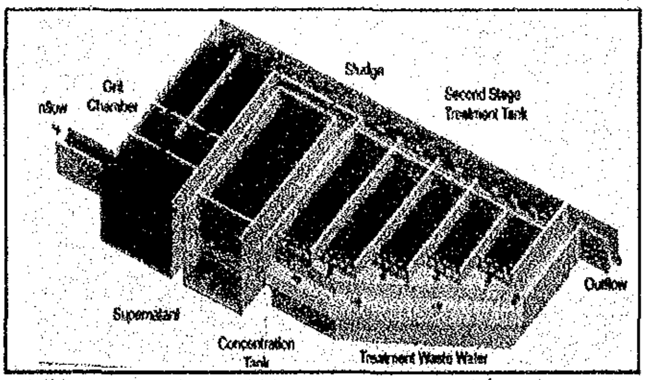

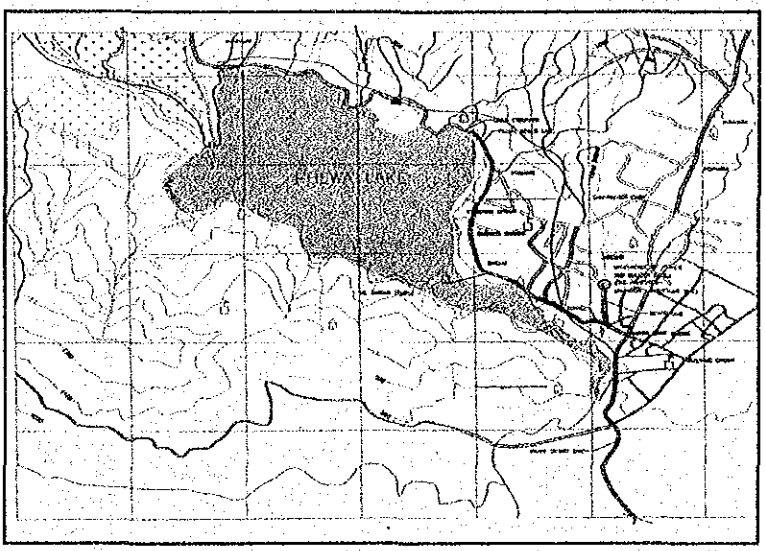

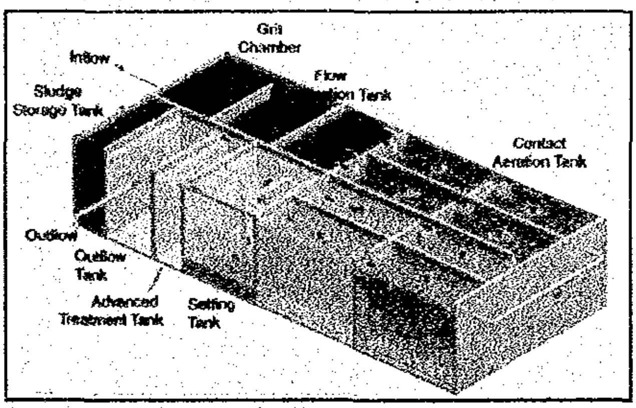

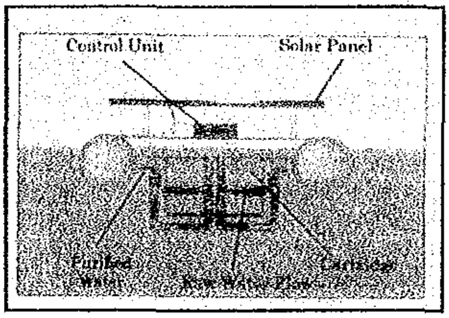

PART - II

FEASIBILITY STUDY FOR PHEWA LAKE WATER QUALITY IMPROVEMENT PROJECT

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CHAPTER 1

EXISTING CONDITIONS

The Development Study on Environmental Conservation of Phewa Lake in Pokhara, Nepal

CHAPTER I
EXISTING CONDITIONS

1.1 STUDY AREA

The Study Area is located in Pokhara City and the watershed areas of Phewa Lake in Western Development Region of Nepal. The city of Pokhara extends to north, to the east across Seti River and to the south up to the bank of Phewa Lake. The western part of city drains into Phewa Lake either directly or indirectly through local streams, where as eastern part of city completely drains into Seti River.

The urban area to be covered for sewage management plan includes Ward No. 2, 3, 4, 5, 6, 8, 9 and 17 of Pokara Sub-metropolis (PSMC), which drains in to Phewa Lake. A map of the PSMC with it's Wards and the drainage area of Phewa Lake considered by the Study is presented in **Fig. II-1.1**.

1.2 NATURAL CONDITION

1.2.1 Climate and General Hydrology

Natural condition that primarily includes climate covering precipitation, wind speed, sunshine hour, relative humidity is presented in **Sub-section 2.2** in **Chapter 2** of **Part I** of this Report.

1.2.2 Geology

- **General Geological Setup of Pokhara Valley**

Pokhara Valley is typical intermountain basin situated around the midstream section of Seti River and the base carved on metamorphic rocks (mainly phyllites), filled with large volume of gravel deposits brought mostly from Annapurna mountain. The gravel fill forms splendid river terraces over the valley. The fill deposits have been divided into nine conspicuous stratographic units. Among them, two namely Pokhara Formation and Ghackhok Formation are most prominent and widespread in the valley.

- **Lithological Characteristic of Ghachok Formation**

This formation is made up of extremely hardened conglomerate cemented by light brown calcareous (lime) material. The aggregate is composed of sub-angular to sub-rounded gravel limestone, sandstone, and shale. It also contains small quantities of gneiss, granite, quartzite and schist gravel. The gravel is ill stored and are of pebble (4 mm -32 mm) and cobble (32 mm -256 mm) in size.

- **Pokhara Formation**

This formation constitutes fluvial gravel deposits by Seti River. The gravel from major part of Pokhara Formation is lacustrine deposits. The gravel of Pokhara Formation are far more weakly cemented in comparison to that of Ghachok Formation. The ill stored gravels of limestone and shale are mainly pebble to cobble in size and sub-angular to sub-rounded in shape.

1.3 HYDROLOGY

The source of water for Phewa Lake is surface water through rivers and streams. These are contributed by surface runoff and groundwater recession. The mean surface inflow varies from 9.0 m^3/sec to 1.0 m^3/sec. Harpan Khola is the largest river that contributes about 70 % of total inflow into

Phewa Lake. Phirke Khola and Seti Canal are two other inflowing source of the Lake that pass through urban centers and carries considerable household sewage. The major outflows from the Lake occurs at Pardi Dam where two canals divert water for irrigation to about 320 hectares of land and also supplies water to a hydropower plant of 1MW capacity.

1.4 POPULATION

The population residing in Ward No 2, 3, 4, 5, 6, 7, 8 and 9 of Pokhara Sub-metropolis is responsible for sewage generation and disposal directly or indirectly into Phewa Lake (see **Fig. II-1.1**). However, the proposed alternative of diversion sewer for sewage management passes through Ward No 17, which is located at downstream of the Lake. In the design, the population of this area has been covered considering that the sewage generated in this area will be allowed to connect in proposed sewer system. For estimating the future population of the project area for 25 years of project life time, annual population growth rates adopted are 6 % in between 2001-2006, 5.5 % in between 2007 to 2011, 5 % in 2011 to 2020 and 4 % in between 2021 to 2027. The population of the service area according to the PSMC Wards is presented in **Table II -1.1**.

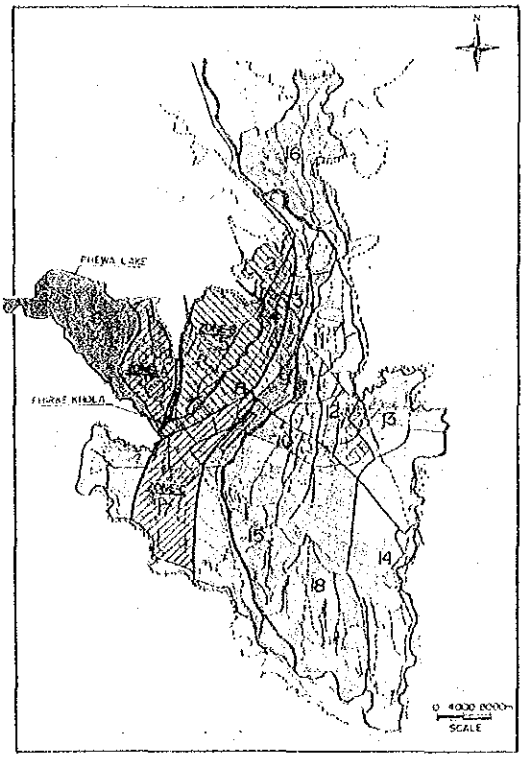

Fig. II-1.1: Service Area of PSMC to be Served by the Proposed Sewer System.

Table II-1.1: Population Projection

SN	Wards	Year 2001	Year 2015	Year 2027
1	2	5,568	7,951	8,621
2	3	1,276	1,616	1,756
3	4	4,343	5,929	6,582
4	5	5,361	17,300	29,569
5	6	9,387	14,761	20,893
6	7	5,871	12,042	15,590
7	8	11,694	17,139	17,729
8	9	1,352	1,709	1,776
9	17	4709	10915	30943
Total		**49,561**	**89,362**	**133,459**

For estimating the amount of sewage and wastewater, the entire service area has been divided into three zones (refer Fig. II-1.1), and presented in **Table II-1.2**.

Table II-1.2: Zonewise Population of Service Area

Zone	In 2001	In 2015	In 2027
A	8,449	13,285	18,804
B	36,403	65,162	83,712
C	4,709	10,915	30,943
Total	**49,561**	**89,362**	**133,459**

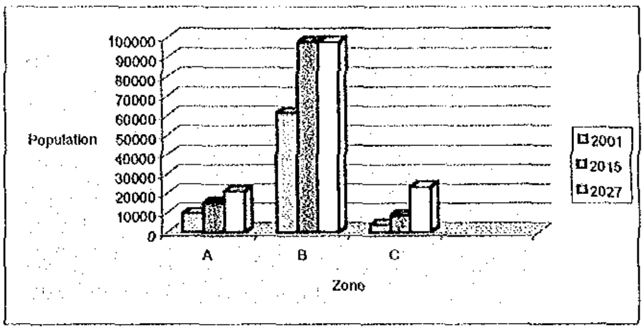

Fig. II-1.2: Zonewise Population of Service Area

1.5 WASTEWATER FLOWS

The waste water flow of the proposed sewer system has been calculated considering population of year 2027. It has also been considered that out of total piped public water supplied to households, 80% will be discharged as wastewater. In addition to this, 10% of the total wastewater will be contributed from ground water intrusion and another 10% will be contributed from industrial waste. However, at present there is no industry located within the service area except hotels. The flow characteristic estimated based on the above assumption are presented in **Table II-1.3.**

Table II-1.3: Flow Characteristics

Category	Average Daily Flow in m^3/day	Average Daily Flow in m^3/sec	Maximum Daily Flow in m^3/sec	BOD (5 days) in kg
Domestic	1,470	36,901	0.4	10,676
Ground water	1,476	3,690	0.04	0
Industry	1,476	3,690	0.04	1,067
Total	**4,422**	**44,281**	**0.48**	**11,744**

Apart from the above discharge, the discharge of Seti Canal upto 0.1 m^3/sec will be accommodated in the Sewer. Similarly, base flow of Phirke Khola where a diversion weir is proposed, is also to be accomodated in the proposed sewerage system. The design discharge for various zones is presented in **Fig. II-1.3.**

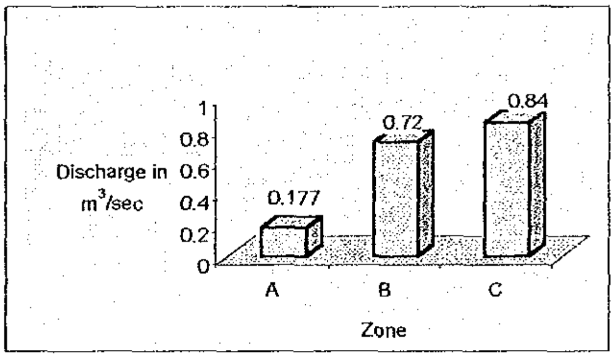

Fig. II-1.3: Design Discharge in m³/sec from Different Zones.

1.6 WASTEWATER CHARACTERISTICS

The allowable parameters i.e. BOD, COD, SS, T-N, and T-P for wastewater has been determined and presented in **Table II-1.4** below.

Table II-1.4: Allowable Parameters for Wastewater

S.N	Description	Threshold Limits
1	BOD	< 3 mg/l
2	COD	<20 mg/l
3	SS	25 mg/l
4	TN	0.3 mg/l
5	TP	0.03 mg/l
6	Total Colifrom	6x10^4 MPN

The present and predicted future BOD level in Phewa Lake is presented in following **Table II-1.5**, and **Fig. II-1.4**.

