WATER QUALITY ASSESSMENT AND CONSERVATION OF UMKHRAH RIVER

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

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CANDIDATE'S DECLARATION

I hereby declare that the work presented in this dissertation entitled "**WATER QUALITY ASSESSMENT AND CONSERVATION OF UMKHRAH RIVER**", in partial fulfilment of the requirements for the award of the degree of **Master of Technology** in "**Conservation of Rivers and Lakes**" submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee is an authentic record of my own work carried out in the period between July 2005 and June 2006 under the guidance of **Dr. M.P.Sharma**, Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology–Roorkee, Roorkee and **Shri Arun Kumar**, Head, Alternate Hydro Energy Centre, Indian Institute of Technology–Roorkee, Roorkee.

The matter contained herein has not been submitted by me for the award of any other degree or diploma elsewhere.

Dated Roorkee, the 30th June, 2006.

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of our knowledge.

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(BANTEHSONGLANG BLAHWAR)

ABSTRACT

Water is a very important natural resource which is being exploited indiscriminately by humans. All over the world, the water resources are getting depleted and polluted by anthropogenic sources. Clean and fresh water has become a rare commodity in many parts of the world. India depends mainly on the monsoon for its water supply. The country's fresh water resources including ground water sources are rapidly getting depleted. With almost 200 million Indians not having access to clean and safe drinking water and with an estimated 90% of the water sources polluted to a great extent, water availability has been identified as one of the serious problems.

Meghalaya has only about 0.3% of the total riverine length in the country and most river stretches are still relatively clean. However, flowing right through the middle of the capital city, Shillong, is the River Umkhrah one of the polluted rivers in the region. This river is also one of the main rivers feeding the Umiam (Barapani) Reservoir located about 15 kms downstream of Shillong for the state's largest source of hydro-electricity. The solid waste and silt in the river has caused a major siltation problem in the Reservoir. The sewage and faecal pollution contained in the river water resulted in Umiam (Barapani) Reservoir unfit for human consumption.

The River Umkhrah is faced with several environmental problems. With the city having no sewerage and sewage treatment system, all the sewage and wastewater from domestic and commercial sources enter the river through the open drains directly. Open defecation along the river banks and human waste discharged directly has caused problem of faecal pollution in the river. The river has also become a dumping site for solid waste and waste of construction activities, which have obstructed the river flow, raised the river bed and caused flash floods very often in the low-lying areas of the city. Encroachment along the banks also has reduced the river width.

In view of the above, the present study on assessing the water quality of the River Umkhrah has been selected. The main objective aimed to assess the water quality of the river at several points along its main course as well as some of its tributaries using water quality indices. Indices help to simplify the understanding of water quality monitoring

data by reducing the bulky data into a single number which shows the water quality at a location based on a given scale and enable planners, decision and policy-makers to take appropriate steps for its conservation. Accordingly, three water quality indices for general water use, viz. National Sanitation Foundation's Water Quality Index (NSFWQI), Oregon Water Quality Index (OWQI) and Said, *et al* Water Quality Index (WQI), were chosen to assess the quality of the river water. Using available water quality monitoring data, the three indices were calculated and compared. All the three indices have shown that the quality of the river water is "bad" or "poor" along its whole stretch and its tributaries. Heavy pollution can be observed right from the upstream most station, Lapalang. The NSFWQI has been found to be the most flexible and versatile of the three indices because the values obtained were found to show a better picture of the water quality of the river. This index has also been tried and tested in several river basins all over the world and it has been found to give satisfactory results. The analysis also shows that the main pollutants in the river are faecal coliforms, bio-chemical oxygen demand (BOD) and the absence of dissolved oxygen (DO).

Index values obtained by the NSFWQI were put into water quality maps showing the spatial and temporal changes in the water quality of the River Umkhrah. From these maps it is observed that the water quality of the river has very less variation throughout the year. It remains polluted throughout the year and no dilution has been observed during the monsoon months. This is mainly due to high faecal coliform counts and high loads of BOD and COD that the river carries.

A land use and land cover classification of the river catchment has also been carried out with the help of satellite imagery and Geographical Information System (GIS). The classification shows that more than 50% of the catchment is under human settlement, which is very dense at many places. As such, the conservation of the river by catchment treatment is not feasible.

Based on the findings, conservation measures have been suggested in order to conserve the river. The measures target the main pollutants in the river, i.e. faecal coliform and solid waste. It is suggested that the wastewater be intercepted before entering the river and conveyed to a treatment plant. The sewage treatment is proposed to be carried out by the Fluidized Aerobic Bio-reactor (FAB) technology. Localized collection and composting of solid waste has been suggested for managing the solid waste in areas outside the Municipality limits. The third suggestion is to set up a centralized slaughterhouse so as to have proper management of the waste generated and also to keep an eye on quality control of the meat industry.

In conclusion, the present study has found that the water quality of the River Umkhrah is very poor from pollution level point of view. Therefore, it is recommended that immediate measures need to be taken by the State Government and Local Bodies, including involving public participation, in order to restore the River Umkhrah back to a condition which is acceptable by human standards.

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

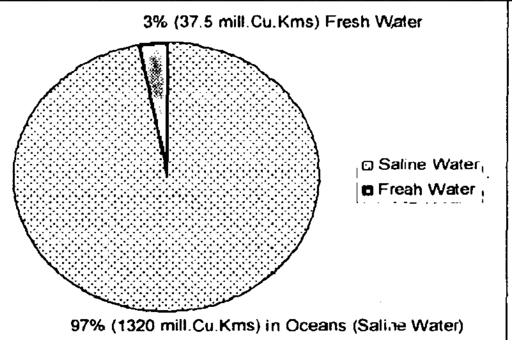
Water is colourless, tasteless, odourless and is made up of only two elements, but it is a substance that no one can live without and is, therefore, the basis for survival and growth not only of human beings but also all plants, animals and micro-organisms on the earth. Water has been the driving force of humankind since time immemorial. All the known ancient civilizations existed along the banks of great rivers. Water also holds an important position in our religious beliefs. Several festivals such as the Kumbh Mela, are observed while standing in water. Baptism, in Christianity, is done by sprinkling water on an individual's head or by immersing the whole body in water. Now-a-days, water has come to be seen as the driving force of the economy through its use in agriculture, industry and hydro-electricity generation. A bad monsoon usually cripples the economy of an agrarian country like India.

Man has always treated air and water as free gifts of nature which are meant to be exploited to their full extent. However, these gifts will not last forever. A time will come when over-exploitation of these resources will result in serious catastrophe. The dearth of fresh drinking water is already being felt around the world. Sohra (Cherrapunjee), which receives some of the heaviest rainfall in the world, lies barren and people have to walk for miles together for a bucket of clean water. For this reason, it is fondly called the "wettest desert in the world".

Fresh water is a very scarce natural resource. However, it has been exploited due to domestic, agriculture and industrial uses and is returned to nature only as waste water laden with all kinds of pollutants. The famous French explorer Jacques Cousteau once said, "Water and air, the two essential fluids on which all life depends, have become global garbage cans". Our waste has choked our rivers and lakes. The fish have either moved away or simply died. The fact that 2003 was declared as the "United Nations International Year of Freshwater" shows as to how this problem has become a global concern even though it is an important input for economic development and environmental sustainability [3].

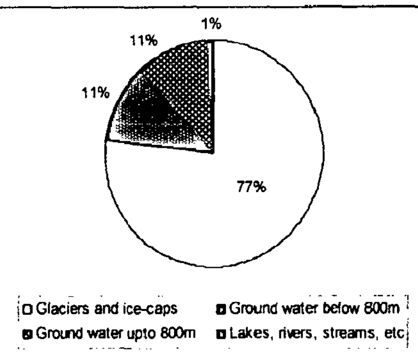
1.2 GLOBAL WATER SCENARIO

Water is available in abundance on the earth. Three fourths of its surface is covered with water. It is estimated that the total water resource on the earth is about 1360 million cubic kilometers which, if spread evenly over its surface, will cover the planet to a height of 2.7 kilometers. However, more than 97% of this is in the form of the saline water of the oceans, 2% is locked up in ice-caps and glaciers and a large proportion of the remaining 1% lies in deep inaccessible aquifers that are too expensive to be exploited. Thus, effectively 0.2 million cubic kilometers of fresh water is available in rivers, lakes, wetlands, soil moisture, shallow ground water and reservoirs to meet the demands of all the plants, animals and humans inhabiting this planet. This constitutes only about 0.01% of all the water on earth. The World Health Organization (WHO) estimates that only 0.007% of all water on earth is readily available for human consumption globally [3]. Figures 1.1 and 1.2 show the total water availability and distribution of fresh water on earth respectively. The small amount of available fresh water is constantly being renewed by the hydrological cycle in the form of rain. However, a large portion of rain water either flows back into the sea as run-off or gets evaporated back to the atmosphere.



Source: [3]

Figure 1.1: Total water on earth



Source: [3]

Figure 1.2: Distribution of fresh water on earth

With the increase in world population, the demand for clean and fresh water also increases. Yet at the same time, human activities leading to degradation of nature and climate changes have put pressure on the hydrological cycle of nature also. The addition of domestic and industrial wastewater into water bodies has further compounded the situation. Figure 1.3, clearly shows as to how freshwater species population in the world has drastically declined between 1970 and 1999. The World Wide Water Development Report estimates that by 2050, at worst, 7 billion in 58 countries and at best 2 billion in 48 countries will face water scarcity due to population growth and policy decision-making. The Report also indicates that there is an estimated 12,000 cubic kilometers of polluted water world wide which is more than the total amount of water contained in the world's 10 largest river basins at any given moment [3].

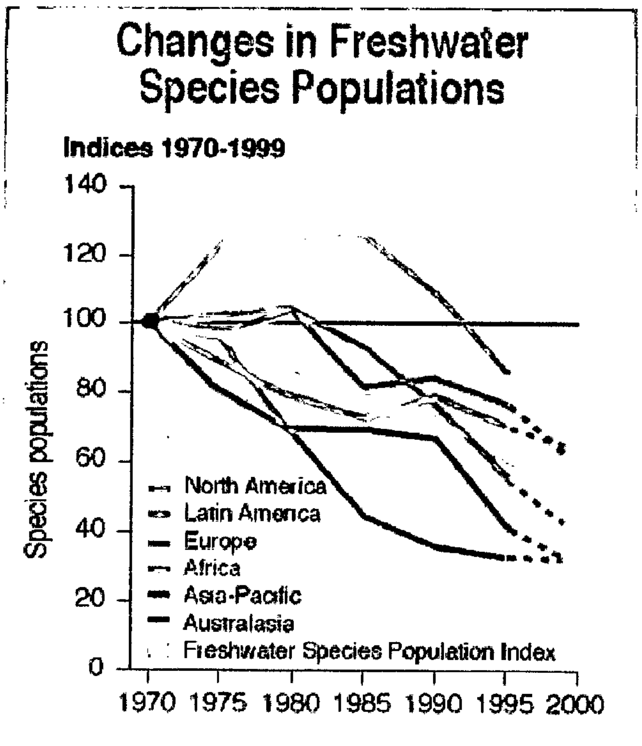


Figure 1.3: Changes in Freshwater Species Population

In Figure 1.4, the United Nations Environment Programme (UNEP) has shown in most parts of the world, freshwater withdrawal was less than 10% of the total water available in the year 1995. However, by 2025, the situation will be highly stressed with many countries withdrawing over 40% of the total water available with India being in this category.

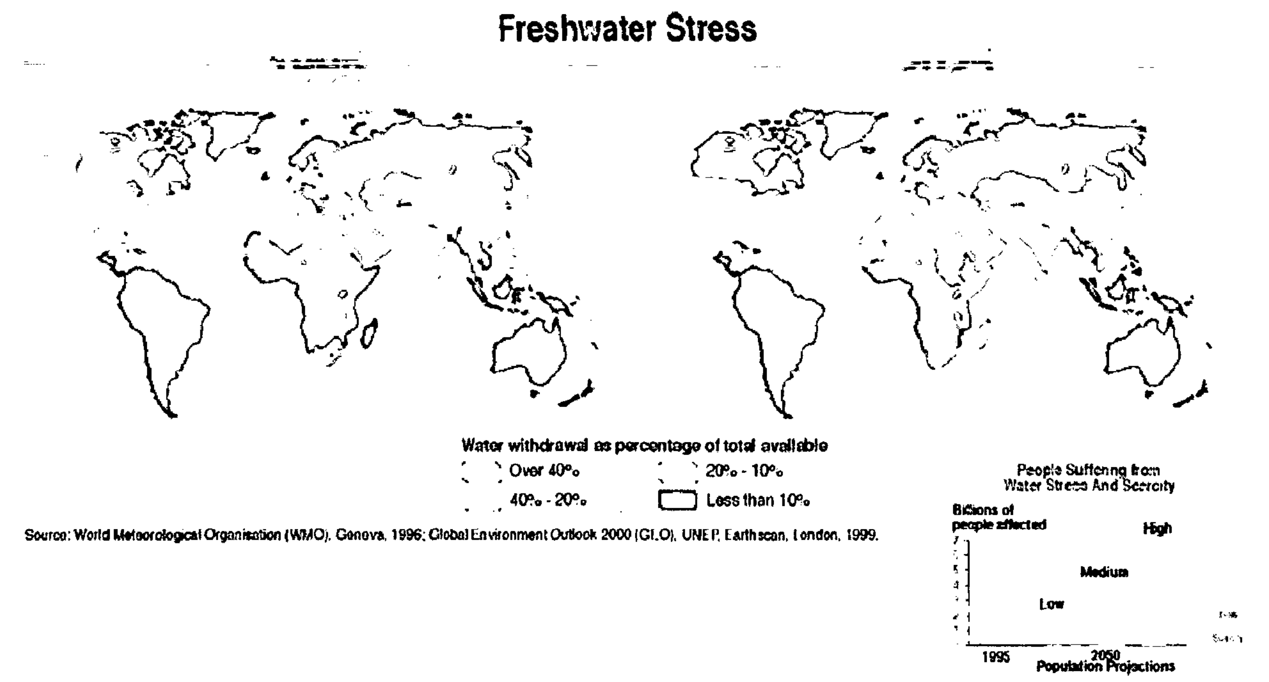


Figure 1.4: Freshwater stress in 1995 and projected for 2025

These statistics paint a very grim picture of the world only a few years ahead. Some of these problems have already surfaced in the perpetually water scarce regions of North Africa and the Middle East. The situation has been appropriately predicted by Ismail Serageldin, World Bank Vice President for Environmental Affairs when he said, "The wars of the twenty first century will be fought over water".

1.3 WATER SCENARIO OF INDIA

India supports 16% of the world's population in about 2% of the world's land area and contains about 4% of the world's fresh water resources. India is basically an agrarian society with its economy highly dependant on irrigated agriculture. The largest use of fresh water in India is, thus, for irrigation. There are a total of 113 major and minor river basins which form the lifeline of thousands of cities, towns and villages in India [23]. Of these, there are 13 major rivers which share 83% of the total drainage, contribute 85% of the total surface flow and also accommodate 80% of the total population [A]. The details of the major river basins in India are given in Table 1.1 and Figure 1.5 shows the drainage map of India.

TABLE 1.1: DETAILS OF MAJOR RIVER BASINS IN INDIA

S. No.	Name of the River	Length in India (Km.)	Basin Area in India (Sq. Km.)	Average annual Discharge (MCM)	Place of origin	Destination
1	Ganga	2525	861404	493400	Gangotri Glacier Uttar Kashi, U.P.	Bay of Bengal
2	Indus	1270	321290	91455	Near Mansarovar Lake, Tibet	Arabian Sea
3	Godavari	1465	312812	105000	Nasik, Maharastra	Bay of Bengal
4	Krishna	1400	258948	67675	Mahabaleshwar Maharashra	Bay of Bengal
5	Brahmaputra	720	187110	510450	Kailash Range, China	Bay of Bengal
6	Mahanadi	857	141600	66640	Raipur, M.P	Bay of Bengal
7	Narmada	1312	98796	40705	Amarkantak, M.P.	Arabian Sea
8	Cauvery	800	87900	20950	Coorg, Karnataka	Bay of Bengal
9	Tapi	724	65145	17982	Batul, M.P.	Gulf of Khambhat
10	Pennar	597	55213	3238	Chennakesva Hills, Karnataka	Bay of Bengal
11	Brahmani	800	39033	18310	Ranchi, Bihar	Bay of Bengal
12	Mahi	533	34842	8500	Ratlam, M.P.	Gulf of Khambhat
13	Sabarmati	300	21674	3200	Aravali Hills Gujarat	Gulf of Khambhat

Source: [B]

India receives an average annual rainfall of about 4000 billion m^3 from the monsoons. The rainfall is highly erratic and unevenly distributed throughout the country. This has led to increased irrigation and ground water extraction. Of the total rainfall received, 1869 billion m^3 is lost as natural run-off in the streams and rivers, 432 billion m^3 goes for recharging the ground water and only about 690 billion m^3 of the surface water can be utilized. Table 1.2 shows the water availability in the country.

These statistics show that India has a good supply of fresh water but this is far from the truth. Almost 200 million Indians do not have access to safe and clean drinking water and an estimated 90% of the country's water sources are polluted to a great extent [3]. Ground water has been grossly exploited and at a number of places in the country, the amount of water withdrawn exceeds the amount that is recharged. States like Punjab and Delhi have developed, i.e. usage compared to its availability, their ground water upto

145% and 170% respectively [27]. This has led to serious problems including salt water intrusion into empty aquifers in the coastal areas.

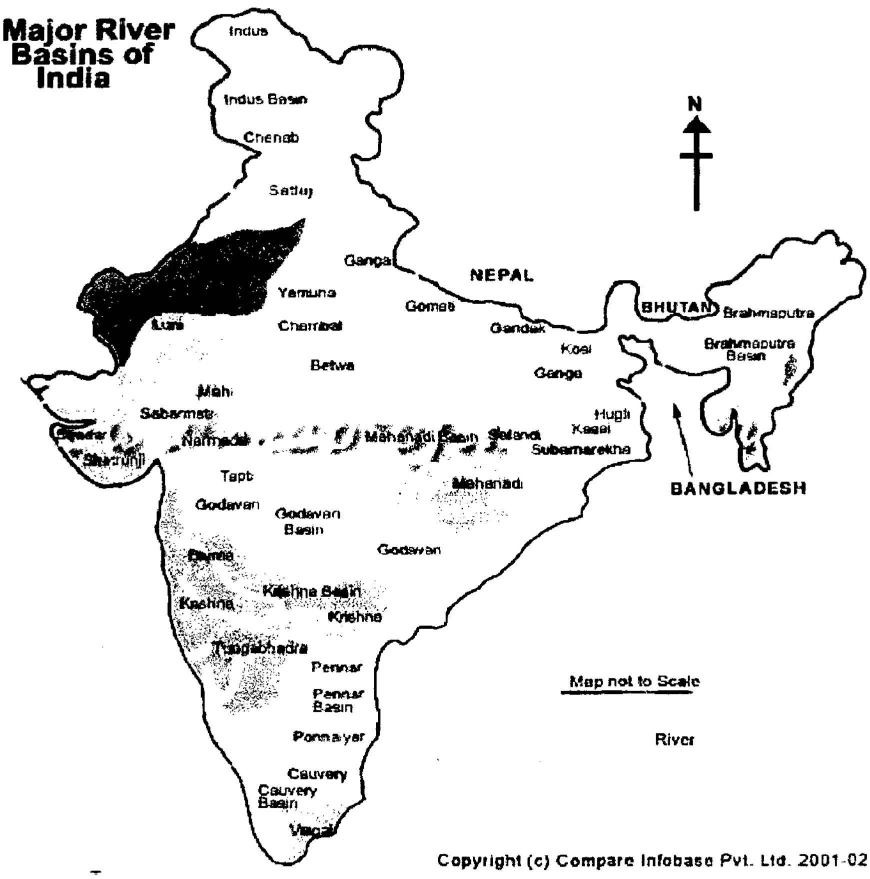


Figure 1.5: Drainage map of India

TABLE 1.2: WATER AVAILABILITY IN INDIA

S. No.	Source of water availability	Quantity (billion cubic meters)
1	Average annual precipitation	4000
2	Average annual water run-off potential	1869
3	Utilizable surface water	690
4	Replenishable ground water	432

Source: [3]

In India, water quality has deteriorated steadily with time. With increase in population, the demand of fresh water also increased which in turn, led to the increased generation of wastewater. Rapid urbanization in the last century has led to the metropolitan and other bigger cities getting choked with myriad environmental problems such as water supply, wastewater and solid waste generation and their collection, treatment and disposal. A study conducted by the Central Pollution Control Board in 2003-04 indicates that about 26,254 million litres per day of waste water are generated in the 921 Class I cities and Class II towns in India (having more than 70% of urban population) with treatment facilities available for about 7044 million litres per day only [4]. Table 1.3 below shows the trend of water supply, waste water generation and treatment available in Class I cities and Class II towns in India.

TABLE 1.3: TREND OF WATER SUPPLY, WASTE WATER GENERATION AND TREATMENT IN CLASS I CITIES/ CLASS II TOWNS

Parameters	Class I Cities				Class II towns			
	1978-79	1989-90	1994-95	2003-04	1978-79	1989-90	1994-95	2003-04
Number	142	212	299	423	190	241	345	498
Population (millions)	60	102	128	187	12.8	20.7	23.6	37.5
Water supply (mld)	8,638	15,191	20,607	29,782	1,533	1,622	1,936	3,035
Wastewater generation (mld)	7,007 (81%)	12,145 (80%)	16,662 (81%)	23,826 (80%)	1,226 (80%)	1,280 (79%)	1,650 (85%)	2,428 (80%)
Wastewater treated (mld)	2,756 (39%)	2,485 (20.5%)	4,037 (24%)	6,955 (29%)	67 (5.44%)	27 (2.12%)	62 (3.73%)	89 (3.67%)
Wastewater untreated (mld)	4,251 (61%)	9,660 (79.5%)	12,625 (76%)	16,871 (71%)	1,160 (94.56%)	1,252 (97.88%)	1,588 (96.27%)	2,339 (96.33%)

Source: [4]

In view of the prevailing population growth rate, it has been predicted that by 2025, India will become a water stressed nation [3]. The demand for fresh water will far exceed the availability. Today, India is ranked 122 out of 130 countries for its water quality and 132 out of 180 countries for its water availability [A].

The Central Pollution Control Board (CPCB) has prescribed different water quality standards for different water uses by introducing the concept of "Designated-Best-Use". This concept states that out of several uses, a particular water body is put to the use demanding the highest quality of water is called its "designated-best-use" and accordingly, the water body has been designated. The Board has identified five such "designated-best-use" classes as shown in Table 1.4 along with their prescribed water quality criteria.

TABLE 1.4: PRIMARY WATER QUALITY CRITERIA FOR DESIGNATED-BEST-USE CLASSES

S. No.	Designated-Best-Use	Class of water	Criteria
1	Drinking Water Source without conventional treatment but after disinfection	A	1. Total Coliforms Organism MPN/100ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 2mg/l or less
2	Outdoor bathing (Organized)	B	1. Total Coliforms Organism MPN/100ml shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 5mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
3	Drinking water source after conventional treatment and disinfection	C	1. Total Coliforms Organism MPN/100ml shall be 5000 or less 2. pH between 6 to 9 3. Dissolved Oxygen 4mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C 3mg/l or less
4	Propagation of Wildlife and Fisheries	D	1. pH between 6.5 to 8.5 2. Dissolved Oxygen 4mg/l or more 3. Free Ammonia (as N) 1.2 mg/l or less
5	Irrigation, Industrial Cooling, Controlled Waste disposal	E	1. pH between 6.0 to 8.5 2. Electrical Conductivity at 25°C μmhos/cm Max. 2250 3. Sodium absorption Ratio Max. 26 4. Boron Max. 2mg/l
6		Below-E	Not Meeting A, B, C, D & E Criteria

Source: [C]

1.3.1 National River Conservation Plan (NRCP)

The Ministry of Environment and Forests, Government of India, started a programme for cleaning up of rivers in the country with the implementation of the Ganga Action Plan (GAP) in 1985. A Central Ganga Authority (CGA) was set up under the Prime Minister with the members being the Chief Ministers of the concerned states, Union Ministers and Secretaries of the concerned Central Ministries alongwith experts in the field of water quality. GAP was extended to GAP Phase – II in 1993 and then to NRCP in 1995. GAP Phase – II was merged into NRCP in 1996. The objective of the NRCP was to improve the water quality of major rivers as the major fresh water source in the country, through the implementation of pollution abatement schemes. Since then, a single scheme of NRCP is under implementation as a Centrally Sponsored Scheme. The CGA was renamed as National River Conservation Authority (NRCA) with a larger mandate to cover all the programmes supported by the National River Conservation Directorate (NRCD).

The functions of the NRCA are as follows:

(1) To lay down, promote and approve appropriate policies and programmes (long and short-term) to achieve the objectives.
(2) To examine and approve the priorities of the NRCP.
(3) To mobilize necessary financial resources.
(4) To review the progress of implementation of approved programmes and give necessary directions to the Steering Committee, and
(5) To make all such measures as may be necessary to achieve the objectives.

GAP Phase – I was started in 1985 as a 100% centrally funded scheme. The main objective was to improve the water quality of the River Ganga to acceptable standards by preventing the pollution load from reaching the river. Under GAP Phase– I pollution abatement works were taken up in 21 Class – I towns in Uttar Pradesh, Bihar and West Bengal. GAP Phase – I was extended to GAP Phase – II, approved in stages between 1993 and 1996. It covered the River Ganga and its major tributaries, viz. Yamuna, Gomati and Damodar. This plan covered pollution abatement works in 95 towns along the polluted stretches of these 4 rivers spread over 7 states. The total approved cost of this action plan was approved on 50:50 cost sharing basis between the Centre and the State Governments.

It was later felt that the river conservation activity needed to be extended to other rivers in the country as well. Accordingly, GAP was merged into a National River Conservation Plan (NRCP) in 1995 on 50:50 cost sharing basis between Centre and State Governments. The Ganga Project Directorate was converted into the National River Conservation Directorate (NRCD) for servicing the National River Conservation Authority and the Steering Committee. It covered pollution abatement works in 46 towns along the polluted stretches of 18 rivers spread over 10 states. The GAP Phase –II was merged with NRCP in 1996.

NRCP was converted into a 100% centrally funded scheme in November 1998 with only the land cost to be borne by the States. However, in March 2001, it was decided to adopt an integrated approach for the river cleaning programme and that all future programmes will be shared on a 70:30 cost sharing basis between the Centre and State Governments respectively.

The activities covered under the NRCP include the following:

(1) Interception and Diversion works to capture the sewage flowing into the river through open drains and divert them for treatment.
(2) Sewage Treatment Plants for treating the diverted sewage.
(3) Low Cost Sanitation works to prevent open defecation on river banks.
(4) Electric Crematoria and Improved Wood Crematoria to conserve the use of wood and help in ensuring proper cremation of bodies brought to the burning ghats.
(5) River Front Development works such as improvement of bathing ghats.
(6) Public awareness and public participation.
(7) HRD, capacity building, training and research in the area of River Conservation.
(8) Other miscellaneous works depend upon location specific conditions including the interface with human population.

The criteria for funding of schemes under NRCP are as follows:

(1) NRCD/Government of India shall bear upto 70% of the Project cost.
(2) States and Local Bodies shall bear 30% of the Project cost of which the share of public would be a minimum of 10% to ensure public participation in the project.

(3) The O&M shall be a part of the project and the costs thereon shall be borne entirely by the State and Local Bodies for which additional resources have to be demonstrably raised and committed to O&M.

(4) The local Bodies may raise loans from financial institutions, such as HUDCO, to contribute their share.

(5) If there is a cost overrun in a project because of a delay, inflation or any other reason, the contribution of NRCD/Government of India shall be limited to its contribution amount initially agreed. Any additional expense on account of any increase in cost shall be borne by the concerned State Government.

(6) In addition, NRCD/Government of India may undertake itself or commission projects to other institutions, voluntary agencies, etc, also.

1.4 RIVER SYSTEM IN SHILLONG

The total riverine length in Meghalaya is 556 kms, which constitutes only about 0.3% of the total riverine length in India (Figure 1.6). Most of the rivers are perennial but their main source of water is the monsoon, which is the reason why the availability of fresh drinking water is greatly reduced during lean season.

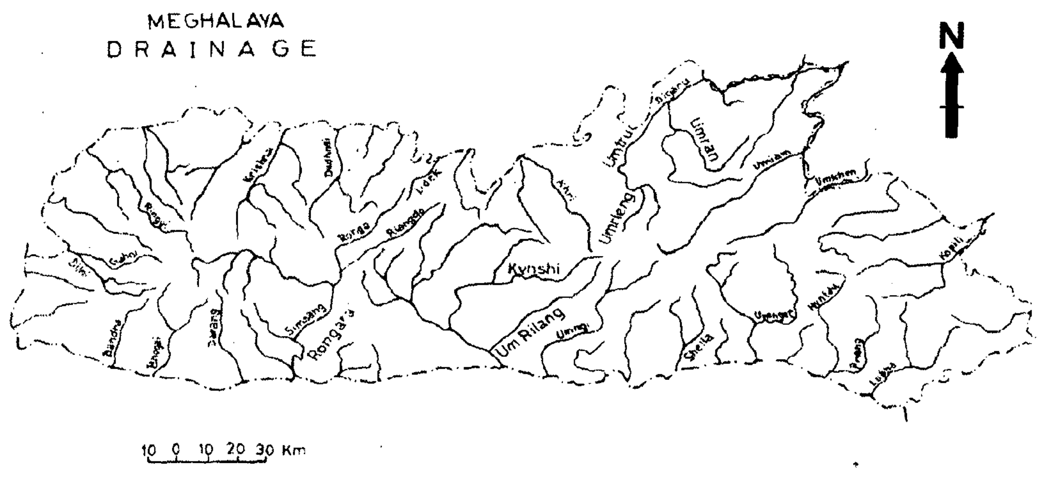


Figure 1.6: Drainage map of Meghalaya

The Umkhrah River and the Umshyrpi River are the two main perennial rivers which flow through the middle of Shillong. They originate in the southeastern part of the city, in the Reserved Forests of the Shillong Peak hill range, and flow in the northwesterly direction meeting each other near Sonapani at Mawlai to form the Wah Ro Ro which in turn joins the Umiam River, the main river feeding the Umiam (Barapani) Reservoir. In the past few decades, these rivers have been reduced to big drains. As there is no sewerage and sewage treatment system, all the sewage and wastewater enter directly into these rivers through the numerous drains joining them, thus augmenting the flow in the rivers. Open defecation and toilets discharging waste directly into the river further add to the pollution. Various commercial activities like quarrying, automobile workshops and servicing centres, hotels, restaurants, slaughter houses and markets existing along the banks of these rivers have added more pollution load to the rivers. Moreover, the encroachment and dumping of construction debris into the rivers have led to serious siltation problems. Despite the pollution, people still use the water of these rivers for bathing, washing and for irrigation purposes. Natural springs along the rivers' banks serve as sources of drinking water to the people till today.

The importance of these rivers lies in the fact that they flow through the capital city and are two of the main rivers feeding the Umiam Reservoir. The waste and silt being carried by these rivers, particularly the Umkhrah River, which receives waste from almost 80% of Shillong, have led to a major siltation problem to the Reservoir. The quality of the lake water has deteriorated to the point of being classified as **not fit for human consumption** [21]. This reason has prompted to study the status and water quality of the Umkhrah River on the basis of water quality indices and to prepare water quality maps showing the status of water quality at several points along the stretch of the river. Moreover, being an important perennial river in the state, a few studies have been conducted on this river and the Meghalaya State Pollution Control Board has been regularly monitoring the water quality of this river which enables more data to be readily available vis-à-vis the other rivers in the state.

1.5 THE STUDY AREA

The study area is located in Shillong, the capital of Meghalaya and the headquarters of the East Khasi Hills District (Figure 1.7). It is situated along the northern slopes and foothills of the Shillong Peak at 25°34' N latitude and 91°53' E longitude at an average altitude of 1496 metres above mean sea level. The city covers an area of about 25.40 square kilometers. The romantic city of Shillong has been one of the important tourist destinations in the Northeast and is considered as one of the most beautiful and picturesque hill-stations in India. It is often referred to as the "Scotland of the East" due to its striking similarity with the Scottish highlands. It is linked with Guwahati, the capital of Assam by National Highway 40 at a distance of about 100km.

1.5.1 History

The city, as the legend goes, has derived its name from Leishyllong, the Superpower or God said to be dwelling on the Shillong Peak, the highest point of Meghalaya at 1965 metres above mean sea level, over-looking the city. During the pre-British period, Shillong was a cluster of a few scattered hamlets. In 1863, the British Administration shifted the Headquarter of United Khasi and Jaiñtia Hills District from Sohra (Cherrapunjee) to Shillong and subsequently upon separation of Assam from Bengal in 1874, Shillong became the provincial Headquarter of Assam. This resulted in a rapid growth of population, from 1363 inhabitants in 1872 to around 4000 in 1875. During this period, the Christian missionaries established various educational institutions and Shillong became the educational centre of the Northeastern region of India. Commercial activities also expanded considerably to serve the growing population. The post-Independence period marked an accelerated growth due to influx of migrants from the neighbouring states as well as from other parts of the country. Defense establishments were increased as the city lies close to the international border.

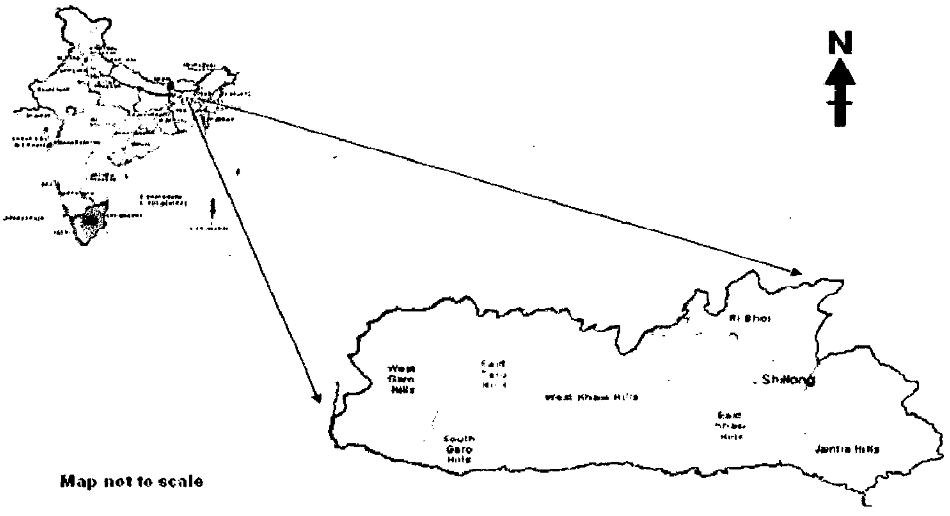


Figure 1.7: Location Map of Study Area

On 21st January 1972, Meghalaya attained its full statehood and Shillong became the capital of the state. Hence, in over a century Shillong has grown from a tiny settlement to a flourishing city which is an important administrative and commercial centre for the entire Northeastern region of India. Some of the important institutions located in Shillong are listed below:

- Shillong is the headquarters of the North Eastern Council.
- The main university is the North Eastern Hill University with campuses in Tura and Shillong.
- A bench of the Guwahati High Court has been set up in Shillong.
- Shillong is a major educational centre in North Eastern India. Major colleges in Shillong are: St. Edmund's College, St. Anthony's College, St. Mary's College, Lady Keane College.
- An Indian Institute of Management has also been sanctioned for Shillong.
- Shillong has a centre of the CIEFL (Central Institute of English and Foreign Languages) which has its headquarters in Hyderabad.
- Shillong also has offices of the Survey of India, the Geological Survey of India, the Anthropological Survey of India and the Zoological Survey of India.
- It has the Head Quarters of the Eastern Air Command of the Indian Air Force.
- It also has the Head Quarters of the oldest paramilitary force in India - the Assam Rifles, the Assam Regimental Centre and the 101 Area of the Indian Army.

1.5.2 Geology

Shillong is part of the sedimentary sequence that occupies the northern slopes of the Meghalaya plateau. It lies on low grade metamorphic rocks of the Shillong group of the very old Miocene period [16]. The rocks are predominantly of quartzites with subordinate phylites and slates. The quartzite band dips at 20° to 40° in north-northeast to south-southwest direction. Usually the rock band is found at a depth of 1m to 3m from the top soil level, except at places where the crusted quartzites bands are exposed. Shillong falls in the seismic zone prominent lineaments and a major sheer zone (Tyrsad-Barapani sheer) occur in the vicinity. However, there is no major fault thrust within the city area [20].

1.5.3 Climate

The climate of Shillong can be classified as humid sub-tropical climate found in the eastern part of the continent. It is characterized by moderate warm wet summers and cool dry winters. The average maximum and minimum temperature is around 17°C and 7.5°C respectively. The average annual rainfall is about 2100mm. The relative humidity is always more than 50% and during the monsoon, it is mostly above 80% [20].

1.5.4 Topography and Drainage

Shillong lies on the Shillong Plateau which is dissected in nature with well developed valleys along which the streams and rivers flow. The region includes a series of hill ranges, hillocks and rugged land surfaces that slope towards the north. The Shillong Plateau forms the watershed from where many rivers and streams emerge. The two rivers Umshyrpi and Umkhrah, flowing through the city, originate from the foothills of the Shillong Peak and flow from the southeast towards the northwest direction. They join to form the River Ro Ro after sudden falls of 122 metres and 107 metres down the Bishop's and Beadon Falls respectively. The River Ro Ro flows through steep and inaccessible gradients before falling into the Umiam River [21].

1.5.5 Soil

The most dominant types of soils in the study area are red loamy and laterite soils. The red loamy soil is said to have been formed by weathering of rocks like granite and gneisses which are rich in clay forming minerals like feldspars and micas [21].

1.5.6 Natural vegetation

The natural vegetation in the catchment varies with topography, soil and temperature. Along the banks of the Umkhrah River, where the vegetation still exists, the species found are *Pinus kesiya*, *Eupatorium* sp., *Bambusa* sp., *Lantana* sp. and *Polygonum* sp. [14]. Reserved and Protected Forests cover a part of the catchment. However, rampant deforestation goes on in the private forests.

1.5.7 Demography

The demographic characteristics of Shillong may be classified into three categories, i.e. Shillong Municipality, Shillong Cantonment and towns outside Municipal limits (Mawlai, Nongthymmai, Pynthorumkhrah, Madanrting and Nongmynsong), collectively called the Shillong Urban Agglomeration. The population trend in the Shillong Urban Agglomeration is given in Table 1.5 which indicates that growth within the Shillong Municipality has more or less stabilized. This is due to the fact that very less land and housing facility are available within the Municipality. This has led to people moving towards the outskirts, with the result that population has grown steadily in the surrounding towns. A very big increase in the military establishment is noted in the decade 1981-91. A saturation point has also been reached in the Cantonment land as is noted with the marginal growth in the last decade.

TABLE 1.5: POPULATION TREND IN SHILLONG URBAN AGGLOMERATION

AREAS	POPULATION						
	1971	1981	Decadal Growth in %	1991	Decadal Growth in %	2001	Decadal Growth in %
1	2	3	4	5	6	7	8
Shillong Municipality	87639	109244	24.65	131719	20.57	132876	0.88
Shillong Cantonment	4730	6620	39.96	11076	67.31	12385	11.82
Mawlai	14260	20405	43.09	30964	51.75	38241	23.50
Nongthymmai	16103	21558	33.88	26938	24.96	34209	26.99
Pynthorumkhrah	*	10711	*	13682	27.74	22108	61.58
Madanrting	*	6165	*	8987	45.77	16700	85.82
Nongmynsong	*	*	*	*	*	11362	**
Shillong Urban Agglomeration	122732	174643	42.30	223366	27.90	267881	19.93

* Not yet declared as towns **Newly declared as towns

Source: [13]

As per the Census of India 2001, the density of population in Meghalaya was 103 persons per square kilometer with 84 persons per square kilometer in rural areas and 1970 persons per square kilometer in urban areas. The highest density of population was recorded in East Khasi Hills District with 141 persons per square kilometer in rural, while in urban, there were 7976 persons per square kilometer. The density of urban population is very high basically because of the location of Shillong in this district. Shillong acts as a primate city in the state. Out of the total urban population of 4,52,612 persons of the state 2,67,881 persons or 59.2 % is concentrated in Shillong itself.

Whereas of the total urban population of 2,77,967 persons in the East Khasi Hills District, 96.37 % is concentrated in Shillong.

1.5.8 Land use pattern

The Master Plan of Shillong 1991-2011 prepared by the Directorate of Urban Affairs, Government of Meghalaya [11] covers an area of 174 square kilometers which includes the Shillong Urban Agglomeration and thirty two other surrounding villages. In this Master Plan, the land resources of the city were divided into five broad categories shown in Table 1.6 below.

TABLE 1.6: LAND RESOURCES OF SHILLONG

S. No.	Land use	Area (hectares)	Percentage to total area (%)
1	Developed area	5494.10	31.58
2	Undeveloped area	1573.88	9.04
3	Developable area	5077.02	29.18
4	Urban agriculture	803.07	4.62
5	Forests and water bodies	4451.93	25.58
	TOTAL AREA	17400.00	100.00

Source: [11]

According to the Master Plan, the existing and proposed land use classifications are shown in Table 1.7 and Table 1.8 below. Figure 1.8 and Figure 1.9 show the maps of the existing and proposed land use according to the Master Plan.

TABLE 1.7: EXISTING LAND USE (SHILLONG MASTER PLAN)

S. No.	Land use	Area (hectares)	Percentage to total area (%)	Per cent to total developed area
1	Residential	2662.78	15.30	48.47
2	Commercial	56.62	0.33	1.03
3	Public and Semi-Public	1202.01		
	(a) Administrative	177.93	0.68	2.16
	(b) Institutional	903.20	5.19	16.44
	(c) Organized open space	118.13	0.68	2.16
	(d) Graveyards	61.75	0.35	1.12
4	Security	799.33	4.48	14.18
5	Industrial	10.00	0.06	0.18
6	Circulation	783.36	4.50	14.26
7	Vacant	6650.90	38.23	-
8	Urban Agriculture	803.07	4.62	-
9	Forests and water bodies	4451.93	25.58	-
	TOTAL	17400.00	100.00	100.00

Source: [11]

TABLE 1.8: PROPOSED LAND USE (SHILLONG MASTER PLAN)

S. No.	Land use	Area (hectares)	Percentage to total area (%)	Per cent to total proposed developed area
1	Residential	5095.27	29.28	60.85
2	Commercial	97.72	0.56	1.17
3	Public and Semi-Public	1326.03		
	(a) Administrative	147.93	0.85	1.76
	(b) Institutional	963.20	5.54	11.51
	(c) Organized open space	153.15	0.88	1.83
	(d) Graveyards	61.75	0.35	0.74
4	Security	779.33	4.48	9.31
5	Industrial	60.00	0.34	0.72
6	Circulation	1013.41	5.82	12.11
7	Urban Agriculture	788.07	4.53	-
8	Forests and water bodies	4391.93	25.24	-
9	Conservation	3848.24	22.13	-
	TOTAL	17400.00	100.00	100.00

Source: [11]

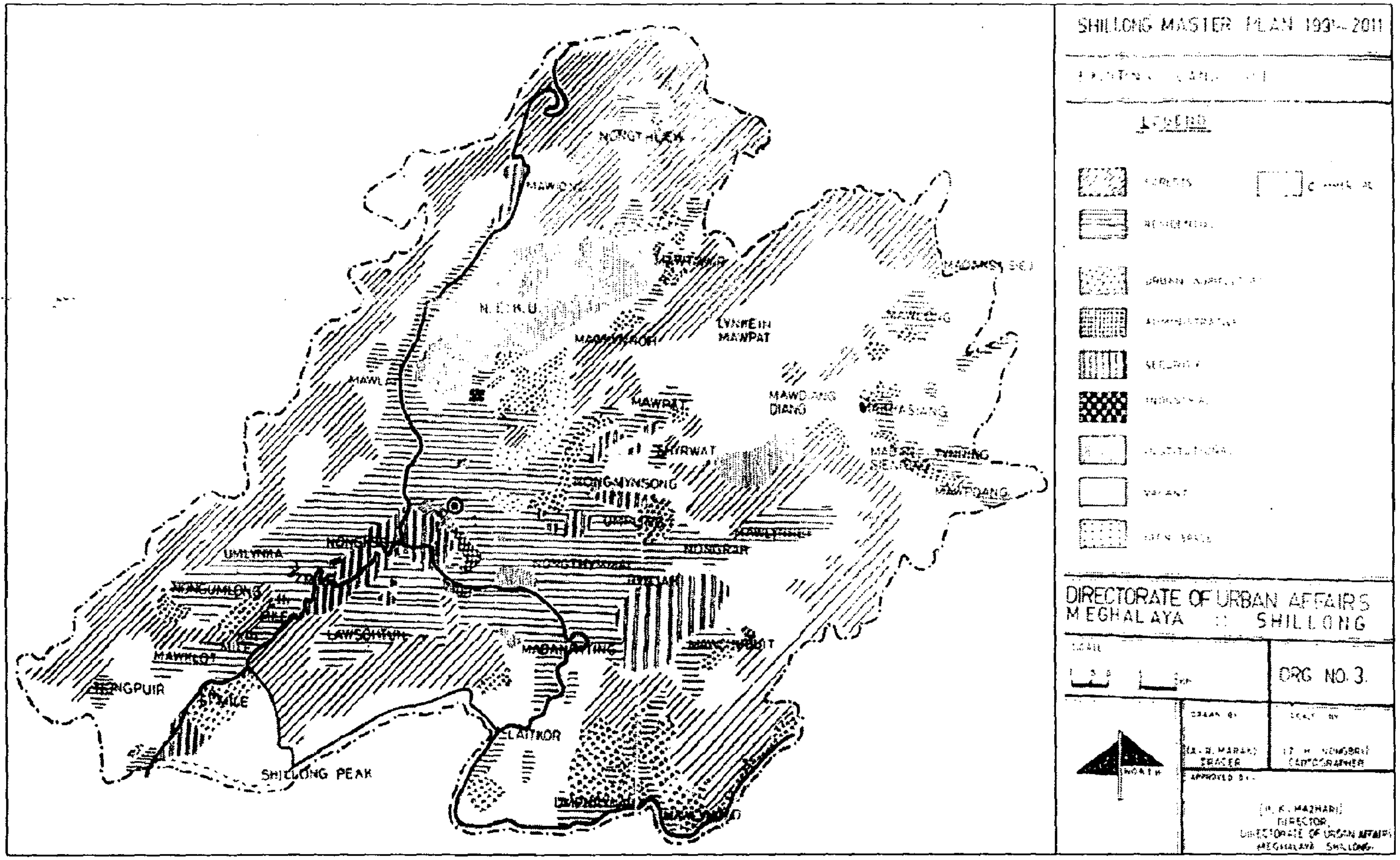


Figure 1.8: Existing land use (Shillong Master Plan 1991-2011)

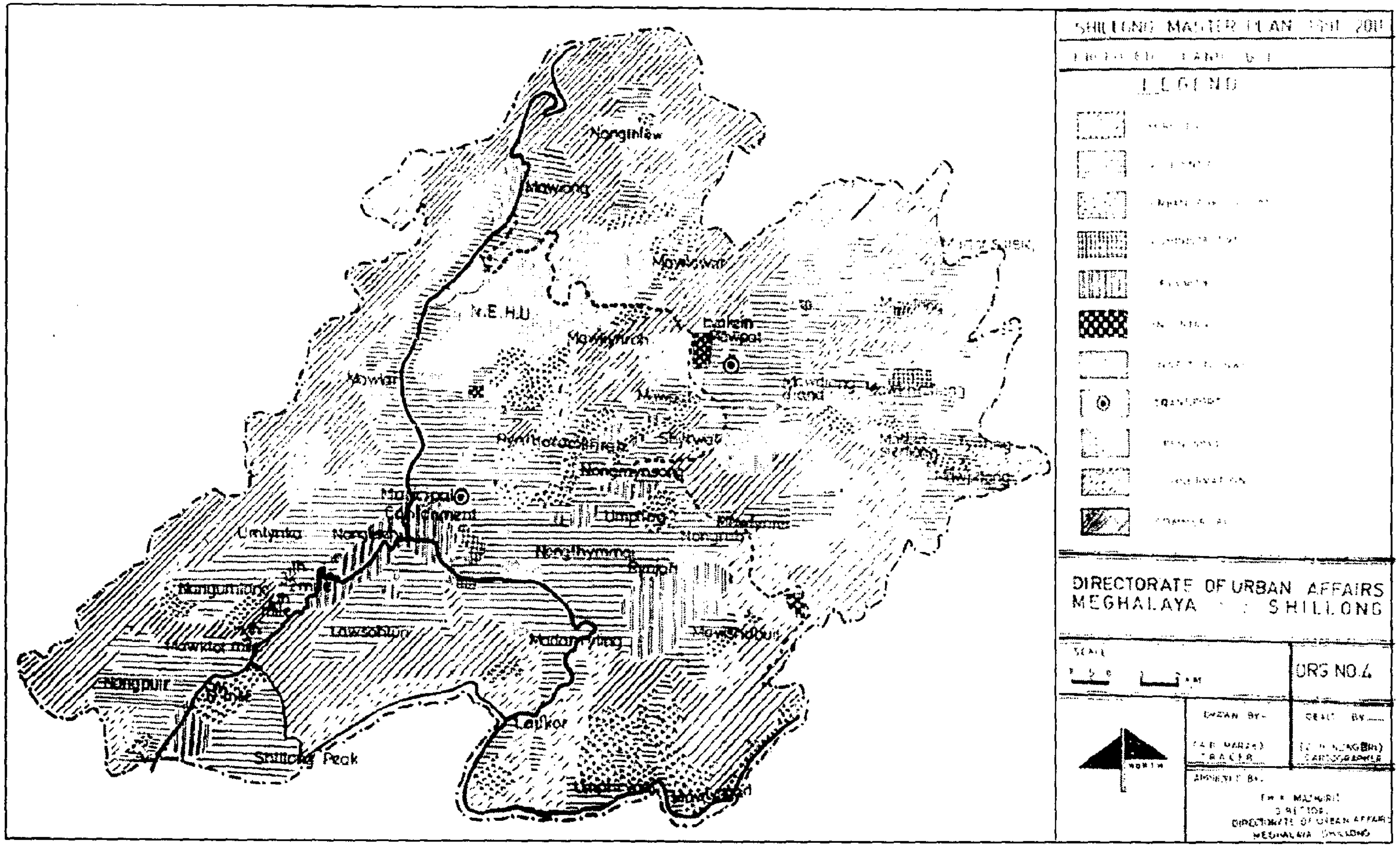


Figure 1.9: Proposed land use (Shillong Master Plan 1991-2011)

1.5.9 Water supply and sanitation

As in the case with other hilly regions, the main sources of water supply are rivers, streams and natural springs. Ground water contribution towards domestic water supply is very less. The main sources of water supply for Shillong are the streams originating from the Protected and Reserved Forests of the Shillong Peak range. The supply is augmented by the various water supply schemes installed by the Public Health Engineering Department, Government of Meghalaya around the city. As these sources are mainly rain-fed, there is acute water shortage in many parts of the city during the dry winter and spring months. While the responsibility of supplying drinking water in the municipal limits lies with the Shillong Municipal Board, the Public Health Engineering Department does the same in the other townships within the Shillong Urban Agglomeration. The different water supply sources, the quantity supplied and their command area are shown in Table 1.9.

TABLE 1.9: WATER SUPPLY SOURCES, QUANTITY AND COMMAND AREA IN SHILLONG

S. No.	Sources	Quantity (MLD)	Command Area
1	*Shillong Municipal Board Sources*		
	(a) Wah Risa Source	0.45	
	(b) Wah Jahlynnoh	0.46	
	(c) Umjasai	0.90	Municipal area
	(d) Madan Laban	0.34	
	(e) Crinoline	0.37	
	(f) Patta Khana	0.34	
	(g) Wah Dienglieng	0.34	
2	*P.H.E. Department Sources*		
	(a) Umkhen Water Supply Scheme	1.20	Nongthymmai and parts of Shillong Municipal Area
	(b) Umsohlang Water Supply Scheme	1.70	Mawlai
	(c) Greater Shillong Water Supply Scheme	16.96	Shillong Municipal Area and parts of the other towns
		23.06	

Source: [D], P.H.E. Department, Meghalaya

Shillong does not have a sewerage system. The domestic and commercial waste water and storm runoff are carried in both open and closed drains and natural drains which discharge into either the Umkhrah or the Umshyrpi Rivers. The drains are all gravity flowing but most of the time their flow is obstructed by the dumping of solid waste into them. Table 1.10 shows the lengths of different sized drains in Shillong. The Shillong Municipal Board has made it mandatory for all houses within the municipal limits to have toilets provided with a septic tank and soak pit. However, many houses still discharge their waste directly into public drains and in the areas outside the municipal limit, dry latrines are still very prominent.

TABLE 1.10: DRAINS IN SHILLONG

S. No.	Type / Shape	Size	Length (m)
1	V-shaped	0.60 m wide	60,136
2	Rectangular	0.60 x 0.60	1,11,703
3	Rectangular and natural drains	1.80 x 1.80	51,822
4	Primary drains	0.30 x 0.30	1,41,630

Source: P.H.E. Department, Meghalaya

Considering the unsanitary conditions in the city and the growing pollution of the rivers and the Umiam Lake in particular, it was felt necessary to provide Shillong with a sewerage and sewage treatment system. In 1989, the Meghalaya State Pollution Control Board took up the scheme and a Feasibility Report prepared by Development Consultants Ltd was submitted [19]. The Report proposed to divide Shillong into a Central Zone, whose sewage will be treated by trickling filter process, and a Peripheral Buffer Zone, where waste stabilization ponds will be used to treat their waste. However, this scheme never materialized perhaps, due to its high cost involvement.

1.5.10 Solid waste and bio-medical waste generation and management

There is no actual data available with respect to the generation of solid waste and bio-medical waste in Shillong. As per an estimate made by the Meghalaya State Pollution Control Board, about 121 TPD of solid waste is generated in the Shillong Urban Agglomeration [20]. The Central Pollution Control Board, in collaboration with the National Environmental Engineering Research Institute (NEERI), has conducted a survey of solid waste management in 59 cities (39 metro cities and 24 state capitals) in 2004-05 and it was found that the generation of solid waste in Shillong was only 45 tonnes per day [E].

With respect to bio-medical waste, there are a total of 2190 beds in the hospitals within the Shillong Urban Agglomeration and by assuming the average generation of infectious bio-medical waste as 250 gm/bed/day [5]; we can estimate that an amount of about 550 kg/day of infectious bio-medical waste is generated in Shillong.

The Shillong Municipal Board collects solid waste and general hospital waste from the municipal areas and dumps them at the trenching ground at Mawiong, located about 6 km outside the city. Here a 100 tonnes per day solid waste processing plant has been set up by a private firm. Using technology supplied by Excel Industries Ltd, the plant produces 15 tonnes of organic fertilizer per day. Even with these arrangements, however, we still find solid waste management in a very pathetic situation in Shillong. The waste from the surrounding townships has no form of collection and disposal and it all goes into the drains and low lying areas, landing up in the Umkhrah and Umshyrpi Rivers and eventually the Umiam Lake. In some localities, Non-Governmental Organizations and Self Help Groups are collecting the waste and dumping it at the processing plant. Hospitals are supposed to be treating and disposing infectious bio-medical waste within their own premises only, however, we still find such waste in the drains and rivers.

1.6 THE IMPORTANCE OF THE RIVER UMKHRAH

The River Umkhrah has a place of importance in the state because it flows through the capital city, Shillong and it is one of the perennial rivers that feed the Umiam (Barapani) Reservoir. It has always been a source of water for domestic, irrigation and commercial purposes to the citizens of Shillong. However, the quality of the river's water has deteriorated appreciably in the past decades due to various reasons stated earlier. The waste dumped into this river has made it a big eye-sore flowing through a city which is considered one of India's premier hill-stations. The desire to clean this river and restore it, as much as possible, to its pristine condition has been felt by most of the citizens.

The River Umkhrah was selected over the River Umshyrpi because it is the one that flows right through the middle of the city with its catchment covering almost 80% of the Shillong Urban Agglomeration. Moreover, water quality data of this river are more readily available vis-à-vis the other rivers and it is also considered to be the lifeline of the city.

It is with this thought in mind that the River Umkhrah has been selected in this present study. A study of its water quality using the concept of water quality indices and representing these in the form of maps will make it very easy to understand how polluted the river has become in the past few years. An attempt is also made to suggest conservation methods so as to be able to restore the quality of this river's water to its pristine condition and make Shillong the tourist paradise it is supposed to be.

1.7 OBJECTIVE OF THE PRESENT STUDY

The water of the River Umkhrah has been used for domestic, industrial and irrigation purposes since time immemorial. However, with the increase in the population of Shillong and its haphazard growth, this river has been converted into a drain used for dumping almost everything. From domestic waste water to direct discharge from latrines, from municipal solid waste to construction debris, this river accepts all types of wastes. The present study aims at studying the effects of all these anthropogenic sources of pollution at several points along the river and some of its tributaries. The study includes the use of water quality indices to study the quality of the river water and to represent these indices on water quality maps for better understanding and interpretation. Based on the findings, conservation measures and recommendations, which will help in preparing and implementing the mitigation measures for improving the water quality of the river, have been suggested.

In the present study, three different water quality indices, viz. National Sanitation Foundation's Water Quality Index, Oregon Water Quality Index and Said, *et al* Water Quality Index, have been chosen to study the quality of the river water. With the available water quality monitoring data, the three indices have been calculated and compared. All the three indices have shown that the quality of the river water is poor and steps are needed to be quickly taken in order to improve it.

The main conclusion drawn from this study is that the River Umkhrah is in a very bad condition. Its water quality has deteriorated to a very large extent that it cannot be utilized for domestic or other purposes. Its quality has been classified as Class E according to the concept of Designated-Best-Use of the Central Pollution Control Board (CPCB), i.e. it can only be used for irrigation, industrial cooling and controlled waste disposal. The figures and maps show that the quality of the river water remains almost the same throughout the year. This may be due to the fact that very large quantities of faecal coliforms, in the form of direct discharge of night soil from toilets and from open defecation, and organic waste are present in the river that very less dilution takes place even during the monsoon.

Based on the findings, conservation measures, like intercepting and treating wastewater, better management of municipal solid waste and establishing a centralized slaughterhouse, have been suggested. These suggested conservation measures may, perhaps, be taken up by the State Government in the future. The role of the public in implementing a conservation plan for the river has also been highlighted.

The concept of water quality indices, though not yet officially adopted in India, is the best way of representing water quality data of a water body in a manner that can be understood by everyone. Mapping the indices further helps in representing the variations in water quality throughout the year and even compare it with variations in other years. In the present study, only the River Umkhrah has been studied. However, this concept can be applied to all the rivers and streams within the state and a water quality map of the whole state can be prepared.

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CHAPTER 2

THE RIVER UMKHRAH

2.1 PROFILE OF THE RIVER UMKHRAH BASIN

The River Umkhrah originates in the southeastern part of Shillong near Demthring at an altitude of about 1600 metres above Mean Sea Level. The river flows in a northeasterly direction before turning sharply towards the west at Umpling. It turns northwards again at the foothills of the Office of the Garrison Engineer, MES, Shillong only to turn westwards again just a little downstream at Umkaliar. The river follows this principal direction till it meets the River Umshyrpi in the northwest of the city at the foothills of Mawprem and Mawlai. The two rivers join to form the River RoRo which joins the River Umiam, the main river feeding the Umiam (Barapani) Reservoir which is the state's biggest hydro-electric power project. The river covers a distance of about 12.5 kilometres and has a catchment area of about 25 square kilometers. Figure 2.1 shows the River Umkhrah and its catchment area.

