Ganga Curriculum

An Environmental Case Study of the River Ganges

Part II - Water Resources

Written by Dr. David Black

funded by a grant from the National Science Foundation

Independent Broadcasting Associates, Inc
111 King St Littleton MA 01460
T: 978-486-9180 • ibaradio@gmail.com

Table of Contents

The Ganga Curriculum provides a case study to topics presented in environmental science curricula for high school.

This pdf viewed **on-line** is interactive with the web site..

The three main sections are:

Water Quality,
Water Resource Management and
Ecological, Economic, Spiritual and Cultural Values of Water

This a printable version of the curriculum which is found on the Ganga site. The links refer back to the curriculum site.

Each section begins with reference to specific broadcast segments that provide the introduction for the material and activities that follow. Discussion questions lead the students to consider both the issues associated with the Ganges River itself, and about water resource protection and management in general.

Classroom activities are practical exercises which can be performed in the field, the laboratory or on a computer.

Educational Resources provides links, glossary, articles etc

The list of key concepts covered in the project.

More information about the APES Curriculum and exam can be found at the College Board Website.

The GANGA curriculum can be covered effectively in five class periods, with additional time needed for completion of all activities.

Water Resources

The waters of Ganga are used by millions from different regions and countries for myriad purposes. Conflicts are inevitable when these uses include drinking water, spiritual purification and industrial waste disposal. The waters serve as habitat for rare species and provide the livelihood for fishermen and trades people who transport goods to all reaches of the River. Bangladesh demands that adequate waters flow to them for their own needs and the ecology of the Sundarbans, perhaps the most serene place on Earth depends on a balance of clean waters with changing salinity throughout the day. As water is removed and diverted from its natural course, the ability of Ganga to meet these demands is diminished and the management of the waters becomes critical to the persistence of cultures, peoples and ecosystems.

Farakka Barrage

Link to audio clip (10 minutes)

Activities

WR1 Modeling Sustainable Water Use (computer based).

WR2 Increasing Water Supplies

WR3 The politics of water: international conflict and agreements (research project).

Farakka Barrage

Background Information

Early in the 19th century the British Government in India saw the benefits of managing Ganga's flows. A famine in 1837 and 1838 led to the construction of the Ganga Canal, beginning in the sacred city of Haridwar and carrying water by gravity over 400 miles to irrigate the fields of Uttar Pradesh. This diversion has certainly saved thousands of lives by preventing famines that would otherwise inevitably follow a devastating drought. The success of this action led to many more projects up and down the length of Ganga and the other rivers of India. And yet, this security comes at a price. As with so many other dams, siltation has caused problems in the reaches of the river above the barrage, restriction of flows has increased the concentrations of pollutants and downstream users suffer from the loss of the water.
top of page

Discussion and Research Questions

1. Major projects involving the management of water resources have enjoyed considerable support from governments and international development organizations. What are the primary reasons for the construction of dams and barrages in developing countries and why are these seen as important for a region's economic growth?

2. Environmental problems associated with such major water management projects are common and well-documented. Well known examples include the Aswan High Dam in Egypt, the James River Project in Canada, and many are concerned about the Three Gorges Dam restricting the flows of the Yangtze River in China. What environmental factors are most important in assessing the long-term effectiveness of a dam?

3. Funding of such major water management projects is under attack from national and international environmental groups. What is the basis of the cost-benefit analysis of the construction of a dam and can these be mitigated with careful design?

Responses

Question 1: Dams and barrages are constructed to increase water supplies in areas with seasonal shortages, provide a source of electricity for an area undergoing industrial growth and/or to reduce flooding in downstream areas allowing for agricultural use of a river's floodplain or increased land development. All of these can lead to economic growth or an improved standard of living for populations in developing countries. In many cases, international support has led to extensive investment in such projects which has enriched governments and individuals in the recipient countries.

