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DETECTION OF WATER SALINITY AND SHORTEST PATH FOR WATER SUPPLY SYSTEM IN KHULNA CITY CORPORATION (KCC) AREA: A GIS BASED APPROACH

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ABSTRACT

It is known to all that water plays a vital role in maintaining natural eco-system. In case of Khulna region, salinity is said to be a major problem and rate of salinity in water bodies is more than other region as Khulna is a southern region of our country and saline contaminated water is a threaten for human health and survival. The main objective of the study is to investigate the physical condition of blue environmental portion throughout the Khulna City Corporation (KCC). Then it aims to detect the saline condition of the water bodies and introduce the new installation of water supply system in KCC area.

Several field surveys were conducted emphasizing on waterbodies condition and salinity for this research and also collecting primary and secondary data for generating accurate result. Collected field survey data and secondary data are recorded in digital form using ArcGIS to bring out necessary analysis. The collected data are prepared as shape files for GIS analysis. Using network analyst, first the served and unserved area of KCC is defined. Then again the unserved area is merged with the salinity raster data of KCC to identify the salinity level of an unserved area of KCC. Then in the highly saline area, a shortest path is defined using the origin, destination tools in Network analyst for water supply of low saline area.

The research highlights three core delineated areas such as high salinity area, moderate saline area and low saline area, depending on the salinity quantity of the wardwise water bodies and also ranged the saline quantity for getting results about which kind of area remain in the high saline area and which in low or moderate and also get the unserved areas of water supply by network analysis.

The paper results in showing that in total, of 0.11% area have no saline while having an area of 18.99% and 25.85% area as low and moderately saline water respectively. More than half of the area (almost 55%) contains high saline water. The paper gives the message that the main reason of unserved areas is having low class people who cannot afford the cost of water facilities and other reason is these areas are located beside riverside or these areas are only used for pisiculture and fish cultivation activities. As a result, 25% areas don't get any community water facilities because of the above mentioned reasons and no or low saline unserved area are feasible to establish water supply facilities for the dwellers. Among these, 25%, more than 17% of unserved area are highly saline affected. The quantity of water bodies and the salinity condition for each ward are explained by charts, tables and map in the research.

***Keywords**: Blue ecosystem service, Salinity, Water supply, Network analyst, Shortest path.*

1. INTRODUCTION

The term "natural environment" refers to the environment and the conditions in which all living and non-living things exist on Earth. (Khan, et al., 2011) The common concept of the natural environment encompasses two different components:

- Ecological units that operate as natural systems (such as soil, vegetation and so on).
- Universal natural resources (such as air and water). (Leda and Anna)

Environmental inventory "is a concise overview of the ecosystem since it occurs in a region contemplating a particular proposed action. The inventory is compiled from a checklist of descriptors for the physical – chemical, biological, cultural, and socioeconomic environments. (Li, Lei, et al., 2015) The "physical-chemical environment" includes such major areas as soils, geology, topography surface-water and groundwater resources, water quality, air quality, and climatology. The inventory of the environment serves as the basis for determining the potential environmental effects of a proposed action, both beneficial and adverse (EIS). (Safety, Khalilmoghadam & Nadian, 2019) Development of the inventory represents an initial step in the environmental impact assessment process. (Forsberg and Fedrik, 2002) The natural environment is in contrast with the 'built environment' which refers to areas that have been fundamentally transformed and influenced by human activity, such as cities, towns, infrastructure, and so on. The Environmental Profiles Technique is a systematic way of defining and evaluating the environmental impacts of construction materials over their life cycle-that is, their collection, storage, use and maintenance and eventual disposal. Many aspects of an ecosystem require us in understanding a specific geographic region such as soil quality, water condition, wastewater management, air condition, slums, and other resources. (Enrique Roman-Morey, 2010) We are given KCC to survey the environmental condition of the area for the project. Our area contains 31 wards of Khulna city. We survey whole wards of KCC for evaluating the environmental condition and pollution rate of the Khulna city. This project helps us to assess the present status of air, noise, water, land, ecology and socioeconomic components of the environment and to prepare an Environmental Management Plan (EMP) with pollution control technologies to be adopted for mitigation of adverse impacts and site-specific remedial measures. The water environment includes coastal zones, rivers, lakes, estuaries, ground water, soil, water and even the atmospheres part of the hydrological cycle. The urban water environment has deteriorated sharply given the acceleration of urbanization and increase of urban population (Postel, 2002; Pei et al., 2013). In addition, the urban water environment treatment is an important task for the government to build a harmonious society. However, the urban water environment treatment involves numerous public infrastructural items, such as sewage treatment, ecological restoration, and landscape green planting. Moreover, this treatment requires highly professional quality (Han, H., Wang, Z., & Li, H. (2019))

