SIMULATION OF URBAN DRAINAGE SYSTEM IN *SAID UL AJAIB*, NEW DELHI USING GIS SOFTWARE

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BY

DEVANSHI GARG

(2K19/HFE/17)

Under the supervision of

DR. T VIJAYA KUMAR

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

(Formerly Delhi College of Engineering)
MAIN BAWANA ROAD, DELHI-110042

AUGUST 2021

DELHI TECHNOLOGICAL UNIVERSITY

DELHI- 110042

CERTIFICATE

This is to certify that the dissertation entitled, "SIMULATION OF URBANDRAINAGE SYSTEM IN *SAID UL AJAIB*, NEW DELHI USING GIS SOFTWARE" being submitted by DEVANSHI GARG for the award of the degree of Master of Technology (HYDRAULICS AND WATER RESOURCE ENGINEERING) of DELHI TECHNOLOGICAL UNIVERSITY, is a record of bona fide research work carried out by her under my supervision and guidance. The contents of this thesis, in full or part, have not been submitted to any other university or institution for the award of any degree or diploma.

DEVANSHI GARG

(2K19/HFE/17)

DR. T VIJAYA KUMAR

DEPARTMENT OF CIVIL ENGINEERING

DELHI TECHNOLOGICAL UNIVERSITY

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With immense pleasure I, Ms. **DEVANSHI GARG** presenting **"Simulation of Urban Drainage System in *Said Ul Ajaib*, New Delhi Using GIS Software"** report as part of the Curriculum of 'Master of Technology' I wish to thank all the people who gave me unending support. While bringing out this thesis to its final form, I came across a number of people whose contributions in various ways helped my field of research and they deserve special thanks. It is a pleasure to convey my gratitude to all of them.

I would like to express my deep sense of gratitude and indebtedness to my supervisor **DR. T VIJAYA KUMAR** for his invaluable encouragement, suggestions and support. I acknowledge him for his advice, supervision, and the vital contribution as and when required during this research.

DEVANSHI GARG
(2K19/HFE/17)

ABSTRACT

Rapid urbanization has opened the way to congested cities such as New Delhi, Mumbai etc. and has been very challenging for urban drainage systems. Poorly designed urban drainage systems, congestion of the stream channel, overcrowding, expansion of urban infrastructure without appropriate consideration of drainage issues, increase in paved surfaces, and climatic conditions are the major causes of these disasters. As a response of these circumstances, flash floods occur, resulting in both ground and surface water quality deterioration. In order to have better results, competent planning, analysis, and design of urban drainage skills are expected. In this study, ArcGIS software is used to simulate the urban drainage system. The rainfall data required is gathered from Irrigation and Flood Control Department, Delhi. For a drainage region in *SAID UL AJAIB*, near Saket metro station, Delhi, India, the simulation was done to understand problems associated with inadequate urban drainage. From the results obtained, it was seen that some parts of Sail ul Ajaib area are frequently affected by flooding.

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GLOSSARY OF TERMS

GIS	Geographic Information System
RS	Remote Sensing
LULC	Land use/Land cover
DEM	Digital Elevation Map
NCT	National Capital Territory

CHAPTER 1

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Flash floods are caused by surface runoff that are accompanied by excess and unpredicted torrential rains. Because there are few impermeable barriers in rural regions and a small population, runoff water is easily absorbed by the earth. However, in light of potential changes in its quantitative and qualitative management within urban water systems, surface runoff from impermeable regions is currently a hot topic. Historically, runoff water was thought to be unneeded since contaminants abound in the streams that flow through impermeable surfaces. It was recommended that the water be collected as soon as possible and drained from the metropolitan areas.

Nonetheless, over the last decade, the topic of urban water system sustainability has received more attention, not just from an ecological standpoint, but also from a social and economic one. A sustainable urban water system, also known as a stormwater system, might have been a matter of not only avoiding unique challenges and unanticipated material in the water, but also of its potential utility as a water resource in society. Due to the obvious massive depletion of water resources, stormwater drainage systems may be construed not only as systems to redirect unwanted water from urban areas, but also as a vital feature for beautifying the spaces around buildings and roadways. The purpose of this article is to provide an overview of different sustainable stormwater management studies that are reportedly being undertaken in India.