Question 2: An evaluation of a dam project requires the examination of three types of impact:

Immediate environmental, social and cultural effects

- Potential disruption of migration routes for aquatic species, especially anadromous and catadromous fish (salmon, alewife, eels).
- Habitat fragmentation for species with large area requirements.
- Habitat changes associated with reductions in flow rates, increases in water temperature, changes in sediment flows, and changes in water depths.
- Loss of wetland and terrestrial habitats adjacent to the river
- Increases in pollution as transport is reduced and materials accumulate behind the dam
- Increases in the transmission of water borne diseases such as schystosomiasis and others
- Flooding of upstream lands and the relocation of inhabitants and loss of agricultural lands
- Sites of historic and cultural importance are frequently located along rivers. Dam or barrage construction can result in the direct loss of these features and can prevent future archaeologic exploration in an area.
- Downstream effects are many, and include the loss of water during dry periods, and the loss of flooding important to maintaining the productivity of agricultural lands in the flood plain
- Elimination of important commerce routes occurs when boats are prevented from traveling upstream

While the above list is long, it is certainly not complete, with many site specific concerns appearing with new proposed projects.

An assessment of the long-term potential of the dam must consider

- The accumulation of sediments behind a dam has historically reduced to ability of the structures to retain water. Lands subject to high levels of erosion or rivers characterized by large amounts of silt are vulnerable to a rapid loss in storage capacity.
- Eutrophication of the waters behind the dam resulting from the increased concentrations of nutrients can result in a reduction of water quality and the rapid loss of storage area as vegetation comes to dominate the water.
- In arid regions evaporative losses can cause significant reductions in the water storage capacity and can increase salinity of a region

An assessment of future risk associated with the dam

• While the construction of a dam reduces downstream flooding, the newly occupied lands are subject to catastrophic loss should the dam fail. Dramatic evidence of this can be seen in the floods in India described in references below and the devastation caused by Hurricane Katrina in the southeastern United States in September of 2005
• The weight of the impounded water can cause geologic instability, especially important in seismically active regions.

Question 3: The World Bank and other international agencies continue to fund dam projects throughout the world although there is evidence of greater sensitivity to the issues raised above. Mitigation can reduce the impacts described, although many measures are costly and some meet with only mixed success.

Sedimentation – A reduction in the effects of sediment accumulation can be achieved by incorporating engineering solutions into the design of the dam, implementing management practices to reduce erosion in the watershed of the river, or committing to periodic dredging of the material above the dam. All such solutions are problematic, with the success reduced by technological limitations or added costs associated with their implementation.

Habitat Issues – The use of fish ladders in dams and barrages can be effective for some species of anadromous and catadromous fish, however they are ineffective for many species. While habitat creation and restoration can mitigate the loss of critical habitats, such practices depend on the availability of sites suitable for such work and the resources needed to create the new habitat areas. It is rare for both of these to be available at the location needed.

Commercial Issues – The disruption of trade routes associated with dam construction can be mitigated by the inclusion of locks adjacent to the dam. Such structures significantly increase the costs of the project, slow the speed of the transport and depend on access to adequate land for construction.

Link to Classroom Activity – Increasing water supplies

Modeling Sustainable Water Use

Background Information

For many societies access to clean water may be the factor most limiting to quality of life. Water-borne disease remains one of the world's leading causes of death, crops wither for lack of irrigation, and industries cannot grow unless supplies are guaranteed. Dams may provide additional water, but as discussed in "Farakka" carry a tremendous cost. Downstream users are perhaps most affected, but even those with access to the water may face challenges unless the increase in supply is adequate to meet the demand. As discussed in the broadcast, the diversion of water from the Ganges during the dry season is causing hardship to Bangladeshi farmers who have historically used these waters for irrigation.

Maximum Sustainable Yield

The concept of a Maximum Sustainable Yield (MSY) is used to determine the quantities of a resource that can be exploited in a sustainable manner, allowing for the exploitation of that resource at a consistent level indefinitely (although the definition of the word "sustainable" seems to be changing in some circles to include the idea of use for a long period of time; e.g. the sustainable use of oil). MSY is used to determine timber harvests, hunting limits, and catch limits for fisheries. In the case of waters, the sustainability of the extraction affects both the users above a dam or barrage and those below.

Model Parameters

The first step in building the model is identifying quantitative factors that are important to understanding the dynamics of the system. While not all will be used in most cases, development of the list causes students to reflect on the complexity of the model and gain an understanding of the important relationships associated with the question being asked.

2. Building a Model

Computer models lie at the foundation of many environmental questions and decisions. Beginning with the simplest factors that influence the process under study, the model can be refined through the addition of more variables or by the inclusion of increasingly sophisticated equations. Some parameters can be varied with precision (amount of water withdrawn from a river), others vary within a range of values (rainfall). Others require the application of some algebraic equations relating the different variables (the amount of evaporation is largely a function of the surface area of the water stored behind a dam or barrage).

