sustainability
- Sustainable Yield
- Systems Thinking: Relationship to:
 - Sanitation
 - Hygiene interventions
 - Other?

Some Factors Affecting Planning

- Geographic Location, Environment & Climate
- Urban vs. Rural – Population Growth and Density
- Settlement Patterns
- Domestic Water Use, Agriculture Water Use
- Culture

Geographic Location, Environment and Climate

Tropical Climates Hinder:

- Agricultural development
 - Year-long insect problems
 - Locusts are endemic in many regions
 - Tsetse flies prevent use of animals for plowing
- Mineral resource development
 - Deep, highly weathered soils
 - Extraction is expensive, special equipment
- Human productivity
 - Disease and malnutrition
 - High temperature and humidity

Tropical Land Degradation

- Commodity crops
- Change from shifting cultivation
- Progressive problems
 - Poor agricultural practices reduce nutrients and organic matter
 - Vegetation and organic material are removed for fuel and fodder
 - Lack of vegetative cover causes erosion
 - Irrigation increases salinity content of soils
 - People abandon degraded land and move to other areas

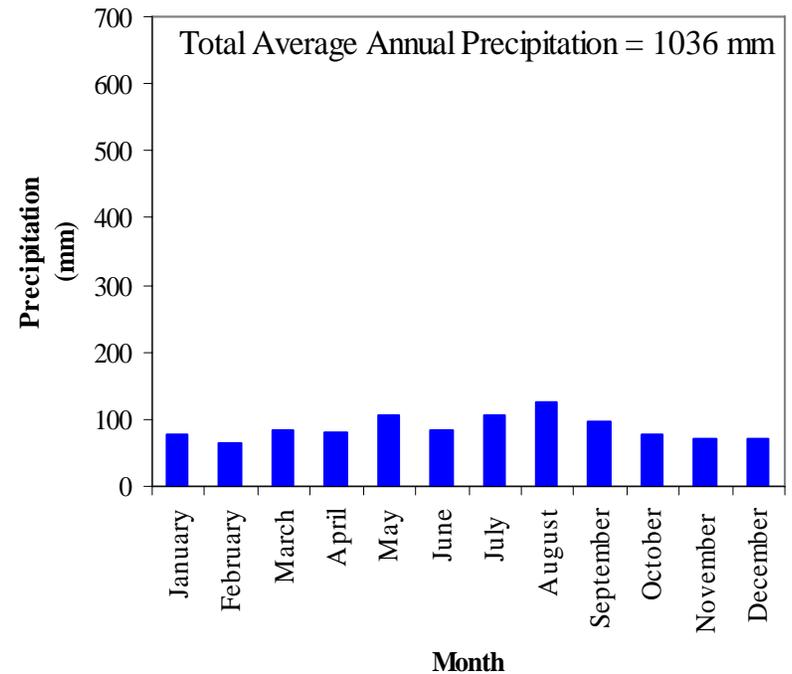
Environmental Factors - Rainfall

- Not uniformly distributed throughout the year
- Distinct wet and dry seasons
- Excessive precipitation and storms during the wet season often destroy crops
- Droughts common

Annual Rainfall Distribution

Map removed due to copyright restrictions.