1.2 IMPLEMENTING STORMWATER MANAGEMENT IN DEVELOPING COUNTRIES

As discussed earlier developing countries face a bunch of issues in managing any socio-economic problems due to its rapidly increasing urban population, sudden commute in climatic conditions and fluctuations in the economy. This makes it difficult to implement solutions for issues like greater capacity to generate runoff, increased erosive capacities, favorable conditions of diseases, all of which are tied to rampant urban expansion. Apart from the economic damages caused, environmental degradation is also a bone of contention that hasn't yet dissolved. A few of the dangerous environmental degradations are caused due to sedimentation and poor solid waste management which contributes to the dissemination of diseases to the population. Hence it is essential that we prevent runoff generation and other such disasters atthe initial stage rather suffering from its aftermath.

1.3 STORMWATER MANAGEMENT IN INDIA

India is the second largest populated country in this entire globe and is still amongst one of the developing nations. Every developing nation is subjected to numerous cultural, social and economic changes such as, Low per capita income, The existence of protracted levels of unemployment, and maybe even some heavy population pressures, Lack of basic establishments, low level of technology, etc. Among these issues, rise in population is one of the debated topics of this era.

As it is predicted that urban population in India will rise up to 57% within 2036 and a decline in rural population, many problems related to congestion willarise.

Unplanned growth of urban population is affecting the natural drainage surface and water drainage system. Thus, short duration intense rainfall causes flash floods from altered catchments of urban areas. Unlike normal flooding these types of floods are unpredictable and intense. It not only affects the areas that are prone to flood making unpredictable and uncontrollable. Serious economic, social environmental impacts are caused so it is necessary to drain this water efficiently. Storm water drains are installed to effectively drain the runoff water to the outlet points that is into rivers or lakes. Hence it becomes essential to planand design an effective drainage system to serve this purpose. In this study ArcGIS software is used to plan, design and generate a storm water model for thefollowing study area, SAID UL AJAIB, near Saket metro station, Delhi, India.