Table II-1.5: BOD Level in Phewa Lake

	Present BOD in Kg/day	Future BOD without intervention Kg/day	Future BOD with intervention Kg/day
Zone A	743	1654	74
Zone B	3203	7366	320
Zone C	414	2722	41
Total BOD	4361	11744	436

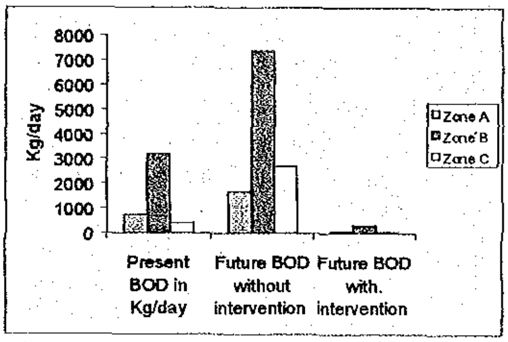

Fig. II-1.4: BOD Level in Phewa Lake

The BOD load from major point sources of Phewa Lake is presented in following **Table II -1.6**, and **Fig. II-1.5** (also refer **Fig. II-1.6**).

Table II-1.6: BOD Level in Phewa Lake Contributed from Point Sources

Major Point Sources	Present BOD in kg	Future BOD with Diversion
Seti Canal	297	29
Storm-water Drain 1	223	22.3
Storm-water Drain 2	223	22.3
Phirke Khola	3203	320

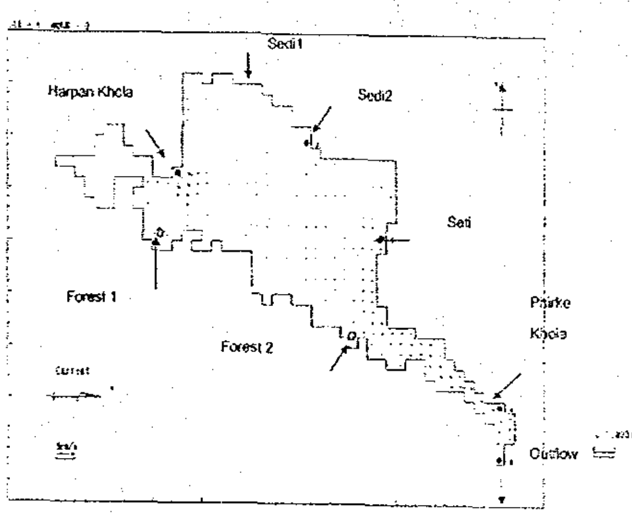

Fig. II-1.6: Inflowing Sources of Phewa Lake

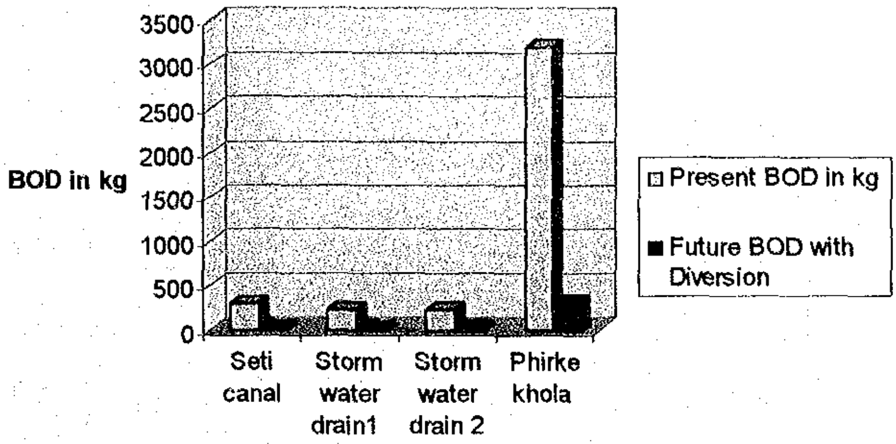

Fig. II-1.5. BOD Level in Phewa Lake Contributes from Point Source

1.7 WATER SUPPLY SYSTEM

At present drinking water in Pokhara is being supplied by Nepal Water Supply Corporation (NWSC) from different sources e.g. Baldhara Muhan, Bhoti Khola, Kali Muda and Mardi Khola. Three reservoirs, Bindhyabasini (100m^3), Aunla Bisauni (500m^3) and a new one of 5000m^3 are now in place.

The maximum total capacity of NWSC is 23.4 MLD. It is informed that leakage in the system is nearly 45% and a rehabilitation project aims to reduce it to 38%.

In the year 2000, 1500 numbers of private connections and 172 numbers of public taps were serving the population of Pokhara. 15 % of the population do not still have direct access to NWSC water supply and cover their needs from lake, springs, rivulets and from Seti Irrigation Canal. Four big hotels have their own deep tubewells of over 100 m deep.

The present total demand of water in Pokhara including both the domestic and non-domestic consumption is estimated to be 25.3 MLD. This accounts to 1.9 MLD deficit in the supply. After the completion of the transport main for additional input from Mardi Khola, the deficit is expected to be met.

The supplied water is treated with only chlorination and therefore is at times not completely safe for consumption. It is often turbid from silted water during the wet season.

1.8 OTHER SANITATION SYSTEM

Sanitation practice in the watershed area is one of the most important factors affecting the quality of water in the Lake.

Phewa Lake Protection Study in 1992 estimated just over 50% of the households having septic tanks, Pokhara Household Survey (STIDP) in 1995 estimated it to be 79%. These studies remarked that all these septic tanks are with open bottoms, not proper side walls, and have overflow drains. All these result in seepage of fecal coliform into soil and ultimately into the Lake.

Survey conducted by Pokhara Environment Improvement Project in 1996, estimated that only 17% households have sanitary facilities of acceptable standard in urban watershed area. 77% have such facilities of unacceptable standard, whereas 6% do not have any such facilities (refer **Fig. II -1.7**).

Open field defecation is also general practice. Squatters on the bank of Bulaundi, Phirke Khola, and Phewa Lake defecate directly in these water bodies.

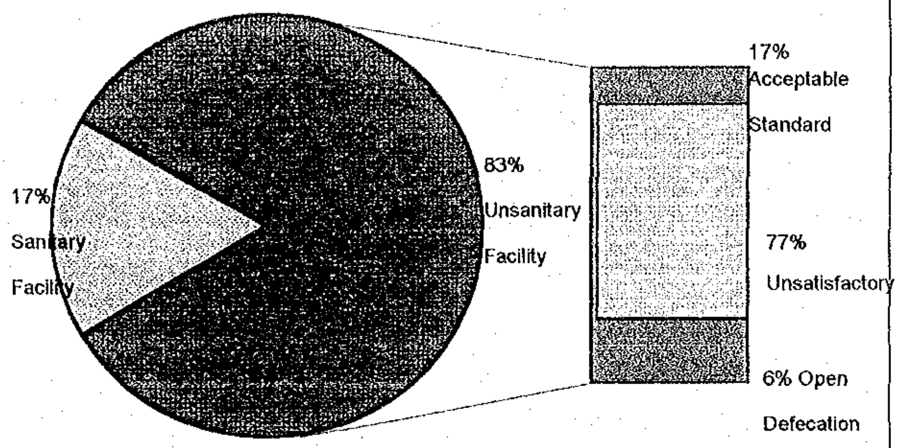

Fig. II-1.7: Existing Sanitation System in PSMC

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CHAPTER 2

ALTERNATIVE PLANS OF LAKE WATER TREATMENT/ PURIFICATION SYSTEM

The Development Study on Environmental Conservation of Phewa Lake in Pokhara, Nepal

CHAPTER 2
ALTERNATIVE PLANS OF LAKE WATER TREATMENT / PURIFICATION SYSTEM

2.1 WATER POLLUTION IN PHEWA LAKE

2.1.1 Causes of Water Pollution

The causes of water pollution of Phewa Lake have been elaborated in detail in **Chapter 4** of **Part** I of this Report. Based on the Study, the primary reasons attributed to Lake water pollution are:

- disposal of untreated urban sewage
- intrusion of sewage from unsanitary, substandard open bottomed septic tanks through sub-surface flow;
- disposal of household wastewater directly into Phewa Lake;
- dumping of solid waste at bank of Lake due to lack of proper solid waste management system;
- urban surface run-off discharging in Phewa Lake carrying concentrated load of pollutants;
- intrusion of agricultural run-off from rural watershed;
- sediment intrusion from rural watershed; and
- undesirable activities such as laundering, and cattle bathing at Lakeshore.

(1) Disposal of Untreated Urban Sewage

Pokhara city still does not have scientific sewer and sewage treatment facility, and is largely dependent on traditional conservancy method of sewage management. In absence of proper sewer system, a considerable numbers of households dispose their wastewater into local streams passing through the urban area. These streams eventually drain into Phewa Lake. Phirke Khola and Seti Canal are such major drains inflowing from urban area into the Lake. These sources have been identified as point source responsible for Lake water quality degradation. The water quality tests of these sources reveal that they contain high BOD, COD, TS, SS, TP, TN and Coliform (above threshold limit) and low DO (refer **Chapter 2** of **Part I** of this Report). The intrusion of such contaminated water into the Lake has resulted into algal growth and foul smell in the Lake.

(2) Illegal Connection of Household Wastewater into Storm-water Drains

In recent years, storm-water drains have been constructed in Pokhara city and some of them drain into Phewa Lake. During the Study, it has been found that most of the households have made connection of their wastewater into these drains. In dry months, these drains will carry only the urban sewage into Phewa. These drains have been also identified as point sources of pollution of Phewa Lake.

(3) Disposal of Household Sewage Directly into Lake

The Study has found that majority of households located at the bank of Phewa, particularly hotels, illegally dispose their wastewater and sewage directly into the Lake. These households have been also identified as point source for Pollution of the Lake.

(4) **Open Dumping of Solid Waste**

Open dumping of solid waste at the bank of Phewa Lake, particularly at discharging point of Seti Canal is causing pollution in the Lake. Even dead animals are dumped or in the Lake. The open dumping of solid waste has been causing Lake water pollution through leaching of pollutant and waste carried into the Lake by surface runoff during rainy season.

(5) **Sub-surface Flow from Open-bottomed Septic Tanks**

The recent survey indicates that a large number of household located in Lakeshore have open - bottomed septic tanks. The porosity of soil in Phokhara is very high. The leakage of wastewater from septic tank flow into Lake through sub-surface flow. It is one of the nonpoint sources responsible for polluting Lake water. The sub-surface flow generated from these septic tanks contain high degree of fecal coliform and nutrient.

(6) **Activities Detrimental to Lake Water Quality**

Undesirable activities by inhabitants, such as laundering, bathing of cattle etc. are some of the identified sources responsible for Lake water pollution. It is also learned from previous study (IUCN, 1997) that about 100 kg of soap and detergents are used everyday for washing of cloths of hotels and residential households in the Lakeshore.

(7) **Nutrients from Agriculture Fields**

The surface run-off carries nutrients from chemical fertilizer applied in agricultural fields of the Lake watershed area causing in high nutrient load (TP and TN) in the Lake. This has resulted in to proliferation of water hyacinth and aquatic weeds in the Lake.

(8) **Sedimentation of the Lake**

Land use analysis indicates nearly half of the land in Phewa watershed is under cultivation including irrigated lowland, rainfed upland and steep terraces. The average run–off from the watershed measured at the outlet of Phewa Lake has been calculated at 9.21 m^3/s (Fleming, 1983). This run-off carries a large volume of sediment load.

It is estimated that during the period of 1990-94, annual sedimentation rate has a range of about 175,000-225,000 m^3/year. At the continuation of this rate, sedimentation of the Lake will decrease the Lake water area and subsequently make it "dead" by next 190 years, assuming loss of 80% to 100% of water volume by sediment deposition (Sthapit et al, 1998). The sediment also contributes in degradation of water quality by adding suspended solids, dissolved solids and nutrients.

2.1.2 Issues of Water Quality and Lake Sedimentation

If the above rate of Lake water pollution and sedimentation continue,

- Lake will turn in to wastewater pond full of water hyacinth,
- Increase in fish mortality and drastic reduction in fish yield,
- Depletion of eco-biodiversity of the Lake, and
- within next 190 years the Lake will be filled with sediments.

2.1.3 Mitigation Measures

In order to curb these problems, the mitigation measures are to be implemented with following goals:

(i) immediate and short-term goal

- restrict water pollution caused by inflow of sewage and other wastes through technical and management interventions, and assist in bringing back Lake in its pristine condition
- check proliferation and infestation of water hyacinth and algal bloom in the Lake, and
- restrict sediment intrusion from watershed and protect Lake surface area

(ii) long-term goal

- minimize soil erosion from cultivated land
- increase in base flow of streams and water bodies in watershed area by increasing infiltration rate through increase of ground vegetation and soil conservation that contributes in reducing peak discharge during heavy downpour
- increase forest cover with native species with minimum evapo-transpiration rate and eventually increase the ground vegetation cover, and
- restrict pollution of water sources due to human activity through legal instrument

2.2 REDUCTION TARGET OF POLLUTION LOAD

This is presented in detail in **Chapter 4** of **Part I** of this Report.

