SANDIA REPORT
SAND2001–0722
Unlimited Release
Printed March 2001

The South Asia Cooperative Environmental Monitoring Project: An Effort to Promote Regional Cooperation and Water Quality Data Sharing in South Asia

Gaurav Rajen, Kent L. Biringer, and J. David Betsill

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Prices available from (703) 605-6000
Web site: http://www.ntis.gov/ordering.htm

Available to the public from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A04
Microfiche copy: A01

SAND2001-0722
Unlimited Release
Printed March 2001

The South Asia Cooperative Environmental Monitoring Project: An Effort to Promote Regional Cooperation and Water Quality Data Sharing in South Asia

Gaurav Rajen, Kent L. Biringer, and J. David Betsill
Cooperative Monitoring Center
Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-1371
USA

Abstract

To promote cooperation in South Asia on environmental research, the Cooperative Monitoring Center (CMC) initiated a regional water quality monitoring and data-sharing project. This report describes the tasks accomplished and proposed future activities. The project is part of the CMC's South Asia regional program on environmental cooperation, in the interest of promoting improved relations between countries.

The broad and long-term interests of the project participants are on the significance of regional information sharing as a means to build confidence and reduce conflict. The more intermediate interests of the group are focused on activities that might eventually foster regional management of some aspects of water resources utilization. The most immediate purpose of the project is to collect and share water quality information at a number of river and coastal estuary locations throughout the region.

A workshop in India in 1998 resulted in interest in studies related to water resources management in the Ganga-Brahmaputra-Meghna river basin and sustainability of the Sundarbans mangrove forest area. Plans were devised to create a network of organizations from several South Asian countries that would collect and share water quality data. In 1999, in Nepal, an international working group of participants from Bangladesh, India, Nepal, Pakistan, Sri Lanka and the United States developed these four products: (1) a deepened understanding of the partner organizations involved; (2) garnering the support of existing regional organizations promoting environmental cooperation in South Asia; (3) identification of sites within the region at which data are to be collected; and (4) instituting a data and information collection and sharing process. Since the Kathmandu workshop, the regional partners have collected and shared water quality data from select locations. This report describes the data that have been collected and other project activities. To view the collected data, go to http://www.cmc.sandia.gov/sasia/southasia.html.

Acknowledgment

The project managers and staff gratefully acknowledge support from the U.S. DOE Office of Nonproliferation and National Security. We also thank Ms. Debbi Seligsohn, Regional Environmental Affairs Officer, of the American Embassy in Kathmandu, Nepal, for support in arranging the workshop in Kathmandu and continued support in achieving the project's objectives. We are also deeply grateful to all of our regional partners whose work and continued interest has helped the project achieve its goals.

Contents

Figures

Tables

Acronyms

ACDA	United States Arms Control and Disarmament Agency
AID	U.S. Agency for International Development
BUP	Bangladesh Unnayan Parishad
CMC	Cooperative Monitoring Center
COMAPS	Coastal Ocean Monitoring and Prediction System
CSBM	confidence and security building measure
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
FRIEND	Flow Regimes from International Experimental and Network Data
GEMS	Global Environment Monitoring System
HKH	Hindu Kush Himalayan
ICIMOD	International Center for Integrated Mountain Development
IHP	International Hydrological Program
IUCN	World Conservation Union
IWAC	International Water Assessment Center
NGO	nongovernmental organization
NIO	National Institute of Oceanography
NWCF	Nepal Water Conservation Foundation
NWS&DB	National Water Supplies and Drainage Board
PEEMAC	Pakistan Energy and Environmental Management Center
PSG	Peace Studies Group, University of Calcutta
RIZA	The Netherlands' Institute for Inland Water Management and Waste Water Treatment
SAARC	South Asian Association for Regional Cooperation
SACEP	South Asia Cooperative Environment Program
SARS	South Asia Research Society
SNL	Sandia National Laboratories
TBIA	Thane-Belapur Industries Association
UN	United Nations
UN/ECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMO	World Meteorological Organization

This page intentionally left blank

1. Introduction and Background

In the context of the nuclear tests of India and Pakistan and the declared intentions by both countries to deploy nuclear weapons as deterrents, there is an urgent need to promote confidence and security building measures (CSBMs) between these two countries. In this context, the lessening of tensions through CSBMs such as cooperative environmental projects can reduce the risk of conflict and enhance collective security objectives in South Asia (Singh 1996; Biringer 1998; Rajen 1999). The driving motivation behind the project described in this report is to develop such CSBMs. As joint Indian and Pakistani projects are difficult to promote in the existing context of severely strained bilateral relations, the effort has sought to promote environmental cooperation in a multilateral regional context involving several countries of South Asia.

No one seriously argues that greater regional cooperation in South Asia is not sorely needed. The real question is how do we go about it. This report documents a project that seeks to promote greater regional cooperation in South Asia through a series of incremental steps. The logic and assumptions underlying the process are as follows:

- Regional cooperation can be promoted by initially fostering regional *environmental* cooperation.
- Greater regional environmental cooperation can be fostered through cooperation in water resources management (especially of cross-border rivers), a critical need for the region.
- Cooperation in water resources management will be enhanced through the sharing of water resources data.
- Less sensitive water resources data, such as water quality data, will be easier to share at first than water quantity data (water quantity data are considered a matter of national security in most South Asian countries).
- Networks of nongovernmental organizations (NGOs) will more easily share water quality data than a network made up of government institutions.

In keeping with this logic, to promote cooperation in South Asia on environmental research, the Cooperative Monitoring Center (CMC) at Sandia National Laboratories (SNL) in Albuquerque, New Mexico, United States, worked with regional partners to initiate a South Asia water quality monitoring and data-sharing project. In future phases, the project will involve more governmental organizations, and progress from sharing water quality data to the sharing of water quantity data, and from water resources management to cooperation in other environmental areas. In this manner, the project will form a part of a larger process that seeks to foster broad regional cooperation. This report describes the project tasks accomplished and proposed future activities.

The CMC has sponsored this project through funding provided by the U.S. Department of Energy (DOE) Office of Nonproliferation and National Security.[1] The CMC promotes collaborations among scientists and researchers in several regions as a means of achieving common regional security objectives. The CMC and SNL have significant technical expertise that can be applied to cooperative monitoring projects, including environmental projects. Examples include high-resolution remote sensing, data transmission and security, computer modeling, data management and decision support tools, and an infrastructure to support cooperative monitoring efforts. In addition, the CMC collaborates with a variety of other agencies such as the U.S. Geological Survey, the U.S. Environmental Protection Agency (EPA), the U.S. Bureau of Reclamation, numerous universities, and local and state governments. To accomplish the project's objectives, the CMC is partnering with a diverse group of organizations from within South Asia and the U.S., representing government, business, academic, and research institutions.

The CMC initiated the project in March 1998 when the Peace Studies Center at Calcutta University and the South Asia Research Society (SARS) hosted an environmental monitoring workshop in Calcutta, India. This workshop was co-sponsored by the United States Arms Control and Disarmament Agency (ACDA) and DOE. Subsequently, in June 1998, regional experts in water resources and policy from India, Nepal, and Bangladesh met at the CMC to discuss potential project ideas. Two of the topics of primary interest that emerged through a consensus of the participants were studies related to water resources management in the Ganga-Brahmaputra-Meghna river basin and sustainability of the Sundarbans mangrove forest area. Through these workshops, plans were devised to expand the list of countries involved to include Pakistan and Sri Lanka, and to create a network of organizations from these South Asian countries that would collect and share water quality data. To implement the plan, an international working group made up of participants from Bangladesh, India, Nepal, Pakistan, Sri Lanka, and the United States convened at the Soaltee Hotel in Kathmandu, Nepal, September 12 to 15, 1999. (Figure 1 shows the workshop participants. Appendix A provides a listing of names.) This workshop was co-hosted by the U.S. Embassy in Kathmandu, Nepal. The aim of the workshop was to initiate a process of sharing water-related data among the participating researchers. The workshop successfully developed these four products: (1) a deepened understanding of the partner organizations involved; (2) garnering the support of existing regional organizations promoting environmental cooperation in South Asia; (3) identification of sites within the region at which data are to be collected; and (4) instituting a data and information collection and sharing process. Since the Kathmandu workshop, the regional partners have collected and shared water quality data from select locations. Refer to http://www.cmc.sandia.gov/sasia/southasia.html for a copy of the collected data. Refer to Section 3.3 for a discussion of the data.

---

[1] A project-related regional workshop was co-hosted by ACDA, now a Bureau within the U.S. Department of State, and another by the U.S. Embassy in Kathmandu, Nepal. Future activities are likely to be co-funded by the U.S. Department of State through AID.

Figure 1. Workshop participants.

The principal idea underlying the project's interests is that cooperation to ensure a sustainable environment can improve relations between countries. Environmental cooperation serves in the role of general nonmilitary CSBMs when the level of hostility and mistrust between parties precludes the possibility of CSBMs in more sensitive military-related areas (Ahmed and Das, 1998). The Red Sea Marine Peace Park in Jordan, created as a part of the Israeli-Jordanian peace-seeking process, provides an excellent example of such environmental cooperation. Even if one contests the premise that environmental cooperation can lead to a solution of security-related problems, the lack of environmental cooperation could exacerbate strained relations between and within countries. Gleditsch (1998) reviews numerous studies that establish a link between environmental scarcity and violent conflict. A recent World Bank study has concluded that there are now more environmental refugees (displaced by the lack of natural resources such as fertile soil and adequate water supplies) than war refugees. Many disputes over territorial borders involve the contested ownership of resources or access to the resources. Degradation and the depletion of agricultural land, forest, water, and fish stocks are examples of environmental factors that can increase the potential for armed conflict. Along with the benefits of improved sustainability, environmental cooperation among countries also has several indirect security-related benefits. Environmental cooperation increases dialogue between policy-makers and scientists that can be maintained even when talks on other more sensitive subjects are suspended. Environmental cooperation also creates an information-sharing infrastructure that can be expanded incrementally to include sensitive security and arms control subjects (Pregenzer, Vannoni, and Biringer 1996).

In South Asia's Indus and Ganga River Basins, effective water management requires rapid access to accurate, reliable, and spatially and temporally continuous data. The development of predictive models that can integrate and analyze water resources data necessitates a holistic approach that transcends the political boundaries dividing the basins. In the Ganga River Basin, for example, effective water resource management is constrained by the lack of data sharing among neighboring countries. Comprehensive predictive models remain difficult to develop. The security of millions of people is endangered through increasing water scarcity, floods, excessive sedimentation, drastic changes in river morphology, reduced dam safety, salinization of fresh waters, loss of arable lands, and environmental degradation of unique habitats such as the mangrove forests of the Sundarbans (in the Ganga delta).

One of the main conclusions of the June 1998 workshop held at the CMC was that a pressing need existed within South Asia to foster greater openness and sharing of water resources information. It was further recognized that water quality data might be easier to gather and share among regional partners than water quantity data that would be considered more sensitive by concerned government agencies. As a result of these findings, a project was initiated by the CMC to develop a partnership with a network of entities within various South Asian countries to begin sharing nonsensitive environmental and water quality data. Currently, the project is focusing on water quality issues of interest to our partners in Bangladesh, India, Nepal, Pakistan, and Sri Lanka. The data of interest include water quality information from select locations on the Ganga and Indus rivers, and some coastal regions. Figure 2 depicts the areas of relevance to the project.

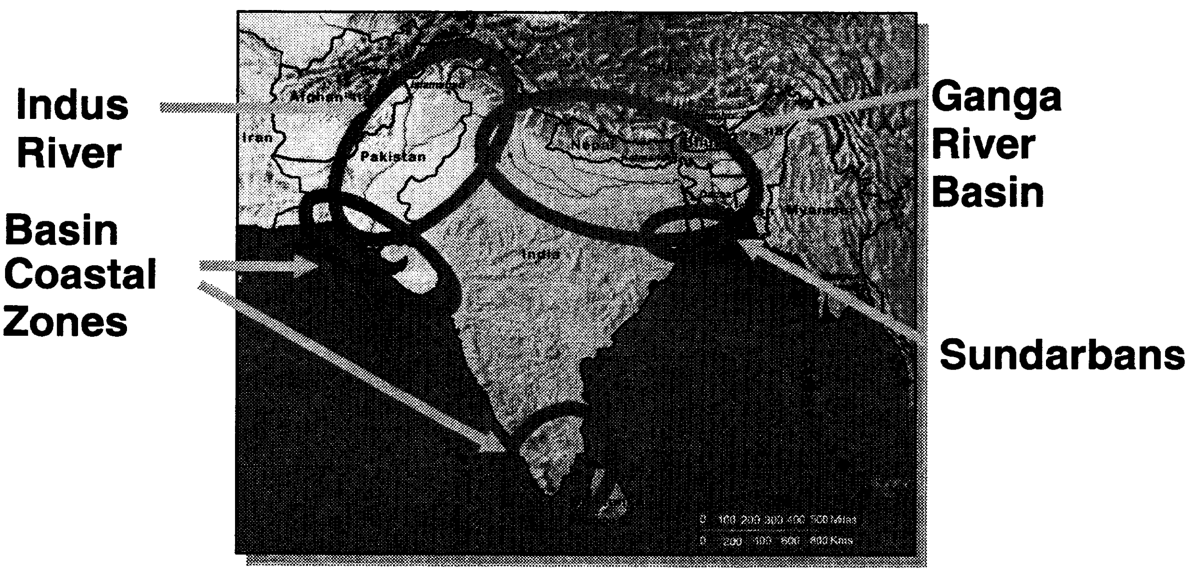


Figure 2. Areas of relevance to the project.

The regional project partners have performed the following tasks:

- Selected sampling locations (along rivers or in estuarine/delta regions) and provided information on the sites chosen;
- Collected data at chosen locations using identical hand-held water quality measurement instruments and shared data gathered among the parties via the CMC over the Internet.

The subsequent phases of this project will focus on cross-border rivers, specifically the Indus and Ganga, involve partners from areas in proximity to these rivers, increase the involvement of governmental organizations, and move to semi-automated data acquisition and transmission. The data will be used collectively to deepen understanding of the hydrological cycles in the countries involved.

The data collection effort has begun through a partnership of governmental, nongovernmental, academic, and industry organizations. Table 1 lists these partners. Progressively, the project intends to increase the number of partners involved and create a broad-based constituency of stakeholders committed to greater regional cooperation in South Asia on water resources management. It is important, therefore, that the project's data collection effort, though modest at this time, be linked to existing frameworks of cooperation related to the monitoring of cross-border rivers and coastal regions. The next section (Section 1.1) of this report reviews existing conventions and agreements relevant to the project. Section 1.2 reviews existing programs of water quality monitoring and data sharing in South Asia.