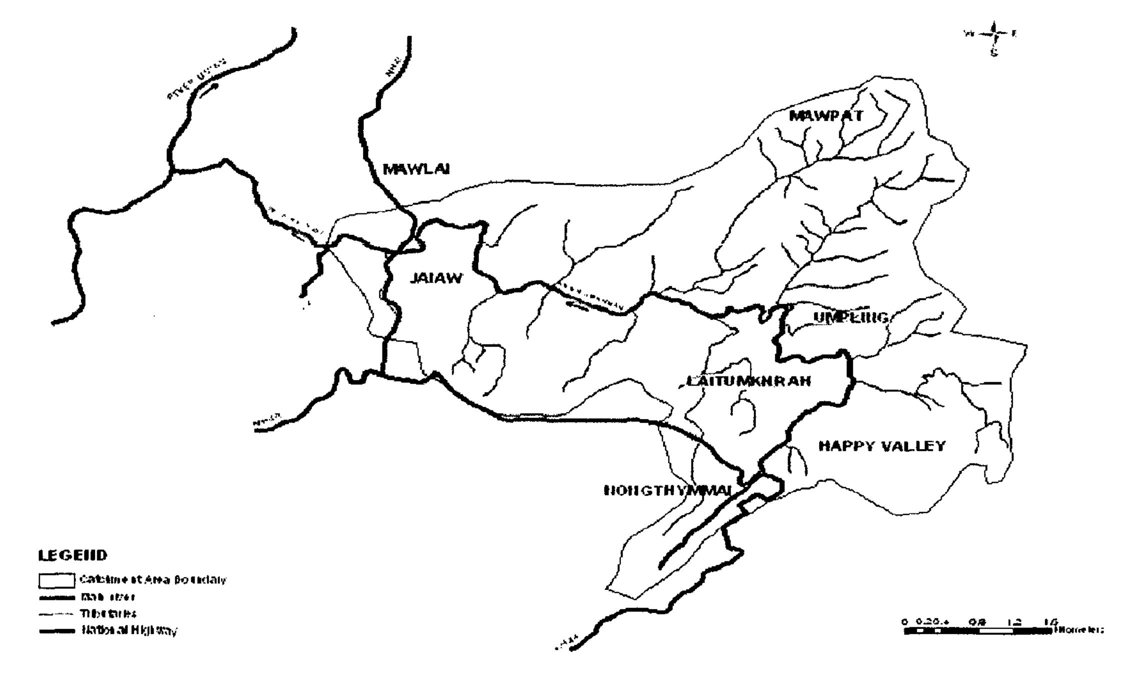

Figure 2.1: River Umkhrah catchment area

Most parts of the catchment lie in the urban area which is densely populated. The eastern and northeastern parts lie on the outskirts of Shillong and are either forested or under agriculture. A stretch of the river, which lies within the city itself, has its northern bank under agriculture.

The River Umkhrah originates from a natural spring located in the Reserved Forest of the Shillong Peak hill range near Demthring. The spring water is collected and used for domestic purposes. The spring is surrounded by residential activities which have shown their impact on the quality of the spring water. This will be discussed in detail in later chapters. A large stone and sand quarry exists near the spring (Plate 2.1). Here, besides quarrying activities, tapping of ground water is also being done. The ground water is pumped into tankers and sold by the land owner.

Plate 2.1: A view of the quarry at Demthring

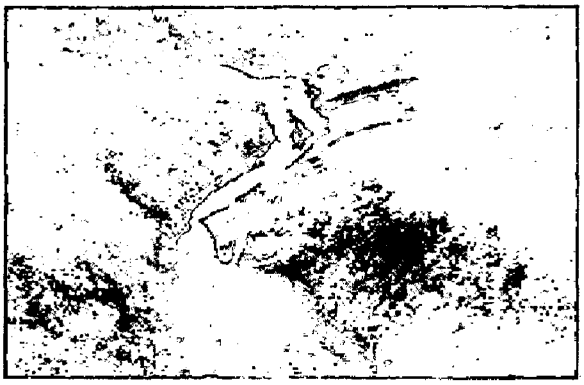

Plate 2.2: Kshaid Umkaliar/Spread Eagle Falls

From Demthring, the river attains the shape of a fast flowing stream as it flows through the foothills of Nongthymmai and Rynjah. Near Lapalang Bridge, the river is joined by the Phud Raimut and the Phud Mawshbuit flowing from the eastern part of the catchment which is primarily under the Military Cantonment at Happy Valley and its surrounding villages. Thus, while flowing through densely populated urban area, the river is joined by streams carrying agricultural runoff from the rural areas also. Table 2.1 shows the salient features of the major tributaries of the River Umkhrah.

TABLE 2.1: SALIENT FEATURES OF THE MAJOR TRIBUTARIES OF RIVER UMKHRAH

S. No.	Name of tributaries or drains	Location of confluence	Command area	Major sources of pollution
1	Wah Disoi	Below Mawpdang Bridge, Mawprem	Mawprem, Garikhana, Lama Villa, Jaiaw Langsning, Slaughter House Area, Naspatighari	Domestic sewage, Trade effluent
2	Jaiaw Lumsyntiew Drain	Behind Old CRPF Camp, Mawlai	K.J.P. Assembly Hospital, Jaiaw	Domestic sewage, Hospital effluent
3	Mawlai Phudmuri Drain	Slaughter House	Mawlai Phudmuri Slaughter House	Domestic sewage, Slaughter house waste
4	Mawlai Stream	Near Cremation Ground, Jaiaw	Mawlai Phudmuri, Nongmali	Domestic sewage, Trade effluent
5	Jaiaw Drain	Near Lawmali Graveyard	Riatsamthiah, Jaiaw	Domestic sewage
6	Riatsamthiah-Wahingdoh Drain	Lawmali Bridge	Riatsamthiah, Wahingdoh	Domestic sewage, Hospital effluent
7	Lawmali Drain	Lawmali Bridge	Ganesh Das Hospital, Pasteur Institute	Domestic sewage, Trade effluent, Hospital effluent
8	Wahingdoh-Raimohan Drain	Wahingdoh Bridge	Keating Road, Mawlonghat, Barabazar (Motphran), Mawkhar, Police Bazar, Umsohsun, Jail Road, Wahingdoh	Domestic sewage, Trade effluent
9	Oakland Drain	Polo Bazar	Botanical Garden, Ward's Lake, Oakland, Jail Road Bazar	Domestic sewage, Trade effluent
10	Laitumkhrah Drain	4th Furlong	Lower Lachumiere, Laitumkhrah	Domestic sewage
11	Wah Thangsniang Stream	Demseiniong	Lawjynriew, Lumpyngngad, Jingkieng Nongthymmai, Nongrim Hills, MES, Nongrimbah, Nongrimmaw, Demseiniong	Domestic sewage, Trade effluent
12	Wah Kdait	Below Spread Eagle Falls	Mawpat, Nongmynsong	Domestic sewage
13	Phud Raimut	Lapalang Bridge	Happy Valley	Domestic sewage

14	Wah Demthring (principal source of the River Umkhrah)	--	Nongthymmai(Demthring), Madanrting	

Source: [20]

After Umpling Bridge, the river flows through a relatively steep gorge which ultimately ends at the Kshaid Umkaliar (Spread Eagle Falls) (Plate 2.2) near the Office of the Garrison Engineer, MES, Shillong. At the foot of the falls, another stream, Wah Kdait, flowing from the rural outskirts of Shillong, joins the river. From this point onwards, i.e. from Umkaliar, the river flows through a relatively plain area. At Demseiniong and Pynthor Umkhrah, the northern bank is under agriculture and there are also several private cowsheds for local supply of milk and dairy products.

On entering 4th Furlong and Polo, vast stretches of the river have been encroached. Retaining walls have been built, land-filling done and now we have residential and commercial buildings on land which once was the bed of the river. The river has been reduced to a drain here and the silt and solid waste it carries gets deposited causing flash floods during the monsoons. After Polo, the river flows through the densely populated localities of Lawmali, Wahingdoh, Riatsamthiah, Jaiaw and Mawlai. Several drains bringing waste water from these localities join the river along the way. Mawpdang is the last accessible point of the river as just a little downstream of this location the river flows into a deep gorge which ends at the Beadon Falls (Plate 2.3). Just downstream of the Falls, the river is joined by the River Umshyrpi to form the River Ro Ro.

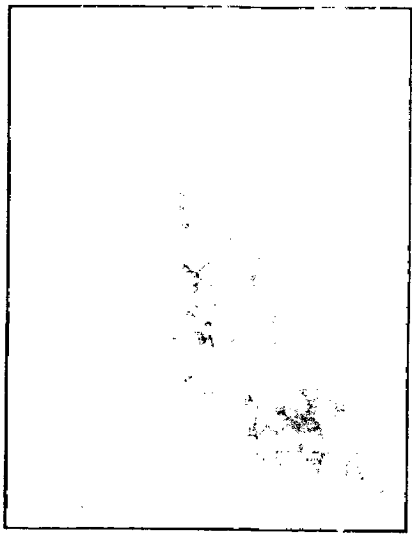

Plate 2.3: Beadon Falls

2.2 SOURCES OF POLLUTION

A number of sources and activities contribute towards the pollution of the River Umkhrah. These sources can be broadly classified as point and non-point or diffused sources.

2.2.1 Point Sources

These include the toilets, which discharge raw sewage directly into the River Umkhrah and its tributaries, and drains carrying effluents from hotels and restaurants, automobile workshops, hospitals and nursing homes, slaughter houses and market places. The joint study conducted by the North Eastern Hill University and the Meghalaya State Pollution Control Board [23] reported that along the River Umkhrah, upto a distance of 100 metres on both banks, there exists 1443 toilets. Of these 51.6 % are sanitary toilets with soak pits, 26.3 % are sanitary toilets without soak pits, 5.8 % are pit latrines, 1.6 % are dry latrines and 14.8 % discharge raw sewage directly. Therefore, more than 40 % of the sewage generated along the river and its tributaries finds its way directly into them. Along the river and its tributaries, there are 56 automobile workshops which directly and indirectly contribute to the river's pollution. There are 7 hospitals and nursing homes in the river's catchment discharging untreated hospital wastewater directly into it. There are 38 hotels and restaurants which also directly discharge wastewater into the river.

2.2.2 Non-point or Diffused Sources

The main source of diffused pollution (Plates 2.4 to 2.9) is the dumping of solid waste into the river. Besides this, activities like stone and sand quarrying, dumping of earth and construction debris, deforestation due to construction activities, erosion and agricultural runoff can be identified as the other sources of diffused pollution.

Plate 2.4: Solid waste accumulated near the mouth of the Jaiaw Drain

Plate 2.5: Open dumping of solid waste near Mawlai Nongpdeng

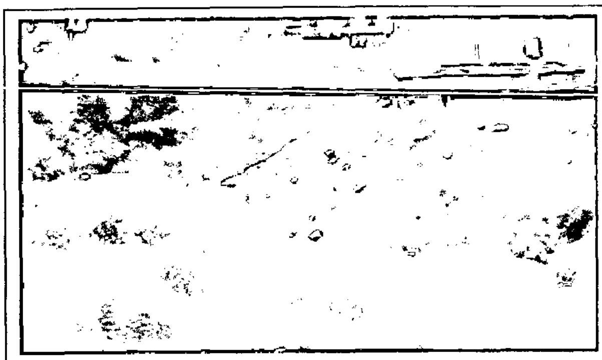

Plate 2.6: Dumping of earth and construction debris at Weiking

Plate 2.7: Dumping of earth and construction debris at Jingthangbriew

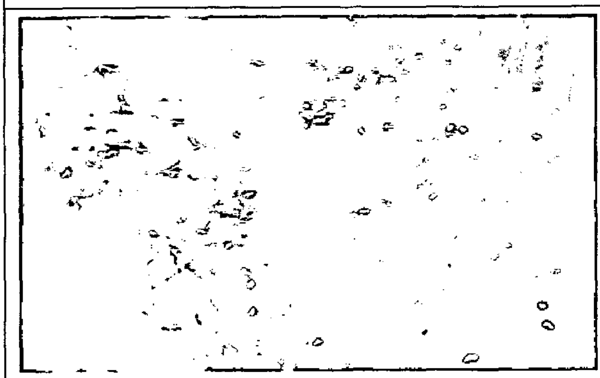

Plate 2.8:Dumping of solid waste and earth at Wahingdoh

Plate 2.9: Toilets discharging raw sewage directly into the river

2.3 STATUS OF THE RIVER UMKHRAH

The Umkhrah River may not be a very big river. However, it has a place of importance as it flows through the capital city of the state and it is one of the main perennial rivers feeding the Umiam reservoir. The widespread pollution that happen along the course of this river has attracted a lot of attention and many studies have been conducted and reports written on the deterioration in quality of the river water and the siltation that it is causing to the Umiam reservoir downstream. Some of these studies showing the status of the river are reviewed below.

Two of the earliest studies made were conducted by the Water and Power Consultancy Services (India) Ltd. (WAPCOS) and by the Agricultural Finance Consultants Ltd (AFC). Both studies were sponsored by the North Eastern Council (NEC). WAPCOS submitted their report in 1990-91 and AFC did so almost simultaneously. These studies were actually on the Umiam reservoir with emphasis on the causes and remedies to its siltation.

WAPCOS, in its report entitled "The Pollution and Siltation Level of the Umiam (Barapani) Lake", found that the main cause of siltation in the reservoir is uncontrolled felling of trees in its catchment area. The storage capacity of the reservoir has reduced by 28.9% in case of dead storage and 5.5% in case of live storage (1989-90 status). The study also suggested some effective and economical measures which can be used to control the silt. Some of these measures are:

i) Reforestation and afforestation of the catchment,
ii) Protection of existing forests,
iii) Plantation of trees along river banks, and
iv) Stopping of jhum cultivation.

The report submitted by AFC was entitled "Status Report on Umiam River Catchment, Meghalaya (Volume1)" [2]. In this study, the whole catchment of the Lake was divided into ten well-defined watersheds. Each watershed was analysed and a list of the badly denuded critical areas were identified and their remedial measures suggested. The major sectors of development suggested by AFC include afforestation and pasture development, agriculture, horticulture, fishery, livestock and infrastructure like roads, rural water supply and community services. To curb jhum cultivation, AFC suggested alternate livelihoods for the jhum cultivators like raising of orchards and rain-fed farms.

Gupta and Michael [14] made a study of diversity distribution, seasonal changes in density and relative abundance of Ephemeroptera (Mayflies) nymphs in five sampling stations located along three rivers in and around Shillong. Three of these stations were located on the Umkhrah River. Two of the stations were located at places with considerable catchment disturbances in the form of stone/sand quarries in the surrounding hills and stone/sand collection spots along the stream bed, besides having extensive urban buildup along the river banks. The third station was located in a gorge with relatively undisturbed surroundings. It was found that the two former stations showed the least diversity of Ephemeroptera nymphs due to catchment and in-stream disturbances. It was noted that disturbances in the study area have resulted in "increased siltation, reduction of substratum heterogeneity and elimination of shelter and shade for the nymphs".

Gupta [15] determined the concentrations of cadmium, copper, manganese, lead and zinc in water, periphytonic algae, detritus and the larvae of three aquatic insects, viz. *Baetis* sp. (Ephemeroptera: Baetidae), *Hydropsyche* sp. (Trichoptera: Hydrosychiidae) and *Chironomus ramosus* Choudhury and Das (Diptera: Chironomidae), found in the Umkhrah River. Metal concentrations were found to be high in all the samples. Among the three insects, it was found that *Baetis* sp. accumulated cadmium, copper and zinc and *Hydropsyche* sp. accumulated manganese to concentrations much higher than those found in the other taxa. The concentrations of all metals were found to be higher in fine detritus than in *Chironomus ramosus*. The concentrations of cadmium and zinc were much higher in *Baetis* as compared to those in periphytonic algae and fine detritus. This, according to Gupta, may be a possible indication of metal bio-concentration in different aquatic species. The source of heavy metal contamination was identified as the diffuse, non-point sources such as:

i) untreated sewage from houses,
i) small industries,
ii) agricultural land, where copper and manganese containing fungicides and phosphate fertilizers are applied,
iii) road surfaces, the dust of which is a major source of lead, and worn tyre rubber which contributes cadmium and zinc,
iv) stone/sand quarries, and
v) automobile workshops and servicing centres.

The North Eastern Hill University (NEHU), Shillong, conducted a study of 15 rivers and 5 lakes in Meghalaya, the Umkhrah River being one of the rivers studied [22]. It was found that this river had the highest biochemical oxygen demand (BOD) and chemical oxygen demand (COD), high load of solids and very large number of coliform bacteria. However, it also contained high values of nitrate-nitrogen which indicated that complete decomposition of biodegradable materials was still going on in the river. It was finally noted that the water of this river was highly polluted and had reached the toxic level, making its water completely unfit for human use.

The Meghalaya State Electricity Board [18] had identified the sources and causes of pollution and siltation that was being disposed into and transported by the Umkhrah and Umshyrpi Rivers into the Umiam reservoir. The main causes of siltation were identified to be developmental activities and dumping of silt in the catchment, dumping of solid waste into the rivers and direct discharge of sewage and night soil into the rivers. The proposed solutions included the construction of check dams, trash racks, suspended type garbage arresters, various kinds of spurs like the sausage walls, bamboo palisading, gully traps, etc. These structures have been proposed to be built at selected locations along the river courses, based on field study. Moreover, the Board also proposed to allow for public participation and co-operation in searching for a permanent solution to the problem. Furthermore, necessary legislations, monitoring and penalties were also proposed.

A study entitled "An Assessment of Environmental Status of Lake Umiam, Rivers Umshyrpi and Umkhrah, Meghalaya" was conducted by Nongbri [21] with the main objective of assessing the environmental status of the Umiam Lake and simultaneously pollution levels in the Umkhrah and Umshyrpi rivers, which are major rivers feeding the lake. Several sampling stations along both rivers and the lake were selected and the samples analysed for physico-chemical and biological characteristics. The water quality was assessed on the basis of visible turbidity, dissolved oxygen, BOD, COD, ammoniacal-nitrogen, total coliform and faecal coliform. Lake sediments were also subjected to elemental analysis and clay mineral identification. Some of the findings with respect to the Umkhrah River include:

i) The river water was unfit for all uses except for irrigation to some extent,
ii) The river was loaded with pollutants even till the last sampling station before it joined the Umshyrpi River and then flow into the lake,
iii) All trace elements tested – cobalt, copper, cadmium, nickel, manganese, lead, zinc, iron and mercury – were below detectable limits.

The author suggested some conservation measures like the installation of a waste water treatment plant and sewerage and conversion of all dry latrines into ones attached with septic tank and soak pit. Legal safeguards have also been recommended to prevent the direct disposal of waste into the river. The pollution problem has to be reviewed collectively by all citizens and public opinion can be raised by the right environmental education.

Rajurkar, *et al* [25] studied the physico-chemical and biological characteristics of the Umkhrah River by selecting six sampling stations along the river course. They found that the continuous discharge of domestic and municipal sewage and the disposal of solid waste into the river had affected the quality of the river water in a major way. All parameters tested showed higher values at all the stations at one point of time or the other during the study period. This was attributed to the direct discharge of solid waste, sewage and even human excreta into the river.

The Central Pollution Control Board (CPCB) also carried out bio-mapping of water quality of all the perennial rivers in the state of Meghalaya using Biological Water Quality Criteria (BWQC) as shown in Table 2.2. This criterion is based on the range of saprobic values and diversity of benthic macro-invertebrate families with respect to water quality. To indicate changes in water quality according to pollution levels, the taxonomic groups of benthic macro-invertebrate families with their saprobic score range from 0 to 10, in combination with the range of diversity score from 0 to 1 have been classified into 5 different classes. The abnormal combination of saprobic score and diversity indicates sudden change in environmental conditions and poor substratum of water body [6].

TABLE 2.2: BIOLOGICAL WATER QUALITY CRITERIA (BWQC)

S. No.	Taxonomic groups	Range of saprobic score (BMWP)	Range of diversity score	Water quality characteristic	Water quality Class	Indicator colour
1.	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Diptera	7 and more	0.2 – 1	Clean	A	Blue
2.	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Planaria, Odonata, Diptera	6 – 7	0.5 – 1	Slight Pollution	B	Light blue
3.	Ephemeroptera, Plecoptera, Trichoptera, Hemiptera, Odonata, Crustacea, Mollusca, Polychaeta, Hemiptera, Coleoptera, Diptera, Hirudinea, Oligochaeta	3 – 6	0.3 – 0.9	Moderate Pollution	C	Green

4.	Mollusca, Hemiptera, Coleoptera, Diptera, Oligochaeta	2 – 5	0.4 & less	Heavy Pollution	D	Orange
5.	Diptera, Oligochaeta No animals	0 – 2	0 – 0.2	Severe Pollution	E	Red

Source: [6]

Being a perennial river in the state, the Umkhrah River was also monitored. The river was divided into different stretches for monitoring purposes, viz. Umkaliar stream (as the river is known at Nongmynsong), River Umkhrah upstream at Demthring, River Umkhrah midstream at Umpling and River Umkhrah downstream at Mawpdang. The water use, the status of the water body at each location and the hydrological status including substratum composition of the river was noted in detail.

The main findings of the study were that the Umkaliar stream stretch and the river's downstream stretch at Mawpdang were moderately polluted, the midstream stretch at Umpling was heavily polluted and the upsteam stretch at Demthring was severely polluted.

In view of the above results it has been found that the most polluted stretch of the river happens to be the upstream most location, Demthring, which is hardly a few hundred meters from the actual source of the river. At this location, no benthic macro-invertebrates were found. This study also led to the development of a classification based on Biological Water Quality for the state of Meghalaya as shown in Table 2.3.

TABLE 2.3: DEVELOPMENT OF BIOLOGICAL WATER QUALITY CRITERIA FOR RIVERS OF MEGHALAYA STATE

S. No.	Taxonomic groups	Range of saprobic score (BMWP)	Range of diversity score	Water quality characteristic	Water quality Class	Indicator colour
1.	EPHEMEROPTERA, PLECOPTERA, TRICHOPTERA, ODONATA, MOLLUSCA, CRUSTACEA, HEMIPTERA, COLEOPTERA, DIPTERA, PLANARIA, MEGALOPTERA	7.0 – 8.6	0.2 – 0.8	Clean	A	Blue

2.	EPHEMEROPTERA, PLECOPTERA, TRICHOPTERA, ODONATA, MOLLUSCA, CRUSTACEA, HEMIPTERA, COLEOPTERA, DIPTERA, PLANARIA	6.0 – 6.7	0.47 – 0.72	Slight Pollution	B	Light blue
3.	EPHEMEROPTERA, TRICHOPTERA, ODONATA, MOLLUSCA, CRUSTACEA, HEMIPTERA, COLEOPTERA, DIPTERA, MEGALOPTERA, HIRUDINEA, OLIGOCHAETA	3.4 – 6.2	0.2 – 0.8	Moderate Pollution	C	Green
4.	MOLLUSCA, DIPTERA, HIRUDINEA, COLEOPTERA, OLIGOCHAETA	2.6 –6.0	0.2 – 0.3	Heavy Pollution	D	Orange
5.	No benthic macro-invertebrates	0.0 – 0.0	0.0 – 0.0	Severe Pollution	E	Red

Source: [6]

The North Eastern Hill University and the Meghalaya State Pollution Control Board conducted a joint study to assess the water quality of the Umkhrah River [23]. The main objectives were to identify the major sources of pollution, to assess the physico-chemical and biological quality of the river and some of its tributaries, to quantify the organic and other major pollution loads of the river and suggest suitable conservation measures for overall improvement of the water quality of the river.

It was reported that low dissolved oxygen levels and high values of biochemical oxygen demand (BOD), chemical oxygen demand (COD), chemical oxygen demand, total coliform bacteria and oil and grease have made the river water unsuitable for human use. The river carries very high pollution load with respect to chemical and biochemical oxygen demands. Values as high as 348 mg/L and 207.1 mg/L respectively were observed at a downstream location, Mawpdang Bridge, when the water quality standards prescribed by CPCB for discharge into inland surface water are 250 mg/L and 30 mg/L respectively. When compared with the Designated Best Use criteria of the CPCB, the quality of the river water can be classified as category E, i.e. the water is only fit for irrigation, industrial cooling and controlled waste disposal.

Some of the suggestions made to prevent and minimize pollution from the different sources include:

i) To develop a comprehensive management plan to restore the river water quality back to a pristine state,
ii) To immediately stop the direct disposal of solid waste, waste water and sewage into the river and to stop all mining and quarrying activities and washing of clothes and vehicles in the river,
iii) To prevent encroachments along the river banks,
iv) To explore the possibilities of having a decentralized waste water treatment system,
v) To have a centralized slaughter house and treatment facility for bio-medical waste,
vi) To develop a green belt along the river banks, and
vii) To involve the community in a river cleaning drive as a short term measure.

The North East Educational and Development Society (NEEDS), a non-governmental organization (NGO), undertook a project entitled "Save and Clean Wah Umkhrah" funded by the Blacksmith Institute, United States of America in the year 2004-05. Realizing the gross pollution in the Umkhrah River which has converted it into more of a big drain rather than a river, NEEDS conducted a pilot survey in four low-lying areas on the river banks, viz. Nongmynsong, Umkaliar, Demseiniong and Pynthorbah. Data was collected under four categories:

i) socio-economic status,
ii) amenities and services (water, sanitation, drainage and solid waste disposal),
iii) health, and
iv) attitudes of the people.

It was found that the condition of sanitation and drainage was in a bad state with no proper drains and toilet facilities. The main source of drinking water was natural springs which were also slowly getting contaminated. There were no proper methods for solid waste disposal and the commercial activities like quarrying, washing of vehicles, fabrication units, automobile workshops, etc are adding to the pollution of the river. The areas studied have quite a high rate of illiteracy (35%) and most of the people were of a lower income group. However, they showed a positive attitude towards a move to clean up their environs.

Several workshops and awareness campaigns were also organized by NEEDS. Experts were invited from the State Health Department, the Shillong Municipal Board and the State Council of Science, Technology and Environment (SCSTE), among others, to impart knowledge and training, particularly on solid waste management, to the people. Another contribution was the implementation of a Composting Shed at Demseiniong with the assistance of the SCSTE. In this shed, heap composting and vermicomposting can be carried out for waste generated within the locality.

2.4 PRESENT STATUS OF THE RIVER UMKHRAH

A survey of the accessible parts of the river reveals that its condition is as bad as ever. At Demthring, an upstream most location surveyed, the river has been reduced to a drain with encroachments on both its sides. High retaining walls reclaiming land from the river have reduced the width to not more than 2.0m (Plates 2.10, 2.11, 2.12). Besides sewage and solid waste, the river also receives a lot of silt and soil from a quarry located nearby. The river then flows through the basically residential areas of Nongthymmai, Rynjah, Lapalang, Nongrah and Umpling after this. More sewage and solid waste gets added all along the way. Toilets discharging their waste directly into the river are a common sight.

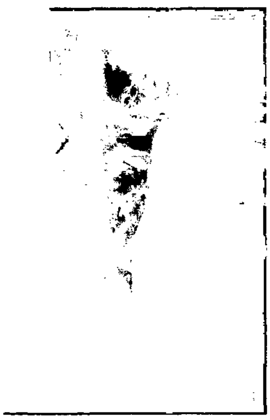	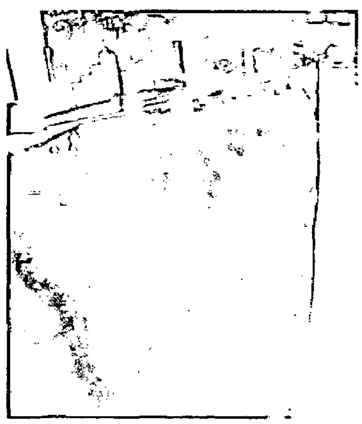	
Plate 2.10	**Plate 2.11**	**Plate 2.12**

The River Umkhrah at Demthring

The river gets aerated and regains some health as it tumbles down the Kshaid Umkaliar (Spread Eagle Falls). However, from this point and for quite a considerable distance, the river enters the low-lying and almost flat areas of Demseiniong, Pynthor Umkhrah, Polo, Wahingdoh, Jaiaw and Mawlai and that is where the river becomes unsightly. Silt and solid waste washed down from the higher reaches settle and obstruct the flow of the river (Plate 2.13). Drains and small streams laden with raw sewage and solid waste join the main river. Toilets along the river banks discharge directly into the river with no form of treatment at all. At Demseiniong and Pynthor Umkhrah, the river flows beside cultivated land and run-off from these fields add a mix of pesticides, fungicides and fertilizers to its waters (Plate 2.14). Commercial activities like quarrying and collection of sand from the river bed are carried on at Umkaliar (Plates 2.15 and 2.16). This place is also a favourite place for washing vehicles (Plate 2.17), adding a lot of oil and grease to the river water. There is also a weir at this place to divert water for irrigation. All along the river stretch, people still use the river water for washing clothes and even household utensils (Plate 2.18). At Polo, the river flows through a market place which dumps all its waste into it. Waste from the market, restaurants, hotels and other shops are simply dumped into the river. There are also several automobile workshops and servicing centres from where discarded oil and grease find their way into the river. It is at this place also that during every Puja the idols are immersed.

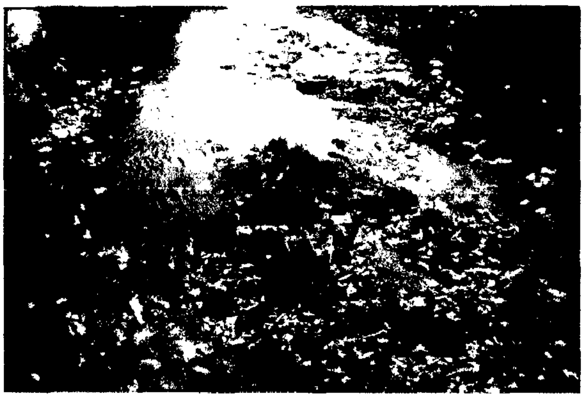

Plate 2.13: Solid waste deposited on the river bed at Polo

Plate 2.14: Urban agriculture at Demseiniong and Pynthor Umkhrah

Plate 2.15: Quarrying activities at Umkaliar

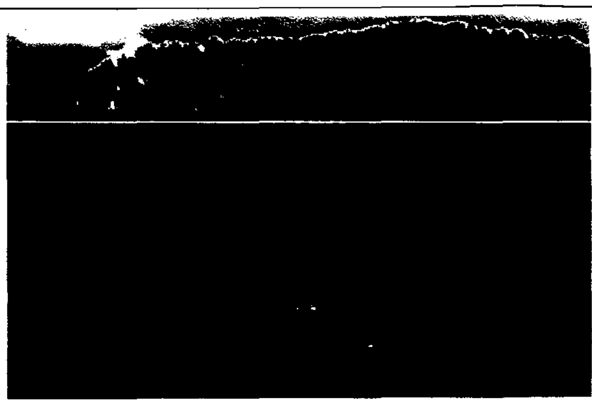

Plate 2.16: Quarrying activities at Umkaliar

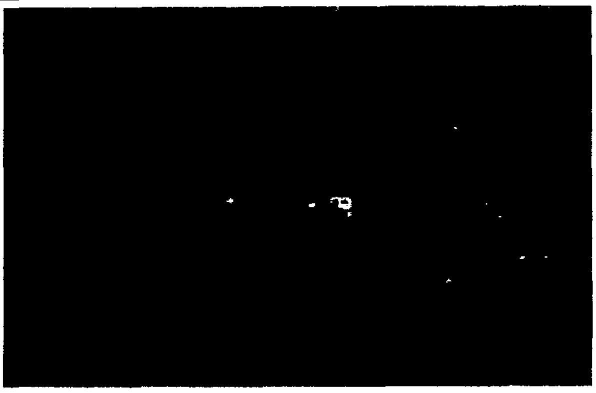

Plate 2.17: Washing of vehicles on the river bed itself at Umkaliar

Plate 2.18: Washing clothes along the river side is a common sight

Another most alarming activity that is going on here is encroachment (Plates 2.19 and 2.20). The bed of the river has been totally shifted with concrete retaining walls and earth fillings for the construction of residential and commercial buildings. One of the sampling locations at Pynthor Umkhrah has become inaccessible because of encroachment. Encroachment into the river's path is the main reason why Shillong has been affected by flash floods almost every monsoon for the past few years now. It is something unheard of before, but in only the past few years many people have been swept away and lost their lives to floods in this hilly town!

Plate 2.19: Encroachment at 4th Furlong

Plate 2.20: Encroachment at Weiking

Downstream of Polo at Lawmali, the river is joined by a drain coming from the Ganesh Das Hospital which brings with it a lot of untreated bio-medical waste. Further downstream, at Mawlai Phudmuri, are the slaughter houses (Plate 2.21). These are located on the bank of the river itself, draining all their waste directly into it. At Jingthangbriew, which on translation literally means "Cremation Place", is located a wood-based crematorium where the dead belonging to the indigenous religion are cremated (Plate 2.22). Further downstream, another weir at the foot of the Jaiaw Lumsyntiew hill diverts water to the Sonapani Mini Hydro Project (Plate 2.23). This is one of the oldest mini hydro projects in the country which has lain in ruins for a long time before its revival in the past few years by the Meghalaya State Electricity Board.

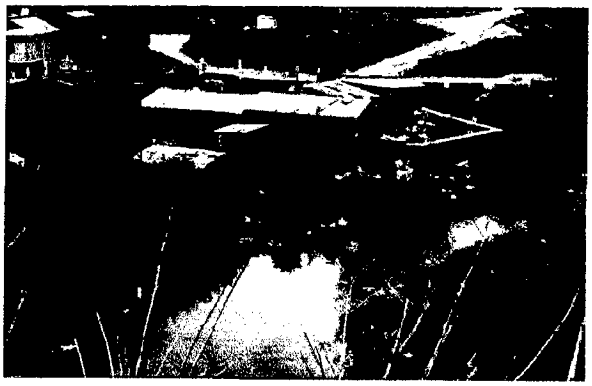

Plate 2.21: Slaughter house at Mawlai

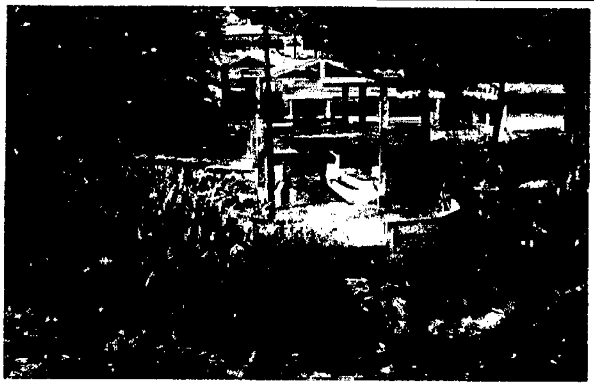

Plate 2.22: Wood-based crematorium at Jingthangbriew

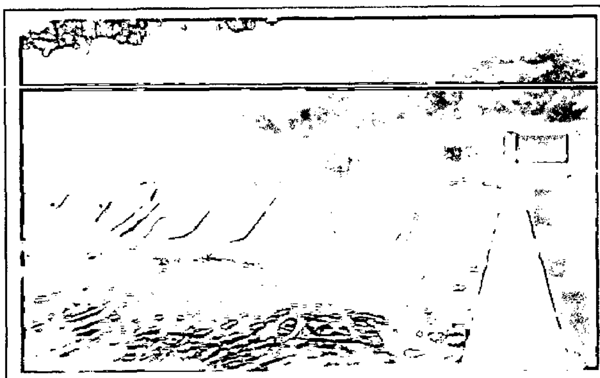

Plate 2.23: Diversion weir for hydro power generation

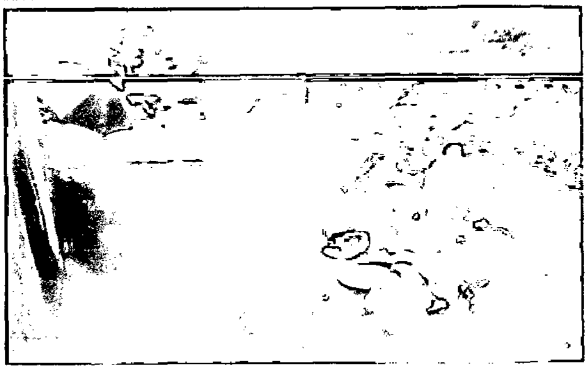

Plate 2.24: Natural spring water collected in a tank and used for domestic purposes at Mawpdang

At the last sampling station, Mawpdang, is a natural spring which has served as a source of drinking water for scores of years now (Plate 2.24). Another natural drain, Wah Disoi, joins the river here. This drain brings with it more solid waste, slaughter house waste and also bio-medical waste from the K.J.P. Assembly Hospital at Jaiaw (Plates 2.25 and 2.26), in addition to all the domestic and commercial waste already in the river.

Plate 2.25: Solid waste accumulated at Mawpdang

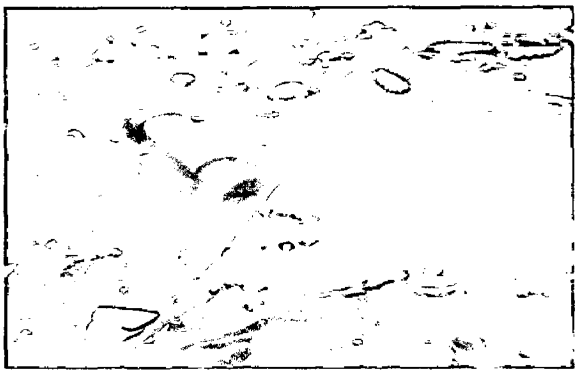

Plate 2.26: Bio-medical and other wastes brought by Wah Disoi to Mawpdang

It is obvious that the water quality of the River Umkhrah is poor and the activities along its banks have contributed a lot to its deterioration. Thousands of households that live on the river banks depend on it for drinking water supply, while also spilling kitchen and toilet waste into it [F]. Therefore, its conservation and restoration is of utmost importance for the citizens of Shillong and necessary steps have to be taken by all concerned.

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CHAPTER 3

WATER QUALITY INDICES

3.1 INTRODUCTION

It is an accepted fact that water is the most important natural resource without which life on earth will not exist. Some anaerobic bacteria can live without oxygen but not without water. The role of water as a life sustainer has been taken for granted by human beings. It was not until the 1960s that consciousness concerning the water quality and not only water quantity has started in the mind of the public [1].

While water quantity can be easily expressed in terms of volume, mass and discharge, water quality is much more complex to explain and express. The quality of water of a particular water body may be good for drinking but it may not be suitable as a coolant in an industry. As water is the 'universal solvent', its quality will depend on the type of materials dissolved in its journey along the hydrological cycle.

One way to express the quality of water is by listing out the concentrations of everything that the water contains. This list will be as long as the number of constituents analyzed and can be anything from twenty common constituents to hundreds. Comparing the quality of different samples of water is thus, almost an impossible task. For example, a sample of water having six parameters – pH, hardness, chloride, sulphate, iron and sodium – 5% above the permissible limits may not be as bad for drinking as another sample with just one constituent – e.g. mercury– at 5% higher than permissible [1].

The quest for determining the quality of water has led to the collection of a large volume of data in the past four to five decades. With the development of technology, this volume of data has been increasing at a very fast pace and it is challenging man's ability to understand and assimilate it [24]. This vast volume of data has to be analyzed and presented in such a way that everyone from the policy and decision makers and layman can understand it. Water quality data is very difficult to present in a simple way but the concept of "water quality index" has been found as the easiest way of expressing it.

An index is a means devised to reduce a large quantity of data down to its simplest form, retaining essential meaning for the questions being asked of the data. In short, an index is designed 'to simplify' [24]. It is a number that is created by mathematically combining a set of numbers. It does not represent a particular measurement, but it can be used to make comparisons simpler. A water quality index (WQI) combines several different water quality parameters. The parameters used to develop a WQI are picked up based on the historical information, ecological importance, human use, seasonal fluctuations, and other considerations [G]. In the process of simplification, some information is lost. However, if designed properly, the lost information will not seriously distort the true picture [24].

Water quality indices are generally of two forms:

i) those in which the index numbers increase with increasing pollution, and
ii) those in which the index numbers decrease with increasing pollution.

Some specialists in the field refer to the former as "environmental pollution" indices and the latter as "environmental quality" indices. However, these terms are not universally accepted. The general terms for these indices are either "increasing scale" form, in which the index values increase with increasing pollution, or "decreasing scale" form, in which the index values decrease with increasing pollution [24].

A versatile WQI generally should satisfy the following conditions:

i) the value of the index changes with changes in the values of each of the water quality variables,
ii) the changes in the value of an index should be more significant due to a variable which produces more significant impact to the water quality,
iii) the value of an index should approach the poorest designated value when a critical variable, whose concentration beyond the permissible levels cannot be compromised, exceeds the permissible limits, and
iv) the value of an index should remain unchanged when a variable's concentration changes within its permissible limits [17].

3.2 HISTORICAL DEVELOPMENT

The concept of using indices to represent in a single value the status of several variables is not a novel idea. It has been a common method in economics and commerce for a very long time now, e.g. the 'consumer price index' is a single value obtained on the basis of an integration of the prices of certain commodities in order to determine whether the market is, overall, cheaper or costlier at any given instant compared to any other past instant. Similarly, a WQI gives a single value to the water quality of a source by integrating the concentrations of its constituents. In this way, one can easily compare the quality of different sources of water [1].

Water quality indices have gained popularity during the last three decades. This concept, in its very rudimentary form, was first introduced in Germany way back in 1848 when the presence or absence of certain biological organisms in water was used as an indicator of its level of purity or pollution. Since then, several European countries have developed and applied different systems to classify the quality of the water within their boundaries. These water classification systems usually were of two types:

i) those concerned with the amount of pollution present, and
ii) those concerned with living communities of macro- and microscopic organisms.

Rather than assigning a numerical value to represent water quality, these classification systems categorized water bodies into one of several pollution classes or levels. By contrast, indices using a numerical scale to represent gradations in water quality levels is a recent phenomenon, beginning with Horton's index in 1965 [24].

3.3 SIGNIFICANCE OF INDICES

It has been emphasized by agencies responsible for water supply and control of water pollution that it is desirable to develop and utilize water quality indices, as the role played by these indices is usually linked to the basic reason for which environmental monitoring data are collected. Indices play a role in evaluating the effectiveness of regulatory activities and in translating the complex data into a form that is easily understood. The indices serve as convenient tools to examine trends, to highlight specific environmental conditions, and to help governmental decision-makers in evaluating the effectiveness of regulatory programme [1].

A report by the Planning Committee on Environmental Indices of the National Academy of Sciences (NAS), United States of America (1975) indicated that the indices play an important role in four ways:

i) To assist in formulating policy;
ii) To provide a means for judging the effectiveness of environmental protection programmes;
iii) To assist in designing these programmes; and
iv) To facilitate communications with the public concerning conditions of the environment and progress towards its enhancement [24].

Wayne Ott [24] identifies six basic uses of indices:

o Resource allocation	Indices may be applied to water related decisions to assist managers in allocating funds and determining priorities.
o Ranking of Locations	Indices may be applied to assist in comparing water quality at different locations or geographical areas.
o Enforcement of standards	Indices may be applied to specific locations to determine the extent to which legislative standards and existing criteria are being met or exceeded.
o Trend Analysis	Indices may be applied to water quality data at different points in time to determine the changes in the quality (degradation or improvement) which have occurred over the period.
o Public Information	Indices may be used to keep the public informed about the overall water quality of any source, or of different alternative sources, on a day-to-day basis.
o Scientific Research	Indices may be used to reduce a large quantity of complex water quality data to a simple form which makes their application very valuable in scientific research.

The development of water quality indices remains quite a controversial issue with the primary debate centering on the amount of information which is lost in the process of simplification from a huge quantity of data to a simple number. One view holds that the raw, undoctored data give the best means of evaluating water quality and the distortions caused by index development are unacceptable. This view is usually held by those involved with water quality measurements. On the contrary, persons not involved in water quality measurement are more willing to accept the distortion for the reason that indices give a simplified picture of the water quality of a source. This argument illustrates the "classic dichotomy" of views towards all types of environmental indices.

3.4 DEVELOPMENT OF INDICES

The calculation of an index consists of the following fundamental steps:

i) selection of pollutant variables or parameters,
ii) transformation of the pollutant variables with different units and dimensions to a common scale by calculating the sub-indices for each variable,
iii) assignment of weightages to the different pollutant variables, and
iv) aggregation of the sub-indices into the overall index.

Selecting pollutant variables for an index is a very difficult job. From among the hundreds of variables a water sample can have, one has to choose only a set of a few variables which together will reflect the overall water quality for the given end use. It is here that subjectivity creeps in as different experts and end users may have different perceptions of the importance of a variable vis-à-vis a given end use. This step in index development is as fraught with uncertainty and subjectivity as it is crucial to the usefulness of the index. Hence, enormous care, attention, experience and consensus-gathering skills are required to ensure that only the most representative variables are included in a particular index.,

Subindices are developed to transform the units and ranges of concentration of the different variables selected into a single scale. If we consider a set of observations for *n* pollutant variables in which X_1 denotes the observed value for the first pollutant variable, X_2 denotes the observed value for the second pollutant variable, and X_i denotes the value of the *ith* pollutant variable, then the set of observations is denoted as (X_1, X_2,....X_i,....X_n). For each pollutant variable X_i, a subindex I_i is computed using subindex function $f_i(X_i)$:

$$I_i = f_i(X_i) \qquad ...(3.1)$$

Generally, indices use different mathematical functions to compute each pollutant variable, giving the subindex functions $f_1(X_1)$, $f_2(X_2)$, ..., $f_n(X_n)$. Essentially, each subindex function represents the environmental characteristics of the particular pollutant variable. It may consist of a simple multiplier, or the pollutant variable raised to a power, or some other functional relationship.

Selecting weightages for the different pollutant variables is another step which is a matter of personal opinion, hence, subjectivity again creeps in. In some indices, equal weightage is given to all the variables. But in a majority of indices, different weightages are assigned to different variables. For this step, well formulated techniques of opinion gathering such as the Delphi Method are utilized to minimize subjectivity and enhance credibility.

Once the subindices are calculated, these are usually aggregated together in a second mathematical step to form the final index:

$$I = g(I_1, I_2, ..., I_n) \qquad ...(3.2)$$

The aggregation function usually consist either of a summation operation, in which individual subindices are added together, or a multiplication operation, in which a product is formed of some or all of the subindices, or a maximum operation, in which just the maximum subindex is reported. The characteristics of the different aggregation functions are shown in Table 3.1.

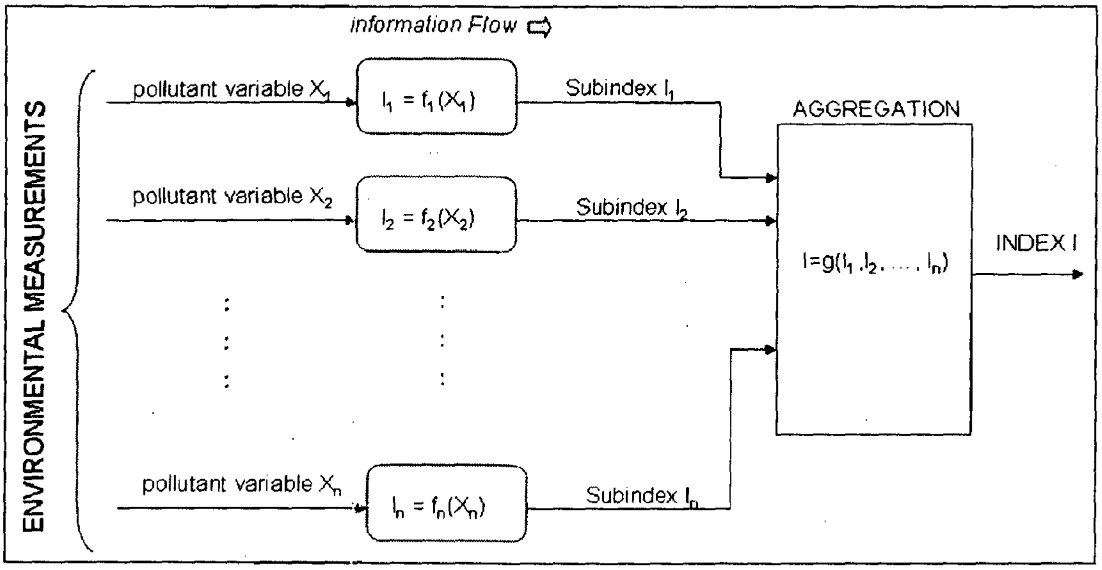
TABLE 3.1: CHARACTERISTICS OF AGGREGATION FUNCTIONS

S. No.	Aggregation Function	Increasing Scale Indices	Decreasing Scale Indices
1	Additive Forms		
	Linear Sum	Ambiguity; no eclipsing	Eclipsing; no ambiguity
	Weighted Sum	Eclipsing; no ambiguity	Eclipsing; no ambiguity
	Root-Sum-Power	Minimizes eclipsing and ambiguity as the power to which the variable is raised to approaches ∞	Eclipsing; no ambiguity

2	Maximum Operator	No eclipsing; no ambiguity	Not applicable
3	Multiplicative Forms Weighted Product	Not applicable	No eclipsing; no ambiguity Nonlinear if weights are small
4	Minimum Operator	Not applicable	No eclipsing; no ambiguity

Source: [24]

The overall process of calculation of subindices and their aggregation to form the final index can be illustrated in a flow diagram shown in Figure 3.1:



Source: [24]

Figure 3.1: Information flow process in a water quality index

3.5 CLASSIFICATION OF WATER QUALITY INDICES

Wayne Ott [24] has classified the different water quality indices developed into four general categories:

1) General water quality indices,
2) Specific-use indices,
3) Planning indices, and
4) Indices based on statistical approach.

3.5.1 General water quality indices

Water has a variety of different uses, such as human consumption, irrigation, recreation and maintenance of fish and wildlife habitats, and the requirements for water quality differ with different intended use. Some indices, however, are based on the assumption that "water quality" is a general attribute of surface waters, irrespective of the use to which the water is put. Such indices are called as general water quality indices which include:

3.5.1.1 ***Horton's Quality Index:*** Horton's index was the first formal water quality index which was introduced in 1965 [24]. Horton selected eight of the most commonly measured water quality variables for his index and fixed weights ranging from 1 to 4 for each variable (Table 3.2). Among the variables, specific conductance served as an approximate measure of total dissolved solids (TDS) and carbon chloroform extract (CCE) reflected the influence of organic matter. The variable "sewage treatment" (percentage of population served) was designed to reflect the effectiveness of abatement activities on the premise that "chemical and biological measures are of little significance until substantial progress has been made in eliminating discharges of raw sewage". A major drawback of Horton's index was that it did not include the effects of toxic substances.

TABLE 3.2: VARIABLES AND THEIR WEIGHTS FOR HORTON'S INDEX

S.No.	Variable	Weights
1	Dissolved Oxygen	4
2	Sewage Treatment	4
3	pH	4
4	Coliforms	2
5	Specific Conductance	1
6	Carbon Chloroform Extract	1
7	Alkalinity	1
8	Chloride	1

Source: [24]

The final index was computed using a linear sum aggregation function. It consists of the weighted sum of the subindices divided by the sum of the weights multiplied by two coefficients, M_1 and M_2, which reflect temperature and obvious pollution respectively.

$$QI = \frac{\sum_{i=1}^{n} w_i I_i}{\sum_{i=1}^{n} w_i} M_1 M_2 \qquad \ldots(3.3)$$

Horton's index has the advantage that it is very easy to calculate though the two coefficients M_1 and M_2 need a lot of "tailoring" to fit into individual situations. The index structure, its weights and rating scale are highly subjective as they are based on the judgment of the author and a few of his associates only. However, the credit goes to Horton for his pioneering efforts in starting a trend which has influenced many later day workers.

3.5.1.2 ***National Sanitation Foundation's Water Quality Index (NSFWQI):*** In 1970, Brown, McClelland, Deininger and Tozer [24] presented a water quality index supported by the National Sanitation Foundation, United States of America. This index came to be popularly known as the National Sanitation Foundation's Water Quality Index (NSFWQI). It was developed using a formal procedure based on the Rand Corporation's Delphi Technique combining the opinions of a large number of water quality experts of the U.S.A. In this approach, the experts were given a questionnaire and their opinions were tabulated and reported to each member. This enabled the members to see and compare his response vis-à-vis that of the others. The experts were given two more sets of questionnaires and were asked to prepare rating curves to finally arrive at a consensus on the index. After analysis of all the questionnaires, the investigators identified 9 individual variables and 2 grouped variables of greatest importance. The individual variables were DO, faecal coliforms, pH, BOD, nitrates, phosphates, temperature, turbidity and total solids. The grouped variables were toxic substances and pesticides. The curves arrived at by the experts are shown in Figures 3.2 to 3.10. In each figure, the solid line represents the arithmetic mean of all panelists' curves, while the dotted lines bounding the shaded area represent the 80% confidence limits.

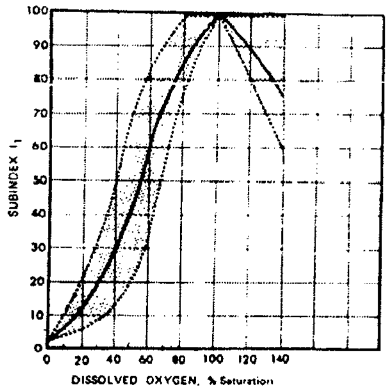


Figure 3.2: Subindex function for DO

(For DO > 140%, $I_1 = 50$)

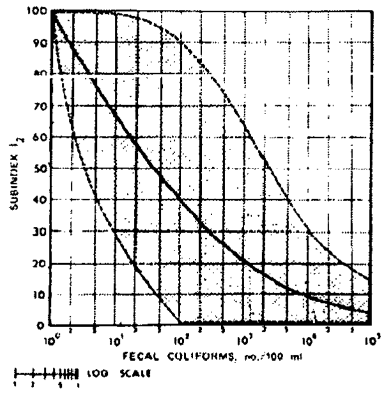


Figure 3.3: Subindex function for faecal coliforms

(For FC > 10^5 / 100ml, $I_2 = 2$)

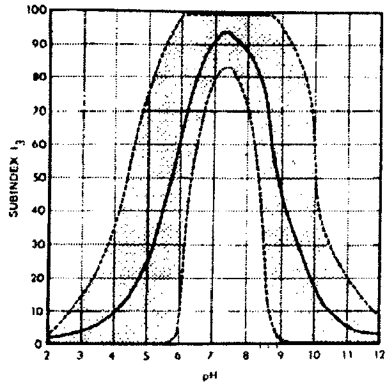


Figure 3.4: Subindex function for pH

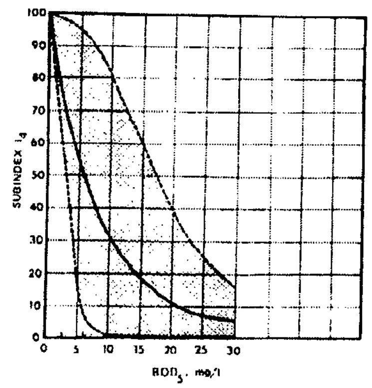


Figure 3.5: Subindex function for BOD

(For BOD > 30 mg/L, $I_4 = 2$)

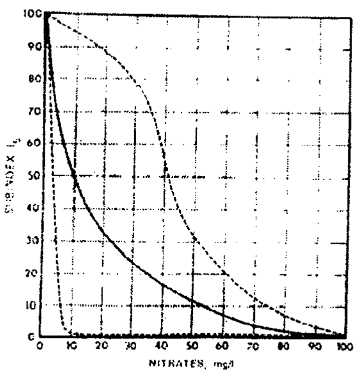


Figure 3.6: Subindex function for nitrates

(For nitrates > 100 mg/L, $I_5 = 1$)

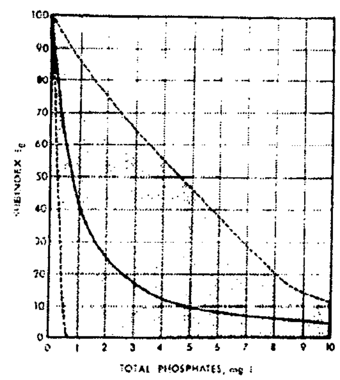


Figure3.7:Subindex function for total phosphates

(For total phosphates > 10 mg/L, $I_6 = 2$)

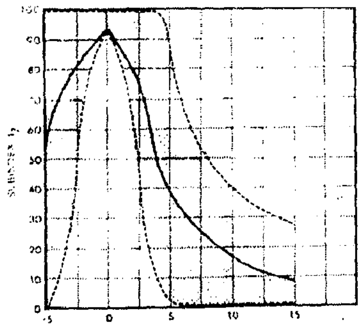


Figure 3.8: Subindex function for temperature deviation from equilibrium (ΔT)

(For $\Delta T > 15°C$, $I_7 = 5$)

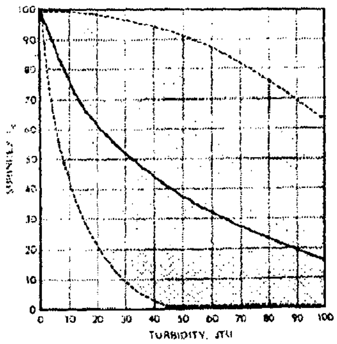


Figure 3.9: Subindex function for turbidity

(For turbidity > 100 JTU, $I_8 = 5$)

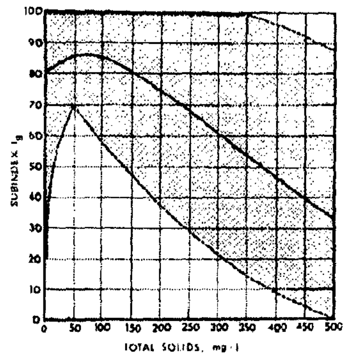


Figure 3.10: Subindex function for total solids

(For total solids > 500 mg/L, $I_9 = 20$)

As for the two grouped variables, it was unanimously agreed by all panelists that for pesticides, the NSFWQI would automatically be set to zero if the concentration of detectable pesticides (of all types) exceeds 0.1 mg/L and for toxic substances and it would be set to zero if any toxic substance exceeded its assigned upper limit, as prescribed in published drinking water standards.

The next step was to derive a set of weights which would sum to 1.0 but which would reflect the significance ratings assigned to the variables by the panelists. The arithmetic means of the significance ratings were calculated for all variables rated (Table 3.3). "Temporary weights" were then derived by dividing the variable with the highest significance rating, i.e. DO which is 1.4, by the significance rating of each variable. Finally, each temporary weight was divided by the sum of the temporary weights to give the subindex weights (last column of Table 3.3).

TABLE 3.3: SIGNIFICANCE RATINGS AND WEIGHTS FOR THE NINE POLLUTANT VARIABLES

S. No.	Parameters	Mean of all significance ratings returned by respondents	Temporary weights	Final weights
1	Dissolved oxygen	1.4	1.0	0.17
2	Faecal coliforms	1.5	0.9	0.15
3	pH	2.1	0.7	0.12
4	BOD (5-day)	2.3	0.6	0.10
5	Nitrates	2.4	0.6	0.10
6	Phosphates	2.4	0.6	0.10
7	Temperature	2.4	0.6	0.10
8	Turbidity	2.9	0.5	0.08
9	Total solids	3.2	0.4	0.08
		Total	**5.9**	**1.00**

Source: [24]

The temperature pollutant variable is defined as the deviation from equilibrium temperature (degrees Celsius). Equilibrium temperature is that which occurs without the influence of a heated or cooled discharge. In field applications, two temperatures are taken: one at the sampling site and one at some point upstream where a heated or cooled discharge is known to be absent.

To calculate the index, one has to read the subindex value I_i from the appropriate curve for the pollutant variable i_n. The subindices are then multiplied by the weighting factor to arrive at a subtotal for each variable. The nine resulting subtotals are then added using a weighted linear summation:

$$NSFWQI_a = \sum_{i=1}^{n} w_i I_i \qquad \ldots(3.4)$$

The results can be entered into a worksheet as shown in Figure 3.11.

Water Quality Index Worksheet

Date/Time of Test ______________________________

Location Sampled______________________________

Tester's Name______________________________

Test Parameter	Test Results	Q- Value	Weighing Factor	Total
BOD	(mg/L)		0.11	
Dissolved Oxygen	(% saturation)		0.17	
Fecal Coliform	(colonies/100 mL)		0.16	
Nitrates	(mg/L)		0.10	
PH	(Units)		0.11	
Temperature			0.10	
Total Dissolved Solids	(mg/L)		0.07	
Total Phosphate	(mg/L)		0.10	
Turbidity	(NTU)		0.08	

Overall Water Quality Index ______________

Figure 3.11: NSFWQI Worksheet

Finally, the developers of the NSFWQI also suggested a way of reporting the index. This reporting procedure relates the index values to five descriptor words and to colours of the spectrum as shown in Table 3.4 below.

TABLE 3.4: DESCRIPTOR WORDS AND COLOURS SUGGESTED FOR REPORTING THE NSFWQI

S.No.	Descriptor Words	Numerical Range	Colour
1	Very Bad	0- 25	Red
2	Bad	26- 50	Orange
3	Medium	51- 70	Yellow
4	Good	71- 90	Green
5	Excellent	91-100	Blue

Source: [24]

The NSFWQI is the most widely used of all existing water quality indices. It has been field-tested and applied to data from a number of different geographical areas and has withstood the tests. It is an effective technique for reporting water quality data, examining trends and evaluating the effectiveness of water pollution control programmes. Another advantage of the NSFWQI is that if data of all the 9 variables are not available, the overall WQI can still be estimated by adding the results and then adjusting for the number of pollutant variables with available data. For example, if there are 2 variables with no available data, the 7 remaining subtotals are added and the 7 weighting factors are added. The former is then divided by the latter to obtain the final WQI [H].

The main limitation of the additive form of the NSFWQI is eclipsing of the result when a single pollutant variable shows extremely poor water quality. This has been overcome by using the multiplicative form, which is equivalent to the weighted product aggregate with the same weights becoming powers of the subindices.

$$NSFWQI_m = \prod_{i=1}^{n} I_i^{w_i} \qquad \ldots(3.5)$$

3.5.1.3 ***Prati's Implicit Index of Pollution:*** This index was developed by Prati, Pavanello and Pesarin [24] in 1971 on the basis of water quality standards used in a number of countries. The concentration values of all the pollutants were transformed into levels of pollution expressed in new units through mathematical expressions. These mathematical expressions were constructed in such a way that the new units were proportional to the polluting effect relative to other factors. In this way even if a pollutant is to be present in smaller concentrations than other pollutants, it still will exert a large impact on the index score if its polluting effect is greater. In the fist step, thirteen pollutant variables were selected and water quality was classified into five Classes based on water quality standards (Table 3.5).