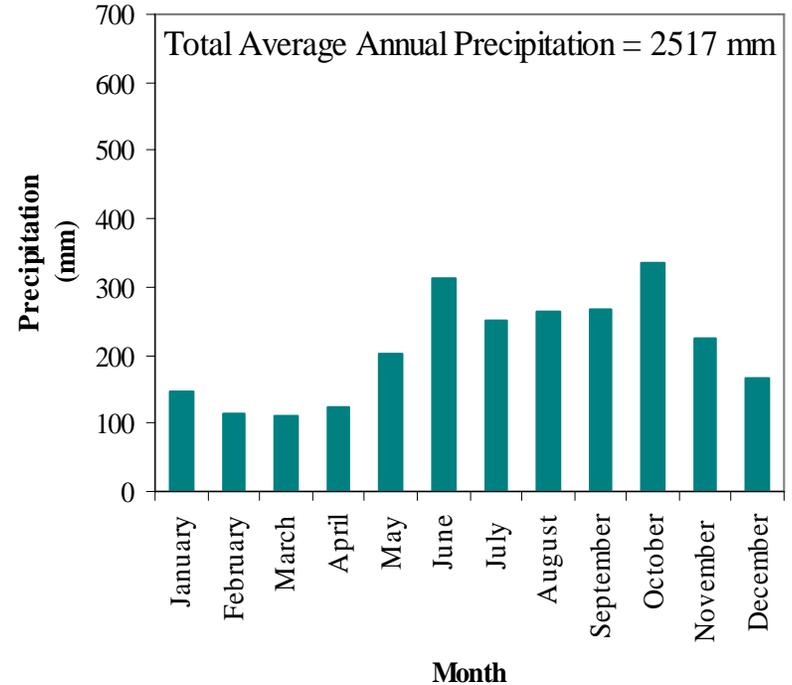
**Average Monthly Precipitation
Washington, DC**



Annual Rainfall Distribution

Map removed due to copyright restrictions.

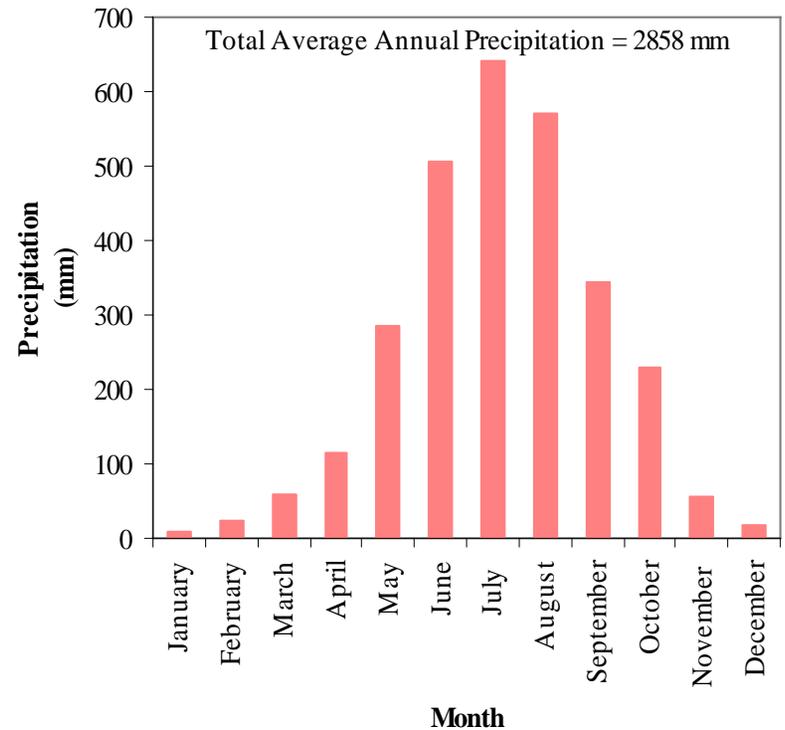
**Average Monthly Precipitation
Coban, Guatemala**



Annual Rainfall Distribution

Map removed due to copyright restrictions.