2.3 HMGN REQUESTED GRANT AID

2.3.1 The Requested Grant Aid

An application for Grant Aid for environmental conservation of Phewa Lake in the name of '***Water Environmental Improvement Project***' was submitted by His Majesty's Government of Nepal to the Government of Japan in June, 2000.

2.3.2 The Objective and Aim of the Grant Aid

The objective of the requested project under Grant Aid included to:

- restrict pollution in Phewa Lake from urban as well as rural areas
- conserve Phewa Lake watershed area
- develop and conserve the Phewa Lake as attractive scenic spot
- enhance the livelihood of local communities living in Phewa watershed area
- acquire foreign currencies through sustained tourism promotion, and
- assist overall rural development program by wise utilization of environment resources of Phewa Lake and its watershed area

To achieve these objectives, the proposed ***Water Environmental Improvement Project of Phewa Lake*** aims to

- minimize water quality deterioration by restricting inflow of polluted water in the Lake through technical intervention
- improve water quality of the Lake by restricting eutrophication of the Lake water,
- conserve water resources for habitants, who live at downstream of the Lake,
- supply adequate water for irrigation and hydropower at downstream of the Lake, and
- remove sediment deposited in the Lake and keep enough Lake water surface area, as well as maintain water volume for irrigation purpose.

2.3.3 The Scope of Grant Aid

To achieve the above mentioned objectives and aims, the requested Grant Aid envisaged the needed technical intervention to be applied through mechanical means. The envisaged equipment under the Grant Aid included following:

1. **Floating Type Lake Water Purification System** to be installed on Lake water surface at various locations. The energy required for operation of the system will be generated by solar panels installed at its top. A sample Photo of such floating type of Lake water purification system with solar panels is shown in following **Fig. II-2.1**. 25 numbers of such type of equipment are proposed to be installed on the Lake surface at an interval of 20 m.

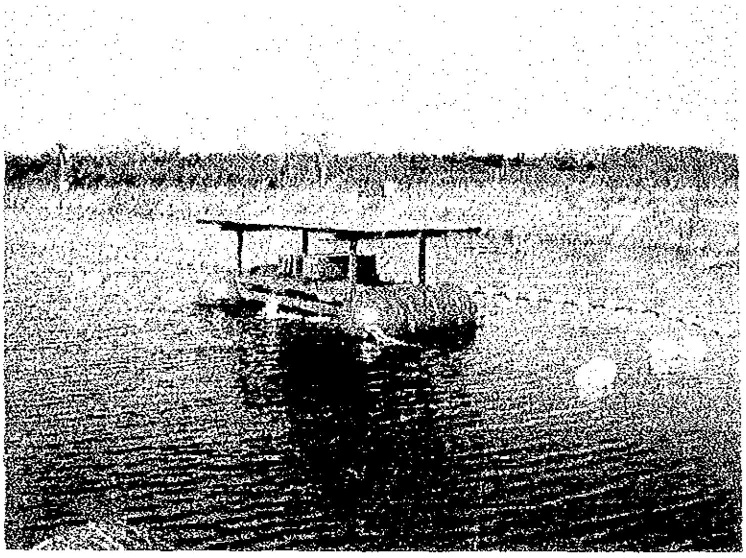


Fig. II-2.1: Floating Type Lake Water Purification System with Solar Panels

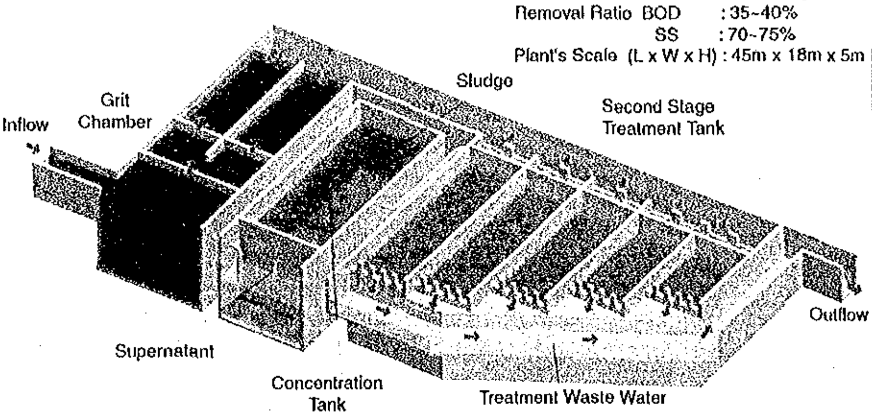
   Such system can be moved on Lake surface according to necessity of water quality improvement. Sludge collected by the purification system is cleaned by automatic backwash system.

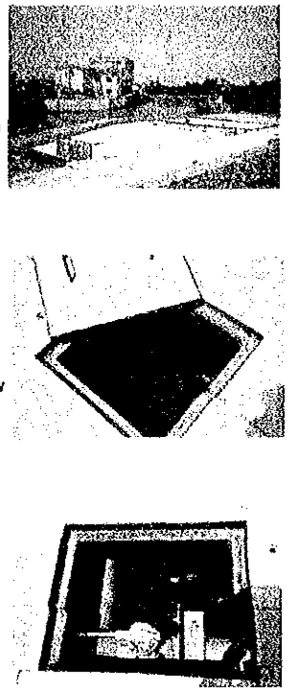
2. **Prefab Type of Small Sewage Treatment Plant** proposed to be installed at the discharging points of streams and urban drains draining into the Lake with pumping mechanism for lifting the water for treatment. The treatment will be through contact aeration process and treated water will be discharged into the Lake. Three numbers of such plants with capacity of treating 240 m^3/day/plant is to be installed. A sample drawing and photograph of this type of system is presented in **Fig. II-2.2**.
3. **Installation of 2 Numbers of Pump Dredger** are provisioned to remove sediment deposited at the bottom of the Lake. The removed sediment is to be converted into fertilizer will and used for agricultural, thus generating revenue.

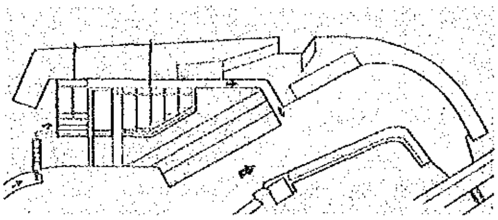
In addition to these, the project also includes provision for transportation of equipment from Japan to Nepal, storage of spare parts, supervision by Japanese experts during installation and commissioning, and training for Nepali engineers for operation and maintenance of the equipment.

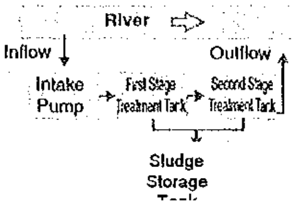
Purification System of River Water (Type A1)

Treated Water Volume : 108 m3/hr
Raw Water BOD : 10~20 mg/l
SS : 10~30 mg/l
Removal Ratio BOD : 35~40%
SS : 70~75%
Plant's Scale (L x W x H) : 45m x 18m x 5m



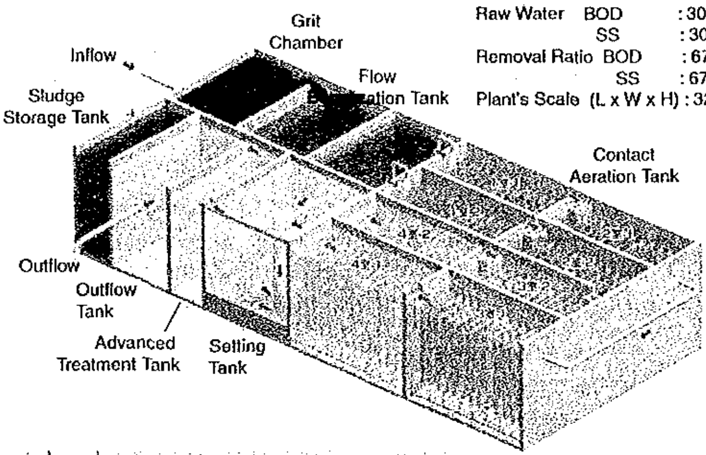


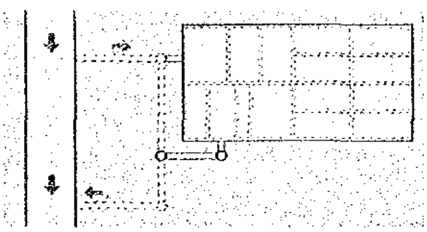




Purification System of Urban Drainage (Type A2)

Treated Water Volume : 192 m3/hr
Raw Water BOD : 30 mg/l
SS : 30 mg/l
Removal Ratio BOD : 67%
SS : 67%
Plant's Scale (L x W x H) : 32m x 14m x 6m





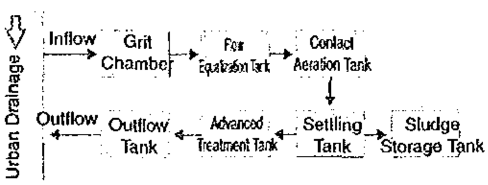


Fig. II-2.2: Sample Drawing and Photograph of Prefab Type of Small River/Urban Drainage Treatment Plant

2.3.4 Expected Social, Economic and Environmental Impact from the Grant Aid Project

The expected social, economic and environmental impact from implementation of the proposed Grant Aid project are as follows:

(1) Social and Economic Development

Conservation of Phewa Lake is nationally important issue of Nepal as it plays significant role in the national economy by making Pokhara as most favored tourist destination. This is attributed to its scenic beauty, lakes and mountain range. Consequently, a large numbers of tourism related business such as hotels, restaurants, shops, travel and tours, trekking, airlines, bus, boating etc. are in operation. Similarly, this has also supported local agricultural activities such as cultivation of fish and vegetables. These activities are providing employment to significant number of people. Thus, by further promoting tourism through environmental conservation of Phewa Lake and its watershed will enhance the employment opportunity and income generation activities both at rural and urban areas.

(2) Environmental Conservation

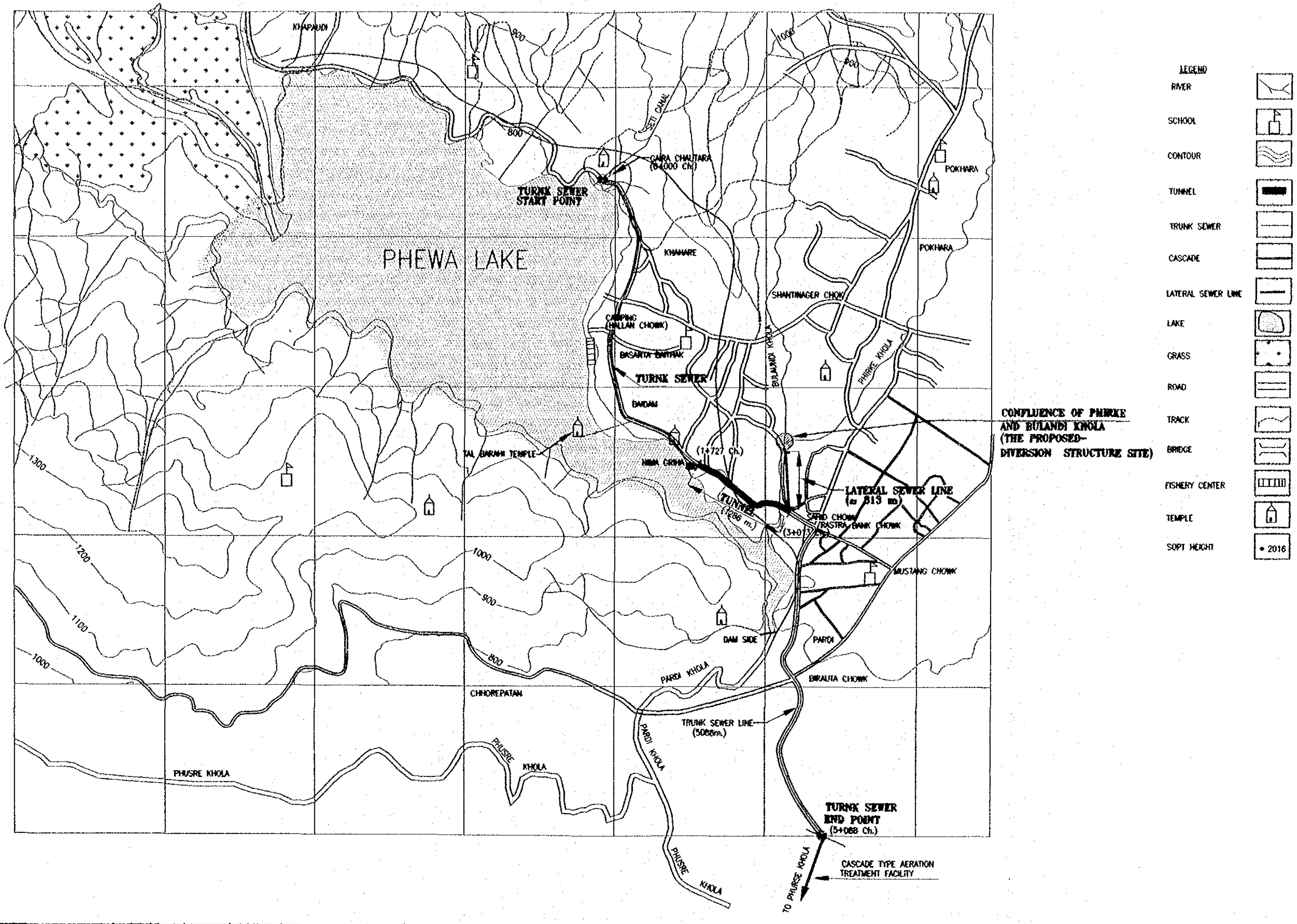
The balance between economic development and conservation of environment is not possible without proper and wise utilization of economic, social, natural and human resources based on their interrelationship. This would only result to attain sustained economic development with increase of quality of human life. The proposed Grant Aid project aims to integrate wise use of social, economic and other natural resources as model for sustained development. The lesson from such model can be then replicated in other parts of the country.