TABLE 3.5: CLASSIFICATION OF WATER QUALITY FOR THE DEVELOPMENT OF PRATI'S INDEX

	Condition:	Excellent	Acceptable	Slightly Polluted	Polluted	Heavily Polluted
	Classes:	I	II	III	IV	V
S.No.	Index of Quality:	1	2	4	8	>8
1	pH	6.5–8.0	6.0–8.4	5.0–9.0	3.9–10.1	<3.9 to >10.1
2	DO (% Sat)	88–112	75–125	50–150	20–200	<20 to >200
3	BOD_5 (ppm)	1.5	3.0	6.0	12.0	>12.0
4	COD (ppm)	10	20	40	80	>80
5	Permanganate (mg/L O_2 Kubel Test)	2.5	5.0	10.0	20.0	>20.0
6	Suspended solids (ppm)	20	40	100	278	>278
7	NH_3 (ppm)	0.1	0.3	0.9	2.7	>2.7
8	NO_3 (ppm)	4	12	36	108	>108
9	Cl (ppm)	50	150	300	620	>620
10	Iron (ppm)	0.1	0.3	0.9	2.7	>2.7
11	Manganese (ppm)	0.05	0.17	0.5	1.0	>1.0
12	Alkyl Benzene Sulphonates (ppm)	0.09	1.0	3.5	8.5	>8.5
13	Carbon Chloroform Extract (ppm)	1.0	2.0	4.0	8.0	>8.0

Source: [24]

In the second step, one pollutant was taken as reference and its actual value was considered directly as reference index. In the third step, mathematical expressions were formed to transform each of the values of the other pollutants into indices. This transformation took into account the polluting capacity of the parameters related to selected reference parameter. In the construction of these functions, the analytical properties of various curves were used to ensure that the resulting transformation would be applicable not only to small values of pollutant concentrations but also to those exceeding Class V. The resulting subindex functions are given in Table 3.6 below.

TABLE 3.6: SUBINDEX FUNCTIONS OF PRATI'S INDEX OF POLLUTION

S. No	Parameter	Subindex Equations	
1	Dissolved Oxygen (%)	$I = 0.00168\ X^2 - 0.249\ X + 12.25$ $I = -0.08\ X + 8$ $I = 0.08\ X - 8$	$0 \le X < 50$ $50 \le X < 100$ $100 \le X$
2	pH (units)	$I = -0.4\ X^2 + 14$ $I = -2\ X + 14$ $I = x^2 - 14x + 49$ $I = -0.4x^2 + 11.2x + 64.4$	$0 \le X < 5$ $5 \le X < 7$ $7 \le X < 9$ $9 \le X < 14$
3	5-Day BOD (mg/L)	$I = 0.666667\ X$	
4	COD (mg/L)	$I = 0.10\ X$	
5	Permanganate, Kubel Test (mg/L O_2)	$I = 0.04\ X$	
6	Suspended Solids (mg/L)	$I = 2^{[2.1 \log (0.1\ X - 1)]}$	
7	Ammonia (mg/L)	$I = 2^{[2.1 \log (10\ X)]}$	
8	Nitrates (mg/L)	$I = 2^{[2.1 \log (0.25\ X)]}$	
9	Chlorides (mg/L)	$I = 0.000228\ X^2 + 0.0314X$ $I = 0.000132\ X^2 + 0.0074\ X + 0.6$ $I = 3.75\ (0.02\ X - 5.2)^{0.5}$	$0 \le X < 50$ $50 \le X < 300$ $300 \le X$
10	Iron (mg/L)	$I = 2^{[2.1 \log(10\ X)]}$	
11	Manganese (mg/L)	$I = 2.5\ X + 3.9\sqrt{X}$ $I = 5.25\ X^2 + 2.75$	$0 \le X < 0.5$ $0.5 \le X$
12	Alkyl Benzene Sulphonates (mg/L)	$I = -1.2\ X + 3.2\ \sqrt{X}$ $I = 0.8\ X + 1.2$	$0 \le X < 1$ $1 \le X$
13	Carbon Chloroform Extract (mg/L)	$I = X$	

Source: [24]

The index was computed as the arithmetic mean of the thirteen subindices by the following formula:

$$I = \frac{1}{13} \sum_{i=1}^{13} I_i \qquad ...(3.6)$$

The index ranges from 0 to 14 (and above) and was applied by Prati *et al* to data on surface waters in Ferrana, Italy. It should be noted that toxic substances were not included in the index as it was felt that in case a toxic substance is present in concentrations above a given limit, the index is automatically classified in the highest category, i.e. heavily polluted.

3.5.1.4 ***McDuffie's River Pollution Index:*** The River Pollution Index was presented by McDuffie and Haney [24] in 1973. It is a relatively simple water quality index consisting of eight pollutant variables. Most subindices were of the general form:

$$I_i = 10\left(\frac{X}{X_N}\right)_i \qquad ...(3.7)$$

where I_i = subindex for the *ith* pollutant variable
X = observed value of the pollutant variable
X_N = natural level of the pollutant variable

Six of the eight subindices described by McDuffie and Haney were explicit linear functions, and two (coliform count and temperature) were explicit non-linear functions (Table 3.7). The index did not include pH or toxic substances.

TABLE 3.7: SUBINDEX FUNCTIONS FOR McDUFFIE'S INDEX

S. No.	Parameter	Subindex	
1	Percent Oxygen Deficit	I = 100 – X	X = DO (%)
2	"Biodegradable" Organic Matter	I = 10 X	X = BOD_5 (ppm)
3	"Refractory" Organic Matter	I = 5 (X - Y)	X = COD Y = BOD_5
4	Coliform Count (no./100 ml)	$I = 10\left(\frac{\log X}{\log 3}\right)$	
5	Nonvolatile Suspended Solids (ppm)	I = X	
6	Average Nutrient Excess	$I = 5\left(\frac{X}{0.2} + \frac{Y}{0.1}\right)$	X = Total N (ppm) Y = Total PO_4 (ppm)

7	Dissolved Salts	$I = 0.25\,X$	X = Specific conductance(µmho/cm)
8	Temperature	$i = \frac{X^2}{6} - 65$	

Source: [24]

The index was computed as the sum of n subindices times a scaling factor 10/(n+1):

$$RPI = \frac{10}{n+1}\sum_{i=1}^{n} I_i \qquad \ldots(3.8)$$

The purpose of the scaling factor was to make the index vary from approximately 100, i.e. the river's "natural levels", to approximately 1000, i.e. "highly polluted" levels of the river. However, the index can go below 100 and theoretically, it can even approach zero. Thus, the theoretical range of this index is from 0 to above 1000.

3.5.1.5 ***Dinius' Social Accounting System:*** This index was introduced in 1972 and it was a first step towards the design of a "rudimentary accounting system" which would measure the costs and impact of pollution control efforts [12]. This index was viewed as the forerunner of the 'planning' or 'decision-making' indices. Eleven parameters were selected and their subindices were represented by explicit mathematical functions (Table 3.8).

TABLE 3.8: SUBINDEX FUNCTIONS FOR DINIUS' WATER QUALITY INDEX

S. No.	Parameter	Subindex	
1	Dissolved Oxygen (%)	$I = X$	
2	5 – Day BOD (mg/L)	$I = 107\,(X)^{-0.642}$	
3	Total Coliforms (MPN/100ml)	$I = 100\,(X)^{-0.3}$	
4	Faecal Coliforms (MPN/100ml)	$I = 100\,(5\,X)^{-0.3}$	
5	Specific Conductance (µmho/cm at 25°C)	$I = 535\,X^{-3565}$	
6	Chlorides (mg/L)	$I = 125.8\,X^{-0.207}$	
7	Hardness ($CaCo_3$, ppm)	$I = 10^{1.974 - 0.00132\,X}$	
8	Alkalinity ($CaCo_3$, ppm)	$I = 108\,X^{-0.178}$	
9	pH	$I = 10^{0.2335\,X + 0.44}$ $I = 100$ $I = 10^{4.22 - 0.293X}$	$X < 6.7$ $6.7 \le X \le 7.58$ $X > 7.58$

10	Temperature (°C)	$I = -4(x_a - x_s) + 112$	x_a = actual temperature X_s= standard temperature
11	Colour (C units)	$I = 128\,X^{-0.288}$	X is in C units measured after all suspended matter, evaluated by turbidity, is removed

Source: [24]

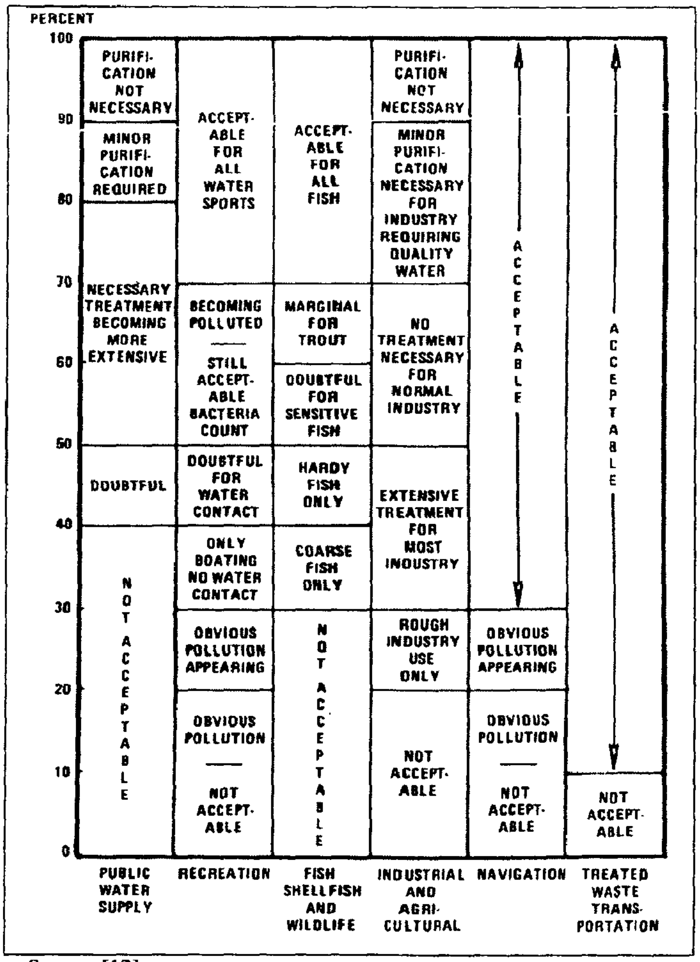
The index was calculated as the weighted sum of the subindices by the following expression:

$$I = \frac{1}{21}\sum_{i=1}^{11} w_i I_i \qquad ...(3.9)$$

The weights ranged from 0.5 to 5 on a "basic scale of importance". On this scale, 1,2,3,4 and 5 denote, respectively, "very little", "little", "average", "great" and "very great" importance. The weights sum to 21, which is the denominator in the index equation. The index is defined over the range from 0 to 100, although limits must be placed on the range of each variable to avoid values above 100.

Although this was a general water quality index, Dinius suggested that specific water used could be accommodated by interpreting the index numbers differently for each water use. She proposed descriptor language for each of the six specific water uses (Figure 3.12). Besides terms like "acceptable" and "not acceptable", the descriptor language differs greatly for the various water uses. This language illustrates the diverse ways in which water quality can be interpreted for different uses.

3.5.1.6 ***Oregon Water Quality Index:*** The Oregon Water Quality Index (OWQI) was introduced in the 1970s and was improved in 1995 to reflect the advances in the knowledge of water quality and in the design of water quality indices. It is a single number that expresses the quality of river water by integrating the measurements of eight water quality variables, viz. temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia+nitrate nitrogen, total phosphorus, total solids and faecal coliform [10]. It aids in the assessment of water quality for general recreational uses (i.e. fishing and swimming). The criginal OWQI was modeled after the National



Source: [12]

Figure 3.12: Descriptor language suggested by Dinius

Sanitation Foundation's Water Quality Index (NSFWQI). The water quality variables were chosen using the Delphi method and logarithmic transforms were used to convert water quality variable results into subindex values. Logarithmic transforms take advantage of the fact that a change in magnitude at lower levels of impairment has a greater impact than an equal change in magnitude at higher levels of impairment. In the original index, six variables, viz. dissolved oxygen saturation, biochemical oxygen demand, pH, total solids, ammonia+nitrate and faecal coliform, and their weighting factors were chosen by a panel of water quality experts. The present OWQI also includes temperature and total phosphorus because of their significance to water quality of the streams.

For calculating the subindices of each pollutant variable, a set of graphs and equations have been presented (Figures 3.13 to 3.21). The subindex can be either read from the graph or calculated by using the equations.

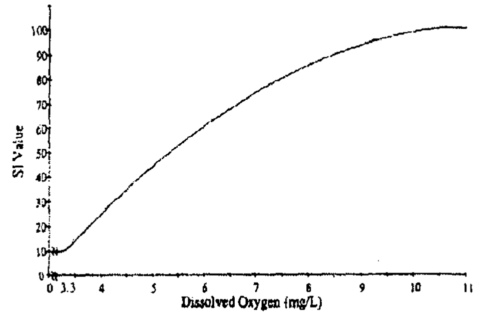


Figure 3.13: Dissolved Oxygen Concentration Subindex (SI_{DOc})

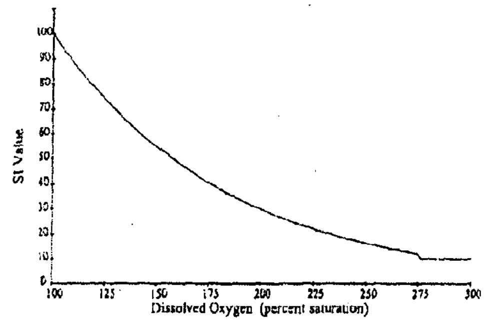


Figure 3.14: Dissolved Oxygen Supersaturation Subindex (SI_{DOs})

DO saturation (DO_s) $\leq$ 100% :

DO concentration (DO_c) $\leq$ 3.3 mg/L	SI_{DO} = 10
3.3 mg/L < DO_c < 10.5 mg/L	$SI_{DO} = -80.29 + 31.88 \times DO_c - 1.401 \times DO_c^2$
10.5 mg/L $\leq$ DO_c	SI_{DO}=100
100% < DO_s $\leq$ 275% :	$SI_{DO} = 100 \times \exp(DO_s - 100) \times -1.197E\text{-}2$
275% < DO_s :	SI_{DO} = 10

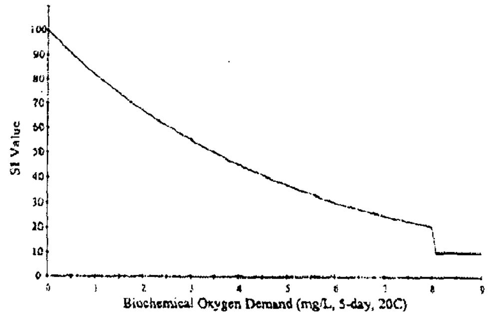


Figure 3.15: Biochemical Oxygen Demand Subindex (SI_{BOD})

BOD $\leq$ 8mg/L: $SI_{BOD} = 100 \times \exp(BOD \times -0.1993)$

8mg/L < BOD: SI_{BOD} = 10

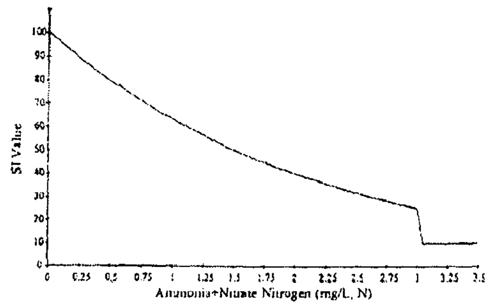


Figure 3.16: Ammonia+Nitrate Nitrogen Subindex (SI_N)

N $\leq$ 3mg/L: $SI_N = 100 \times \exp(N \times -0.4605)$

3mg/L < N: SI_N = 10

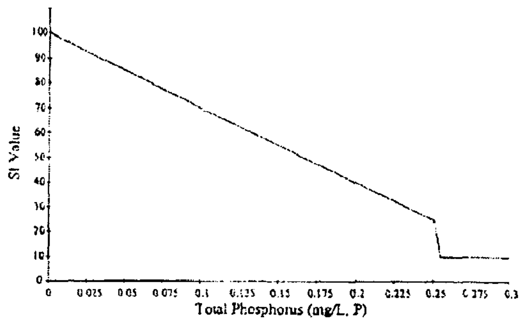


Figure 3.17: Total Phosphorus Subindex (SI_P)

$P \leq 0.25 mg/L$: $SI_P = 100 - 299.5 \times P - 0.1384 \times P^2$

$0.25 mg/L < P$: $SI_P = 10$

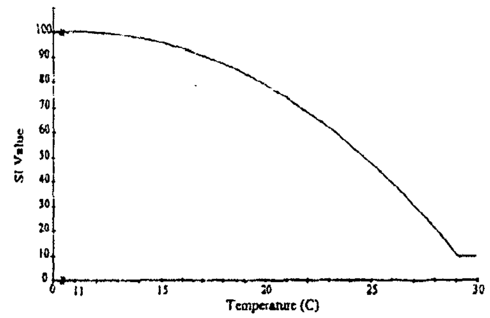


Figure3.18: Temperature Subindex (SI_T)

$T \leq 11°C$: $SI_T = 100$

$11°C < T \leq 29°C$: $SI_T = 76.54 + 4.172 \times T - 0.1623 \times T^2$

$29°C < T$: $SI_T = 10$

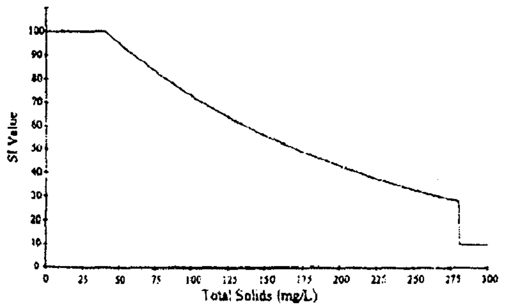


Figure 3.19: Total Solids Subindex (SI_{TS})

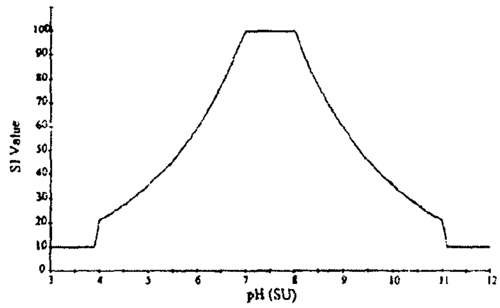


Figure 3.20: pH Subindex (SI_{pH})

$pH < 4$: $SI_{pH} = 10$

$4 \leq pH < 7$: $SI_{pH} = 2.628 \times \exp(pH \times 0.5200)$

$7 \leq pH \leq 8$: $SI_{pH} = 100$

$8 < pH \leq 11$: $SI_{pH} = 100 \times \exp((pH-8) \times -0.5188)$

$11 < pH$: $SI_{pH} = 10$

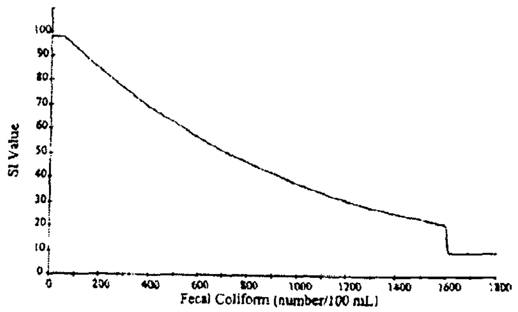


Figure 3.21: Faecal Coliform Subindex (SI_{FC})

$FC \leq 50$ #/100mL: $SI_{FC} = 98$

50 #/100mL $< FC \leq 1600$ #/100mL: $SI_{FC} = 98 \times \exp((FC-50) \times -9.9178E-4)$

1600 #/100mL $< FC$: $SI_{FC} = 10$

The final WQI was calculated by combining a group of subindices by using the unweighted harmonic square mean formula for aggregation. The formula is given by:

$$WQI = \sqrt{\frac{n}{\sum_{i=1}^{n} \frac{1}{SI_i^2}}} \qquad ...(3.10)$$

where *WQI* is Water Quality Index, *n* is the number of subindices and SI_i is the subindex *i*. This formula allows the most impaired variable to impart the greatest influence on the water quality index. It also acknowledges the fact that the different water quality variables will have different impacts to overall water quality at different times and locations.

The OWQI scores are classified as follows:

S.No.	SCORES	CLASSIFICATION
1	10 – 59	Very poor
2	60 – 79	Poor
3	80 – 84	Fair
4	85 – 89	Good
5	90 - 100	Excellent

The OWQI has been successfully used in comparing conditions across several river basins and to detect trends over time. The OWQI is also useful for indicating impairment of water quality and the progress of water quality management practices. The OWQI has helped to improve the comprehension of general water quality issues and to communicate water quality status to the public.

The main limitations of the OWQI are that it cannot determine the quality of water for specific uses and it cannot be used to provide exact information about water quality without considering all appropriate chemical, biological and physical data. Moreover, it cannot evaluate all health hazards and, most importantly, as it was developed for Oregon's streams only, its application to other geographical regions or waterbody types may not give the desired results.

3.5.1.7 ***Said, Stevens and Sehlke Water Quality Index:*** The Said, *et al* Water Quality Index (WQI) [26] was developed with a view to have an index which uses fewer water quality variables and which can be used to compare sites having different water quality. This WQI was constructed using only the basic water quality variables, which include dissolved oxygen (DO), faecal coliform, turbidity, total phosphorus and specific conductance. The other variables that affect the water quality, such as pH, temperature, and nitrogen are reflected to a certain degree by these basic variables. This index is further simplified by the fact that the step for calculating subindices has been eliminated. The measured water quality variables need not be standardized and the final WQI is calculated using a mathematical equation. After the water quality variables chosen for the index had been ranked according to their significance, several forms were tested to give DO the highest weight followed by faecal coliform and total phosphorus. Dissolved oxygen expressed in percent saturation reflects the temperature effect. Turbidity and specific conductance were given the least influence. A final form was selected which keeps the index in a simple equation and a reasonable numerical range. The logarithm was used to give small numbers that are easily used by the decision-makers, the stakeholders and the general public. The proposed index is calculated by:

$$WQI = log\left[\frac{(DO)^{1.5}}{(3.8)^{TP}(Turb)^{0.15}(15)^{FCol/10000} + 0.14(SC)^{0.5}}\right] \quad \ldots(3.11)$$

where DO is the dissolved oxygen (% oxygen saturation)

Turb is the turbidity (Nephelometric turbidity units) [NTU]

TP is the total phosphorus (mg/L)

FCol is the faecal coliform (counts/100ml)

SC is the specific conductivity (μS/cm at 25°C)

The powers of the variables chosen for the WQI were based on the effect of each variable on water conditions. For example, as higher values of faecal coliform and total phosphorus will be very harmful for health and aquatic life, the forms of these variables in the index formula were chosen to give strong responses to these effects, whereas turbidity and specific conductance have linear effects and are less sensitive for changing the values of the variables.

The index was designed to range from 0 to 3. The maximum or ideal value of this index is 3 and is possible in very good waters that have 100% dissolved oxygen, no TP, no faecal coliform, turbidity less than 1 NTU, and specific conductance less than 5 µS/cm. From 3 to 2, the water is acceptable and values less than 2 mean that the water is marginal and some remediation processes are needed. If one or two variables have deteriorated, the value of this index will be less than 2. If most of the variables have deteriorated, the index is less than 1, which means that water quality is poor.

The limitations of this index are:

(1) It can only be used to assess water quality for general uses.
(2) It cannot be used in making regulatory decisions or to indicate water quality for specific uses.
(3) It cannot always show the impact of random short-term changes, such as a spill, except if it occurs repeatedly or for a long time. The best results with this index can be obtained only in natural conditions and natural measurement sites (not downstream of river outfall).
(4) Localized changes in water quality are not immediately reflected.
(5) Changes in the stream habitat are not reflected by this index.
(6) The index cannot be used to indicate contamination from trace metals, organic contaminants, or other toxic substances.
(7) This index has also not considered the effects of biochemical oxygen demand which is a very important pollutant variable.

3.5.2 Specific-use indices

These are indices designed for specific water use and include indices such as O'Connor's Indices designed for public water supply, Deininger and Landwehr's Public Water Supply Index, Walski and Parker's Index designed for recreation, Stoner's Index designed for public water supply and irrigation, etc.

3.5.2.1 ***O'Connor's Indices:*** O'Connor developed two water quality indices for specific, but very different, water uses. His first index was the Fish and Wildlife (FAWL) index and it was intended to describe the quality of a surface body of raw water used to sustain a population of fish and wildlife. His second index was the Public Water Supply (PWS) index which was intended to describe the quality of a surface body of raw water which will be treated as necessary and used for public water supplies. Both indices were developed using Delphi technique to reduce the subjectivity in selection of the pollutant variables and their weights. The pollutant variables and their weights for both indices were compared with the NSFWQI in Table 3.9.

TABLE 3.9: COMPARISON OF WEIGHTS USED IN THREE WATER QUALITY INDICES

S. No.	Pollutant Variable	NSFWQI	O' Connor's Indices	
			FAWL	PWS
1	Dissolved Oxygen	0.17	0.206	0.056
2	Faecal Coliforms	0.15	-	0.171
3	pH	0.12	0.142	0.079
4	BOD_5	0.10	-	-
5	Nitrates	0.10	0.074	0.070
6	Phosphates	0.10	0.064	-
7	Temperature	0.10	0.169	-
8	Turbidity	0.08	0.088	0.058
9	Total Solids	0.08	-	-
10	Dissolved Solids	-	0.074	0.084
11	Phenols	-	0.099	0.104
12	Ammonia	-	0.084	-
13	Fluorides	-	-	0.079
14	Hardness	-	-	0.077
15	Chlorides	-	-	0.060
16	Alkalinity	-	-	0.058
17	Colour	-	-	0.054
18	Sulphates	-	-	0.050
	Total	**1.00**	**1.00**	**1.00**

Source: [24]

The overall FAWL and PWS indices were computed as the weighted sum of the subindices times a factor which takes into account pesticides and toxic substances:

$$I_{FAWL} = \delta \sum_{i=1}^{9} w_i I_i \qquad ...(3.12)$$

$$I_{PWS} = \delta \sum_{i=1}^{11} w_i I_i \quad \text{...(3.13)}$$

where δ = 0 if pesticides or toxic substances exceeded recommended limits

δ = 1 otherwise

3.5.2.2 *Deininger and Landwehr's Public Water Supply Index:* In 1971, Deininger and Landwehr presented a water quality index which was intended for water used for public water supply (PWS). They employed an 11-variable index for surface water sources and a 13-variable index for ground water sources. To finally calculate the index, two aggregation functions were considered – an additive form and a geometric mean. The 11-variable and 13-variable versions of the index were computed for each aggregation function:

<u>Additive</u>

$$PWS_{11} = \sum_{i=1}^{11} w_i I_i \quad \text{...(3.14)}$$

$$PWS_{13} = \sum_{i=1}^{13} w_i I_i \quad \text{...(3.15)}$$

<u>Geometric Mean</u>

$$PWS_{11} = \left[\prod_{i=1}^{11} I_i^{w_i}\right]^{1/11} \quad \text{...(3.16)}$$

$$PWS_{13} = \left[\prod_{i=1}^{13} I_i^{w_i}\right]^{1/13} \quad \text{...(3.17)}$$

The variables along with their associated weights for the two versions are compared with NSFWQI in Table 3.10.

TABLE 3.10: COMPARISON OF WEIGHTS IN THE NSFWQI AND THE TWO (ADDITIVE) WATER SUPPLY INDICES

S. No.	Pollutant Variable	NSFWQI	Deininger and Landwehr	
			PWS_{11}	PWS_{13}
1	Dissolved Oxygen	0.17	0.06	0.05
2	Fecal Coliforms	0.15	0.14	0.12
3	pH	0.12	0.08	0.07
4	5 – Day BOD	0.10	0.09	0.08
5	Nitrates	0.10	0.10	0.09

6	Phosphates	0.10	-	-
7	Temperature	0.10	0.07	0.06
8	Turbidity	0.08	0.09	0.08
9	Total Solids	0.08	-	-
10	Dissolved Solids	-	0.10	0.08
11	Phenols	-	0.10	0.08
12	Colour	-	0.10	0.08
13	Hardness	-	0.08	0.07
14	Fluorides	-	-	0.07
15	Iron	-	-	0.07
	Total	**1.00**	**1.01**	**1.00**

Source: [24]

3.5.2.3 *Walski and Parker's Index:* Walski and Parker introduced this index in 1974. It was based on empirical information on the suitability of water for a particular use, and was developed specifically for the recreational water, such as swimming and fishing. The authors introduced four general categories of variables:

(1) Those which affect aquatic life (e.g. DO, pH, and temperature),

(2) Those which affect health (e.g. coliforms),

(3) Those which affect taste and odour (e.g. threshold odour number); and

(4) Those which affect the appearance of the water (e.g. turbidity, grease and colour).

The subindices consist of nonlinear and segmented nonlinear explicit functions (Table 3.11). The authors determined values for the parameters which would be considered "perfect", "good", "poor" and "intolerable" and assigned each of these values the numbers 1.0, 0.9, 0.1 and 0.01 respectively. With these sets of values, the sensitivity functions could be found easily.

TABLE 3.11: SUBINDEX FUNCTIONS OF WALSKI AND PARKER'S INDEX

S. No.	Pollutant Variable	Equation	Range
1	Dissolved oxygen (mg/L)	$I = e^{[0.3\,(X-8)]}$	$0 < X \leq 8$
		$I = 0$	$8 < X$
2	pH (Standard Units)	$I = 0$	$X < 2$
		$I = 0.04\,[25 - (X-7)^2]$	$2 \leq X \leq 12$
		$I = 0$	$12 < X$

3	Total Coliforms (no./100 ml)	$I = e^{-0.0002X}$	
4	Temperature (°C) Actual Deviation	$I = 0.0025 [1 - (X - 20)^2]$ $I = 0$ $I = 0.01 (100 - \Delta X^2)$ $I = 0$	$0 \leq X \leq 40$ $\Delta X < -10$ $-10 \leq \Delta X \leq 10$ $10 < \Delta X$
5	Phosphates (mg/L)	$I = e^{-2.5X}$	
6	Nitrates (mg/L)	$I = e^{-0.16X}$	
7	Suspended Solids (mg / L)	$I = e^{-0.02X}$	
8	Turbidity (JTU)	$I = e^{-0.001X}$	
9	Colour (C units)	$I = e^{-0.002X}$	
10	Grease Thickness (μ) Concentration (mg/ L)	 $I = e^{-0.35X}$ $I = e^{-0.016X}$	
11	Odour (threshold odour number)	$I = e^{-0.1X}$	
12	Secchi Disk Transparency (m)	$I = \log (X+1)$ $I = 1$	$X \leq 9$ $9 < X$

Source: [24]

The final index was calculated by aggregating the subindices using a geometric mean function as follows:

$$I = \left[\prod_{i=1}^{12} I_i^{w_i} \right]^{1/12} \qquad \ldots (3.18)$$

3.5.2.4 ***Stoner's Index:*** Stoner proposed an index designed for use in public water supply and irrigation. This index employed a single aggregation function which selected from two sets of recommended limits and subindex equations. This approach was viewed as a general structure designed to accommodate any water use. Although Stoner applied the index to just two water uses, it could be adapted to additional water uses as well. Two types of water quality parameters were used in the Stoner's index:

Type 1: Parameters normally considered toxic (e.g. lead, chlordane and radium–226)

Type 2: Parameters which affect health or aesthetic characteristics (e.g. chlorides, sulphur, colour, taste and odour).

The Type 1 pollutant variables were treated in a dichotomous manner, giving subindex step functions. Each Type 1 subindex was assigned the value of zero if the concentration was less than or equal to the recommended limit and the value negative 100 if the recommended limit is exceeded. A total of 26 Type 1 pollutant variables were used in the public water supply version and 5 Type 1 variables were used in the irrigation version of the index. The Type 2 pollutant variables were represented by explicit mathematical functions. A total of 13 Type 2 pollutant variables were included in the public water supply version and 16 Type 2 variables in the irrigation version of the index. The constants in each subindex equation were selected so that I=0 when a recommended limit is reached and I=100 when the "ideal" value of that pollutant variable was attained. The overall index was computed by combining the unweighted Type 1 subindices with the weighted Type 2 subindices:

$$I = \sum_{i=1}^{n} T_i + \sum_{j=1}^{m} w_j I_j \qquad \text{...(3.19)}$$

where T_i = subindex for the i^{th} Type 1 pollutant variable

w_j = weight for the j^{th} Type 2 pollutant variable

I_j = subindex for the j^{th} Type 2 pollutant variable

3.5.3 Planning indices

These indices are designed specifically for management decision-making and they do not usually depict ambient water quality or related conditions. Instead, they are "custom-designed" to assist the user in making specific decisions or in solving particular problems. Planning indices often incorporate variables other than those routinely measured by water pollution monitoring programmes. For example, a planning index designed for allocating water pollution abatement funds might include the "cost of wastewater treatment facilities". Some of such indices are MITRE's National Planning Priorities Index (NPPI), Dee's Environmental Evaluation System, Inhaber's Canadian National Index, Johanson and Johnson's Pollution Index, etc.

3.5.3.1 ***MITRE's National Planning Priorities Index (NPPI):*** It was designed as a tool for assigning priorities to different demand sectors in order to ensure that funds are granted and used in a cost-effective manner for the planned water treatment projects.

Each subindex was calculated using a segmented linear function and the final index was computed as the weighted sum of 10 sub indices:

$$\text{NPPI} = \sum_{i=1}^{10} w_i I_i \qquad \ldots(3.20)$$

3.5.3.2 ***Dee's Environmental Evaluation System:*** Dee *et al* proposed a system for evaluating the environmental impact of large scale water resources projects. The system included a water quality index, which was represented by 12 common water quality variables (such as DO pH, turbidity and faecal coliforms), besides pesticides and toxic substances. The subindices of various water quality variables were similar to those in the NSFWQI. The index was calculated with and without considering the proposed water resources project. The difference between the two scores provided a measure of the environmental impact (EI) of the project:

$$\text{EI} = \sum_{i=1}^{78} w_i I_i[\text{with}] - \sum_{i=1}^{78} w_i I_i[\text{without}] \qquad \ldots(3.21)$$

3.5.3.3 ***Inhaber's Canadian National Index:*** The Environmental Quality Index was suggested by Inhaber in 1974 as a national index for Canada. It included an air quality index, a water quality index, and a land quality index. The water quality index combined two subindices in a root mean square operation – an ambient water quality subindex and a pollutant source subindex based on effluents from point sources. The ambient water quality subindex, in turn, comprised of three subindices:

(1) a trace metals subindex based on cadmium, lithium, copper, zinc and the hardness of water;
(2) a turbidity subindex; and
(3) a commercial fish catch subindex based on weight and mercury content of fish landed by Canadian ships.

The pollutant source subindex was based on pollutant variables measured in effluents from five sources, viz. municipal wastes, the petroleum-refining, chlor-alkali, fish-processing and paper industries. The subindices were combined in successive root mean square operations.

3.5.3.4 ***Johanson and Johnson's Pollution Index:*** Johanson and Johnson (1976) developed a planning index as a tool to assist in the process of identifying locations of in-place pollutants, particularly toxic pollutants, in harbours and navigable waterways and to take steps to remove and dispose of them. They used the index to screen 652 data sets from waterways across the United States of America. For each location Pollution Index (PI) was computed as follows:

$$PI = \sum_{i=1}^{n} w_i C_i \qquad \dots(3.22)$$

where w_i = weight for pollutant variable i,

C_i = highest concentration of pollution variable i reported in a location of interest.

For each pollutant i, the weight was based on the reciprocal of the median of observed national concentrations. Using the index, it was possible to scan the data by computer and identify the locations receiving the highest priority for removal of pollutants.

3.5.4 Indices based on statistical approach

These indices usually employ some standard statistical procedure, already available in literature, adapted for use with water quality data. The statistical approaches have the advantage that they incorporate fewer subjective assumptions than the traditional indices. However, they are more complex and often more difficult to apply. Harkin's Index is an example of this type of indices.

3.5.4.1 ***Harkin's Index:*** Harkin presented a statistical approach for analyzing water quality data based on the rank order of observations. It begins with ranking the observations for each pollutant variable, including a control value, which is usually a water quality standard or recommended limit. For each observation j of pollutant variable i, the transform Zij was computed as the difference between the rank order of the observation and the rank order of the control value (R_{ic}), divided by the standard deviation of the ranks S:

$$Z_{ij} = \frac{R_{ij} - R_{ic}}{S_i} \qquad ...(3.23)$$

where R_{ij} = rank of the j^{th} observation of the i^{th} variable

R_{ic} = rank of the control value for the i^{th} variable

S_i = standard deviation of the ranks for the i^{th} variable

The index was computed for each observation by adding the square of the transform for n pollutant variable:

$$I_j = \sum_{i=1}^{n} z_i{}^2{}_j \qquad ...(3.24)$$

The standard deviation s_i was calculated as follows:

$$s_i = \sqrt{\frac{m_i^2 - 1}{12}} \qquad ...(3.25)$$

where m_i = number of values (observation + control value) for pollutant variable i.

In Harkin's treatment, the same value often appears more than once; these repeated values reduce the variance and must be taken into account. When repeated values occur, the standard deviation s_i is calculated as follows:

$$s_i = \left[\frac{1}{12m_i}\left[m_i^3 - m_i - \sum_{k=1}^{q_i}\left(t^3 - t\right)_k\right]\right] \qquad ...(3.26)$$

where m_i = number of values for each variable I

t = number of repeated values (ties)

q_i = number of separate occurrences of ties

Harkin's index is a relative rather than an absolute index. Values generated with one data set can not be compared directly with those generated with a different data set.

3.6 INDICES SELECTED FOR DETERMINING THE WATER QUALITY OF THE RIVER UMKHRAH

Three indices for general water use were selected for studying the water quality of the River Umkhrah, viz. the National Sanitation Foundation's Water Quality Index (NSFWQI), the Oregon Water Quality Index (OWQI) and the Said, Stevens and Sehlke Water Quality Index. With the river being visibly much polluted, no specific uses were possible with its water. Hence, only general water quality indices were selected. Sufficient literature was available explaining how to calculate these three indices. Further, the water quality data available was insufficient for calculating the other general water use indices. Many variables required for their calculation were either not available or not reported.

The NSFWQI was selected because it was the most widely used water quality index in the world. It had been field tested in different river basins all over the world and it had proven its applicability. The pollutant variables included in this index were variables commonly monitored in all river monitoring programmes. Hence, data availability became easier. The calculation of the final index was a very simple aggregation function only. The colour scheme suggested by Brown *et al* for representing the index, made interpretation and understanding of the water quality at different points along the river very easy.

The OWQI was an offshoot of the NSFWQI. Baring a few, the pollutant variables selected were almost identical. This index was chosen basically to have a comparison of the index values obtained by the two indices. This index was also easy to calculate and the only limitation was that data for only six out of the eight variables was available. Despite this, the similarity in results could be observed.

The Said *et al* water quality index was selected only on the basis that it did not have a step for calculating subindex and the final index was calculated by putting the concentration values of the pollutant variables directly into a mathematical formula. The intention was to observe how different it was from the previous two traditionally constructed indices.

These three indices were chosen to assess the water quality of the River Umkhrah at different locations along its stretch and along a few of its tributaries. These indices will help us to reduce the large amount of water quality data into simple numbers which can easily be interpreted and understood. Index values, thus, calculated can be mapped to show the spatial and temporal changes of water quality in the river. The index values can also form the basis for making decisions on the type and extent of conservation measures to be taken to restore the river back to its original condition.

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CHAPTER 4

WATER QUALITY ASSESSMENT OF RIVER UMKHRAH

4.1 INTRODUCTION

For the present study, no fresh water quality data was generated. The data used has been taken from a report on a joint study, conducted by the Centre of Environmental Studies, North Eastern Hill University (NEHU), Shillong and the Meghalaya State Pollution Control Board (MSPCB), Shillong, entitled "Assessment of the Water Quality of River Umkhrah" [23]. The data taken from this report has been used in the calculation of all the three water quality indices chosen. The methodology adopted for sampling and description of the sampling locations are as follows.

4.2 WATER QUALITY SAMPLING

The first step of the sampling programme was to conduct a preliminary survey along the River Umkhrah and its tributaries and incoming drains so as to be able to select sampling locations which will be representative of the entire river and also to identify the river water uses and polluting activities. The next step was the selection of the physico-chemical and bacteriological parameters for monitoring of the river water.

Ten sampling locations were selected along the River Umkhrah and five locations on the major tributaries and feeding drains. Table 4.1 summarized the description of the sampling locations.

TABLE 4.1 DESCRIPTION OF SAMPLING LOCATIONS

S. No.	Location designation	Name of location	Description	Visible pollution
1	1	Lapalang (Plate 4.1)	• It is located in the outskirts of the city • It is surrounded by human settlements • A small part is also under cultivation	• Domestic waste water • Outlets of latrines open directly into the river • Solid waste from the houses and surrounding shops

2	2	Umpling Bridge (Plate 4.2)	• It is surrounded by urban settlements • A perennial spring exists near the location. Water from the spring is used for domestic purposes	• Domestic waste water • Solid waste • Direct discharge from latrines
3	3	Umkaliar (Plate 4.4)	• It is located between two hillocks • Upwelling of ground water in the surroundings has formed small swamps • River water used for washing clothes and vehicles • Increased water flow due to addition from ground water	• Waste water from washing of clothes and vehicles • Oil and grease from washing of vehicles
4	4	Demseiniong (Plate 4.5)	• Northern bank is under cultivation while southern bank is urban settlement	• Domestic waste water • Solid waste • Direct discharge from latrines
5	5	Pynthorumkhrah	• It is located among dense human settlement • Many household drains join the river directly	• Domestic waste water • Solid waste • Direct discharge from latrines
6	6	Polo (behind Stadium) (Plate 4.6)	• It is located behind the Jawaharlal Nehru Sports Complex • The river flows through a sandy pool • Banks are vegetated on stadium side and under settlement on the opposite side	• Domestic waste water • Solid waste from surrounding houses, shops and restaurants • Direct discharge from latrines
7	7	Rooprekha (Plate 4.7)	• It is surrounded by human settlement • Several drains join the river	• Domestic waste water • Solid waste • Direct discharge from latrines
8	8	Jingthangbriew (Plate 4.8)	• It is surrounded by settlements	• Domestic waste water • Solid waste

			• A wood-based crematorium exists near the location	• Direct discharge from latrines • Construction debris
9	9	Wah Thangsning	• It is located near the slaughter house in Mawlai Phudmuri • Presence of some vegetation along the banks • A natural spring joins the river here	• Slaughter house waste • Animal blood • Domestic waste water • Solid waste • Direct discharge from latrines
10	10	Mawpdang Bridge (Plate 4.9)	• It is surrounded by human settlements • Banks are vegetated • A natural spring exists near the location. The spring water is collected in a tank and used for domestic purposes	• Waste water from washing of clothes • Solid waste
11	A	Refugee Colony (Plate 4.10)	• It is one of the major tributaries. It starts from Lawjynriew and flows through Lower Nongthymmai and Laitumkhrah, which are densely populated localities	• Domestic waste water • Solid waste from surrounding houses, shops and restaurants • Direct discharge from latrines
12	B	Shillong College (Plate 4.11)	• It is another major tributary which starts from Lower Lachumiere and flows at the foothills of Shillong College • At midstream, this stream has more open spaces and fewer household, but the upstream and downstream are surrounded by human settlements	• Domestic waste water • Solid waste from houses, shops and restaurants
13	C	Polo Bridge (Plate 4.12)	• This tributary comes from the water overflowing from the Ward's Lake • It flows through densely	• Domestic waste water • Solid waste from surrounding houses, shops, restaurants and

			populated areas of Oakland, Jail Road and Polo	market places at Jail Road and Polo • Waste water overflowing from septic tanks
14	D	Opposite Jingthangbriew (Plate 4.13)	• It starts from a spring inside the Lawmali Reserved Forest • It is surrounded by cultivated fields	• Domestic waste water • Solid waste
15	E	Opp Mawpdang Bridge (Plate 4.14)	• This tributary joins the river near the Mawpdang Bridge sampling location • It flows through Lower Mawprem and beside a slaughter house	• Slaughter house waste • Animal blood • Domestic waste water • Solid waste • Hospital waste

The sampling locations are also shown in the map (Figure 4.1) and plates as below:

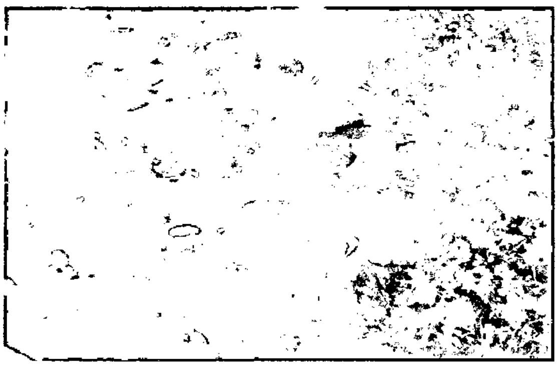

Plate 4.1 Lapalang

Plate 4.2 Umpling Bridge

Plate 4.3 Natural spring at Umpling Bridge

Plate 4.4 Umkaliar

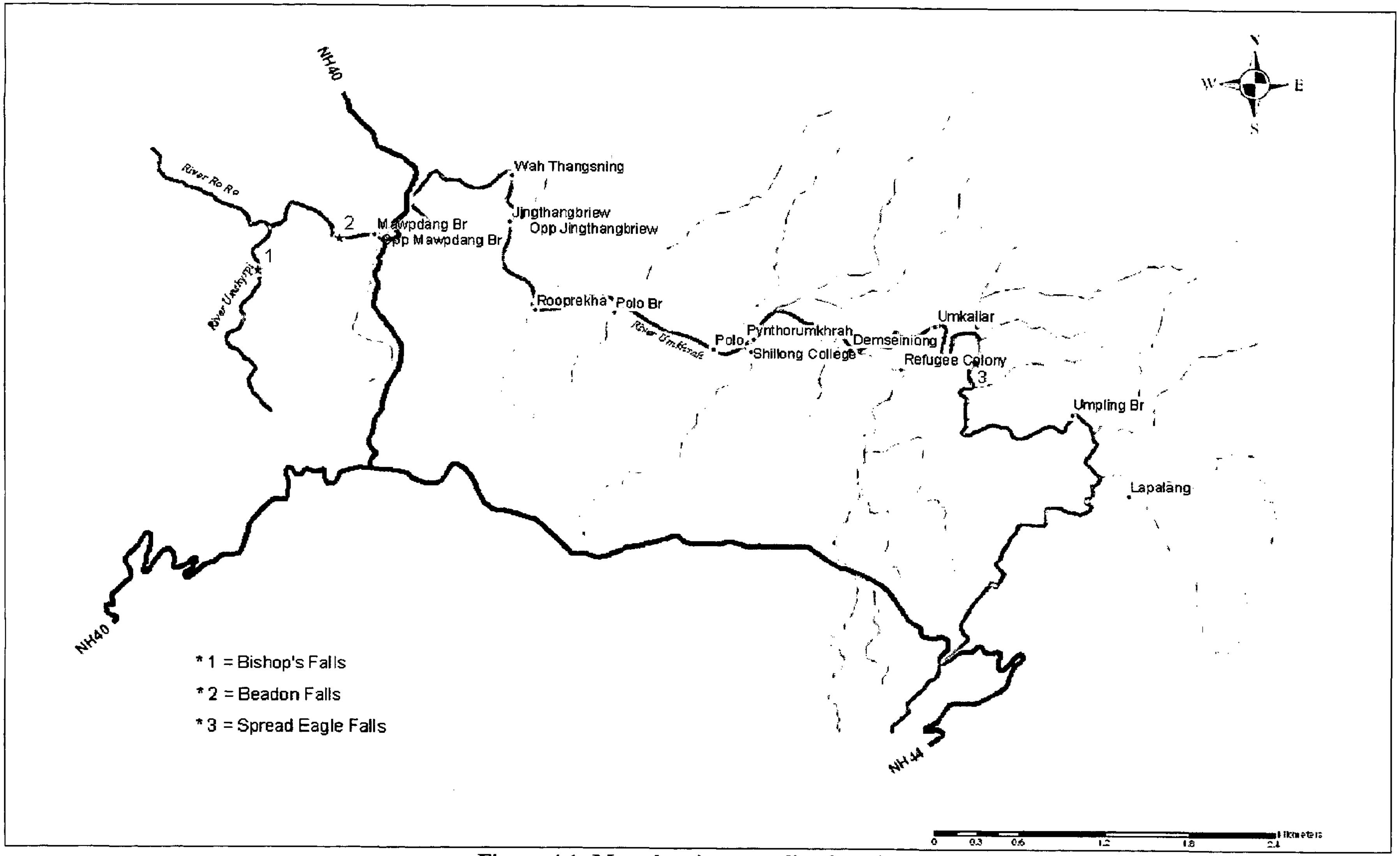

Figure 4.1: Map showing sampling locations

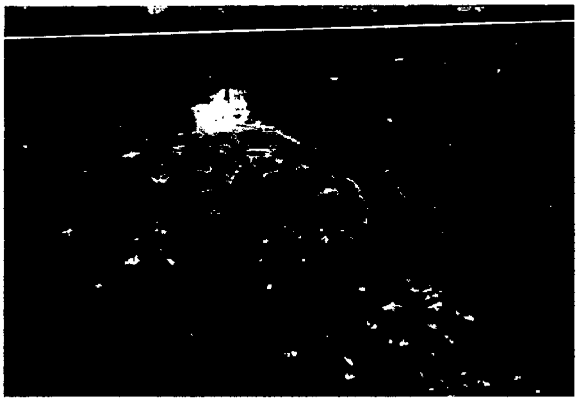

Plate 4.5 Demseiniong

Plate 4.6 Polo (behind Stadium)

Plate 4.7 Rooprekha

Plate 4.8 Jingthangbriew

Plate 4.9 Mawpdang Bridge

Plate 4.10 Refugee Colony

Plate 4.11 Shillong College

Plate 4.12 Polo Bridge

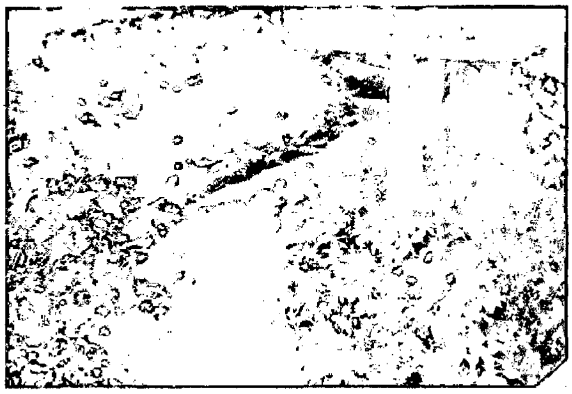

Plate 4.13 Opposite Jingthangbriew

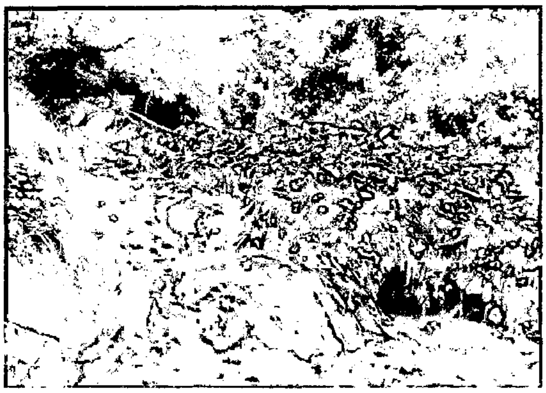

Plate 4.14 Opp Mawpdang Bridge

The water samples from these sampling locations were collected on monthly intervals for a period of one year starting from November 2001 upto October 2002. Water sampling, preservation of the samples and analysis were performed as per methods prescribed in the Standard Methods for Examination of Water and Wastewater, American Public Health Association, American Water Works Association and Water Environment Federation (17^{th} Edition) (APHA-AWWA-WEF, 1989). The physico-chemical and biological parameters monitored included temperature, turbidity, conductivity, pH, nitrate-nitrogen, dissolved oxygen, chemical oxygen demand, bio-chemical oxygen demand, coliforms, etc.

4.3 COMPUTATION OF WATER QUALITY INDICES

The NSFWQI was calculated using a software which was available on the internet from the site of the Wilkes University, Centre for Environmental Quality, Pennsylvania, U.S.A., viz. www.water-research.net/watrqualindex/waterqualityindex.htm [1]. To calculate the index, firstly, dissolved oxygen concentration had to be converted into percent saturation. This was done using the chart shown in Figure 4.2. For quick and easy determination of the percent saturation value for dissolved oxygen at a given temperature, this saturation chart can be used. This was done by pairing up the concentration (mg/L) of dissolved oxygen measured and the temperature of the water in degrees Celsius. A straight line was then drawn between the water temperature and the concentration of dissolved oxygen. The percent saturation was the value where the line intercepts the saturation scale. Secondly, input the concentration values of the pollutant variables one by one in the spaces provided in the software and note the subindex value that was returned. These subindex values were then inputted in a different table, which aggregated them and returned the NSFWQI value of the particular location. A flowchart showing the steps for calculating the NSFWQI is shown in Figure 4.3. The values returned by the software were validated by manual calculation and the difference in the values was found to be about 5% (Annexure 1).

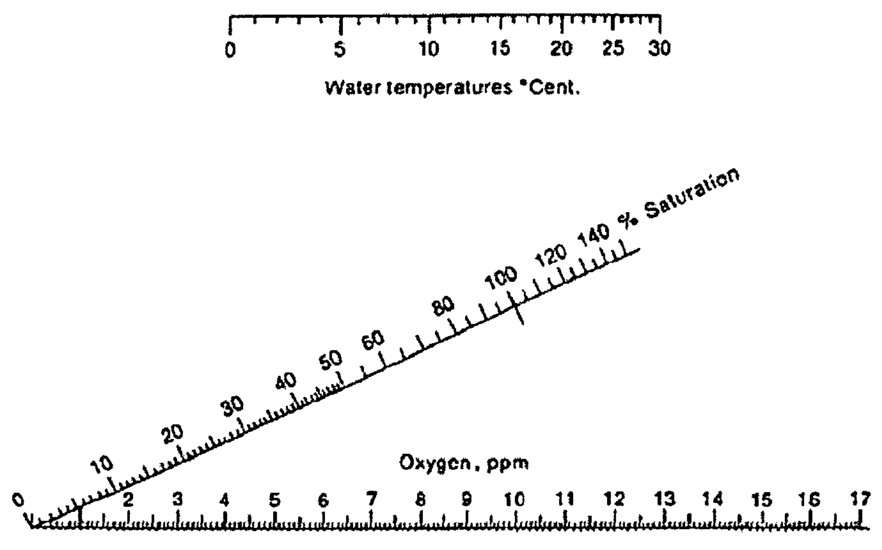

Figure 4.2: Chart for calculating percent DO

Source: [J]

The Oregon Water Quality Index and the Said, *et al* Water Quality Index were calculated manually by putting the concentration values of the pollutant variables directly in the mathematical equations provided ([10], [26]).

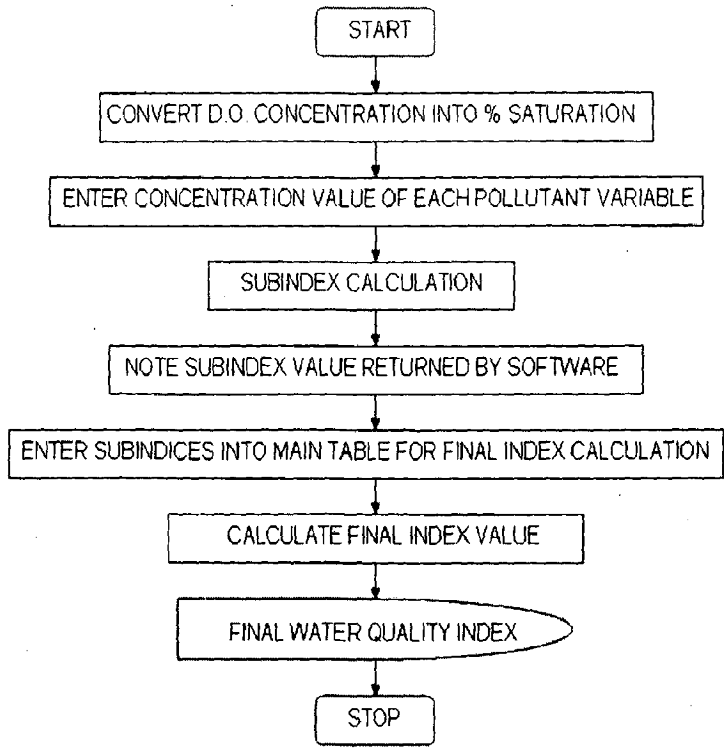

Figure 4.3: Flowchart showing the steps for calculating NSFWQI

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CHAPTER 5

RESULTS AND DISCUSSION

5.1 INTRODUCTION

As mentioned earlier, no fresh water quality data was generated for the present study. The water quality analysis results, of some of the relevant parameters only, taken from the report of the joint study conducted by the Centre of Environmental Studies, North Eastern Hill University (NEHU), Shillong and the Meghalaya State Pollution Control Board (MSPCB), Shillong, entitled "Assessment of the Water Quality of River Umkhrah" [23] are given in Annexure 2. Based on the above data, the three different water quality indices have been calculated and the results are shown and discussed below.

5.2 SAID, STEVENS and SEHLKE WATER QUALITY INDEX

The results of the Said, et al Water Quality Index, obtained by manually putting the values of the pollutant variable concentrations in Equation 3.11, are given in Table 5.1 (A, B and C).

From the table, we observe that most of the values are negative which indicate that the water quality is poor. The values obtained in 2001-02 and 2005 show no change in the quality of the river water. The highest index value obtained is 1.84, calculated for Umpling Bridge location in November 2001. However, even this value puts the water quality of that location for that month only in the marginal category. Sampling in 2005 was done in the lean season, so the water quality is very poor and at some locations, no result can be obtained because the dissolved oxygen concentration was zero. Since more weightage has been given to dissolved oxygen and faecal coliforms, this index shows very less variation when these two variables become critical. As the River Umkhrah has very high values of faecal coliforms and low values, even nil as recorded in 2005 (Annexure 2), of dissolved oxygen, the index returned negative or no values for most readings.

TABLE 5.1 SAID, STEVENS AND SEHLKE WATER QUALITY INDEX

A. River Umkhrah 2001-02

S. No.	Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
1.	Lapalang	-4.03	-4.67	-0.16	-1.87	0.09	0.54	-0.42	-0.42	0.89	0.81	0.42	-4.62
2.	Umpling Bridge	**1.84**	1.54	1.61	1.49	1.37	1.02	0.64	1.31	1.42	1.29	1.01	0.34
3.	Umkaliar	0.31	0.70	-1.22	0.56	-0.17	-1.09	0.24	0.58	0.36	0.59	0.67	-1.28
4.	Demseiniong	-1.17	-1.44	1.28	0.50	0.21	1.07	0.81	1.16	0.79	1.04	-0.21	-1.15
5.	Pynthor Umkhrah	-0.57	-0.66	-1.47	-0.26	-0.19	0.07	-0.26	0.34	0.64	-0.05	0.31	-1.73
6.	Polo (behind Stadium)	1.28	-0.07	0.88	-0.53	0.77	0.62	0.70	0.96	0.63	0.84	-0.06	-2.63
7.	Rooprekha	0.11	-0.72	-1.46	0.77	0.05	-1.04	-3.42	0.02	-1.07	-1.29	-1.71	-0.87
8.	Jingthang Briew	0.12	-5.09	-0.30	-14.95	-1.25	-0.06	-0.38	-23.91	-3.35	-1.20	-1.58	-1.45
9.	Wah Thang Sning	-15.16	-0.33	0.88	-4.76	-4.47	-1.12	-3.17	-1.04	-0.88	-1.19	-3.36	-1.11
10.	Mawpdang Bridge	-4.36	-4.96	-1.21	-5.00	-4.83	-4.25	-23.85	-1.23	-0.06	-1.67	-1.60	-14.82

B. River Umkhrah Tributaries 2001-02

S. No.	Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
1.	Refugee Colony	0.28	0.02	-0.10	0.00	-0.89	1.05	-0.29	-0.88	-0.11	-0.78	-1.59	-0.35
2.	Shillong College	-2.72	0.43	0.34	0.21	-1.77	-0.02	-1.63	-1.65	0.25	1.28	-1.10	-0.84
3.	Polo Bridge	-1.26	-3.74	-0.16	0.19	-0.59	-0.85	-1.18	-0.82	0.71	-1.08	-0.15	-1.76
4.	Opposite Jingthang Briew	-2.58	-3.53	0.67	-1.47	0.58	0.21	-0.04	-2.82	-1.76	-0.32	-2.15	-1.26
5.	Opposite Mawpdang Bridge	-6.43	-3.45	**-25.48**	-2.17	-3.02	-1.46	-20.18	-5.29	-1.13	-2.82	-14.96	-6.00

C. River Umkhrah 2005

S. No.	Sampling Location	22-4-2005	26-4-2005	6.5.2005	13-5-2005
1.	Wah Demthring	1.68	1.85	1.98	1.87
2.	Nongrah	0.14	-0.77	-0.54	-1.69
3.	Marboh Bridge	-5.87	-6.06	-7.81	-7.48
4.	Demseiniong	-6.35	*	-7.97	*
5.	Lawmali	-13.11	*	-10.11	*
6.	Wahingdoh	*	*	-18.61	*

CLASSIFICATION	INDEX VALUE
VERY GOOD	3
ACCEPTABLE	2 – 3
MARGINAL	1 – 2
POOR	< 1

This index may have reduced calculation time by considering only five pollutant variables and eliminating the step of subindex calculation, however, **it is not suitable for use in Indian conditions**. First of all, biochemical oxygen demand which is considered to be a very critical pollutant variable, especially in India, has not been considered. With the amount of organic waste dumped into the Indian rivers, dissolved oxygen saturation alone cannot reflect the organic pollutant that is being caused. Further, there are cases in which the dissolved oxygen level in the river is zero, as recorded in 2005 (Annexure 2). When this happens, the index cannot be calculated as there is no value for log (0). Secondly, faecal coliform is also a very important variable and its values are generally very high in Indian rivers. This automatically reduces the index value, even bringing it to the negative side, indicating poor water quality all the time. Thirdly, with only five pollutant variables selected and a fixed mathematical formula to work with, this index does not leave much room for further analysis.