Table 1. Partners Collecting and Sharing Data

Country	Organization	Point of Contact
Bangladesh	Bangladesh Unnayan Parishad, Dhaka, Bangladesh (NGO)	Ahsan Uddin Ahmad, Director of Environment Programs
India	Thane-Belapur Industries Association, Mumbai (Industry) South Asia Research Society (SARS), Calcutta (NGO)	Dinesh Parekh, President J.K. Ray, Director
Nepal	Nepal Water Conservation Foundation (NWCF), Kathmandu (NGO)	Dipak Gyawali, Managing Director
Pakistan	Pakistan Energy and Environmental Management Center (PEEMAC), Islamabad (NGO), Islamabad, working with the National Energy Conservation Centre (ENERCON) (Government).	Arif Alauddin, Managing Director, ENERCON
Sri Lanka	National Water Supplies and Drainage Board (NWS&DB), Colombo, Sri Lanka (Government)	Nimal Padmasiri, Director of Laboratories
USA	Cooperative Monitoring Center, Albuquerque (Government and Industry)	Kent Biringer, Distinguished Member, Technical Staff J. David Betsill, Senior Member, Technical Staff Gaurav Rajen, Visiting Scholar

1.1 Framework Conventions and Agreements

1.1.1 United Nations Convention on the Law of the Non-Navigational Uses of International Watercourses

The United Nations (UN) Convention on the Law of the Non-Navigational Uses of International Watercourses provides a framework for the data collection and sharing process that has been initiated in this project[2] (UN 2000). The UN General Assembly adopted the draft resolution on this Convention, referred to as the International Watercourses Convention (document A/51/L.72), on May 21, 1997. The International Watercourses Convention applies to the "uses of international watercourses and of their waters for purposes other than navigation and to measures of protection, preservation and management related to the uses of the watercourses and their waters".[3] For the purposes of the International Watercourses Convention, "watercourse" means "a system of surface waters and groundwaters constituting by virtue of their physical relationship a unitary whole and normally flowing into a common terminus," and "international watercourse" means "a watercourse, parts of which are situated in different States."[4]

The General Principles underlying the International Watercourses Convention (described in Articles 5–10) involve equitable and reasonable utilization and participation, general obligations not to cause significant harm and to cooperate, and the **regular exchange of data and information.**[5] The International Watercourses Convention also provides for the "protection and

---

[2] The UN General Assembly adopted the draft resolution on a Convention on the Law on Non-Navigational Uses of International Watercourses (document A/51/L.72) by a recorded vote of 103 in favor to 3 against, with 27 abstentions, as follows:

In favor: Albania, Algeria, Angola, Antigua and Barbuda, Armenia, Australia, Austria, Bahrain, Bangladesh, Belarus, Botswana, Brazil, Brunei Darussalam, Burkina Faso, Cambodia, Cameroon, Canada, Chile, Costa Rica, Côte d'Ivoire, Croatia, Cyprus, Czech Republic, Denmark, Djibouti, Estonia, Federated States of Micronesia, Finland, Gabon, Georgia, Germany, Greece, Guyana, Haiti, Honduras, Hungary, Iceland, Indonesia, Iran, Ireland, Italy, Jamaica, Japan, Jordan, Kazakstan, Kenya, Kuwait, Lao Peoples Democratic Republic, Latvia, Lesotho, Liberia, Libya, Liechtenstein, Lithuania, Luxembourg, Madagascar, Malawi, Malaysia, Maldives, Malta, Marshall Islands, Mauritius, Mexico, Morocco, Mozambique, Namibia, Nepal, Netherlands, New Zealand, Norway, Oman, Papua New Guinea, Philippines, Poland, Portugal, Qatar, Republic of Korea, Romania, Russian Federation, Samoa, San Marino, Saudi Arabia, Sierra Leone, Singapore, Slovakia, Slovenia, South Africa, Sudan, Suriname, Sweden, Syria, Thailand, Trinidad and Tobago, Tunisia, Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela, Viet Nam, Yemen, and Zambia.

Against: Burundi, China, and Turkey.

Abstaining: Andorra, Argentina, Azerbaijan, Belgium, Bolivia, Bulgaria, Colombia, Cuba, Ecuador, Egypt, Ethiopia, France, Ghana, Guatemala, India, Israel, Mali, Monaco, Mongolia, Pakistan, Panama, Paraguay, Peru, Rwanda, Spain, United Republic of Tanzania, and Uzbekistan.

Absent: Afghanistan, Bahamas, Barbados, Belize, Benin, Bhutan, Cape Verde, Comoros, Democratic People's Republic of Korea, Dominican Republic, El Salvador, Eritrea, Fiji, Guinea, Lebanon, Mauritania, Myanmar, Niger, Nigeria, Palau, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, Senegal, Solomon Islands, Sri Lanka, Swaziland, Tajikistan, The former Yugoslav Republic of Macedonia, Turkmenistan, Uganda, Zaire, and Zimbabwe.

[3] Article 1, Scope of the Convention, http://www.un.org/law/watere.htm.

[4] Article 2, Use of terms, http://www.un.org/law/watere.htm.

[5] "Article 9 Regular exchange of data and information

1. Pursuant to article 8 [General obligation to cooperate] watercourse States shall on a regular basis exchange readily available data and information on the conditions of the watercourse, in particular that of a hydrological, meteorological, hydrogeological and ecological nature and related to the water quality as well as related forecasts.

2. If a watercourse State is requested by another watercourse State to provide data or information that is not readily available, it shall employ its best efforts to comply with the request but may condition its

preservation of ecosystems" (Article 20), the "prevention, reduction and control of pollution" (Article 21), the prevention of the "introduction of alien or new species" (Article 22), the "protection and preservation of the marine environment" (Article 23), and consultations regarding "management" (Article 24). "Management" refers to "planning the sustainable development of an international watercourse" and "providing for the implementation of any plans adopted," and to "promoting the rational and optimal utilization, protection and control of the watercourse."

Among the countries from which organizations are participating in this project, Bangladesh and Nepal voted for the International Watercourses Convention, India and Pakistan abstained, and Sri Lanka was absent. Although not yet binding on any South Asian countries (as none has ratified), the International Watercourses Convention provides guidelines on the possibilities for future cooperation. As it enters into force and practice, the International Watercourses Convention may increasingly become a part of customary international law and tend to provide models for the cooperative monitoring of cross-border rivers. In particular, the obligations for the regular exchange of data and information, and the need to prevent, reduce, and control pollution will require States to develop cooperative monitoring programs on cross-border rivers. An excellent starting point of study for proposing cross-border river monitoring cooperation in South Asia is the United Nations Economic Commission for Europe (UN/ECE) Convention on the Protection and Use of Transboundary Watercourses and International Lakes (created in Helsinki in 1992, and known as the UN/ECE Water Convention).

1.1.2 Lessons for South Asia from the United Nations Economic Commission for Europe Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Helsinki, 1992)

The UN/ECE Water Convention covers "the monitoring and assessment of transboundary waters, the assessment of the effectiveness of measures taken to prevent, control and reduce transboundary impact, the exchange of information between riparian countries and public information on the results of water and effluent sampling." The UN/ECE Water Convention requires that "riparian parties shall also harmonize rules for setting up and operating monitoring programs, including measurement systems and devices, analytical techniques, data processing and evaluation procedures."

Under the UN/ECE Water Convention, an International Water Assessment Center (IWAC) has been created as a Collaborating Center for monitoring and assessment activities. The IWAC is a virtual platform of leading European institutes in the field of water management. The Netherlands' Institute for Inland Water Management and Waste Water Treatment (RIZA) is host to the IWAC. For the UN/ECE Water Convention, the IWAC operates a Working Group on

---

compliance upon payment by the requesting State of the reasonable costs of collecting and, where appropriate, processing such data or information.

3. Watercourse States shall employ their best efforts to collect and, where appropriate, to process data and information in a manner which facilitates its utilization by the other watercourse States to which it is communicated."

Monitoring and Assessment. This Working Group has prepared Guidelines on Water-Quality Monitoring and Assessment of Transboundary Rivers (IWAC 2000). For determining Monitoring Objectives, these guidelines state the following:

> "Monitoring objectives emerge from the core elements of river-basin management and from the issues that are in the public interest. The main monitoring objectives for both effluents and rivers are:
>
> a. The assessment of the actual status of a river basin by regular testing for compliance with standards. Standards should be defined for various human uses and targets should be established for the ecological functioning of the river basin concerned;
>
> b. Testing for compliance with discharge permits, or for setting levies;
>
> c. Verification of the effectiveness of pollution control strategies, by indicating the degree of implementation of measures, by detecting long-term trends in concentrations and loads, and by demonstrating how well the intended targets were reached;
>
> d. Provision of early warning to protect the intended water uses in the event of accidental pollution;
>
> e. Recognition and understanding of water-quality issues through in-depth investigations by surveys, for example, related to the presence of toxic substances.
>
> The specification of a monitoring objective should principally make clear why the information is needed (e.g. for what decision-making process). It should also show the intended use of the information (purpose) and the management concern (e.g. protection of a specific use)."

In the formative stages of the CMC's South Asia Cooperative Environmental Monitoring project, there were numerous constraints on the number of watercourses selected, the parameters to be monitored, and the sampling locations. These constraints were financial, time and site accessibility, and the need to select parameters and locations that are nonsensitive. The monitoring objective was restricted to beginning the development of a database of long-term trends in basic water quality parameters. The focus was on initiating water quality data collection and sharing among several organizations in South Asian countries. As the project increases in scope and complexity, more comprehensive plans are being developed for monitoring cross-border rivers.

1.2 Existing Agreements Related to South Asian Cross-Border Rivers and Water Quality Monitoring

Two major agreements on cross-border rivers in South Asia are the Indus Waters Treaty between India and Pakistan and the India-Bangladesh Ganga Waters Accord. These treaties are specifically oriented to the quantitative sharing of river waters and do not deal directly with water quality issues, nor do they require the regular collection and sharing of water quality data.

The South Asian Seas Action Plan is a regional agreement that deals with coastal pollution issues and to this extent the plan does commit the marine states of South Asia (Bangladesh, India, Maldives, Pakistan, and Sri Lanka) to the sharing of water quality data from estuarine and delta regions.[6]

There are global programs of the UN through which water quality data are being shared in South Asia. The United Nations Environment Program (UNEP) operates a program called Global Environment Monitoring System (GEMS)/Water. The GEMS/Water program is a multifaceted water science program oriented toward understanding freshwater quality issues throughout the world. Major activities include monitoring, assessment, and capacity building. The implementation of the GEMS/Water program involves several UN agencies as well as organizations around the world. The World Wide Web site of the UNEP GEMS/Water Program is operated by the UNEP/GEMS Collaborating Center for Freshwater Quality Monitoring and Assessment at the National Water Research Institute of Environment Canada. Figure 3 presents a map depicting all the countries participating (shown as grey areas) in the GEMS/Water program. Bangladesh, India, Nepal, Pakistan, and Sri Lanka are all participants in the GEMS/Water program. A complete listing of all GEMS/Water stations is available at the UN GEMS/Water web site (UNEP 2000).

Figure 3. Countries participating in the GEMS/Water program (UNEP 2000).

6 A more detailed description of the South Asian Seas Action Plan is provided in a paper by Rajen (1999).

The CMC project is collecting data that complement the GEMS/Water program. The data are not official because NGOs are performing the data collection (except in the case of Sri Lanka). The aim of the CMC project is to create a network that is focused primarily on issues of common interest to South Asian countries, such as those related to cross-border rivers, and to share data in as near real-time as possible. In the GEMS/Water program, for instance, India and Pakistan do not have complementary stations on the Indus and its tributaries. All of India's GEMS/Water stations are on rivers that do not cross India's borders. Pakistan does have GEMS/Water stations on the Indus River and its tributaries. GEMS/Water data are published after a period of several years of analyses and careful reviews—the most current data available on the GEMS/Water web site is from 1996. The GEMS/Water data will serve as a quality assurance check on the CMC project data, as a small subset of sites is common to both efforts.

The International Hydrological Program (IHP) is another program of the UN that is involved in collecting water quality data in South Asia. The IHP is a part of the United Nations Educational, Scientific and Cultural Organization (UNESCO). The IHP's prime role is to act as a catalyst to promote cooperation among United Nations' member States. The general objective of the IHP is the improvement of the scientific and technological basis for the development of methods and the human resource base for the rational management of water resources, including the protection of the environment. Currently, emphasis is on the role of water resources management for sustainable development and the adaptation of the hydrological sciences to cope with the expected changing climate and environmental conditions. The IHP is developing "Water for Peace" demonstration case studies. As water has the potential to become a source of conflict, the IHP is also developing formalized negotiation support methodologies for water-related emergency management and conflict resolution strategies.

At the national level, the IHP is coordinated and executed by National Committees. The UNESCO Regional Offices are responsible for regional implementation. At the global level, the Intergovernmental Council for the IHP plans, coordinates, and monitors all the activities of the IHP that the Secretariat undertakes. The National Committees include public agencies in hydrology and water resources, private individuals, relevant university faculties and departments, research institutes, consulting agencies, and professional and learned societies. As the CMC project develops, we will progressively involve the IHP's National Committees working directly with the National Committees and through our regional partners.

The IHP has created a program called Flow Regimes from International Experimental and Network Data (FRIEND) that has been successful in many regions of the world in fostering the sharing of hydrological data among countries. A FRIEND program in Europe has been particularly effective in allowing hydrological studies on a continental scale. These studies have resulted in improved hydrological designs on issues related to water usage, the discharge of effluents, and aquatic habitats. The Hindu Kush Himalayan FRIEND (HKH-FRIEND) is the South Asian program for sharing hydrological research within the framework of the FRIEND project of the IHP.

The HKH-FRIEND was formally established in 1996 through the initiative of countries of the HKH region, UNESCO/IHP and the International Center for Integrated Mountain Development (ICIMOD), with support from the World Meteorological Organization (WMO), and some

European national IHP committees and research institutes (Chalise and Khanal 1996). Under the HKH-FRIEND, six different research groups cover floods, low-flow regimes, rainfall-runoff modeling, river water quality, snow and glaciers, and data management. One of the main activities of HKH-FRIEND is the establishment of the Regional Hydrological Data Center that is located within the ICIMOD in Kathmandu, Nepal.

The CMC project plans to work closely with the ICIMOD and the HKH-FRIEND program in future activities.

2. Project Objectives and Process

The broad and long-term interests of the project organizers and participants are on the significance of regional information sharing as a means to build confidence and reduce conflict. In an area of high tensions such as South Asia, information-sharing efforts set the stage for expanded future cooperation in resolving contentious disputes such as overlapping territorial claims. The more intermediate interests of the group are focused on activities that might eventually foster regional management of some aspects of water resources utilization. The immediate purpose of the ongoing project is to implement the collection and sharing of water quality information at river and coastal estuary/delta locations throughout the region.

The data collection activity of the project was initiated at the workshop held in Kathmandu, Nepal, September 12–15, 1999. The workshop brought together regional partners as well as U.S. government personnel from the American Embassy, the U.S. Agency for International Development (AID), and SNL. The group included six organizations that are working actively with the CMC to gather and share water quality data from locations in South Asia, as well as several regional government and nongovernmental organizations that may be involved in an informal or more active role in the future. Rajen, Biringer, and Betsill (2000) have prepared a detailed workshop report. The workshop and project concept have been strongly endorsed by the U.S. State Department, and the U.S. Ambassador to Nepal, Ralph Frank, provided the opening workshop address (Figure 4) and hosted workshop participants at a reception at his residence. Since the workshop, under a combination of contractual and voluntary arrangements, regional partners have collected water quality data using instrumentation provided by the CMC. All data are being posted to a central Internet web site for collaborative use in the region.