2.4 ALTERNATIVE OPTIONS

Other alternatives than the one requested under Grant Aid to address the problem of water quality degradation of Phewa Lake were also explored and examined thoroughly by this Study. These alternatives include:

- Gravity flow sewerage system from Seti Canal at Gaira Chautara to Phusre Khola beyond the Lake (**refer Fig. II-2.3**). The alignment of trunk sewer line pass through eastern Lakeshore along Lakeside, Pardi, Shahid Chowk, Rastra Bank Chowk, Birauta to Phusre Khola. Tunnel section will be provided where excavation depth for laying the sewer pipe is more than 5 m. A cascade structure will be provided at the end of the trunk sewer line, which will assist in aeration of the sewage before disposing it in Phusre Khola.

  Phirke Khola will also be diverted in the trunk sewer by construction of a diversion structure at the confluence of Phirke and Bulaundi Khola near Shahid Chowk, and transportation of the diverted flow in the trunk sewer by laying a lateral sewer. Similarly, the flow of Seti Canal and storm-water drain will also be diverted into the trunk sewer.
- This alternative includes all the provisions similar as mentioned in the above gravity sewerage system with trunk sewer, lateral sewer and cascade structure. However, instead of tunnel section for maintaining hydraulic gradient, the sewage will be pumped up to lift the head and again transport it by gravity flow. Thus, mechanized sewage pump will be needed in this alternative.
- This alternative includes construction of Read Bed Treatment System (RBTS), which is also called constructed wet land treatment system at the discharge points of all the polluted streams, urban drains, canal etc. The naturally treated water from RBTS will be allowed into the Lake. However, this type of treatment system requires big area of land, which is very difficult to acquire at commercially rich area like the Lakeshore of Phewa. Similarly, as the area is touristically important,



JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	THE DEVELPOMENT STUDY ON THE ENVIRONMENTAL CONSERVATION OF PHEWA LAKE POKHARA NEPAL	DRAWING TITLE: LAYOUT MAP OF PROPOSED SEWERAGE SYSTEM	SCALE 0 250 500 750 1000 1250m	SILT Consultants (P.) Ltd. Baneswor, Kathmandu, Nepal P.O Box: 2724 Fax: 977-1-473673 Phone: 473573, 470866, 487598, 495163 E-mail: silt@wlink.com.np Website: silt.com.np	Fig. No. II-2.3 Page No. 7

there will be social conflict and residents will not want any type of wastewater/sewage treatment plant in the area. Similar experience has been observed in case of Pokhara Environment Improvement Project assisted storm-water drains, where people opposed and did not allow construction of sediment settling tank of the storm-water drains at Lakeshore areas.

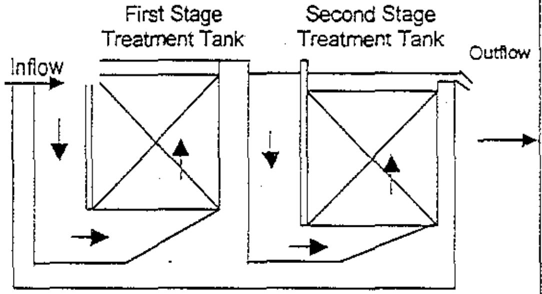
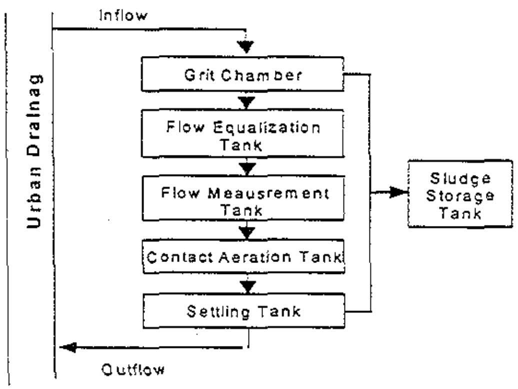
- This alternative includes laying of gravity flow sewer line along the eastern shore of Phewa Lake and transport entire sewage at a common point beside the Lake. The sewage thus transported will be treated by conventional type of treatment plant, and treated effluent will be allowed into the Lake.

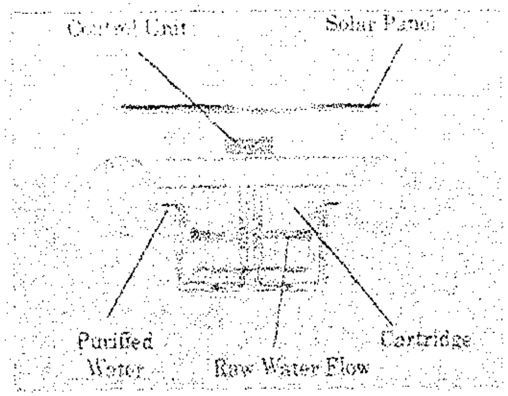
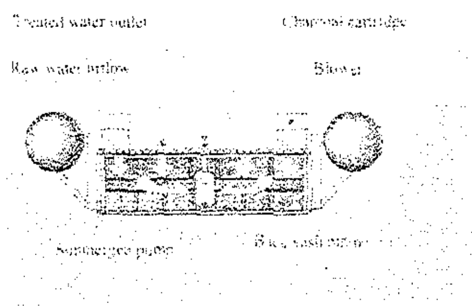
2.5 COMPARATIVE ANALYSIS OF ALTERANTIVES

2.5.1 Qualitative Analysis

A qualitative comparison between different alternatives, including the HMGN requested type under Japanese Grant Aid has been done with respect to their efficiency in pollution removal ratio (BOD, COD, BOD, SS, TN, and TP), advantages in terms of cost, operation and maintenance, and overall performance of these alternatives. It is presented in following **Table II-2.1**

Table II-2.1: Qualitative Comparison Table for Sewage Treatment Systems

SN	System Type	Operation System	Removal Ratio (%)					Advantage	Disadvantage
			BOD	COD	SS	TN	TP		
A. HMGN Requested Grant Aid from GOJ									
1	3 numbers of small prefab type of sewage treatment plant (See Fig. II-2.2)	Up-flowing contact oxidation system. Works on river water with BOD ≤ 20 mg.	40		70-75	15-20		▪ Removal ratio of daily wastewater is fair except runoff load from rain water ▪ Assembling of treatment plant is easy ▪ Can start working within a year 	▪ O/M cost is fair ▪ Repair and maintenance cannot be done by local skill ▪ The period of durability is short (< 10 years), and replacement is not assured ▪ Removal of pollution load is influenced by rainwater ▪ Mechanical trouble of plant at any stage will cause complete failure of overall project, and Phewa Lake will be back to its polluted condition ▪ Land acquisition is necessary, and difficult ▪ Past performance of such plants is not much known in developing countries ▪ Existing pollution from open bottomed septic tanks at Lakeshore areas will continue.
		Contact aeration system. Used for urban drain wastewater with BOD>20mg	75		67	15-20			▪ O/M cost is fair ▪ Repair and maintenance cannot be done by local skill ▪ The period of durability is short (< 10 years), and replacement is not assured ▪ Removal of pollution load is influenced by rainwater ▪ Mechanical trouble of plant at any stage will cause complete failure of overall project, and Phewa Lake will be back to its polluted condition ▪ Land acquisition is necessary, and difficult ▪ Past performance of such plants is not much known in developing countries ▪ Existing pollution from open bottomed septic tanks at Lakeshore areas will continue.

SN	System Type	Operation System	Removal Ratio (%)					Advantage	Disadvantage
			BOD	COD	SS	TN	TP		
2	25 nos. of Lake water purification system	Floating type Lake water purification system. - Raw water down flows into the cartridge from the upper side of the charcoal purifier - Purification and decomposition take place by food chain - The treated water is collected in the collection tube - Treated water discharged into the lake in a horizontal flow by the submerged pump. - A diffuser attached to the side supplies the dissolved oxygen		40				▪ No space is required for installation of the equipment (except for the space of the control panel) ▪ Low maintenance and management cost, low running cost by employing compact type high performance submerged pump and blower. ▪ No sludge treatment, no removing of sludge to outside the system, no sludge treatment cost ▪ Fully automatic operation. Attached with an automatic back washing function that requires no routine operation. ▪ High performance coal purification ▪ Excellent purifying performance with the use of filter material made of charcoal. ▪ Timber for thinning is the original source of charcoal. 	▪ The period of durability is short (<10 years), and replacement is not assured ▪ Life of solar battery is only 4 years, but the solar panel if used only on day time may not require the battery ▪ Removal of pollution load is possible only in small area (20 m diameter only). ▪ Mechanical trouble of plant will cause complete failure of overall project, and Phewa Lake back to its polluted condition ▪ Past performance of such plants are not known in developing countries. ▪ 25 numbers of floating equipment on Lake surface will diminish aesthetic beauty of Lake 

SN	System Type	Operation System	Removal Ratio (%)					Advantage	Disadvantage
			BOD	COD	SS	TN	TP		
B. Other Alternatives									
1.	Gravity sewerage system	Trunk Sewer (5088 m total length) with tunnel (1286 m length and 1.2 m dia.) + cascade type aeration structure before discharging in the Phusre Khola (refer Fig II-2.3)	100	100	100	100	100	▪ Removal ratio of daily wastewater is 100% except a part of runoff load from rain water ▪ Removal of pollution load influenced by rainwater is fairly possible. ▪ O/M cost is relatively cheap ▪ Relatively little requirement of maintenance, and is easy ▪ The period of durability of the system is long (more than 25 years) ▪ System with minimum trouble as no mechanical devices are installed ▪ Land acquisition is not necessary in most of the places because sewer line will be below existing roads ▪ Past performance of such system are encouraging in developing countries like Nepal ▪ Local skill available in the country ▪ Large amount of benefit of construction cost goes to local people and local construction material industry ▪ Tunnel construction will assist in this essential area of technology transfer in hilly country like Nepal.	▪ Construction period is longer (min 2 years) ▪ Land acquisition is necessary in some locations (minimal) ▪ Traffic has to be diverted from by-pass roads during construction (available) ▪ Short-term impact on business along the Lakeside during construction ▪ Construction related impacts, which can be mitigated
	Modified gravity sewerage system	Trunk sewer + lifting pump + cascade type aeration treatment plant before discharging in the Phusre Khola.	100	100	100	100	100	▪ Lifting pump assist in elevating the sewage and maintain gravity flow, and thus expensive option of tunnel construction is not needed ▪ Removal ratio of daily wastewater is 100% except a part of runoff load from rain water ▪ Removal of pollution load influenced by rainwater is fairly possible. ▪ The period of durability of the system is long (more than 25 years for sewer system and 10 years for mechanical pump)	▪ Construction duration is long (min 2 years) ▪ Land acquisition is necessary for some locations. ▪ Past performance of such mechanical pumps are not very encouraging in developing countries. ▪ Construction work requires special attention ▪ The period of durability is short for pump (10 years) ▪ OMM is relatively difficult ▪ O&M cost is relatively expensive and not sustainable ▪ Trouble in lifting mechanism is possible, failure will allow the sewage in the Lake again.
	Gravity system including treatment plant	Sewer line +treatment plant. Allow treated water in the Lake.	75	75	75	60	60	▪ Removal ratio of daily wastewater is good except a part of runoff load from rain water ▪ Removal of pollution load influenced by rainwater is fairly possible. ▪ Removal ratio of pollution from lake water is fair	▪ O/M cost is expensive and OMM is difficult ▪ Period of equipment durability is short (less than 10 years) ▪ Construction work is difficult than diversion canal system plan (1 and 2) due to mechanized treatment plant ▪ Social conflict possible due to odor nuisance ▪ Land acquisition is necessary

2.5.2 Quantitative Analysis

The quantitative analysis is presented in following sections comparing the involvement of cost for various alternatives, operation maintenance cost, life span and its benefit in terms of local employment generation. The comparison of gravity sewer with tunnel, gravity sewer without tunnel with cut and fill section and mechanical alternatives are presented in following Sub-sections.

(1) Cost Estimate for Mechanized System

The estimated cost for the mechanized system as envisaged in Japanese Grand Aid application is presented in **Table II-2.2**. The basis for cost estimation is unit cost of mechanical items obtained from manufacturers. Other costs such as mobilization and demobilization, preparatory works, miscellaneous works, engineering cost, and contingencies have been included in the cost and are presented in **Table II-2.2** below.