Model Design – developing the question

For Ganga, questions of water resource management frequently center on the use of barrages to reduce the seasonal fluctuations in water supplies to provide more consistent availability for agricultural, domestic and industrial use. As water levels drop over the course of the dry season, more water must be diverted to meet the demands of the users in India.

The Farakka barrage is capable of diverting 40,000 cusecs (cubic feet per second) of water. Dry season flows of the Ganges at Kanpur were historically approximately 55,000 cusecs, although this figure varied considerably given differences in rainfall patterns.

3. ExCel Model

The excel model linked to this page can be used in a variety of ways. First, research is needed into the basic input parameters: what is per capita water usage in an area? How much precipitation reaches a reservoir or aquifer? A basic calculation of sustainability can thus be made, with the effects of the water cycle added to include complexity in the model.

The model can then be made more dynamic by including random variations in the amount of rainfall and water use. Increased population can be factored in over time, and a loss of volume associated with siltation included.

Use the model to explore the following questions:

1. Assuming that the dry season flow of water through Kanpur is 55,000 cusecs and that 25,000 cusecs of water are currently, how long can a 5% increase in the amount of water diverted be sustained?

2. Rates of evaporation change as a function of the depth of the water, which can be approximated by the volume of flow. Using the figures in Table 1, calculate the net effect of withdrawals of water on downstream users based on the volume diverted.

Table 1. Evaporative water losses as a function of volume of water diverted.

Amount of Water Diverted (cusecs)	Evaporative Losses
0	15%
5000	17%
10000	20%
15000	25%
20000	30%
25000	35%
30000	43%
35000	52%
40000	65%

3. Siltation is occurring rapidly behind dams and barrages around the world. If the operators of Farakka commit to withdrawing 25,000 cusecs of water per year, and siltation reduces flows from the current 55,000 cusecs per year by approximately 6% how long can water be diverted before flow rates reach 0 below the barrage?

The Challenge of Increasing Water Supplies

Background Information

Handout (at the end of this section

Many areas in the United States and Europe are currently experiencing water deficits that result in restrictions places on water use and in some cases prevent the development of lands. There are many techniques available to increase water supplies: more wells, impounding surface waters, treating and reusing wastewater, and conservation. Using a topographic map of an area, students will analyze the suitability of a site for dam construction and will develop an impact analysis of the probably effects of altering the flow patterns of the waterway. The evaluation of a site for suitability for the construction of a dam requires:

Appropriate topography (enough elevation change to create a storage basin)

Lack of valuable land that would be flooded (developed or agricultural)
Lack of sources of contaminants in the upstream watershed
Lack of areas of significant erosion that could lead to accelerated sedimentation

Environmental issues likely to arise include:

Disruption of wildlife habitats, especially loss of wetlands
Disruption of migratory routes for anadromous and catadromous fish
An elevation in the water table changing the effectiveness of certain soils for agriculture
Loss of water to downstream users

Using a United States Geological Survey Topographic Quadrangle (USGS Quad; available from TOPOZONE for the United States and as ordinance surveys for much of Europe), evaluate a chosen reach of the river for suitability of dam locations.

Methods:

1. The area with the greatest topographic relief, that which allows for the greatest storage volume and an increase in storage area of 15 meters (45 feet). Figure 1 shows two sites, one with steep slopes that would allow for dam construction, the other with little change in elevation, requiring an impracticable length of dam. After finding the

steepest site, draw in the dam, extending it perpendicularly to the river until you reach the required height (see Figure 2).