The main objective of the study is to make a detailed inventory of water bodies and supply installation and give a tentative recommendation for the future. Although it is not a big project still the study has some limitations. Such as identifying the ward boundary and lacking of many necessary data and instruments.

2. LITERATURE REVIEW

The environment involves naturally occurring living things as well as non-living things meaning not biological. The term is mostly used on the Earth or in certain parts of the Earth. (European Commission, 2006)

Profiling of Environment means assessing the impressions of a building material, product or system during its working life, not only during its manufacture, but also during its use in a building over an average lifespan. This contains their abstraction, processing, use and maintenance, as well as their necessary dumping. (Enrique Roman-Morey, 2010)

Lucknow, capital of Uttar Pradesh, between 260 52'. N latitude and 800 56' longitude, 120 m above sea level and having a population of 22, 45, 509 as per 2001 census and has an area of 310 sq. km density 7244. sq. km. with the fundamental growth of population, transportation modes, infrastructure

construction actions are increasing day by day. The vehicular population of Lucknow is extensively increasing every year. Number of vehicles were 614794 during 2002-03 while the number stands for 2003-04 at 679326 showing a growth rate of 10.5%, which is comparatively higher in comparison to the present infrastructure of the city or carrying capacity of the road. Sound exposure is steadily increasing for this phenomenon, sometimes causing discomfort and sometimes pain, noise does not cause ears to bleed, and noise-induced hearing loss usually takes years to develop. The necessary investigation was carried out to assess the ambient day and night time noise levels of Lucknow city and to bring down the pollution level through public participation and to suggest mitigate measures. (Kisku, et al., 2006)

There's been a growing interest in environmental assessments of the built environment and today we can find a large range of tools for environmental assessment of the built environment, concentrating on energy use in buildings, sick building syndrome, indoor atmosphere, building materials containing harmful substances and/or other factors in fractured or integrated ways. Two types of methods are used for qualitative and quantitative assessments of the built environment. GBTool, BREAM, and LEED are examples of common and well-known quality tools. (Hassall and Zaveri, 1978) Qualitative methods are always based on creating auditing, assigning a score to each parameter being investigated, resulting in one or more total creation of scores, certain parameters being investigated are quantitative, such as energy usage, while others are based entirely on the criteria. (Foresberg and Von malmborg, 2004)

The severity of salinity problem in Bangladesh increases with the desiccation of the soil. It affects crops depending on the degree of salinity at the critical stages of growth, which reduces yield and in severe cases total yield is lost. Bangladesh is a diuretic country by total area of 147,570 km. The major part (80%) of the country consists of alluvial sediments deposited by the rivers Ganges, Brahmaputra, Tista, Jamuna, Meghna and their tributaries. Bangladesh cover more than 30% of the cultivable lands of the country. About 53% of the coastal areas are affected by salinity. Agricultural land use in these areas is very poor, which is much lower than the country's average cropping intensity. Salinity causes unfavorable environment and hydrological situation that restrict the normal crop production throughout the year.

Salinity problem received very little attention in the past. Nevertheless, symptoms of such land degradation with salinization are becoming too pronounced in recent years to be ignored. Increased pressure of growing population demands more food. It has become imperative to explore the possibilities of increasing potential of these (saline) lands for increased production of food crops. Thus, combating land salinization problem is vital for food security in the country through adoption of long-term land management strategy (Haque, S. A. 2006)

3. METHODS AND MATERIALS

3.1 Study Area

Khulna City Corporation (Figure 1) is selected as the study area for this project, consisting of 31 wards. Khulna city is the area having about 40% agricultural land. Generally, the environment of the area is considered as moderately good. Only 2% area within ward no. 12 & partially 24 are highly suitable for water distribution facilities (Haque & Mustafa, 2018). At a glance the area profile be

Table 1 Study Area Profile

General Information	
Name	Khulna City Corporation
Area	54.65 square km
Geographical Location	Between $22^0$45'30'' and $22^0$54'30'' north latitude and between $89^0$29' and $89^0$35'30'' east longitude.