It can, therefore, be concluded that this index only gives values which indicate that the water quality of the River Umkhrah is poor. Besides this, **it is not a flexible index and it cannot be used to represent water quality of rivers in India.**

5.3 OREGON WATER QUALITY INDEX

The Oregon Water Quality Index (OWQI) actually requires eight subindices to be calculated to obtain the final index value. In the present study, only six subindices have been calculated, viz. temperature, dissolved oxygen, biochemical oxygen demand, pH, faecal coliform and instead of total phosphorus, phosphates was considered. The reason for this is that data for ammonia, total solids and total phosphorus are not available from the water quality monitoring results. However, by putting the value of $n = 6$ in Equation 3.10, the final index value can be calculated. The results of the subindex calculations and the final OWQI, obtained by manually putting the values of the pollutant variable concentrations in the various equations, are shown in Table 5.2 to Table 5.5.

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(i) TEMPERATURE

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	93.323	100.000	93.323	95.665	90.460	87.062	83.118	90.460	95.665	93.323	95.665	95.665
Umpling Bridge	95.665	95.665	87.062	95.665	93.323	67.882	78.614	93.323	90.460	93.323	90.460	95.665
Umkaliar	93.323	95.665	91.957	95.665	93.323	87.062	78.614	90.460	90.460	93.323	93.323	90.460
Demseiniong	73.540	95.665	93.323	90.460	83.118	67.882	78.614	90.460	93.323	93.323	90.460	90.460
Pynthor Umkhrah	93.323	95.665	93.323	95.665	93.323	87.062	78.614	90.460	90.460	93.323	95.665	95.665
Polo (behind Stadium)	93.323	93.323	93.323	95.665	93.323	87.062	73.540	87.062	93.323	93.323	95.665	95.665
Rooprekha	93.323	95.665	93.323	95.665	93.323	87.062	73.540	87.062	93.323	93.323	95.665	95.665
Jingthang Briew	93.323	93.323	93.323	95.665	93.323	87.062	67.882	87.062	95.665	95.665	95.665	95.665
Wah Thang Sning	93.323	93.323	93.323	93.323	93.323	87.062	61.628	93.323	93.323	95.665	95.665	93.323
Mawpdang Bridge	93.323	95.665	91.957	93.323	93.323	87.062	61.628	93.323	93.323	95.665	93.323	95.665

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	95.665	95.665	91.957	93.323	93.323	90.460	83.118	87.062	95.665	93.323	93.323	93.323
Shillong College	93.323	94.558	90.460	93.323	93.323	87.062	78.614	87.062	95.665	91.957	93.323	93.323
Polo Bridge	93.323	95.665	93.323	93.323	93.323	87.062	78.614	87.062	95.665	95.665	93.323	93.323
Opposite Jingthang Briew	93.323	93.323	93.323	93.323	93.323	87.062	73.540	87.062	95.665	93.323	93.323	93.323
Opposite Mawpdang Bridge	93.323	93.323	93.323	93.323	93.323	87.062	73.540	95.665	93.323	93.323	95.665	95.665

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(ii) DISSOLVED OXYGEN

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	40.455	10.000	10.000	11.906	10.000	10.000	10.000	10.000	11.906	10.000	10.000	10.000
Umpling Bridge	42.284	11.906	18.486	18.486	10.000	10.000	10.000	14.128	10.000	11.906	10.000	10.000
Umkaliar	38.598	28.892	14.128	18.486	10.000	24.814	24.814	14.128	10.000	10.000	10.000	10.000
Demseiniong	14.128	10.000	10.000	11.906	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Pynthor Umkhrah	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Polo (behind Stadium)	11.906	10.000	10.000	10.000	10.000	10.000	10.000	20.624	10.000	10.000	10.000	10.000
Rooprekha	10.000	10.000	10.000	18.486	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Wah Thang Sning	10.000	10.000	20.624	11.906	10.000	10.000	10.000	10.000	10.000	40.455	10.000	10.000
Mawpdang Bridge	10.000	10.000	10.000	32.859	10.000	14.128	14.128	28.892	10.000	10.000	10.000	10.000

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	22.733	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Shillong College	42.284	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	11.906	10.000	10.000
Polo Bridge	10.000	10.000	18.486	14.128	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Mawpdang Bridge	10.000	10.000	10.000	11.906	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(iii) BIO-CHEMICAL OXYGEN DEMAND

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Umpling Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Umkaliar	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Demseiniong	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Pynthor Umkhrah	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Polo (behind Stadium)	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Rooprekha	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Wah Thang Sning	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Mawpdang Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Shillong College	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Polo Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Mawpdang Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(iv) pH

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	85.646	62.691	77.186	90.217	100.000	90.217	100.000	77.186	100.000	100.000	85.646	100.000
Umpling Bridge	90.217	77.186	90.217	100.000	100.000	85.646	77.186	81.306	100.000	100.000	90.217	81.306
Umkaliar	100.000	77.186	100.000	100.000	85.646	90.217	59.515	77.186	90.217	100.000	100.000	100.000
Demseiniong	100.000	66.037	77.186	85.646	100.000	100.000	100.000	77.186	100.000	85.646	100.000	90.217
Pynthor Umkhrah	100.000	66.037	66.037	90.217	100.000	90.217	90.217	69.562	100.000	90.217	100.000	100.000
Polo (behind Stadium)	100.000	77.186	90.217	100.000	100.000	90.217	66.037	100.000	100.000	100.000	100.000	100.000
Rooprekha	95.033	59.515	81.306	100.000	77.186	69.562	90.217	100.000	100.000	100.000	95.033	100.000
Jingthang Briew	100.000	77.186	77.186	100.000	66.037	69.562	100.000	100.000	100.000	100.000	100.000	100.000
Wah Thang Sning	77.186	77.186	77.186	100.000	90.217	73.275	100.000	100.000	95.033	100.000	100.000	95.033
Mawpdang Bridge	77.186	90.217	90.217	95.033	100.000	69.562	95.033	95.033	100.000	95.033	81.306	100.000

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	100.000	77.186	90.217	90.217	90.217	70.275	90.217	77.186	100.000	100.000	100.000	85.646
Shillong College	100.000	59.515	69.562	100.000	90.217	90.217	77.186	90.217	95.033	100.000	100.000	100.000
Polo Bridge	100.000	77.186	100.000	100.000	90.217	70.275	69.562	81.306	90.217	100.000	100.000	100.000
Opposite Jingthang Briew	59.515	62.691	77.186	100.000	100.000	66.037	81.306	81.306	81.306	100.000	90.217	100.000
Opposite Mawpdang Bridge	66.037	77.186	90.217	100.000	81.306	81.306	90.217	90.217	100.000	100.000	100.000	90.217

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(v) PHOSPHATES

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	100.000	73.044	80.020	10.000	10.000	100.000	10.000	10.000	64.058	70.049	40.094	55.072
Umpling Bridge	100.000	88.020	61.063	10.000	76.039	100.000	67.053	67.053	79.034	10.000	28.112	49.081
Umkaliar	100.000	100.000	82.029	79.034	10.000	100.000	100.000	100.000	100.000	91.015	88.020	100.000
Demseiniong	88.020	10.000	25.116	10.000	10.000	55.072	10.000	10.000	64.058	64.058	10.000	55.072
Pynthor Umkhrah	97.005	85.025	67.053	10.000	67.053	73.044	73.044	73.044	85.025	94.010	58.067	94.010
Polo (behind Stadium)	94.010	88.020	64.058	10.000	55.072	55.072	67.053	67.053	82.029	88.020	10.000	64.058
Rooprekha	100.000	70.049	52.076	10.000	91.015	55.072	70.049	70.049	88.020	67.053	61.063	73.044
Jingthang Briew	88.020	10.000	10.000	10.000	100.000	49.081	85.025	85.025	64.058	10.000	10.000	79.034
Wah Thang Sning	94.010	10.000	10.000	10.000	100.000	49.081	94.010	97.005	67.058	10.000	10.000	25.116
Mawpdang Bridge	10.000	10.000	10.000	10.000	94.010	100.000	28.112	28.112	10.000	10.000	28.112	94.010

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	49.081	10.000	10.000	10.000	10.000	34.103	25.116	25.116	10.000	34.103	67.053	88.020
Shillong College	100.000	34.103	73.044	10.000	10.000	100.000	10.000	10.000	100.000	73.044	10.000	37.099
Polo Bridge	10.000	10.000	10.000	64.058	10.000	52.076	10.000	10.000	10.000	10.000	61.063	10.000
Opposite Jingthang Briew	100.000	40.094	67.053	10.000	10.000	10.000	64.058	64.058	97.005	40.094	79.034	94.010
Opposite Mawpdang Bridge	10.000	10.000	10.000	10.000	10.000	100.000	10.000	10.000	10.000	10.000	10.000	10.000

TABLE 5.2: OREGON WATER QUALITY INDEX 2001-02 – SUB-INDEX CALCULATIONS

(vi) FAECAL COLIFORM

River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Umpling Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Umkaliar	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Demseiniong	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Pynthor Umkhrah	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Polo (behind Stadium)	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Rooprekha	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Wah Thang Sning	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Mawpdang Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Tributaries of River Umkhrah 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Shillong College	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Polo Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Jingthang Briew	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Opposite Mawpdang Bridge	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

TABLE 5.3: OREGON WATER QUALITY INDEX 2001-02

RIVER UMKHRAH 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Lapalang	16.9	14.0	14.0	12.7	12.2	14.1	12.2	12.2	14.8	14.0	13.9	14.0
Umpling Bridge	16.9	14.8	16.0	13.5	14.0	14.0	14.0	15.3	14.0	12.7	13.8	14.0
Umkaliar	16.9	16.7	15.4	16.0	12.2	16.5	16.5	15.4	14.1	14.1	14.1	14.1
Demseiniong	15.4	12.2	13.7	12.7	12.2	14.0	12.2	12.2	14.0	14.0	12.2	14.0
Pynthor Umkhrah	14.1	14.0	14.0	12.2	14.0	14.0	14.0	14.0	14.1	14.1	14.0	14.1
Polo (behind Stadium)	14.8	14.0	14.0	12.2	14.0	14.0	14.0	16.2	14.1	14.1	12.2	14.0
Rooprekha	14.1	14.0	14.0	13.5	14.0	14.0	14.0	14.0	14.1	14.0	14.0	14.0
Jingthang Briew	14.1	12.2	12.2	12.2	14.0	14.0	14.0	14.1	14.0	12.2	12.2	14.1
Wah Thang Sning	14.0	12.2	13.5	12.7	14.1	14.0	14.0	14.1	14.0	13.9	12.2	13.7
Mawpdang Bridge	12.2	12.2	12.2	13.9	14.1	15.3	15.0	16.3	12.2	12.2	13.8	14.1

TRIBUTARIES OF RIVER UMKHRAH 2001-02

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony	16.3	12.2	12.2	12.2	12.2	13.9	13.7	13.7	12.2	14.0	14.0	14.0
Shillong College	17.0	13.8	14.0	12.2	12.2	14.1	12.2	12.2	14.1	14.8	12.2	13.9
Polo Bridge	12.2	12.2	13.5	15.3	12.2	14.0	12.2	12.2	12.2	12.2	14.0	12.2
Opposite Jingthang Briew	14.0	13.9	14.0	12.2	12.2	12.2	14.0	14.0	14.1	13.9	14.0	14.1
Opposite Mawpdang Bridge	12.2	12.2	12.2	12.7	12.2	14.0	12.2	12.2	12.2	12.2	12.2	12.2

CLASSIFICATION

10-59 = VERY POOR
60-79 = POOR
80-84 = FAIR
85-89 = GOOD
90-100 = EXCELLENT

TABLE 5.4: OREGON WATER QUALITY INDEX 2005 – SUB-INDEX CALCULATIONS

SUB-INDEX 5 : PHOSPHATES

River Umkhrah

Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
Wah Demthring	70.049	40.094	40.094	70.049
Nongrah	49.081	40.094	40.094	46.085
Marboh Bridge	64.058	52.076	40.094	10.000
Demseiniong	10.000	10.000	10.000	10.000
Lawmali	10.000	10.000	10.000	10.000
Wahingdoh	10.000	10.000	10.000	10.000

SUB-INDEX 6 : FAECAL COLIFORM

River Umkhrah

Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
Wah Demthring	92.338	95.221	95.221	92.338
Nongrah	10.000	10.000	10.000	10.000
Marboh Bridge	10.000	10.000	10.000	10.000
Demseiniong	10.000	10.000	10.000	10.000
Lawmali	10.000	10.000	10.000	10.000
Wahingdoh	10.000	10.000	10.000	10.000

TABLE 5.5: OREGON WATER QUALITY INDEX 2005

RIVER UMKHRAH 2005

S.No.	Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
1.	Wah Demthring	17.1	22.4	22.9	22.6
2.	Nongrah	16.8	13.9	16.5	14.0
3.	Marboh Bridge	14.7	14.0	13.9	12.2
4.	Demseiniong	12.2	12.2	12.2	12.2
5.	Lawmali	14.0	12.2	12.2	12.2
6.	Wahingdoh	12.2	12.2	12.2	12.2

CLASSIFICATION
10-59 = VERY POOR
60-79 = POOR
80-84 = FAIR
85-89 = GOOD
90-100 = EXCELLENT

TABLE 5.4: OREGON WATER QUALITY INDEX 2005 – SUB-INDEX CALCULATIONS

SUB-INDEX 5 : PHOSPHATES

River Umkhrah

Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
Wah Demthring	70.049	40.094	40.094	70.049
Nongrah	49.081	40.094	40.094	46.085
Marboh Bridge	64.058	52.076	40.094	10.000
Demseiniong	10.000	10.000	10.000	10.000
Lawmali	10.000	10.000	10.000	10.000
Wahingdoh	10.000	10.000	10.000	10.000

SUB-INDEX 6 : FAECAL COLIFORM

River Umkhrah

Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
Wah Demthring	92.338	95.221	95.221	92.338
Nongrah	10.000	10.000	10.000	10.000
Marboh Bridge	10.000	10.000	10.000	10.000
Demseiniong	10.000	10.000	10.000	10.000
Lawmali	10.000	10.000	10.000	10.000
Wahingdoh	10.000	10.000	10.000	10.000

TABLE 5.5: OREGON WATER QUALITY INDEX 2005

RIVER UMKHRAH 2005

S.No.	Sampling Location	22-4-05	26-4-05	6-5-05	13-5-05
1.	**Wah Demthring**	17.1	22.4	22.9	22.6
2.	**Nongrah**	16.8	13.9	16.5	14.0
3.	**Marboh Bridge**	14.7	14.0	13.9	12.2
4.	**Demseiniong**	12.2	12.2	12.2	12.2
5.	**Lawmali**	14.0	12.2	12.2	12.2
6.	**Wahingdoh**	12.2	12.2	12.2	12.2

CLASSIFICATION

10-59 = VERY POOR
60-79 = POOR
80-84 = FAIR
85-89 = GOOD
90-100 = EXCELLENT

It is observed in Table 5.3 and Table 5.5 that the values of OWQI for the years 2001-02 and 2005 respectively are low, the highest being 22.9, calculated for the Wah Demthring location in May 2005 and the lowest being 12.2, calculated for several locations. As per the classification given for the OWQI, the water quality of the River Umkhrah falls under the "very poor" category [10] and no change in the water quality is observed in the two years.

The OWQI is a more flexible index than the Said, *et al* Index. The effects that faecal coliforms, dissolved oxygen and BOD have on the quality of the river water have been observed by using this index. These three variables are generally considered to be the most important ones for any water quality monitoring. To achieve this, the index value has been calculated separately without considering each of the three variables. Then it has been calculated without considering combinations of the above three variables and finally, without considering them at all. The results of these calculations are tabulated in Table 5.6 (i) to (xv). Graphics have also been used to represent these variations (Figure 5.1 (i) to (xv)).

From all the tables and figures, it is observed that the OWQI shows very less variation either when each of the three variables is removed or when their combinations are removed. The entire values lie clumped together within a very small range only. There is some variation when faecal coliform, dissolved oxygen and BOD are removed all together. An improvement in the water quality is observed with an increase in the index value. However, this trend is also not consistent with the index value showing very high variation. This happens because, even after the three most polluting variables are removed, the remaining variables have deteriorated so badly that the index values remain in the "very poor" category.

The OWQI uses an unweighted square mean formula for aggregation of the subindices to obtain the final water quality index. Therefore, if any of the pollutant variables has deteriorated, the index value immediately becomes low and the river water quality is classified as "very poor". This, perhaps, is a disadvantage of the index as it classifies the quality of river water as "very poor" even if it is one of the less harmful variables, like phosphorus or total solids, that has deteriorated.

TABLE 5.6: VARIATION OF OWQI WITH REMOVAL OF FAECAL COLIFORM, DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND

) LAPALANG

arameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
WQI	16.9	14.0	14.0	12.7	12.2	14.1	12.2	12.2	14.8	14.0	13.9	14.0
idex without F.Col	21.4	15.6	15.6	13.5	12.9	15.7	12.9	12.9	16.9	15.6	15.5	15.6
idex without DO	15.7	15.6	15.6	12.9	12.9	15.7	12.9	12.8	15.6	15.6	15.5	15.6
idex without BOD	21.4	15.6	15.6	13.5	12.9	15.7	12.9	12.9	16.9	15.6	15.5	15.6
idex without F.Col and DO	19.7	19.5	19.6	14.1	14.1	19.6	14.1	14.0	19.6	19.6	19.2	19.5
idex without F.Col and BOD	64.5	19.5	19.6	15.2	14.1	19.6	14.1	14.0	23.1	19.6	19.2	19.5
idex without DO and BOD	19.7	19.5	19.6	14.1	14.1	19.6	14.1	14.0	19.6	19.6	19.2	19.5
idex without F.Col, DO and BOD	92.4	74.4	82.7	17.1	17.1	91.9	17.1	17.1	81.4	84.7	58.8	74.6

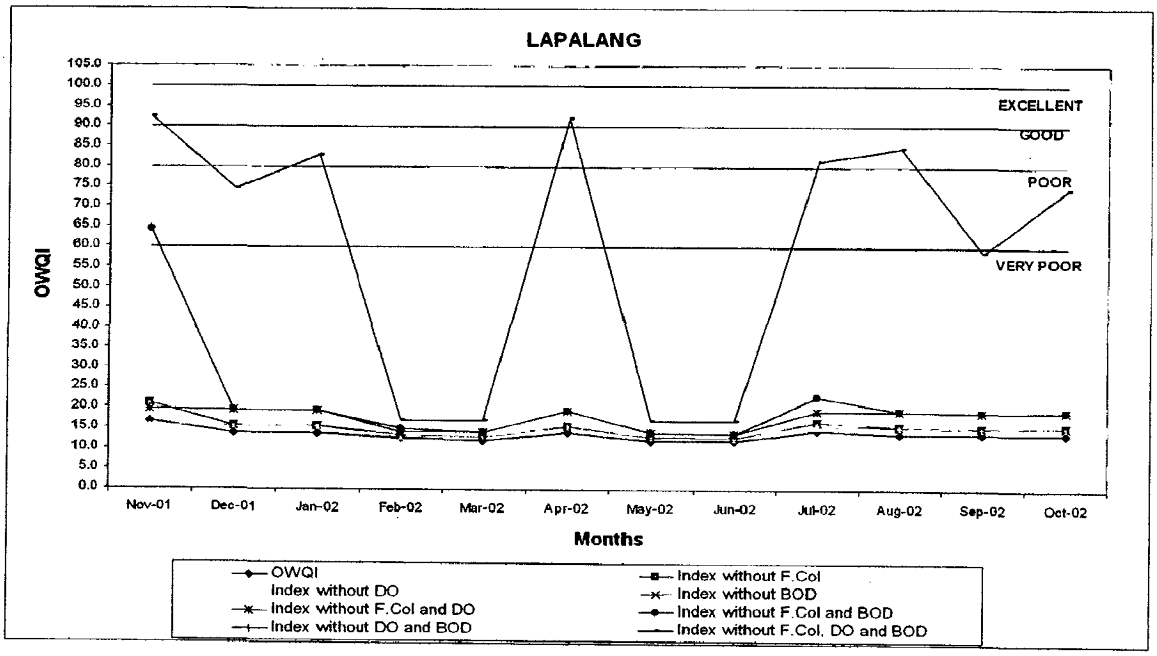

Figure 5.1 (i): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Lapalang

(ii) UMPLING BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
OWQI	16.9	14.8	16.0	13.5	14.0	14.0	14.0	15.3	14.0	12.7	13.8	14.0
Index without F.Col	21.4	16.9	19.3	14.7	15.7	15.6	15.6	18.0	15.7	13.5	15.2	15.5
Index without DO	15.7	15.6	15.6	12.9	15.7	15.6	15.6	15.6	15.7	12.9	15.2	15.5
Index without BOD	21.4	16.9	19.3	14.7	15.7	15.6	15.6	18.0	15.7	13.5	15.2	15.5
Index without F.Col and DO	19.7	19.6	19.5	14.1	19.6	19.6	19.5	19.5	19.6	14.1	18.6	19.4
Index without F.Col and BOD	67.0	23.1	34.1	17.4	19.6	19.6	19.5	27.0	19.6	15.2	18.6	19.4
Index without DO and BOD	19.7	19.6	19.5	14.1	19.6	19.6	19.5	19.5	19.6	14.1	18.6	19.4
Index without F.Col, DO and BOD	95.0	85.9	75.7	17.1	87.9	81.3	73.7	78.4	88.6	17.1	44.6	66.6

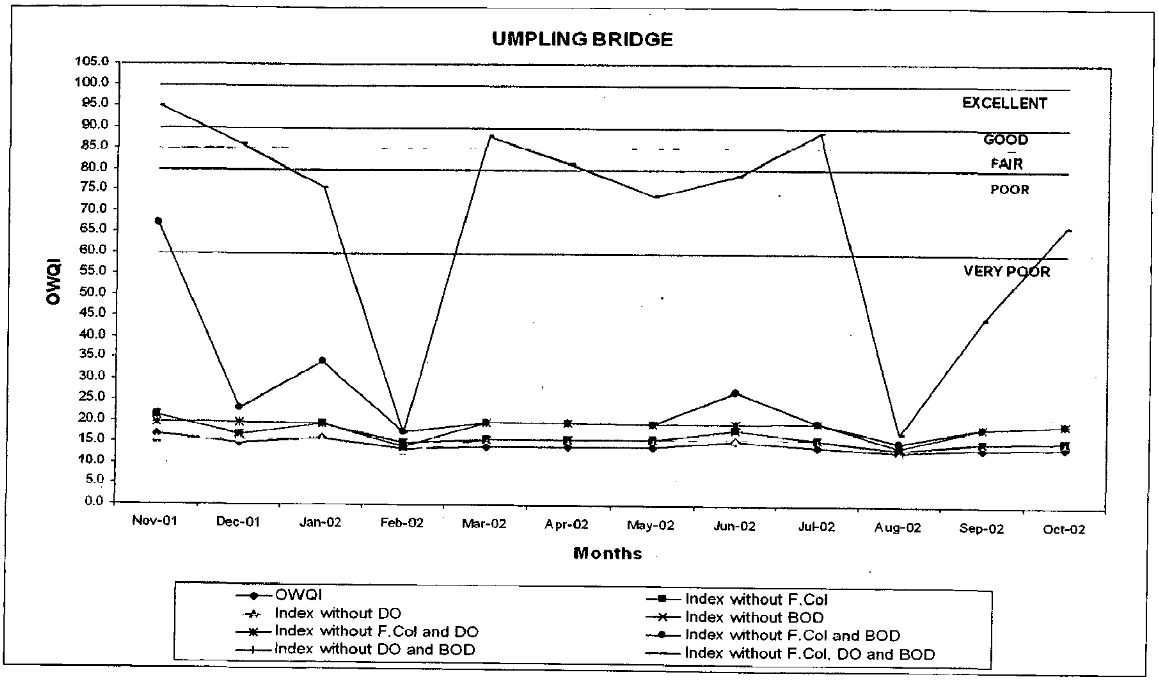

Figure 5.1 (ii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Umpling Bridge

(iii) UMKALIAR

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
OWQI	16.9	16.7	15.4	16.0	12.2	16.5	16.5	15.4	14.1	14.1	14.1	14.1
Index without F.Col	21.3	20.8	18.0	19.4	12.9	20.4	20.3	18.0	15.7	15.7	15.7	15.7
Index without DO	15.7	15.7	15.7	15.7	12.9	15.7	15.6	15.7	15.7	15.7	15.7	15.7
Index without BOD	21.3	20.8	18.0	19.4	12.9	20.4	20.3	18.0	15.7	15.7	15.7	15.7
Index without F.Col and DO	19.7	19.6	19.6	19.6	14.1	19.7	19.5	19.6	19.7	19.7	19.7	19.7
Index without F.Col and BOD	63.7	50.4	27.3	34.8	14.1	45.0	43.0	27.2	19.7	19.7	19.7	19.7
Index without DO and BOD	19.7	19.6	19.6	19.6	14.1	19.7	19.5	19.6	19.7	19.7	19.7	19.7
Index without F.Col, DO and BOD	97.6	89.2	90.4	90.1	17.1	91.9	74.2	87.7	93.2	94.6	93.4	96.5

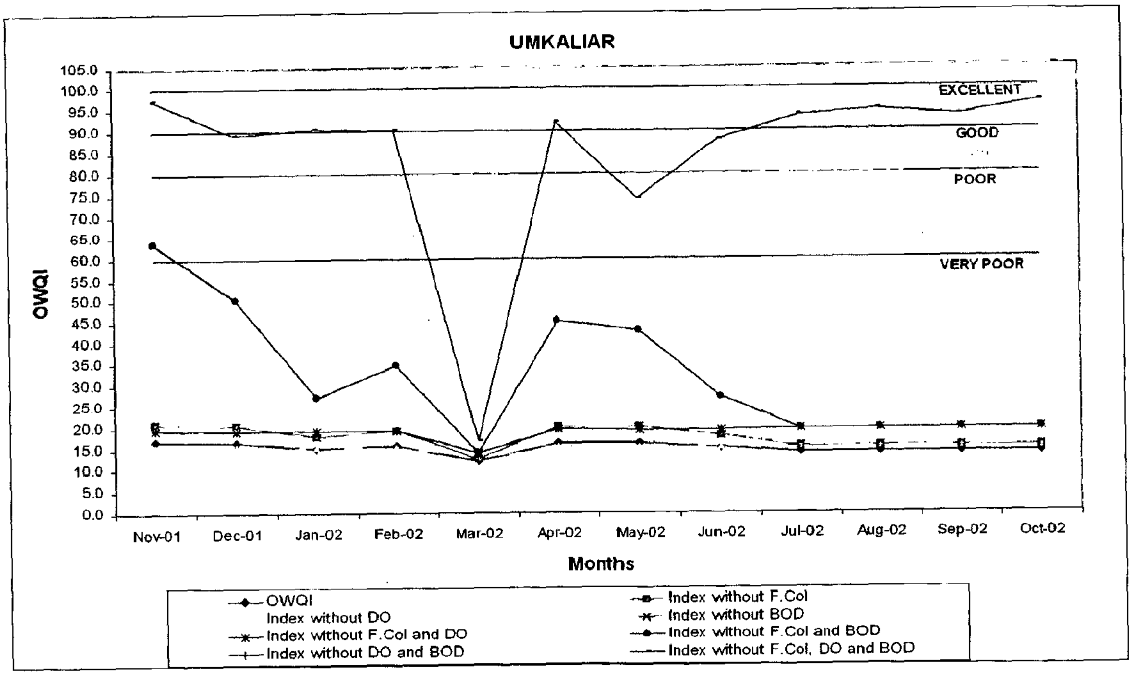

Figure 5.1 (iii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Umkaliar

(iv) DEMSEINIONG

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	O 0
OWQI	15.4	12.2	13.7	12.7	12.2	14.0	12.2	12.2	14.0	14.0	12.2	14
Index without F.Col	18.0	12.9	15.1	13.5	12.9	15.6	12.9	12.9	15.6	15.6	12.9	15
Index without DO	15.6	12.8	15.1	12.8	12.9	15.6	12.8	12.8	15.6	15.6	12.9	15
Index without BOD	18.0	12.9	15.1	13.5	12.9	15.6	12.9	12.9	15.6	15.6	12.9	15
Index without F.Col and DO	19.6	14.0	18.4	14.1	14.1	19.4	14.1	14.0	19.6	19.5	14.1	19
Index without F.Col and BOD	27.2	14.0	18.4	15.2	14.1	19.4	14.1	14.0	19.6	19.5	14.1	19
Index without DO and BOD	19.6	14.0	18.4	14.1	14.1	19.4	14.1	14.0	19.6	19.5	14.1	19
Index without F.Col, DO and BOD	85.1	17.1	40.1	17.1	17.1	68.1	17.1	17.1	80.9	77.9	17.1	72

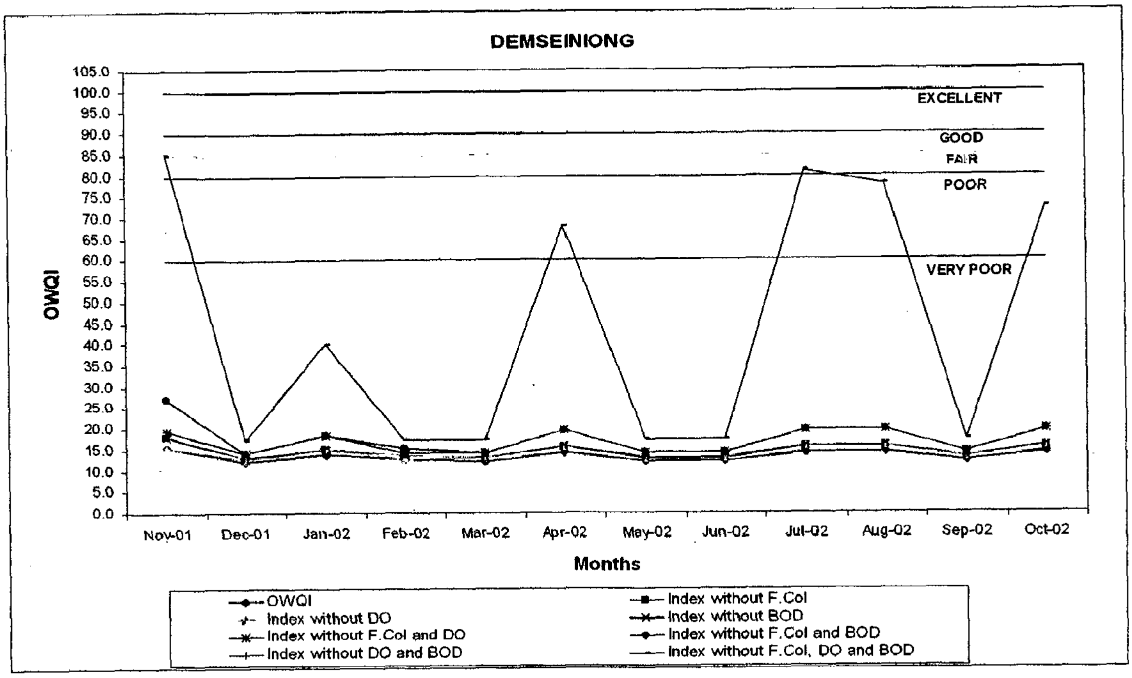

Figure 5.1 (iv): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Demseiniong

·) PYNTHORUMKHRAH

arameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
'WQI	14.1	14.0	14.0	12.2	14.0	14.0	14.0	14.0	14.1	14.1	14.0	14.1
ıdex without F.Col	15.7	15.6	15.6	12.9	15.6	15.6	15.6	15.6	15.7	15.7	15.6	15.7
ıdex without DO	15.7	15.6	15.6	12.9	15.6	15.6	15.6	15.6	15.7	15.7	15.6	15.7
ıdex without BOD	15.7	15.6	15.6	12.9	15.6	15.6	15.6	15.6	15.7	15.7	15.6	15.7
ıdex without F.Col and DO	19.7	19.5	19.5	14.1	19.6	19.6	19.5	19.5	19.6	19.7	19.5	19.7
ıdex without F.Col and BOD	19.7	19.5	19.5	14.1	19.6	19.6	19.5	19.5	19.6	19.7	19.5	19.7
ıdex without DO and BOD	19.7	19.5	19.5	14.1	19.6	19.6	19.5	19.5	19.6	19.7	19.5	19.7
ıdex without F.Col, DO and BOD	96.7	79.3	72.8	17.1	82.8	82.4	79.7	76.2	91.2	92.5	77.0	96.5

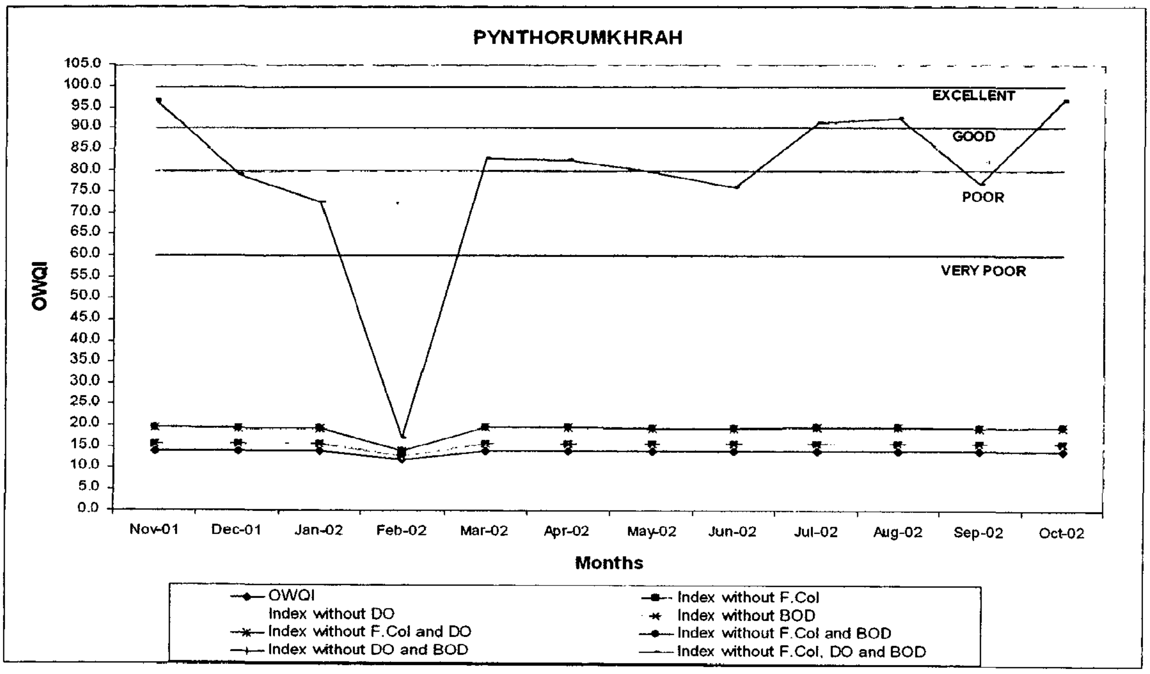

Figure 5.1 (v): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Pynthorumkhrah

(vi) POLO (behind Stadium)

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	O (
OWQI	14.8	14.0	14.0	12.2	14.0	14.0	14.0	16.2	14.1	14.1	12.2	1
Index without F.Col	17.0	15.6	15.6	12.9	15.6	15.6	15.6	19.8	15.7	15.7	12.9	1
Index without DO	15.7	15.6	15.6	12.9	15.6	15.6	15.6	15.6	15.7	15.7	12.9	1
Index without BOD	17.0	15.6	15.6	12.9	15.6	15.6	15.6	19.8	15.7	15.7	12.9	1
Index without F.Col and DO	19.7	19.6	19.5	14.1	19.5	19.4	19.4	19.6	19.6	19.7	14.1	19
Index without F.Col and BOD	23.3	19.6	19.5	14.1	19.5	19.4	19.4	19.6	19.6	19.7	14.1	19
Index without DO and BOD	19.7	19.6	19.5	14.1	19.5	19.4	19.4	19.6	19.6	19.7	14.1	19
Index without F.Col, DO and BOD	95.6	85.4	78.9	17.1	74.2	82.4	68.6	81.3	90.8	93.4	17.1	81

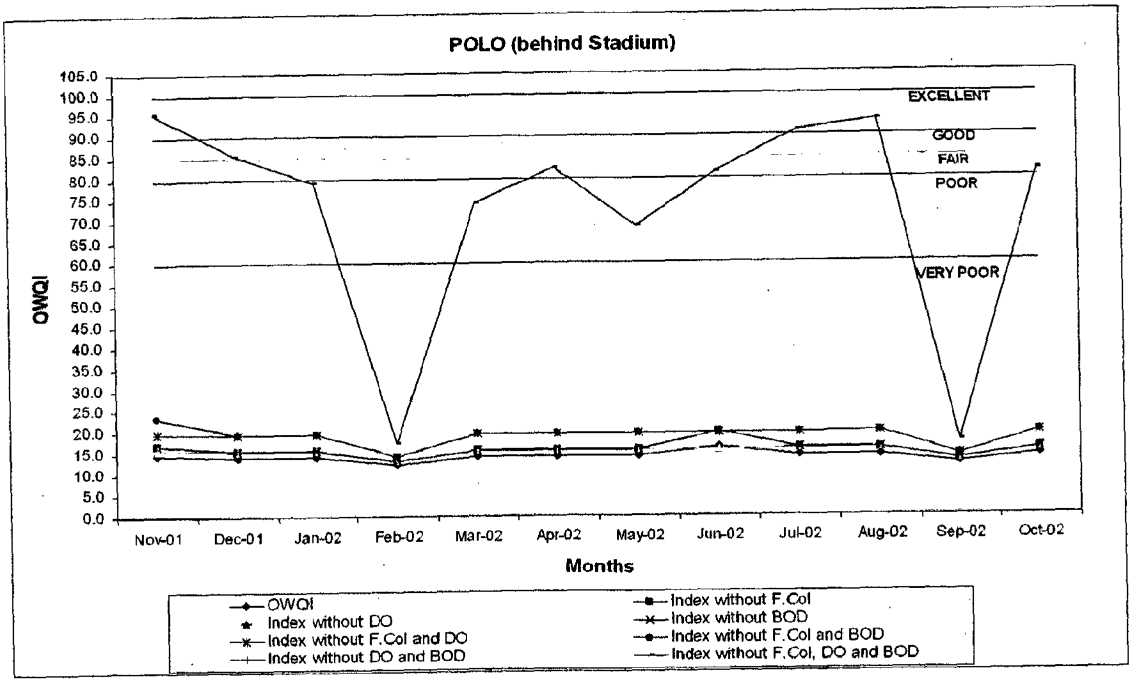

Figure 5.1 (vi): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Polo (behind Stadium)

ii) ROOPREKHA

arameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
WQI	14.1	14.0	14.0	13.5	14.0	14.0	14.0	14.0	14.1	14.0	14.0	14.0
dex without F.Col	15.7	15.6	15.6	14.7	15.6	15.6	15.6	15.6	15.7	15.6	15.6	15.6
dex without DO	15.7	15.6	15.6	12.9	15.6	15.6	15.6	15.6	15.7	15.6	15.6	15.6
dex without BOD	15.7	15.6	15.6	14.7	15.6	15.6	15.6	15.6	15.7	15.6	15.6	15.6
dex without F.Col and DO	19.7	19.4	19.4	14.1	19.6	19.4	19.5	19.6	19.7	19.6	19.5	19.6
dex without F.Col and BOD	19.7	19.4	19.4	17.4	19.6	19.4	19.5	19.6	19.7	19.6	19.5	19.6
dex without DO and BOD	19.7	19.4	19.4	14.1	19.6	19.4	19.5	19.6	19.7	19.6	19.5	19.6
dex without F.Col, DO and BOD	96.0	71.0	68.7	17.1	86.2	67.0	76.6	83.0	93.4	82.8	78.4	87.0

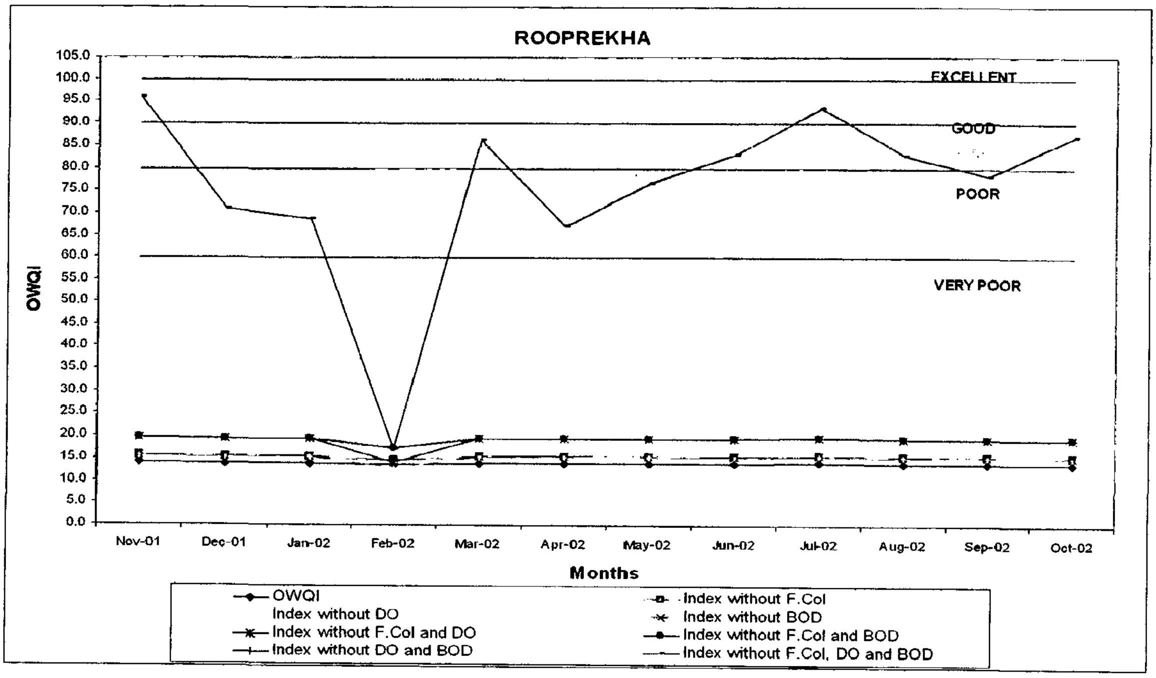

Figure 5.1 (vii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Rooprekha

(viii) JINGTHANGBRIEW

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	O 0
OWQI	14.1	12.2	12.2	12.2	14.0	14.0	14.0	14.1	14.0	12.2	12.2	14
Index without F.Col	15.7	12.9	12.9	12.9	15.6	15.6	15.6	15.7	15.6	12.9	12.9	15
Index without DO	15.7	12.9	12.9	12.9	15.6	15.6	15.6	15.7	15.6	12.9	12.9	15
Index without BOD	15.7	12.9	12.9	12.9	15.6	15.6	15.6	15.7	15.6	12.9	12.9	15
Index without F.Col and DO	19.7	14.0	14.1	14.1	19.6	19.3	19.6	19.7	19.6	14.1	14.1	19
Index without F.Col and BOD	19.7	14.0	14.1	14.1	19.6	19.3	19.6	19.7	19.6	14.1	14.1	19
Index without DO and BOD	19.7	14.0	14.1	14.1	19.6	19.3	19.6	19.7	19.6	14.1	14.1	19
Index without F.Col, DO and BOD	93.4	17.1	17.1	17.1	82.2	63.1	81.2	90.0	81.4	17.1	17.1	90

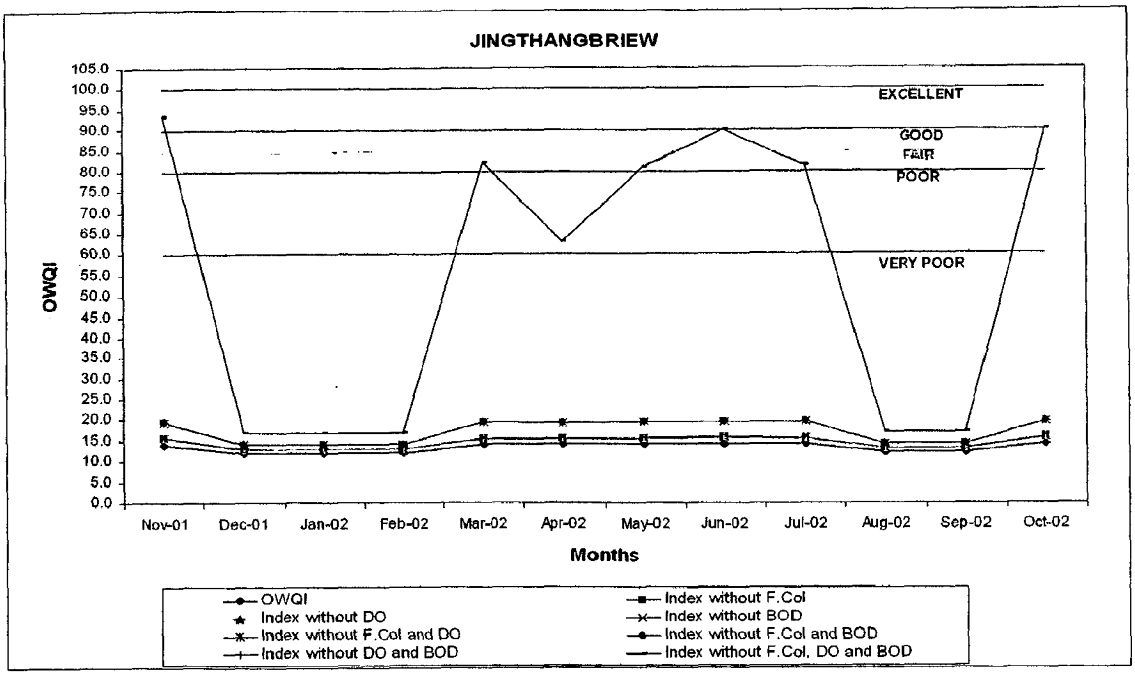

Figure 5.1 (viii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Jingthangbriew

ı) WAH THANGSNING

ırameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
WQI	14.0	12.2	13.5	12.7	14.1	14.0	14.0	14.1	14.0	13.9	12.2	13.7
dex without F.Col	15.6	12.9	14.7	13.5	15.7	15.6	15.6	15.7	15.6	15.5	12.9	15.1
dex without DO	15.6	12.9	12.8	12.9	15.7	15.6	15.6	15.7	15.6	12.9	12.9	15.1
dex without BOD	15.6	12.9	14.7	13.5	15.7	15.6	15.6	15.7	15.6	15.5	12.9	15.1
dex without F.Col and DO	19.6	14.0	14.0	14.1	19.7	19.3	19.5	19.7	19.6	14.1	14.1	18.4
dex without F.Col and BOD	19.6	14.0	17.7	15.2	19.7	19.3	19.5	19.7	19.6	19.2	14.1	18.4
dex without DO and BOD	19.6	14.0	14.0	14.1	19.7	19.3	19.5	19.7	19.6	14.1	14.1	18.4
dex without F.Col, DO and BOD	87.1	17.1	17.1	17.1	94.3	64.0	79.3	96.7	81.8	17.1	17.1	40.7

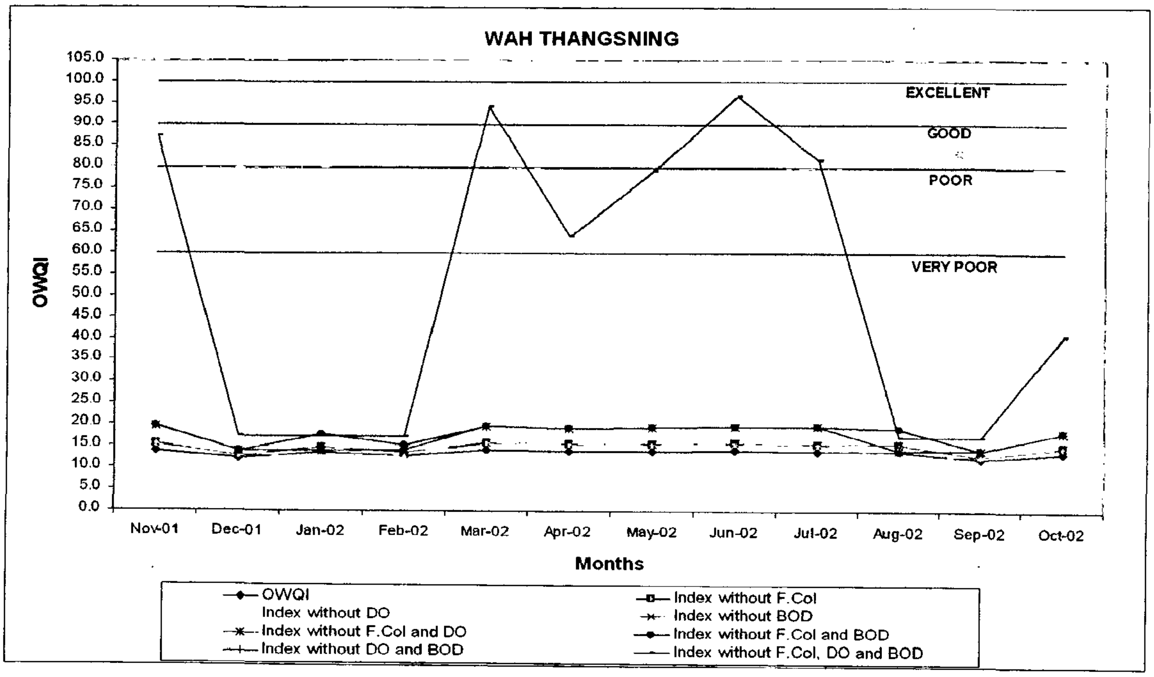

Figure 5.1 (ix): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Wah Thangsning

(x) MAWPDANG BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oc 0:
OWQI	12.2	12.2	12.2	13.9	14.1	15.3	15.0	16.3	12.2	12.2	13.8	14.
Index without F.Col	12.9	12.9	12.9	15.5	15.7	18.0	17.3	19.8	12.9	12.9	15.2	15.
Index without DO	12.9	12.9	12.9	12.9	15.7	15.6	15.2	15.2	12.9	12.9	15.2	15.
Index without BOD	12.9	12.9	12.9	15.9	15.7	18.0	17.3	19.8	12.9	12.9	15.2	15.
Index without F.Col and DO	14.0	14.1	14.0	14.1	19.7	19.6	18.5	18.7	14.1	14.1	18.6	19.
Index without F.Col and BOD	14.0	14.1	14.0	18.9	19.7	27.1	24.5	38.6	14.1	14.1	18.6	19.
Index without DO and BOD	14.0	14.1	14.0	14.1	19.7	19.6	18.5	18.7	14.1	14.1	18.6	19.
Index without F.Col, DO and BOD	17.1	17.1	17.1	17.1	95.6	82.7	42.8	44.9	17.1	17.1	44.3	96.