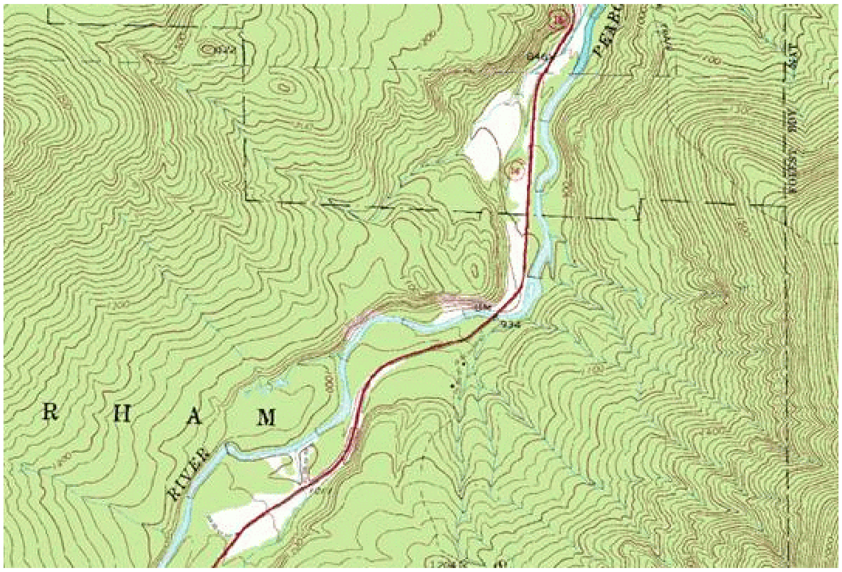

Figure 1 Topography suitable to dam construction. Steep slopes on both sides of the river will allow for a confined storage basin and a dam of reasonable length.

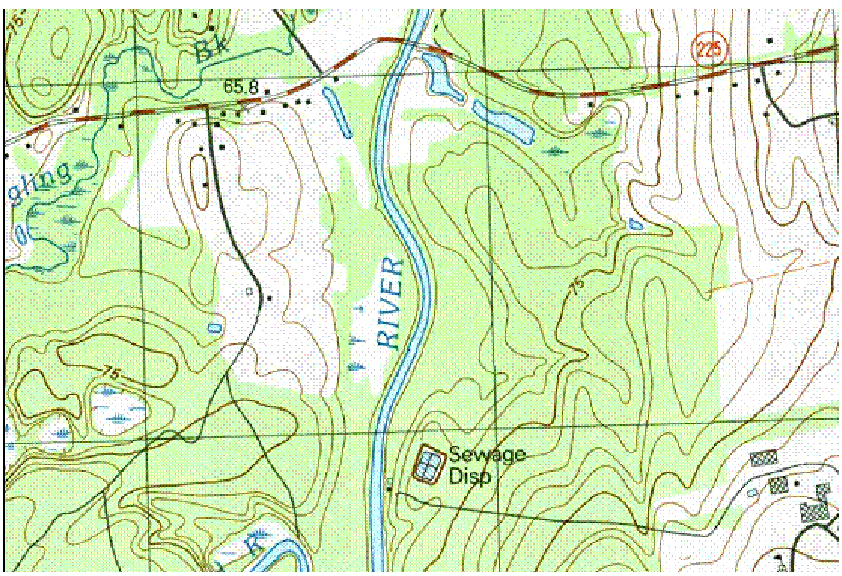

Figure 2. Topography unsuitable to dam construction. While the steep slopes to the east of the river are sufficient to store the water, the gentle slopes to the west would result in the loss of a large land area and require a dam of extreme length

2. Using the topographic lines on the map, draw in the area that would be flooded following dam construction (Figure 3). Using graph paper as an overlay, measure the surface area of the reservoir created. Count the number of structures and roads and the area of agricultural, forest and other open space that would be flooded.

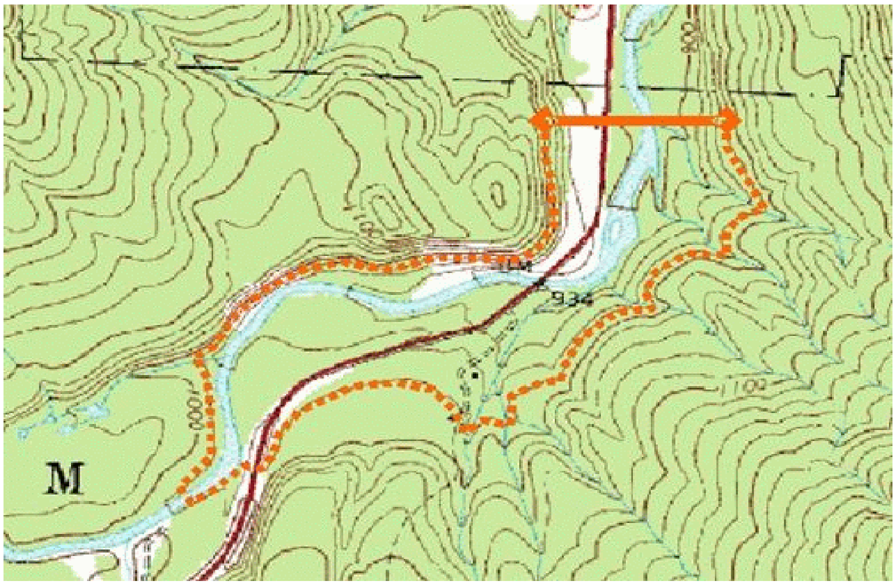

Figure 3. Extent of flooding for a dam with a 15 m maximum depth (site shown on Figure 1).