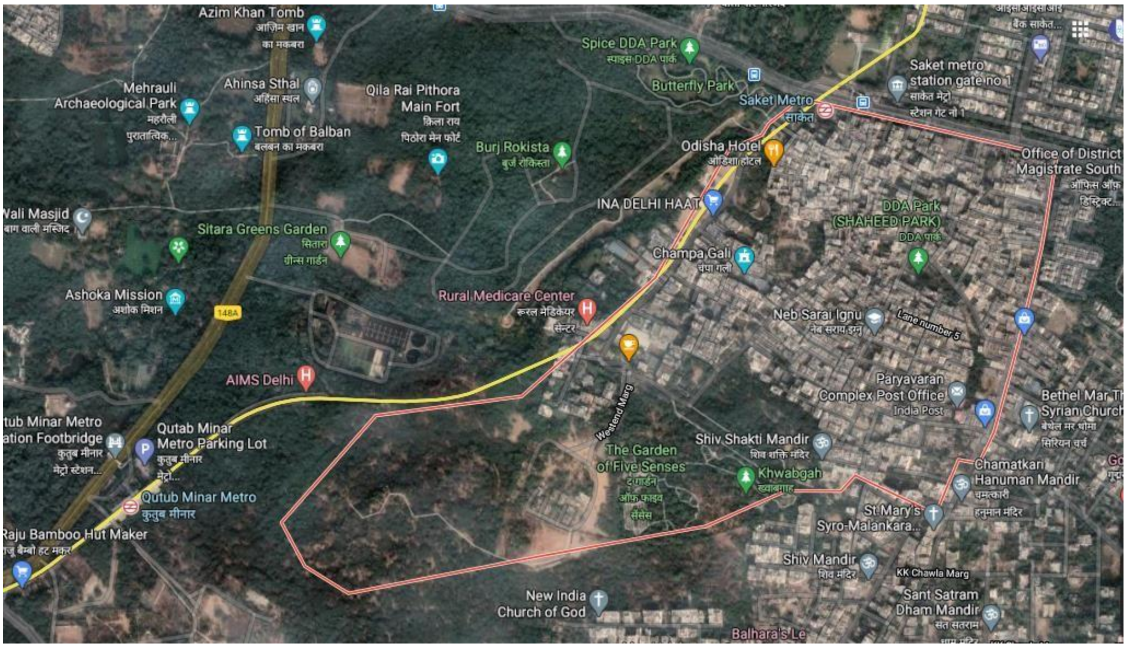

Fig.1 Location map of SAID UL AJAIB

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CHAPTER 2

CHAPTER 2

2.1 LITERATURE REVIEW

World Meteorological Organization (2013), in Associated Programme on Flood Management, Switzerland states that floods of various magnitudes may be replicated using GIS software, RS (microwave and optical satellite pictures), hydrological, and hydraulic data. For detailed flood assessment, the modelling technique is commonly employed. The floods for 20,30 or 100years can be predicted mathematically. To produce flood hazard maps, the modelling technique uses geographic data such topography, land use and land cover, bathymetry; hydrological/hydraulic data include river discharge, rainfall, peak discharge, water velocity and amplitude; soil geology, and so on. Models of flood plain are represented in different dimensions using mapping systems.

P. Sayers et al (2013) studied that given the spatiotemporal nature of satellite data and the use of satellite images in conjunction with software, the modelling technique has the benefit of being able to be applied over a broad region in a relatively short amount of time. It allows for direct 23 flood event observations as well as flood event and behavior prediction. Optical satellite imaging has the drawback of requiring cloud-free occurrences, being obtained only during the daylight, and being unable to penetrate flooded regions under tree canopies. This is not a concern with microwave aerial surveillance.

T. KAFLE et al (2007) assessed the flood plain of Bagmati river in Nepal. Combining GIS with other data sources like RS and hydraulic and hydrological facts are used by several authors to create flood models. Due to the cyclic calculations required to perform the hydrologic – GIS combo is comparatively intense and expensive, but it serves as an ideal answer if the goal is to calibrate depth of water flowing, water flow rate and the water discharge.

The Advanced Spaceborne Thermal Emission and Reflection (ASTER) image in conjunction with the Hydrologic Engineering Centre River Analysis System (HEC-RAS) were availed to acknowledge areas with high flood risk by flood simulation through the rivers and the discharge plains. that made reference to the ASTER image. The maximum annual instantaneous discharges for the years 1965–2004 were used to achieve this. Water quality index and hazard mapping in the Bagmati River flood plain in Nepal were carried out.

Ologunorisa (2004) analyzed flood susceptibility in the Delta areas of Niger with a hydrological approach based on measurable physical aspects of flooding, observed flood frequency, elevation, and vulnerability variables (social-economic). The criteria were applied to 18 towns chosen at random from three ecological zones in the region. Severe flood danger zones, moderate flood risk zones, and low flood risk zones were discovered as a result of the research.

Karagiozi et al (2011) employed hydrological models in a GIS context to conduct flood hazard assessment in the chosen area. Research was proceeded while considering geographical characteristics of the study area. The hydrographic network and hydrological basins layer were constructed using a DEM as input data to the Arc hydro model.

Ar. K. Lavanya (2012) discussed the factors that are affecting the flood risks in Chennai and different strategies to reduce the flood risks. Whilst Tamil Nadu is not flood prone, a few low-lying territories well within state are unfortified to natural disasters, which is caused largely by constructions near major drainage systems, encroachment of water bodies, inability of major canals to handle severe floods, and overflowing reservoirs. Chennai, one of the fastest-growing metros, is projected to be damaged by a drainage deficit due to uncontrolled expansions of concrete areas, encroachment of critical drainage routes, shrinkage of marshlands, and other causes. This traces the development of flood dangers in Chennai, as well as the critical need for effective flood risk reduction and management methods.

Forkuo (2011) A practical and cost-effective mapping of flood hazard occurring in the northern part of Ghana's and Atonsu, was helped build by using level 1b ASTER photos to produce contours and elevation. He also created a 1:50000 scale topographic map and a land cover map for the research region. He then used a GIS environment to assimilate the produced maps and demographic data to build a zonal map that shows floodable spots in every sole district.

Fosu (2011) made use of digital elevation models for watershed and flood hazard mapping. Aster image, contour generated from DEM, geometric data extracted from DEM, topographic map and field measurements collections, and the HEC-RAS model are preconceived model of flood management along the Susan River. The topographic maps were combined with the coalescing geometric data to create a danger map that encompassed an area of roughly 2.93 km^2, and a maximum water level of 4.02 meters was suggested. This highwater level developed throughout the channel and subsequently extended to the floodplains.

Sinha et al (2008) used Analytical Hierarchy Process (a multi-parametric method) to combine geomorphological, geographic, topographic, and sociological (population density) characteristics to propose a Flood Risk Index (FRI) in a GIS context in the Kosi river basin in North Bihar, India.