Population	15,00,689	
Density	67,994 per square km	
No. of Holdings	66,257	
Wards	31	
Transportation Network	No. of Roads	1215
	Total length of road	356.64 km
	Bridges	No data available
No. of Bazar	21	
Super Market	04	
Surrounding rivers	Bhoirab river and Rupsha river	
Environment and Climate Information		
Climate	Humid during summer and pleasant during winter	
Temperature	Maximum	35.5^0c
	Minimum	12.5^0c
Average rainfall	1605 mm	
No. of park	6 (include 1 modernized)	
Solid waste Generation and disposal	450 metric tons averagely	

(Source: Khulna City Corporation 2019)

3.2 Environmental State of KCC

The existing scenario of the study area, Khulna City Corporation (KCC) is collected via survey and site inventory. With the collected data from survey study, required analysis is brought out related to the environment. Besides the survey data, some secondary data have also collected. For example, the data related to temperature, annual rainfall in CM (Centimeter), DEM data, Salinity data, structural uses, road etc.

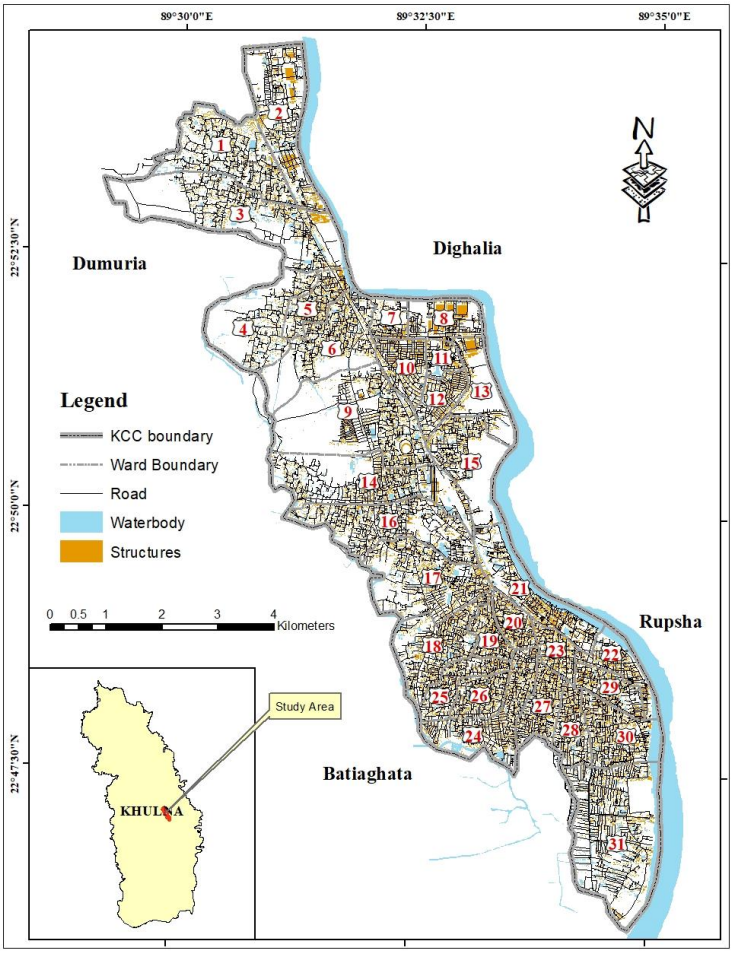

Figure 1 Khulna City Corporation (Study Area)**,** *Source: Author 2019*

3.3 Data Collection

Required data for the analysis related to the environment of the study area are collected via social survey and site inventory. Some secondary data from different author are also collected related to the study. The data that are collected are as follows:

Table 2 Required Data

Sl No.	Data Name	Data Type	Data Source
1	Population	Secondary	KCC
2	GIS shape files	Secondary	Author
3	Site information	Primary	Field Survey

(Source: Author, 2019)

3.4 Data Preparation

Required shape files for GIS based spatial analysis are prepared. The shape files were created from the map that is provided by KCC authority. The shape files that are prepared or collected for this study are as follows:

Table 3 Data preparation for analysis

SL No	Data	Type	Co-ordinate system	Source
1	Roads	.shp	WGS 1984 46N	Author 2019
2	Structures	.shp	WGS 1984 46N	Author 2019
3	Waterbodies	.shp	WGS 1984 46N	Author 2019
4	KCC boundary & ward boundary	.shp	WGS 1984 46N	Author 2019
5	Salinity	.ppt	WGS 1984 46N	Author 2019
6	DEM (Digital Elevation Model)	.shp	WGS 1984 46N	KCC

3.5 Data Analysis and Interpretation

With the collected data, various analyses related to the environment have brought. These analyses are done and solved by ArcGIS using various analytical tools and necessary calculations. Prepared data were filtered to check error and eliminate errors. Topology check for road data were done under two criteria such as “Must not have dongles” and “Must not have so nodes”. An error that is determined is eliminated by trimming line and extending line where necessary. Besides salinity data were converted to .shp format and classified into three classes based on the salinity present on the water. The salinity range is determined depending on the experts’ opinion. Although the range (8.65-9.80 g/kg) for low saline almost brackish water and unsuitable for the household and industrial production uses, according to the experts’ whom have given their opinion we can use it as low saline for the study area as an alternative of brackish water.

Salinity Range (g/kg)	Salinity Range (mg/l)	Salinity Type
10.80 - 11.72	**10800-11720**	High Saline (Brine water)
9.80 - 10.80	**9800-10800**	Moderate Saline
8.65- 9.80	**8650-9800**	Low saline (brackish water)

(Source: Expert Opinion Survey 2019)

From the road data, a new road network data set has been prepared which contains road edges and junctions. The data set has taken the road line as edges and intersection and turning as junctions. From the prepared waterbodies and ward data, ward wise waterbodies are calculated depending on the type of the waterbodies. Then these were merged with the saline shapes to determine if the source contains saline or not. From the structural data, water supply source for drinking purposes are identified and determined ward wise. After the identification, the service area of water supply sources is determined using network analyst tools. Here the standard that used for the service area is 200m, by Private Residential Housing Regulations 2012. Then from the whole KCC, the served area is erased and the

unserved area is determined. Then the served and unserved layer is merged with the salinity data set to determine the saline water sources. After that, possible shortest path to supply water to the unserved area are determined from network analyst tools. From the service area and salinity merged data, it is easier to recommend where to install new water sources for drinking and household uses.

4. FINDINGS AND RECOMMENDATION

In this research the water bodies that are determined are ditch, pond, river, khal, lake and beel. On the other hand, the water supply installation that are considered be water pump, overhead water tank, tube well and other community water sources.

4.1 Existing Waterbodies Analysis

From the field survey, about 3813 water bodies including 1028 ponds can be identified. Most of them are used for bathing, pisci-culture and also for fish production. The usage of the ponds gives an idea