3. Identify any wastewater treatment plants or urban centers located above the dam.

Questions:

1. Using the formula below, determine the amount of water potentially stored by the dam. If the residents of the area require 500 liters of water per day during the dry season, how many people could be supported by the dam assuming that no rain fell for one month? Use meters for all measurements; 1 cubic meter of water equals 1000 liters.

Volume of water stored (meters3) = (1/2 * widest point (W) * length (L)) * (1/3 * (depth (D)/2))

2. If each house lost to the reservoir is valued at $250,000, what would the cost of structures be for the construction of the dam?

3. Assume that land values in your area are approximately $100,000 per hectare (or correct for a more accurate value for your area) and that agricultural lands are worth approximately 50% of residential land. What is the value of the land lost to the reservoir?

The Challenge of Increasing Water Supplies

Background Information

Many areas in the United States and Europe are currently experiencing water deficits that result in restrictions places on water use and in some cases prevent the development of lands. There are many techniques available to increase water supplies: more wells, impounding surface waters, treating and reusing wastewater, and conservation. Using a topographic map of an area, students will analyze the suitability of a site for dam construction and will develop an impact analysis of the probably effects of altering the flow patterns of the waterway. The evaluation of a site for suitability for the construction of a dam requires:

Appropriate topography (enough elevation change to create a storage basin)
Lack of valuable land that would be flooded (developed or agricultural)
Lack of sources of contaminants in the upstream watershed
Lack of areas of significant erosion that could lead to accelerated sedimentation

Environmental issues likely to arise include:

Disruption of wildlife habitats, especially loss of wetlands
Disruption of migratory routes for anadromous and catadromous fish
An elevation in the water table changing the effectiveness of certain soils for agriculture
Loss of water to downstream users

Using a United States Geological Survey Topographic Quadrangle (USGS Quad; available from TOPOZONE for the United States and as ordinance surveys for much of Europe), evaluate a chosen reach of the river for suitability of dam locations.

Methods:

1. The area with the greatest topographic relief, that which allows for the greatest storage volume and an increase in storage area of 15 meters (45 feet). Figure 1 shows two sites, one with steep slopes that would allow for dam construction, the other with little change in elevation, requiring an impracticable length of dam. After finding the steepest site, draw in the dam, extending it perpendicularly to the river until you reach the required height (see Figure 2).

Figure 1 Topography suitable to dam construction. Steep slopes on both sides of the river will allow for a confined storage basin and a dam of reasonable length.

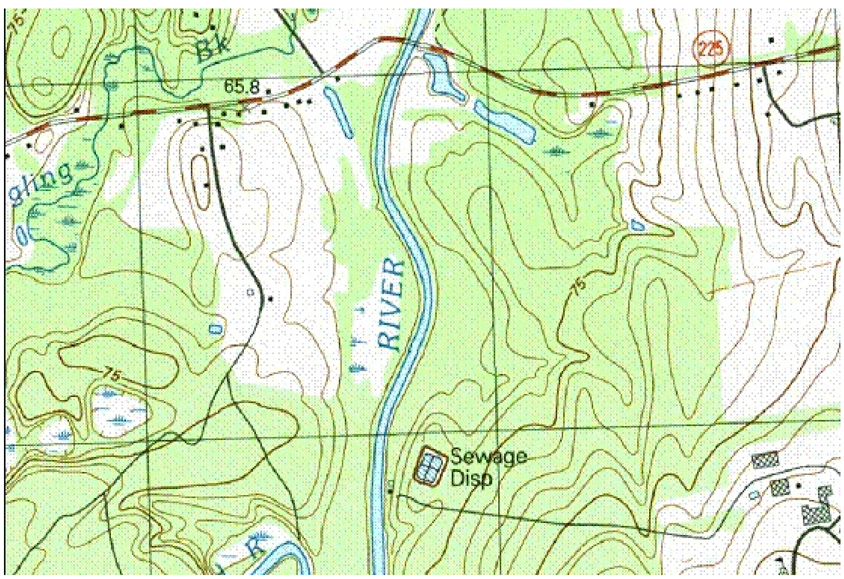

Figure 2. Topography unsuitable to dam construction. While the steep slopes to the east of the river are sufficient to store the water, the gentle slopes to the west would result in the loss of a large land area and require a dam of extreme length