Table II-2.2: Cost for Mechanized Sewage Treatment Facility.

S.N	Description	Cost in NRs (,000)
1	Mobilization and demobilization	15,575
2	Preparatory works	15,575
3	**Main works**	
3.1	Floating type lake water purification system *including transportation and installation*	190,058
3.2	Pre-fab type river water and urban drainage treatment system including transportation and installation	118,947
3.3	Cost for land	2,500
	Subtotal	***311,505***
4	Miscellaneous works	31,150
5	Engineering cost	31,150
6	Administrative cost	215
7	Contingencies	31,150
	Total project cost	**436,323**
	In Million NRs	***436***
	In Million US$	***5.6***

(2) Cost Estimation for Gravity System

(a) Basis of Cost Estimate

The cost estimate for the construction of proposed sewer system includes the construction cost of trunk sewer, lateral sewer from Phirke to trunk sewer, construction of cascade type oxidation structure, diversion structure across Phirke Khola including head regulator, check gate and turnout structure at Seti Canal, division box and junction structure at storm-water drain. The estimation of project cost has been done based on the following assumptions:

- All base cost are expressed under the economic condition prevailing in January, 2002;
- Engineering service cost is including all services for detailed design, tendering assistance, and construction supervision. The cost is assumed to be 10% of construction cost;
- Administrative cost for project management assumed as 2.5 % of construction cost;
- Physical contingencies allowance is assumed as 10% of construction cost, and

- Assumption has been made based on other similar projects in Nepal.

(b) **Construction Cost**

The construction cost comprises the following costs:

- Mobilization and demobilization cost (5% of main construction cost);
- Cost for preparatory work (5% of main construction work)
- Cost for main works (direct and indirect cost)
- Cost for miscellaneous works

The direct cost for main works (cost for civil works and mechanical equipment) has been estimated based on the design, drawing, and unit rate. The quantity estimates have been prepared for each item based on the design and drawing, and the construction cost has been obtained by multiplying unit rate for each item.

(c) **Project Cost**

The cost estimate has been made considering two options for gravity flow type sewer system viz. (i) gravity sewer system with tunnel where cutting depth is more than 5.0 meter, and (ii) gravity sewer system without tunnel considering the excavation will be done with appropriate scaffolding and shoring arrangement. The cost of sewer system with tunnel is presented in **Table II-2.3** and for without tunnel (cut and cover) is presented in **Table II-2.4.**

Table II-2.3: Project Cost with Tunnel

S.N.	Description	Cost in NRS (,000)
1	*Mobilization and demobilization*	*17,055*
2	*Preparatory works*	*17,055*
3	***Main works***	
3.1	E/W in excavation	14,101
3.2	Earthwork in rock	498
3.3	E/W in filling (back filling)	5,900
3.4	Hume Pipe laying and fitting	26,968
3.5	PCC for hume pipe bed and fitting	7,819
3.6	Manhole	13,083
3.7	Cascade	3,500
3.8	Check gate and turn out	200
3.9	Division box	400
3.10	Weir and head regulator	5,000
3.11	Reconstruction of road	19,295
3.12	Tunnel work	244,340
	Total cost	***341,104***
4	*Miscellaneous works*	*34,110*
5	*Engineering cost*	*34,110*
6	*Administrative cost*	*8,527*
7	*Contingencies*	*34,110*
	Total Project cost	486,074
	In Million (NRs.)	***486***
	In Million (US$)	***6***

Table II-2.4: Project Cost without Tunnel

S.N.	Description	Cost in NRS (,000)
1	*Mobilization and demobilization*	7,772
2	*Preparatory works*	7,772
3	*Main works*	
3.1	E/W in excavation ordinary soil	17,923
3.2	Earthwork in rock	4,396
3.3	E/W in filling (back filling)	8,751
3.4	Hume pipe laying and fitting	32,716
3.5	PCC for hume pipe bed and fitting	6,147
3.6	Manhole	13,083
3.7	Cascade	3,500
3.8	Check gate and turn out	200
3.9	Division box	400
3.10	Weir and head regulator	5,000
3.11	*Reconstruction of road*	24,119
3.12	Shoring	*39,205*
	Total cost	***155,440***
4	*Miscellaneous works*	*15,544*
5	*Engineering cost*	*15,544*
6	*Administrative cost*	*3,886*
7	*Contingencies*	*15,544*
	Total project cost	***221,502***
	In Million (NRs.)	***221.5***
	In Million (US$)	***2.8***

(3) Operation and Maintenance Cost for Mechanized System

The operation and maintenance (O&M) cost for the mechanized alternative as per the current price has been estimated. The annual operation and maintenance cost is presented in **Table II-2.5**.

Table II-2.5: Operation and Maintenance Cost for Mechanized Treatment Facilities

S.N.	*Description*	*Unit*	Rate (NRs)	Amount (NRs)
1	Operation Staff	months	238,000	2,856,000
2	Laboratory Expenditure	months	20,000	240,000
3	Fuel for Equipment	months	100,000	1,200,000
4	Repair and Maintenance cost @ 1% per year of total cost			3,115,058
	Sub-total			***7,411,058***
5	Others 10% of above			741,105
	Grand Total (NRs.)			***8,152,163***
	US $ in million			**0.1**

(4) Operations and Maintenance Cost of Sewerage System

The operation and maintenance cost of the sewer system has been estimated as 1 % of capital cost per year from the year of commissioning of the system to 5 th year of service, 2 % of capital cost per year from 6th year to 15th year of service, 3 % of capital cost from 16 th year to 20 th years and 4% of capital cost from 21st year onward. This cost includes the cost of operation (paying salary to operation staff, monitoring of water quality, operation of equipment), emergency and regular maintenance. The operation cost for gravity system for tunnel and without tunnel are presented in **Table II-2.6** and **II- 2.7** respectively.

Table II-2.6: Operation and Maintenance for Gravity System with Tunnel

S.N.	Description	Unit	Rate (NRs)	Amount (NRs)
1	Salary for operation staff	months	86,000	1,032,000
2	Laboratory expenditure	months	20,000	240,000
3	Fuel for equipment an vehicle	months	25,000	300,000
4	Repair and maintenance cost @ 1% per year of total cost			4,860,778
	Sub-total			**6,432,778**
	Others 10% of above			643,277
	Grand total			***7,076,055***
	US $ in million			0.09

Table II-2.7: Operation and Maintenance for Gravity System Without Tunnel

S.N.	Description	Unit	Rate (NRs)	Amount (NRs)
1	Salary for operation staff	months	86,000	1,032,000
2	Laboratory expenditure	months	20,000	240,000
3	Fuel for Equipment	months	25,000	300,000
4	Repair and Maintenance cost @ 1% per year of total cost			2,215,067
	Sub-total			**3,787,067**
5	Others 10% of above			378,706
	Grand Total (NRs)			***4,165,773***
	US $ in million			*0.05*

2.6 COMPARISON OF COST

The estimated cost on three main alternative options viz. mechanized system, gravity system with tunnel, and gravity system without tunnel is presented in **Table II-2.8** and **Fig. II- 2.4.**

Table II-2.8: Comparison of Cost for Various Alternatives in Million NRs.

S.N	Description	Mechanized System	Gravity System With Tunnel	Gravity System Without Tunnel
1	Initial cost for installation/construction	436	486	221.5
2	Replacement cost	463	0	0
	Total	**899**	**486**	**221.5**

The life of the mechanized system is for 10 years only and the life of gravity system is 25 years. The replacement is made in every 10 years. Considering the replacement cost the total cost of mechanized option becomes 899 millions NRs.

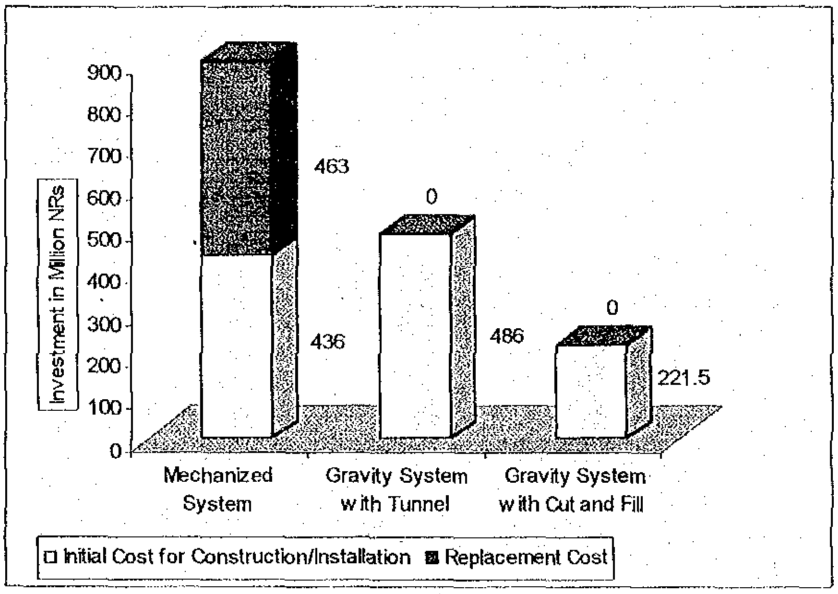


Fig. II-2.4: Comparison of Investment in Various Options in Million NRs

2.7 COMPARISON OF OPERATION AND MAINTENANCE COST

The comparison of operation and maintenance cost for various alternatives is presented in **Table II-2.9** and **Fig. II-2.5**.

Table II-2.9: Comparison of Annual Operation and Maintenance Cost in NRs. (,000)

S.N	Description	*Mechanized* System	*Gravity System With* Tunnel	*Gravity System* Without Tunnel
1	Operation and Maintenance Cost	8,152	7,076	4,165

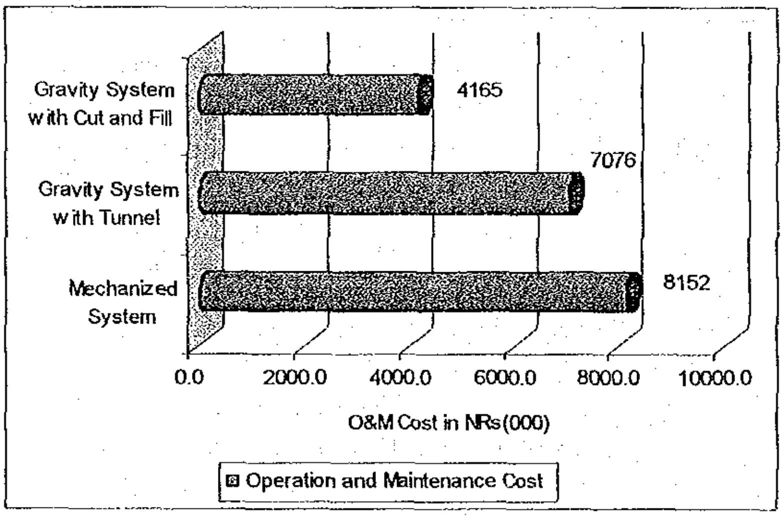


Fig. II-2.5: Comparison of Operation and Maintenance Cost

2.8 LOCAL EMPLOYMENT GENERATION

Local employment generation is one of the most important benefits of any development project. The comparison of all above mentioned alternatives in terms of employment generation has been compared and presented in **Fig. II-2.6.** In estimating this, it is assumed based on prevailing experience that mechanized option will provide local employment of about 10% of capital cost. The 10% amount will generate employment to local people for handling the equipment and installation. In tunnel option, about 25% of capital cost will be spent on local employment as contractor, engineers, skilled and unskilled labor. Similarly, 40 % of capital cost of gravity system without tunnel will be spent on local employment. The local employment has been estimated only for construction and installation period.

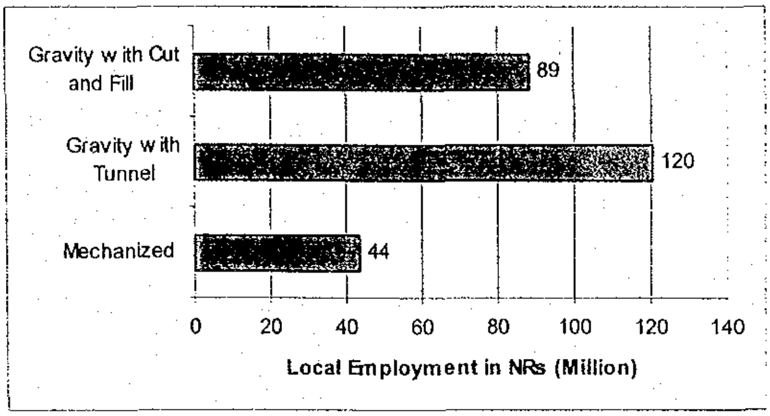


Fig. II-2.6: Local Employment Generation Scenario

2.9 TECHNICAL EVALUATION FOR VARIOUS ALTERNATIVES

Although various alternatives including gravity system with tunnel, gravity system with cut and cover, gravity system with treatment plant and mechanized system has been compared in qualitative comparison. However, in quantitative comparison, mechanized, gravity system with cut and fill and gravity system with tunnel has been compared. Similarly, a lake simulation study was also carried out by the Study. The result of simulation study has shown that the diversion sewerage system is the best alternative having potential to reduce pollution of the Lake in greater extent than the mechanized alternative (refer **Fig II-2.7**). In addition, the gravity system with tunnel as well as cut and fill has been considered as best option requiring minimum operation and maintenance problems and longer life span. However, in quantitative analysis, in terms of cost, the cut and fill alternative has been identified as most cost effective solution for the sewage management.