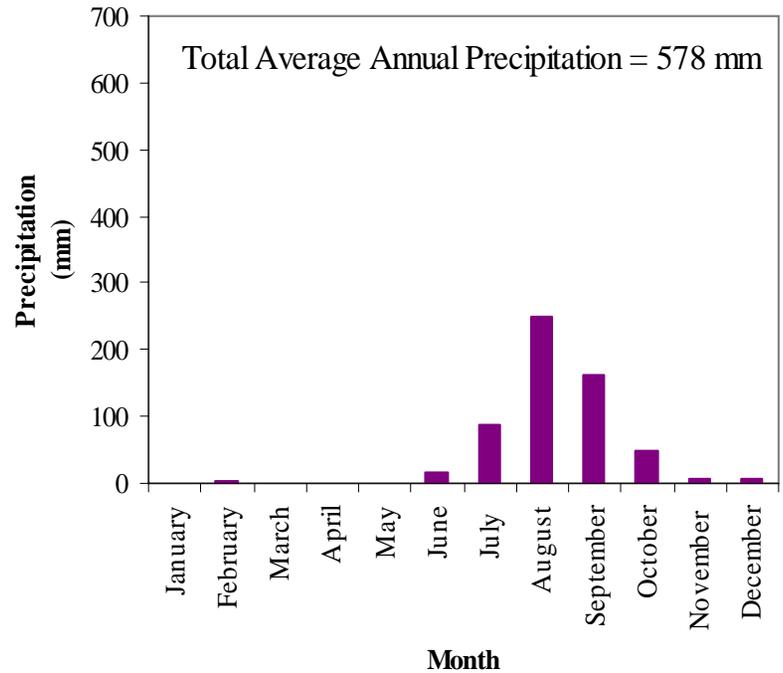
**Average Monthly Precipitation
Chittagong, Bangladesh**



Annual Rainfall Distribution

Map removed due to copyright restrictions.

**Average Monthly Precipitation
Dakar, Senegal**



Environmental Factors - Heat

- No freezing temperatures in the tropics
 - Plant and animal pests and diseases reproduce throughout the year
 - Intense ecological competition
 - Quick turnover of soil organic matter
- UV radiation destroys plastics, rubber, and synthetics
- Heat and humidity cause corrosion of machinery

Environmental Factors - Soils

- Tropical soils are highly weathered
 - Low organic matter
 - Low nutrient contents
- Laterites (high iron clays)
 - Harden when exposed to sun and air
 - Used to build roads
- Alluvial and volcanic soils are the exception – rich and fertile

Community and Cultural Factors

Communities in Northern Region Ghana



Non-Traditional



Traditional

(Photos: Rachel Peletz, 2006)