2. Using the topographic lines on the map, draw in the area that would be flooded following dam construction (Figure 3). Using graph paper as an overlay, measure the surface area of the reservoir created. Count the number of structures and roads and the area of agricultural, forest and other open space that would be flooded.

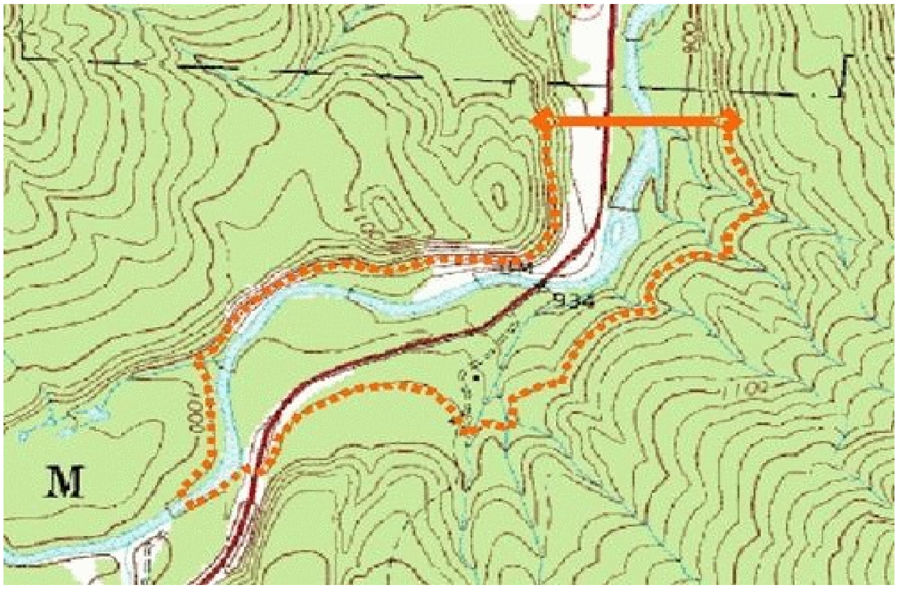

Figure 3. Extent of flooding for a dam with a 15 m maximum depth (site shown on Figure 1).

3. Identify any wastewater treatment plants or urban centers located above the dam.

Questions:

1. Using the formula below, determine the amount of water potentially stored by the dam. If the residents of the area require 500 liters of water per day during the dry season, how many people could be supported by the dam assuming that no rain fell for one month? Use meters for all measurements; 1 cubic meter of water equals 1000 liters.

Volume of water stored (meters3) = (1/2 * widest point (W) * length (L)) * (1/3 * (depth (D)/2))

2. If each house lost to the reservoir is valued at $250,000, what would the cost of structures be for the construction of the dam?

3. Assume that land values in your area are approximately $100,000 per hectare (or correct for a more accurate value for your area) and that agricultural lands are worth approximately 50% of residential land. What is the value of the land lost to the reservoir?

The politics of water
The use of applied geography in
predicting international conflict

Background Information

Handout (at the end of the section)

International conflicts over water resources threaten regional stability in many areas, including the Middle East, Asia and North America. "A United Nations report has predicted that access to water may be the single biggest cause of conflict and war in Africa in the next 25 years". Four of the five fasting growing states in the US lie in the Colorado River basin and the population of northern Mexico dependent on this water is growing at a rate of 5% per year. Similar conflicts can be found in many regions of the world.

A tremendous body of geographic information is now available on the web. ArcGIS Explorer is a free download that will allow you to explore many aspects of a region and work to identify potential water resource issues. Google Earth provides similar information and is again available as a free download. Because the web sites for both of these projects changes, use a search engine like Google to find the site and download the necessary software.

While water resource issues exist on most continents, they are frequently most severe in the arid regions of the world. Select one such region and identify a river that flows from one country to another. Alternatively, use the search engines built into the mapping to software to look for a river that is known to be a source of tension. Examples include the Ganges, the Nile, the Jordan or the Colorado River.