2.1 Project Structure and Process

The regional partners developed specific project water monitoring plans. The plans included the selections of monitoring sites. The data collected were planned to be nonsensitive and freely sharable, and from locations that are freely accessible, at least to the partners from the specific country in which the site exists.

Figure 4. Ambassador Ralph Frank inaugurating the workshop.

Table 2 presents a list of the parameters being measured. Currently the project involves manual data collection and transmittal. In the next phase, the project aims to set up systems in which data are gathered remotely and sent to an Internet web site electronically.

Identical water quality instrumentation has been provided to each project partner by the CMC. Figure 5 shows some of the workshop participants observing a demonstration of the instrument. The instrument selected for the project is a commercial meter with a digital read-out of pH, temperature, conductivity, and salinity.

Table 2. List of Parameters Measured

Parameter Measured	Relevant Water Quality Issue
pH	Acidification
Conductivity/Specific Conductivity	Salinization
Salinity	Salinization
Temperature	Habitat suitability for species

The sites at which the data are being collected were chosen principally at the discretion of our partners, with some interaction among the group regarding a site's suitability and its relevance to the overall goals of the project. The sites selected are:

- Bangladesh: Various sites on the Ganga, Brahmaputra, and Meghna Rivers
- India: Thane Creek, Mumbai; Hoogli River, Calcutta
- Nepal: Bagmati River, Kathmandu
- Pakistan: Rawal Dam, Islamabad
- Sri Lanka: Kelani River, Colombo

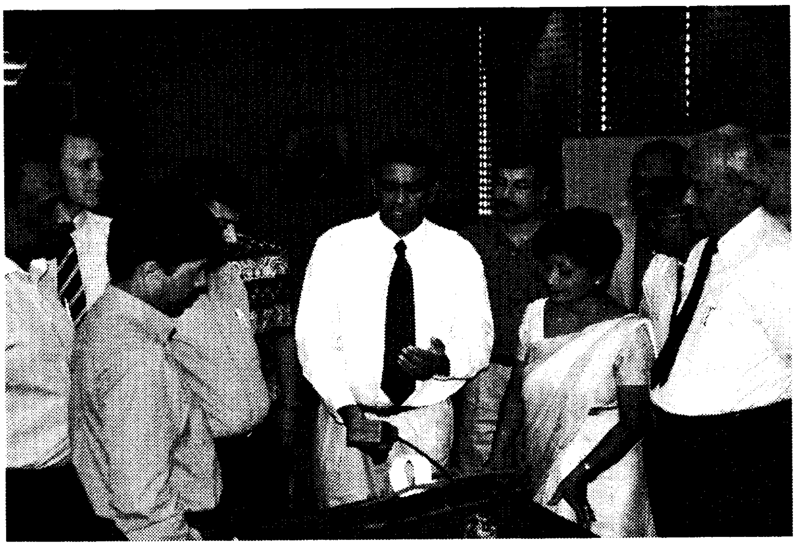


Figure 5. Workshop participants observing an instrument demonstration.

An Internet web site developed for the project was demonstrated at the workshop. This site is serving as a home to data gathered and a link to regional web sites on the environment. The web site is further described in Section 3.4. Data format and transmission issues were addressed. The workshop concluded with a ceremonial collection of the first project data in the Bagmati River in Kathmandu (Figure 6). Table 3 lists the water quality values measured in this first data collection effort of the project.

Table 3. Water Quality Values Measured at the Bagmati River by Workshop Participants

Parameter Measured	Value
pH	7.25
Conductivity	207.8 microSiemens
Specific Conductivity	201.3 microSiemens
Salinity	0.1 parts per thousand
Temperature	26.7°C

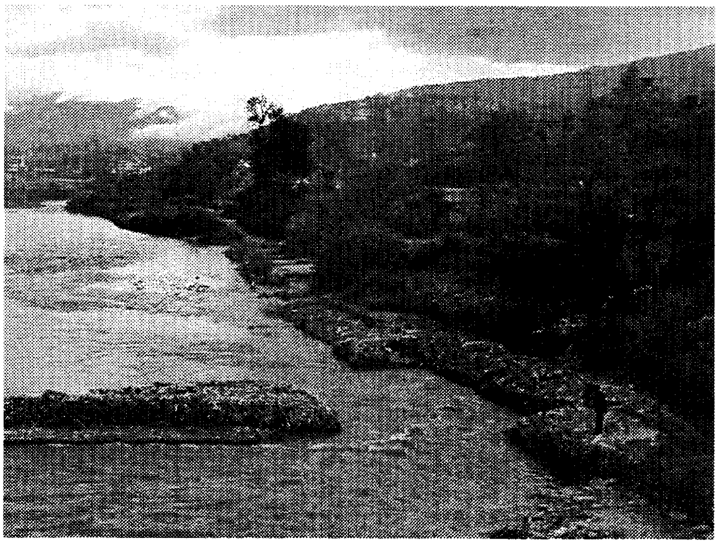


Figure 6. Collection of data at the Bagmati River.

3. Project Results

This section summarizes the major results of the project to date. These results involve creating a fledgling network of partner organizations that will promote environmental cooperation in South Asia, and identifying sites within the region at which a data and information collection and sharing process has been instituted. Since the Kathmandu workshop, the regional partners have collected and shared water quality data from select locations. This section describes the data that have been collected and other project activities.

Descriptions of the organizations involved are primarily from informational materials provided by the participants at the workshop. Similarly, the project partners have provided the information on the sampling sites. Complete sets of the data received are provided in http://www.cmc.sandia.gov/sasia/southasia.html. Section 3.3 provides some details of the data received from the project partners.

3.1 Understanding the Organizations Involved and Regional Support

Three types of organizations are involved in the project. Active partners (listed in Table 1) are organizations that have collected and shared water quality data in collaboration with the CMC. The second type represents regional or country-specific organizations that are committed to progressively becoming more involved in the project. This second set is already involved in the gathering and sharing of environmental information, including water quality data. This set includes the South Asia Cooperative Environment Program (SACEP), the ICIMOD, and the U.S. Department of State's Regional Environmental Affairs Office. The third set includes organizations that were present at the Kathmandu workshop purely to observe and offer advice and assistance in future coordination efforts with other ongoing regional activities. These include the World Conservation Union (IUCN), the South Asian Association for Regional Cooperation (SAARC), the World Bank, the Nepal Department of Hydrology and Meteorology, and AID.[7]

3.1.1 Active Partners

3.1.1.1 Bangladesh Unnayan Parishad

The Bangladesh Unnayan Parishad (BUP) is a center for research and action on environment and development. Established in 1980, it is a nonprofit, private organization. It is one of the leading think tanks of Bangladesh. The BUP promotes basic and applied research on social, economic, cultural, political, and environmental issues relating to the imperatives of development.

---

7 Given their informal level of participation and the considerable volume of publicly available information that exists for most of these organizations, these organizations are not described here in any detail.

BUP's research, studies, and other related activities are organized within the framework of the following three basic thrusts:

- Economic and Social Policy Research
- Environment and Development Studies
- Social Weather Analysis

The above three broad themes subsume relevant core areas including:

- Agriculture
- Industry
- Infrastructure Development
- Rural Development
- Poverty Alleviation
- Social Sectors
- Environment
- Natural Resources including Water Resources
- Sustainable Development
- Public Opinion Research

Over the years BUP has acquired and developed the required expertise for carrying out research and studies on projects relating to the listed subjects. Besides professional staff in its employ drawn from different appropriate disciplines, BUP maintains a roster of resource personnel/experts as well as field staff who can be pressed into service for project-specific work. The core full-time professional staff strength at different levels – senior scholars, research directors, senior specialists/fellows, fellows, senior associates, and associates – currently stands at 22, besides other administrative and support staff.

Through its Planning Forum, the BUP organizes policy debates, seminars, workshops, symposia, and discussion meetings on pertinent socioeconomic, technological, environmental, and other issues relating to development. Conferences/seminars/workshops are a continuous process with BUP. The main purpose is to disseminate research findings and bring together people of diverse backgrounds to debate policy options and development alternatives.

The BUP has published over a hundred research reports, monographs, compilations of papers/articles, and books on national and regional development issues. The BUP publishes three journals. A quarterly journal in Bengali named ***Unnayan Bitarka*** (Development Dialogue) carries research and analytical papers. The monthly ***Prodyot*** (Glow), also in Bengali, carries short articles on a wide array of subjects including economic policies and problems, environmental policies and issues, social issues, culture, education, market prices, etc. The third is a biannual journal in English titled ***Asia Pacific Journal on Environment and Development***. Its main focus is on an integrated approach to economic and environmental issues.

3.1.1.2 South Asia Research Society

The SARS, located in Calcutta, India, is a nonprofit research organization created by retired high-level government officials, industry, and academic personnel. The main focus of the SARS is on regional economic development through technological innovation. The SARS is actively involved in a number of governmental and nongovernmental initiatives to promote the efficient use of water resources between Bangladesh, India and Nepal; as well as other projects ranging from education and social science research to the eradication of rural poverty.

An example of a SARS project is Project Nirdhan (a project directed towards alleviating the problems of rural poverty) launched in June 1993. The Asia Pacific Development Center (a UN affiliate) and the Grameen Trust (an associate of the Grameen Bank of Bangladesh) supplied recoverable grants to SARS for this purpose. Project Nirdhan aims not only at removing poverty through developing the business skills of the rural poor, but also at fostering the holistic development of a community. Project Nirdhan treats the empowerment of women as one of the principal tasks of integrated rural development. In pursuit of such empowerment, Project Nirdhan replicates the Grameen Bank Financial System of Bangladesh, an extraordinary innovation of Professor Muhammad Yunus involving micro-credit and loans to the very poor.

Prof. Jayanta Kumar Ray is the Executive Director of SARS. He is a Centenary Professor of International Relations at the University of Calcutta's Department of History, Peace Studies Group (PSG), and a recognized international expert on issues of regional cooperation and the Ganga River Basin. The PSG provides intellectual support to SARS. The PSG has helped SARS organize two international workshops, leading to two publications: one on India-Bangladesh cooperation, and the other on India-Nepal cooperation.

3.1.1.3 Thane-Belapur Industries Association

The Thane-Belapur Industries Association (TBIA) is an association representing over 3,000 industries located along the mainland across from the island city of Mumbai, India. The association has established a common effluent treatment plant, one of the first in India, with World Bank assistance. The TBIA is committed to the restoration of Thane Creek (which runs adjacent to their industrial areas) through preventing untreated effluents and nonpoint source pollution from reaching the creek. More rigorous monitoring studies are an essential part of the association's future plans for reducing effluent quantity and toxicity.

3.1.1.4 Nepal Water Conservation Foundation

The Nepal Water Conservation Foundation (NWCF) located in Kathmandu, Nepal, is a non-profit, nongovernmental research organization dedicated to the interdisciplinary study of water and related issues. The main objectives of the NWCF are to ensure growth and dissemination of scientific knowledge for correct decision making and to promote sustainable development, management, and protection of water. The NWCF pursues these objectives through its efforts in

- interdisciplinary research and dissemination,

- capacity building and training, and
- water documents repository.

The NWCF provides help to journalists and activists in scientifically researching issues. The organization is known worldwide for its analysis of water resources-related issues in the Himalayas. The NWCF also supports community groups' small-scale water development activities. For example, rainwater-harvesting techniques are among the options promoted by the NWCF.

The NWCF publishes a biannual scientific journal called *Water Nepal*, a water development journal. This journal focuses on the study of climate effects, such as cloudbursts, and social vulnerability. Other topics relate to ground water, micro-hydro, irrigation, and water conflicts. The NWCF also organizes "Pani Satsang," a forum for discussions on issues related on water and its management, and publishes a bulletin of the same name.

Among its many activities, the NWCF is currently involved in a collaborative transboundary study (with Indian NGOs) on the Rohini River that flows from Nepal into India. Activities with a regional focus include establishing the Duryog Nivaran Network, a South Asian network on disaster management. The NWCF also manages a fellowship program for South Asian scholars called the Fellowship on South Asian Alternatives.

3.1.1.5 Pakistan Energy and Environment Management Center

The Pakistan Energy and Environment Management Center (PEEMAC) is an NGO dedicated to the cause of promoting the efficient use of energy resources and protecting the environment. PEEMAC publishes a quarterly newsletter called EnvironNews. PEEMAC works closely and is affiliated with the Pakistan Ministry of Environment. An example of a PEEMAC project is a study of the building design of primary schools and health centers with a view to improving ventilation, insulation, lighting, and overall physical comfort. Fuel cells, solar and wind energy, and reducing vehicular air pollution are some other areas of interest to PEEMAC. PEEMAC is developing strategies of pollution control from untreated wastewater, and has identified Rawal Lake (near Islamabad and Rawalpindi) as a target area for further study.

3.1.1.6 National Water Supplies and Drainage Board

The National Water Supplies and Drainage Board (NWS&DB) of Sri Lanka is responsible for the supply of water to Colombo and surrounding areas, serving a population of approximately 1.4 million. The NWS&DB currently operates a remote data acquisition system that collects data from numerous locations on the NWS&DB's water distribution infrastructure. The Kelani River is also monitored at an intake point of the NWS&DB water supply system. The NWS&DB has agreed in principle at this time (pending further review and approvals as needed from various government agencies) to share near-real-time data on the depth of the Kelani River at their water intake point. Data already shared demonstrate clearly the effects of tidal fluctuations at this location. The NWS&DB will also monitor water quality at this same location, and share the data with the project partners. Salinity levels and water depth fluctuation could be very valuable data for validating tidal flow and transport models for the Kelani River estuary.

3.1.2 Regional Organizations Committed to More Involvement in the Future

3.1.2.1 South Asia Cooperative Environment Program

The South Asia Cooperative Environment Program (SACEP), based in Colombo, Sri Lanka, is an association of eight South Asian countries: Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka. SACEP came into existence in February 1981 at a meeting of the Environment Ministers of the member countries with the adoption of the Colombo Declaration and the Articles of Association of SACEP. SACEP became a legal entity in January 1982 after at least three member countries ratified the Articles of Association. Among its many activities, SACEP serves as the secretariat for implementing the South Asian Seas Action Plan[8] that has been developed through a collaborative regional process to implement aspects of the United Nations Convention on the Law of the Sea. The SACEP is responsible for implementing the plan. The plan includes strategies for promoting regional and cooperative environmental monitoring and, therefore, represents an excellent opportunity for promoting cooperation in coastal issues.

3.1.2.2 International Center for Integrated Mountain Development

The ICIMOD is active in Afghanistan, Bangladesh, Bhutan, China, India, Myanmar, Nepal, and Pakistan. "The ICIMOD is the first international organization to make a commitment to promoting the development of an economically and environmentally sound mountain ecosystem and improving the quality of life of mountain people. The Center was founded amidst widespread recognition of the alarming environmental degradation of mountain habitats and the consequent increasing impoverishment of mountain communities in the Hindu Kush-Himalayan region. It works mainly at the interface between research and development and acts as a 'knowledge bank' on the Hindu Kush-Himalayas and a facilitator for generating new mountain-specific knowledge of relevance to mountain development. It also attempts to ensure that new knowledge is shared among all relevant institutions, organizations, and individuals in the region."[9]

---

[8] The formal title of the South Asian Seas Action Plan is the Action Plan for the Protection and Management of the Marine and Coastal Environment of the South Asian Seas Region.