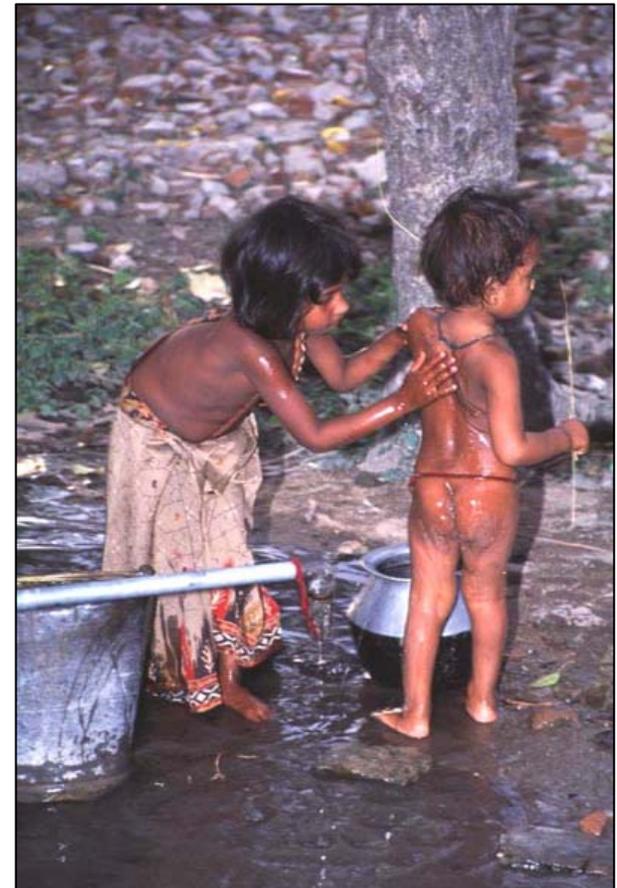


Patterns of Domestic Water Use

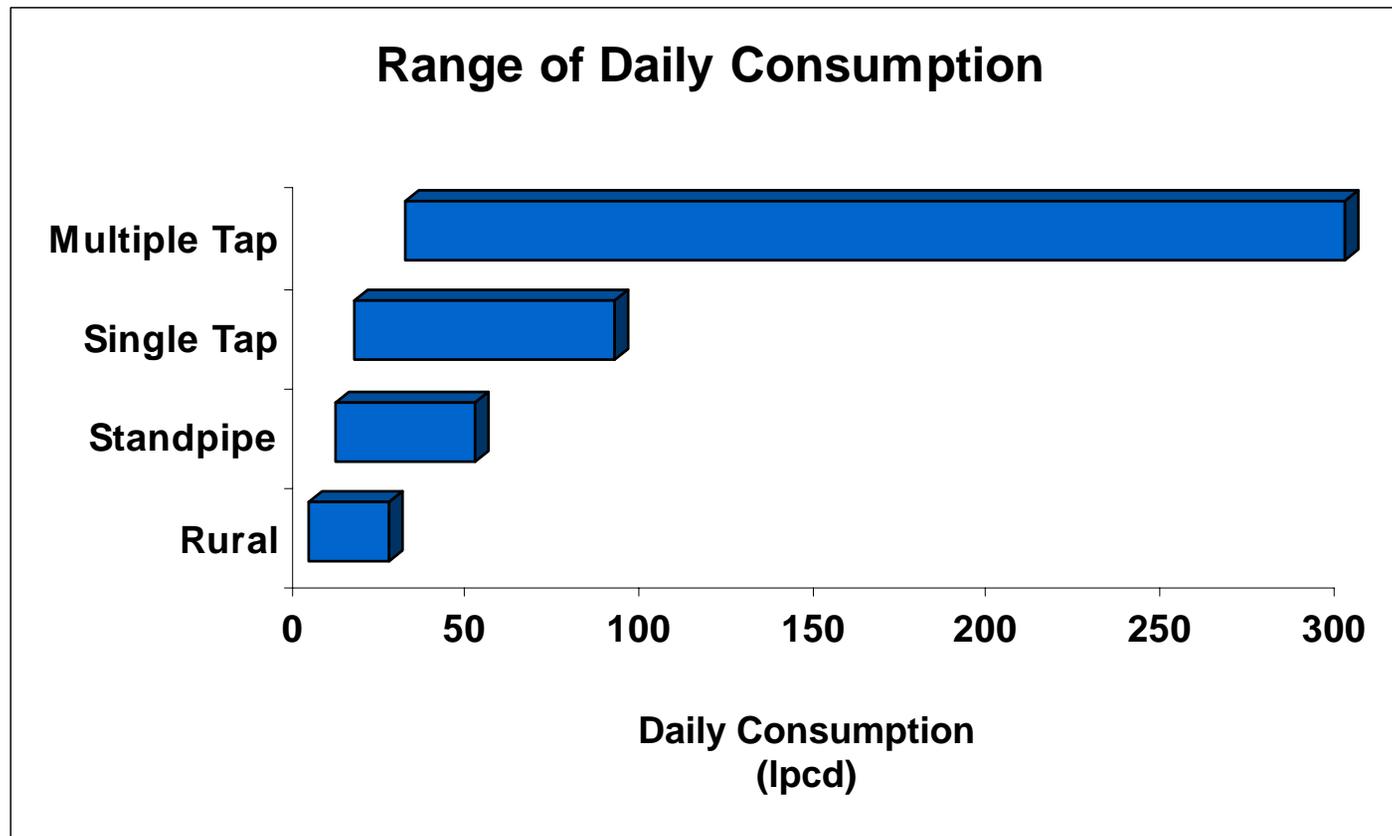
- Volume of water used depends on income
- Only the wealthy have large amounts of safe water
- In rural areas, water is often carried from a source outside the home
 - Performed by women and children
 - Requires time and energy
 - Opportunity cost for agriculture and other productive activities
- People may use different sources for different uses