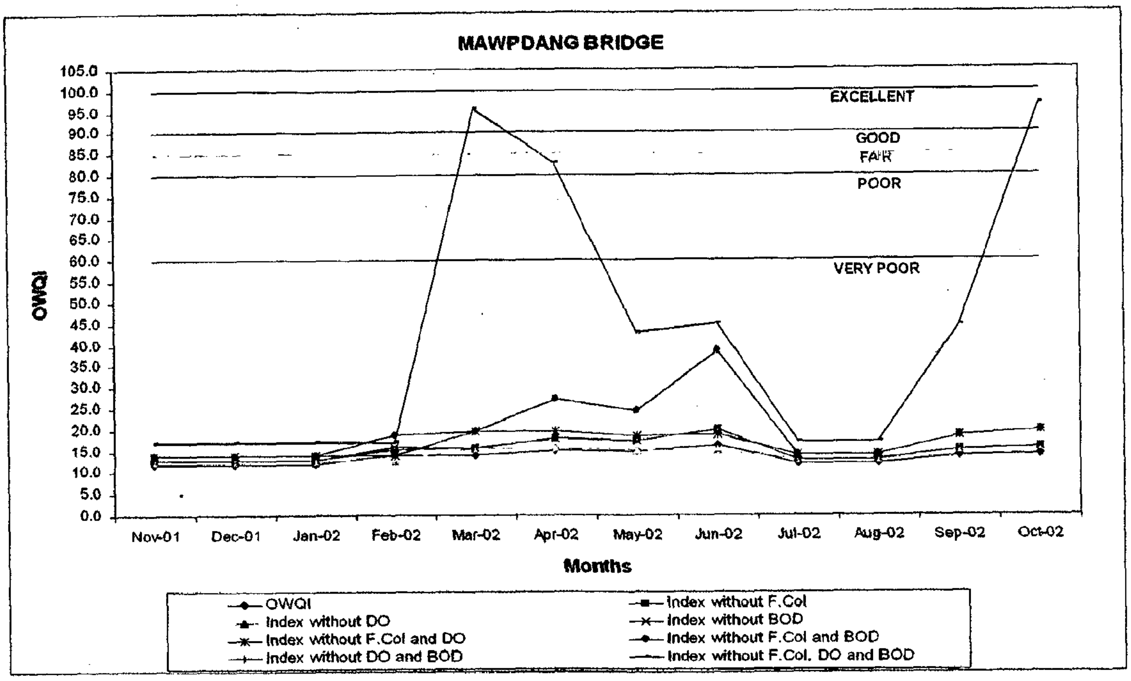

Figure 5.1 (x): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Mawpdang Bridge

REFUGEE COLONY

rameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
/QI	16.3	12.2	12.2	12.2	12.2	13.9	13.7	13.7	12.2	14.0	14.0	14.0
ex without F.Col	20.0	12.9	12.9	12.9	12.9	15.4	15.1	15.1	12.9	15.6	15.6	15.6
ex without DO	15.6	12.9	12.9	12.9	12.9	15.4	15.1	15.1	12.9	15.6	15.6	15.6
ex without BOD	20.0	12.9	12.9	12.9	12.9	15.4	15.1	15.1	12.9	15.6	15.6	15.6
ex without F.Col and DO	19.4	14.0	14.1	14.1	14.1	18.9	18.4	18.3	14.1	19.0	19.6	19.6
ex without F.Col and BOD	39.5	14.0	14.1	14.1	14.1	18.9	18.3	18.3	14.1	19.0	19.6	19.6
ex without DO and BOD	19.4	14.0	14.1	14.1	14.1	18.9	18.4	18.3	14.1	19.0	19.6	19.6
ex without F.Col, DO and BOD	69.3	17.1	17.1	17.1	17.1	50.7	40.2	39.9	17.1	52.8	82.8	88.8

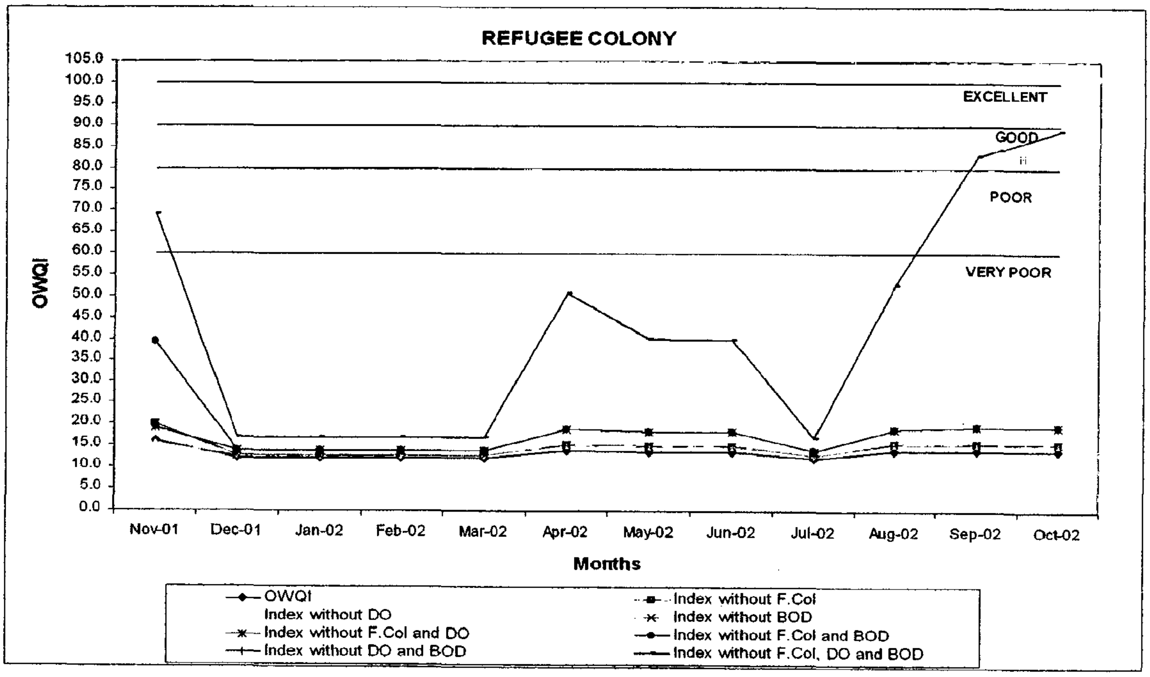

Figure 5.1 (xi): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Refugee Colony

(xii) SHILLONG COLLEGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
OWQI	17.0	13.8	14.0	12.2	12.2	14.1	12.2	12.2	14.1	14.8	12.2	13.9
Index without F.Col	21.4	15.3	15.6	12.9	12.9	15.7	12.9	12.9	15.7	16.9	12.9	15.5
Index without DO	15.7	15.3	15.6	12.9	12.9	15.7	12.9	12.9	15.7	15.7	12.9	15.4
Index without BOD	21.4	15.3	15.6	12.9	12.9	15.7	12.9	12.9	15.7	16.9	12.9	15.5
Index without F.Col and DO	19.7	18.8	19.5	14.1	14.1	19.6	14.0	14.1	19.7	19.6	14.1	19.1
Index without F.Col and BOD	67.6	18.8	19.5	14.1	14.1	19.6	14.0	14.1	19.7	23.2	14.1	19.1
Index without DO and BOD	19.7	18.8	19.5	14.1	14.1	19.6	14.0	14.1	19.7	19.6	14.1	19.1
Index without F.Col, DO and BOD	97.6	48.9	76.2	17.1	17.1	91.9	17.1	17.1	96.8	86.0	17.1	56.4

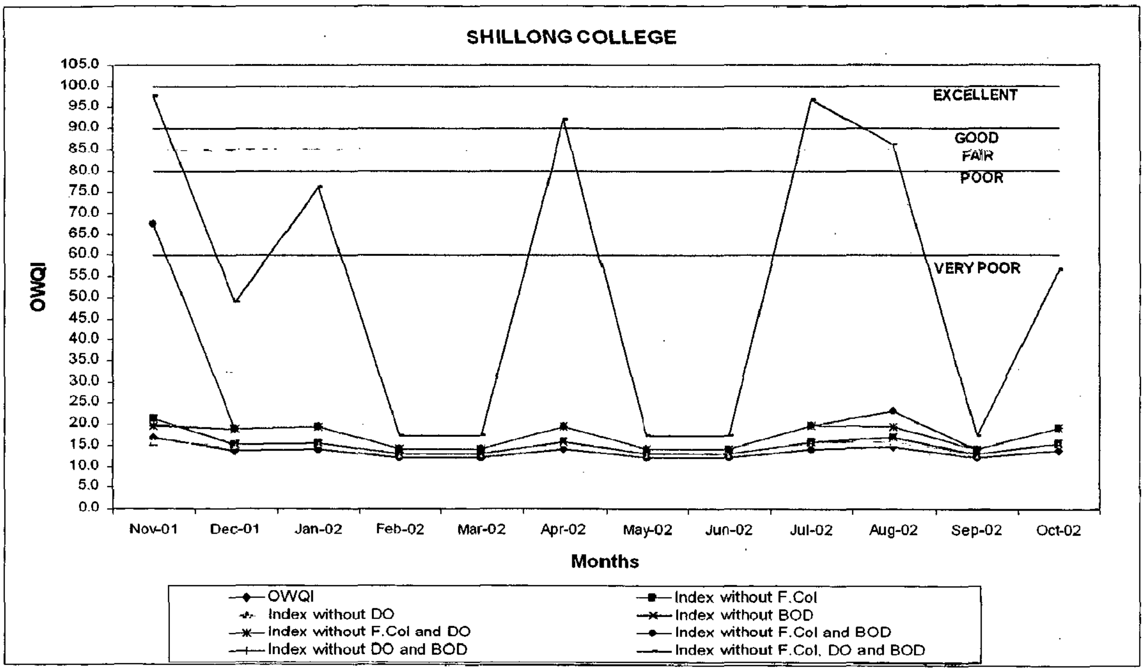

Figure 5.1 (xii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Shillong College

(xiii) POLO BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
OWQI	12.2	12.2	13.5	15.3	12.2	14.0	12.2	12.2	12.2	12.2	14.0	12.2
Index without F.Col	12.9	12.9	14.7	18.0	12.9	15.6	12.9	12.9	12.9	12.9	15.6	12.9
Index without DO	12.9	12.9	12.9	15.6	12.9	15.6	12.9	12.9	12.9	12.9	15.6	12.9
Index without BOD	12.9	12.9	14.7	18.0	12.9	15.6	12.9	12.9	12.9	12.9	15.6	12.9
Index without F.Col and DO	14.1	14.0	14.1	19.6	14.1	19.3	14.0	14.0	14.1	14.1	19.5	14.1
Index without F.Col and BOD	14.1	14.0	17.4	27.0	14.1	19.3	14.0	14.0	14.1	14.1	19.5	14.1
Index without DO and BOD	14.1	14.0	14.1	19.6	14.1	19.3	14.0	14.0	14.1	14.1	19.5	14.1
Index without F.Col, DO and BOD	17.1	17.1	17.1	80.9	17.1	66.1	17.1	17.1	17.1	17.1	78.8	17.1

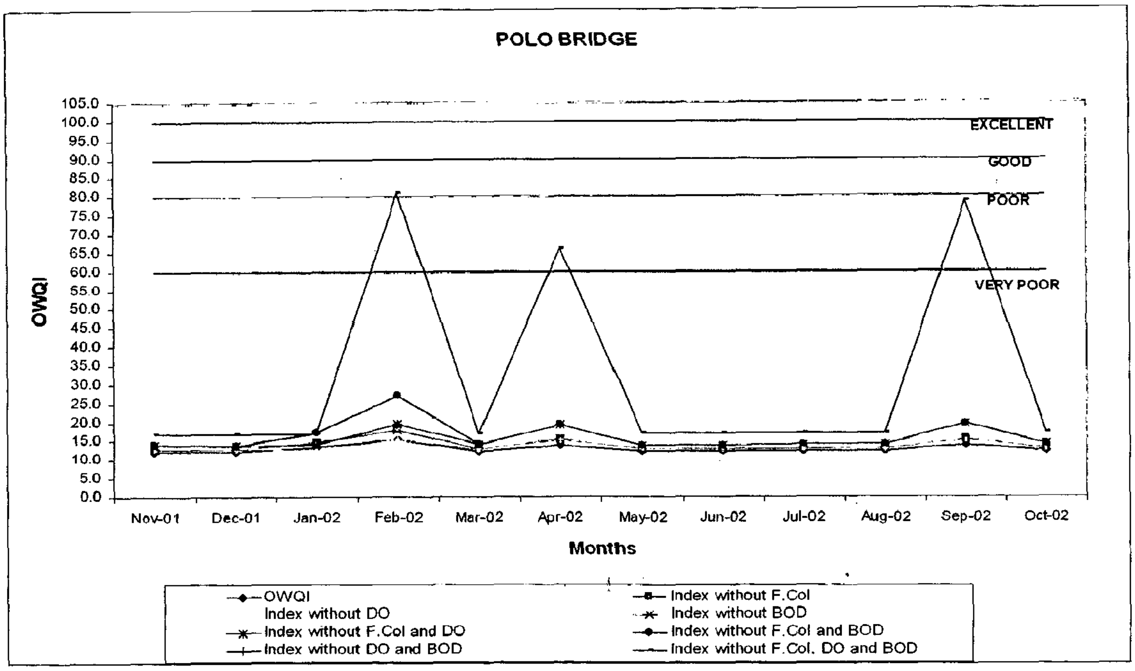

Figure 5.1 (xiii): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Polo Bridge

(xiv) OPPOSITE JINGTHANGBRIEW

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	(
OWQI	14.0	13.9	14.0	12.2	12.2	12.2	14.0	14.0	14.1	13.9	14.0	1
Index without F.Col	15.6	15.4	15.6	12.9	12.9	12.9	15.6	15.6	15.7	15.5	15.6	1
Index without DO	15.6	15.4	15.6	12.9	12.9	12.9	15.6	15.6	15.7	15.5	15.6	1
Index without BOD	15.6	15.4	15.6	12.9	12.9	12.9	15.6	15.6	15.7	15.5	15.6	1
Index without F.Col and DO	19.5	19.1	19.5	14.1	14.1	14.0	19.4	19.5	19.6	19.2	19.6	1
Index without F.Col and BOD	19.5	19.1	19.5	14.1	14.1	14.0	19.4	19.5	19.6	19.2	19.6	1
Index without DO and BOD	19.5	19.1	19.5	14.1	14.1	14.0	19.4	19.5	19.6	19.2	19.6	1
Index without F.Col, DO and BOD	77.7	55.0	77.1	17.1	17.1	17.1	71.9	75.5	90.4	59.9	86.8	9

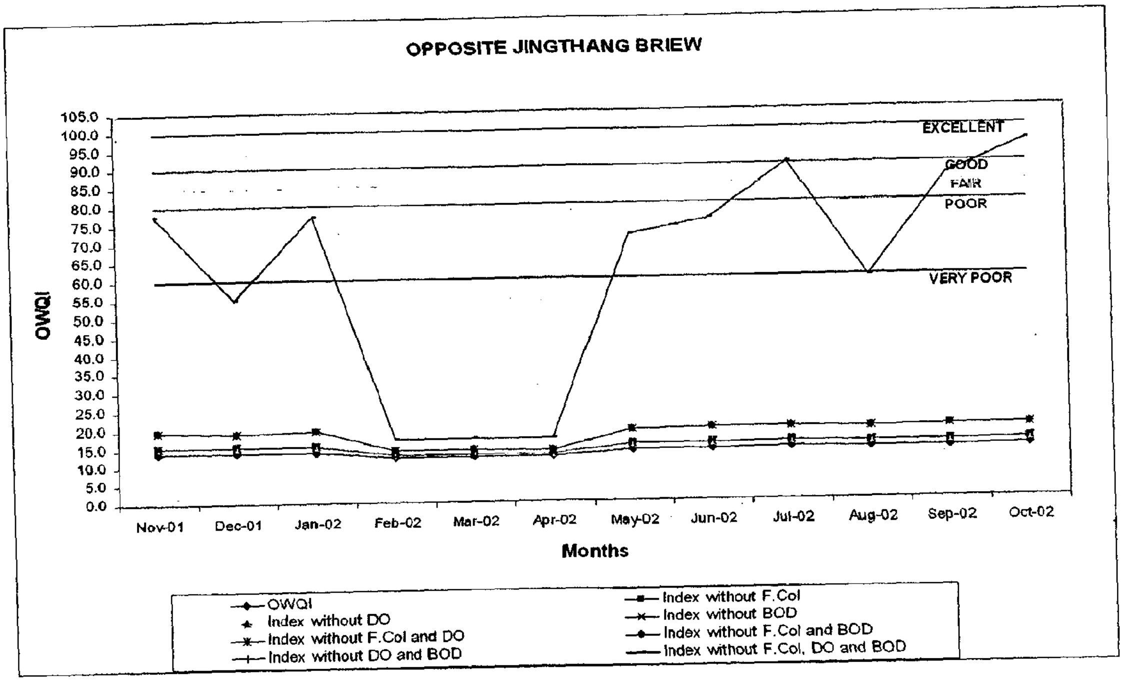

Figure 5.1 (xiv): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Opposite Jingthangbriew

/) OPPOSITE MAWPDANG BRIDGE

rameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
VQI	12.2	12.2	12.2	12.7	12.2	14.0	12.2	12.2	12.2	12.2	12.2	12.2
lex without F.Col	12.9	12.9	12.9	13.5	12.9	15.6	12.9	12.9	12.9	12.9	12.9	12.9
lex without DO	12.9	12.9	12.9	12.9	12.9	15.6	12.9	12.9	12.9	12.9	12.9	12.9
lex without BOD	12.9	12.9	12.9	13.5	12.9	15.6	12.9	12.9	12.9	12.9	12.9	12.9
lex without F.Col and DO	14.0	14.0	14.1	14.1	14.1	19.6	14.0	14.1	14.1	14.1	14.1	14.1
lex without F.Col and BOD	14.0	14.0	14.1	14.1	14.1	19.6	14.0	14.1	14.1	14.1	14.1	14.1
lex without DO and BOD	14.0	14.0	14.1	14.1	14.1	19.6	14.0	14.1	14.1	14.1	14.1	14.1
lex without F.Col, DO and BOD	17.1	17.1	17.1	17.1	17.1	88.5	17.1	17.1	17.1	17.1	17.1	17.1

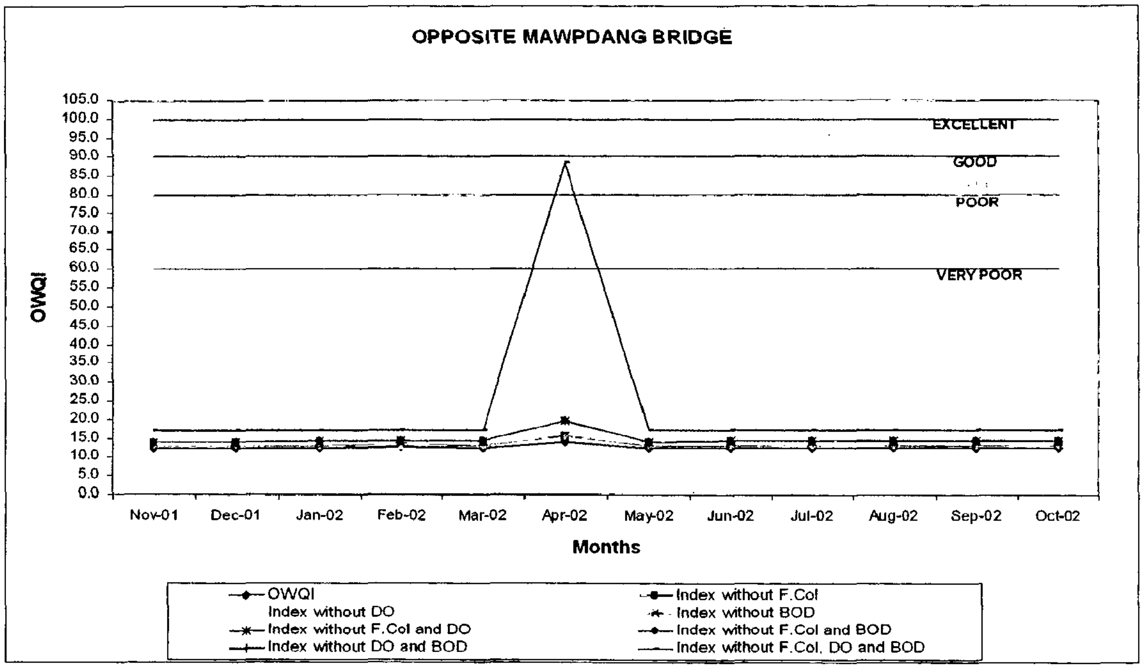

Figure 5.1 (xv): Variation of OWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Opposite Mawpdang Bridge

When the OWQI values are compared with the Designated-Best-Use (DBU) concept of the Central Pollution Control Board, Delhi, it is observed that no comparison can be made. The index values obtained are so low that they can be compared only to the DBU Class of "Below E". However, this is not true as the river water can still be classified in Class "E" which is water that can be used for irrigation, industrial cooling and controlled waste disposal.

It can, therefore, be concluded that the OWQI is a very sensitive index. Its value is greatly influenced by the quality of all the selected pollutant variables. Even if one of the variables shows deterioration, the index obtained will classify the water quality as "very poor". This index can be used to classify rivers that are still relatively clean. Using it on a polluted river, like the River Umkhrah, does not show very clear results.

5.4 NATIONAL SANITATION FOUNDATION'S WATER QUALITY INDEX

The National Sanitation Foundation's Water Quality Index (NSFWQI) has nine pollutant variables whose subindices are aggregated to obtain the final index value. In the present study, eight of the nine variables have been used to calculate the final index. The reason is as for the OWQI, the data for the total solids variable is not available in the report from where the water quality monitoring results have been taken. This, however, does not affect the calculation of the index. As explained in Section 3.5.1 of this report, when data for less than the nine variables is available, the index is calculated by summing up the subindex values of the variables present and dividing it by the sum of their weights. The work-sheets for the NSFWQI are appended as Annexure 3. Table 5.7 and Table 5.8 show the final NSFWQI values calculated for the different locations for 2001-02 and 2005 respectively.

TABLE 5.7: NSFWQI 2001-02

RIVER UMKHRAH

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
LAPALANG	54	46	49	44	47	46	46	46	49	49	47	51
UMPLING BRIDGE	57	49	53	52	51	46	48	52	49	49	46	48
UMKALIAR	54	51	52	53	48	53	50	48	49	51	49	50
DEMSEINIONG	50	45	50	42	44	44	49	51	47	50	44	48
PYNTHOR UMKHRAH	49	45	48	50	53	50	50	52	49	49	51	50
POLO (behind Stadium)	53	47	52	45	50	45	43	48	48	50	45	48
ROOPREKHA	50	44	49	47	46	42	48	49	48	49	46	48
JINGTHANG BRIEW	50	43	49	44	46	42	48	49	47	47	47	49
WAH THANG SNING	47	45	49	43	51	43	49	48	47	51	46	47
MAWPDANG BRIDGE	40	39	44	44	48	49	49	52	44	42	43	48

TRIBUTARIES

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
REFUGEE COLONY	49	40	49	46	41	45	47	48	44	45	47	48
SHILLONG COLLEGE	56	44	48	48	45	46	46	47	48	49	45	51
POLO BRIDGE	42	38	50	50	43	47	39	38	41	46	47	45
OPP. JINGTHANG BRIEW	45	43	50	48	48	44	48	47	48	49	48	48
OPP. MAWPDANG BRIDGE	36	36	40	38	38	48	41	38	44	41	47	41

CLASSIFICATION:

WQI VALUE	0-25	26-50	51-70	71-90	91-100
CLASSIFICATION	Very Bad	Bad	Medium	Good	Excellent
COLOUR CODING					

TABLE 5.8: NSFWQI 2005

S.No.	Sampling Location	22-4-2005	26-4-2005	6.5.2005	13-5-2005
1.	WAH DEMTHRING	58	58	60	57
2.	NONGRAH	59	51	54	50
3.	MARBOH BRIDGE	52	53	50	49
4.	DEMSEINIONG	49	46	47	43
5.	LAWMALI	51	41	41	40
6.	WAHINGDOH	37	36	38	36

The two Tables have a lot of orange colour all over them, which indicates that the water of the River Umkhrah falls mostly in the "bad" category. The patches of yellow colour indicate that the river water at that location and that time falls in the "medium" category. As observed by the previous two indices, this index also shows that there has been no change in the river quality between the years 2001-02 and 2005.

As with the OWQI, this index has also been used to observe changes in river water quality with respect to removal of faecal coliform, dissolved oxygen and BOD as pollutant variables. In a similar manner, the index value has been calculated separately without considering each of the three variables. Then it has been calculated without considering combinations of the above three variables and finally, without considering them at all. The results of these calculations are shown in Table 5.9 (i) to (xv) and the accompanying graphics (Figure 5.2 (i) to (xv)).

It can be observed in from the graphics that there are four distinct levels of index values. The bottom-most level shows the NSFWQI as obtained by considering all available parameters. The level just above this shows the NSFWQI obtained by removing faecal coliform, dissolved oxygen and BOD individually. This indicates that when each of the variables is removed, the quality of the river water improves. The third level above this is occupied by index values obtained by the removal of combinations of these variables. Again, removing a pair of the pollutant variables further improves the water quality. The top-most level is the level of index values when all three variables have been removed together.

TABLE 5.9: VARIATION OF NSFWQI WITH REMOVAL OF FAECAL COLIFORM, DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND

(i) LAPALANG

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	54	46	49	44	47	46	46	46	49	49	47	51
Index without F.Col	64	54	57	52	55	54	54	53	57	57	54	60
Index without DO	57	54	57	50	54	54	52	52	56	56	54	59
Index without BOD	61	52	55	50	53	52	52	52	55	55	53	57
Index without F.Col and DO	71	66	70	61	66	66	64	63	68	68	65	73
Index without F.Col and BOD	75	63	66	60	63	63	62	62	66	66	63	69
Index without DO and BOD	67	62	66	58	62	63	61	60	65	65	63	69
Index without F.Col, DO and BOD	87	81	85	75	80	81	78	77	82	83	80	89

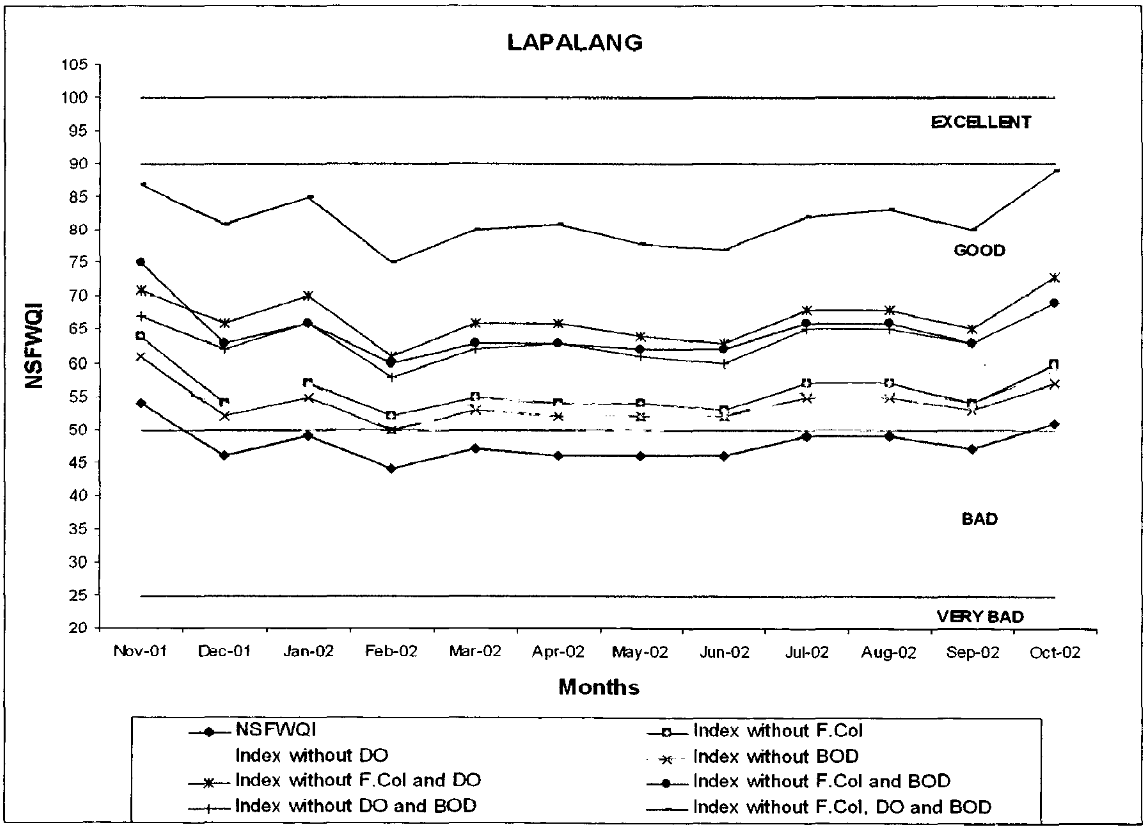

Figure 5.2 (i): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Lapalang

(ii) UMPLING BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	57	49	53	52	51	46	48	52	49	49	46	48
Index without F.Col	65	56	60	59	57	52	56	60	56	56	52	56
Index without DO	60	56	59	59	59	54	57	58	56	55	55	56
Index without BOD	64	55	59	59	57	51	54	59	56	55	52	54
Index without F.Col and DO	72	66	70	70	70	63	69	71	67	66	65	68
Index without F.Col and BOD	76	65	70	69	67	60	65	70	65	65	61	64
Index without DO and BOD	70	65	68	68	68	62	66	68	65	64	63	65
Index without F.Col, DO and BOD	88	81	85	85	85	77	84	86	81	80	79	83

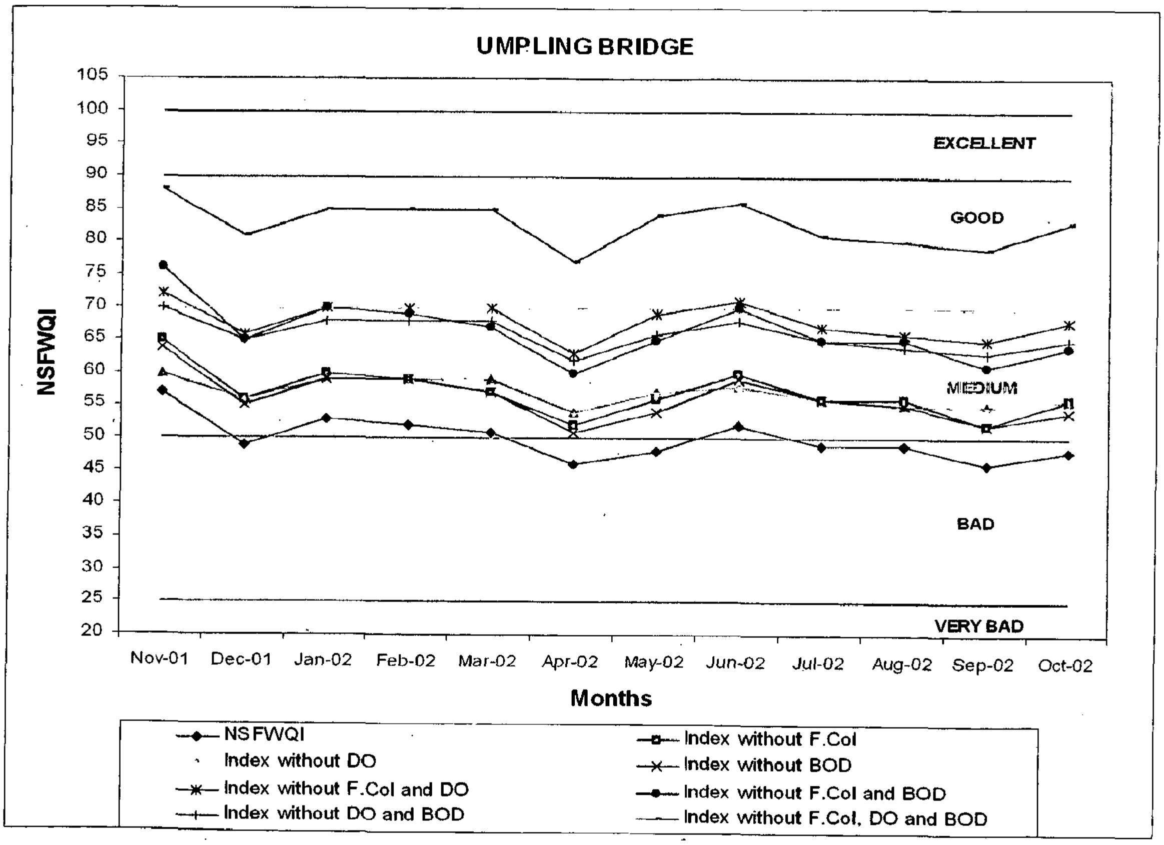

Figure 5.2 (ii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Umpling Bridge

(iii) UMKALIAR

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	54	51	52	53	48	53	50	48	49	51	49	50
Index without F.Col	63	60	61	62	57	62	59	56	57	60	57	59
Index without DO	57	56	59	60	55	58	54	54	56	59	55	57
Index without BOD	61	57	59	60	55	59	57	54	53	58	55	57
Index without F.Col and DO	70	68	72	74	68	71	66	66	68	72	68	71
Index without F.Col and BOD	73	69	71	72	66	72	68	64	64	69	66	69
Index without DO and BOD	67	65	68	70	64	67	63	62	62	69	64	67
Index without F.Col, DO and BOD	86	83	88	90	82	87	80	79	80	88	82	86

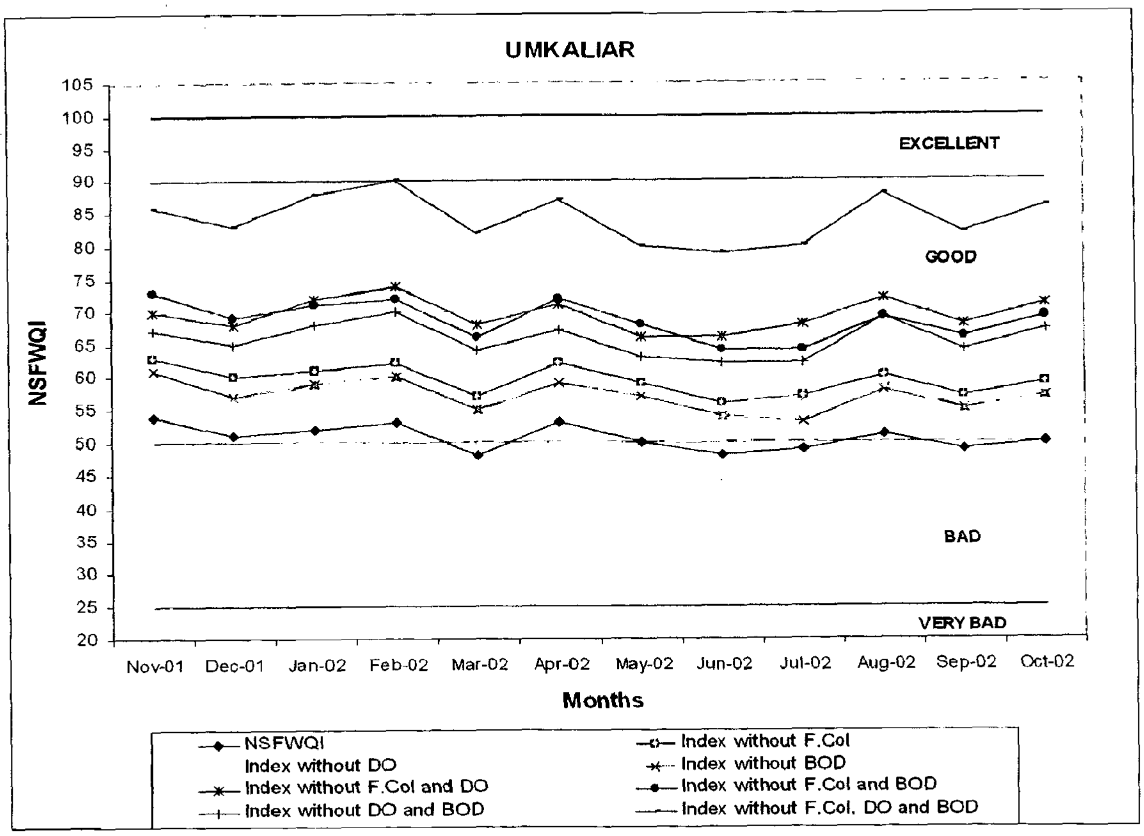

Figure 5.2 (iii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Umkaliar

(iv) DEMSEINIONG

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	50	45	50	42	44	44	49	51	47	50	44	48
Index without F.Col	59	53	56	47	50	50	57	59	54	58	51	56
Index without DO	56	51	57	46	51	50	56	59	56	58	51	56
Index without BOD	57	51	56	47	48	49	55	52	53	56	49	54
Index without F.Col and DO	69	63	68	55	62	59	68	71	67	70	62	69
Index without F.Col and BOD	69	61	66	55	57	58	66	62	63	67	59	65
Index without DO and BOD	65	59	67	54	58	58	66	62	65	67	60	66
Index without F.Col, DO and BOD	84	76	83	67	74	72	83	77	82	85	76	85

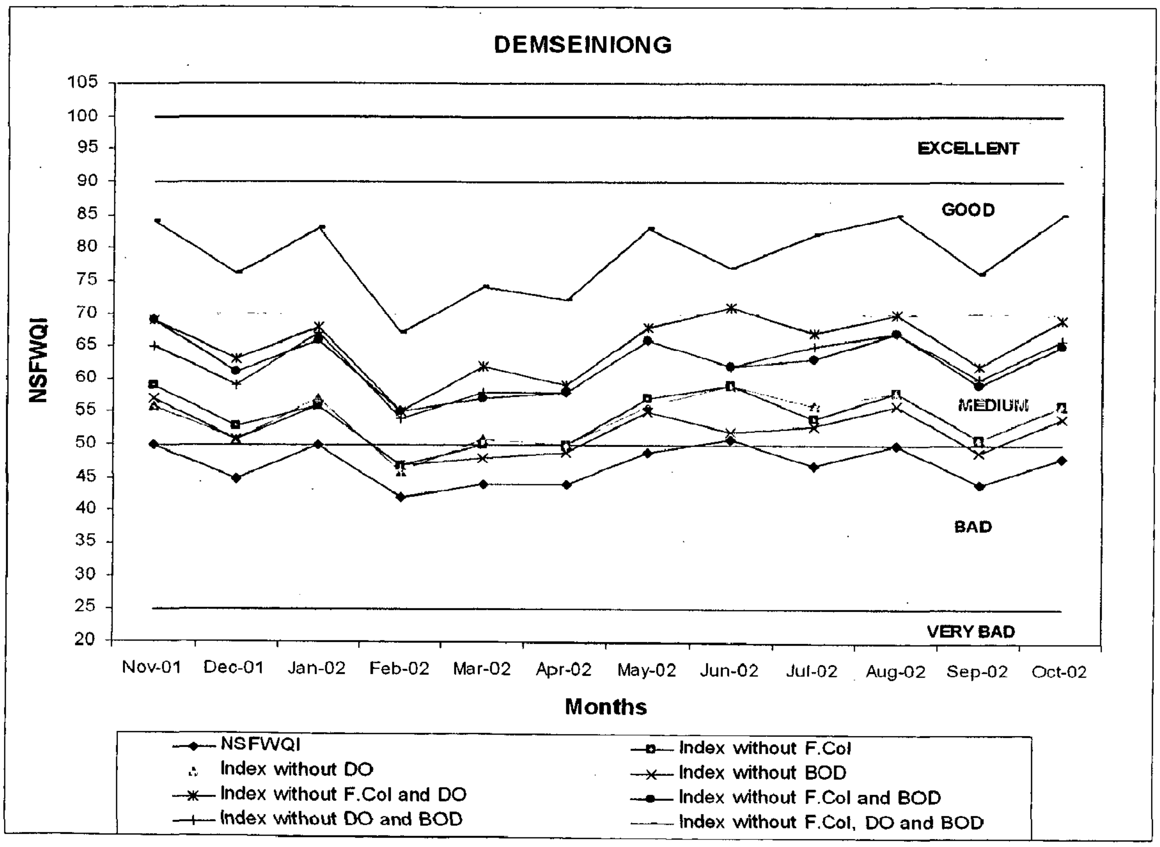

Figure 5.2 (iv): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Demseiniong

(v) PYNTHORUMKHRAH

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	49	45	48	50	53	50	50	52	49	49	51	50
Index without F.Col	57	53	57	58	63	59	58	61	58	57	60	59
Index without DO	56	52	56	57	62	58	58	60	57	58	60	59
Index without BOD	55	52	54	56	58	57	56	59	56	55	58	57
Index without F.Col and DO	69	64	69	70	76	71	71	73	69	71	73	73
Index without F.Col and BOD	67	61	66	68	71	68	68	71	67	67	70	69
Index without DO and BOD	65	60	65	66	69	68	67	70	66	67	69	69
Index without F.Col, DO and BOD	83	77	85	85	89	87	86	89	84	86	89	89

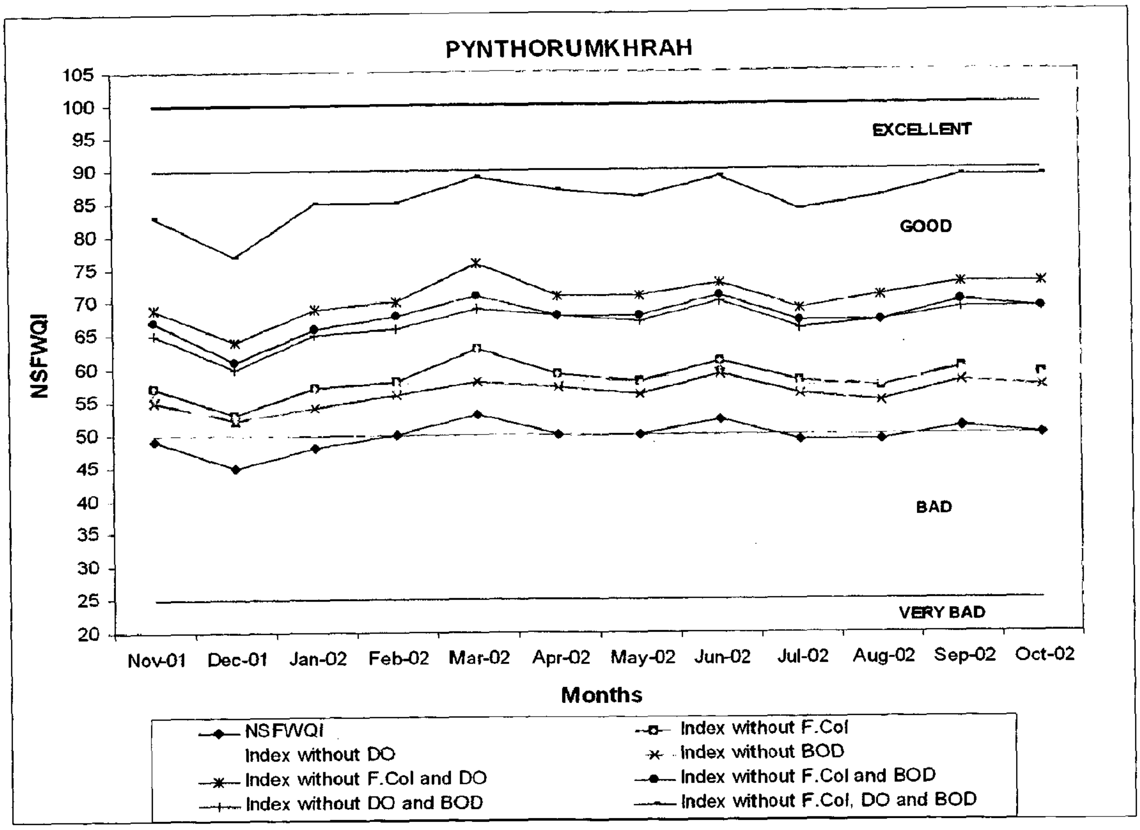

Figure 5.2 (v): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Pynthorumkhrah

(vi) POLO (behind Stadium)

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	53	47	52	45	50	45	43	48	48	50	45	48
Index without F.Col	62	54	60	53	58	52	49	56	55	58	52	57
Index without DO	61	55	59	54	59	51	49	53	55	57	51	58
Index without BOD	60	53	58	51	57	50	48	54	54	56	50	55
Index without F.Col and DO	74	67	72	66	71	62	59	64	68	69	63	72
Index without F.Col and BOD	72	63	70	61	68	60	57	65	64	67	60	66
Index without DO and BOD	71	64	68	63	69	60	57	61	64	66	60	68
Index without F.Col, DO and BOD	90	81	88	81	87	76	72	78	82	85	76	88

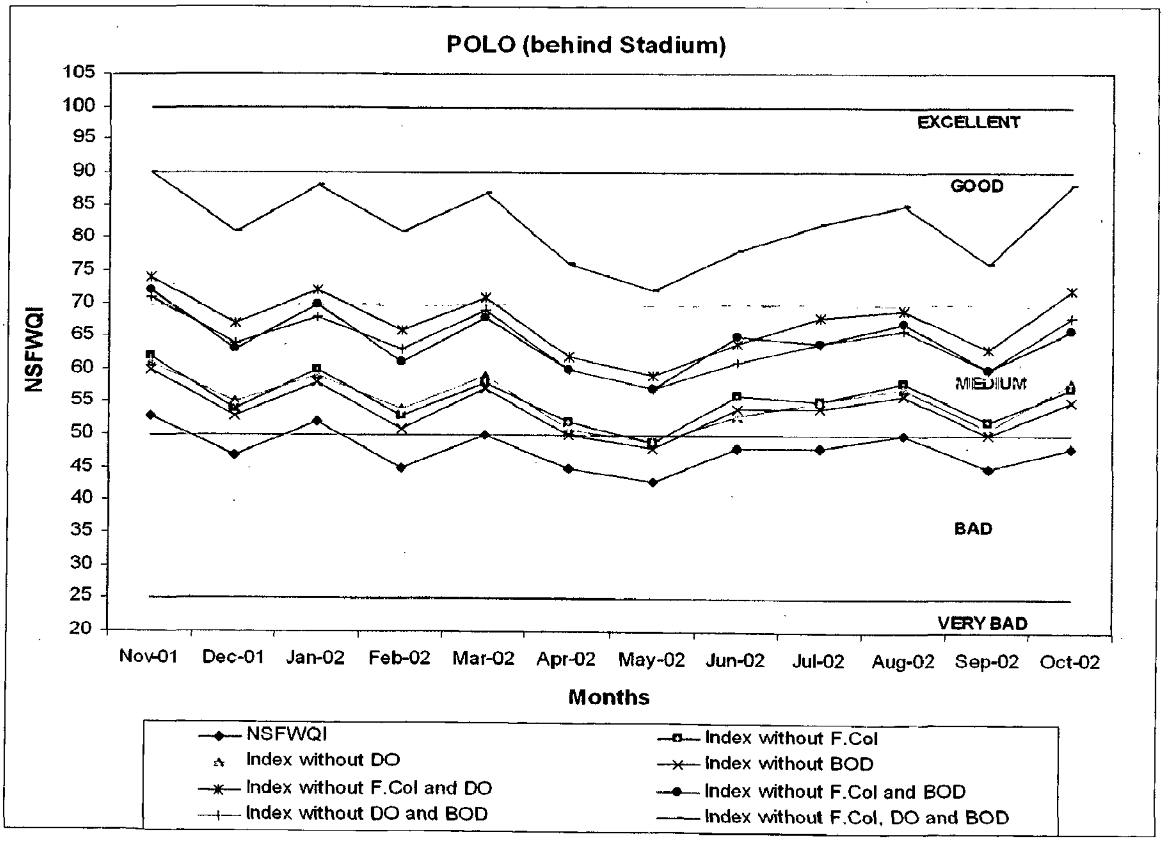

Figure 5.2 (vi): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Polo (behind Stadium)

(vii) ROOPREKHA

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	50	44	49	47	46	42	48	49	48	49	46	48
Index without F.Col	58	51	58	55	53	49	56	57	56	57	54	57
Index without DO	59	51	57	53	54	49	56	56	55	58	54	57
Index without BOD	56	49	56	53	51	48	54	53	54	55	52	54
Index without F.Col and DO	73	63	70	64	66	60	69	69	68	71	67	71
Index without F.Col and BOD	68	59	67	64	62	57	65	64	65	67	63	66
Index without DO and BOD	69	60	66	61	63	57	65	63	65	67	63	67
Index without F.Col, DO and BOD	88	77	85	78	80	73	84	81	83	86	81	86

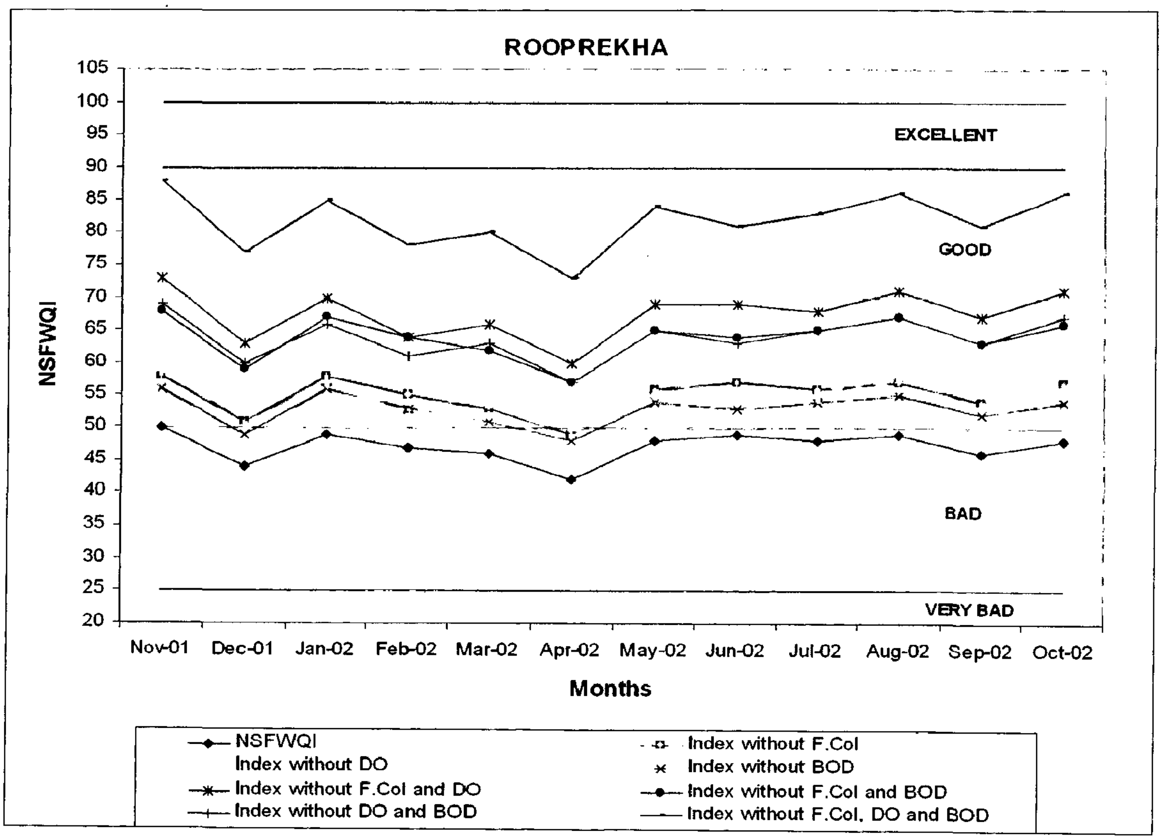

Figure 5.2 (vii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Rooprekha

(viii) JINGTHANGBRIEW

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct 02
NSFWQI	50	43	49	44	46	42	48	49	47	47	47	49
Index without F.Col	58	50	58	53	54	49	56	59	54	55	55	58
Index without DO	59	50	56	50	55	50	57	56	54	55	54	59
Index without BOD	56	48	56	50	50	48	54	55	53	53	53	56
Index without F.Col and DO	72	62	69	62	68	61	70	70	66	67	66	72
Index without F.Col and BOD	67	58	67	61	61	57	65	68	63	64	64	67
Index without DO and BOD	68	58	65	58	61	58	67	65	62	63	63	68
Index without F.Col, DO and BOD	87	76	84	76	79	74	85	85	80	82	81	88

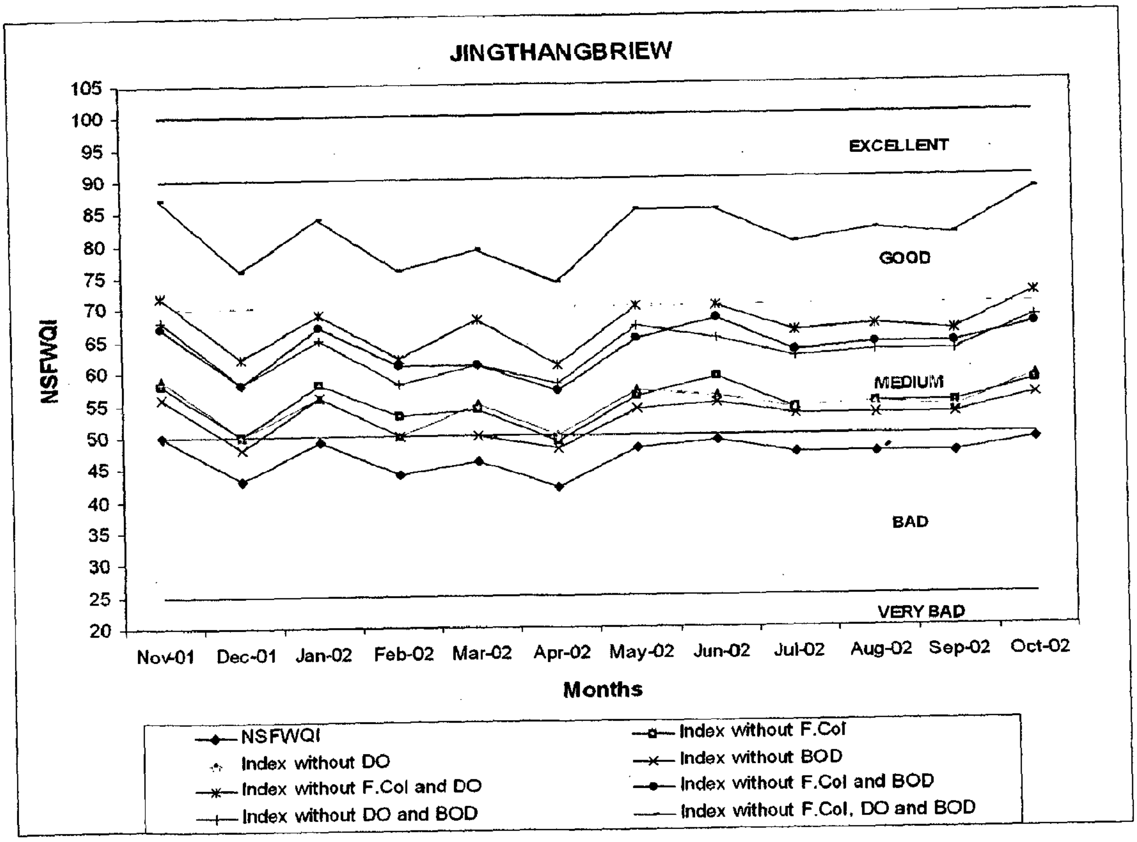

Figure 5.2 (viii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Jingthangbriew

(ix) WAH THANGSNING

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	47	45	49	43	51	43	49	48	47	51	46	47
Index without F.Col	56	53	57	51	60	50	58	56	55	61	54	55
Index without DO	56	52	54	48	59	49	57	55	53	54	53	56
Index without BOD	53	51	55	49	56	48	56	54	53	58	52	53
Index without F.Col and DO	70	63	65	60	73	60	70	68	65	67	65	68
Index without F.Col and BOD	65	61	66	59	68	58	68	65	64	70	63	63
Index without DO and BOD	65	60	62	56	66	57	66	64	62	63	61	65
Index without F.Col, DO and BOD	85	77	80	73	86	73	86	83	79	82	80	83

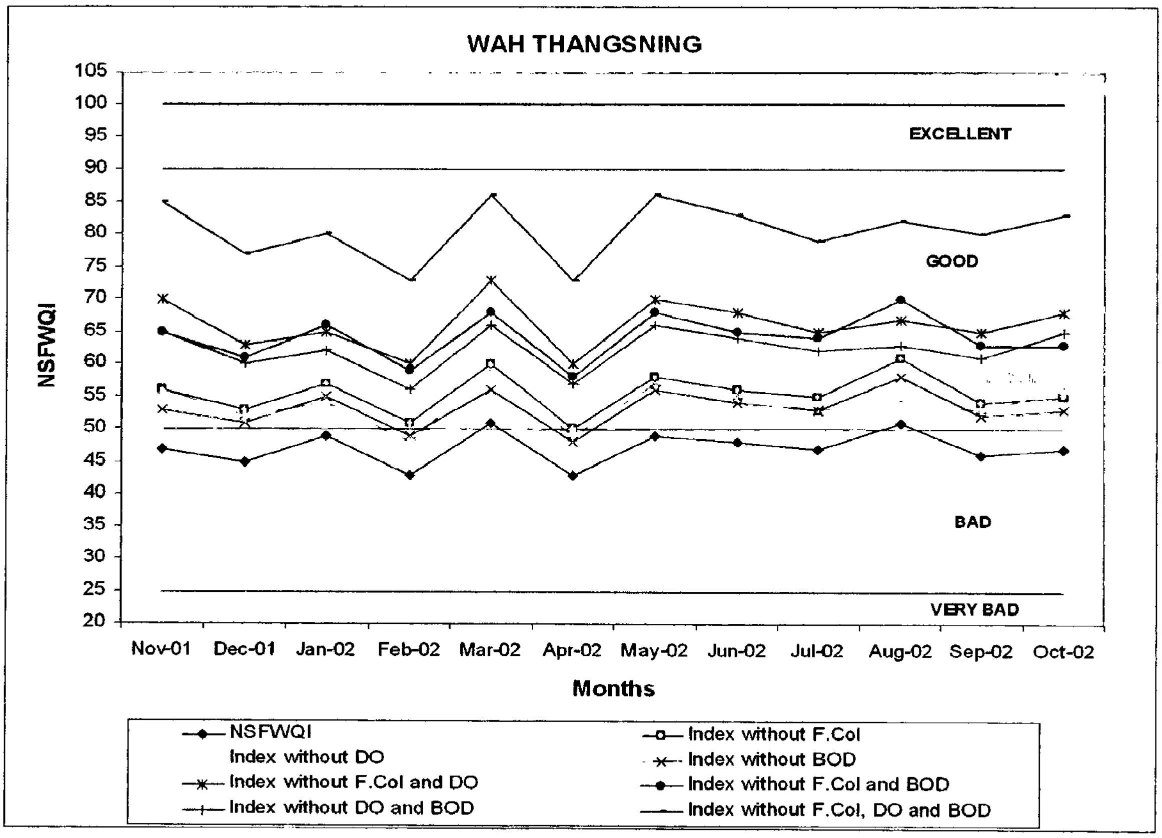

Figure 5.2 (ix): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Wah Thangsning

(x) MAWPDANG BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	40	39	44	44	48	49	49	52	44	42	43	48
Index without F.Col	47	46	52	52	57	58	58	61	51	49	51	58
Index without DO	47	45	50	46	57	55	54	57	50	49	49	58
Index without BOD	45	44	50	49	54	55	55	58	50	47	49	54
Index without F.Col and DO	58	55	61	57	70	68	67	70	61	60	61	71
Index without F.Col and BOD	54	53	60	60	66	67	68	71	60	57	59	67
Index without DO and BOD	54	52	58	54	66	64	62	66	58	57	58	66
Index without F.Col, DO and BOD	70	67	75	69	85	82	82	85	74	73	74	86

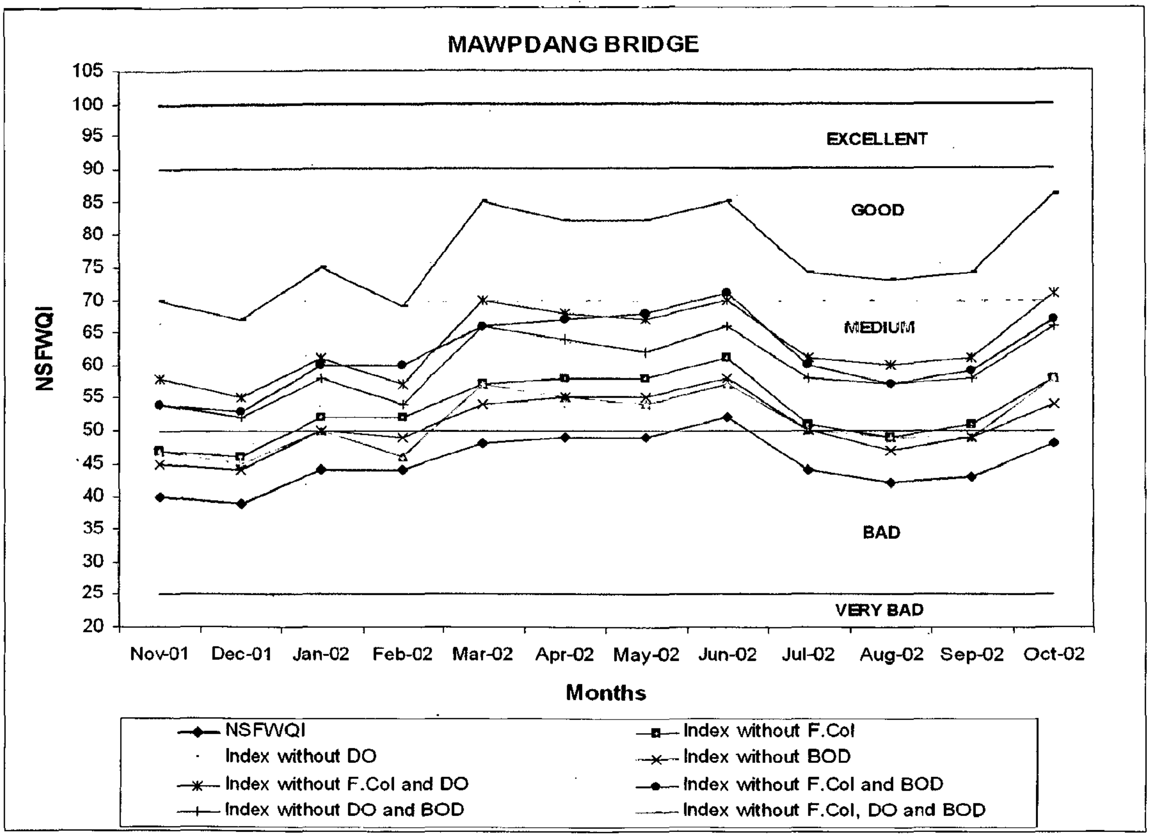

Figure 5.2 (x): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Mawpdang Bridge

(xi) REFUGEE COLONY

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	49	40	49	46	41	45	47	48	44	45	47	48
Index without F.Col	57	46	57	54	47	52	55	56	51	53	55	56
Index without DO	55	47	57	53	48	51	53	55	50	52	55	56
Index without BOD	55	45	55	52	46	51	53	53	50	51	53	54
Index without F.Col and DO	67	57	70	64	58	62	66	68	61	63	68	69
Index without F.Col and BOD	66	54	66	62	55	60	64	64	59	62	64	65
Index without DO and BOD	64	54	67	61	56	60	62	63	59	60	64	65
Index without F.Col, DO and BOD	82	69	86	78	71	75	80	81	75	77	82	84

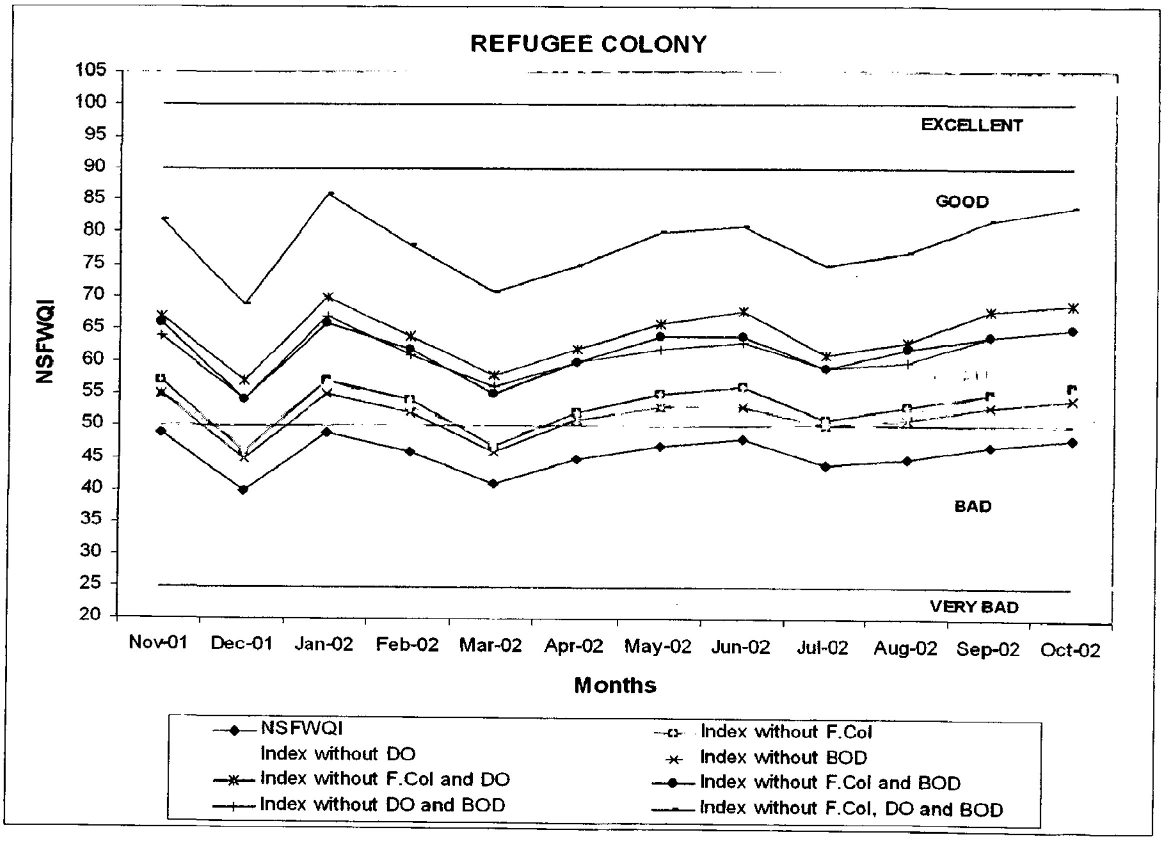

Figure 5.2 (xi): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Refugee Colony

(xii) SHILLONG COLLEGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	56	44	48	48	45	46	46	47	48	49	45	51
Index without F.Col	66	51	56	56	52	53	54	55	56	57	53	59
Index without DO	59	51	55	54	52	54	55	54	55	55	52	59
Index without BOD	63	49	54	54	50	52	50	53	54	55	51	56
Index without F.Col and DO	73	61	67	66	64	66	68	67	67	67	63	72
Index without F.Col and BOD	77	59	65	65	61	62	61	64	65	65	61	68
Index without DO and BOD	69	59	64	63	60	63	62	63	64	64	60	68
Index without F.Col, DO and BOD	89	75	82	81	78	81	80	81	82	80	77	87

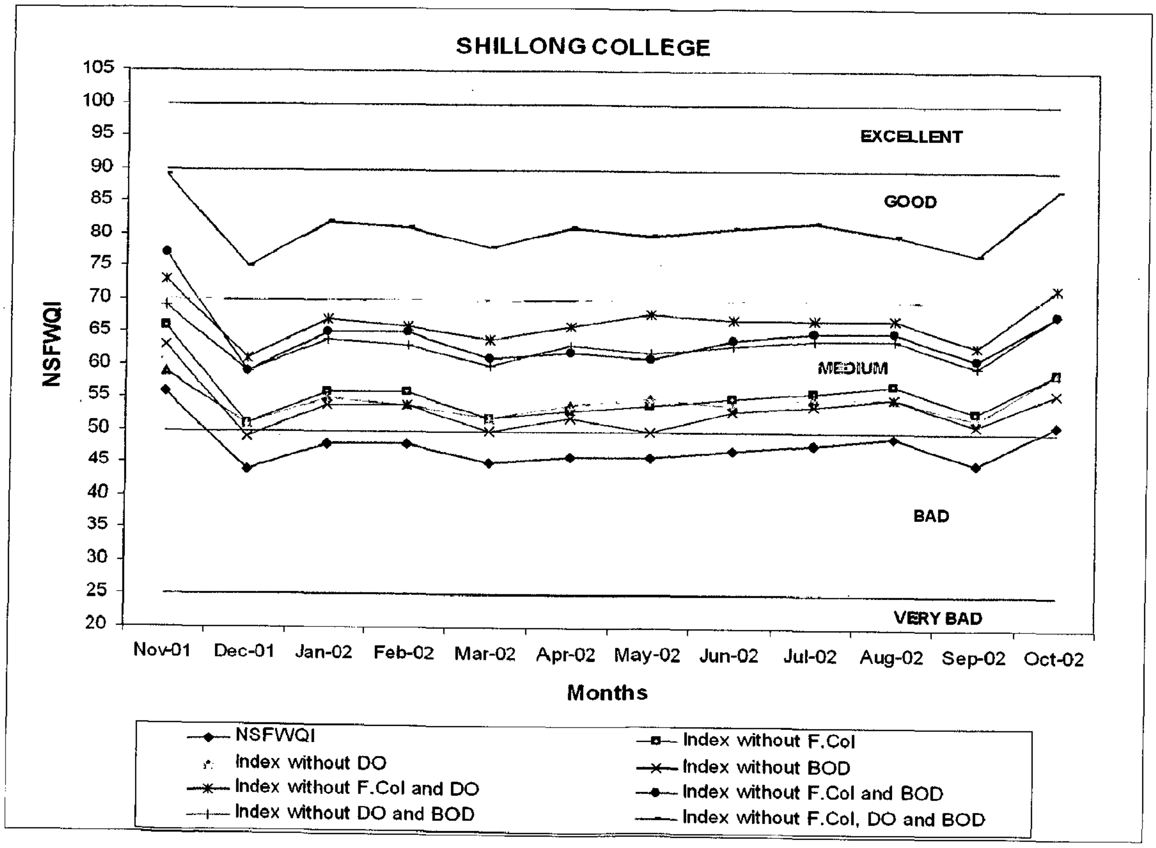

Figure 5.2 (xii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Shillong College