[9] Quoted from the web site of ICIMOD: http://www.icimod.org.

3.1.2.3 U.S. Department of State's Regional Environmental Affairs Office, Kathmandu

Recognizing that a single country cannot solve regional environmental issues, the U.S. Department of State has established regional environmental hubs in designated embassies around the world. The hubs are predicated on the idea that transboundary environmental problems can best be addressed through regional cooperation. Rather than dealing with a single country on environmental issues, the hub officers look almost exclusively at transboundary issues. Hub officers engage with several countries in a region on a particular issue, with the aim of promoting regional environmental cooperation, sharing of environmental data, and adoption of environmentally sound policies that will benefit all countries in the region. The South Asia Hub office is located in Kathmandu, Nepal. "Central to U.S. policy in South Asia is the objective of improving political stability by engaging and enhancing dialogue with and between the countries of the region" (DoS 1999). Toward this end, the South Asia Regional Environmental Hub located at the U.S. Embassy in Kathmandu identifies issues and opportunities to promote and improve cooperation on global and regional environmental issues. The South Asian Hub's initial focus is toward:

- regional oil spill response capabilities,
- management of coastlines and forests,
- clean alternative energies, and
- air and water pollution.

The South Asian Hub recognizes a growing consensus that regional cooperation on the use of the great rivers of South Asia, particularly the Ganga, Brahmaputra, and Indus, will be essential to solving some of the region's environmental problems. U.S. interest in river development projects in South Asia is to ensure that they proceed in a socially, economically, and environmentally sound manner. The Hub plans to analyze the potential for establishing a regional structure to promote regional water cooperation in South Asia and determine what role, if any, the U.S. should play in it.

3.2 Identification of Sites

At the workshop, the active partners suggested a mix of rivers, coastal locations, and lakes as project sites. Since then, specific sampling locations along the chosen water bodies were selected. Maps identifying these locations are also available on the project web site.

3.2.1 Bangladesh

The BUP selected 26 distinct locations on major and minor streams in the Ganga-Brahmaputra-Meghna Delta for sampling. These locations are presented in Table 4. Data for these locations are provided in http://www.cmc.sandia.gov/sasia/southasia.html.

Table 4. Rivers and Locations Selected by the BUP

River	Location
Baleswari	Kowkhali
Baleswari/Ghashiakhali Confluence	Baramusa
Brahmaputra	Mymensingh
Buriganga	Dhaka (Sadar Ghat)
Dhaleswari	Pagla (Dhaka)
Dhaleswari/Sitalakhya Confluence	Munshiganj
Gabkhan	Hularhat
Gabkhan/Salidaha Confluence	Charkhali
Ganga (Padma)	Mawa
	Pakshi
	Rajshahi
Ganga/Jamuna Confluence	Aricha/Daulatdia
Ghashiakhali	Morrelgonj
Jamuna	Bhuapur
Karnaphuli	Chittagong (Jetty)
	Chittagong (Patenga–sea front)
Karotoa	Bogra
Kirtankhola	Barisal
Kirtankhola/Bishkhali Confluence	Jhalokathi
Meghna	Norshingdi
Meghna (Lower)	Chandpur
Pasur	Mongla
Rupsha/Bhairab Confluence	Khulna
Sitalakhya	Narayanganj
Surma	Sylhet
Turag	Tongi

3.2.2 India

The SARS selected two sampling sites along the Hoogli branch of the Ganga River near Calcutta. The specific locations are at Palta and Uluberia. The Palta station is upstream from Calcutta near Barrackpore, in the North 24 Parganas district of the Indian State of West Bengal. The Uluberia station is in the Howrah district, downstream from Calcutta. Figure 7 shows a view of the Hoogli River at the Palta station, and Figure 8 depicts a sampling team of the SARS.

One of the world's highest concentrations of chemical industries is on the Indian mainland adjacent to the island of Mumbai in an area called Thane-Belapur. The region is densely populated, with approximately 8,000,000 inhabitants in the city of Mumbai and over 14,000,000 in the Mumbai metropolitan region. The TBIA selected a location along Thane Creek on the Indian mainland at a ferry station in the town of Belapur. Their sampling was done from the banks of the creek standing at the shore. Figure 9 depicts a view from a bridge across this creek.

There is concern that pollutants discharged into Thane Creek, which divides the island of Mumbai from the Thane-Belapur region, are trapped by the tidal flows that move in and out of the creek system. Tidal flows in this area, however, are not well understood, and the pollution load is not well characterized. The Indian government is proceeding with massive plans to develop a new city called Navi Mumbai (or New Mumbai) on the Indian mainland, to ease pressures from the overcrowded city of Mumbai. Since 1991, India's Department of Ocean Development, headquartered in New Delhi, has measured marine environmental parameters under its Coastal Ocean Monitoring and Prediction System (COMAPS). The National Institute of Oceanography (NIO), with headquarters in Panjim, Goa, administered the COMAPS program through its Regional Center in Mumbai. In the vicinity of Mumbai, the COMAPS program has identified several areas of potential and known concern. In the areas of known concern, "the levels of dissolved oxygen reached 'nil' values during low tides and showed abnormal values of human pathogens" (1997-98 Annual Report of the Indian Department of Ocean Development). These levels are presumed to occur mainly because of the disposal of untreated sewage and industrial effluents.

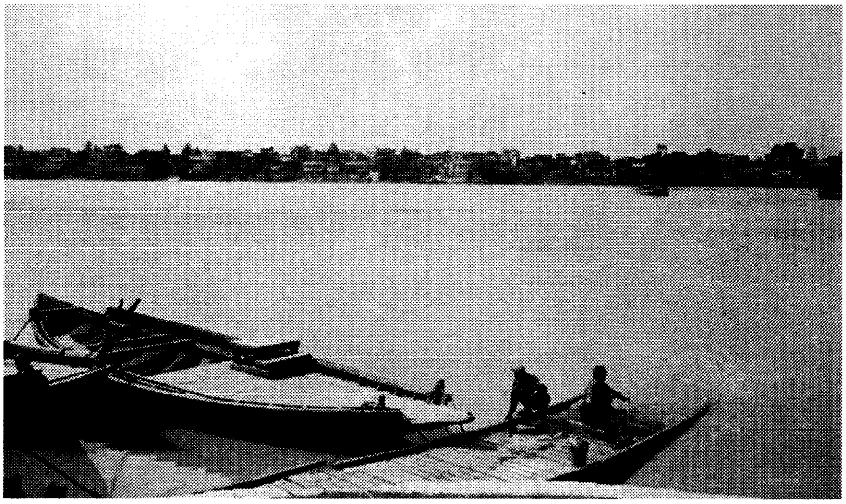


Figure 7. A view near the Palta station on the Hoogli river.

Figure 8. A sampling team of the SARS doing fieldwork at the Palta station.

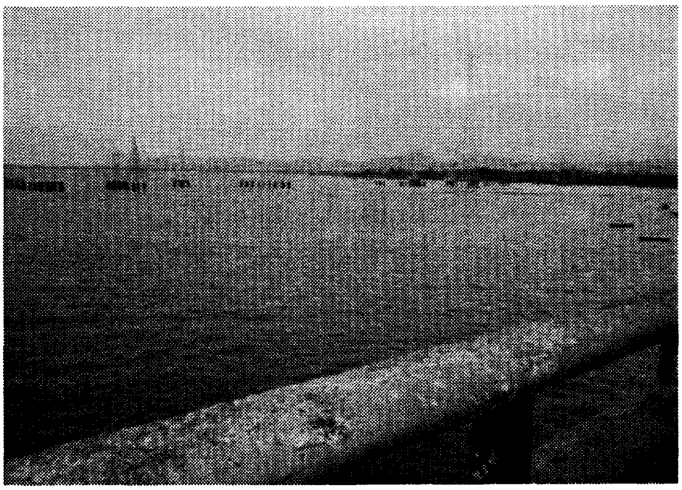


Figure 9. A view from the Chembur-Thana bridge on Thane Creek (looking northeast).

3.2.3 Nepal

The NWCF has selected a stretch of the Bagmati River within the city of Kathmandu for sampling.

The Bagmati River is the main perennial water body of Kathmandu valley, originating from Baghdwar, which is situated at an altitude of 2650 m north of the valley at Mahabharat hills. The river flows along the slope of Kathmandu valley of 662 sq km, and comes down to the plains of Nepal and enters into India to merge with the Ganga. It runs more than 30 km within the Valley. The main source of water for the Bagmati is rainfall and spring flow. The flow is at a minimum in the months of April and May and peaks in the monsoon, usually in July or August. The river serves as a major source of water resources in Kathmandu Valley. The river water is used for drinking, irrigation, domestic, religious, cultural, and hydroelectricity production purposes.

Approximately seven hundred and forty thousand people inhabited the Kathmandu Valley as per the census of 1991. It has three important cities—Kathmandu, Patan and Bhaktapur. The Valley is partly urban and partly rural. The average population growth is estimated at 3.5% per annum for urban areas of Greater Kathmandu. The urban and population growth in the Kathmandu Valley has led to problems of pollution in the Bagmati. Figure 10 illustrates some of the urban runoff that drains into the Bagmati River.

Figure 10. A view of urban runoff draining into the Bagmati River in Kathmandu.

Within the past decade, the Bagmati – considered sacred by most Nepalis – has turned into a major sewage outlet of Kathmandu City. Pollution in the river stems from rapid urbanization, the inadequacy of solid waste, wastewater, and industrial effluents disposal, agricultural runoff, and malfunctioning of the sewer system. Previous studies (to which NWCF staff provided guidance) demonstrated that water quality stays degraded for at least 7 km past the city of Kathmandu. High concentrations of fecal and total coliform bacteria and low oxygen levels were characteristic of the river water quality in most sections within Kathmandu.

To assess trends in the water quality of the Bagmati, the NWCF is coordinating its planned sampling program with the Nepal Department of Hydrology and Meteorology. Approximately six locations are being studied as candidate sites for further sampling.

3.2.4 Pakistan

The PEEMAC has selected the reservoir at Rawal Dam near the Cities of Islamabad and Rawalpindi as the site for data gathering. The PEEMAC developed an independent web site and posted the data it gathered directly on the web. The CMC web site made a link to this web site.

Rawal Dam forms a lake that is the sole drinking water reservoir for the City of Rawalpindi. Untreated urban wastewater effluents, runoff from poultry farms, and pollutants released during the recreational use of motorboats are among the sources suspected of contaminating the lake. The climatic temperature at Rawal Dam/Lake varies from an average maximum in winter of 17°C to an average minimum of 3°C. In summer, the temperature varies from 34°C to 24°C. Rawal Dam is situated at the foot of the Murree Hills, in an area that forms the northeast part of the Potwar Plateau. The lake is an important resource as a sports and commercial fishery. Fish yields in the lake have declined in recent years. Figure 11 shows PEEMAC-sponsored water quality sampling at Rawal Lake.

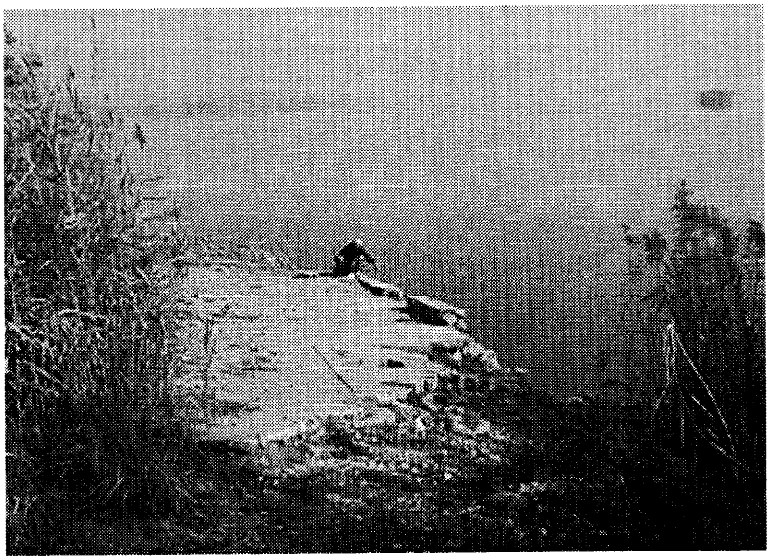


Figure 11. Water quality sampling at Rawal Lake.

3.2.5 Sri Lanka

The NWS&DB selected the Kelani River estuary for further study. This river originates in highlands in two main tributaries, Kehelgamuoya and Maskelioya that flow along valleys to join and form the Kelani. The Kelani River eventually flows out into the Indian Ocean from the West Coast of Sri Lanka near the city of Colombo. Figure 12 depicts a view of the Kelani River upstream from the coast near Colombo. From an economic perspective, the Kelani forms the most significant watershed in Sri Lanka for the following reasons:

- It flows through the economically important Western Province in which the Capital city Colombo is located.
- Major industrial establishments and rapidly industrializing areas are located along its banks (textiles, footwear, leather goods, rubber products, processed foods, metal products, electronics assembly).
- Timber is transported from the highlands along the Kelani.
- The banks are densely populated and the residents utilize the river water for all their daily requirements.

- Intake of water for the supply of water to the city of Colombo is located about 13 km from the river mouth.

- Sand mining along the river has created a problem of salt water intrusion.

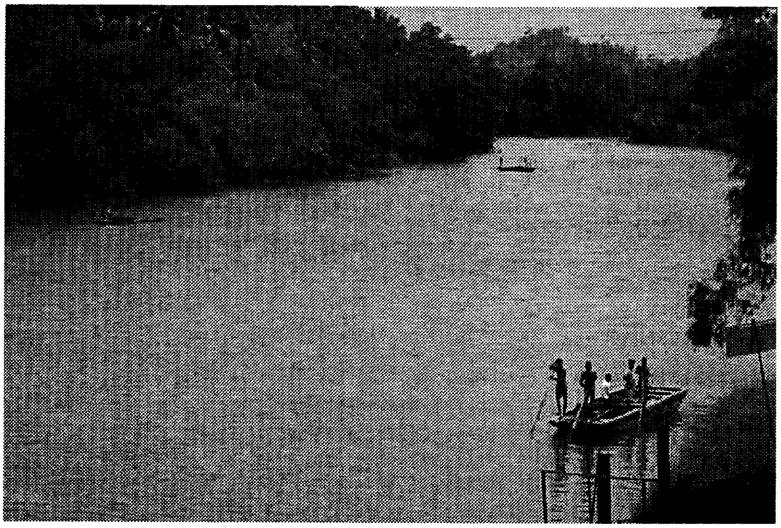


Figure 12. A view of the Kelani River upstream from the coast near Colombo.