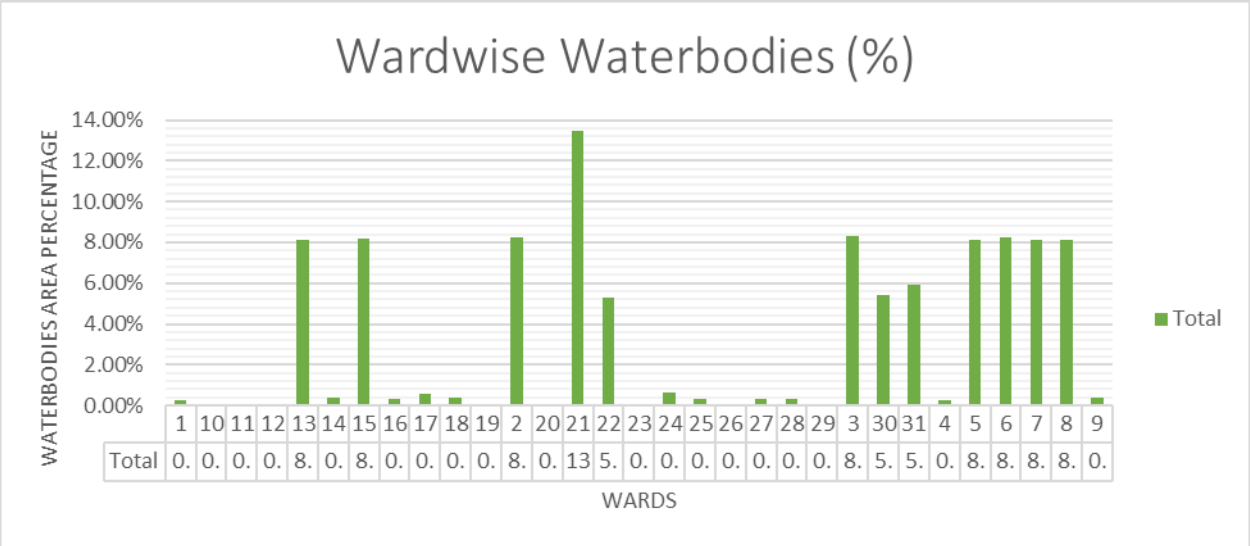

Figure 2 Ward wise Waterbodies Analysis**,** *Source: Author 2019*

about the quality of the water and the pollution extent of the water. The water of the pond is not potable but the ecosystem is the fish production oriented. These are opened for public uses. These waterbodies major function is during rainy weather, draining the rain water from the high land besides it.

Table 4 Ward wise Waterbodies Salinity

Wards	No Saline	Low Saline	Moderately Saline	High Saline	Grand Total
1	0.01%	4.83%	0.00%	0.00%	**4.84%**
2	0.01%	4.72%	0.00%	0.00%	**4.73%**
3	0.01%	7.93%	0.00%	0.00%	**7.94%**
4	0.01%	0.40%	3.92%	0.08%	**4.42%**
5	0.00%	0.70%	0.99%	0.00%	**1.68%**
6	0.01%	0.28%	3.84%	0.56%	**4.69%**
7	0.00%	0.13%	0.89%	0.00%	**1.02%**
8	0.00%	0.00%	2.05%	0.00%	**2.05%**
9	0.00%	0.00%	4.63%	3.05%	**7.69%**
10	0.00%	0.00%	1.76%	0.00%	**1.76%**
11	0.00%	0.00%	0.79%	0.00%	**0.79%**

Wards	No Saline	Low Saline	Moderately Saline	High Saline	Grand Total
12	0.00%	0.00%	1.43%	0.00%	**1.43%**
13	0.00%	0.00%	2.43%	0.00%	**2.43%**
14	0.00%	0.00%	0.07%	5.77%	**5.84%**
15	0.00%	0.00%	3.05%	0.55%	**3.60%**
16	0.01%	0.00%	0.00%	4.89%	**4.89%**
17	0.01%	0.00%	0.00%	4.99%	**4.99%**
18	0.00%	0.00%	0.00%	3.51%	**3.51%**
19	0.00%	0.00%	0.00%	1.07%	**1.07%**
20	0.00%	0.00%	0.00%	1.08%	**1.08%**
21	0.00%	0.00%	0.00%	3.74%	**3.75%**
22	0.00%	0.00%	0.00%	1.79%	**1.79%**
23	0.00%	0.00%	0.00%	1.11%	**1.11%**
24	0.01%	0.00%	0.00%	3.64%	**3.64%**
25	0.00%	0.00%	0.00%	1.65%	**1.66%**
26	0.00%	0.00%	0.00%	1.44%	**1.44%**
27	0.00%	0.00%	0.00%	1.76%	**1.76%**
28	0.00%	0.00%	0.00%	1.60%	**1.60%**
29	0.00%	0.00%	0.00%	1.43%	**1.43%**
30	0.00%	0.00%	0.00%	2.87%	**2.87%**
31	0.02%	0.00%	0.00%	8.45%	**8.47%**
Grand Total	**0.11%**	**18.99%**	**25.85%**	**55.05%**	**100.00%**

(Source: Author 2019)

From the table we have get results about the salinity of waterbodies wardwise and we notice that total no saline quantity is 0.11%, low saline quantity is 18.99%, moderate saline is about 25.85% and lastly the high saline quantity is about 55.05%. It is clarified that most of the waterbodies contain high saline water. Waterbodies of 31 ward contain more saline (8.47%) than other wards and on the contrary waterbodies of 11 no ward contains low saline (0.79%) than others.