In case of the proposed system, the deepest cutting depth required to maintain hydraulic gradient for gravity flow is up to 11.0 meter from existing ground level. The excavation deeper than 5 meter in urban area will have difficulties during construction. Furthermore, the construction period may take longer period of time. There are chances of side slumping if adequate shoring arrangements are not made. The slumping may inflict damages in the roadside buildings. This is a much grater risk in urban area. The result of geotechnical investigation has indicated boulders with cemented conglomerate below 5 m depth making it very difficult to excavate. To avoid such risk, the tunnel alternative has been selected as most suitable alternative and recommended for adoption.

In tunnel alternative, the tunnel has been proposed along the stretch where the depth of cutting becomes more than 5.0 meter. In less than 5.0 meter, the construction method applied will be simply excavation and lying of precast concrete pipe. For this also, mechanical equipments will be optimally utilized to expedite the work in minimum time. The construction of tunnel will be done with greater care so that the vibration will be minimum along the tunnel route and no damage will be inflicted.

2.10 CONCLUSION OF ANALYSIS

Based on the qualitative and quantitative analysis, the best alternative is found to be diversion system with cut and fill option. However, considering the difficulties in construction, gravity system with tunnel alternative appears most suitable option due to the following:

- Relatively cheaper capital cost (including life span);
- Cheaper operation and maintenance cost in comparison to mechanized system;
- Significant opportunities for local employment;
- Easy operation and maintenance; and
- High efficiency with more than 90% reduction in pollution load in Lake water.

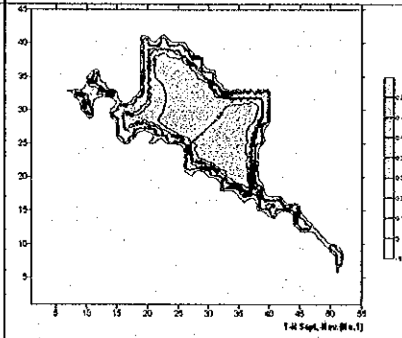
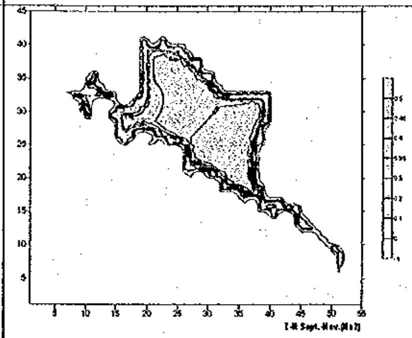
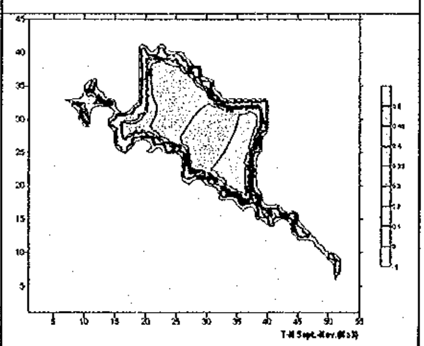
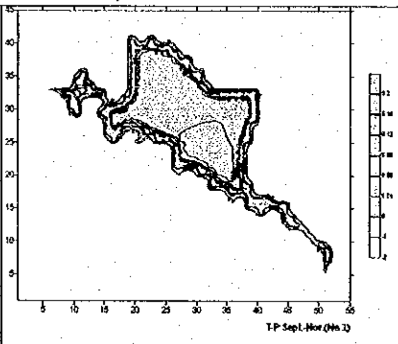
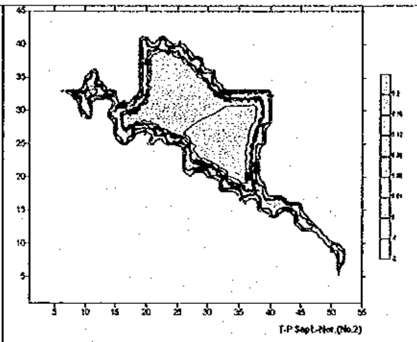
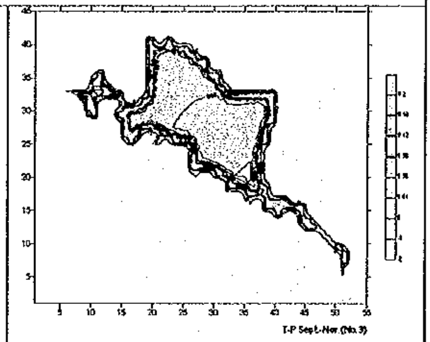
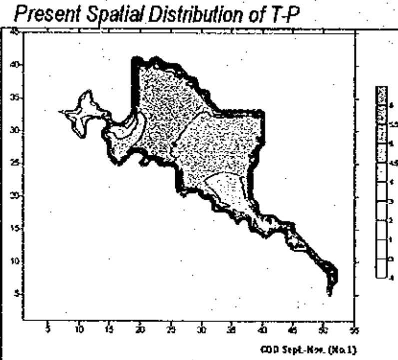
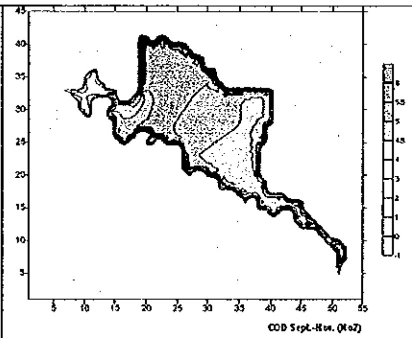
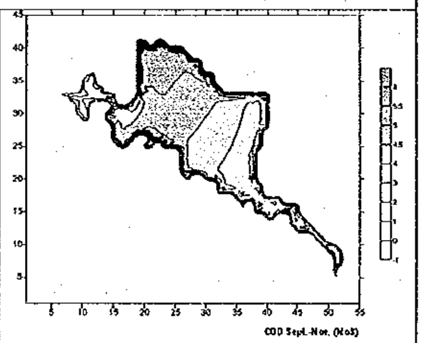
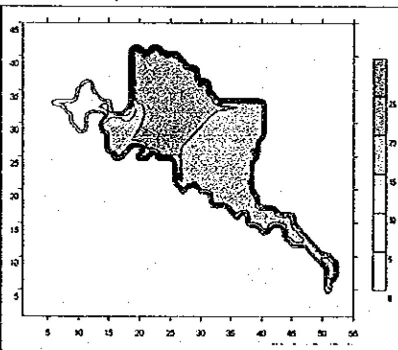
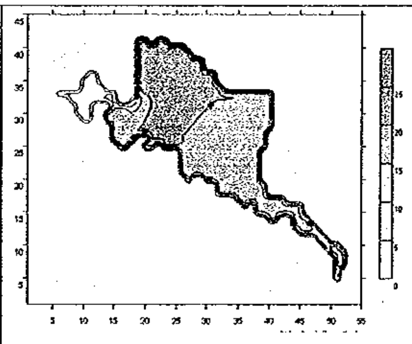
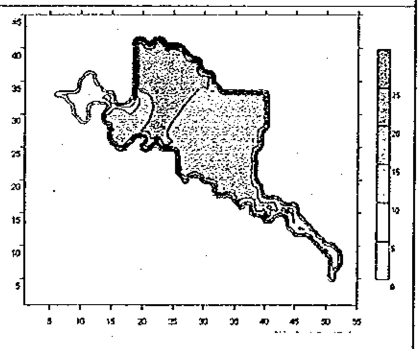
	Present Status	After Equipment Installation (Requested Grant Aid)	After Diversion Sewerage
TN	 *Present Spatial Distribution off T-N*		
TP	 *Present Spatial Distribution of T-P*		
COD	 *Present Spatial Distribution of COD*		
Chl-a	 *Present Spatial Distribution of Chl-a*		

Fig. II-2.7: Present Pollution Load and Pollution Load Condition after Technical Intervention

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CHAPTER 3

PLANNING BASIS AND PRELIMINARY ENGINEERING

The Development Study on Environmental Conservation of Phewa Lake in Pokhara, Nepal

CHAPTER 3

PLANNING BASIS AND PRELIMINARY ENGINEERING

3.1 GENERAL

This Chapter deals with the concept of preliminary engineering works to be adopted in feasibility study for sewerage system and treatment facility. The concepts have been developed based on the results of field survey, review of existing literatures and existing plans.

The preliminary engineering design provides a technical basis to evaluate feasibility of the proposed project. The basic concept of the preliminary engineering works includes the cost effectiveness, technical viability, and easy operation and maintenance of the system. Considering various tradeoffs involved in each alternative, final planning with appropriate scope has been prepared.

The following sub-sections present preliminary engineering of the selected gravity type diversion sewerage system with trunk sewer and tunnel combination.

3.2 SCOPE OF PRELIMINARY ENGINEERING

The scope of preliminary engineering works for the selected gravity type sewerage system includes the selection of various alternatives, as follows:

- *Construction of trunk sewer system from Seti Canal near Gaira Chautara to Phusre Khola* following the road alignment,
- Construction of diversion weir across Phirke Khola near the confluence of Phirke and Bulaundi Kholas to divert it's sewer and base flow,
- Construction of lateral sewer system from diversion weir of Phirke Khola to trunk sewer near Rastra Bank Chowk,
- Construction of Tunnel for about 1,286 meter length of 1200 mm diameter for passing trunk sewer where the cutting of depth is more than 5 meter.
- Provision of special junction structure for connecting existing storm-water drain with trunk sewer. This will allow highly polluted dry season discharge to be diverted into sewer. However, during wet season when pollution load is reduced due to dilution, the storm-water will not be diverted and *allowed to flow into Phewa. It is also expected that the illegal connection of household wastewater* into storm-water drain will be fully stopped after the construction of sewer line, as households will make their wastewater connection in the sewer. In such cases and with regular monitoring, the non-polluted storm-water will be allowed to flow into the Lake even during dry season.
- Construction of cascade system of natural swage treatment at its discharging point, near penstock pipe of Phewa Powerhouse to Phusre Khola. The length of cascade in designed to be 100m.
- Suitable numbers of Manholes and other pertinent structures.

The details of feasibility level design works and drawings are presented in **Annex 4** to this Report.

3.3 DETERMINATION OF DESIGN BASIS

The determination of design basis for gravity sewerage system primarily include the parameters as presented in following Sub-sections.

3.3.1 Types of Area Served

The quantity of sewage flow depends upon the nature of the area to be served. The quantity of sewage from the residential area varies with industrial and commercial area.

The area to be served by the proposed alternative of sewerage system basically is located in urban watershed of the Lake from where the sewage and surface runoff generated flow through natural gradient, i.e. under gravity flow.

There are no industries in the service area. The contribution of present and projected numbers of hotels and total number of beds has been accounted for estimating the sewage flow.

3.3.2 Allowable Wastewater Flow

Numerous natural streams and storm-water drains constructed recently within the project area have been currently being used for sewage disposal, which eventually reach and affect the water quality of Phewa Lake. Among them, Phirke Khola is almost an open drain, which carries most of the sewage generated in the proposed service area falling under catchment of the Khola with large temporal variation of pollution load.

In the monsoon, the pollution load is low or within the threshold limit due to availability of high discharge, and on the contrary, pollution load is high during dry season due to the limitation of dilution capacity of available discharge.

Under the proposed sewage management, the allowable wastewater generated within the service area that is allowed to flow into the Lake through Phirke Khola or storm-water drainage during monsoon is presented in **Table II-3.1.**

Table II-3.1: Pollutant Load Limits of Wastewater Flow into Lake

S. No.	Description	Threshold Limit
1	pH	6.5-8.5
2	BOD	3 mg/liter at 20degree C
3	COD (Cr)	20 mg/lit
4	DO	5 mg/liter
5	Amonia	1.5 mg/lit
6	Nitrate	10 mg/lit
7	Phosphorous	0.3 mg/lit
8	Total Coliform	1000 MNP/100 ml
9	Total Dissolved Solid	500 mg/lit
10	SAR	12

Note: Threshold limit has been adopted as per WHO and FAO standard

If the wastewater characteristics are above the threshold limits as presented in Table II-3.1, the sewage will be diverted into sewer line and disposed beyond the Lake after oxidation through cascade structure.

3.3.3 Population to be Served

The population is one of the most crucial parameter for determining the sewer size. The population of project area needs to be estimated for entire designed life span of sewerage system. For the proposed sewerage system, the estimation has been done considering the annual growth factor. The life span of the proposed sewerage system has been considered for 25 year (up to year 2027). The current population of the service area is estimated at 49,561.

The estimated population of year 2027 is 133,459. The population estimation has been done according to the zones of the service area. The delineation of the service area has been done to facilitate the economical design.