3.3 Data Collected and Discussion

The BUP provided five sets of data at 26 locations over a five-week period, starting from October 18, 1999. The SARS provided eight sets of data from two locations starting from November 1, 1999, and ending on January 25, 2000. The TBIA provided three sets of data starting from March 29, 2000, and ending on April 25, 2000.[10] The NWCF provided 14 sets of data starting on January 2, 2000, and ending on April 25, 2000. The PEEMAC provided 22 sets of data starting from December 5, 1999, and ending on July 31, 2000. The NWS&DB provided 55 sets of data from July 1, 1999, and ending on October 15, 2000. Figure 13 depicts the sampling locations across a regional map of all the concerned watersheds. Figures 14 through 19 depict the approximate locations at which these data were collected.

[10] The TBIA's location was on the banks of a tidal creek, and could be considered a coastal location. Once the sampling had begun, it was realized that the sharing of data might fall within the "Guidelines for the Distribution and Exchange of Samples and Data" developed by the Indian National Oceanographic Data Center of the NIO. Therefore, although the TBIA is continuing to collect data, working in partnership with other conservation groups active along Thane Creek, no data are being shared pending clarification from the NIO.

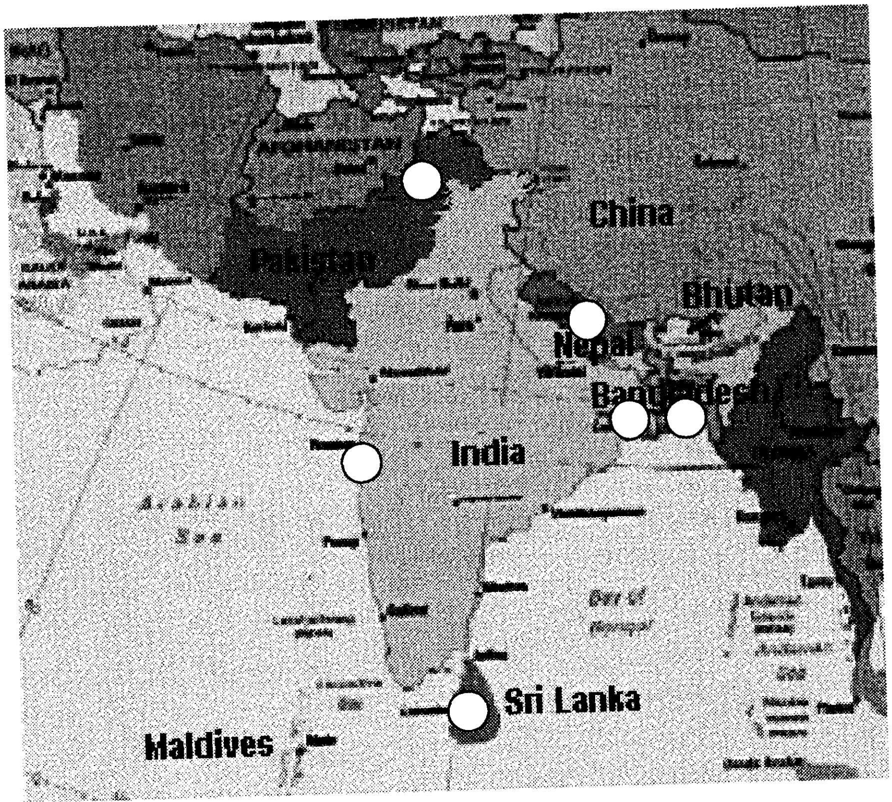


Figure 13. Regional map showing the approximate location of all sampling locations.

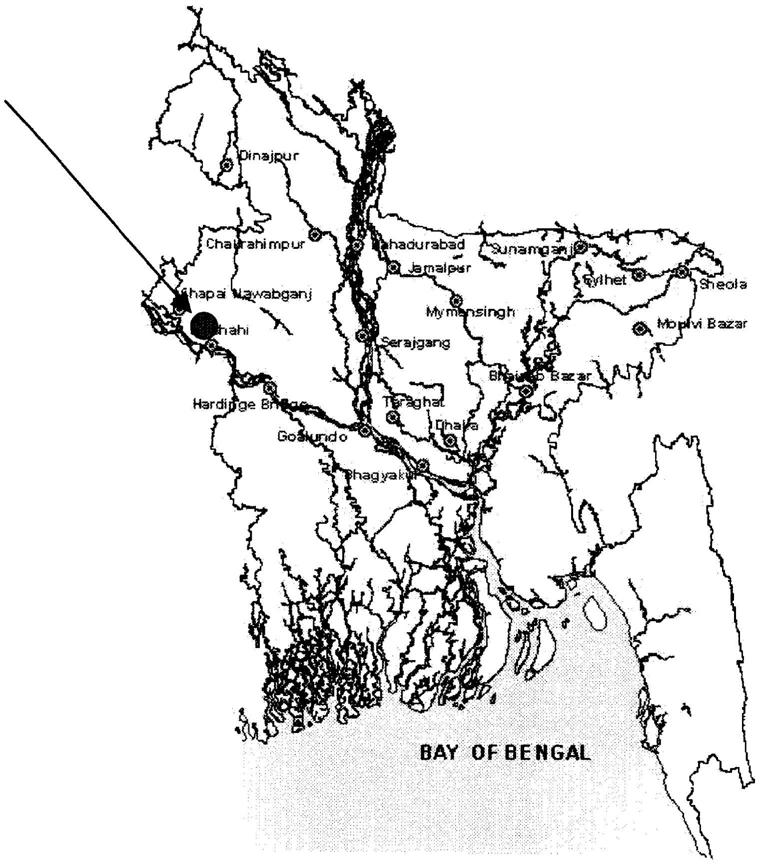


Figure 14. Map showing the rivers of Bangladesh and the location from where data are plotted in Figures 20 through 22.

Data from 25 other locations are also being collected. These locations are spread out over the delta region.

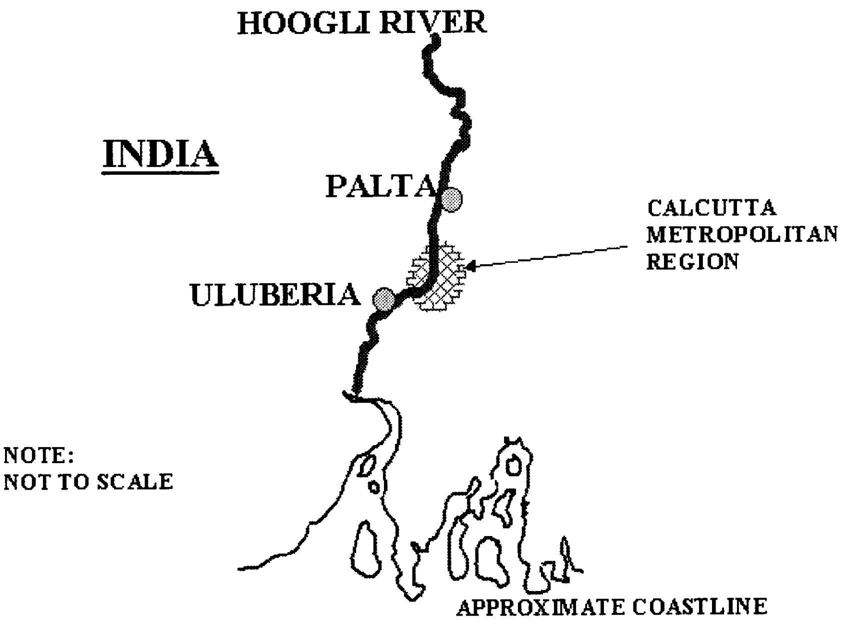


Figure 15. SARS data gathering locations.

The Palta and Uluberia stations are upstream and downstream of the Calcutta Metropolitan Region.

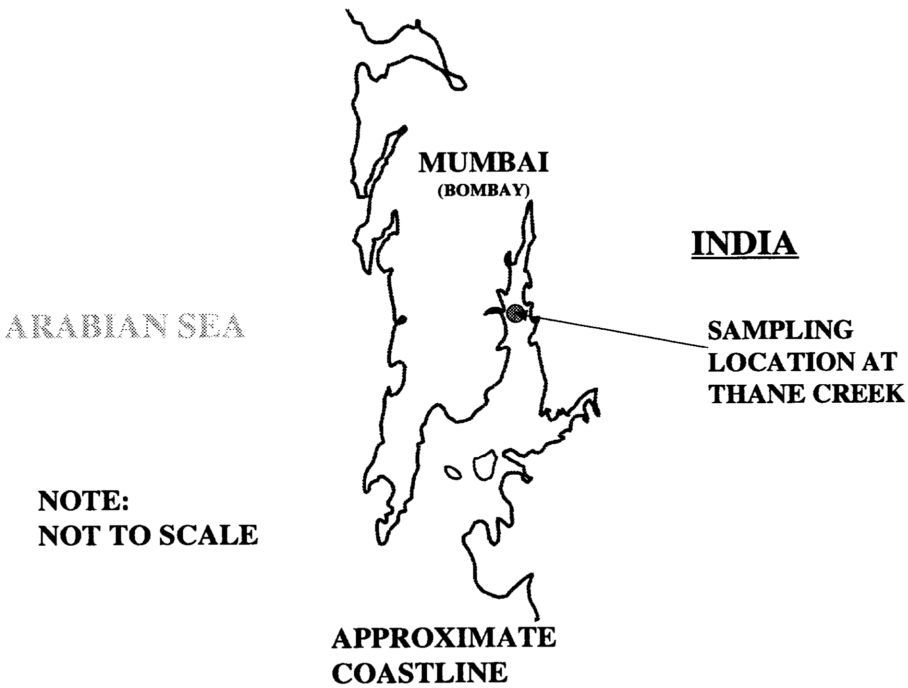


Figure 16. TBIA sampling location along Thane Creek.

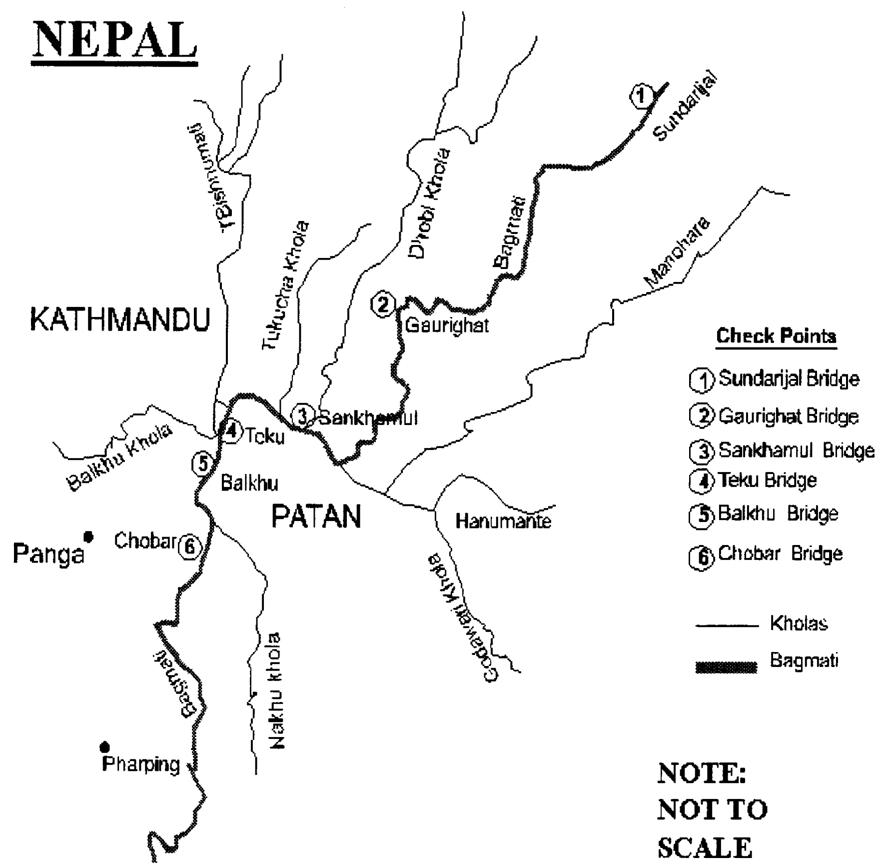


Figure 17. Map showing the locations at which the NWCF is gathering data along the Bagmati in and near Kathmandu, Nepal.

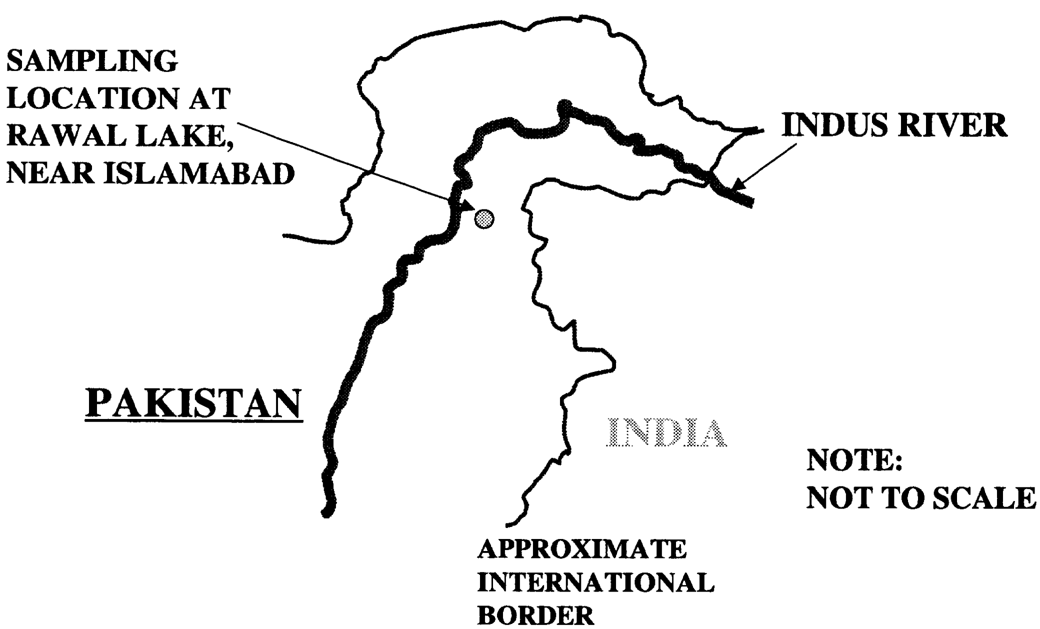


Figure 18. Map showing the locations at Rawal Lake at which the PEEMAC collected data.