District level maps, topographic maps, and census data from 1991 were utilized, as well as digital elevation data (GTOPO30) and digital remote sensing pictures Liss-IV and Liss-III.

Georgakakos et al (1997) estimated flash flood potential for large areas. GIS would be used to integrate digital spatial data, remotely sensed data, and physically-based hydrological, hydraulic models of watershed response to predict the possibility for flash floods across broad regions. The most effective mode of determination of volume of rainfall an index called runoff threshold was implemented. This mechanism is extremely good for very vast regions and areas with poor or non-existent hydrological data, such as Ghana, because of the accessibility of ready satellite imagery (eg. Landsat) and very easy to collect.

Ghana Statistical Service (GSS) (2012) states that detailed status updates are required by decision makers and rescue personnel during floods in order to identify flood-affected regions, conduct rescue operations, and adopt mitigating appraise. The status reports provide correct and up-to-date information. Remote sensing aids in rapid flood damage evaluation even when other more modern and compliable methods of imagery and data gathering are available. "The facts collected about something, a region or any phenomena through research of the data without having any physical contact is a science and art of Remote sensing". Sensors that operate in the visible and microwave spectral ranges are used.

In a GIS setting, the coupling of techniques of remote sensing and other data enable the speedy grouping and dispersion of quantitative information covering broad regions.

Information obtained via the use of these techniques may be utilized to analyze and simulate the contemporary damage picture, evaluate processes and trends, and pose questions for flood-affected regions' rehabilitation.

Long et al (2014) analyzed the Chobe floodplain in Namibia's Caprivi area using change detection and thresholding (CDAT) with synthetic aperture radar (SAR) images to show the concentrations of flooding. Using ENVISAT/ASAR and Radarsat-2 satellite pictures, change detection and thresholding algorithms such as image subtraction, decision-based classification using threshold values, and adaptive filtering and segmentation were fully exploited to assess the amount of flooding during seasonal rainfall in the area.

Suhyung Jang et al (2007) said that to limit the threat of urban growth, a hydrologic impact assessment is required for a planned development region while building detention storage for urban drainage systems. In this work, the use of the Storm Water Management Model (SWMM) to couple single or two hydrologic models for pre- and post-development sort of situations is recommended. The new technique can overcome the irrationalities that might emerge when two distinct models are combined, such as lesser peak flow and longer time to peak for post-development conditions, according to the results of former evaluations done for the same sites.

Allison H. Roy et al (2008) If autonomous stormwater management methods such as low impact development (LID) or water sensitive urban design (WSUD) are applied at a watershed size, then they would also provide a better long-term solution to stormwater management. Ponding water, infiltration and collection of water at their source, facilitating evaporation, evapotranspiration, recharge water in the ground, and reusing of sewage fluids are enabled by these technologies. This paper shows different obstacles to sustainable urban stormwater management: (1) performance and cost uncertainties, (2) insufficient engineering policies and regulations, (3) fragmented responsibilities, (4) institutional capacity, (5) legislative ignorance, (6) underfunding and market reliable incentives, and (7) unwillingness to accept change. Finally, we'll look at how to overcome each of the seven roadblocks.

Nivedita G Gogate and Pratap M Rawal (2012) According to them, in India, rapid urbanization and unregulated changing lifestyles have made urban water management a difficult task. The primary issues that emerging countries confront are as follows:

The following issues were identified: (i) Inadequate considerations of acceptable stormwater reuse alternatives, (ii) Lack of institutional co-ordination, (iii) Conventional centralized decision-making procedures, and (iv) Inadequate considerations of environmental management complexity. A comprehensive micro-level analysis for a watershed in Pune will be carried out to assess the current conditions, applicability of LID approaches, and overall stormwater management in a sustainable manner.

G. Krebs et al (2013) developed and implemented low impact development (LID) technologies and green infrastructure methods to reduce the effects of urbanization on rising runoff and pollutant wash off. The current work is the first step in a bigger project to use the Stormwater Management Model to up-scale high-resolution research catchments and simulate LID scenarios for a large-scale urban catchment (SWMM). The setup, calibration, validation, and results of a parameter sensitivity analysis of a high-resolution SWMM model for a heavily urbanized small catchment in Southern Finland are presented in this work.