Patterns of Domestic Water Use

- Domestic water uses
 - Bathing
 - Cooking
 - Dishwashing
 - Drinking
- Other water uses
 - Clothes washing (often done at water source)
 - Gardening
 - Livestock



Patterns of Domestic Water Use



Patterns of Domestic Water Use

Water Source	Consumption (lpcd)
Rural springs, streams, etc.	2-25
Standpipes in cities/villages	10-50
Single tap in the home	15-90
Multiple taps in the home	30-300
United States	375-600

Patterns of Domestic Water Use

- Factors influencing water use and consumption
 - Cost – money, time, and energy
 - How much women and children can carry
 - Distance to source
 - Time spent in line
 - Effort to pump or haul water from well
 - Woman's perception of quality – based on aesthetics
 - Family size and family power structure
 - The larger the family, the lower the amount available per person
 - How much water the husband uses for bathing
 - Social norms
 - Is clothes washing usually done at source?
 - Socializing

Patterns of Domestic Water Use

- Factors influencing water use and consumption
 - Technology – are pumps functional?
 - Reliability of the water source
 - Time of year (rainy or dry season)
 - Competing uses
- Other considerations
 - Women do most of the carrying, but men make most of the decisions
 - Location of house
 - Community improvements
 - How income is spent
 - Women are the ones most affected by community water projects, but they have little public voice