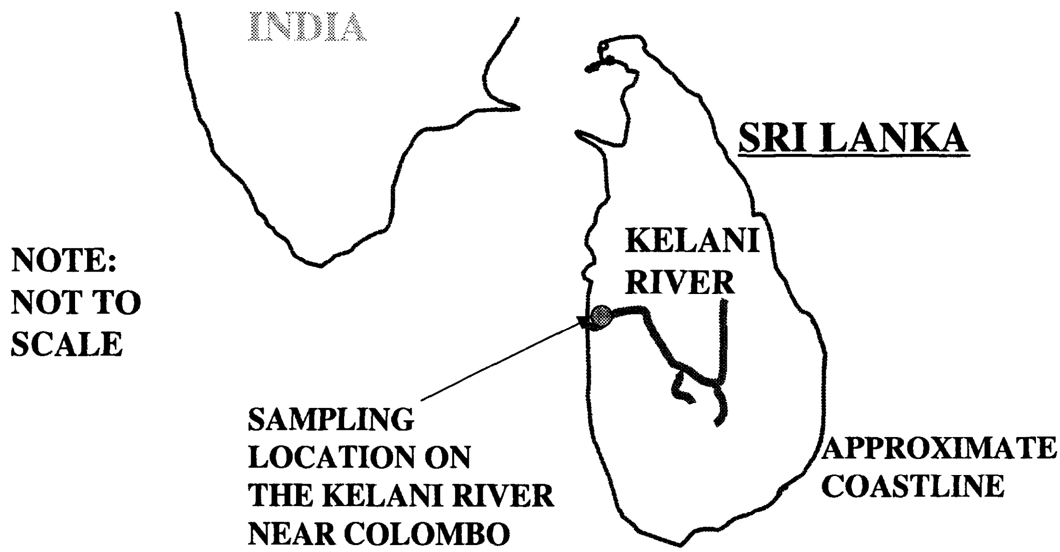


Figure 19. Map showing the sampling location on the Kelani river at which the NWS&DB collected data.

3.3.1 Project Data Along Cross-border Rivers and Watersheds

The data being collected may be used to investigate trends within a cross-border river and watershed. For example, the data gathered to date allow us to compare trends in basic water quality parameters at locations in Nepal, India, and Bangladesh within the Ganga watershed. The data have been gathered at the Bagmati River in Kathmandu, Nepal (a tributary of the Ganga), the Hoogli, a branch of the Ganga, near Calcutta, India, and numerous locations along the Ganga and its branches within the Ganga Delta in Bangladesh. Figures 20, 21, and 22 present the arithmetic mean values of pH, the temperature, and the specific conductivity averaged across seven locations on the Bagmati, two locations along the Hoogli, and one location on the Ganga near Rajshahi, Bangladesh.

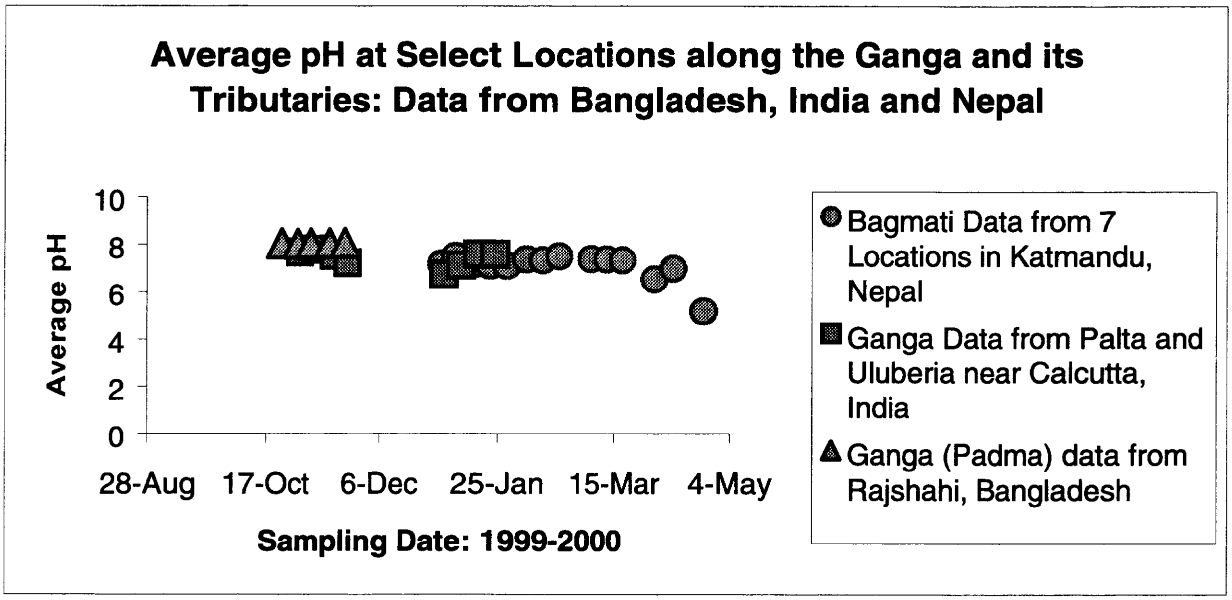


Figure 20. Average pH at select locations along the Ganga and its tributaries: data from Bangladesh, India, and Nepal.

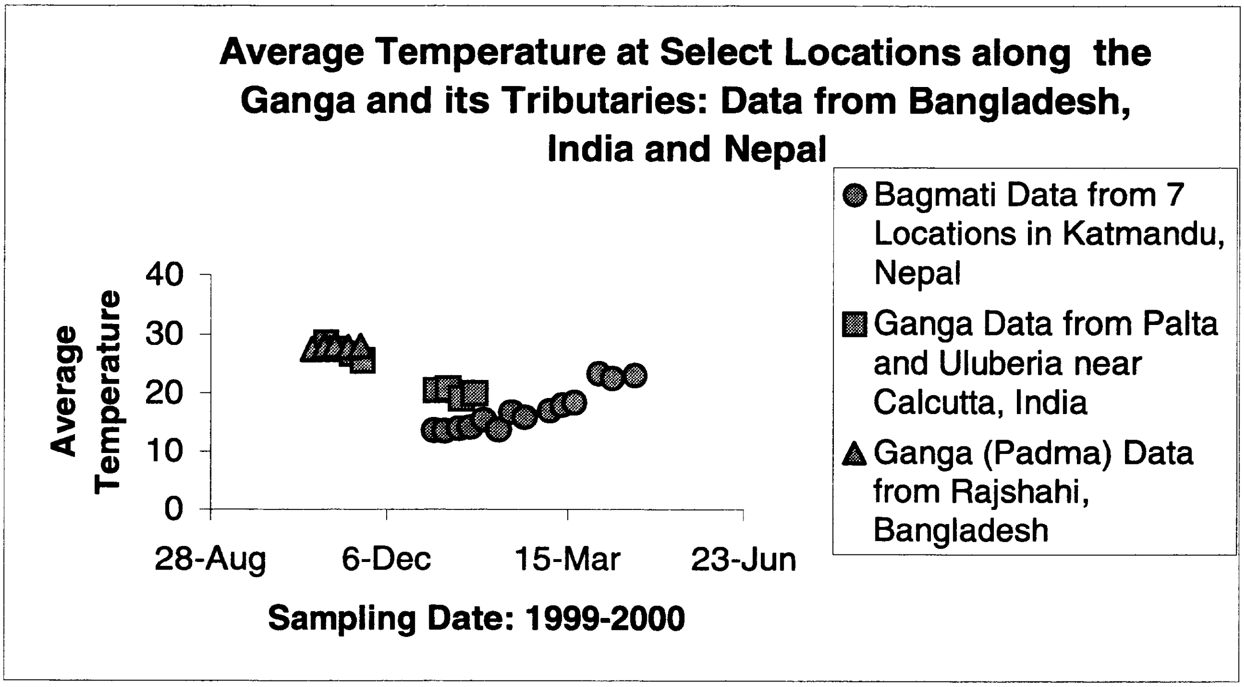


Figure 21. Average temperature at select locations along the Ganga and its tributaries: data from Bangladesh, India, and Nepal.

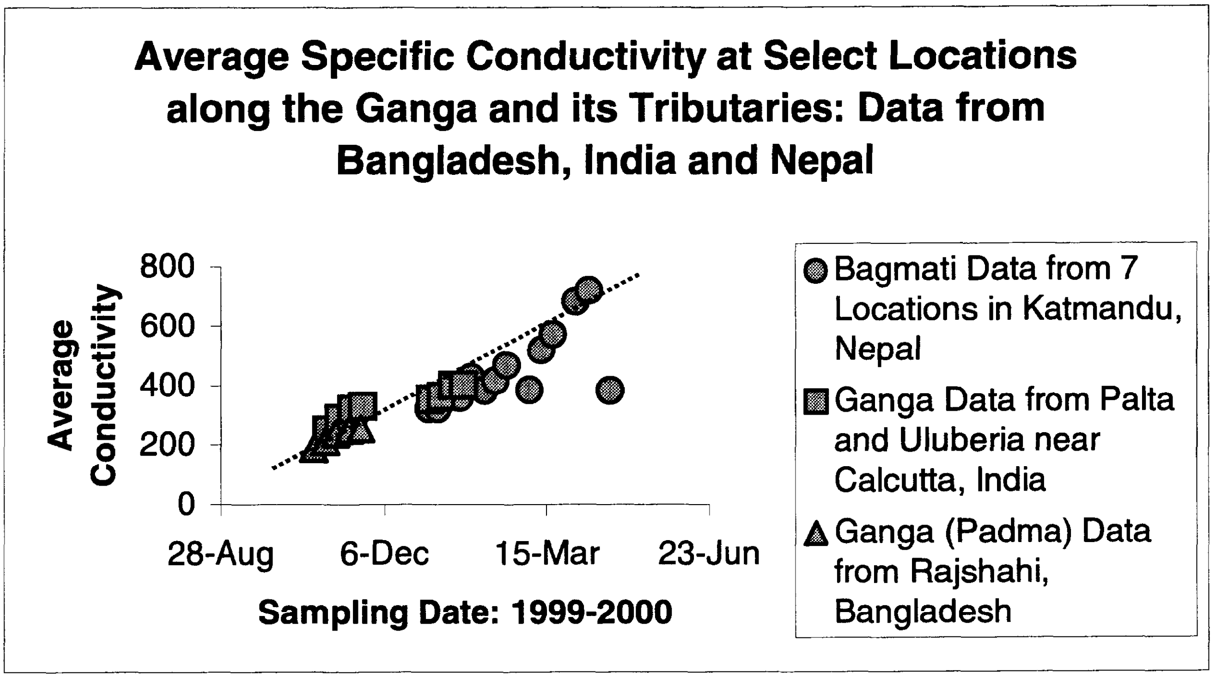


Figure 22. Average specific conductivity at select locations along the Ganga and its tributaries: data from Bangladesh, India, and Nepal.

The pH stayed relatively constant over the time period reflected in Figure 20. As should be expected, temperatures were higher in the downstream low-lying regions of the Ganga watershed compared to the upstream higher elevation regions. Temperatures fell in the downstream regions of the Ganga watershed with the onset of winter, and then began to rise with spring in the upstream higher elevation regions of Nepal. The specific conductivity continually rose across all three sampling regions, between the period of August 1999 through April 2000. This effect is probably related to the winter monsoons that increase sediment load in the Ganga watershed. The fact that the specific conductivity rose consistently across the watershed points to the value of increased cross-border water quality data sharing. For example, with increased numbers of data points, it may be possible to develop spatial and temporal correlations for changes in the specific conductivity across the entire Ganga watershed.

Figure 23 describes the changes in specific conductivity at the Rawal Lake (Naval Club station) in the Indus watershed in Pakistan. This lake is fed by streams and created by a man-made dam. At this location, the specific conductivity is decreasing (consistently across all stations) in the same time period as that in which it was increasing within the Ganga watershed. The amount of data we have at this time, and our understanding of the specific situation at each sampling site, is not sufficient to make generalizations about the reverse trends observed between Rawal Lake and within the Ganga watershed. However, it should be noted that the winter monsoons are not as strong in the western regions of South Asia as in the eastern. Also, Rawal Lake is within the Murree Hills, and the surrounding forests may ensure that increasing precipitation does not result in much increased sediment loads. Finally, although streams feed Rawal Lake and the lake discharges through a spillway, it is a reservoir and will have different characteristics from a river.

Figures 20 to 23 illustrate that collecting data from cross-border locations across entire watersheds can lead to insights that are not available from solely localized sets of data.

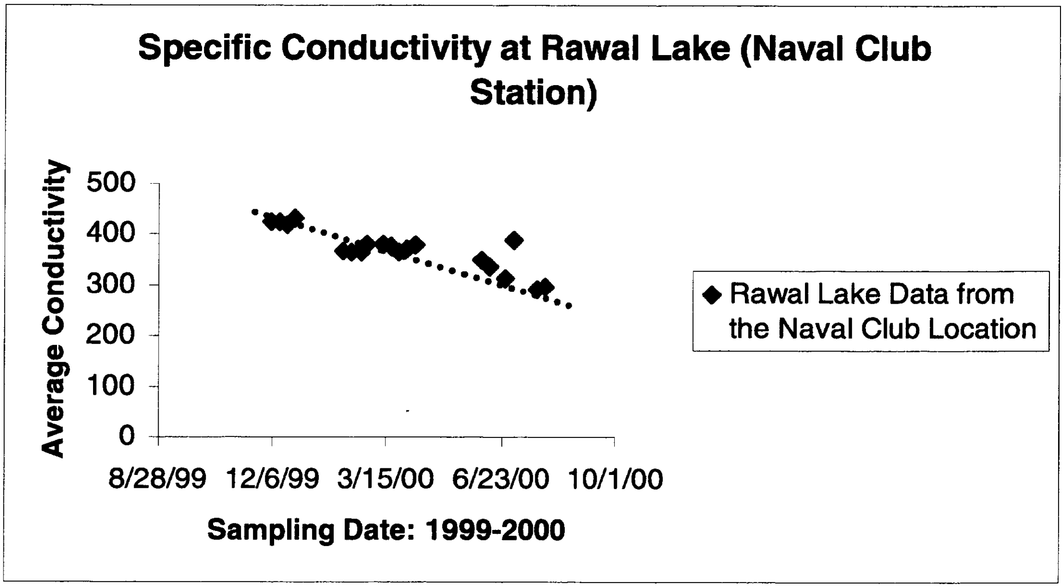


Figure 23. Specific conductivity at the Rawal Lake (Naval Station) near Islamabad, Pakistan.

3.3.2 Sampling in Tidal Creeks and Estuarine Regions

The TBIA in Mumbai, India, and the NWS&DB in Colombo, Sri Lanka, collected samples in a tidal creek and an estuary, respectively. In areas near such coastal regions, tidal fluctuations play an extremely important role in determining variations in water quality parameters. Therefore, knowing the time of data collection and the tidal frequency and amplitude is important in analyzing the data.

As seawater enters an estuary or tidal creek, the salinity increases and there is a corresponding change in conductivity. Numerous computer models have been developed that can predict tidal flows. Comparing physical data that have been collected in a tidal area with the values predicted by a computer model allows for the validation of the computer model. Physical data are often sparse in terms of the number of locations at which it is gathered, or the length of the time span covered. Through the validation of computer models, sparse physical data increase its utility. The TBIA and the NWS&DB data collection efforts hold this promise for future work.

Seawater is usually slightly alkaline, and its pH is generally slightly above 7, on average about 8. However, the pH in a coastal setting will vary considerably based on various factors, such as the mixing of effluents, runoff from land sources, rainfall and the mixing of rainwater. Figure 24 depicts a graph of the values of pH measured by the TBIA along the shore of Thane Creek.[11]

[11] As mentioned earlier, working through a consortium of partners, the TBIA has collected more extensive sets of data.