(xiii) POLO BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	42	38	50	50	43	47	39	38	41	46	47	45
Index without F.Col	49	44	58	58	50	55	45	45	47	53	55	52
Index without DO	50	46	56	56	50	55	46	44	48	53	55	54
Index without BOD	48	43	56	56	48	53	44	43	47	51	53	51
Index without F.Col and DO	62	56	69	69	61	68	56	54	57	65	67	66
Index without F.Col and BOD	57	52	67	68	58	64	53	52	55	62	64	61
Index without DO and BOD	59	53	66	66	58	65	54	51	56	61	64	63
Index without F.Col, DO and BOD	75	68	84	84	75	83	68	65	70	79	82	81

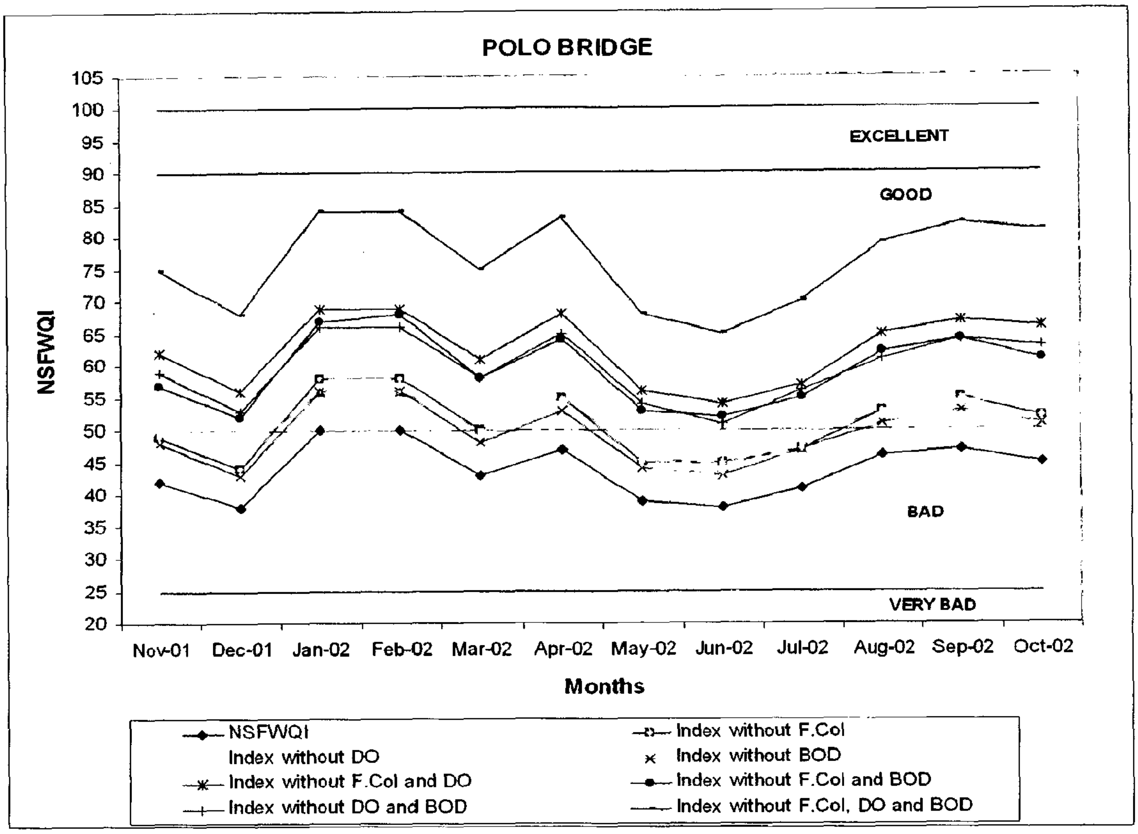

Figure 5.2 (xiii): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Polo Bridge

(xiv) OPPOSITE JINGTHANGBRIEW

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	45	43	50	48	48	44	48	47	48	49	48	48
Index without F.Col	52	51	58	56	56	51	57	55	57	58	56	57
Index without DO	54	50	57	54	55	51	56	56	57	58	57	58
Index without BOD	50	48	56	54	55	50	55	53	54	56	54	55
Index without F.Col and DO	66	62	69	67	67	62	69	69	70	71	70	71
Index without F.Col and BOD	61	59	67	65	65	59	66	64	66	67	65	66
Index without DO and BOD	63	59	66	63	64	60	65	65	66	68	67	68
Index without F.Col, DO and BOD	81	76	84	81	81	76	84	84	86	87	86	87

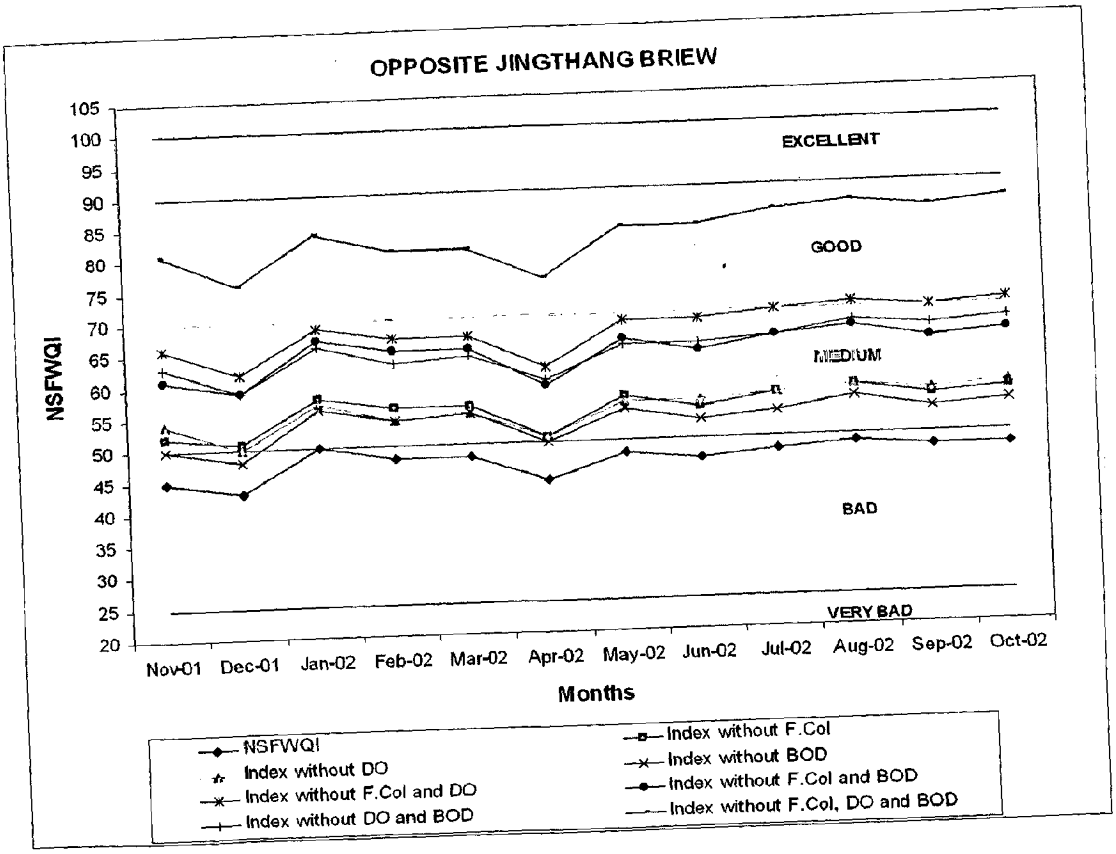

Figure 5.2 (xiv): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Opposite Jingthangbriew

(xv) OPPOSITE MAWPDANG BRIDGE

Parameters	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
NSFWQI	36	36	40	38	38	48	41	38	44	41	47	41
Index without F.Col	42	42	48	44	44	57	49	45	52	49	56	48
Index without DO	42	42	47	41	44	56	46	43	51	48	55	48
Index without BOD	40	40	45	42	42	55	46	43	50	47	53	46
Index without F.Col and DO	52	52	59	50	54	69	58	53	62	59	69	60
Index without F.Col and BOD	48	48	56	51	51	66	56	52	60	56	65	56
Index without DO and BOD	49	49	55	48	51	65	54	50	59	56	64	56
Index without F.Col, DO and BOD	63	63	72	61	66	84	71	64	76	72	84	72

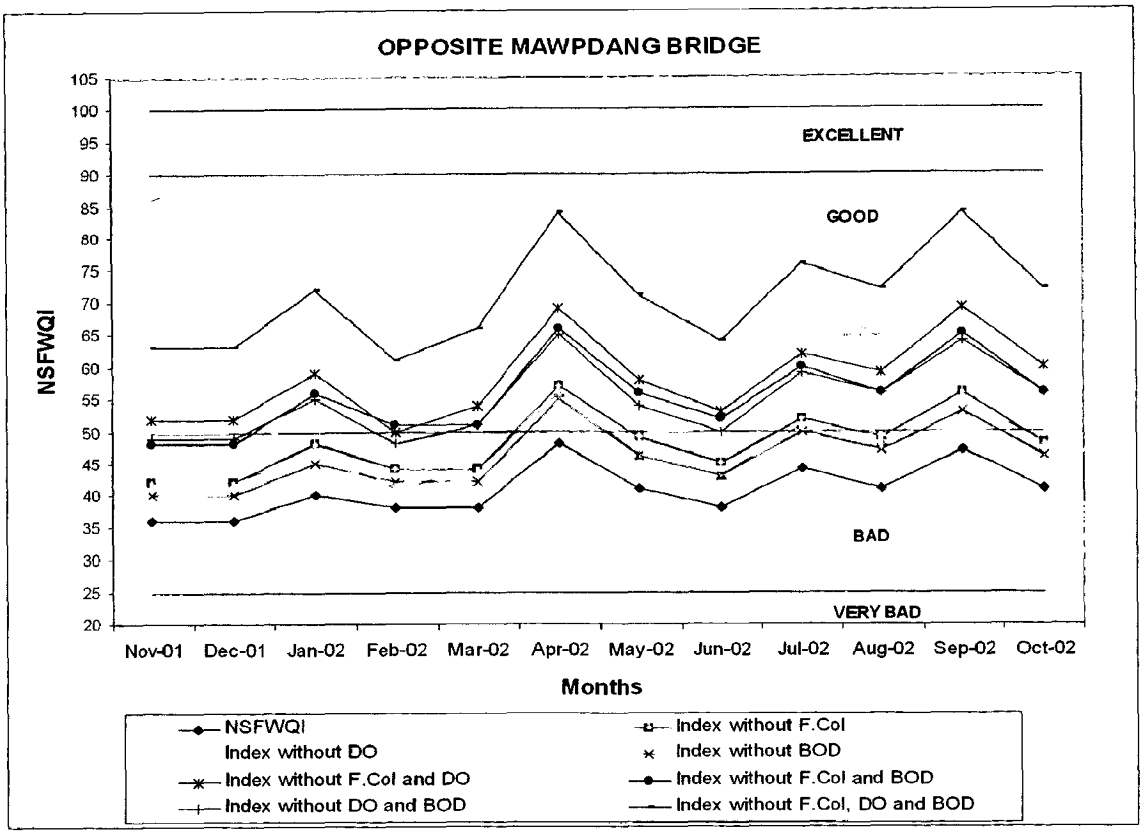

Figure 5.2 (xv): Variation of NSFWQI with removal of faecal coliform, dissolved oxygen and biochemical oxygen demand at Opposite Mawpdang Bridge

When all the available variables are considered, the index values have stayed more or less in the "bad" and "medium" categories. Upon removal of faecal coliform only, the index values increase considerably. Though, the values remain in the "medium" category for all sampling locations at all times, a marked increase can be observed. Similarly, when dissolved oxygen is removed, there is an obvious improvement in the index values. Dissolved oxygen has been given the highest weightage (0.17), but the variation after its removal is found to be less than that of faecal coliform in many of the locations. BOD has been given a weightage of only 0.10, but its removal also shows an appreciable variation, which proves that it is a critical pollutant variable.

When the pollutant variables are removed in combination, the index values further increase to indicate improved water quality. When the combination of faecal coliform and dissolved oxygen is removed, there is a big increase from the original index value. The other combinations, i.e. faecal coliform – BOD and dissolved oxygen – BOD, also show appreciable increase from the original value, but less than that of the faecal coliform – dissolved oxygen combination.

Finally, when all three pollutant variables are removed, the index value shoots up to the "good" category, even touching the "excellent" category at some points. This is a clear indication that these three variables are very important for a river monitoring programme. They are the main pollutants in the River Umkhrah. Faecal coliform comes from the direct discharge of sewage from the latrines on the river banks and also from open defecation. Low dissolved oxygen levels and high BOD are due to the solid and other waste dumped into the river.

Using the NSFWQI values, a water quality profile of the River Umkhrah has been plotted for the year 2001-02. To obtain a profile of the entire river, besides the 10 sampling locations, an eleventh one is also added. This location is Demthring, which is located very near to the source of the river. Since only annual average water quality monitoring data are available for Demthring (Annexure 2), the NSFWQI is calculated with these average values ana the index obtained is used in the plotting the river profile. Table 5.10 shows the NSFWQI at Demthring and the river profile is given in Figure 5.3.

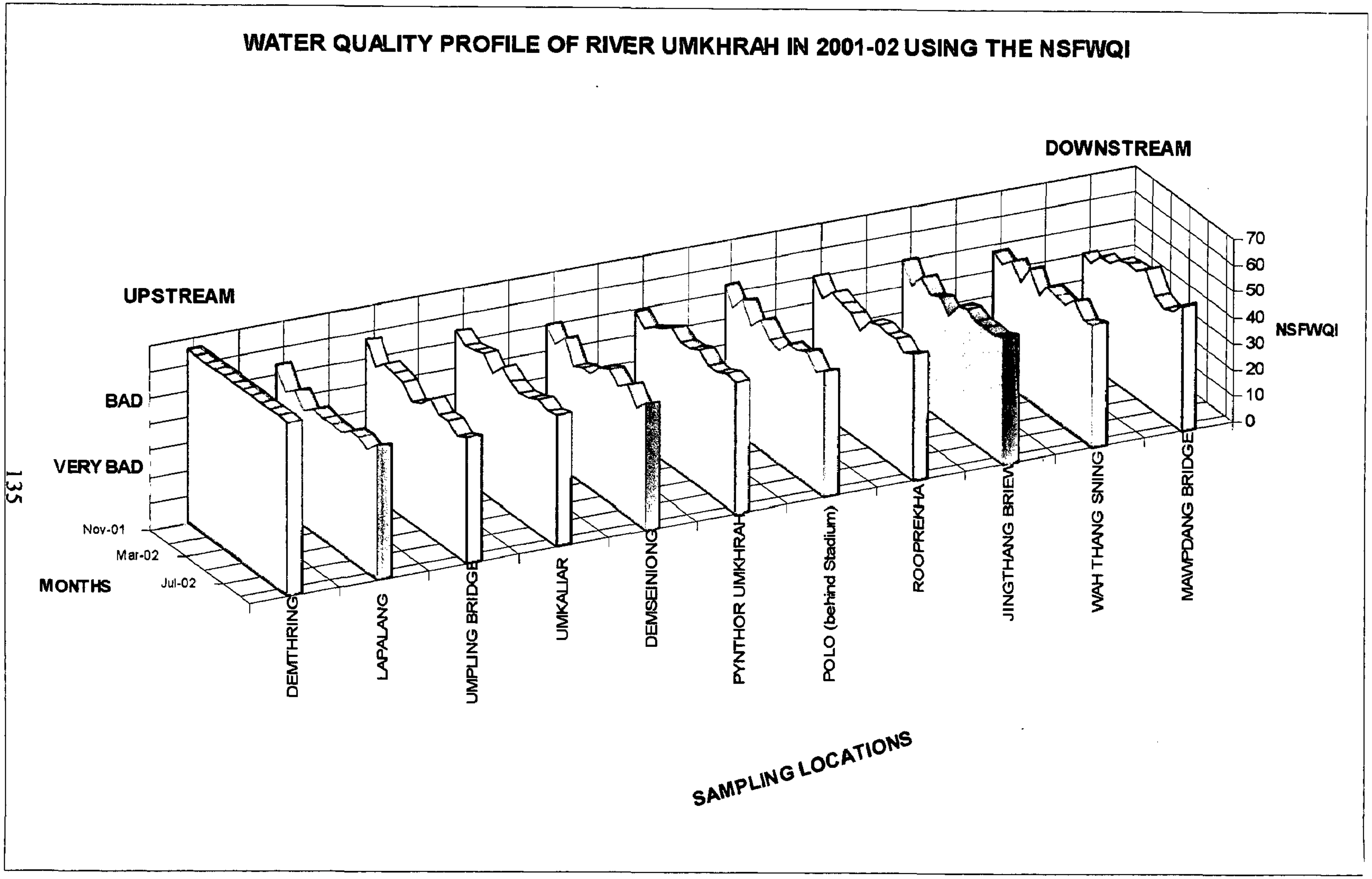

Figure 5.3: Water quality profile of River Umkhrah in 2001-02 using the NSFWQI

TABLE 5.10: NSFWQI VALUES AT DEMTHRING

YEAR	NSFWQI
2002	66
2003	69
2004	70

The sampling location at Demthring is located in a residential area. There also exists a saw-mill and a hollow cement concrete block making unit nearby. For these reasons, high faecal coliform concentrations are observed even at this upstream location and the NSFWQI values are in the "medium" category only. In the profile, at Demthring the NSFWQI value for the year 2002 has been used and for the other 10 locations, values calculated for the year 2001-02 have been used.

From the water quality profile of River Umkhrah in Figure 5.3, it is observed that there is very little variation in the water quality throughout the length of the river throughout the year. The NSFWQI values remain in the "bad" and "medium" categories throughout. This evidently shows that the river is in a very bad state of pollution and its entire stretch has been affected.

When the NSFWQI values are compared with the Designated-Best-Use (DBU) concept of the Central Pollution Control Board, Delhi, it is observed that some comparison can be made. This comparison is shown in Table 5.11.

TABLE 5.11: COMPARISON BETWEEN NSFWQI AND DBU CONCEPT

S. No.	NSFWQI VALUES	NSFWQI CLASSIFICATION	DBU CLASSIFICATION	COMMENTS
1	0 – 25	Very bad	Below E	In both classifications, all the variables have completely deteriorated to an extent that the water cannot be used for any purpose anymore
2	26 – 50	Bad	E	In both classifications, most of the variables have deteriorated but the water can still be used for some activities like irrigation, industrial cooling and controlled waste disposal

3	51 – 70	Medium	D	In both classifications, the dissolved oxygen levels are good enough for the propagation of aquatic animals and wild life
4	71 – 90	Good	B & C	In both classifications, most of the variables are within pollution control limits and the water can even be used for drinking after conventional treatment and disinfection
5	91 – 100	Excellent	A	In both classifications, the water quality is still in its pristine condition

Finally, it can be concluded that the NSFWQI is a versatile and flexible index which can be used even in Indian conditions to give satisfactory results.

5.5 COMPARISON OF THE THREE INDICES

The variation of the three indices at different stations along the river for the data of the year 2001-02 has been shown in Figure 5.4. The NSFWQI and the OWQI showed very less variation between the stations throughout the year and the Said, *et al* WQI showed a lot of variation in the negative Y-axis direction indicating poor water quality. The NSFWQI showed values mostly in the "bad" and "medium" categories and the OWQI had all the values in the "very poor" category. While the Said, *et al* WQI showed very large variation in values, the OWQI showed very less variation with all the values clumped together at the lower part of the graph. The NSFWQI showed a clearer picture of the difference in values between the sampling locations.

The classification of water quality in the OWQI and Said, *et al* WQI was more inclined towards the "poor" water quality classification as both required all the pollutant variables to be in acceptable limits to give a "good" index value. The classification of water quality was more distributed in NSFWQI and it was comparable to the DBU concept of the CPCB.

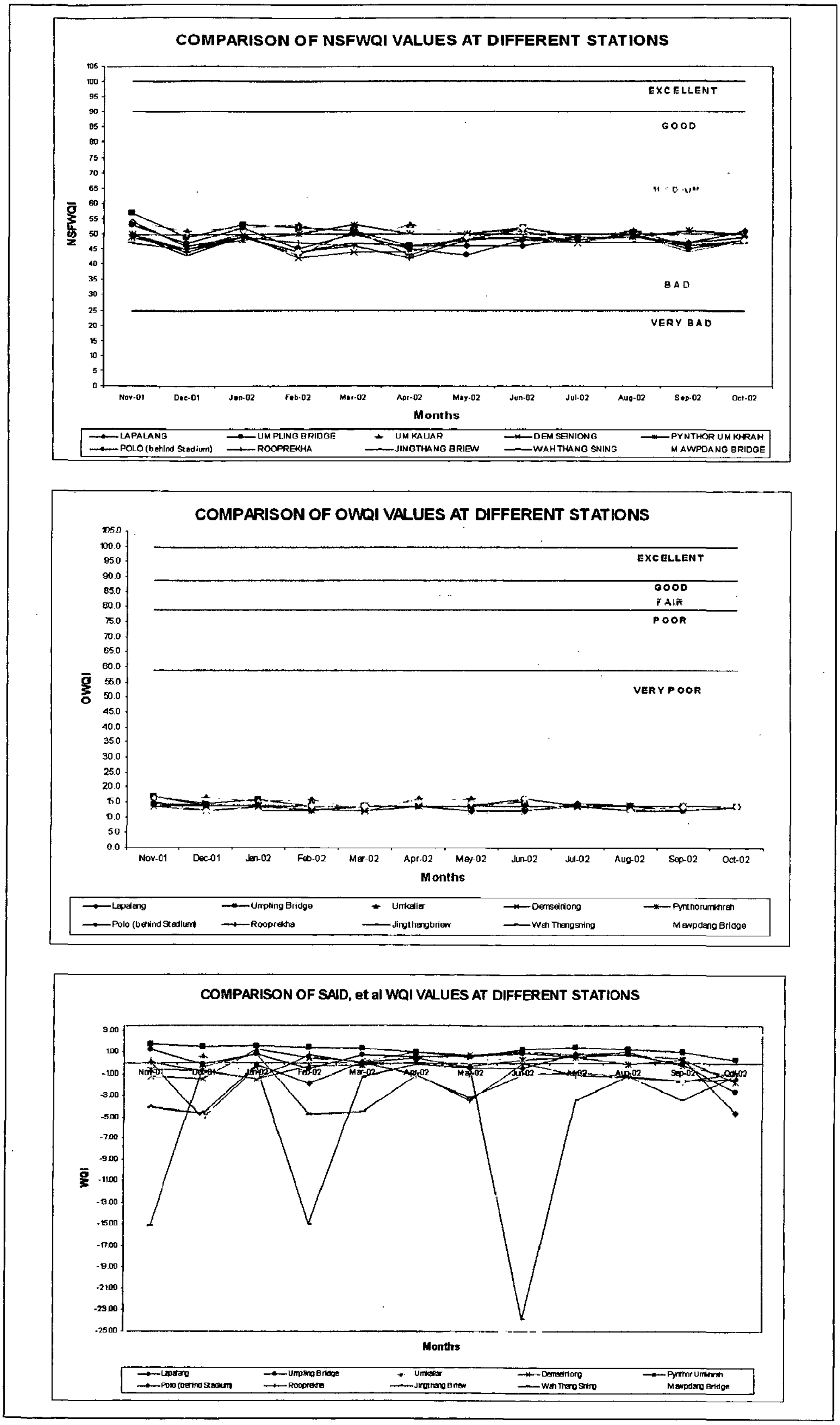

Figure 5.4: Comparison of the three indices at sampling locations along the river

Both OWQI and Said, *et al* WQI showed the water quality as "very poor" as soon as any one of the pollutant variables deteriorated. The NSFWQI, on the other hand, did not show such trends, mainly because of the weights given to the different pollutant variables. This indicated that the NSFWQI was more flexible and versatile than the other two indices. The results obtained through the NSFWQI were found to be satisfactory. The colour coding prescribed by the NSFWQI helped in making the index very user-friendly. Mapping of the index values also became very easy and a clear picture of the water quality of a water body can easily be obtained at a glance. The NSFWQI has been tried and tested in many river basins across the world and it has proved that it was more superior to other indices.

5.6 MAPPING OF THE INDICES

The index values obtained by NSFWQI have been selected for mapping purposes. The base map has been digitized from the Survey of India tourist guide map of Shillong, of scale 1:15,000, using Arc Map 8.3. The latitude and longitude of each sampling location has been noted in the field by using E-Trex Global Positioning System meter and entered into the base map for the purpose of geo-referencing. The maps showing the variation in NSFWQI values in the year 2001-02 are shown in Figure 5.5 (i) to (xv).

Mapping of the calculated index values gives a clear picture of the extent of pollution in the river. From these water quality maps, we can see that right from an upstream location, Lapalang, the river is already polluted. There is not much variation in the water quality throughout the year either along the whole stretch of the river or its tributaries. The pollution is so bad that there is no dilution in the monsoon. With very high faecal coliform counts and high BOD and COD loads, the natural self purification mechanism of the river has also been completely disrupted. We can conclude by saying that something needs to be done quickly to restore the quality of the river water to its original condition, otherwise Shillong will be forever stained by a filthy river flowing through it.