4.2 Water Supply Analysis

There is community water tube well and other water source for the purpose of providing drinking water. Again, from the service area by network analysis, it is clarifying that about 25% of the area still

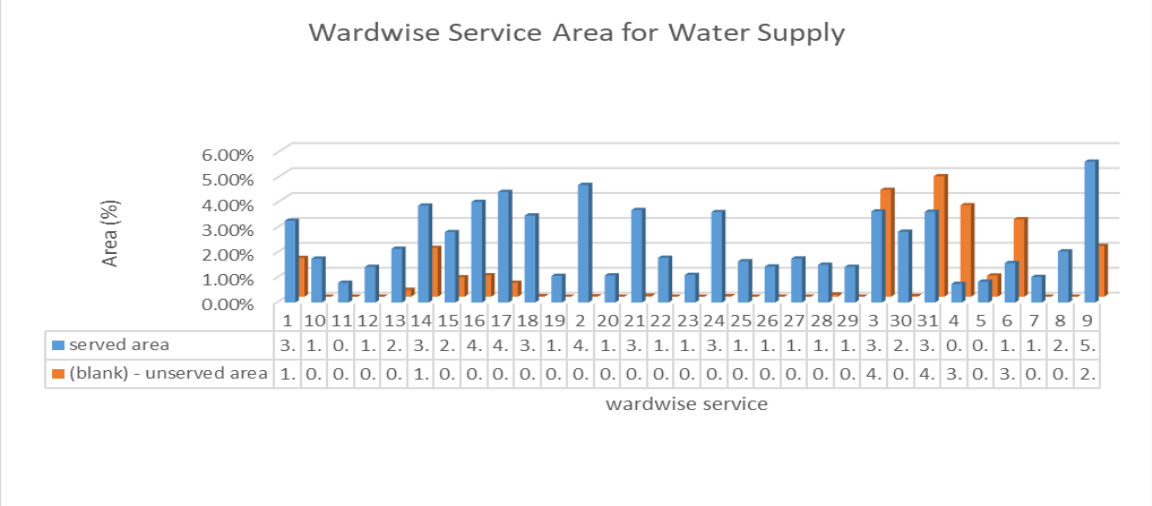

Figure 3 Ward wise Service Area for Water Supply *(Source: Author 2019)*

doesn't get the service of these community water sources. It is necessary to provide more deep tube wells or community water resources to provide optimum services in the purpose of drinking water.

Table 5 The Salinity portion of unserved area

Wards	No Saline	High Saline	Moderately Saline	Low Saline	Grand Total
1	0.03%	6.20%	0.00%	0.00%	6.23%
2	0.00%	0.06%	0.00%	0.00%	0.06%
3	0.05%	17.13%	0.00%	0.00%	17.18%
4	0.03%	0.00%	14.36%	0.32%	14.71%
5	0.00%	0.05%	3.34%	0.00%	3.39%
6	0.02%	0.00%	10.17%	2.26%	12.45%
9	0.01%	0.00%	1.43%	6.72%	8.16%
13	0.00%	0.00%	1.10%	0.00%	1.11%
14	0.01%	0.00%	0.00%	7.82%	7.83%
15	0.02%	0.00%	2.69%	0.41%	3.12%
16	0.03%	0.00%	0.00%	3.41%	3.43%
17	0.02%	0.00%	0.00%	2.20%	2.23%
18	0.00%	0.00%	0.00%	0.09%	0.09%
21	0.00%	0.00%	0.00%	0.14%	0.14%
24	0.00%	0.00%	0.00%	0.06%	0.07%
28	0.00%	0.00%	0.00%	0.33%	0.33%
30	0.00%	0.00%	0.00%	0.12%	0.12%
31	0.08%	0.00%	0.00%	19.29%	19.36%
Grand Total	**0.29%**	**23.44%**	**33.09%**	**43.18%**	**100.00%**