Patterns of Domestic Water Use

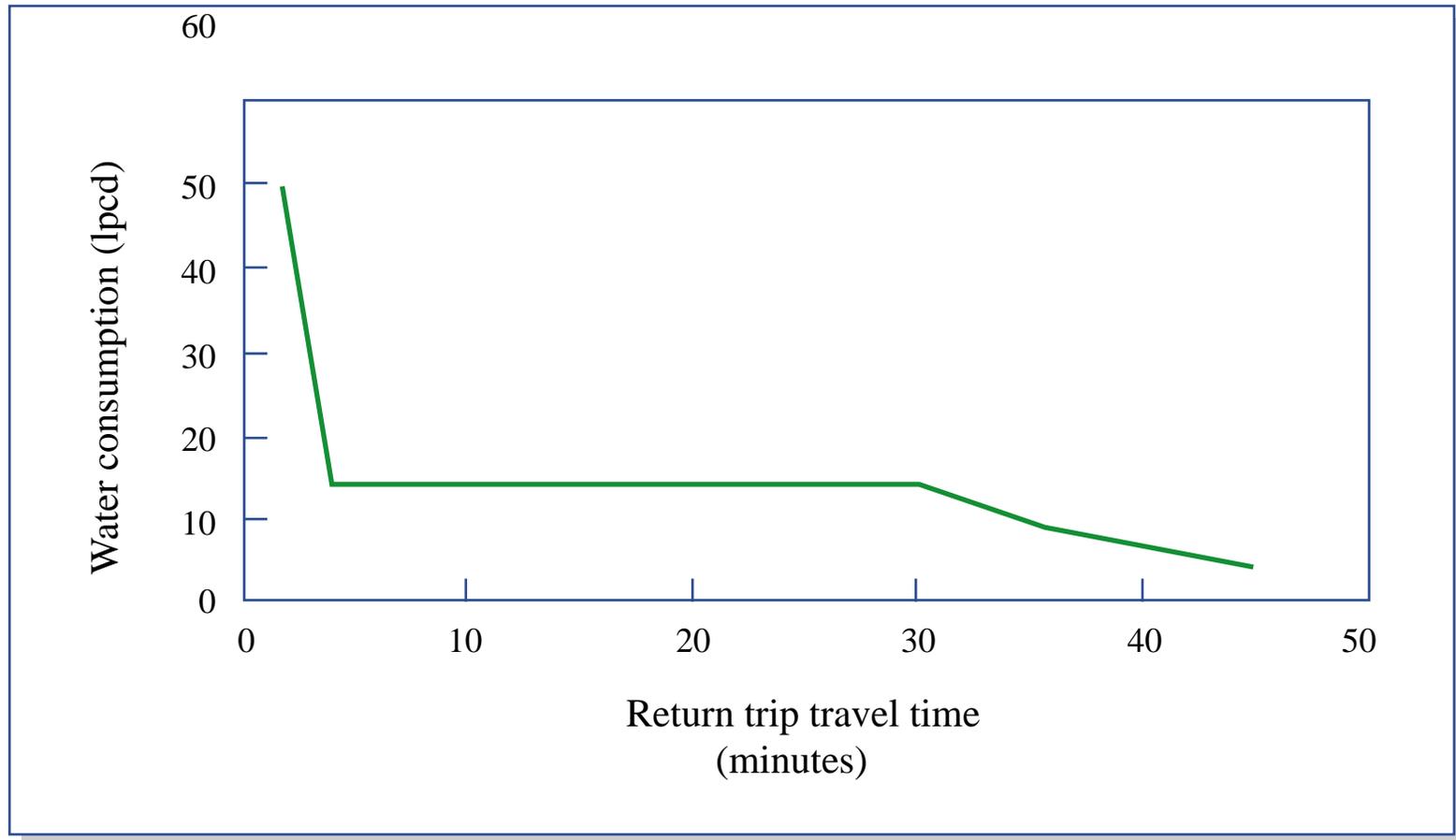


Figure by MIT OpenCourseWare.

Domestic Water Use

- 20 m³/person/year represents a global average.
- But water consumption varies widely
- Oman = 7 m³/person/year
- Japan = 90 m³/person/year
- USA = 200 m³/person/year

Global Water Use by Sector

	m ³ /person/yr	km ³ /yr	%
Domestic*	20	100	3
Industrial		200	5
Cooling		225	6
Livestock		40	1
Sub-Total		565	15
Agriculture		3,300	85
Total		3,865	100

(Clarke, R, 1993 and Vovich, M.I. 1977)

Global Water Use

- Irrigation = 70%
- Industry/Commercial = 20%
- Domestic = 10%

(Brown, L. 2003)

- Today, 2B people (1/3 human population) depend on groundwater for their water needs.

Water Systems Planning

- Case studies
 - Tanzania
 - Increased number of standpipes (increased access)
 - Consumption increased only 2 lpcd
 - Access was apparently reasonable prior to the project
 - Thailand
 - Designed system assuming 50-80 lpcd
 - Actual consumption
 - Standpipes: 9.6-36.8 lpcd
 - House connections: 24.4-65 lpcd
 - System was over designed, scarce resources were wasted
 - Could have provided water to more people for same cost

Water Systems Planning

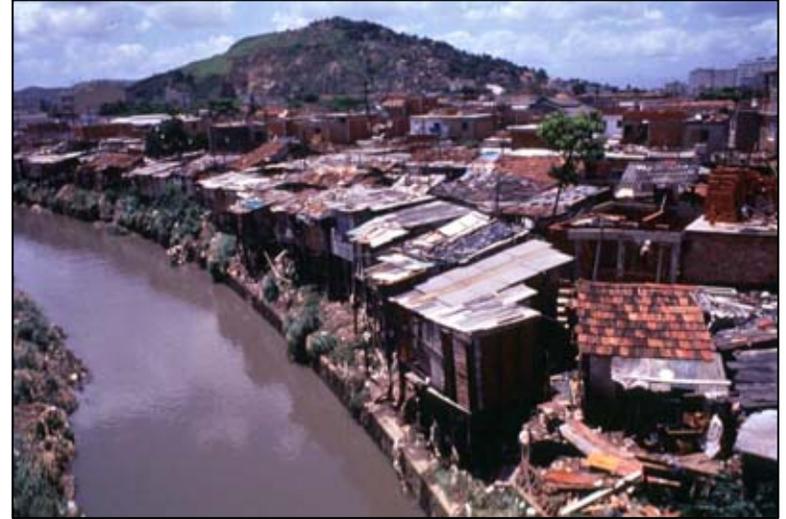
- Recommended design figures
 - Standpipes: 25 lpcd
 - House connections: 50 lpcd
- Plan for losses – leakage, illegal connections
- Planning for future growth
 - Should consider future growth and increased demand
 - Overestimating demand will waste limited capital funds
 - Try to make projects expandable, extendable, improveable