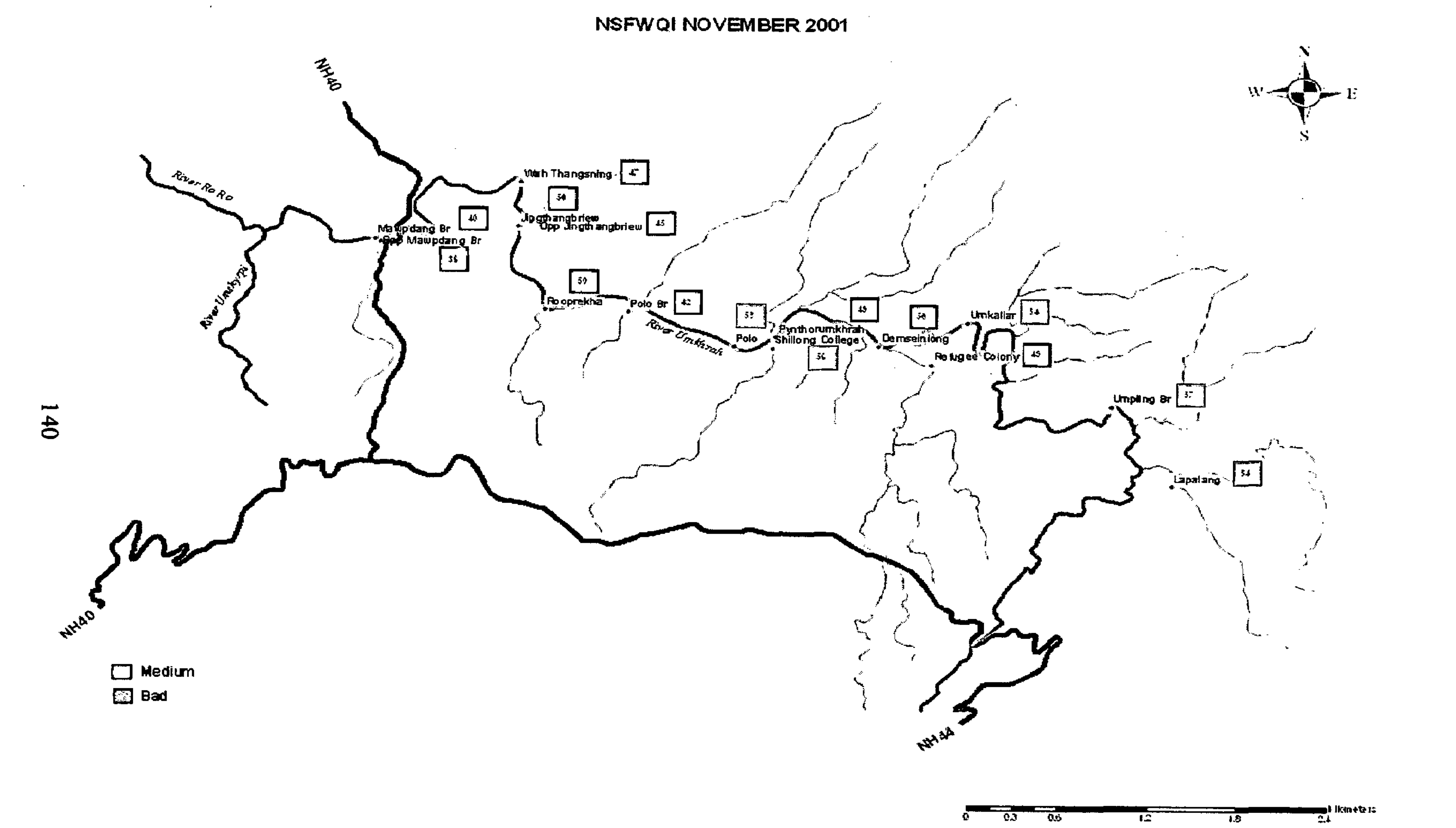

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(i) November 2001

NSFWQI DECEMBER 2001

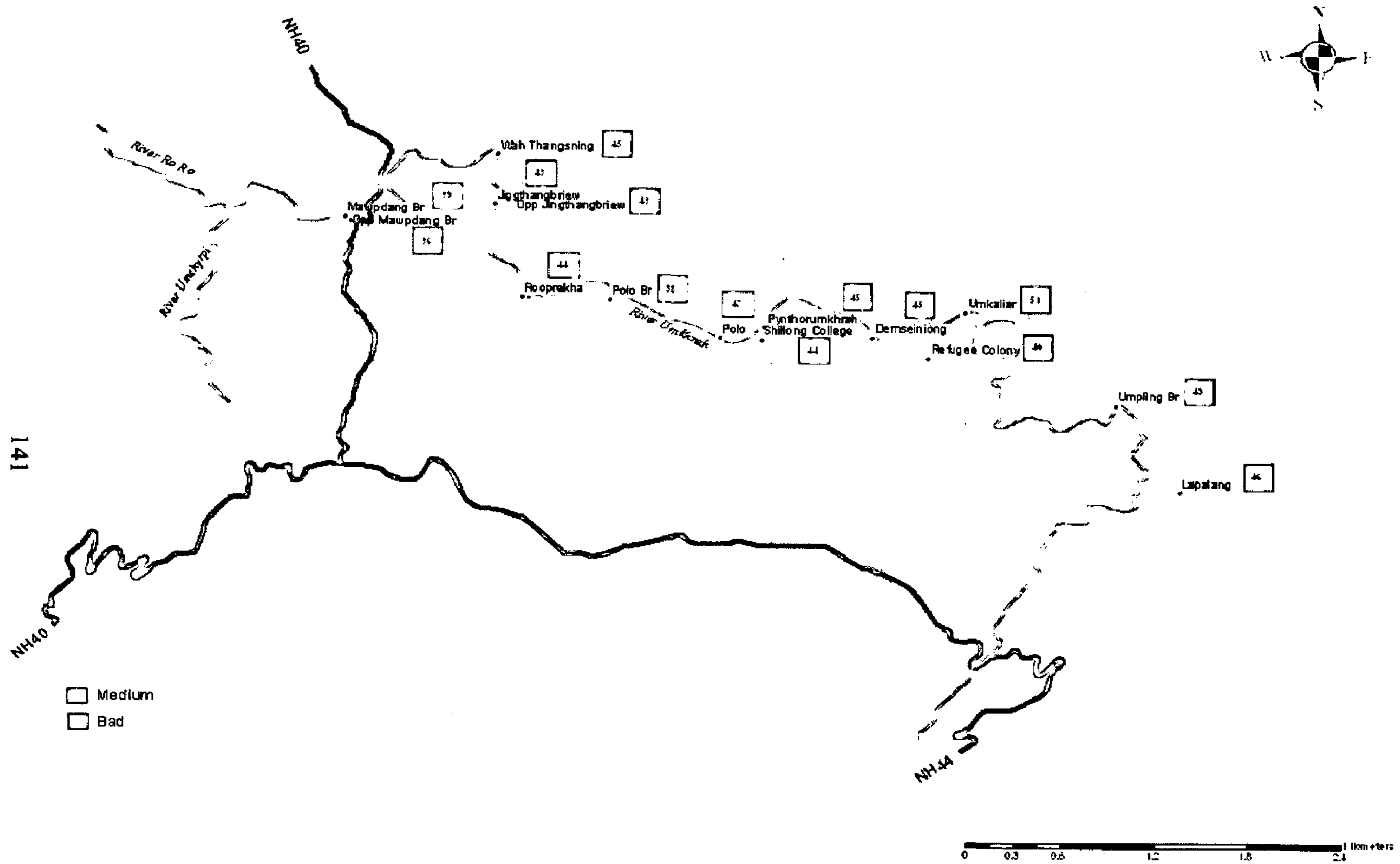

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(ii) December 2001

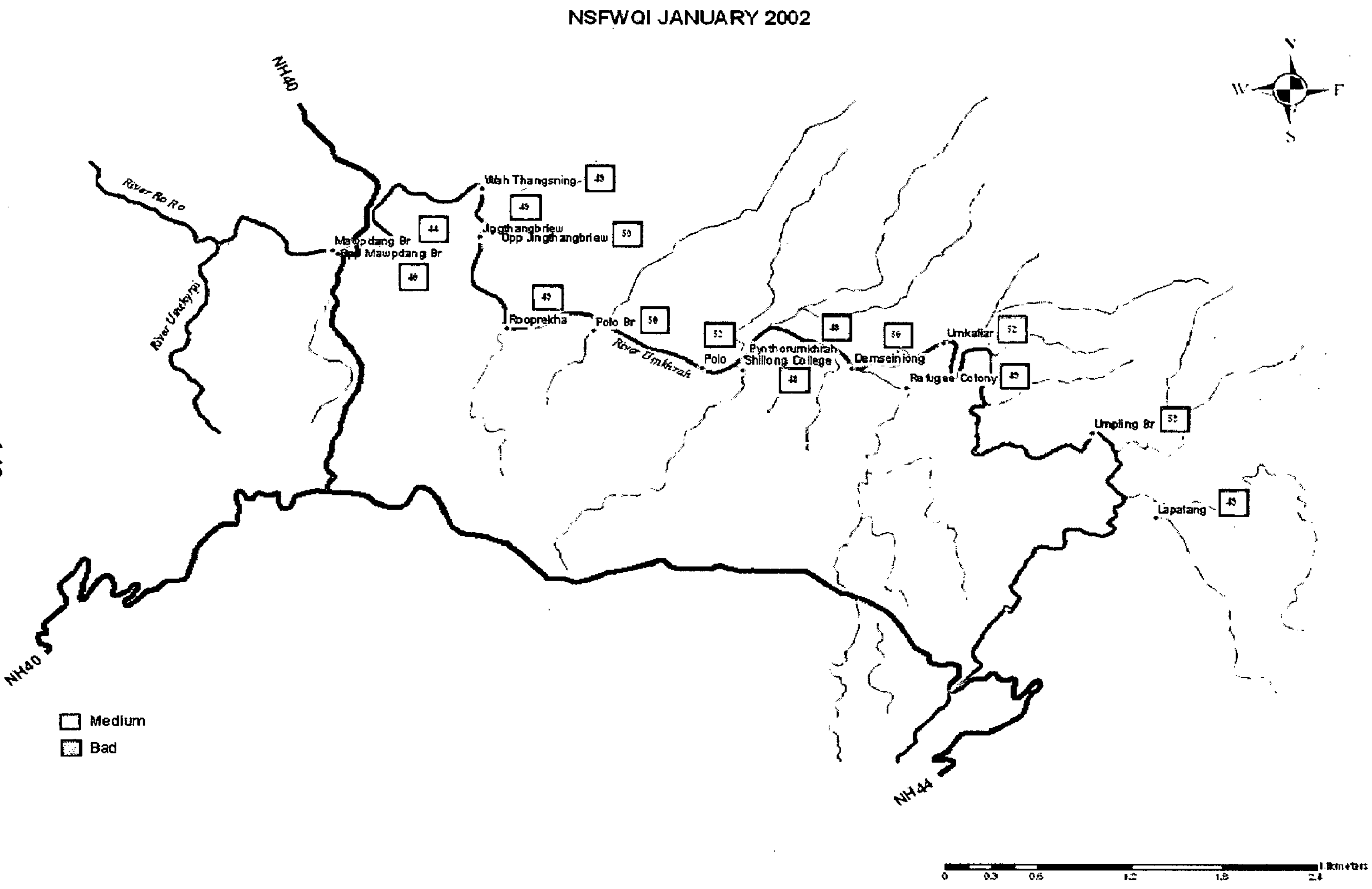

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(iii) January 2002

NSFWQI FEBRUARY 2002

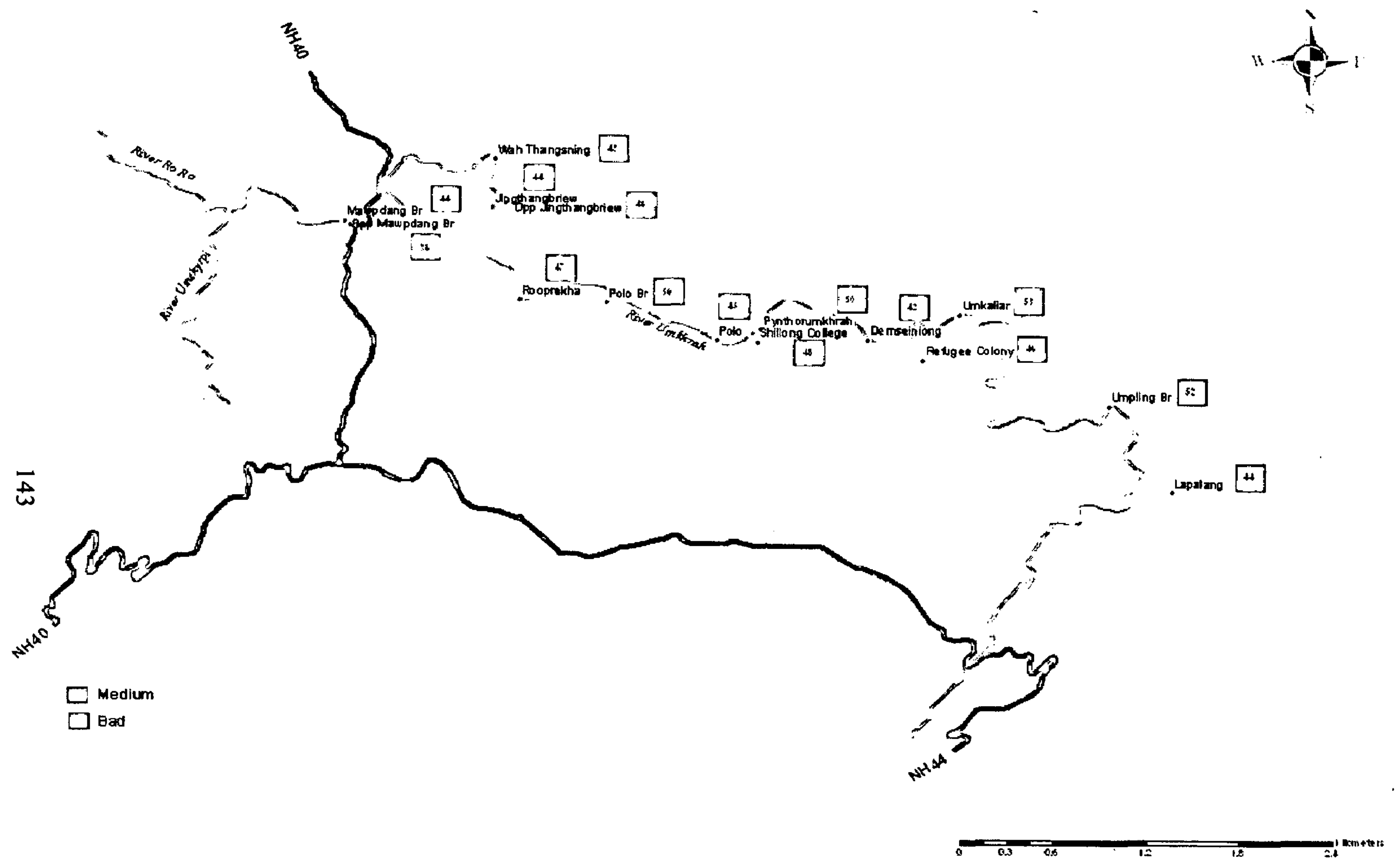

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(iv) February 2002

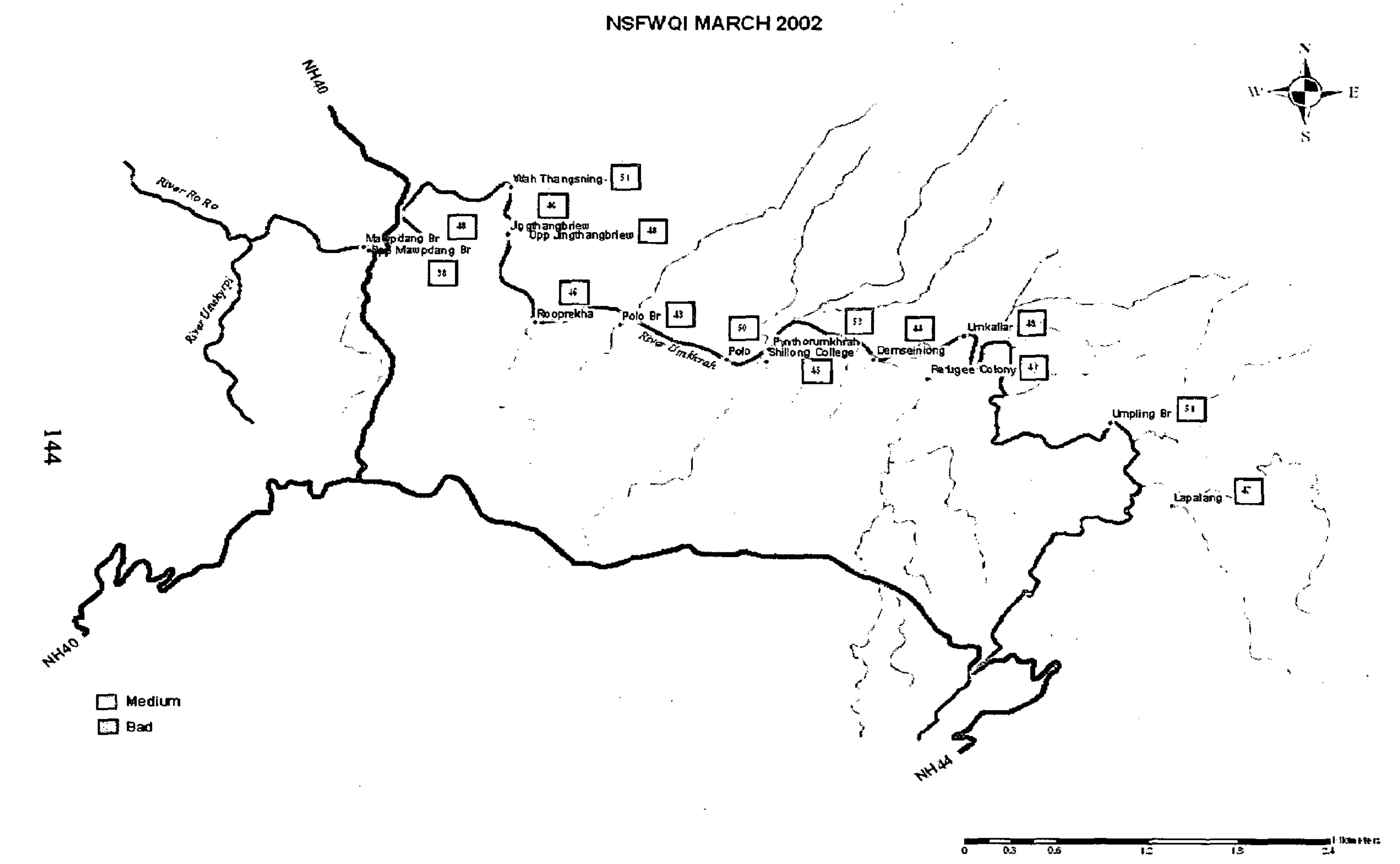

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(v) March 2002

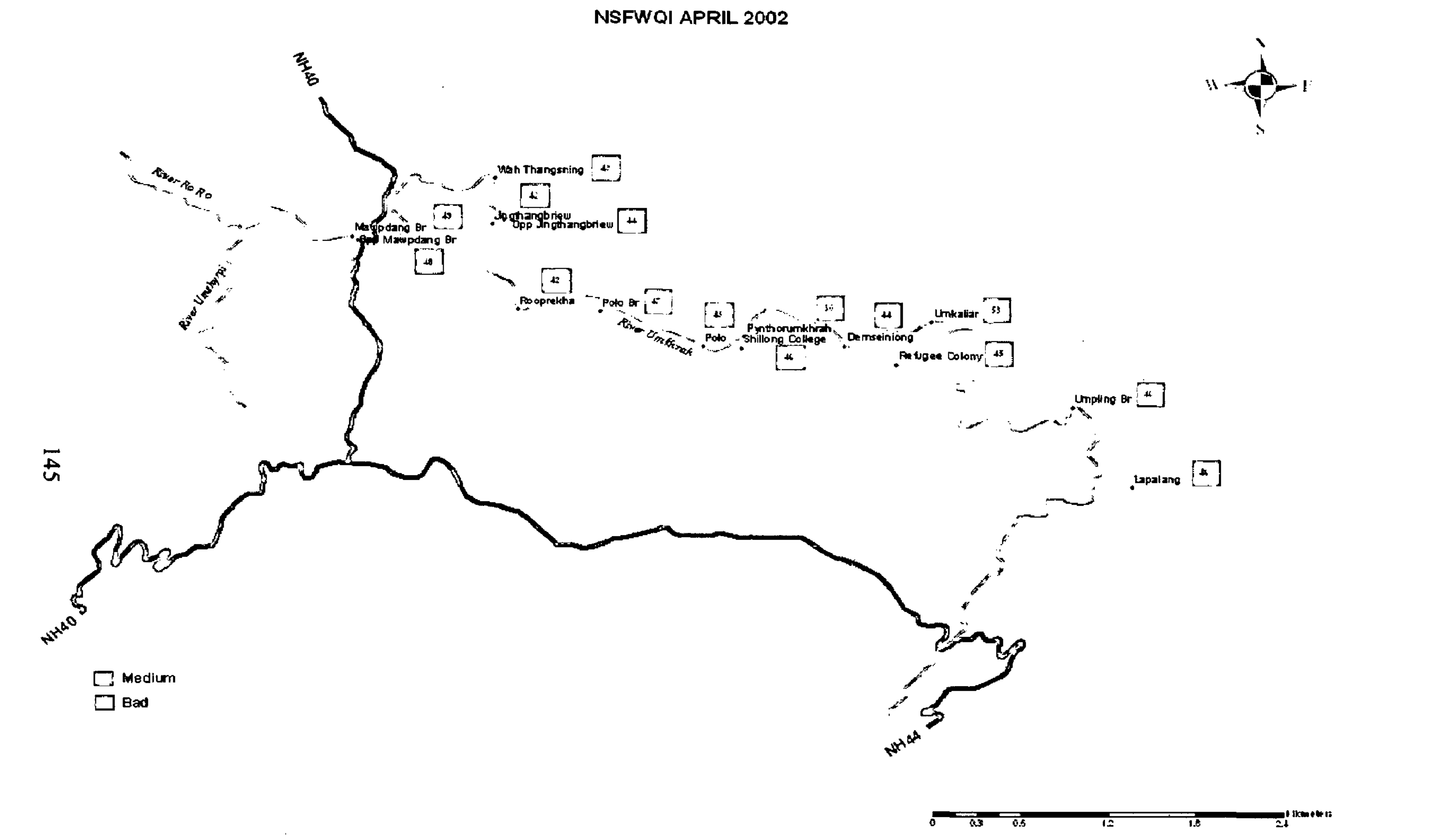

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(vi) April 2002

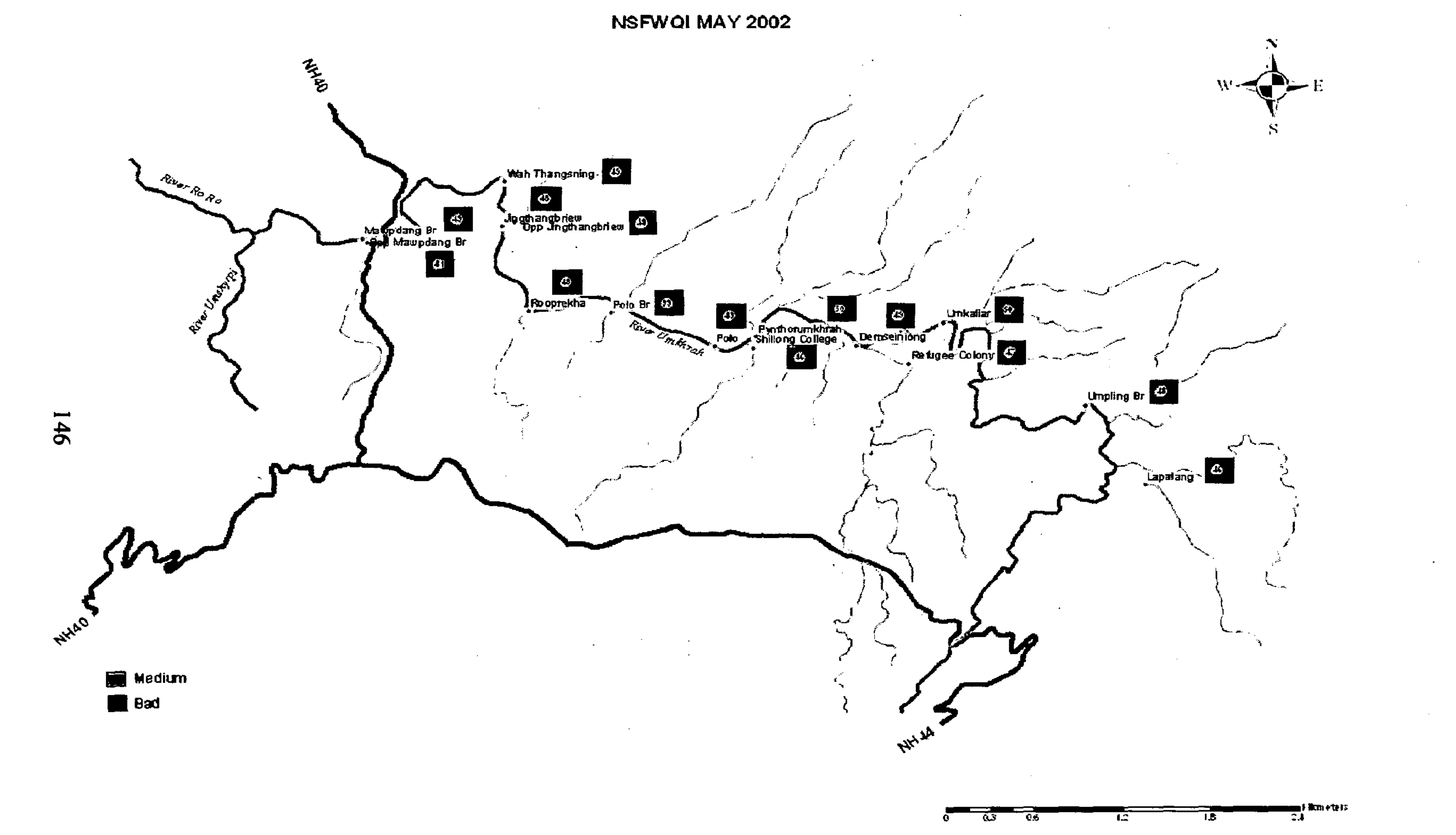

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(vii) May 2002

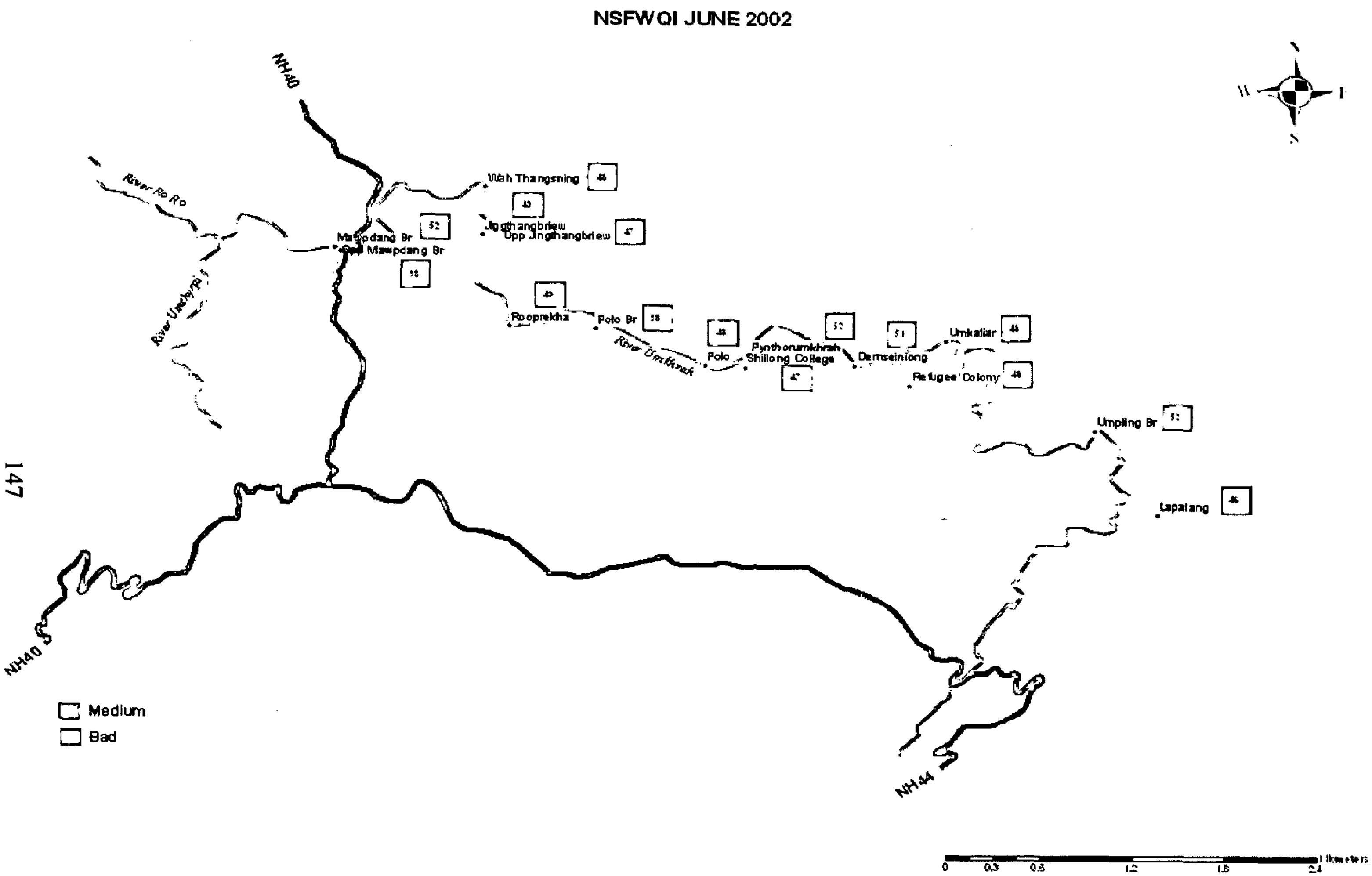

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(viii) June 2002

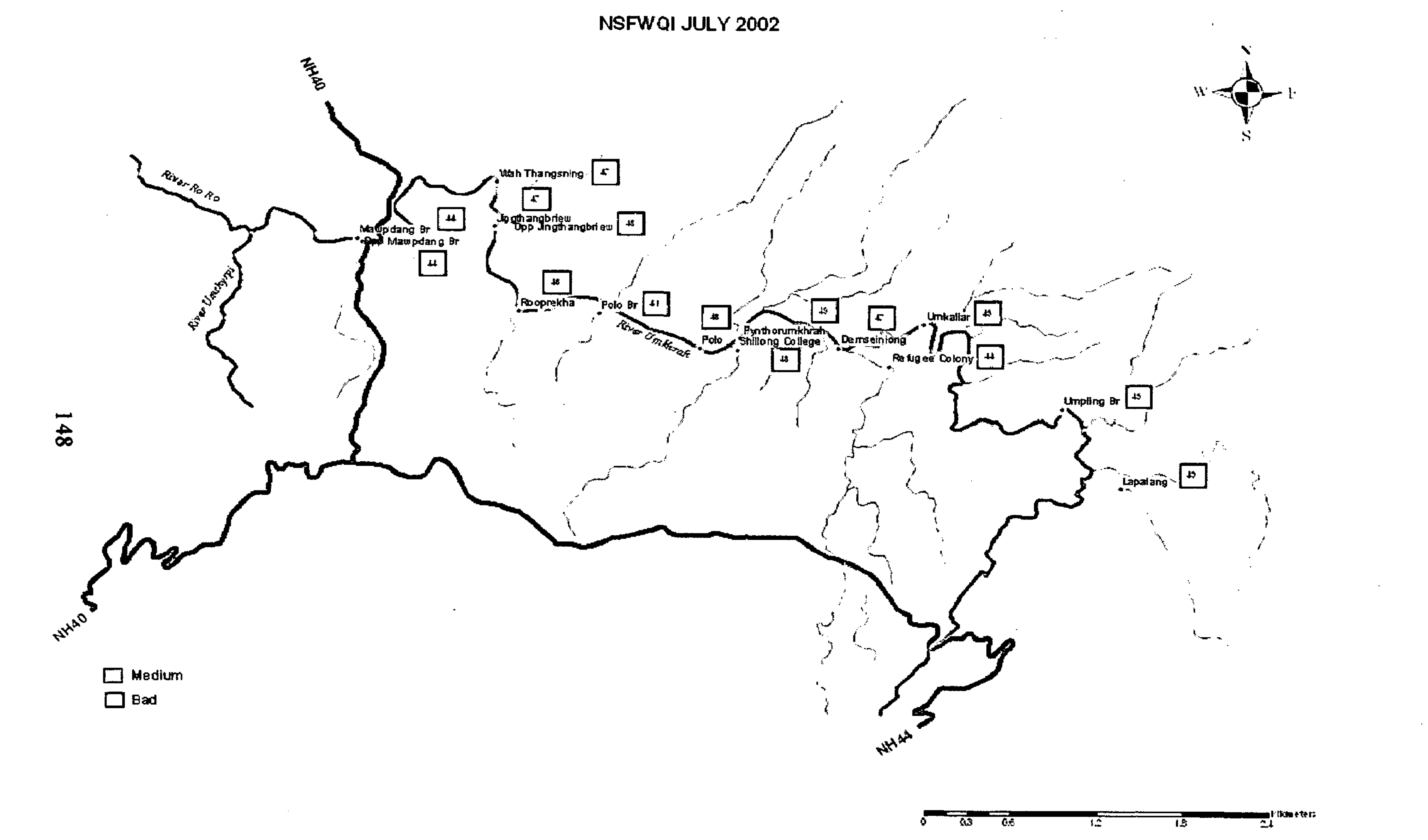

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(ix) July 2002

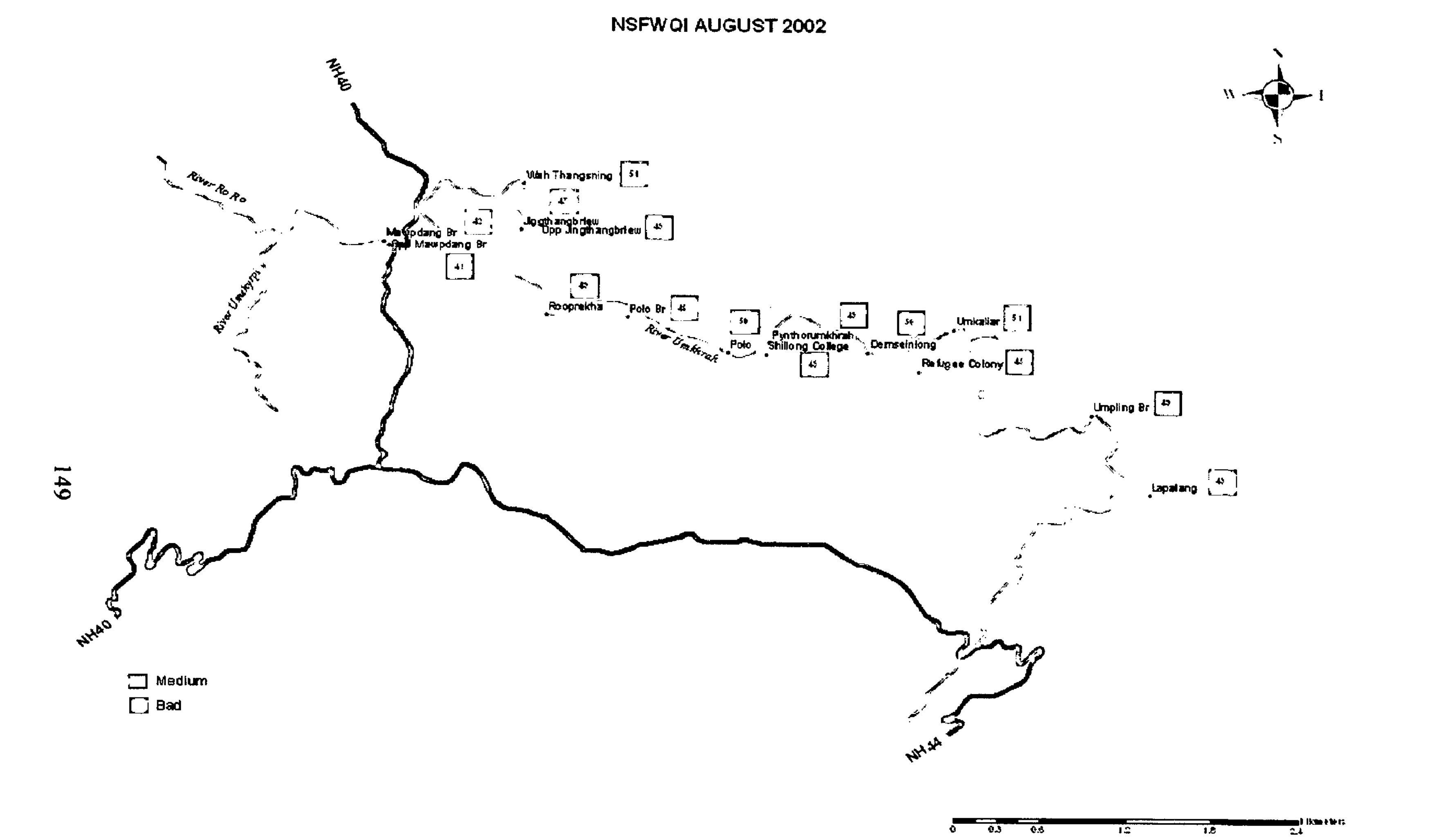

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(x) August 2002

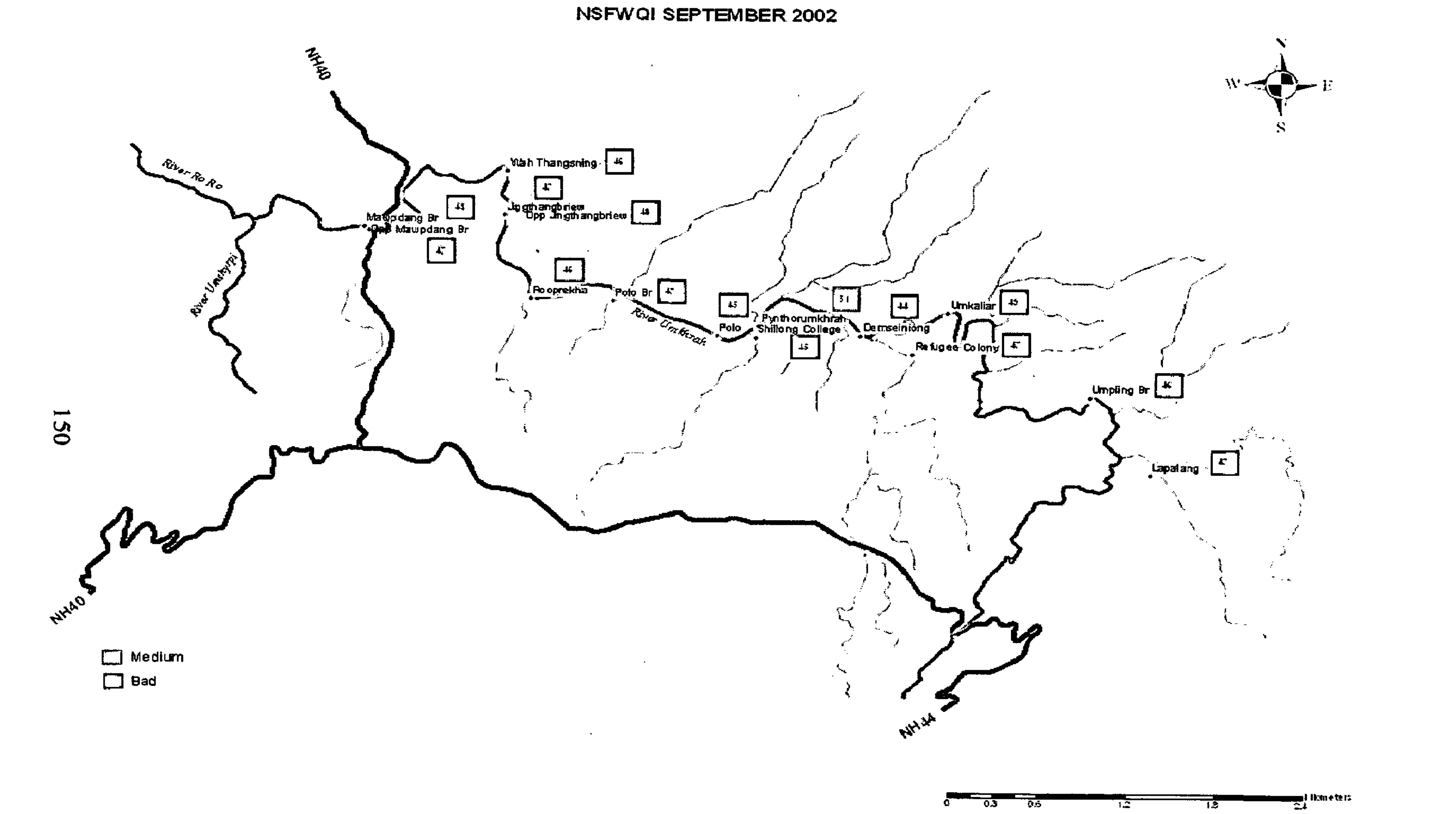

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(xi) September 2002

NSFWQI OCTOBER 2002

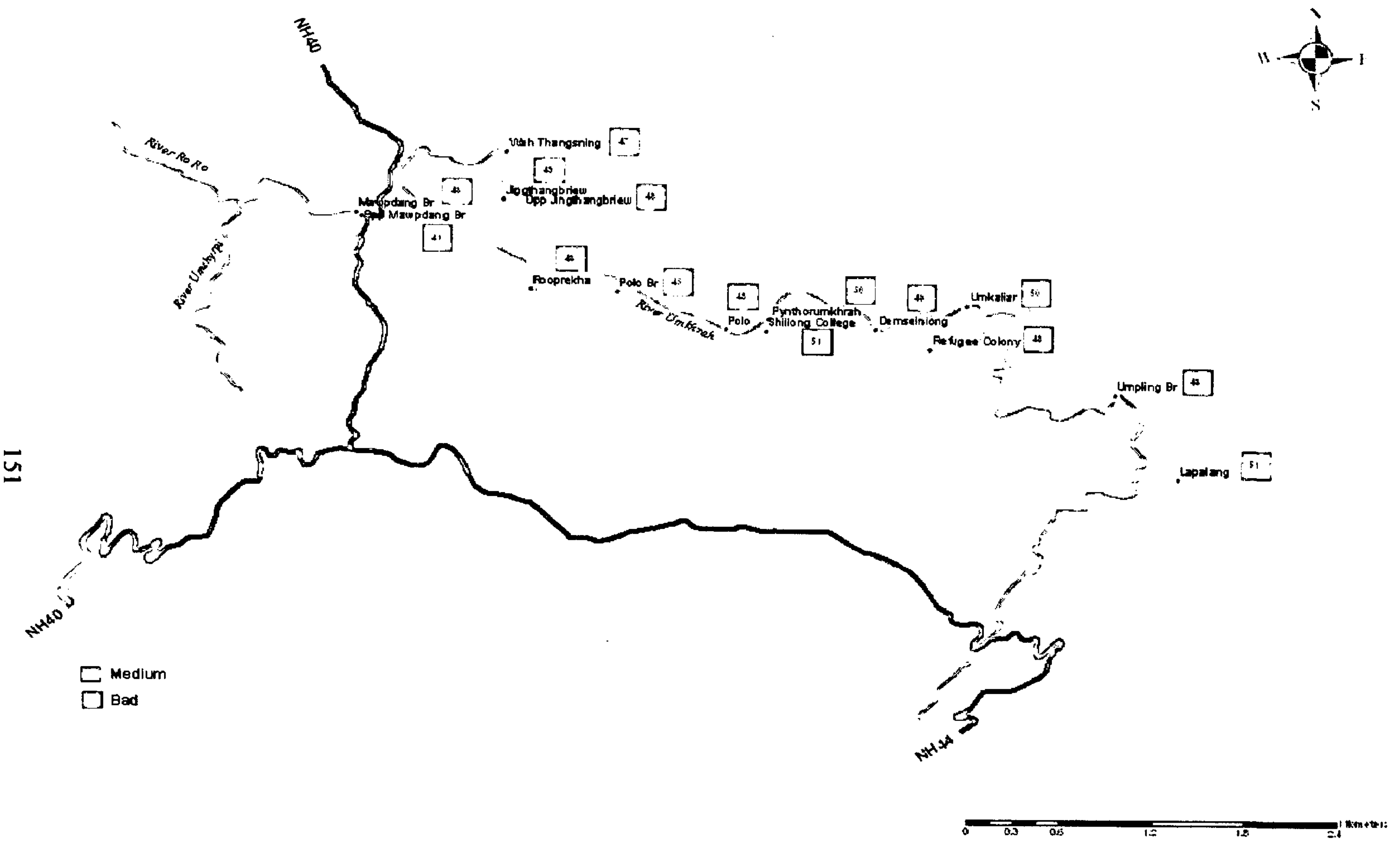

Figure 5.4: Map showing variation of NSFWQI in the year 2001-02
(xii) October 2002

5.7 LAND USE AND LAND COVER ANALYSIS USING G.I.S.

To verify the type of land use and land cover that exists in the catchment area, an analysis has been carried out using Geographical Information System (GIS). The land use and land cover map of the catchment has been prepared and classification of the different land uses has been carried out.

The base map of the catchment area has been prepared by digitizing it from a geo-referenced Survey of India Topo-sheet No. 78-O/14 using Arc Map 8.3 software. The raw satellite data used is of year 2000 and it has been downloaded from the University of Maryland's "Global Land Cover Facility" website [K]. The details of the image are given in Table 5.12. Attempts were also made to get the satellite data from N.R.S.A., Hyderabad, and typically they have not supplied it even in four months time inspite of our best persuasion.

TABLE 5.12: DETAILS OF SATELLITE IMAGE

S. No.	Particulars	Description
1	File Format	MrSid
2	Platform	Landsat
3	Sensor	ETM
4	Bands	70,40,20
5	Row Start	1
6	Column Start	1
7	Row Count	39090
8	Column Count	51078

This image has been first re-projected into geographical latitude-longitude co-ordinate system so that the digitized catchment map can be overlaid on it. After overlaying the two maps, the catchment area has been subset from the image. Supervised classification has been carried out using ERDAS 8.7 software. Maximum likelihood classification option has been chosen and four land use classifications have been identified (Figure 5.6).

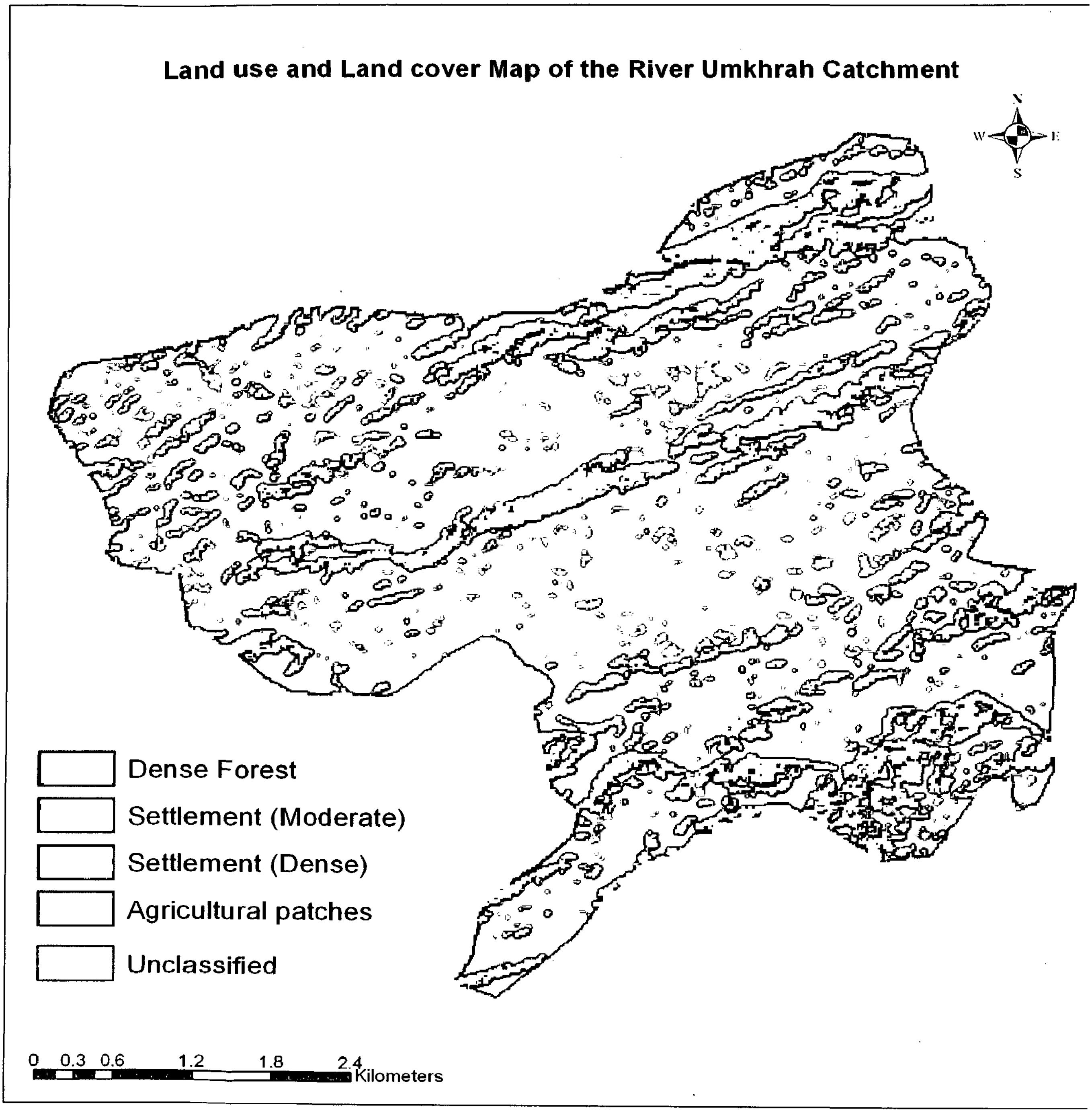

Figure 5.6: Land use and land cover map of the River Umkhrah catchment

Table 5.13 shows the area of the different land use classes identified. From the table it can be concluded that the catchment is predominantly covered by dense human settlement (41.53%), which has been the main source of pollution to the river.

TABLE 5.13: AREA OF DIFFERENT LAND USE CLASSES

S. No.	Class	Area (sq km)	Percentage of total area (%)
1	Dense Forest	6.6159	26.45
2	Settlement (dense)	10.3896	41.53
3	Settlement (moderate)	2.8215	11.28
4	Agricultural patches	0.7029	2.81
5	Unclassified	4.4864	17.93
	TOTAL	**25.0163**	**100.00**

From this land use and land cover classification, it can be concluded that conserving the river by catchment treatment methods will not be feasible as more than 50% of the catchment is under human settlement. Cleaning up the river has to be done in some other way. Some conservation methods have been suggested in the later chapters.

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CHAPTER 6

CONSERVATION MEASURES SUGGESTED

6.1 INTRODUCTION

As seen from the discussions in the preceding sections, the main pollutants in the River Umkhrah are faecal coliform and organic waste. The conservation measures to be adopted should target the removal of these two main pollutants first. The main source of faecal coliform is waste water coming into the river from the numerous drains and the direct sewage generated near the river banks. The lack of proper management of municipal solid waste has led to its being dumped indiscriminately into drains and the river itself. The slaughterhouses along the river banks also add a lot of organic waste into the river. Given below are some suggestions how to tackle these three main sources of pollution of the River Umkhrah.

6.2 SEWAGE TREATMENT

From Table 1.9, it is seen that the total water supply for Shillong, from both Shillong Municipal Board and Public Health Engineering Department sources, is 23.06 MLD. Assuming that 80% of the water supply is discharged as waste water [9], we find that 18.448 MLD of waste water is generated in Shillong. In absence of a sewerage system and sewage treatment and disposal facility, all the waste water generated finds its way into the River Umkhrah and its tributaries through the network of drains in the city. Some of the bigger drains are actually streamlets having their own perennial sources. Therefore, in reality, the discharge in the drains will exceed what has been estimated above.

From the land use and land cover analysis carried out, it is seen that the catchment of the River Umkhrah consists mainly of settlement and some of it is very dense. Shillong has grown in a haphazard manner with absolutely no planning at all. To plan and lay a sewer system in the city is an impossible task as of now. The only way to stop the waste water from entering the river is to intercept all the drains and tributaries at their point of confluence with the river. Two large trunk sewers may be laid along both banks and all along the entire stretch of the river to intercept the waste water. The sewers can follow the gradient of the river itself. The size of the sewers can be worked out only after measurement of discharge in all the drains and tributaries. These sewers will convey the waste water to the treatment plant.

The treatment of sewage generated from Shillong may be treated by the Fluidized Aerobic Bio-reactor (FAB) technology patented by M/S Thermax Limited, Pune. Another treatment technology that can be used is the Cyclic Activated Sludge Technology or the C-TECH System.

In the project feasibility report for Greater Shillong Sewerage Scheme prepared by the Development Consultants Limited for the Meghalaya State Pollution Control Board [19], it has been suggested that the nucleus sewage treatment plant be located at a plot of flat land beside the Umiam (Barapani) Reservoir, accessible through the old Guwahati-Shillong Road (NH-40). This same location may, perhaps, be used for setting up the treatment system.

The C-TECH System specifically refers to the use of variable volume treatment in combination with a biological selector and biorate control, which is operated in a fed-batch reactor mode. In this process the sequences of fill, aeration, settle and decant are consecutively and continuously operated in a compartment reactor. A basic cycle comprises of:

- Fill-Aeration
- Settlement
- Decanting

These phases in a sequence constitute a cycle, which is then repeated. During the period of a cycle, the liquid volume inside the tank increases from a set minimum operating bottom water level. Aeration ends at a predetermined period of the cycle to allow the biomass to flocculate and settle under quiescent conditions. After a specific settling period the treated supernatant is removed (decanted), using a moving weir decanter. The liquid level in the vessel is so returned to the bottom water level after which the cycle is repeated. Solids are wasted from the tanks during the decanting phase (Figure 6.1).

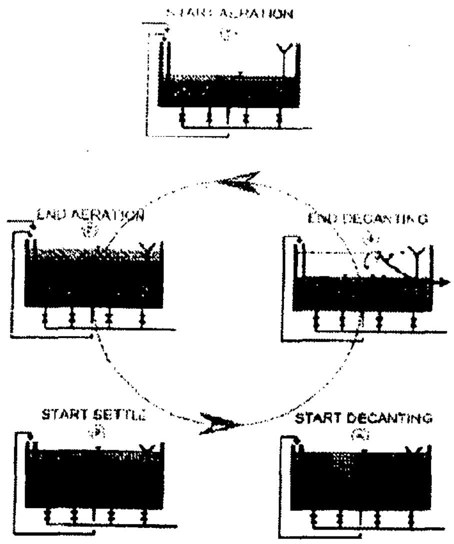

Figure 6.1: The C-TECH Cycle

Some advantages C-TECH System has over conventional Activated Sludge Process are:

(1) It requires smaller area, which reduces land cost.

(2) It can handle varying daily flow and load fluctuations.

(3) It does not require high sludge recirculation.

(4) It consists of very few electro-mechanical equipment and moving parts, which reduces the cost of operation and maintenance.

(5) It can detect toxicity at the beginning of the cycle and does not allow other basins to be filled.

However, C-TECH System is effective in removing nutrients only from wastewater. By co-current nitrification and denitrification, low concentrations of nitrogen and phosphorus (upto <5 gm/L) can be achieved without any chemical addition. For this reason, a second treatment process (FAB) has also been suggested here.

FAB works on the principles of attached growth process where the media supports the biomass. The basic idea behind the Fluid Bed Reactor development is to have a continuous operating non-clogging bio film reactor which requires:-

(1) No back-washing,

(2) Has low head loss and

(3) High specific bio film surface area.

This was achieved by having the biomass to grow on small carrier elements that move along with the water in the reactor. The movement within the reactor is generated by aeration in the aerobic reactor. These bio-film carriers are made of special grade plastic having density close to that of water.

The FAB plant is very compact. The reactors are generally tall (6m and above) thereby reducing the cross-sectional area. As a rule of thumb the bio-reactor can be accommodated in only 10% area that is required for conventional aeration tanks. Therefore, the area it requires is only about $1/10^{th}$ the area required for a conventional treatment plant treating the same quantity of sewage.

The fixed film principle of the attached growth process makes the plant more user-friendly because it does not require sludge recycle as in conventional Activated Sludge Process (ASP). The plant operator, therefore, does not have to continuously monitor the MLSS levels in the reactor for adjusting the recycle ratio. This technology produces very small quantity of digested sludge which does not smell like that in conventional plant and which requires no further treatment.

The FAB technology can be used for treating a variety of waste waters – from city sewage to industrial waste containing very high COD, even exceeding 40,000 mg/L. Due to fixed film nature these plants can accept shock loads much better than those employed for suspended growth process.

For treatment of coliforms, FAB technology utilizes a tertiary treatment step whereby nominal chlorination is carried out to reduce the coliform count from an inlet level of $10^6 - 10^7$ MPN/100ml to within the prescribed limit.

The treatment scheme of the FAB technology consists of, firstly, the collection of raw sewage in the sump and then pumping it for further treatment into three distinct parts:

1. **Pre-treatment**, which comprises of screening and grit removal,
2. **Biological treatment** comprising of moving bed aerobic bioreactors, followed by clarification, and

3. **Tertiary treatment** comprising of addition of chlorine to remove coliforms.

The process flow diagram is shown as Figure 6.2.

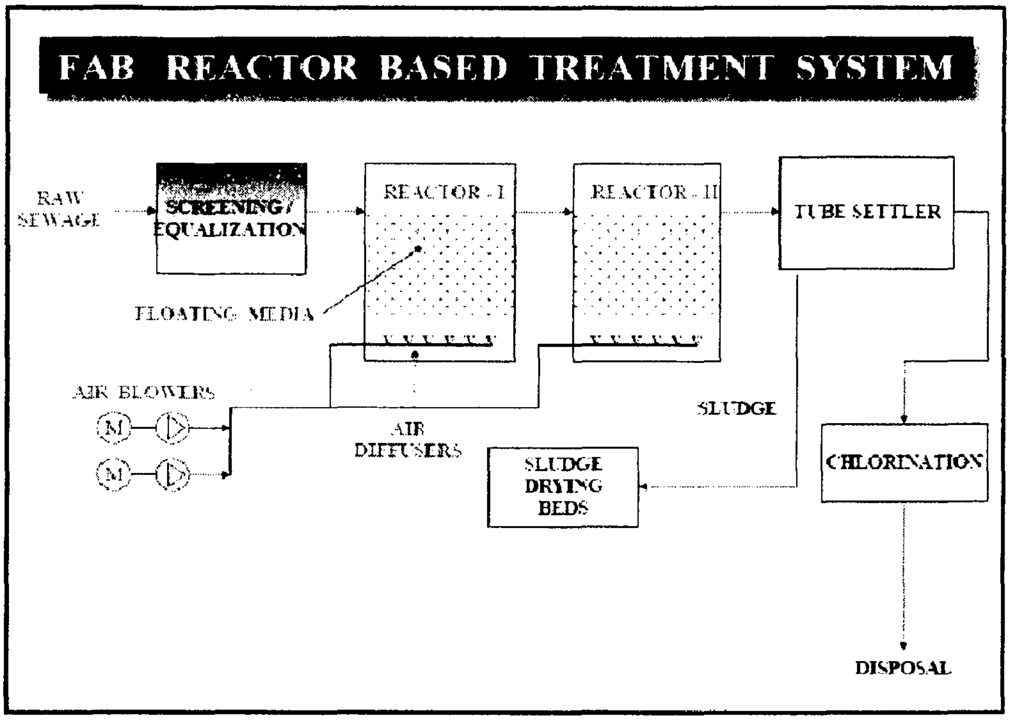

Figure 6.2: Process flow diagram of FAB technology

The main advantages of FAB technology over conventional treatment systems are:-

(1) It requires very small area, thus, saving on expensive land costs.

(2) It consumes less power in achieving aeration of the raw sewage because it uses tanks of smaller sizes.

(3) It remains in operation even in freezing temperature because of smaller bio-reactor area and the use of hot air for aeration.

(4) It adopts very less moving parts and there are none inside the reactors. Therefore, the bio-reactor can run under widely fluctuating conditions.

(5) Since sludge recycle is not required, the work load for the operator reduces and makes the plant simple to operate and control.

(6) Coliform bacteria are removed to acceptable levels by very low chlorine dosing which also ensures less residual chlorine. The effluent is more suitable for disposal into water bodies.

(7) The sludge generated in the bio-reactors is totally digested and easy to dispose.

6.3 MUNICIPAL SOLID WASTE MANAGEMENT

There is no actual data available with respect to the generation of municipal solid waste in Shillong. An estimate of the quantity of municipal solid waste can be made by assuming the average per capita generation as 0.21 kg/capita/day as shown in Table 6.1 and Figure 6.3. This quantity is the average per capita waste generation in cities of population between 1 lakh and 5 lakhs [8].

TABLE 6.1: MUNICIPAL SOLID WASTE GENERATION IN SHILLONG

S.No.	AREAS	POPULATION	SOLID WASTE GENERATION @0.21kg/capita/day
1	SHILLONG MUNICIPALITY	132867	27902.07
2	SHILLONG CANTONMENT	12396	2603.16
3	MAWLAI	38303	8043.63
4	PYNTHOR UMKHRAH	22115	4644.15
5	NONGMENSONG	11371	2387.91
6	NONGTHYMMAI	34292	7201.32
7	MADANRTING	16318	3426.78
	TOTAL	**267662**	**56209.02**

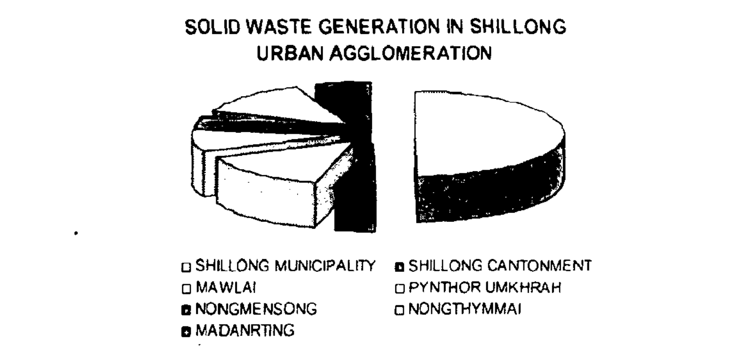

Figure 6.3: Municipal solid waste generation in Shillong

Due to the time constraint, waste characterization could not be carried out. From Table 6.1, it is observed that about 31 tonnes of solid waste is generated within the Shillong Municipality and Shillong Cantonment only. The Shillong Municipal Board carries out door to door collection of solid waste from the different localities and hospitals falling under its jurisdiction and dumps them at the trenching ground at Mawiong, located about 6 km outside the city. Here a 100 tonnes per day solid waste processing plant has been set up by a private firm. Using composting technology supplied by Excel Industries Ltd, the plant produces 15 tonnes of organic fertilizer per day. The remaining 26 tonnes of solid waste generated in the adjoining townships of Shillong is not managed in any form and most of it finds its way into the low lying areas or into drains and streams which eventually carry it to the River Umkhrah and finally the Umiam (Barapani) Reservoir.

The first step for an effective solid waste management programme is to educate the people about it. A mass awareness campaign has to be organized all over the city to highlight the impacts of dumping of solid waste into the water bodies. Unless people understand this, they will never change their attitude and continue throwing garbage into the nearest drain or stream.

The next step is to select a technology which is cost effective and easy to operate for treatment and disposal of solid waste. Since the waste from the densely populated Municipality and the Shillong Cantonment has been taken care of by the Shillong Municipal Board. the focus should be on management of solid waste in the adjoining townships.

The most effective method to manage waste in these semi-urban areas is by localizing the collection and treatment of the waste, i.e. waste generated within one locality is collected and treated within that locality itself. Self help groups of unemployed youth or women's organizations can be drafted to look after door to door collection of waste and bringing it to a common treatment site. In the commercial areas, it shall be the responsibility of the traders to collect their own waste and store it at sites designated by the Shillong Municipal Board for collection or transport it themselves to the treatment sites.

The cheapest methods of waste treatment are heap composting and vermicomposting. The localities can choose any of the technologies and adopt it for managing their waste. The organic fertilizer produced from composting can be sold off to generate money. The process rejects can be thrown at a designated site from where they can be collected by the Municipality trucks for disposal at Mawiong. The use of plastics must be reduced and the indiscriminate dumping of solid waste stopped totally. Laws can be enacted giving powers to the local Headmen to impose heavy fines on anyone found guilty of indiscriminate dumping of solid waste or dumping of soil or construction debris into the water bodies.

Finally, solid waste management depends on the people's attitude and co-operation. If the entire community shows willingness to mange their waste, there is nothing that can stop them from doing it. To create this willingness, it takes a lot of hard work on the part of the experts to educate and spread awareness about solid waste and its management.

6.4 SLAUGHTERHOUSE WASTE

Meghalaya is primarily a non-vegetarian state with meat production of 29,000 tonnes in 1997-98 [7]. There is, however, no centralized facility for animal slaughtering. All the slaughterhouses are small, unorganized and in primitive condition. They are generally located near a river or stream to ensure good supply of water for washing and to also serve as a good dumping site for offal and other wastes. Being unorganized, there is no check on the quality of meat supplied as there is no veterinary doctor to check the animal before slaughter.

The CPCB has classified slaughterhouses in India into 3 types [7]:

(1) ***Large:*** with slaughtering capacity above 70 tonnes of live weight killed per day

(2) ***Medium:*** with slaughtering capacity between 15 and 70 tonnes of live weight killed per day

(3) ***Small:*** with slaughtering capacity below 15 tonnes of live weight killed per day

The slaughterhouses located on the banks of the River Umkhrah and its tributaries fall in the last category. All these slaughterhouses have no system of waste management. All the blood and wastes generated are simply discharged into the nearby stream or river.

In order to help conserve the river, what is needed urgently is a centralized slaughterhouse provided with modern amenities, good supply of water and a waste treatment system. A centralized slaughterhouse will ensure quality control as the Veterinary and Animal Husbandry Department can keep a check on the animals slaughtered.

Generally, there are two types of waste that are generated in a slaughterhouse [7]. These are:

(1) ***Type-1:*** vegetable matter, such as rumen, stomach and intestinal contents, dung, agriculture residues, etc
(2) ***Type-2:*** animal matter, such as inedible offals, tissues, meat trimmings, waste and condemned meat, bones, etc.

For Type-1 waste, the recommended waste treatment method in medium and small slaughterhouses is either composting or biomethanation. Type-2 wastes can be treated either by composting or by rendering with burial being the final alternative.

Composting is the easiest and cheapest method for waste treatment. Both types of waste can be composted. A compost stack can be prepared by laying alternate layers of Type-1 and Type-2 wastes upto a height of 4 to 5 feet (Figure 6.4). The stack should preferable be laid directly on the ground on top of a 6 inch layer of course material, such as maize or millet stalks, straw, grass, etc, to achieve proper ventilation. Wasted large organs should be chopped into small pieces before placing them in the compost stack.

Sufficient moisture for bacterial activity can be obtained from the ruminal and intestinal wastes. Proper aeration has to be maintained and the stack has to be turned at least twice in 4 weeks to obtain uniform compost material. The compost can be removed after 4 to 5 weeks. The total time required for complete composting is about 90 days. The quality of compost can be improved with experience by proper combination of different wastes, moisture control and appropriate time intervals for mixing.

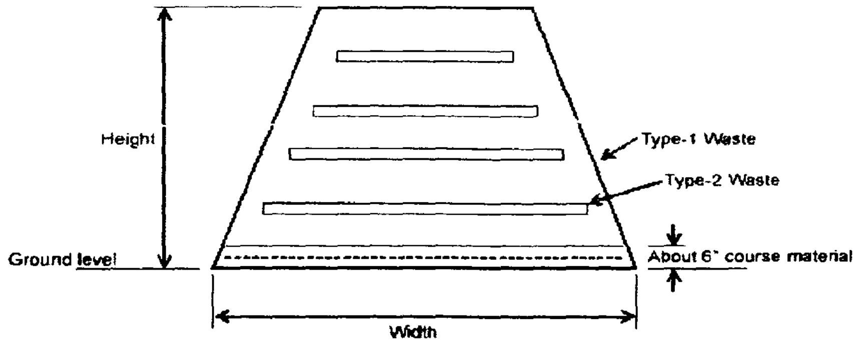

Figure 6.4: Schematic of compost stack making

Biomethanation is the process of producing methane gas from decomposing waste matter. Figure 6.5 shows a conventional floating drum type biomethanation/biogas plant. An inverted drum with a diameter slightly less than that of the cylindrical digester serves as the gas holder. The plant delivers gas at a uniform pressure and provides good seal against gas leakage. Suitably diluted waste should be fed into the digester as it can handle feed with solid content upto 8% only. The digested sludge of a biogas plant has higher nitrogen content and serves as good manure. The biogas generated can be used for water heating, boiler or power generation. The success of a biomethanation plant depends on factors such as quality of raw materials, temperature, water to solids ration and the type of bacteria present.

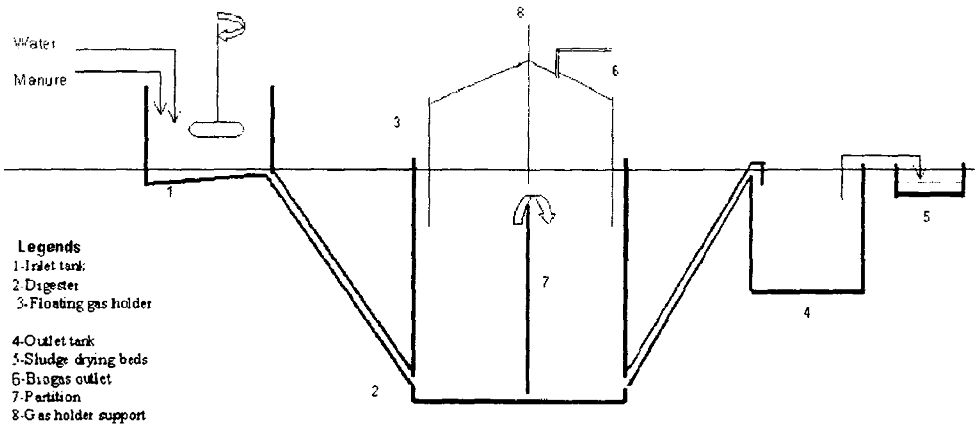

Figure 6.5: Schematic Diagram of Conventional Biogas Plant

Rendering is the process to physically separate the fat, the water and the solids in slaughterhouse waste. This is achieved by heating and rupturing connective tissue of individual fat and muscle cells so that raw fat and other material bound within is freed. In rendering, fat recovered is used for industrial purposes, such as making soap and greases. Fat recovered from flesh of healthy parts can also be used for edible purposes. Solid portion, which is known as meat meal or bone meal, is utilized for the manufacture of stock feed and fertilizers.

Rendering is, however, a more complex and expensive method for waste treatment which, perhaps, may not be considered in the present case. Composting and biomethanation are better options which can be adopted. Composting requires no initial investment and once it is in operation, it produces manure which can be sold as soil conditioner. Biomethanation requires an initial installation investment but in the long run, it produces methane gas which can be used for various purposes and manure which has better fertilizing value than that of manure from composting.

Setting up of a centralized slaughterhouse provided with waste treatment facilities will not only prevent waste from entering the River Umkhrah but will also improve sanitation and hygiene in the meat industry. The recovery and use or sale of the treatment by-products can benefit the slaughterhouse in the long run. Further, it may be mentioned that for modernization of existing slaughterhouses, the Ministry of Agriculture, Government of India provides assistance to the States. Financial incentives are also provided by the Ministry of Non-conventional Energy Sources for setting up of biogas plants under its programmes on energy recovery from urban and industrial wastes and biogas management programmes [7].

6.5 THE ROLE OF PUBLIC PARTICIPATION

In any conservation project, the role to be played by the public is of utmost importance. There are many stakeholders involved with the River Umkhrah. Various Government Departments, like the Department of Urban Affairs, the Shillong Municipal Board, the Meghalaya State Electricity Board, the Meghalaya State Pollution Control Board, the Agriculture Department, the Tourism Department, etc, have a direct role to play with regards to the river. The main stakeholders are, of course, the public. A clean River Umkhrah means better living environs, clean water to use and even recreation.

The only source of pollution in the river is from anthropogenic activities. Stopping these activities will be the only solution to restore the river to its pristine state. The attitude of the people should change completely. They should manage their wastes in a proper manner instead of directly discharging or dumping them into the river. The Government departments can only create awareness among the public about the river and its conservation. It is finally only up to the people to see that the river is clean.

Traditionally, the authority in a village or locality rests with the "Durbar Shnong" (Village Council). These are elected bodies, where members are directly elected by the residents of the areas. It functions till such time it has the confidence of the people. The office bearers can be removed, if so desired by the people. The "Rangbah Shnong" (Headmen) of the "Durbars" within the Shillong Municipality have been functioning more or less like Ward Commissioners and looking after the needs of the citizens. It is these traditional bodies that should be given more powers to tackle the problem of waste management at the grassroots level. Strict regulations have to be enacted against direct discharge and dumping of waste into the river with more powers given to the "Durbars" to enforce them. Action against defaulters should be taken immediately by the Headmen and the "Durbar" instead of going through the various levels of a Government department.

Women's groups have been found to be very effective in tackling social problems. These groups can also act as a potent force when it comes to managing waste in a society. They should be actively involved in any plan to conserve the River Umkhrah. Several NGOs and Self Help Groups are doing a lot of work in spreading awareness and in trying to clean up the River Umkhrah. These groups should be encouraged to carry on with their work.

Finally, the Government with its experts and man-power should start an extensive awareness campaign about cleaning the River Umkhrah. No work has been done in the grassroots so far. The high-level meetings and committees should now start their work in the field and ensure that the people are made aware about the danger of our losing a natural resource and how we can join hands together to restore it back to an acceptable level, if not to its original pristine condition.

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CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the results of water quality assessment of the River Umkhrah in Shillong in terms of water quality indices, it can be concluded that the water quality of the River Umkhrah is "bad" or "poor" and this fact has been reflected by all the three selected indices. The whole stretch of the river and its tributaries, right from the source, has been affected by anthropogenic activities, especially, by the direct discharge of sewage. The analysis also shows that the main pollutants in the river are faecal coliforms, bio-chemical oxygen demand (BOD) and the absence of dissolved oxygen (DO).

Index values obtained by the NSFWQI have been put into water quality maps to show the spatial and temporal changes in the water quality of the River Umkhrah. From these maps, it is observed that the water quality of the river has very less variation throughout the year. It remains polluted throughout the year and no dilution has been observed during the monsoon months. This is mainly due to high faecal coliform counts and high loads of BOD and COD that the river carries.

A few conservation measures have also been suggested in order to restore the River Umkhrah back to its pristine state. However, as there is no available data regarding the flow and discharge of the river and its tributaries, the conservation measures suggested are based only on qualitative analysis. A lot of work still has to be done in order to find concrete measures how to conserve the river. There is no doubt that the River Umkhrah is a polluted river. However, if all the stakeholders join hands together and seriously act to conserve it, there is still a chance to restore it back to acceptable levels.

7.2 RECOMMENDATIONS

It has been noted that the main pollutants in the River Umkhrah are sewage and organic waste. The former comes from the direct discharge from toilets along the river banks, open defecation and also the overflow from septic tanks and soak pits into public drains from all over the city. The latter comes from the indiscriminate dumping of solid waste directly into the river and its tributaries. Another major problem faced is the obstruction to the water flow by encroachments and the dumping of soil, construction debris and plastics into the river. This has led not only to increased siltation of the Umiam (Barapani) Reservoir, but also to flash floods in the low lying areas of Shillong.

The main recommendation is to enact strict laws and ensure their enforcement in order to prevent the further degradation of the River Umkhrah.

To prohibit the manufacture, sale, use and throwing of low density plastic bags in the state, the Department of Urban Affairs, Government of Meghalaya has enacted the "Meghalaya Prohibition of Manufacture, Sale, Use and Throwing of Low Density Plastic Bags Act, 2001", subsequent Rules in 2002 and Amendment Act, 2004 (Annexure 4). Manufacturers of low density plastic bags do not exist in the state but the sale, use and throwing of such bags continues unabated. The concerned authorities to look into these activities have not done a satisfactory job.

The Shillong Municipal Board has made it mandatory for all houses within its jurisdiction to have toilets provided with septic tank and soak pit. This rule may have been implemented, but houses outside the municipal limits continue with the old practices of dry or pit latrines. Houses on the banks of the river and its tributaries directly discharge their sewage into them. Also, the septic tanks have filled up and soak pits clogged and many of them are now overflowing directly into public drains which discharge into the river and, ultimately into the Reservoir. Therefore, laws have to be enacted, to cover the entire state, and their implementation should be ensured, to remove all toilets discharging directly into water bodies and to discourage the use of dry or pit latrines, especially in close proximity to water bodies.

There are no laws regarding encroachment and dumping of soil or construction debris into the river. New laws have to be enacted so as to prevent any new construction within a distance of at least 10m on both banks of the river. Also, anyone found guilty of dumping soil, construction debris or any other solid waste into the river or its tributaries has to be punished with heavy fines.

The successful implementation of any law can be achieved only if the public are aware of and co-operate with it. Therefore, another major recommendation is for all concerned Government Departments, NGO's and social organizations to undertake rigorous public awareness campaigns at the grassroots level and ensure public participation at every level of implementation. Rivers are the lifelines of every society and unless the society itself undertakes the job of looking after and cleaning them, the rivers will one day run dry.

In conclusion, it is clear that something needs to be done quickly in order to restore the water quality of the River Umkhrah to its pristine state. The public needs to be educated and aware about the advantages of a clean river. Their support is a must in any endeavour to clean up the river. As water is our most precious natural resource, we must conserve and preserve it so that it can be passed on to our future generations. In the words of Mikhail Gorbachev, President of Green Cross International, "We must treat water as if it were the most precious thing in the world, the most valuable natural resource. Be economical with water! Don't waste it! We still have time to do something about this problem before it is too late."

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ANNEXURES

ANNEXURE 1

COMPARISON OF NSFWQI VALUES CALCULATED MANUALLY AND BY THE SOFTWARE

Sampling Location	Nov-01		Dec-01		Jan-02		Feb-02		Mar-02		Apr-02		May-02		Jun-02		Jul-02		Aug-02		Sep-02		Oct-02	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
LAPALANG	51.63	54.00	43.67	46.00	46.60	49.00	42.34	44.00	44.69	47.00	44.38	46.00	44.00	46.00	43.76	46.00	46.80	49.00	46.73	49.00	44.36	47.00	48.26	51.0
UMPLING BRIDGE	53.98	57.00	46.67	49.00	50.08	53.00	49.66	52.00	48.27	51.00	43.40	46.00	45.79	48.00	49.52	52.00	46.87	49.00	46.68	49.00	44.24	46.00	45.38	48.0
UMKALIAR	51.32	54.00	48.45	51.00	49.44	52.00	50.76	53.00	46.25	48.00	50.04	53.00	47.55	50.00	45.80	48.00	46.56	49.00	48.82	51.00	46.37	49.00	47.90	50.0
DEMSEINIONG	48.15	50.00	42.72	45.00	47.18	50.00	40.03	42.00	41.53	44.00	41.65	44.00	46.89	49.00	48.50	51.00	45.24	47.00	47.46	50.00	42.00	44.00	45.61	48.0
PYNTHOR UMKHRAH	46.72	49.00	43.03	45.00	45.86	48.00	47.55	50.00	50.88	53.00	48.00	50.00	47.49	50.00	50.00	52.00	47.28	49.00	46.86	49.00	49.12	51.00	47.79	50.0
POLO (behind Stadium)	50.97	53.00	44.50	47.00	49.12	52.00	43.37	45.00	48.03	50.00	42.53	45.00	40.48	43.00	45.63	48.00	45.51	48.00	47.33	50.00	42.65	45.00	46.16	48.0
ROOPREKHA	47.67	50.00	41.42	44.00	46.90	49.00	45.10	47.00	43.50	46.00	40.22	42.00	45.42	48.00	46.29	49.00	45.54	48.00	46.62	49.00	44.05	46.00	46.02	48.0
JINGTHANG BRIEW	47.27	50.00	40.70	43.00	47.07	49.00	42.12	44.00	43.89	46.00	40.41	42.00	46.00	48.00	46.64	49.00	44.41	47.00	44.97	47.00	44.72	47.00	47.20	49.0
WAH THANG SNING	44.57	47.00	43.02	45.00	46.23	49.00	41.35	43.00	48.38	51.00	40.63	43.00	47.05	49.00	45.53	48.00	44.67	47.00	49.00	51.00	43.84	46.00	44.45	47.0
MAWPDANG BRIDGE	38.00	40.00	37.36	39.00	42.03	44.00	41.69	44.00	45.85	48.00	46.37	49.00	46.47	49.00	49.38	52.00	42.30	44.00	40.07	42.00	41.13	43.00	45.89	48.0

TRIBUTARIES

Sampling Location	Nov-01		Dec-01		Jan-02		Feb-02		Mar-02		Apr-02		May-02		Jun-02		Jul-02		Aug-02		Sep-02		Oct-02	
	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S	M	S
REFUGEE COLONY (A)	46.29	49.00	38.40	40.00	46.68	49.00	43.60	46.00	39.16	41.00	42.70	45.00	44.68	47.00	45.20	48.00	41.89	44.00	43.22	45.00	44.95	47.00	45.72	48.0
SHILLONG COLLEGE (B)	53.08	56.00	41.68	44.00	45.81	48.00	45.78	48.00	42.69	45.00	43.65	46.00	44.06	46.00	44.82	47.00	45.51	48.00	46.76	49.00	43.23	45.00	48.27	51.0
POLO BRIDGE (C)	40.63	42.00	36.46	38.00	47.38	50.00	47.51	50.00	40.94	43.00	44.52	47.00	37.32	39.00	36.79	38.00	39.57	41.00	43.55	46.00	44.97	47.00	42.87	45.0
OPP. JINGTHANG BRIEW (D)	42.42	45.00	40.93	43.00	47.36	50.00	45.60	48.00	46.05	48.00	41.84	44.00	46.10	48.00	44.43	47.00	45.93	48.00	47.18	49.00	45.42	48.00	46.19	48.0
OPP. MAWPDANG BRIDGE (E)	33.92	36.00	34.21	36.00	38.54	40.00	35.99	38.00	35.83	38.00	46.00	48.00	39.01	41.00	36.75	38.00	42.47	44.00	39.63	41.00	44.61	47.00	39.02	41.0

N.B.: M = Manually calculated index value
S = Index value obtained from software

WATER QUALITY MONITORING RESULTS

1. Water quality monitoring results of River Umkhrah at Demthring

Year	pH	Cond	Turb	DO	BOD	NO_2	NO_3	PO_4	TC	FC	TEMP	DO (%sat)
2002	5.1	190	15	6.4	3.5	BDL	2	BDL	540	240	26	76
2003	6.9	200.2	24	6	4	BDL	2	0.05	790	490	26	71
2004	6.9	2.1	14	6.6	5.6	0.06	2.4	0.1	1100	700	26	80

2. Water quality monitoring results of River Umkhrah in 2001 – 02

Temperature of River Umkhrah (°C)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	16.0	10.0	16.0	15.0	17.0	18.0	19.0	17.0	15.0	16.0	15.0	15.0
Umpling Bridge	15.0	15.0	18.0	15.0	16.0	22.0	20.0	16.0	17.0	16.0	17.0	15.0
Umkaliar	16.0	15.0	16.5	15.0	16.0	18.0	20.0	17.0	17.0	16.0	16.0	17.0
Demseiniong	21.0	15.0	16.0	17.0	19.0	22.0	20.0	17.0	16.0	16.0	17.0	17.0
Pynthor Umkhrah	16.0	15.0	16.0	15.0	16.0	18.0	20.0	17.0	17.0	16.0	15.0	15.0
Polo (behind Stadium)	16.0	16.0	16.0	15.0	16.0	18.0	21.0	18.0	16.0	16.0	15.0	15.0
Rooprekha	16.0	15.0	16.0	15.0	16.0	18.0	21.0	18.0	16.0	16.0	15.0	15.0
Jingthang Briew	16.0	16.0	16.0	15.0	16.0	18.0	22.0	18.0	15.0	15.0	15.0	15.0
Wah Thang Sning	16.0	16.0	16.0	16.0	16.0	18.0	23.0	16.0	16.0	15.0	15.0	16.0
Mawpdang Bridge	16.0	15.0	16.5	16.0	16.0	18.0	23.0	16.0	16.0	15.0	16.0	15.0

Temperature of River Umkhrah Tributaries (°C)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	15.0	15.0	16.5	16.0	16.0	17.0	19.0	18.0	15.0	16.0	16.0	16.0
Shillong College (B)	16.0	15.5	17.0	16.0	16.0	18.0	20.0	18.0	15.0	16.5	16.0	16.0
Polo Bridge (C)	16.0	15.0	16.0	16.0	16.0	18.0	20.0	18.0	15.0	15.0	16.0	16.0
Opposite Jingthang Briew (D)	16.0	16.0	16.0	16.0	16.0	18.0	21.0	18.0	15.0	16.0	16.0	16.0
Opposite Mawpdang Bridge (E)	16.0	16.0	16.0	16.0	16.0	18.0	21.0	15.0	16.0	16.0	15.0	15.0

Turbidity of River Umkhrah (NTU)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	17.0	18.0	15.0	20.0	21.0	17.0	14.0	19.0	16.0	16.0	20.0	13.0
Umpling Bridge	14.0	17.0	17.0	16.0	11.0	26.0	17.0	14.0	20.0	22.0	15.0	27.0
Umkaliar	17.0	12.0	19.0	14.0	12.0	22.0	19.0	18.0	21.0	20.0	17.0	31.0
Demseiniong	19.0	10.0	16.0	11.0	36.0	45.0	19.0	17.0	15.0	11.0	11.0	21.0
Pynthor Umkhrah	14.0	9.0	11.0	12.0	11.0	16.0	18.0	12.0	11.0	17.0	12.0	18.0
Polo (behind Stadium)	14.0	11.0	15.0	16.0	15.0	54.0	32.0	30.0	20.0	18.0	31.0	19.0
Rooprekha	18.0	12.0	14.0	20.0	14.0	26.0	19.0	20.0	26.0	25.0	30.0	22.0
Jingthang Briew	27.0	14.0	18.0	32.0	33.0	26.0	22.0	21.0	34.0	32.0	25.0	24.0
Wah Thang Sning	16.0	12.0	10.0	19.0	26.0	38.0	16.0	14.0	31.0	21.0	32.0	30.0
Mawpdang Bridge	29.0	13.0	12.0	58.0	38.0	28.0	25.0	22.0	19.0	48.0	41.0	35.0

Turbidity of River Umkhrah Tributaries (NTU)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	28.0	19.0	14.0	56.0	24.0	26.0	15.0	18.0	42.0	36.0	42.0	32.0
Shillong College (B)	17.0	14.0	17.0	16.0	16.0	20.0	14.0	15.0	19.0	27.0	25.0	15.0
Polo Bridge (C)	14.0	13.0	16.0	42.0	42.0	20.0	23.0	20.0	31.0	18.0	19.0	17.0
Opposite Jingthang Briew (D)	19.0	13.0	19.0	31.0	31.0	20.0	16.0	14.0	17.0	22.0	18.0	20.0
Opposite Mawpdang Bridge (E)	51.0	33.0	28.0	43.0	43.0	25.0	20.0	42.0	38.0	31.0	27.0	26.0

pH of River Umkhrah

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	6.7	6.1	6.5	6.8	7.1	6.8	7.0	7.0	7.0	7.1	6.7	7.0
Umpling Bridge	6.8	6.5	6.8	7.0	7.0	6.7	6.5	7.0	7.0	7.0	6.8	6.6
Umkaliar	7.0	6.5	7.0	7.1	6.7	6.8	6.0	6.8	6.8	7.1	7.0	7.1
Demseiniong	7.0	6.2	6.5	6.7	7.0	7.0	7.0	7.0	7.0	6.7	7.0	6.8
Pynthor Umkhrah	7.0	6.2	6.2	6.8	7.0	6.8	6.8	7.0	7.0	6.8	7.0	7.0
Polo (behind Stadium)	7.1	6.5	6.8	7.0	7.0	6.8	6.2	7.1	7.1	7.0	7.1	7.0
Rooprekha	6.9	6.0	6.6	7.0	6.5	6.3	6.8	7.0	7.0	7.0	6.9	7.0
Jingthang Briew	7.0	6.5	7.0	7.0	6.2	6.3	7.0	7.0	7.0	7.0	7.0	7.1
Wah Thang Sning	6.5	6.5	6.2	7.0	6.8	6.4	7.0	6.9	6.9	7.0	7.0	6.9
Mawpdang Bridge	6.5	6.8	6.3	6.9	7.0	6.3	6.9	7.1	7.1	6.9	6.6	7.0

pH of River Umkhrah Tributaries

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	7.0	6.5	6.8	6.8	6.8	6.4	6.8	6.5	7.0	7.0	7.0	6.7
Shillong College (B)	7.0	6.0	6.3	7.0	6.8	6.8	6.5	6.8	6.9	7.0	7.0	7.0
Polo Bridge (C)	7.0	6.5	7.0	7.0	6.8	6.4	6.3	6.6	6.8	7.0	7.0	7.0
Opposite Jingthang Briew (D)	6.0	6.1	6.5	7.1	7.1	6.2	6.6	6.6	6.6	7.1	6.8	7.0
Opposite Mawpdang Bridge (E)	6.2	6.5	6.8	7.0	6.6	6.6	6.8	6.8	7.0	7.0	7.0	6.8

Concentration of Nitrate-N in River Umkhrah (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	2.5	2.4	2.8	2.3	2.9	6.6	3.1	3.0	4.9	4.6	4.0	1.4
Umpling Bridge	2.3	2.4	2.5	1.7	3.8	4.3	2.4	3.3	4.1	3.4	4.6	1.2
Umkaliar	3.6	1.5	1.4	2.0	2.5	2.5	2.0	10.1	4.9	2.8	4.6	1.3
Demseiniong	1.2	1.7	2.1	4.2	1.2	9.3	1.5	6.2	4.9	3.4	3.0	1.4
Pynthor Umkhrah	5.3	3.5	0.1	0.1	1.3	2.5	0.8	1.6	3.8	3.1	2.1	1.3
Polo (behind Stadium)	2.3	2.0	1.0	4.3	2.5	5.2	5.1	8.0	4.5	3.7	4.2	2.1
Rooprekha	1.8	1.8	2.3	3.9	4.0	7.5	3.0	5.1	3.6	2.8	3.9	3.2
Jingthang Briew	1.2	2.8	1.2	1.9	2.9	5.7	1.7	3.2	4.8	1.9	3.5	1.4
Wah Thang Sning	2.5	2.7	1.6	3.8	2.0	6.0	2.1	4.6	4.7	3.2	3.8	2.1
Mawpdang Bridge	2.8	4.6	1.2	1.3	1.3	1.4	1.5	2.2	4.8	1.8	4.4	2.0

Concentration of Nitrate-N in River Umkhrah Tributaries (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	3.6	3.6	1.0	0.8	2.4	4.3	4.8	2.7	6.7	6.4	3.2	2.0
Shillong College (B)	2.1	3.0	2.6	3.5	3.8	5.7	2.2	2.7	5.3	5.0	4.3	1.3
Polo Bridge (C)	3.2	1.3	1.4	1.4	2.0	1.1	2.3	4.6	6.5	2.7	3.9	2.7
Opposite Jingthang Briew (D)	2.7	2.4	1.8	2.9	2.7	2.9	1.4	2.9	2.7	1.7	2.5	2.4
Opposite Mawpdang Bridge (E)	2.6	1.4	1.3	11.6	2.9	2.8	2.8	3.9	4.1	1.6	2.5	1.3

Concentration of Phosphates in River Umkhrah (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	0.00	0.09	0.04	1.07	0.51	0.00	0.73	0.73	0.12	0.10	0.20	0.15
Umpling Bridge	0.00	0.04	0.13	0.32	0.08	0.00	0.11	0.11	0.07	0.38	0.24	0.17
Umkaliar	0.00	0.00	0.06	0.07	0.34	0.00	0.00	0.00	0.00	0.03	0.04	0.00
Demseiniong	0.04	0.33	0.25	1.96	0.87	0.15	0.34	0.34	0.12	0.12	0.97	0.15
Pynthor Umkhrah	0.01	0.05	0.11	0.34	0.11	0.09	0.09	0.09	0.05	0.02	0.14	0.02
Polo (behind Stadium)	0.02	0.04	0.12	0.28	0.15	0.15	0.11	0.11	0.06	0.04	0.39	0.12
Rooprekha	0.00	0.10	0.16	0.38	0.03	0.15	0.10	0.10	0.04	0.11	0.13	0.09
Jingthang Briew	0.04	0.33	0.36	0.82	0.00	0.17	0.05	0.05	0.12	0.33	0.30	0.07
Wah Thang Sning	0.02	0.30	0.36	0.82	0.00	0.17	0.02	0.01	0.11	0.31	0.27	0.25
Mawpdang Bridge	1.11	0.73	0.69	1.42	0.02	0.00	0.24	0.24	0.50	0.82	0.24	0.02

Concentration of Phosphates in River Umkhrah Tributaries (mg/L)

Sampling Location	Nov-01	Dec-01	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02
Refugee Colony (A)	0.17	0.56	0.26	0.31	1.73	0.22	0.25	0.25	0.28	0.22	0.11	0.04
Shillong College (B)	0.00	0.22	0.09	0.33	0.37	0.00	0.38	0.38	0.00	0.09	0.33	0.21
Polo Bridge (C)	1.18	1.71	0.37	0.12	0.61	0.16	1.34	1.34	0.56	0.55	0.13	0.45
Opposite Jingthang Briew (D)	0.00	0.20	0.11	0.33	0.34	0.39	0.12	0.12	0.01	0.20	0.07	0.02
Opposite Mawpdang Bridge (E)	1.88	2.47	1.99	1.60	2.31	0.00	1.53	1.53	0.33	1.85	0.28	1.61

Dissolved Oxygen in River Umkhrah (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	4.8	2.3	2.4	3.4	2.6	1.7	2.7	2.9	3.4	2.9	2.4	2.3
Umpling Bridge	4.9	3.4	3.7	3.7	2.4	1.5	1.5	3.5	2.9	3.4	1.7	1.7
Umkaliar	4.7	4.2	3.5	3.7	3.1	4.0	4.0	3.5	3.0	2.6	3.0	3.2
Demseiniong	3.5	3.1	2.6	3.4	1.6	2.6	2.6	2.7	1.7	2.5	1.7	1.5
Pynthor Umkhrah	3.0	2.6	2.4	3.2	2.9	2.4	2.4	3.0	2.7	1.7	2.7	1.7
Polo (behind Stadium)	3.4	1.9	3.3	0.9	2.0	2.4	2.4	3.8	2.3	2.9	2.5	0.4
Rooprekha	1.3	1.2	2.6	3.7	1.2	1.7	1.7	2.3	2.3	1.7	2.0	1.1
Jingthang Briew	1.9	1.3	3.2	3.3	1.2	1.2	1.2	2.9	2.5	2.4	2.7	1.2
Wah Thang Sning	1.1	2.7	3.8	3.4	2.6	2.3	2.3	2.3	3.2	4.8	2.6	0.8
Mawpdang Bridge	1.7	2.2	2.9	4.4	1.5	3.5	3.5	4.2	3.0	1.9	2.5	1.9