(Source: Author 2019)

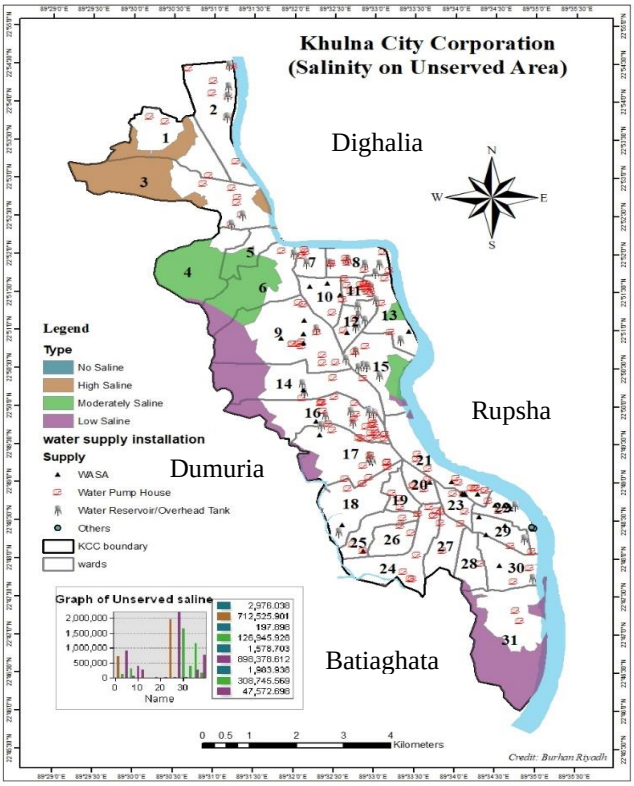

Figure 4 Unserved Area Salinity Ward wise, *Source: Author 2019*

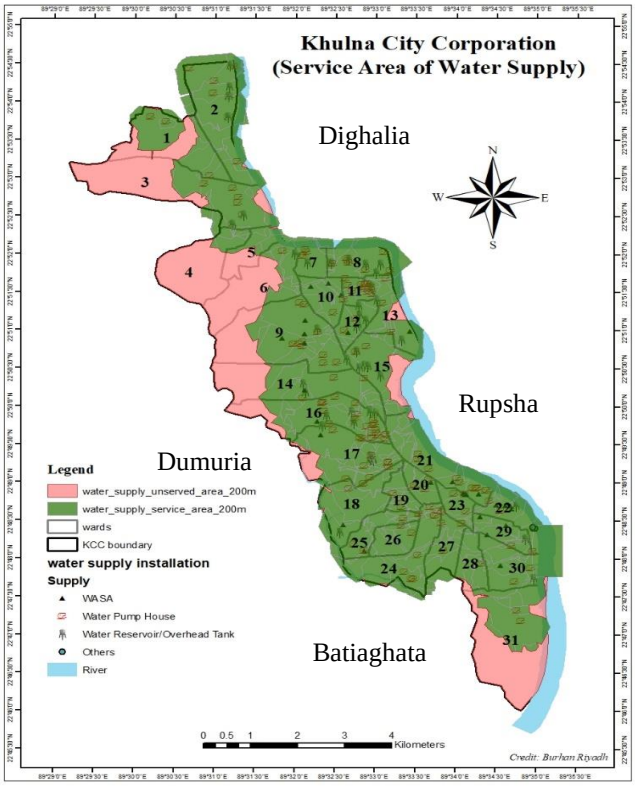

Figure 5 Service Area of Water Supply Ward wise, *Source: Author 2019*

From network analysis it is seen in Figure 4 and 5 that 25% unserved area and about 18 wards have partially unserved area. In this unserved area, we notice that 43.18% areas contain low saline. To establish more water sources for water supply, this mentioned low saline areas can be recommended, which is also shown in the map.