Water Systems Planning

- Planning for future growth
 - Providing excess capacity now may be more economical than adding it in the future – economies of scale
 - Industrialized countries – design to meet demand for next 20 years
 - Developing countries
 - Design for next 5-10 years
 - Funds may not be available for longer periods
 - Do not want to tie up valuable resources that could be used elsewhere

Settlement Patterns

- Urban peripheries
- Rural clustered
- Rural scattered



Settlement Patterns – Urban Peripheries

- Usually unplanned housing layouts
- Includes both rural poor and urban poor (different views)
- High unemployment
- Water supply and sanitation is inadequate
- Public health is usually precarious
- Urban dwellers generally use more water than rural people
- Places for washing clothes and dishes or bathing may not be available
- Disposal of sullage (graywater) may be a significant problem

Settlement Patterns – Urban Peripheries

- Standpipes
 - May require a guard to prevent wastage, vandalism, and contamination by wastewater
 - Single standpipes often serve 500-3000 families – long lines
 - Better figures are 50-100 families per pump
 - Overuse of hand pumps cause frequent pump failures
 - Inconvenience and unreliability may result in people using less desirable sources
 - Need to consider demand and maintenance during planning process

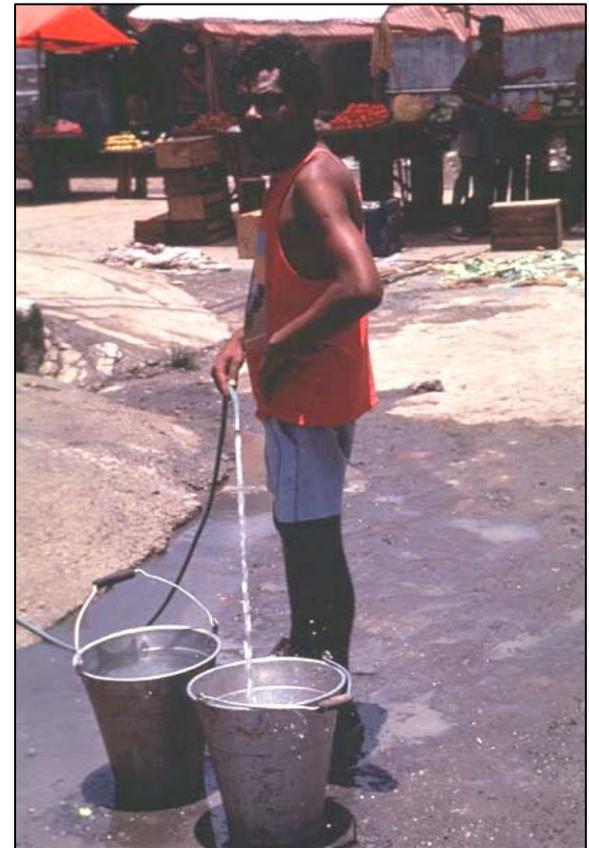


Shantytown outside Rio de Janeiro



Settlement Patterns – Urban Peripheries

- Vendors
 - Sell water from tank with a hose, or from tins from a cart
 - Women may not want to be out on urban streets
 - May be of dubious quality
 - Costly