The TBIA measured values of pH are close to a neutral value of 7.0, ranging from 6.5 to 6.9, and slightly acidic. Along with the pH, the salinity at this location increased (see http://www.cmc.sandia.gov/sasia/southasia.html), implying the influx of more saline and alkaline seawaters with the tides. Trace metals become more soluble as the pH decreases, and such dissolved metals can be toxic to aquatic organisms. The survival of organisms depends on pH being greater than 5 and less than 8. A pH level between 6.5 and 8.5 would be a safe level for Thane Creek. The values measured by the TBIA are within the normal expected range of pH for seawater in a tidal creek.

At the Kelani River site, the NWS&DB has collected extensive sets of data through 1999 and 2000. As a board managing water supplies, the NWS&DB collects much of this data for its own purposes. The NWS&DB is now also sharing the data collected with regional partners. Figure 25 depicts a graph of Specific Conductivity at the Kelani River site chosen by the NWS&DB. Figure 26 depicts a graph of the variation of water depth at this same site over a 24-hour period. The time-variation in depth clearly illustrates the influence of tidal fluctuations at this site. A similar cyclical variation is discernible in the Specific Conductivity data.

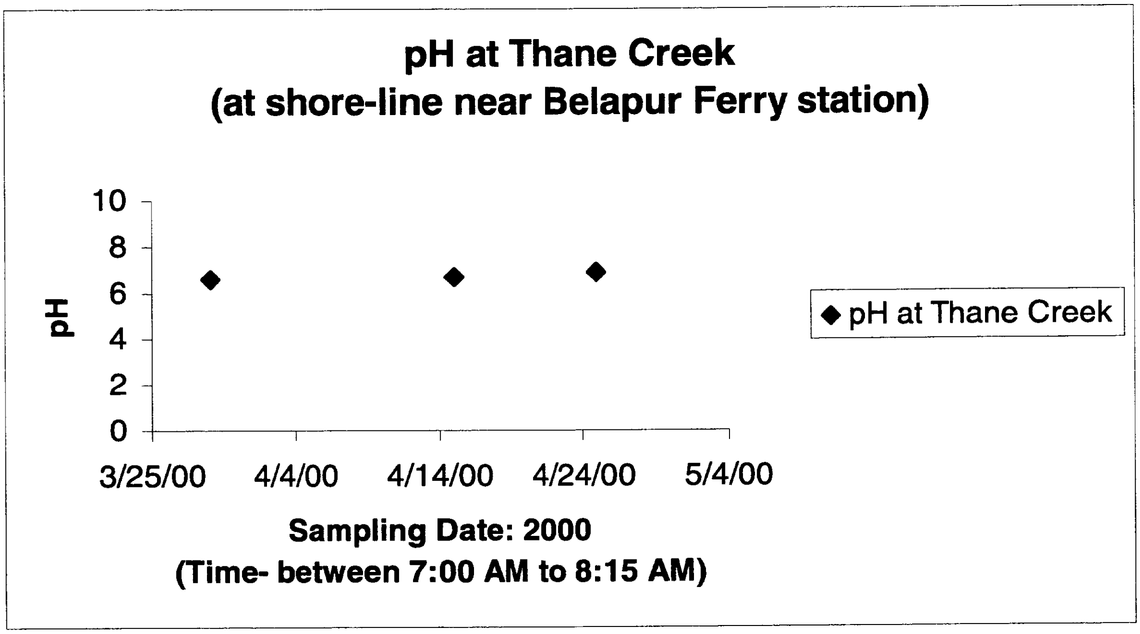


Figure 24. pH in Thane Creek as measured by the TBIA.

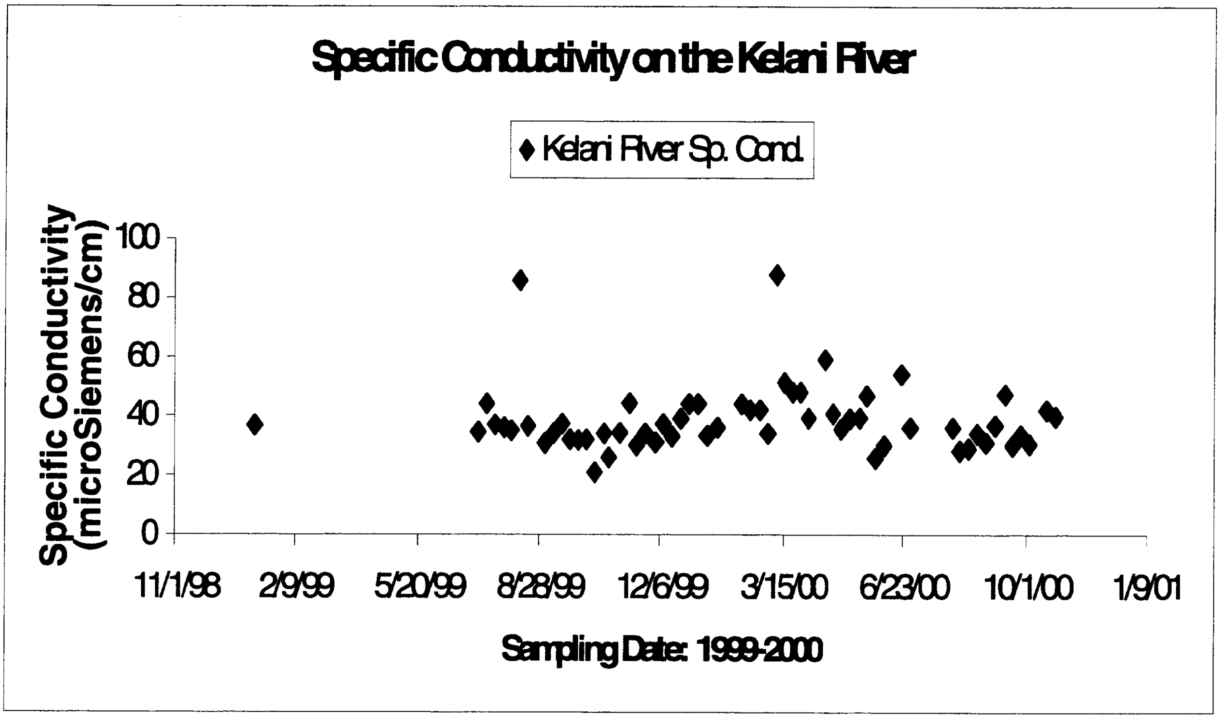
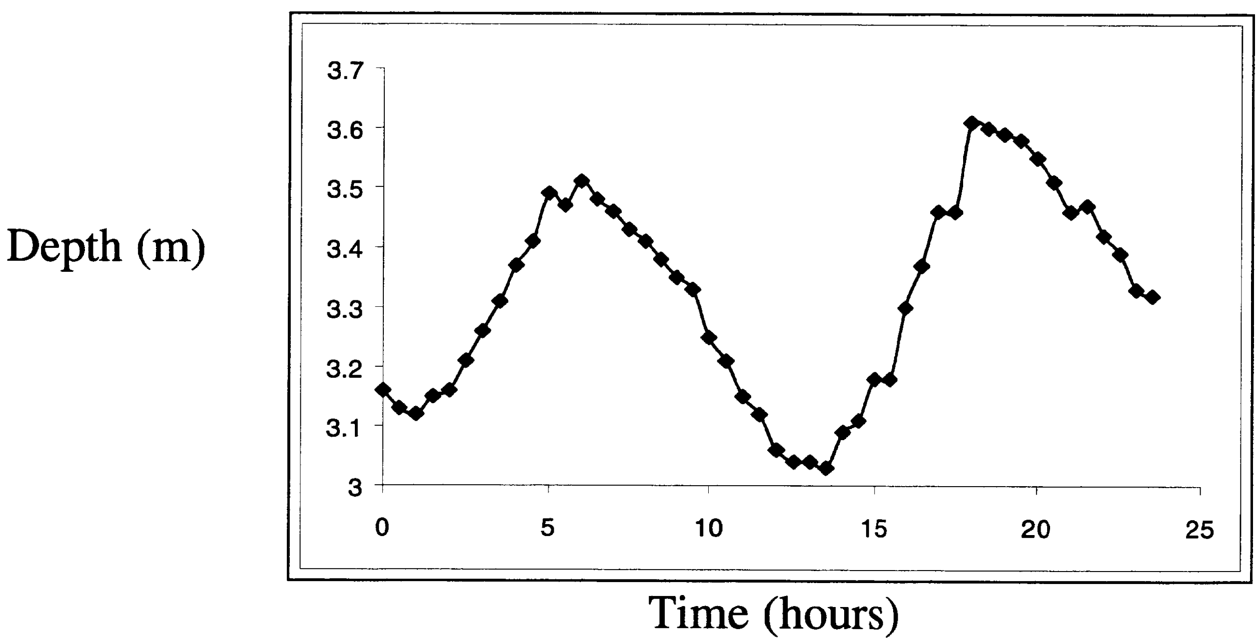


Figure 25. Specific conductivity measured by the NWS&DB at the Kelani River site through 1999 and 2000.



Measured variation of depth of Kelani River at a location upstream from the coast, March 9, 1999

Figure 26. Water depth along the Kelani at the NWS&DB's sampling location.

3.3.3 Sampling and Communication Protocols

As more specific site details become available, comprehensive sampling and quality assurance plans will be prepared. The specific monitoring that will be needed within each of the selected areas will be determined on the basis of the physical layout of the basin, the objectives of the study within that area, and on the availability of instrumentation within the basin. With the establishment of large-scale monitoring efforts, the periodic observations made will be able to detect the impact of human activities and natural processes simultaneously in different locations across national boundaries.

As the project continues, we anticipate expanding the number of partners, and have each partner follow environmental sampling guidelines and Standard Operating Procedures developed by the appropriate environmental regulatory authority in the country of data collection. Sharing this information will itself create greater transparency. The partners will maintain thorough field notes in bound and numbered record books. A field data collection form developed by the EPA has been selected as a guide. An example of this form as filled out by the SARS is provided in http://www.cmc.sandia.gov/sasia/southasia.html. Communication of the data collected will continue to be via the Internet (e-mail/ftp), and will be progressively automated.

Each party generating data has the responsibility to implement procedures that assure that the parameters measuring data quality are known and documented. These measures are:

- precision
- accuracy
- representativeness
- comparability
- completeness

Each partner is expected to assess and document the level of data quality. Sampling situations vary widely. No general rules can specify the extent of information that must be entered in a logbook. However, records should contain sufficient information so that someone can reconstruct the sampling activity without relying on the collector's memory. The logbook should preferably be stored in a location that is freely accessible to the project staff and managers.

Communication will be via Internet (e-mail/ftp). The following types of information will be sent:

- Static and quasi-static information sent infrequently. This information will describe sampling sites in detail. This information can be faxed/mailed/sent as electronic attachments.
- Periodic information on a site that is already described will be sent (at a minimum) weekly via e-mail/ftp and will consist of the following:
  - Site ID number
  - Date and time
  - Brief field notes
  - Data in the units as reported on the meter

A web-based form is under development that will allow each partner to enter data as needed from the project web site.

3.4 Web Site

The project web site is designed to provide links to data sources, present partner information, and share water quality data generated by partners. As depicted in Figure 27, the web site opens with some background text on the project, and a series of hypertext links in a side frame in the form of buttons to click. The more important buttons provide the viewer with the following options:

- More information about the project
- More information about the partners
- Links to international, regional, and country-specific data sources

The Data Sources button links to numerous sources that are relevant to or from the South Asian region. We hope to make this a data and information system that will be continually expanded and of value to South Asian researchers. We also plan to transition operation and maintenance of the site to regional entities.

Other buttons provide language support, a utility to search the site, and acknowledgments. A graphical display with a map of South Asia provides access to the data being collected through the project.

Figures 27 through 31 describe the sequence of frames that allow a viewer to access the water quality data being gathered. This sequence is described in the figures using data gathered in Nepal by the NWCF as an example. A similar sequence of frames leads the viewer to data for each South Asian country. The sequence starts by the viewer clicking on the circles representing sample collection sites in a country of choice. As shown in Figure 28, clicking on the graphical display brings up a map with active points that can be clicked again to access more information. Figure 29 shows how clicking on the Nepal project site (shown as a button on the map of South Asia) brings up a regional map with buttons representing regional data collection points. Figures 30 and 31 depict how clicking on the regional site buttons brings up even more detailed maps with buttons that can be clicked again to access local site data. Eventually, by selecting a specific local sampling site, the viewer sees photographs and can access graphical and numerical displays of data.

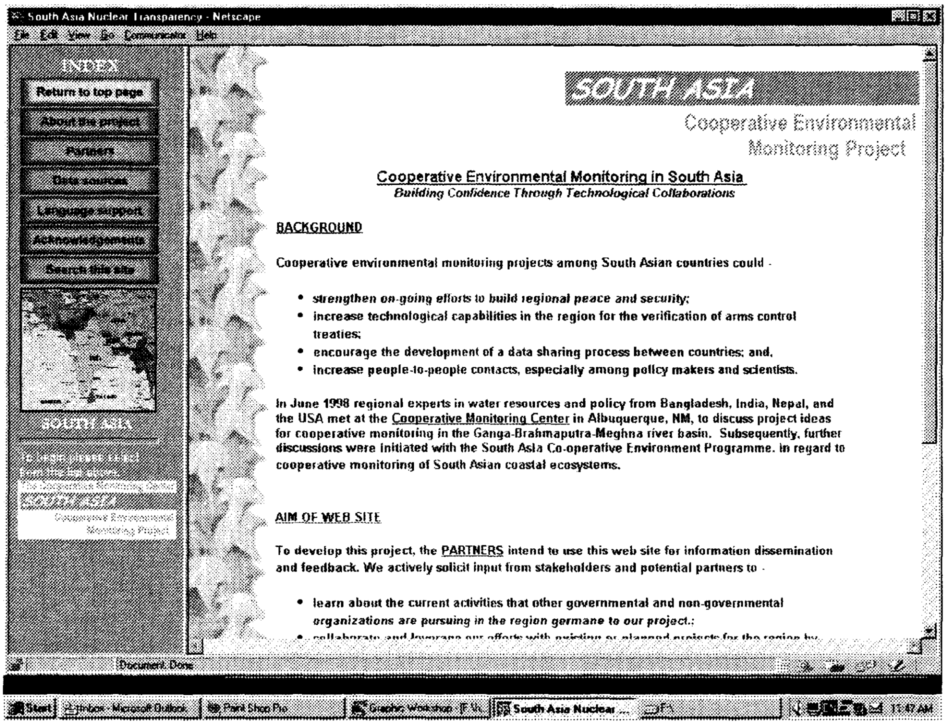


Figure 27. Web site introductory frame.