The service area of Phirke Khola has been divided into three zones, zone A, B and C. The Zone A includes sewer system ranging from Seti Canal to confluence of Phirke and Bulaundi Khola and Zone B has been considered for entire service area of Phirke Khola in which their sewage is discharged . The area downstream of Phirke to disposal point of the sewerage system has been included in Zone C. The population of these zones in the year 2015 and 2027, and map showing different zones are presented in Table II-1.1 and Fig. II-1.1 respectively in **Chapter 1** of **Part II** of this Report.

3.3.4 Total Sewage Discharge

The total discharge to be carried by the sewer varies with served population. The discharge in the beginning is less and it goes on increasing with the increase of the connection of lateral household sewers. For the proposed sewers, the discharge has been determined with manhole to manhole for economical design by multiplying the served population with adopted per capita sewege per day. The discharge in terms of liter per second has been calculated and presented in Annex 4 to the Report. The method adopted is:

Q = Population of Service Area x q / (60 x 60 x 24) liter per second.

Where,

Q = total sewage discharge.

q = per capita sewage per day.

3.3.5 Dry Weather Flow

The dry weather flow of proposed sewer system will be determined by the supply of drinking water through public system. 80 percent of per capita per person per day supply of water will be considered as dry weather flow of sewer. However, the design discharge for the proposed sewer will be determined by adding the ground water contribution. The ground water intrusion into the sewer through joints will be about 10 percent of dry weather sewer flow.

The total discharge accounted for designing the sewer system is:

q = 0.8 x130

Where per capita water supply from public system in urban area is 130 liter per person per day.

3.3.6 Peak Factor

The rate of flow is not constant but varies every hour of the day, every day of the season and every season of the year. To get average flow for designing the sewer line, a factor should be considered that is known as Peak Factor. The Peak Factor is the ratio of maximum flow to the average flow.

Generally, the Peak Factor varies from 1.5 to 3. For the proposed design, 2.5 have been adopted. Therefore, the Peak Discharge, (Qp) will be:

Qp = 2.5 x Q average

3.3.7 Hydraulic Design Parameters

When the flow enters into a pipe or channel at a constant rate and escapes freely at the lower end, a steady uniform flow needs to be established. The steady flow may be assumed in the usual sewer design with progressively increasing cross section. Water moves downstream in a pipe impelled by the force of gravity. Thus the sewers are normally designed as open channels where sewer runs under gravity. The sewers seldom runs full and the Hydraulic Gradient Line always fall within sewer. The velocity in the sewer line is calculated by Manning's Formula that is applicable for open channel.

$V = 1/n \times R^{2/3} \times S^{1/2}$

Where V = velocity of flow in m/sec

n = Manning's Rougosity Coefficient (n = 0.013 normally considered for cement concrete pipe.)

R = wetted area of cross section per wetted area of perimeter (A/P) in meter

S = longitudinal slope of sewer

The discharge of flow running into the sewer is calculated by continuity equation:

Q = A x V

A = Cross sectional area in sq.m.

V = Velocity of flow in m/s

Q = Discharge in m^3/sec

Velocity Requirement:

In order to have unobstructed flow, the velocity should be capable to carry particle in suspension. But it should not exceed to create turbulence in the flow that unnecessarily mix the particle and scours the pipe walls. The minimum velocity in the pipeline should be at least 0.6 m/sec and maximum range should be 3.0 m/sec. While designing the sewer, the velocity should be greater successively in downstream reaches. Depending upon the diameter of the pipe, the permissible velocity range is taken as:

- Minimum velocity
    - 1 m/s for sewer diameter of 150 mm to 250 mm,
    - 0.75 m/sec for sewer diameter of 300 mm to 600 mm
    - 0.6 m/sec for sewer greater than 600 mm diameter pipes.
- Maximum velocity in cement concrete pipe should not be greater than 3.0 m/sec.

Minimum Slope :

One of the important parameter in sewer design is the minimum velocity (self cleaning velocity) to be maintained in order to prevent settlement and deposition of solids. Since the slopes of the sewer lines strictly governs the velocity of flow, minimum slope should be provided to achieve the minimum permissible velocity. The greater slope can also cause problem of erosion on pipe wall. The minimum slope can be calculated by using the following formula:

$S_{min} = 7.65 \times 10^{-4} / D$

Where, D = diameter of pipe in meter

S = slope

While designing the sewer line, the slopes are taken nearly parallel to the ground slope, that is greater than the minimum slope and velocity fall into permissible range.

Cover Depth :

Sewage is mostly conveyed through underground sewer pipes. The minimum cover depth to be adopted is governed by the weight of pipe, weight of backfill, and super imposed load of traffic. These parameters shall be considered for finalizing the cover depth. Generally, the minimum cover depth of sewer pipes are 1.2 m for vehicle load and 0.8 m for without vehicle load. However, the minimum cover depth has been adopted as 1.3 m and maximum of 5 m in the proposed design. If the cover depth is more than 5 m , the tunnel alternative has been proposed.

Depth to Diameter Ratio:

The depth of water flowing into the sewer depends upon the diameter of sewer pipe. So, the maximum value of depth (H) to diameter (D) ratio: H/D is adopted as per the following **Table II-3.2.**

Table II-3.2: H/D Ratio for Sewer Pipe

Diameter	200-400 mm	400-900 mm	> 900mm
H/D	0.5	0.67	0.75

Manhole and Flushing Devices

Manhole should be provided at the points where there is change in direction, change in diameter, and change in slope. Drop manholes are provided at the points where main sewer line is deeper than laterals.

3.4 INTERCEPTOR SYSTEM

Interceptors are to transfer the wastewater generated from the service area to wastewater treatment and disposal location. During the course of this Study, it has been identified that no sewer system that carries the city sewage exists in Pokhara except the storm-water drainage network that has been constructed in recent past. Considering the current practice of sewage disposal directly or indirectly to the Phewa, a trunk sewer starting from Seti Canal at Gaira Chautara to Phusre Khola along the east shore of Phewa Lake has been proposed. Similarly, a diversion weir across the confluence of Phirke Khola and Bulaundi Khola and lateral sewer from the diversion weir to the trunk sewer at Rastra Bank Chowk has been proposed. The design of sewer system has been made in accordance with criteria cited above. Other pertinent structures such as weir and siphons have been designed according to the standard hydraulic and engineering principles.

3.5 SELECTION OF TREATMENT PROCESS

The primary objective of selection of treatment process is to select the most appropriate treatment system that treats wastewater to desired level in minimum construction cost, operation and maintenance cost, maintains operation flexibility and expandability, is easy in operation, and complies with social acceptability of the area (particularly related with odor nuisance).

Based on these criteria, cascade type of simple natural treatment and discharge system has been selected and designed (see **Fig. II-3.1**). However, it has been envisaged that Reed bed type constructed wetland treatment system may need to be designed for future when the amount and quality of sewage reaches a level which the cascade type natural oxidation system cannot treat to acceptable standard before discharging it into Phushre Khola.

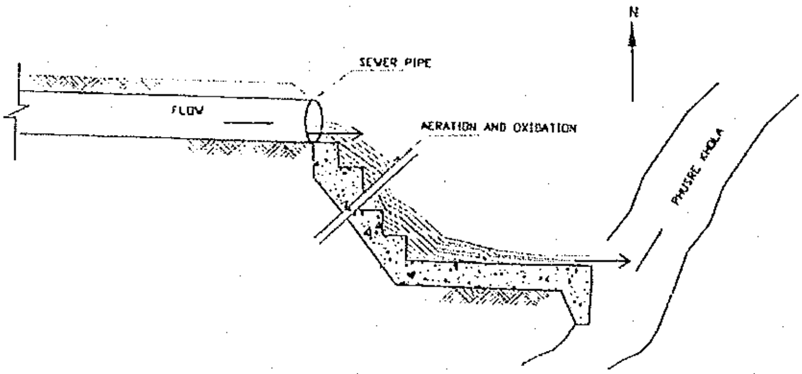

Fig. II-3.1: Cascade Type of Wastewater Treatment System

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SEWERAGE SYSTEM PLANNING (OPERATIONAL PHASE)

The Development Study on Environmental Conservation of Phewa Lake in Pokhara, Nepal

CHAPTER 4
SEWERAGE SYSTEM PLANNING (OPERATIONAL PHASE)

4.1 PLANNING PRINCIPLE

4.1.1 Hydraulic Principle

The capacity of the sewer system has been determined based on maximum daily wastewater flow. The estimation of daily wastewater flow has been done on the basis of designed population for 2027 and per capita public water supply. The maximum daily flow has been converted to flow rate per second. The total design discharge at the outfall has been estimated at 0.54 m^3/sec. The dry season flow of Seti Canal (starting point of sewer) of 0.1 m^3/sec and base flow of Phirke Khola of 0.2 m^3/sec have also been added in the maximum wastewater flow. Consequently, the design discharge at most downstream reach of the proposed sewerage system has been determined as 0.85 m^3/sec.

In order to carry out the economical design, the entire service area has been divided into three zones, as presented in Fig II-1.1 of Chapter 1 of Part II of this Report. The most upstream Zone A will have only 0.18 m^3/sec as design discharge (based on the population) including the flow of Seti Canal. The Zone B will have design discharge of 0.71 m^3/sec. This includes the wastewater generated in Zone B, base flow of Phirke Khola, and total design discharge of Zone A. Similarly, Zone C will have 0.85 m^3/sec, which includes total design discharge of Zone B and wastewater generated in Zone C area.

4.1.2 Facility Planning Basis

(1) Gravity Type System

The design basis for gravity flow sewer has been adopted with the discharge estimated as stated in Subsection 4.1.1 above. The alignment of gravity sewer system has been fixed along the eastern shore of Phew Lake following the existing road at Lakeside. The design has been made in accordance with the standard engineering principles using Mannings Formula and Standard Hydraulic Continuity Equation. The slope of gravity flow sewer varies depending upon the topography. The longitudinal slopes (V:H) adopted is presented in the following **Table II- 4.1.**

Table II-4.1: Longitudinal Slope (V:H)

SN	Chainage	Longitudinal Slope (V:H)	Remark
1	0+000 to 0+160	1:350	trunk sewer
2	0+160 to 1+336	1:700	trunk sewer
3	1+336 to 1+727	1:900	trunk sewer
4	1+727 to 3+075	1:900	tunnel
5	3+075 to 4+146	1:500	trunk sewer
6	4+146 to 5+088	1:300	trunk sewer

The diameter of sewer pipe in accordance with the design vary with respect to the discharge to be carried. From Chainage 0+000 to 1+335, 600 mm (internal diameter) pre-cast concrete pipe; from chainage 1+335 to 1+727, 700 mm (internal diameter) pre-cast concrete pipe; from 3+013 to 3+048

700 mm (internal diameter) pre-cast concrete pipe, and from 3+048 to 5+088, 1000 mm diameter pre-cast concrete pipe has been adopted.

However, for carrying the sewage from chainage 1+727 to 3+048, where cutting depth is more than 5 m, tunnel section has been designed. This is to avoid the deep cutting of earth and possible associated risks in city area. In remaining stretch, the pre-cast concrete pipe with partial flow condition under gravity flow has been designed.

(2) Division Box at Seti Canal

A provision of division box at Seti Canal has been made to regulate it's discharge. Low flow discharge with high pollution load will be diverted towards the sewer system, and high flow with low pollution load discharge will be allowed to flow into Phewa. It has been assumed that if the flow in the canal is less than 0.1 m^3/sec, the flow will be diverted to the sewer. If it is higher than this, the flow will be allowed into Phewa assuming that the pollutants are within the threshold limit due to natural dilution.

For this, a division box with a cross regulator across Seti Canal and orifice type turn out structure has been provisioned in the design.

(3) Division Box on Storm-water Drains

A division box has been provisioned in existing storm-water drain. This division box will be provided with two-orifice type turnout structures. The main principle of such structure is to divert the sewage illegally connected into the storm-water drain to the trunk sewer during dry season (when the pollution is high) and allow to flow into Phewa when the pollution load in storm-water is within the permissible limit. Gates will be fixed on both the orifices and regulated properly. Apart from this type of division box, a conveyance pipe will be provided and connected to trunk sewer through manhole. The diameter of pipe for conveyance will be of 0.3 m.

(4) Diversion Structure Across Phirke Khola

In order to minimize the pollution load in Phewa from Phirke Khola, a low height weir has been provisioned to facilitate the diversion of low flow into sewer system. The principle adopted for designing the weir is mainly safety and economy. The safety consideration has been adopted against maximum flood flow of 50 years return period. For economic consideration, the height of the weir has been optimized to divert only low flow discharge. The maximum flood discharge of 75 m^3/sec for 50 years return period has been adopted in design of the weir.

The main purpose of constructing diversion structure is to divert the flow of Phirke Khola in dry time when the flow is highly polluted by opening the gate of diversion sewer. The Phirke Khola will be allowed to flow into Phewa by closing the gate of sewer during monsoon, when pollution level of water is within permissible level due to dilution.

(5) Sewer Line from Phirke Diversion to Trunk Sewer

A piped sewer system from the diversion of Phirke Khola to join the trunk sewer at Shahid Chowk has been designed to discharge the diverted flow into Phusre Khola.