Public Vendors - Cameroon

Public Water Vendor

Kibera,
Kenya

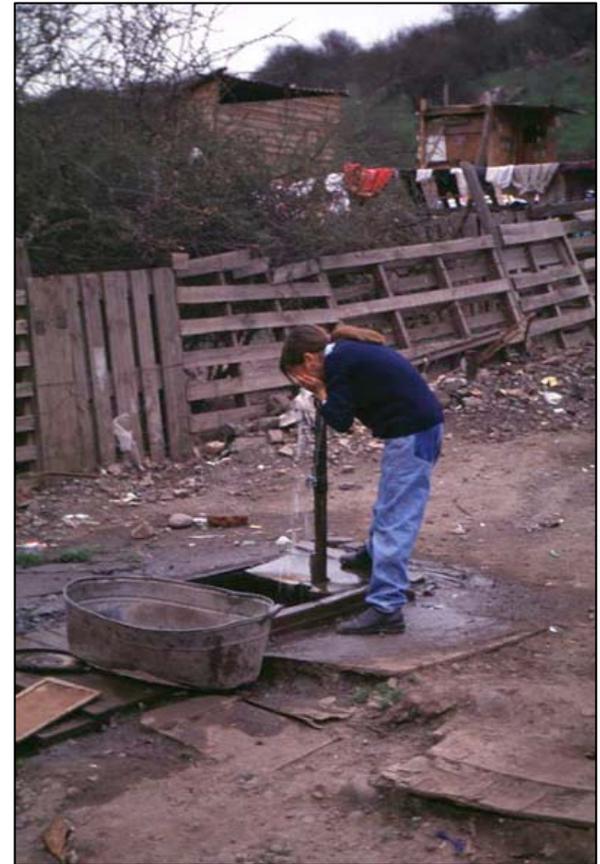


Settlement Patterns – Urban Peripheries

Source	Health Hazard	Cost
Taps	Low	High
Standpipes	Medium	Medium
Vendors	High	High
Surface	High	Low
Underground	High	Low
Rain-barrels	High	Low

Settlement Patterns – Rural Clustered

- Villages ranging from 50 to 5000 people
- Develop around a reliable source
- Have reasonable access to water
- Consumption does not change much until water is piped to homes





India



Nigeria

Settlement Patterns – Rural Clustered

Source	Health Hazard	Cost
Taps	Low	High
Standpipes	Low	Medium
Vendors	High	High
Surface	High	Low/High
Underground	High/Low	Low/High
Rain-barrels	Medium	Low

Settlement Patterns – Rural Scattered

- Considering women's role
 - Time spent carrying water is time lost from other activities
 - 80% of women participate in agriculture
 - In Africa, women produce approximately 80% of the food consumed by their families
 - Women collect and gather 80% of fuel supplies
 - Women perform 50% of house repairs
 - Women participate in 33% of house construction
 - Women do 100% of the cooking, cleaning, washing, and child care
 - Women receive a disproportionately smaller share of food, leisure time, and health care than men

Settlement Patterns – Rural Scattered

- Hauling water consumes a considerable portion of women's time
- Women may carry up to 40 liters (40 kg – 88 lbs) per trip and may make several trips per day
- Men use more water for bathing since they don't carry the water
- Water stored in the home in 200-300 liter containers – not much storage
- Sullage often used for watering animals or irrigation – reduces water to be hauled

Settlement Patterns – Rural Scattered

Source	Health Hazard	Cost
Surface	High	Low/High
Underground	Low	Low/High
Rain-barrels	Low	Low



Carrying Water, Northern Region, Ghana



Kenya – Waiting for water



Kenya – Women-run water vending

References and More Info

- Brown, L. 1993. State of the World. World Watch Institute. W.W. Norton and Co. New York.
- Clarke, R. 1993. Water: The International Crisis, MIT Press, Cambridge, Massachusetts
- Shiklomanov, Igor. 1993. "World Fresh Water Resources," In Water in Crisis. Edited by P. H. Gleick. New York: Oxford University Press.
- USGS, 2006.
http://capp.water.usgs.gov/GIP/gw_gip/how_a.html
- Vovich, M.I., 1997. "World Water Resources Present and Future," *Ambio* 6(1), 12-21. 1977 .