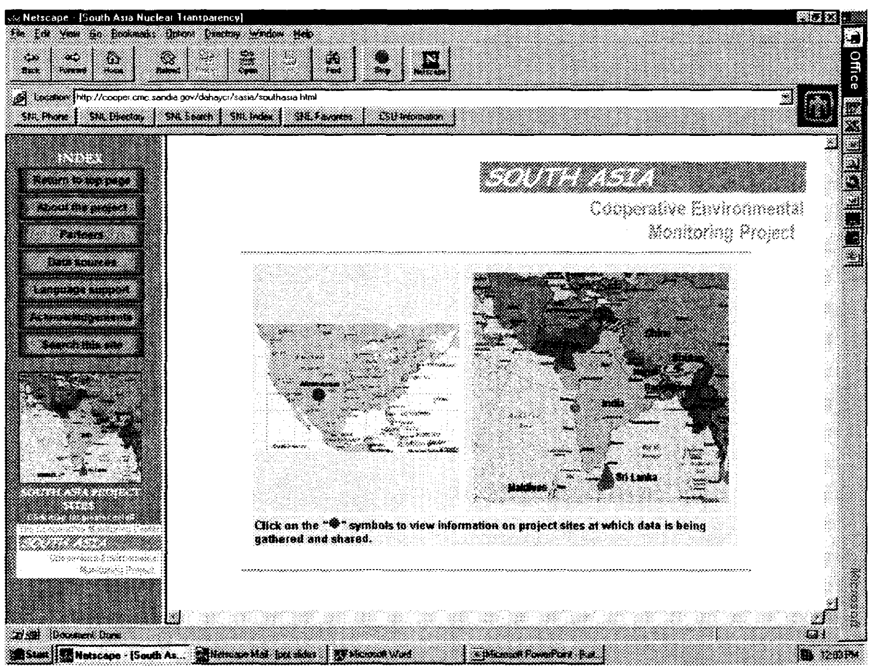


Figure 28. Graphical display with active points that can be clicked to access more information.

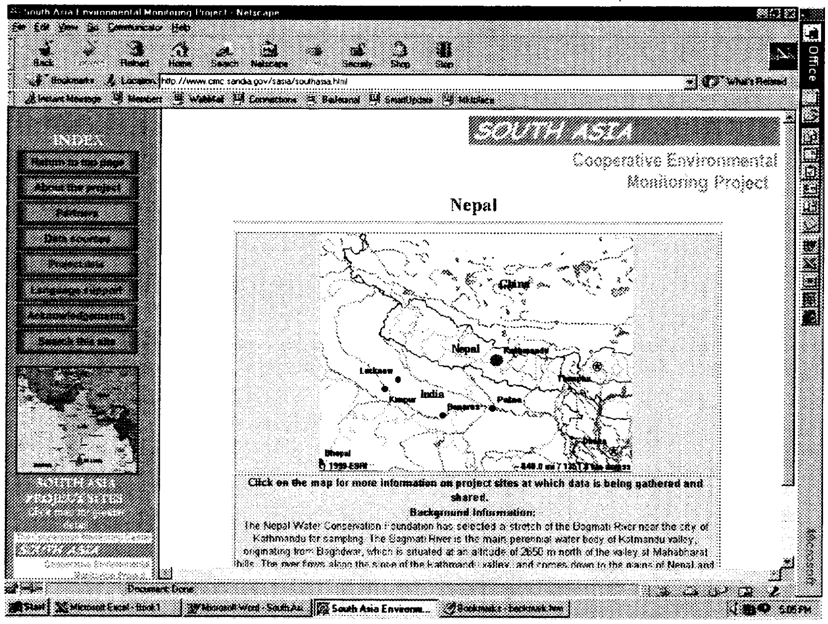


Figure 29. The Nepal site regional map with buttons representing regional data collection points.

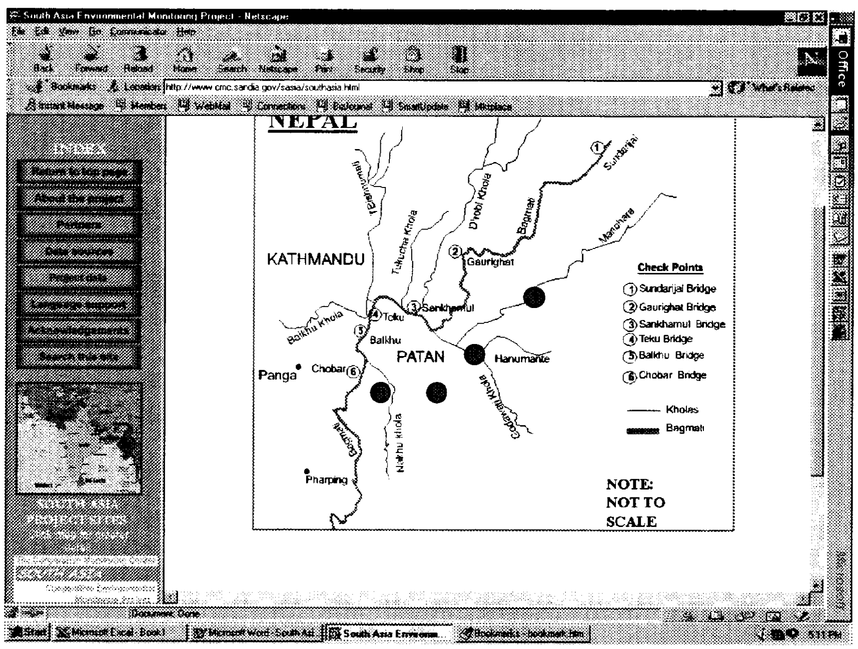


Figure 30. Detailed map of the Nepal project sampling area with buttons that can be clicked again to access local sampling station data.

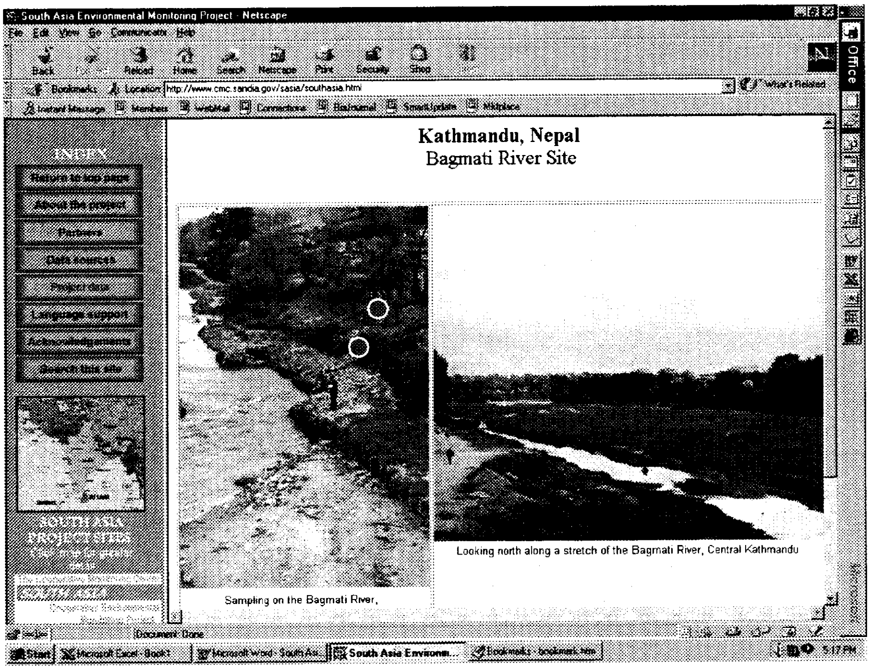


Figure 31. Photographs and links to graphs of temporal and spatial variation of data.

4. Conclusions

The database being created is unique in its regional focus, and is, therefore, likely to become an important part of future South Asian water resources studies.

Although presently limited in scope to a few parameters, the sparse data collected to date could be used to validate computer models that predict flow and transport. For example, salinity levels in a coastal estuarine region predicted by a flow model can be compared with the measured observations, and the model improved. Information at nonsampled locations can then be inferred from the model with greater validity.

The monitoring studies that have been initiated in this project are a small step towards the large-scale regional and well-coordinated monitoring programs that are needed to fully understand the complex watersheds of South Asia. The approach cited above can increase the utility of sparse and scattered data being collected. However, in the future, in each of the study areas, a larger set of hydrologic parameters will need to be monitored on a frequent basis. The specific monitoring that will be needed within each of the selected areas will be determined on the basis of the physical layout of the basin, the objectives of the study within that area, and on the availability of instrumentation within the basin. With the establishment of large-scale monitoring efforts, the periodic observations made will be able to detect the impact of human activities and natural processes simultaneously in different locations across national boundaries.

The immediate purpose of the project network is to demonstrate technology and data-sharing capabilities. Therefore, the focus of the project is on promoting a regional water-related data sharing process, and not simply on the data. After the transfer of appropriate technologies and the training of regional participants, it is expected that the network will be expanded in subsequent projects by regional entities. By demonstrating the ease and utility of cross-border sharing of data, the effort begun through this project hopes to expand into a regional government-led, comprehensive data collection and sharing process.

4.1 Future Activities

The long-term goal of this project is to promote regional cooperation in South Asia through more effective management of cross-border rivers. The project is promoting such cooperation through technical collaborations in environmental and water resources research. Therefore, future activities will focus more on the sharing of environmental monitoring information related to cross-border rivers between parties in several South Asian countries. The project will build upon the existing network through which basic water quality parameters have been measured and shared over the Internet by various governmental and nongovernmental groups in Bangladesh, India, Nepal, Pakistan, and Sri Lanka.

There are four main tasks to be completed from November 1, 2000, to September 30, 2001.

Task 1: Expand the list of current project partners in South Asia to better focus on cross-border rivers.

Task 2: Collect project-specific water quality data at sites identified in concert with regional partners, increasing the number of water quality parameters presently being monitored.

Task 3: Expand and improve the project web site.

Task 4: Hold a workshop in the U.S. and (possibly) a workshop in the region, along with site visits.

Much of South Asia consists of semi-arid regions and the regional economy is predominantly based on rain-fed agriculture. Proper use of the region's water resources is key to the long-term sustainability of the region. Parts of this region of 1.5 billion people are facing acute scarcities of clean drinking water. Ineffective water management leads to annual devastation from floods at the scale of war, followed by periods of severe drought. With increasing use of cross-border river waters, there is a possibility that the Indus Waters Treaty between India and Pakistan and the Ganga Waters Accord between India and Bangladesh could break down. This could seriously exacerbate tensions in the region. For these reasons, a prime focus of our project is to facilitate a process of water-related data sharing among regional countries with an emphasis on cross-border rivers.

5. References

Ahmed, S., and S. Das, 1998, *Movements of People, Ideas, Trade and Technology: Toward a Peaceful Coexistence of India and Pakistan*, Occasional Paper, Cooperative Monitoring Center, Sandia National Laboratories, Albuquerque, New Mexico, USA, SAND98-0505/3.

Biringer, K.L., 1998, *Siachen Science Center: A Concept for Cooperation at the Top of the World*, Occasional Paper, Cooperative Monitoring Center, Sandia National Laboratories, Albuquerque, New Mexico, USA, SAND98-0505/2.

Chalise, S.R., and N.R. Khanal, 1996, Hydrology of the Hindu-Kush Himalayas. A report of the Regional Workshop, International Center for Integrated Mountain Development, Kathmandu, March 23–24, 1996.

Gleditsch, N.P., 1998, "Armed Conflict and the Environment: A Critique of the Literature," *Journal of Peace Research*, Vol. 35, No. 3, Sage Publications, London, pp. 381-400.

International Water Assessment Center (IWAC), 2000, Guidelines on Water-Quality Monitoring and Assessment of Transboundary Rivers, available at http://www.iwac-riza/IWAC/iwacsite.nsf.org.

Pregenzer, A., M. Vannoni, and K. Biringer, 1996, *Cooperative Monitoring of Regional Security Agreements*, Cooperative Monitoring Center, Sandia National Laboratories, Albuquerque, New Mexico, USA, SAND96-1121.

Rajen, G., 1999, *Cooperative Environmental Monitoring in the Coastal Regions of India and Pakistan,* Cooperative Monitoring Center, Sandia National Laboratories, Albuquerque, New Mexico, USA, SAND98-0505/11.

Rajen, G., K.L. Biringer, and J.D. Betsill, 2000, *South Asia Water Resources Workshop: An Effort to Promote Water Quality Data Sharing in South Asia*, Sandia National Laboratories, Albuquerque, New Mexico, USA, SAND2000-0809.

Singh, J., 1996, "Military Postures, Risks, and Security Building," in *Mending Fences: Confidence and Security-Building in South Asia*. Editors: Sumit Ganguly and Ted Greenwood. Westview Press, Colorado, USA, pp. 163–80.

U.S. Department of State, 1999, Official web site http://www.dos.gov/.

United Nations, 2000, Convention on the Law of the Non-Navigational Uses of International Watercourses, available at http://www.un.org/law/watere.htm.

United Nations Environment Programme, 2000, World Wide Web Site of the United Nations Environment Programme Global Environmental Monitoring System (GEMS)/Water Programme, http://www.cciw.ca/gems/.

Appendix A. List of Participants in Photograph Depicted in Figure 1

Back Row (L to R)

Dinesh Parekh, President, Thane Belapur Industries Association, Mumbai, India (Industry)
Arif Alauddin, Managing Director, Pakistan Energy and Environmental Management Center, Ministry of Environment, Local Government and Rural Development, Islamabad, Pakistan (Govt.)
William Robert Laitos, U.S. AID, Nepal (U.S. Govt.)
Dipak Gyawali, Managing Director, Nepal Water Conservation Foundation, Kathmandu, Nepal (NGO)
Ahsan Uddin Ahmad, Director of Environment Programs, Bangladesh Unnayan Parishad, Dhaka, Bangladesh (NGO)
Nimal Padmasiri, Director of Laboratories, National Water Supplies and Drainage Board, Colombo, Sri Lanka (Govt.)
Kent L. Biringer, Distinguished Member of Technical Staff, CMC (Sandia National Laboratories, U.S.)
Tony Carvalho, U.S. AID, Nepal (U.S. Govt.)
Debbi Seligsohn, Regional Environmental Affairs Officer, U.S. Embassy, Nepal (U.S. Govt.)
Gaurav Rajen, Visiting Research Scholar, CMC (Sandia National Laboratories, U.S.)
J. David Betsill, Senior Member of Technical Staff, CMC (Sandia National Laboratories, U.S.)

Front Row (L to R)

Keshari Bajracharya, Nepal Ministry of Hydrology and Meteorology, Kathmandu, Nepal (Govt.)
J.K. Ray, professor, Peace Studies Center, University of Calcutta, and Director, South Asia Research Society, Calcutta, India (Academic and NGO)
Ananda R. Joshi, Director-General, South Asia Co-operative Environment Programme (NGO/ Semi-Govt. – SACEP has members from the governments of all South Asian countries)
Shyam Sundar Ranjitkar, Irrigation Specialist, World Bank, Kathmandu, Nepal (International financial institution)
Drona Ghimire, Program Manager, World Conservation Union, Kathmandu, Nepal (NGO)
Suresh Raj Chalise, Director of Mountain Development Programs, International Center for Integrated Mountain Development, Kathmandu, Nepal (NGO)

Distribution

350	MS 1373	CMC Library, 5341
1	MS 9018	Central Tech Files, 8945-1
2	MS 0899	Technical Library, 9616
1	MS 0612	Review & Approval Desk, 9612 for DOE/OSTI