(6) Cascade Structure

A cascade structure at the end of sewer has been designed to oxidize the sewage and safely dispose into Phusre Khola.

4.2 PROCESS DESIGN

1) Diversion Structure at Seti Canal

(a) Cross Regulator

As stated earlier, a cross regulator (check structure) across Seti Canal combined with a turn out has been designed. The design of check structure has been made using the discharge formula of flow through weir as follows:

$Q = C \times Be \times He^{3/2}$

Where, C = Constant, Be = Length of weir, He = Head over the crest.

The design data of check structure is as follows:

Discharge of Seti Canal = 0.5 m^3/sec

Canal floor level has been taken as crest level = 800.14 m amsl

U/S floor level = 800.04 m

D/S cistern length = 2.0 m

U/S floor length = 1.0 m

D/S cut off depth = 1.0 m

U/S cutoff depth = 0.5 m

Gate size = 0.4 m x 0.6 m

Operation deck = 1.0 m wide RCC with 0.15 m thick (mild steel).

(b) Turn Out Structure

A turn out structure near the cross regulator has been designed to allow the flow up to 0.1 m^3/sec. The turn out has been designed by using the standard Mannings formula:

$V = 1/n \times (R)^{2/3} \times (1/S)^{0.5}$

The turn out has been provided with concrete pipe and gate at its mouth. The dimensions as per design are:

Pipe size = 0.4 m internal diameter

Length of pipe = 5.0 m

Gate size = 0.4 m x 0.5 m (mild steel)

U/S floor level =799.90 m

Bottom elevation of pipe = 800.2 m

Top elevation of pipe = 800.42

Trash rack size = 0.4 m x 0.5 m with (15 mm spacing and 10 mm diameter trash bar)

Trash rack bars diameter =10 mm

Clear spacing = 0.15 mm

(c) Sewer Lines

The sewer lines have been designed by using the Mannings formula for open channel. The sewer line has been designed as open channel assuming that the sewage will flow through gravitational force. The cross section of pipe for various chainage are different depending upon the discharge and slope condition. The designed dimensions are as follows:

Chainage 0+000 to 0+123

Slope = 1/350

Design discharge = 0.18

Mannings coefficient = 0.013

Velocity of flow = 1.32 m/sec

Internal diameter of pipe = 0.6 m (pre-cast concrete pipe, NP3 Series)

Cross section area of sewer = 0.21 sq. m.

Perimeter of sewer = 1.88 m

Chainage 0+123 to 1+274

Slope = 1/700

Design discharge = 0.18 m^3/sec

Mannings coefficient = 0.013

Velocity of flow = 0.93 m/sec

Internal diameter of pipe = 0.6 m (pre-cast concrete pipe, NP3 Series)

Cross section area of sewer = 0.21 sq. m.

Perimeter of sewer = 1.19 m

Chainage 1+274 to 3+013

Slope = 1/900

Design discharge = 0.18 m^3/sec

Mannings coefficient = 0.013

Velocity of flow = 0.91 m/sec

Internal diameter of pipe = 0.7 m (pre-cast concrete pipe, NP3 Series)

Cross section area of sewer = 0.29 sq. m.

Perimeter of sewer = 1.39 m

(in chainage between 1+727 to 3+013 a tunnel is being considered to avoid the deep excavation for sewer pipe laying).

Chainage 3+013 to 3+794

Slope = 1/500

Design discharge = 0.72 m^3/sec

Mannings coefficient = 0.013

H/D = 0.66

Velocity of flow = 1.54 m/sec

Internal diameter of pipe = 1.0 m (pre-caste concrete pipe, NP3 Series)

Cross section area of sewer = 0.59 sq. m.

Perimeter of sewer = 1.98 m

Chainage 3+794 to 5+088

Slope = 1/300

Design discharge = 0.85 m^3/sec

Mannings coefficient = 0.013

H/D = 0.66

Velocity of flow = 1.99 m/sec

Internal diameter of pipe = 1.0 m (pre-cast concrete pipe, NP3 Series)

Cross section area of sewer = 0.59 sq. m.

Perimeter of sewer = 1.98 m.

(2) Weir

A low height concrete weir has been designed to divert the flow (low flow contained with pollution load) of Phirke Khola. The design of weir on pervious soil has been made in accordance as with standard hydraulic principles considering the safety against surface flow, sub-surface flow, and hydraulic jumps. The designed data are as follows:

Maximum designed flood = 75 m^3/sec (100 year return period)

Length of weir = 12 m

Length of under sluice = 6.0 m

D/S floor length = 14.5 m

U/S floor length = 4.0 m

Glacis length = 1.5 m

Downstream cutoff depth = 3.3 m

U/S cut off depth = 2.5 m

Height of weir = 0.5 m

U/S floor = 803.0 m

D/S floor = 802.5 m

Gates on under sluice = 0.5 m x 2 m (3 numbers)

Operation deck slab on under sluice = 7.0 m with 0.5 m width

Turn Out (Head Regulator)

A turn out structure near the cross regulator has been designed to allow the flow up to 0.2 m^3/sec. The turn out has been designed by using the standard Mannings formula:

$V = 1/n \times (R)^{2/3} \times (1/S)^{0.5}$

The turn out has been provided with concrete pipe and gate at its mouth. The dimensions as per design are:

Pipe size = 0.5 m internal diameter

Length of pipe = 5.0 m

Gate size = 0.4 m x 0.5 m (mild steel)

U/S floor level = 802.90 m

Bottom elevation of pipe = 803.02 m amsl

Top elevation of pipe = 803.39 m amsl

Trash rack size = 0.4 m x 0.5 m (15 mm spacing and 10 mm diameter trash bar)

Trash rack bars diameter = 10 mm

Clear spacing = 0.15 mm

(3) Division Box on Storm-water Drain

Division boxes on storm-water drain at near Barahi temple and Hallan Chowk has been provisioned. The designed dimensions are as follows:

<u>Concrete Box</u>

L = 2.0 m, B = 1.5 m, H = 1.5 m

Thickness of vertical wall = 0.2 m (with nominal reinforcement)

Orifice for sewage with 0.3 m diameter pipe and caste iron gate with 0.4 m diameter

Orifice for storm-water with 1.0 m diameter pipe. Steel gate (mild steel) sliding type with 1 m x 1.25 m.

A conveyance pipe line from division box to manhole of trunk sewer = 50 m

Diameter of pipe for conveyance = 0.3 m

(4) Lateral Sewer (from Phirke Khola to Trunk Sewer)

Lateral sewer length = 840 m

Design discharge = 0.2 m^3/sec

Pipe size = 0.5 m

Slope = 1:700

Velocity = 0.83 m^3/sec

Perimeter = 1.88 m

(5) Cascade Structure

At the end of sewer line, a cascade structure combined with other type of fall has been designed. The hydraulic formula used for designing the structure is as follows:

$L_d = 4.3 \times Z \times D^{0.27}$ m

Where, L_d = hydraulic drop length

$D = q^2/gz$

Where, q = intensity discharge , g = 9.81 m/sec^2

$L = L_d + 0.1$ m

The designed parameters and dimensions are as follows:

Design discharge =0.85 m^3/sec

Width of cascade =3.5 m

Intensity of discharge = 0.25 m^3/sec/m

Hydraulic drop length L = 1.0 m

Z (drop height) = 0.75 m

Depth of sidewall = 0.45 m

U/S protection box 2 m x 3.5 m and 0.2 m crest depth.

<u>Chute (Sloping Stilling Basin)</u>

Length of chute = 20 m

Drop height = 9.0 m

Width of chute = 2.0 m

Intensity discharge = 0.425 m^3/sec/m

D/S cistern length = 7.0 m (side wall 1.2 m to accommodate the hydraulic jump)

Side wall = 0.45 m

Nominal reinforcement will be provided.

(6) Concrete Flume

After chute drop, in mild slope a concrete flume has been designed. The design has been done with hydraulic principle. The dimensions are as follows:

Slope: 0.02

n = 0.015

Velocity = 2.9 m/sec

Width = 2.0 m

D = 0.2 with free board = 0.5 m

Side wall thickness = 0.2 m (with nominal reinforcement)

Bottom floor will also have nominal reinforcement.

(7) Manhole and Other Pertinent Structures

4.5 m diameter of manhole has been provisioned along trunk sewer and lateral sewer. The manhole along the trunk sewer should be located almost in every 200 m or in every possible junction locations.

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CHAPTER 5

IMPLEMENTATION PROGRAM

The Development Study on Environmental Conservation of Phewa Lake in Pokhara, Nepal

CHAPTER 5
IMPLEMENTATION PROGRAM

5.1 CONSTRUCTION PLAN

The major facilities to be constructed under the proposed project include:

- construction of trunk sewer system including manhole and other pertinent structures
- construction of diversion structures across Phirke Khola,
- construction lateral sewer (from Phirke to trunk sewer)
- construction of small structures at Seti Canal and storm-water drain
- cascade type structure at final discharge location

As stated earlier, the construction of sewer between chainage 1+727 to 3+013 require deep excavation of more than 5 m for pipe laying. Thus, in this section, 1.2 m diameter tunnel has been proposed.

The construction plan for the proposed project has been prepared based on the following considerations:

- the daily working hour is assumed as eight hours,
- construction equipment will be utilized for smooth and faster implementation,
- preparation of bid document and pre-qualification of contractors will be done during the detailed design and pre-contract services.

The construction schedule is presented in **Table II-5.1**.

Table II-5.1: Construction Schedule of Sewerage System

Description	1st year			2nd year		
	Jan-Apr	May-Aug	Sept-Dec	Jan-Apr	May-Aug	Sept-Dec
Preparation of Bid Document and Prequalification of Contractor						
Selection of Contractor and Award of Contract						
Mobilization by Contractor						
Construction of Trunk Sewer/ Tunnel						
Construction of Diversion Structure						
Construction of Cascade						
Construction of Other Facilities						
Commissioning						

Note: Rainy season

5.2 OPERATION AND MAINTENANCE

The operation and maintenance (O&M) of the proposed project is one of the crucial elements for sustainable services in future. The proposed sewer system almost comprises the civil infrastructure even for wastewater treatment. The operation and maintenance cost for such structure is very nominal in comparison to mechanical equipment. However, the operation and maintenance requirement is presented below.

- **Operation**

The operation requirement of this system is very minimal. However, the operation at gates of Phirke Khola, Seti Canal and storm-water drainage are important woks. These structures are made to divert the polluted water of the drainage during dry season into sewerage system and water with acceptable limit of pollution load during rainy season to be allowed into Phewa Lake. Operation staff will be needed to be deployed at these locations.

- **Maintenance**

There will be two types of maintenance system required for the proposed sewer and wastewater treatment. They are (i) emergency maintenance, and (ii) regular maintenance.

The emergency maintenance are normally needed without knowing in advance, such as choking of sewer pipe, damage of cascade structure by river, erosion of downstream protection of weir etc. and repair and maintenance is immediately needed. For this, adequate resources (finance, skilled labor and equipment) should be arranged.

Regular maintenance includes the maintenance works that are pre-scheduled. This includes mainly the maintenance of weir primarily in downstream protection, and regular maintenance of gates etc.

About 3 % of capital cost is recommended every year for entire operation and maintenance works in initial years. However, after 10 years, the operation and maintenance cost should be 5 percent of capital cost.

5.3 DISBURSEMENT SCHEDULE

The proposed annual disbursement schedule for sewerage system is presented in **Table II-5.2.**

Table II-5.2: Disbursement Schedule (NRs in million)

S.N.	Description	Total	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
1	Detail Design	10.23	8.187	2.05												
2	Preparatory Works	17.06	8.528	7.81												
3	Construction															
	Mobilization and Demobilization	17.0554		7.81		8.528										
	Construction of sewerage system including other structures	96.7673		29.03	38.707	29.03										
	Construction of tunnel	*244.34*		73.302	97.736	21.99										
4	Construction supervision	23.88		4.7755	9.551	9.551										
5	Administration	8.52768	2.132	2.1319	2.1319	2.132										
6	Miscellenous	341.107														
7	Contingencies	34.1107		8.5277	10.233	15.35										
8	O&M						7.076	7.076	7.076	7.076	7.076	12.42	12.42	12.42	12.42	12.42
	Total Disbursement	793.07	18.85	135.43	158.36	86.58	7.08	7.08	7.08	7.08	7.08	12.42	12.42	12.42	12.42	12.42

S.N.	Description	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	28	29	30
1	Detail Design															
2	Preparatory Works															
3	Construction															
	Mobilization and Demobilization															
	Construction of sewerage system including other structures															
	Construction of tunnel															
4	Construction supervision															
5	Administration															
6	Miscellenous															
7	Contingencies															
8	O&M	12.42	12.42	12.42	12.42	12.42	17.77	17.77	17.77	17.77	17.77	23.12	23.12	23.12	23.117	23.117
	Total Disbursement	12.42	12.42	12.42	12.42	12.42	17.77	17.77	17.77	17.77	17.77	23.12	23.12	23.12	23.12	23.12