Identify the major cities that lie along the river and record their populations. From this information determine the total number of people in urban areas that depend on the river as a water supply and as a waste disposal facility. Zoom in on the cities and look for evidence of dams or barrages: are there areas where the river is quite wide upstream and narrows rapidly at a specific point? Are there straight channels running alongside the river or leading away from it that suggest that the population is extracting water at a rate that exceeds the normal flow rate, forcing them to store seasonal waters for later use?

Using the British Broadcasting Site below as a source of information, search for the river that you are analyzing to determine if there are currently conflicts over the water supply.

How would a requirement that a certain minimum flow remain in the stream affect upstream users? Are there agricultural lands that depend on irrigation from the river that would be lost if the water flowed through? What are the likely effects of a reduction in the total amount of water available to an urban center?

The answers to the questions above provide represent the first step in understanding the critical role of water in national security. Do you feel that water shortages currently threaten relationships between the affected countries? What would the affects of global climate change be on these countries should less precipitation fall in the region?

Additional Resources:

The Worldwatch Institute (http://www.worldwatch.org/) has many publications available discussing conflicts associated with the management of water resources. Their annual "State of the World" publication frequently contains information relevant to the consideration of water supply issues, and they have put out several topic specific publications on water resources which are still available from on their web site.

The British Broadcasting Corporation (http://news.bbc.co.uk/2/hi/in_depth/world/2003/world_forum/water/default.stm#) hosted a forum in 2003, discussing whether water, and not oil, would be the basis of the next major war fought on the planet. In this discussion, many specific examples of conflicts were identified and the critical importance of the issue of water allocation discussed.

The politics of water
The use of applied geography in predicting international conflict

Background Information

International conflicts over water resources threaten regional stability in many areas, including the Middle East, Asia and North America. "A United Nations report has predicted that access to water may be the single biggest cause of conflict and war in Africa in the next 25 years". Four of the five fasting growing states in the US lie in the Colorado River basin and the population of northern Mexico dependent on this water is growing at a rate of 5% per year. Similar conflicts can be found in many regions of the world.

A tremendous body of geographic information is now available on the web. ArcGIS Explorer is a free download that will allow you to explore many aspects of a region and work to identify potential water resource issues. Google Earth provides similar information and is again available as a free download. Because the web sites for both of these projects changes, use a search engine like Google to find the site and download the necessary software.

While water resource issues exist on most continents, they are frequently most severe in the arid regions of the world. Select one such region and identify a river that flows from one country to another. Alternatively, use the search engines built into the mapping to software to look for a river that is known to be a source of tension. Examples include the Ganges, the Nile, the Jordan or the Colorado River.

Identify the major cities that lie along the river and record their populations. From this information determine the total number of people in urban areas that depend on the river as a water supply and as a waste disposal facility. Zoom in on the cities and look for evidence of dams or barrages: are there areas where the river is quite wide upstream and narrows rapidly at a specific point? Are there straight channels running alongside the river or leading away from it that suggest that the population is extracting water at a rate that exceeds the normal flow rate, forcing them to store seasonal waters for later use?

Using the British Broadcasting Site below as a source of information, search for the river that you are analyzing to determine if there are currently conflicts over the water supply.

How would a requirement that a certain minimum flow remain in the stream affect upstream users? Are there agricultural lands that depend on irrigation from the river that would be lost if the water flowed through? What are the likely effects of a reduction in the total amount of water available to an urban center?

The answers to the questions above provide represent the first step in understanding the critical role of water in national security. Do you feel that water shortages currently threaten relationships between the affected countries? What would the affects of global climate change be on these countries should less precipitation fall in the region?

Additional Resources:

The Worldwatch Institute (http://www.worldwatch.org/) has many publications available discussing conflicts associated with the management of water resources. Their annual "State of the World" publication frequently contains information relevant to the consideration of water supply issues, and they have put out several topic specific publications on water resources which are still available from on their web site.

The British Broadcasting Corporation (http://news.bbc.co.uk/2/hi/in_depth/world/2003/world_forum/water/default.stm#) hosted a forum in 2003, discussing whether water, and not oil, would be the basis of the next major war fought on the planet. In this discussion, many specific examples of conflicts were identified and the critical importance of the issue of water allocation discussed.