It is visualized from the map (Figure 6) that the shortest path from low salinity areas to high salinity areas. It allows DEM elevation for finding the shortest path and this also essential for reduce salinity problems. Following the shortest path for water supply will reduce the cost of installation of the supply system. Besides, for efficient water supply, it is necessary to follow the shortest pattern and low land.

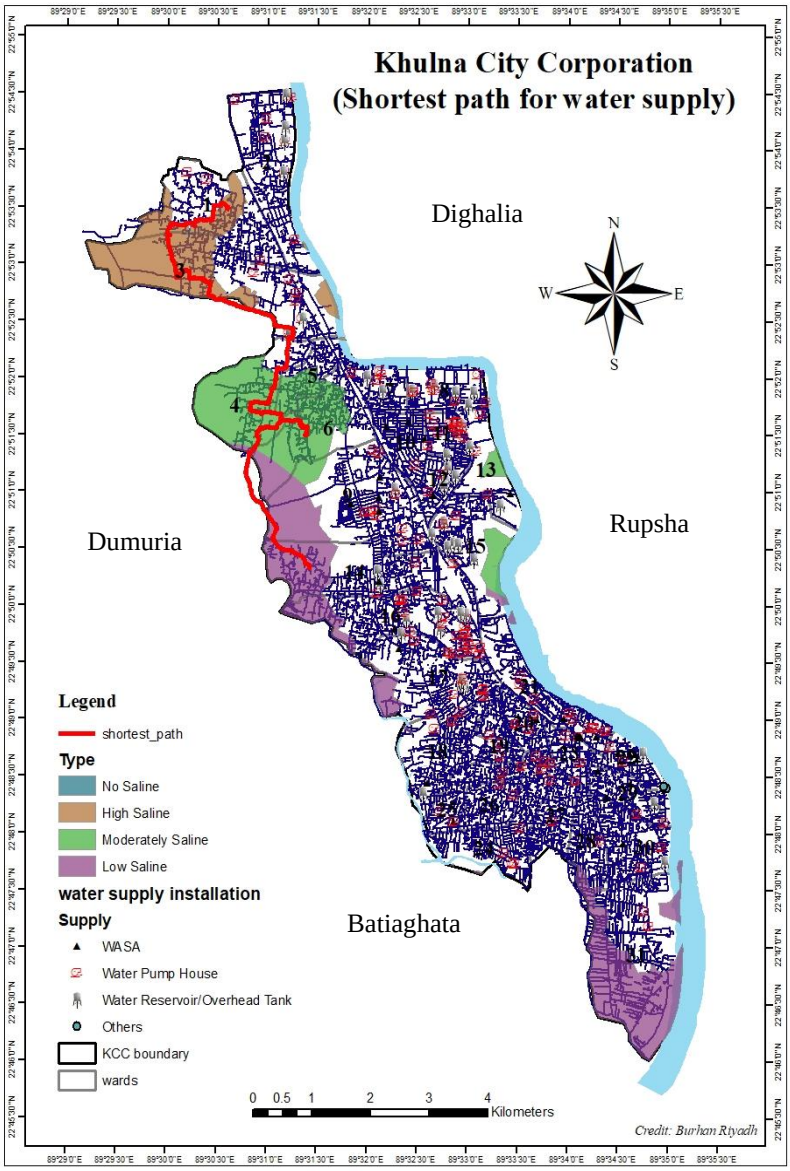

Figure 6 Shortest Path for Water Supply from Low to High Saline Zone,
Source: Author 2019

5. CONCLUSIONS

Water and soil salinity are a communal problem in different coastal districts of Bangladesh and Khulna is one of the districts where water salinity is found more than other regions. Salinity roots various types of dangerous diseases which in the future leads to death and it is also accountable for human migration. With a growing concern for rising salinity, awareness and interest in climate change

impacts on water sources are also increasing. This study associates us to about the water condition for each ward and salinity condition and we become aware about particular wards which are confined in high salinity areas and these areas are threatened for human health and human living. The result shows that most of Ward 3 has a high saline than others. Almost 17.3% of the total KCC area are found as high saline in Ward 3. On the other hand, most of the area in Ward 4, 6 and 13 are low saline affected. The final result of the study suggests to define a water supply installation path newly to serve the high saline unserved areas of KCC.

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