Dissolved Oxygen in River Umkhrah Tributaries (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	3.9	1.9	1.9	2.6	1.3	2.6	2.6	2.3	2.5	2.9	2.3	2.3
Shillong College (B)	4.9	2.5	3.2	3.3	2.0	0.9	0.9	2.3	2.6	3.4	2.7	2.4
Polo Bridge (C)	0.8	0.5	3.7	3.5	1.6	1.2	1.2	1.9	2.2	2.3	1.9	0.4
Opposite Jingthang Briew (D)	0.5	1.7	3.3	3.3	3.3	2.0	2.0	0.5	1.5	1.5	0.6	0.5
Opposite Mawpdang Bridge (E)	0.8	1.1	1.6	3.4	1.0	2.3	2.3	3.0	2.6	1.6	1.9	1.1

Biochemical Oxygen Demand in River Umkhrah (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Lapalang	116.4	64.2	121.4	57.1	116.4	107.8	132.8	65.7	83.6	75.0	115.7	173.5
Umpling Bridge	66.4	92.8	107.1	85.7	66.4	65.7	107.8	91.4	170.0	174.2	74.2	232.1
Umkaliar	190.0	71.4	92.8	85.7	182.1	165.4	75.0	25.0	16.4	99.2	91.4	165.7
Demseiniong	90.7	92.8	100.0	35.7	24.2	82.8	90.7	7.8	172.1	124.2	49.2	74.2
Pynthor Umkhrah	74.2	64.2	92.8	85.7	16.4	107.1	74.2	165.7	49.2	174.2	75.0	74.2
Polo (behind Stadium)	157.1	64.2	28.5	71.4	124.2	116.4	132.8	174.2	50.0	182.8	91.4	90.7
Rooprekha	82.8	78.5	35.7	64.2	140.7	49.2	66.4	16.4	115.7	107.8	116.4	99.2
Jingthang Briew	49.2	85.7	100.0	178.5	16.4	99.2	141.4	41.4	149.2	165.7	173.5	149.2
Wah Thang Sning	99.2	78.5	135.7	85.7	16.4	124.2	91.4	116.4	124.2	182.1	215.0	174.2
Mawpdang Bridge	91.4	71.4	42.8	28.5	91.4	75.0	207.1	74.2	157.8	207.1	157.8	91.4

Biochemical Oxygen Demand in River Umkhrah Tributaries (mg/L)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oct-2002
Refugee Colony (A)	41.4	92.8	78.5	214.2	41.4	91.4	32.8	25.2	132.1	65.7	231.4	140.7
Shillong College (B)	82.8	42.8	42.8	121.4	98.5	71.4	17.1	124.2	99.2	25.0	32.8	25.0
Polo Bridge (C)	41.4	135.7	50.0	107.1	41.4	90.7	50.0	223.5	124.2	57.8	57.8	90.7
Opposite Jingthang Briew (D)	41.1	271.4	64.2	157.1	165.4	173.5	107.8	41.4	89.2	116.4	35.7	174.2
Opposite Mawpdang Bridge (E)	41.4	114.2	85.7	100.0	41.4	148.5	82.8	82.8	16.4	149.2	140.7	99.2

Faecal Coliform in River Umkhrah (MPN/100ml)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oc 20
Lapalang	54000	54000	17000	28000	13000	9200	17000	17000	9200	9200	11000	540
Umpling Bridge	2800	2800	2800	2800	2200	2800	7000	5800	2800	4100	2800	92
Umkaliar	17000	13000	28000	13000	17000	28000	17000	13000	14000	11000	11000	280
Demseiniong	28000	28000	2800	3900	7000	5800	7900	4300	5800	6300	11000	220
Pynthor Umkhrah	22000	22000	28000	18000	18000	15000	18000	14000	11000	14000	13000	280
Polo (behind Stadium)	6300	15000	9200	13000	7000	9200	9200	9200	9200	9200	14000	240
Rooprekha	11000	18000	28000	9200	11000	22000	43000	15000	24000	24000	28000	180
Jingthang Briew	11000	54000	18000	140000	22000	11000	15000	220000	15000	24000	28000	240
Wah Thang Sning	140000	18000	9200	54000	54000	24000	43000	24000	24000	28000	43000	180
Mawpdang Bridge	43000	54000	24000	54000	54000	54000	220000	28000	15000	24000	28000	1400

Faecal Coliform in River Umkhrah Tributaries (MPN/100ml)

Sampling Location	Nov-2001	Dec-2001	Jan-2002	Feb-2002	Mar-2002	Apr-2002	May-2002	Jun-2002	Jul-2002	Aug-2002	Sep-2002	Oc 20
Refugee Colony (A)	14000	11000	14000	14000	11000	5400	18000	22000	15000	22000	28000	180
Shillong College (B)	43000	11000	14000	14000	28000	11000	22000	28000	14000	5400	24000	220
Polo Bridge (C)	14000	28000	17000	15000	15000	18000	15000	15000	5400	22000	15000	150
Opposite Jingthang Briew (D)	28000	43000	11000	28000	11000	11000	15000	28000	28000	15000	24000	150
Opposite Mawpdang Bridge (E)	54000	28000	220000	28000	24000	28000	180000	54000	24000	28000	140000	540

3. Water quality monitoring results of River Umkhrah in 2005

Temperature in River Umkhrah (°C)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	17.0	18.0	19.0	19.0
Nongrah	18.0	18.0	20.0	21.0
Marboh Bridge	18.0	18.0	20.0	21.0
Demseiniong	18.0	18.0	21.0	21.0
Lawmali	18.0	18.0	21.0	22.0
Wahingdoh	18.0	18.0	21.0	22.0

Turbidity in River Umkhrah (NTU)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	0.2	19.0	20.0	20.0
Nongrah	0.1	18.0	16.5	15.0
Marboh Bridge	0.1	0.5	1.4	1.0
Demseiniong	0.3	0.3	1.0	1.0
Lawmali	10.2	8.8	8.5	8.2
Wahingdoh	15.0	12.4	12.0	10.5

pH in River Umkhrah

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	7.0	6.8	6.8	6.9
Nongrah	6.8	6.8	6.9	6.9
Marboh Bridge	6.6	6.8	7.0	7.0
Demseiniong	6.9	7.0	7.0	6.8
Lawmali	6.8	6.8	6.9	7.0
Wahingdoh	7.0	6.8	6.7	7.0

Nitrate in River Umkhrah (mg/L)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	5.50	4.50	5.20	4.80
Nongrah	1.10	1.00	1.40	1.20
Marboh Bridge	1.90	2.20	2.80	3.10
Demseiniong	0.74	1.20	1.50	2.00
Lawmali	3.50	4.10	4.40	4.50
Wahingdoh	10.00	12.20	11.00	11.00

Phosphate in River Umkhrah (mg/L)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	0.10	0.20	0.20	0.10
Nongrah	0.17	0.20	0.20	0.18
Marboh Bridge	0.12	0.16	0.20	0.30
Demseiniong	0.50	0.80	0.60	1.00
Lawmali	0.40	0.60	0.72	0.70
Wahingdoh	0.85	1.00	1.20	0.95

Dissolved Oxygen in River Umkhrah (mg/L)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	2.8	4.4	5.2	4.2
Nongrah	5.0	3.2	4.2	3.0
Marboh Bridge	3.4	3.0	1.2	2.0
Demseiniong	2.6	NIL	1.2	NIL
Lawmali	5.0	NIL	1.0	NIL
Wahingdoh	NIL	NIL	3.0	NIL

BOD in River Umkhrah (mg/L)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	22.4	20.2	20.0	24.0
Nongrah	20.4	30.2	25.3	31.4
Marboh Bridge	60.5	65.8	70.2	68.8
Demseiniong	146.0	165.0	160.0	168.2
Lawmali	90.4	102.2	107.8	110.0
Wahingdoh	108.0	124.2	115.0	125.0

Faecal Coliform in River Umkhrah (MPN/100ml)

Sampling Location	22.4.2005	26.4.2005	6.5.2005	13.5.2005
Wah Demthring	110	79	79	110
Nongrah	21000	23000	23000	31000
Marboh Bridge	70000	70000	79000	79000
Demseiniong	70000	94000	79000	79000
Lawmali	130000	110000	94000	140000
Wahingdoh	140000	180000	170000	170000

ANNEXURE 3

WORK-SHEETS FOR NSFWQI

1. Water quality of River Umkhrah at Demthring

2002

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
DEMTHRING	Dissolved Oxygen	76	% sat	82	0.17	
	Faecal Coliform	240	MPN/100ml	36	0.15	
	pH	5.1		30	0.12	
	BOD	3.5	mg/L	64	0.10	66
	Nitrates	2	mg/L	95	0.10	
	Phosphates	BDL	mg/L	100	0.10	
	Temperature		°C		0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	

2003

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
DEMTHRING	Dissolved Oxygen	71	% sat	76	0.17	
	Faecal Coliform	490	MPN/100ml	29	0.15	
	pH	6.9		86	0.12	
	BOD	4	mg/L	61	0.10	69
	Nitrates	2	mg/L	95	0.10	
	Phosphates	0.05	mg/L	98	0.10	
	Temperature		°C		0.10	
	Turbidity	24	NTU	58	0.08	
	Total Solids		mg/L		0.08	

2004

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
DEMTHRING	Dissolved Oxygen	80	% sat	87	0.17	
	Faecal Coliform	700	MPN/100ml	25	0.15	
	pH	6.9		86	0.12	
	BOD	5.6	mg/L	53	0.10	70
	Nitrates	2.4	mg/L	93	0.10	
	Phosphates	0.1	mg/L	96	0.10	
	Temperature		°C		0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	

2. Water quality of River Umkhrah in 2001 – 02

November-01

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	47	% sat	40	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.7		79	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	54
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	48	% sat	41	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.8		83	0.12	
	BOD	66.4	mg/L	2	0.10	
	Nitrates	2.3	mg/L	94	0.10	57
	Phosphates	0	mg/L	100	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	46	% sat	38	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	190	mg/L	2	0.10	
	Nitrates	3.6	mg/L	78	0.10	54
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	36	% sat	25	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	90.7	mg/L	2	0.10	
	Nitrates	1.2	mg/L	96	0.10	50
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	5	°C	73	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	5.3	mg/L	64	0.10	49
	Phosphates	0.01	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	33	% sat	21	0.17	
	Faecal Coliform	6300	MPN/100ml	12	0.15	
	pH	7.1		90	0.12	
	BOD	157.1	mg/L	2	0.10	
	Nitrates	2.3	mg/L	94	0.10	**53**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.9		86	0.12	
	BOD	82.8	mg/L	2	0.10	
	Nitrates	1.8	mg/L	95	0.10	**50**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	13	% sat	9	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	49.2	mg/L	2	0.10	
	Nitrates	1.2	mg/L	96	0.10	**50**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	27	NTU	55	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	10	% sat	7	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	6.5		72	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	**47**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	6.5		72	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	**40**
	Phosphates	1.11	mg/L	38	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	29	NTU	54	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	32	% sat	20	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	3.6	mg/L	78	0.10	**49**
	Phosphates	0.17	mg/L	93	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	28	NTU	55	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	48	% sat	41	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	82.8	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	**56**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	7	% sat	6	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	3.2	mg/L	86	0.10	**42**
	Phosphates	1.18	mg/L	36	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	4	% sat	4	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6		55	0.12	
	BOD	41.1	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**45**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	7	% sat	6	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.2		60	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	2.6	mg/L	92	0.10	**36**
	Phosphates	1.88	mg/L	28	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	51	NTU	38	0.08	
	Total Solids		mg/L		0.08	

December-01

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	19	% sat	12	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.1		57	0.12	
	BOD	64.2	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	**54**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.5		72	0.12	
	BOD	92.8	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	**57**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	5	°C	73	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	40	% sat	30	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	6.5		72	0.12	
	BOD	71.4	mg/L	2	0.10	
	Nitrates	1.5	mg/L	96	0.10	**54**
	Phosphates	0	mg/L	100	0.10	
	Temperature	5	°C	73	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.2		60	0.12	
	BOD	92.8	mg/L	2	0.10	
	Nitrates	1.7	mg/L	95	0.10	**50**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	5	°C	73	0.10	
	Turbidity	10	NTU	76	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.2		60	0.12	
	BOD	64.2	mg/L	2	0.10	
	Nitrates	3.5	mg/L	80	0.10	**49**
	Phosphates	0.05	mg/L	98	0.10	
	Temperature	5	°C	73	0.10	
	Turbidity	9	NTU	78	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.5		72	0.12	
	BOD	64.2	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	**53**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	6	°C	67	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6		55	0.12	
	BOD	78.5	mg/L	2	0.10	
	Nitrates	1.8	mg/L	95	0.10	**50**
	Phosphates	0.1	mg/L	96	0.10	
	Temperature	6	°C	67	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.5		72	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	**50**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	6	°C	67	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.5		72	0.12	
	BOD	78.5	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**47**
	Phosphates	0.3	mg/L	81	0.10	
	Temperature	6	°C	67	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.8		83	0.12	
	BOD	71.4	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	**40**
	Phosphates	0.73	mg/L	49	0.10	
	Temperature	6.5	°C	64	0.10	
	Turbidity	13	NTU	70	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	17	% sat	11	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.5		72	0.12	
	BOD	92.8	mg/L	2	0.10	
	Nitrates	3.6	mg/L	78	0.10	**49**
	Phosphates	0.56	mg/L	57	0.10	
	Temperature	5	° C	73	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6		55	0.12	
	BOD	42.8	mg/L	2	0.10	
	Nitrates	3	mg/L	90	0.10	**56**
	Phosphates	0.22	mg/L	90	0.10	
	Temperature	5.5	° C	70	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	3	% sat	4	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.5		72	0.12	
	BOD	135.7	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**42**
	Phosphates	1.71	mg/L	29	0.10	
	Temperature	5	° C	73	0.10	
	Turbidity	13	NTU	70	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	6.1		57	0.12	
	BOD	271.4	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	**45**
	Phosphates	0.2	mg/L	92	0.10	
	Temperature	6	° C	67	0.10	
	Turbidity	13	NTU	70	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	10	% sat	7	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.5		72	0.12	
	BOD	114.2	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**36**
	Phosphates	2.47	mg/L	24	0.10	
	Temperature	6	° C	67	0.10	
	Turbidity	33	NTU	51	0.08	
	Total Solids		mg/L		0.08	

January-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	6.5		72	0.12	
	BOD	121.4	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	49
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	37	% sat	26	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.8		83	0.12	
	BOD	107.1	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	53
	Phosphates	0.13	mg/L	95	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	34	% sat	22	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	92.8	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	52
	Phosphates	0.06	mg/L	98	0.10	
	Temperature	0.5	°C	91	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.5		72	0.12	
	BOD	100	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	50
	Phosphates	0.25	mg/L	87	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.2		60	0.12	
	BOD	92.8	mg/L	2	0.10	
	Nitrates	0.1	mg/L	97	0.10	48
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.8		83	0.12	
	BOD	28.5	mg/L	2	0.10	
	Nitrates	1	mg/L	96	0.10	**52**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.6		75	0.12	
	BOD	35.7	mg/L	2	0.10	
	Nitrates	2.3	mg/L	94	0.10	**49**
	Phosphates	0.16	mg/L	94	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	30	% sat	19	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	100	mg/L	2	0.10	
	Nitrates	1.2	mg/L	96	0.10	**49**
	Phosphates	0.36	mg/L	75	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	37	% sat	26	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.2		60	0.12	
	BOD	135.7	mg/L	2	0.10	
	Nitrates	1.6	mg/L	95	0.10	**49**
	Phosphates	0.36	mg/L	75	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	10	NTU	76	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.3		64	0.12	
	BOD	42.8	mg/L	2	0.10	
	Nitrates	1.2	mg/L	96	0.10	**44**
	Phosphates	0.69	mg/L	51	0.10	
	Temperature	0.5	°C	91	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	78.5	mg/L	2	0.10	
	Nitrates	1	mg/L	96	0.10	**49**
	Phosphates	0.26	mg/L	86	0.10	
	Temperature	0.5	°C	91	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.3		64	0.12	
	BOD	42.8	mg/L	2	0.10	
	Nitrates	2.6	mg/L	92	0.10	**48**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	50	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**50**
	Phosphates	0.37	mg/L	74	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.5		72	0.12	
	BOD	64.2	mg/L	2	0.10	
	Nitrates	1.8	mg/L	95	0.10	**50**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	220000	MPN/100ml	2	0.15	
	pH	6.8		83	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**40**
	Phosphates	1.99	mg/L	27	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	28	NTU	55	0.08	
	Total Solids		mg/L		0.08	

February-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.8		83	0.12	
	BOD	57.1	mg/L	2	0.10	
	Nitrates	2.3	mg/L	94	0.10	**44**
	Phosphates	1.07	mg/L	39	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	35	% sat	23	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	7		88	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	1.7	mg/L	95	0.10	**52**
	Phosphates	0.32	mg/L	79	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	35	% sat	23	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	7.1		90	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	**53**
	Phosphates	0.07	mg/L	97	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	33	% sat	21	0.17	
	Faecal Coliform	3900	MPN/100ml	15	0.15	
	pH	6.7		79	0.12	
	BOD	35.7	mg/L	2	0.10	
	Nitrates	4.2	mg/L	69	0.10	**42**
	Phosphates	1.96	mg/L	27	0.10	
	Temperature	2	° C	85	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	30	% sat	19	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	0.1	mg/L	97	0.10	**50**
	Phosphates	0.34	mg/L	77	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	8	% sat	6	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	71.4	mg/L	2	0.10	
	Nitrates	4.3	mg/L	69	0.10	**45**
	Phosphates	0.28	mg/L	83	0.10	
	Temperature	0	°C	3	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	34	% sat	22	0.17	
	Faecal Coliform	9200	MPN/100ml	110	0.15	
	pH	7		88	0.12	
	BOD	64.2	mg/L	2	0.10	
	Nitrates	3.9	mg/L	72	0.10	**47**
	Phosphates	0.38	mg/L	73	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	30	% sat	19	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	7		88	0.12	
	BOD	178.5	mg/L	2	0.10	
	Nitrates	1.9	mg/L	95	0.10	**44**
	Phosphates	0.82	mg/L	46	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	32	NTU	51	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	32	% sat	2	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	85.7	mg/L	2	0.10	
	Nitrates	3.8	mg/L	74	0.10	**43**
	Phosphates	0.82	mg/L	46	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	42	% sat	33	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.9		86	0.12	
	BOD	28.5	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**44**
	Phosphates	1.42	mg/L	32	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	58	NTU	34	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	214.2	mg/L	2	0.10	
	Nitrates	0.8	mg/L	96	0.10	**46**
	Phosphates	0.31	mg/L	80	0.10	
	Temperature	1	° C	89	0.10	
	Turbidity	56	NTU	35	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	121.4	mg/L	2	0.10	
	Nitrates	3.5	mg/L	80	0.10	**48**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	1	° C	89	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	33	% sat	21	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	100	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**50**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	1	° C	89	0.10	
	Turbidity	42	NTU	44	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7.1		90	0.12	
	BOD	157.1	mg/L	2	0.10	
	Nitrates	2.9	mg/L	91	0.10	**48**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	1	° C	89	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	34	% sat	22	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	100	mg/L	2	0.10	
	Nitrates	11.6	mg/L	48	0.10	**38**
	Phosphates	1.6	mg/L	30	0.10	
	Temperature	1	° C	89	0.10	
	Turbidity	43	NTU	43	0.08	
	Total Solids		mg/L		0.08	

March-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	7.1		90	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	2.9	mg/L	91	0.10	**47**
	Phosphates	0.51	mg/L	60	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	21	NTU	60	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	2200	MPN/100ml	18	0.15	
	pH	7		88	0.12	
	BOD	66.4	mg/L	2	0.10	
	Nitrates	3.8	mg/L	74	0.10	**51**
	Phosphates	0.08	mg/L	97	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	6.7		79	0.12	
	BOD	182.1	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	**48**
	Phosphates	0.34	mg/L	77	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	7000	MPN/100ml	12	0.15	
	pH	7		88	0.12	
	BOD	24.2	mg/L	8	0.10	
	Nitrates	1.2	mg/L	96	0.10	**44**
	Phosphates	0.87	mg/L	44	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	36	NTU	48	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	27	% sat	17	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	16.4	mg/L	17	0.10	
	Nitrates	1.3	mg/L	96	0.10	**53**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	19	% sat	12	0.17	
	Faecal Coliform	7000	MPN/100ml	12	0.15	
	pH	7		88	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	**50**
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.5		72	0.12	
	BOD	140.7	mg/L	2	0.10	
	Nitrates	4	mg/L	70	0.10	**46**
	Phosphates	0.03	mg/L	99	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.2		60	0.12	
	BOD	16.4	mg/L	17	0.10	
	Nitrates	2.9	mg/L	91	0.10	**46**
	Phosphates	0	mg/L	100	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	33	NTU	51	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.8		83	0.12	
	BOD	16.4	mg/L	17	0.10	
	Nitrates	2	mg/L	95	0.10	**51**
	Phosphates	0	mg/L	100	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**48**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	38	NTU	47	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.8		83	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	41
	Phosphates	1.73	mg/L	29	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	24	NTU	58	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	19	% sat	12	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.8		83	0.12	
	BOD	98.5	mg/L	2	0.10	
	Nitrates	3.8	mg/L	74	0.10	45
	Phosphates	0.37	mg/L	74	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	43
	Phosphates	0.61	mg/L	55	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	42	NTU	44	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7.1		90	0.12	
	BOD	165.4	mg/L	2	0.10	
	Nitrates	.2.7	mg/L	92	0.10	48
	Phosphates	0.34	mg/L	77	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	9	% sat	7	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.6		75	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	2.9	mg/L	91	0.10	38
	Phosphates	2.31	mg/L	25	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	43	NTU	43	0.08	
	Total Solids		mg/L		0.08	

April-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	17	% sat	11	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.8		83	0.12	
	BOD	107.8	mg/L	2	0.10	
	Nitrates	6.6	mg/L	59	0.10	46
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.7		79	0.12	
	BOD	65.7	mg/L	2	0.10	
	Nitrates	4.3	mg/L	69	0.10	46
	Phosphates	0	mg/L	100	0.10	
	Temperature	4	° C	77	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	40	% sat	30	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.8		83	0.12	
	BOD	165.4	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	53
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	5800	MPN/100ml	13	0.15	
	pH	7		88	0.12	
	BOD	82.8	mg/L	2	0.10	
	Nitrates	9.3	mg/L	53	0.10	44
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	4	° C	77	0.10	
	Turbidity	45	NTU	42	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	107.1	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	50
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.8		83	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	5.2	mg/L	64	0.10	45
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	54	NTU	37	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	17	% sat	11	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.3		64	0.12	
	BOD	49.2	mg/L	2	0.10	
	Nitrates	7.5	mg/L	57	0.10	42
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.3		64	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	5.7	mg/L	62	0.10	42
	Phosphates	0.17	mg/L	93	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.4		68	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	6	mg/L	60	0.10	43
	Phosphates	0.17	mg/L	93	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	38	NTU	47	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	35	% sat	23	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.3		64	0.12	
	BOD	75	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	49
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	28	NTU	55	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	5400	MPN/100ml	13	0.15	
	pH	6.4		68	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	4.3	mg/L	69	0.10	**45**
	Phosphates	0.22	mg/L	90	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	10	% sat	7	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.8		83	0.12	
	BOD	71.4	mg/L	2	0.10	
	Nitrates	5.7	mg/L	62	0.10	**46**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.4		68	0.12	
	BOD	90.7	mg/L	2	0.10	
	Nitrates	1.1	mg/L	96	0.10	**47**
	Phosphates	0.16	mg/L	94	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	20	% sat	12	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.2		60	0.12	
	BOD	173.5	mg/L	2	0.10	
	Nitrates	2.9	mg/L	91	0.10	**44**
	Phosphates	0.39	mg/L	72	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.6		75	0.12	
	BOD	148.5	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	**48**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	25	NTU	57	0.08	
	Total Solids		mg/L		0.08	

May-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	132.8	mg/L	2	0.10	
	Nitrates	3.1	mg/L	88	0.10	**46**
	Phosphates	0.73	mg/L	49	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	7000	MPN/100ml	12	0.15	
	pH	6.5		72	0.12	
	BOD	107.8	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	**48**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	42	% sat	33	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	6		55	0.12	
	BOD	75	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	**50**
	Phosphates	0	mg/L	100	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	7900	MPN/100ml	11	0.15	
	pH	7		88	0.12	
	BOD	90.7	mg/L	2	0.10	
	Nitrates	1.5	mg/L	96	0.10	**49**
	Phosphates	0.34	mg/L	77	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	0.8	mg/L	96	0.10	**50**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.2		60	0.12	
	BOD	132.8	mg/L	2	0.10	
	Nitrates	5.1	mg/L	65	0.10	**43**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	32	NTU	51	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	6.8		83	0.12	
	BOD	66.4	mg/L	2	0.10	
	Nitrates	3	mg/L	90	0.10	**48**
	Phosphates	0.1	mg/L	96	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	141.4	mg/L	2	0.10	
	Nitrates	1.7	mg/L	95	0.10	**48**
	Phosphates	0.05	mg/L	98	0.10	
	Temperature	3	°C	81	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	**49**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	4	°C	77	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	38	% sat	27	0.17	
	Faecal Coliform	220000	MPN/100ml	2	0.15	
	pH	6.9		86	0.12	
	BOD	207.1	mg/L	2	0.10	
	Nitrates	1.5	mg/L	96	0.10	**49**
	Phosphates	0.24	mg/L	88	0.10	
	Temperature	4	°C	77	0.10	
	Turbidity	25	NTU	57	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	27	% sat	17	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	32.8	mg/L	2	0.10	
	Nitrates	4.8	mg/L	66	0.10	47
	Phosphates	0.25	mg/L	87	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	8	% sat	6	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.5		72	0.12	
	BOD	17.1	mg/L	16	0.10	
	Nitrates	2.2	mg/L	94	0.10	46
	Phosphates	0.38	mg/L	73	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	11	% sat	8	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.3		64	0.12	
	BOD	50	mg/L	2	0.10	
	Nitrates	2.3	mg/L	94	0.10	39
	Phosphates	1.34	mg/L	33	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	23	NTU	59	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.6		75	0.12	
	BOD	107.8	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	48
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	180000	MPN/100ml	2	0.15	
	pH	6.8		83	0.12	
	BOD	82.8	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	41
	Phosphates	1.53	mg/L	31	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	

June-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	17000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	65.7	mg/L	2	0.10	
	Nitrates	3	mg/L	90	0.10	**46**
	Phosphates	0.73	mg/L	49	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	35	% sat	23	0.17	
	Faecal Coliform	5800	MPN/100ml	13	0.15	
	pH	7		88	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	3.3	mg/L	84	0.10	**52**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	-1	° C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	35	% sat	23	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	25	mg/L	7	0.10	
	Nitrates	10.1	mg/L	51	0.10	**48**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	27	% sat	17	0.17	
	Faecal Coliform	4300	MPN/100ml	14	0.15	
	pH	7		88	0.12	
	BOD	7.8	mg/L	43	0.10	
	Nitrates	6.2	mg/L	60	0.10	**51**
	Phosphates	0.34	mg/L	77	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	30	% sat	19	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	165.7	mg/L	2	0.10	
	Nitrates	1.6	mg/L	95	0.10	**52**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	37	% sat	26	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	7.1		90	0.12	
	BOD	174.2	mg/L	2	0.10	
	Nitrates	8	mg/L	56	0.10	**48**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	30	NTU	53	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	16.4	mg/L	17	0.10	
	Nitrates	5.1	mg/L	65	0.10	**49**
	Phosphates	0.1	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	220000	MPN/100ml	2	0.15	
	pH	7		88	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	3.2	mg/L	86	0.10	**49**
	Phosphates	0.05	mg/L	98	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	21	NTU	60	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.9		86	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	**48**
	Phosphates	0.01	mg/L	100	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	40	% sat	30	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7.1		90	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	2.2	mg/L	94	0.10	**52**
	Phosphates	0.24	mg/L	88	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.5		72	0.12	
	BOD	25.2	mg/L	7	0.10	
	Nitrates	2.7	mg/L	92	0.10	**48**
	Phosphates	0.25	mg/L	87	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.8		83	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**47**
	Phosphates	0.38	mg/L	73	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	19	% sat	12	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	6.6		75	0.12	
	BOD	223.5	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	**38**
	Phosphates	1.34	mg/L	33	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	3	% sat	4	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.6		75	0.12	
	BOD	41.4	mg/L	2	0.10	
	Nitrates	2.9	mg/L	91	0.10	**47**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	14	NTU	69	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.8		83	0.12	
	BOD	82.8	mg/L	2	0.10	
	Nitrates	3.9	mg/L	72	0.10	**38**
	Phosphates	1.53	mg/L	31	0.10	
	Temperature	-2	°C	85	0.10	
	Turbidity	42	NTU	44	0.08	
	Total Solids		mg/L		0.08	

July-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	32	% sat	20	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	83.6	mg/L	2	0.10	
	Nitrates	4.9	mg/L	66	0.10	**49**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	7		88	0.12	
	BOD	170	mg/L	2	0.10	
	Nitrates	4.1	mg/L	70	0.10	**49**
	Phosphates	0.07	mg/L	97	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	30	% sat	19	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	16.4	mg/L	17	0.10	
	Nitrates	4.9	mg/L	66	0.10	**49**
	Phosphates	0	mg/L	100	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	21	NTU	60	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	5800	MPN/100ml	13	0.15	
	pH	7		88	0.12	
	BOD	172.1	mg/L	2	0.10	
	Nitrates	4.9	mg/L	66	0.10	**47**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	27	% sat	17	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	49.2	mg/L	2	0.10	
	Nitrates	3.8	mg/L	74	0.10	**49**
	Phosphates	0.05	mg/L	98	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	7.1		90	0.12	
	BOD	50	mg/L	2	0.10	
	Nitrates	4.5	mg/L	68	0.10	**48**
	Phosphates	0.06	mg/L	98	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	115.7	mg/L	2	0.10	
	Nitrates	3.6	mg/L	78	0.10	**48**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	149.2	mg/L	2	0.10	
	Nitrates	4.8	mg/L	66	0.10	**47**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	34	NTU	50	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.9		86	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	4.7	mg/L	67	0.10	**47**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7.1		90	0.12	
	BOD	157.8	mg/L	2	0.10	
	Nitrates	4.8	mg/L	66	0.10	**44**
	Phosphates	0.5	mg/L	60	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	132.1	mg/L	2	0.10	
	Nitrates	6.7	mg/L	58	0.10	**44**
	Phosphates	0.28	mg/L	83	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	42	NTU	44	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.9		86	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	5.3	mg/L	64	0.10	**48**
	Phosphates	0	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	20	% sat	12	0.17	
	Faecal Coliform	5400	MPN/100ml	13	0.15	
	pH	6.8		83	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	6.5	mg/L	59	0.10	**41**
	Phosphates	0.56	mg/L	57	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	14	% sat	9	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.6		75	0.12	
	BOD	89.2	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**48**
	Phosphates	0.01	mg/L	100	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	16.4	mg/L	2	0.10	
	Nitrates	4.1	mg/L	70	0.10	**44**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	38	NTU	47	0.08	
	Total Solids		mg/L		0.08	

August-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	7.1		90	0.12	
	BOD	75	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	**49**
	Phosphates	0.1	mg/L	96	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	16	NTU	66	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	34	% sat	22	0.17	
	Faecal Coliform	4100	MPN/100ml	15	0.15	
	pH	7		88	0.12	
	BOD	174.2	mg/L	2	0.10	
	Nitrates	3.4	mg/L	82	0.10	**49**
	Phosphates	0.38	mg/L	73	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7.1		90	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	**51**
	Phosphates	0.03	mg/L	99	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	6300	MPN/100ml	12	0.15	
	pH	6.7		79	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	3.4	mg/L	82	0.10	**50**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	6.8		83	0.12	
	BOD	174.2	mg/L	2	0.10	
	Nitrates	3.1	mg/L	88	0.10	**49**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	0	° C	93	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	182.8	mg/L	2	0.10	
	Nitrates	3.7	mg/L	76	0.10	**50**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	107.8	mg/L	2	0.10	
	Nitrates	2.8	mg/L	91	0.10	**49**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	25	NTU	57	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	165.7	mg/L	2	0.10	
	Nitrates	1.9	mg/L	95	0.10	**47**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	32	NTU	51	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	46	% sat	38	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	182.1	mg/L	2	0.10	
	Nitrates	3.2	mg/L	86	0.10	**51**
	Phosphates	0.31	mg/L	80	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	21	NTU	60	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.9		86	0.12	
	BOD	207.1	mg/L	2	0.10	
	Nitrates	1.8	mg/L	95	0.10	**42**
	Phosphates	0.82	mg/L	46	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	48	NTU	40	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	28	% sat	17	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	65.7	mg/L	2	0.10	
	Nitrates	6.4	mg/L	59	0.10	**45**
	Phosphates	0.22	mg/L	90	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	36	NTU	48	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	33	% sat	21	0.17	
	Faecal Coliform	5400	MPN/100ml	13	0.15	
	pH	7		88	0.12	
	BOD	25	mg/L	7	0.10	
	Nitrates	5	mg/L	65	0.10	**49**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	0.5	°C	91	0.10	
	Turbidity	27	NTU	55	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	22	% sat	13	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	57.8	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**46**
	Phosphates	0.55	mg/L	58	0.10	
	Temperature	-1	°C	89	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7.1		90	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	1.7	mg/L	95	0.10	**49**
	Phosphates	0.2	mg/L	92	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	149.2	mg/L	2	0.10	
	Nitrates	1.6	mg/L	95	0.10	**41**
	Phosphates	1.85	mg/L	28	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	

September-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	6.7		79	0.12	
	BOD	115.7	mg/L	2	0.10	
	Nitrates	4	mg/L	70	0.10	47
	Phosphates	0.2	mg/L	92	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	2800	MPN/100ml	17	0.15	
	pH	6.8		83	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	46
	Phosphates	0.24	mg/L	88	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	29	% sat	18	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	4.6	mg/L	67	0.10	49
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	16	% sat	10	0.17	
	Faecal Coliform	11000	MPN/100ml	10	0.15	
	pH	7		88	0.12	
	BOD	49.2	mg/L	2	0.10	
	Nitrates	3	mg/L	90	0.10	44
	Phosphates	0.97	mg/L	41	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	11	NTU	74	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	13000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	75	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	51
	Phosphates	0.14	mg/L	94	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	12	NTU	72	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	14000	MPN/100ml	9	0.15	
	pH	7.1		90	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	4.2	mg/L	69	0.10	**45**
	Phosphates	0.39	mg/L	72	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.9		86	0.12	
	BOD	116.4	mg/L	2	0.10	
	Nitrates	3.9	mg/L	72	0.10	**46**
	Phosphates	0.13	mg/L	95	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	30	NTU	53	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	173.5	mg/L	2	0.10	
	Nitrates	3.5	mg/L	80	0.10	**47**
	Phosphates	0.3	mg/L	81	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	25	NTU	57	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	25	% sat	15	0.17	
	Faecal Coliform	43000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	215	mg/L	2	0.10	
	Nitrates	3.8	mg/L	74	0.10	**46**
	Phosphates	0.27	mg/L	85	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	32	NTU	51	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	24	% sat	15	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	6.6		75	0.12	
	BOD	157.8	mg/L	2	0.10	
	Nitrates	4.4	mg/L	68	0.10	**43**
	Phosphates	0.24	mg/L	88	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	41	NTU	44	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	22	% sat	13	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	231.4	mg/L	2	0.10	
	Nitrates	3.2	mg/L	86	0.10	**47**
	Phosphates	0.11	mg/L	96	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	42	NTU	44	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	26	% sat	16	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	32.8	mg/L	2	0.10	
	Nitrates	4.3	mg/L	69	0.10	**45**
	Phosphates	0.33	mg/L	78	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	25	NTU	57	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	57.8	mg/L	2	0.10	
	Nitrates	3.9	mg/L	72	0.10	**47**
	Phosphates	0.13	mg/L	95	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	4	% sat	4	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	35.7	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	**48**
	Phosphates	0.07	mg/L	97	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	7		88	0.12	
	BOD	140.7	mg/L	2	0.10	
	Nitrates	2.5	mg/L	93	0.10	**47**
	Phosphates	0.28	mg/L	83	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	27	NTU	55	0.08	
	Total Solids		mg/L		0.08	

October-02

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAPALANG	Dissolved Oxygen	21	% sat	13	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	7		88	0.12	
	BOD	173.5	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**51**
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	13	NTU	70	0.08	
	Total Solids		mg/L		0.08	
UMPLING BRIDGE	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	9200	MPN/100ml	10	0.15	
	pH	6.6		75	0.12	
	BOD	232.1	mg/L	2	0.10	
	Nitrates	1.2	mg/L	96	0.10	**48**
	Phosphates	0.17	mg/L	93	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	27	NTU	55	0.08	
	Total Solids		mg/L		0.08	
UMKALIAR	Dissolved Oxygen	31	% sat	19	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7.1		90	0.12	
	BOD	165.7	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**50**
	Phosphates	0	mg/L	100	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	31	NTU	52	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	14	% sat	9	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**48**
	Phosphates	0.15	mg/L	94	0.10	
	Temperature	2	°C	85	0.10	
	Turbidity	21	NTU	60	0.08	
	Total Solids		mg/L		0.08	
PYNTHOR UMKHRAH	Dissolved Oxygen	15	% sat	10	0.17	
	Faecal Coliform	28000	MPN/100ml	7	0.15	
	pH	7		88	0.12	
	BOD	74.2	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**50**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	18	NTU	63	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
POLO (behind Stadium)	Dissolved Oxygen	2	% sat	3	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	90.7	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	**48**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	19	NTU	62	0.08	
	Total Solids		mg/L		0.08	
ROOPREKHA	Dissolved Oxygen	10	% sat	7	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	7.1		90	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	3.2	mg/L	86	0.10	**48**
	Phosphates	0.09	mg/L	96	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	22	NTU	59	0.08	
	Total Solids		mg/L		0.08	
JINGTHANG BRIEW	Dissolved Oxygen	12	% sat	8	0.17	
	Faecal Coliform	24000	MPN/100ml	8	0.15	
	pH	7.1		90	0.12	
	BOD	149.2	mg/L	2	0.10	
	Nitrates	1.4	mg/L	96	0.10	**49**
	Phosphates	0.07	mg/L	97	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	24	NTU	58	0.08	
	Total Solids		mg/L		0.08	
WAH THANG SNING	Dissolved Oxygen	7	% sat	6	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.9		86	0.12	
	BOD	174.2	mg/L	2	0.10	
	Nitrates	2.1	mg/L	95	0.10	**47**
	Phosphates	0.25	mg/L	87	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	30	NTU	53	0.08	
	Total Solids		mg/L		0.08	
MAWPDANG BRIDGE	Dissolved Oxygen	18	% sat	11	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	7		88	0.12	
	BOD	91.4	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	**48**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	35	NTU	49	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
REFUGEE COLONY (A)	Dissolved Oxygen	22	% sat	13	0.17	
	Faecal Coliform	18000	MPN/100ml	8	0.15	
	pH	6.7		79	0.12	
	BOD	140.7	mg/L	2	0.10	
	Nitrates	2	mg/L	95	0.10	**48**
	Phosphates	0.04	mg/L	98	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	32	NTU	51	0.08	
	Total Solids		mg/L		0.08	
SHILLONG COLLEGE (B)	Dissolved Oxygen	23	% sat	14	0.17	
	Faecal Coliform	22000	MPN/100ml	8	0.15	
	pH	7		88	0.12	
	BOD	25	mg/L	7	0.10	
	Nitrates	1.3	mg/L	96	0.10	**51**
	Phosphates	0.21	mg/L	91	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	15	NTU	67	0.08	
	Total Solids		mg/L		0.08	
POLO BRIDGE (C)	Dissolved Oxygen	2	% sat	3	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	90.7	mg/L	2	0.10	
	Nitrates	2.7	mg/L	92	0.10	**45**
	Phosphates	0.45	mg/L	65	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	17	NTU	65	0.08	
	Total Solids		mg/L		0.08	
OPP. JINGTHANG BRIEW (D)	Dissolved Oxygen	3	% sat	4	0.17	
	Faecal Coliform	15000	MPN/100ml	9	0.15	
	pH	7		88	0.12	
	BOD	174.2	mg/L	2	0.10	
	Nitrates	2.4	mg/L	93	0.10	**48**
	Phosphates	0.02	mg/L	99	0.10	
	Temperature	1	°C	89	0.10	
	Turbidity	20	NTU	61	0.08	
	Total Solids		mg/L		0.08	
OPP. MAWPDANG BRIDGE (E)	Dissolved Oxygen	10	% sat	7	0.17	
	Faecal Coliform	54000	MPN/100ml	6	0.15	
	pH	6.8		83	0.12	
	BOD	99.2	mg/L	2	0.10	
	Nitrates	1.3	mg/L	96	0.10	**41**
	Phosphates	1.61	mg/L	30	0.10	
	Temperature	0	°C	93	0.10	
	Turbidity	26	NTU	56	0.08	
	Total Solids		mg/L		0.08	

3. Water quality of River Umkhrah in 2005

22-4-2005

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
WAH DEMTHRING	Dissolved Oxygen	27.0	% sat	17	0.17	
	Faecal Coliform	110	MPN/100ml	43	0.15	
	pH	7.0		88	0.12	
	BOD	22.4	mg/L	9	0.10	
	Nitrates	5.50	mg/L	63	0.10	**58**
	Phosphates	0.10	mg/L	96	0.10	
	Temperature	0.0	°C	93	0.10	
	Turbidity	0.2	NTU	98	0.08	
	Total Solids		mg/L		0.08	
NONGRAH	Dissolved Oxygen	51.0	% sat	45	0.17	
	Faecal Coliform	21000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	20.4	mg/L	11	0.10	
	Nitrates	1.10	mg/L	96	0.10	**59**
	Phosphates	0.17	mg/L	93	0.10	
	Temperature	1.0	°C	89	0.10	
	Turbidity	0.1	NTU	99	0.08	
	Total Solids		mg/L		0.08	
MARBOH BRIDGE	Dissolved Oxygen	33.0	% sat	21	0.17	
	Faecal Coliform	70000	MPN/100ml	5	0.15	
	pH	6.6		75	0.12	
	BOD	60.5	mg/L	2	0.10	
	Nitrates	1.90	mg/L	95	0.10	**52**
	Phosphates	0.12	mg/L	95	0.10	
	Temperature	1.0	°C	89	0.10	
	Turbidity	0.1	NTU	99	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	25.0	% sat	15	0.17	
	Faecal Coliform	70000	MPN/100ml	5	0.15	
	pH	6.9		86	0.12	
	BOD	146.0	mg/L	2	0.10	
	Nitrates	0.74	mg/L	96	0.10	**49**
	Phosphates	0.50	mg/L	60	0.10	
	Temperature	1.0	°C	89	0.10	
	Turbidity	0.3	NTU	98	0.08	
	Total Solids		mg/L		0.08	
LAWMALI	Dissolved Oxygen	51.0	% sat	45	0.17	
	Faecal Coliform	130000	MPN/100ml	2	0.15	
	pH	6.8		83	0.12	
	BOD	90.4	mg/L	2	0.10	
	Nitrates	3.50	mg/L	80	0.10	**51**
	Phosphates	0.40	mg/L	71	0.10	
	Temperature	1.0	°C	89	0.10	
	Turbidity	10.2	NTU	76	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
LAWMALI	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	110000	MPN/100ml	2	0.15	
	pH	6.8		83	0.12	
	BOD	102.2	mg/L	2	0.10	
	Nitrates	4.10	mg/L	70	0.10	41
	Phosphates	0.60	mg/L	55	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	8.8	NTU	78	0.08	
	Total Solids		mg/L		0.08	
WAHINGDOH	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	180000	MPN/100ml	2	0.15	
	pH	6.8		83	0.12	
	BOD	124.2	mg/L	2	0.10	
	Nitrates	12.20	mg/L	48	0.10	36
	Phosphates	1.00	mg/L	40	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	12.4	NTU	71	0.08	
	Total Solids		mg/L		0.08	

6.5.2005

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
WAH DEMTHRING	Dissolved Oxygen	53.0	% sat	48	0.17	
	Faecal Coliform	79	MPN/100ml	47	0.15	
	pH	6.8		83	0.12	
	BOD	20.0	mg/L	12	0.10	
	Nitrates	5.20	mg/L	64	0.10	60
	Phosphates	0.20	mg/L	92	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	20.0	NTU	61	0.08	
	Total Solids		mg/L		0.08	
NONGRAH	Dissolved Oxygen	44.0	% sat	36	0.17	
	Faecal Coliform	23000	MPN/100ml	8	0.15	
	pH	6.9		86	0.12	
	BOD	25.3	mg/L	7	0.10	
	Nitrates	1.40	mg/L	96	0.10	54
	Phosphates	0.20	mg/L	92	0.10	
	Temperature	1.0	° C	89	0.10	
	Turbidity	16.5	NTU	65	0.08	
	Total Solids		mg/L		0.08	
MARBOH BRIDGE	Dissolved Oxygen	12.0	% sat	8	0.17	
	Faecal Coliform	79000	MPN/100ml	5	0.15	
	pH	7.0		88	0.12	
	BOD	70.2	mg/L	2	0.10	
	Nitrates	2.80	mg/L	91	0.10	50
	Phosphates	0.20	mg/L	92	0.10	
	Temperature	1.0	° C	89	0.10	
	Turbidity	1.4	NTU	95	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
WAHINGDOH	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	7.0		88	0.12	
	BOD	108.0	mg/L	2	0.10	
	Nitrates	10.00	mg/L	51	0.10	37
	Phosphates	0.85	mg/L	45	0.10	
	Temperature	1.0	° C	89	0.10	
	Turbidity	15.0	NTU	67	0.08	
	Total Solids		mg/L		0.08	

26-4-2005

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
WAH DEMTHRING	Dissolved Oxygen	44.0	% sat	36	0.17	
	Faecal Coliform	79	MPN/100ml	47	0.15	
	pH	6.8		83	0.12	
	BOD	20.2	mg/L	12	0.10	
	Nitrates	4.50	mg/L	68	0.10	58
	Phosphates	0.20	mg/L	92	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	19.0	NTU	62	0.08	
	Total Solids		mg/L		0.08	
NONGRAH	Dissolved Oxygen	31.0	% sat	19	0.17	
	Faecal Coliform	23000	MPN/100ml	8	0.15	
	pH	6.8		83	0.12	
	BOD	30.2	mg/L	2	0.10	
	Nitrates	1.00	mg/L	96	0.10	51
	Phosphates	0.20	mg/L	92	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	18.0	NTU	63	0.08	
	Total Solids		mg/L		0.08	
MARBOH BRIDGE	Dissolved Oxygen	30.0	% sat	19	0.17	
	Faecal Coliform	70000	MPN/100ml	5	0.15	
	pH	6.8		83	0.12	
	BOD	65.8	mg/L	2	0.10	
	Nitrates	2.20	mg/L	94	0.10	53
	Phosphates	0.16	mg/L	94	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	0.5	NTU	98	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	94000	MPN/100ml	4	0.15	
	pH	7.0		88	0.12	
	BOD	165.0	mg/L	2	0.10	
	Nitrates	1.20	mg/L	96	0.10	46
	Phosphates	0.80	mg/L	47	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	0.3	NTU	98	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
DEMSEINIONG	Dissolved Oxygen	13.0	% sat	9	0.17	
	Faecal Coliform	79000	MPN/100ml	5	0.15	
	pH	7.0		88	0.12	
	BOD	160.0	mg/L	2	0.10	
	Nitrates	1.50	mg/L	96	0.10	**47**
	Phosphates	0.60	mg/L	55	0.10	
	Temperature	2.0	° C	85	0.10	
	Turbidity	1.0	NTU	96	0.08	
	Total Solids		mg/L		0.08	
LAWMALI	Dissolved Oxygen	10.0	% sat	7	0.17	
	Faecal Coliform	94000	MPN/100ml	4	0.15	
	pH	6.9		86	0.12	
	BOD	107.8	mg/L	2	0.10	
	Nitrates	4.40	mg/L	68	0.10	**41**
	Phosphates	0.72	mg/L	49	0.10	
	Temperature	2.0	° C	85	0.10	
	Turbidity	8.5	NTU	79	0.08	
	Total Solids		mg/L		0.08	
WAHINGDOH	Dissolved Oxygen	31.0	% sat	19	0.17	
	Faecal Coliform	170000	MPN/100ml	2	0.15	
	pH	6.7		79	0.12	
	BOD	115.0	mg/L	2	0.10	
	Nitrates	11.00	mg/L	49	0.10	**38**
	Phosphates	1.20	mg/L	36	0.10	
	Temperature	2.0	° C	85	0.10	
	Turbidity	12.0	NTU	72	0.08	
	Total Solids		mg/L		0.08	

<u>**13-5-2005**</u>

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
WAH DEMTHRING	Dissolved Oxygen	43.0	% sat	34	0.17	
	Faecal Coliform	110	MPN/100ml	43	0.15	
	pH	6.9		86	0.12	
	BOD	24.0	mg/L	8	0.10	
	Nitrates	4.80	mg/L	66	0.10	**57**
	Phosphates	0.10	mg/L	96	0.10	
	Temperature	0.0	° C	93	0.10	
	Turbidity	20.0	NTU	61	0.08	
	Total Solids		mg/L		0.08	
NONGRAH	Dissolved Oxygen	31.0	% sat	19	0.17	
	Faecal Coliform	31000	MPN/100ml	7	0.15	
	pH	6.9		86	0.12	
	BOD	31.4	mg/L	2	0.10	
	Nitrates	1.20	mg/L	96	0.10	**50**
	Phosphates	0.18	mg/L	93	0.10	
	Temperature	2.0	° C	85	0.10	
	Turbidity	15.0	NTU	67	0.08	
	Total Solids		mg/L		0.08	

Sampling Location	Parameter	Result	Unit	Individual Quality Rating (qi)	Weight Factor (wi)	Water Quality Index
MARBOH BRIDGE	Dissolved Oxygen	21.0	% sat	13	0.17	
	Faecal Coliform	79000	MPN/100ml	5	0.15	
	pH	7.0		88	0.12	
	BOD	68.8	mg/L	2	0.10	
	Nitrates	3.10	mg/L	88	0.10	**49**
	Phosphates	0.30	mg/L	81	0.10	
	Temperature	2.0	°C	85	0.10	
	Turbidity	1.0	NTU	96	0.08	
	Total Solids		mg/L		0.08	
DEMSEINIONG	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	79000	MPN/100ml	5	0.15	
	pH	6.8		83	0.12	
	BOD	168.2	mg/L	2	0.10	
	Nitrates	2.00	mg/L	95	0.10	**43**
	Phosphates	1.00	mg/L	40	0.10	
	Temperature	2.0	°C	85	0.10	
	Turbidity	1.0	NTU	96	0.08	
	Total Solids		mg/L		0.08	
LAWMALI	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	140000	MPN/100ml	2	0.15	
	pH	7.0		88	0.12	
	BOD	110.0	mg/L	2	0.10	
	Nitrates	4.50	mg/L	68	0.10	**40**
	Phosphates	0.70	mg/L	50	0.10	
	Temperature	3.0	°C	81	0.10	
	Turbidity	8.2	NTU	80	0.08	
	Total Solids		mg/L		0.08	
WAHINGDOH	Dissolved Oxygen	0.0	% sat	2	0.17	
	Faecal Coliform	170000	MPN/100ml	2	0.15	
	pH	7.0		88	0.12	
	BOD	125.0	mg/L	2	0.10	
	Nitrates	11.00	mg/L	49	0.10	**36**
	Phosphates	0.95	mg/L	42	0.10	
	Temperature	3.0	°C	81	0.10	
	Turbidity	10.5	NTU	75	0.08	
	Total Solids		mg/L		0.08	

ANNEXURE 4

Registered No. N.E.-771

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EXTRAORDINARY

PUBLISHED BY AUTHORITY

No. 44 Shillong, Monday, April 23, 2001, 3rd Vaisakha, 1923 (S.E.)

PART - IV

GOVERNMENT OF MEGHALAYA

LAW (B) DEPARTMENT

ORDERS BY THE GOVERNOR

NOTIFICATION

The 23rd April, 2001

No.LL(B).16/99/13.—The Meghalaya Prohibition of Manufacture, Sale, Use and Throwing of Low Density Plastic Bags Act, 2001 (Act No. 4 of 2001), is hereby published for general information.

MEGHALAYA ACT NO. 4 OF 2001

(As passed by the Meghalaya Legislative Assembly)

Received the assent of the Governor on 19th April, 2001

Published in the Gazette of Meghalaya *Extra-Ordinary* issue dated 23rd April, 2001

THE MEGHALAYA PROHIBITION OF MANUFACTURE, SALE, USE AND THROWING OF LOW DENSITY PLASTIC BAGS ACT, 2001

An

Act

to provide for prohibiting manufacture, sale, use and throwing of low density plastic bags in Meghalaya and to make provisions for other matters connected therewith.

Be it enacted by the Legislature of the State of Meghalaya in the Fifty-second Year of the Republic of India as follows :—

Short title, extent and commencement.

1. (1) This Act may be called the Meghalaya Prohibition of Manufacture, Sale, Use and Throwing of Low Density Plastic Bags Act, 2001.

(2) It extends to the whole State of Meghalaya.

(3) It shall come into force on such date as this State Government may by a notification in the Official Gazette appoint :

Provided that the State Government, may appoint different dates for different places or areas.

Definitions.

2. *In this Act, unless the context otherwise requires,*

(a) "Act" means the Meghalaya Prohibition of Manufacture, Sale, Use and Throwing of Low Density Plastic Bags Act, 2001;

(b) "Code" means the Code of Criminal Procedure 1973 (Act 2 of 1974) ;

(c) "Low Density Plastic Bag" means a bag, in whatever form may be, made of plastic the thickness of which is less than twenty microns and includes any other such low density plastic container for carrying things; and

(d) "State Government" means the Government of the State of Meghalaya.

Prohibition of manufacture, sale [illegible] density [illegible] bag.

3. No person shall—

(a) manufacture bags made of low density plastic;

(b) sell or use bags made of such low density plastic for storing, carrying, dispensing or packing of food stuff and other articles; and

(c) throw, or discard low density plastic bags in public places including roads, drains and parks.

Power of Government to authorise officers to act under this Act.

4. (1) The State Government may by notification in the Official Gazette authorise one or more persons who will be competent to act under this Act.

(2) Every person authorised under Clause (1) shall deem to be public servant within the meaning of Section 21 of the Indian Penal Code.

Penalties.

5. Any person who contravenes the provision of the Act shall be punishable with fine which may extend to rupees one hundred and in case of second and subsequent offence with a minimum fine of rupees two hundred which may extend to rupees five hundred.

Court competent to try offence under this Act and take cognizance of offence.

6. (1) No court other than the Court of Judicial Magistrate of the First Class shall take cognizance of any offences under this Act.

(2) No court shall take cognizance of any offence under this Act, except on a complaint in writing by an authorised Officers.

Offences to be cognizable and bailable.

7. Notwithstanding anything contained in the Code, offences under this Act shall be cognizable and bailable.

Offences under the Act to be tried summarily.

8. All offences under this Act shall be tried summarily in the manner provided for summary trial under the Code.

Compounding of offences.

9. The State Government or any person authorised by it by general or special order in this behalf may either before or after the institution of the proceedings compound any offences made punishable by or under this Act.

Power to make rules.

10. (1) The State Government may, subject to previous publication, make rules to carry out the purpose of this Act.

(2) Every rule made under this Act shall be laid before the Legislative Assembly.

L. M. SANGMA,
Deputy Secretary to the Government of Meghalaya,
Law (B) Department.

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PART — IV

GOVERNMENT OF MEGHALAYA
LAW (B) DEPARTMENT
ORDERS BY THE GOVERNOR

NOTIFICATION

The 28th July 2004

No.LL(B).16/99/42.—The Meghalaya Prohibition of Manufacture, Sale, Use and Throwing of Low Density Plastic Bag (Amendment) Act, 2004 (Act No.6 of 2004) is hereby published for general information.

Meghalaya Act No.6 of 2004

As passed by the Meghalaya Legislative Assembly, Received the assent of the Governor on the 23rd July, 2004, published in the Gazette of Meghalaya Extra-Ordinary issue dated 28th July, 2004.

THE MEGHALAYA PROHIBITION OF MANUFACTURE, SALE, USE AND THROWING OF LOW DENSITY PLASTIC BAGS (AMENDMENT) ACT, 2004

An
Act

to amend the Meghalaya Prohibition of Manufacture, Sale, Use and throwing of Low Density Plastic Bags Acts, 2001,

Be it enacted by the legislature of the State of Meghalaya in the fifty five year of the Republic of India as follows:—

Short title and commencement.—1. (1) This Act may be called the Meghalaya Prohibition of Manufacture, Sale, Use and throwing of Low Density Plastic Bags (Amendment) Act 2004.

(2) It shall come into force at once.

Amendment of Section 2(c) of Act 4 of 2001.—2. In the Meghalaya Prohibition of Manufacture, Sale, Use and throwing of Low Density Plastic Bags Act, 2001, for clause (c) of Section 2, the following new Clause shall be substituted, namely,—

> "(c)" Low Density Plastic Bags" means a bags, in whatever form it may be made of plastic, the thickness of which is less than 40 (forty) microns and includes any other such low density plastic container for carrying things and"

L. M. SANGMA,
Deputy Secy. to the Govt. of Meghalaya,
Law (B) Deptt.

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The Gazette of Meghalaya

EXTRAORDINARY

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PART IIA

GOVERNMENT OF MEGHALAYA

URBAN AFFAIRS DEPARTMENT

ORDERS BY THE GOVERNOR

NOTIFICATION

The 4th April 2002

No UA.M.70/2000/37.—In exercise of the powers conferred by sub-section (1) & (2) of Section 10 of the Meghalaya Prohibition of Manufacture Sale, use and Throwing of Low Density Plastic Bags Act, 2001 (Act No.4 of 2001) the State Government hereby, make the following rules, namely—

1. **Short title and commencement.**—(i) These rules may be called the Meghalaya Prohibition of Manufacture, Sales, Use and Throwing of Low Density Plastic Bags Rules, 2001.

(2) They shall come into force from the date of publication in the Official Gazette.

Definitions.—In these rules, unless the context requires,

(a) "Act" means the Meghalaya Prohibition of Manufacture, Sales, Use and Throwing of Low Density Plastic Bags Act, 2001 (Act No.4 of 2001).

(b) "Prescribed Authority":

(i) The Prescribed authority for enforcement of the provision of the Act related to "manufacture" shall be the Meghalaya Pollution Control Board and the General Manager, District Industry Centre of concerned District.

(ii) The prescribed authority for enforcement of the provision of the Act related to "sale" shall be the Deputy Commissioner of the concerned District outside the Municipal jurisdiction and the Chief Executive Officer of the concerned Municipal Board within the Municipal area.

(iii) The prescribed authority for enforcement of the provision of the Act related to "use and throwing" shall be the concerned Municipal Boards and/or any other authority or person to be authorised by the State Government, and

(iv) Any other Officer/Person/Authority as may be notified by the State Government.

3. **Self regulation by all persons.**—Without prejudice, all persons residing in the State and other persons entering for any specific or general purpose shall undertake self regulatory measures.

4. **Complaint of Offence.**—Any person or Organisation may inform or lodge a complaint in writing to the prescribed authority against any individual or firm manufacturing, storing, selling, using and throwing low density plastic bags. Upon receipts of such information or complaint, the prescribed authority shall make an enquiry and if satisfied may proceed against and impose penalties as per provisions of the Act.

5. **Inspection.**—The prescribed authority for the purpose of implementation of these rules, may enter and inspect any premises of a building between 6.00 a.m. to 6.00 p.m.

Provided that nothing herein before contained shall authorize any entry into any residential building or building used for religious purposes, unless prior notice in writing not less than 4 (four) hours is given.

6. **Seizure of Low Density Plastic Bags.**—The prescribed authority may seize the low-density plastic bags and retain such bags until such time the case is disposed of finally according to the Act and these Rules.

7. **Prevention of transport of Low Density Plastic Bags in the State.**—The prescribed authority or any Officer authorized by the State Government may prevent or seize the low-density plastic bags from being carried in to the State at the entry points.

8. **Protection of action taken in good faith.**—No suit, prosecution or other Legal proceeding shall lie against the State Government or the prescribed authority or any officer authorized by the State Government for anything which is done or intended to be done in good faith under the Act or rules made herein.

9. **Deposition of fine/penalty.**—The fine/penalty collected by the prescribed authorities in rule above shall be deposited under Head of Account as may be notified by the Government.

Commr. & Secy. to the Govt. of Meghalaya,
Urban Affairs Department.