Koo, Young Mina Seo, Dongila (2017) According to them, given the widespread use of hydrological models to evaluate and plan for surface runoff during storm events, the accuracy of the projected outcomes has been questioned due to a scarcity of field data for model calibration. Using an automated monitoring system, intensive field measurements were taken for storm incidences in a sub-basin of the Gwanpyung cheon, Daejeon, Republic of Korea, between July 2015 and July 2016. A system, as well as manual measurements Continuous precipitation and surface runoff data were utilized to increase the accuracy of the SWMM model's prognostication of stream flow during storm occurrences.

Bryant E. McDonnell et al (2020) used the Rainwater Collection Model (SWMM) of the US Department of Environment (EPA) which is a vibrant rainfall-runoff model to simulate single-event or long-term hydrologic, hydraulic, and water quality simulations. It is widely used for drainage system planning, analysis, and design all over the world. The modeler cannot interact with the SWMM model during simulation time or access all of the simulated data and outcomes with the EPA distribution of SWMM. Several libraries have been built during the last decade to read, parse, and run SWMM models (*.inp). These tools were founded using a range of computer languages, including Python, R, MATLAB, and Visual Basic.

Amarpreet Singh Arora (2017) outlines a plan to manage urban stormwater and sewage that solves the problems and difficulties related to long-term urban water management. This model suggests isolating sewage into black water and greywater, as well as stormwater-greywater system integration at the urban sub-watershed level. During dry periods, this system will solely handle greywater, reclaiming it as reclaimed water to be used in place of the fresh water source. During rainy weather, the system will collect and treat both storm water and greywater, with any excess treated water being disposed of via groundwater recharge.

Sanjay B. Parmar, Prof. Vikash D. Bhavsar (2017) used Stormwater management to reduce or eliminate stormwater runoff's harmful effects. This strategy is being utilized in Gandhinagar to prepare for the prevention of stormwater effects. Industrial and residual sewage systems have already contaminated the river or lake. Vehicle oil and grease, metal, sediments, nitrogen, garbage, phosphate, pesticides, bacteria, and other pollutants contaminate stormwater runoff on the ground surface. Land infiltration is reduced as a result of urbanization, and floods produces scouring and waterlogging. This report highlights the use of management principles to reduce stormwater effect, as well as the use of stormwater to sustain green infrastructure and absorb into the earth.

The next step is to pinpoint the source of the problem and recommend BMPs.

Vinay Ashok Rangari et al (2018) used Storm water modelling is extremely crucial for detecting vulnerabilities such as flash floods and poor urban water quality. For modelling floods in metropolitan settings, the SWMM (Storm Water Management Model) is shown to be a useful tool. A SWMM model is constructed in this study to assess the drainage network for the National Institute of Technology, Warangal campus in Warangal, Telangana, India. For processing spatial data at the same time, GIS technique is used. According to the findings, flooding is a regular occurrence on campus in several areas., Within a week of two design storms and one day of continuous rainfall/precipitation measurements are analyzed.

Ali Moafi Rabori Reza Ghazavi (2018) The massive goal of this research was to show how to use the Storm Water Management Model (SWMM) to predict urban floods in a semiarid region (Zanjan city in the northwest of Iran). In the research region, the performance of an urban drainage system was also studied. In this work, a calibrated model was used to mimic urban peak flow with sufficient accuracy. The capacity of the major canals in the research region is sufficient for peak runoff transferring for a design storm with 50year return periods, according to the results of the model simulation. Localized and surface flooding has been seen in several metropolitan locations, based on local sightings and model results.

Zuxin Xu et al (2019) simulated the runoff of two typical urban green land types in Shanghai with the Stormwater Management Model (SWMM). Runoff sensitivity was analyzed and runoff parameters were calibrated. The capacity of the major canals in the proposed network is sufficient for peak runoff transferring for a design storm with 50-year return periods, according to the results of the model simulation. Localized and surface flooding has been seen in several metropolitan locations, based on local observations and model results.

2.2 OBJECTIVES

The main objectives of this study are

- To identify the problems associated with the study area as it has been a constant prey to flash floods which leads to water contamination.
- To collect both spatial data (for physical representation like shape, size or location of the study area) and non-spatial data (for eg. LULC maps) for this study.
- To present the stimulated model using GIS tool.
- To suggest the preventive measures to minimize stormwater disasters.

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CHAPTER 3

CHAPTER 3

METHODOLOGY

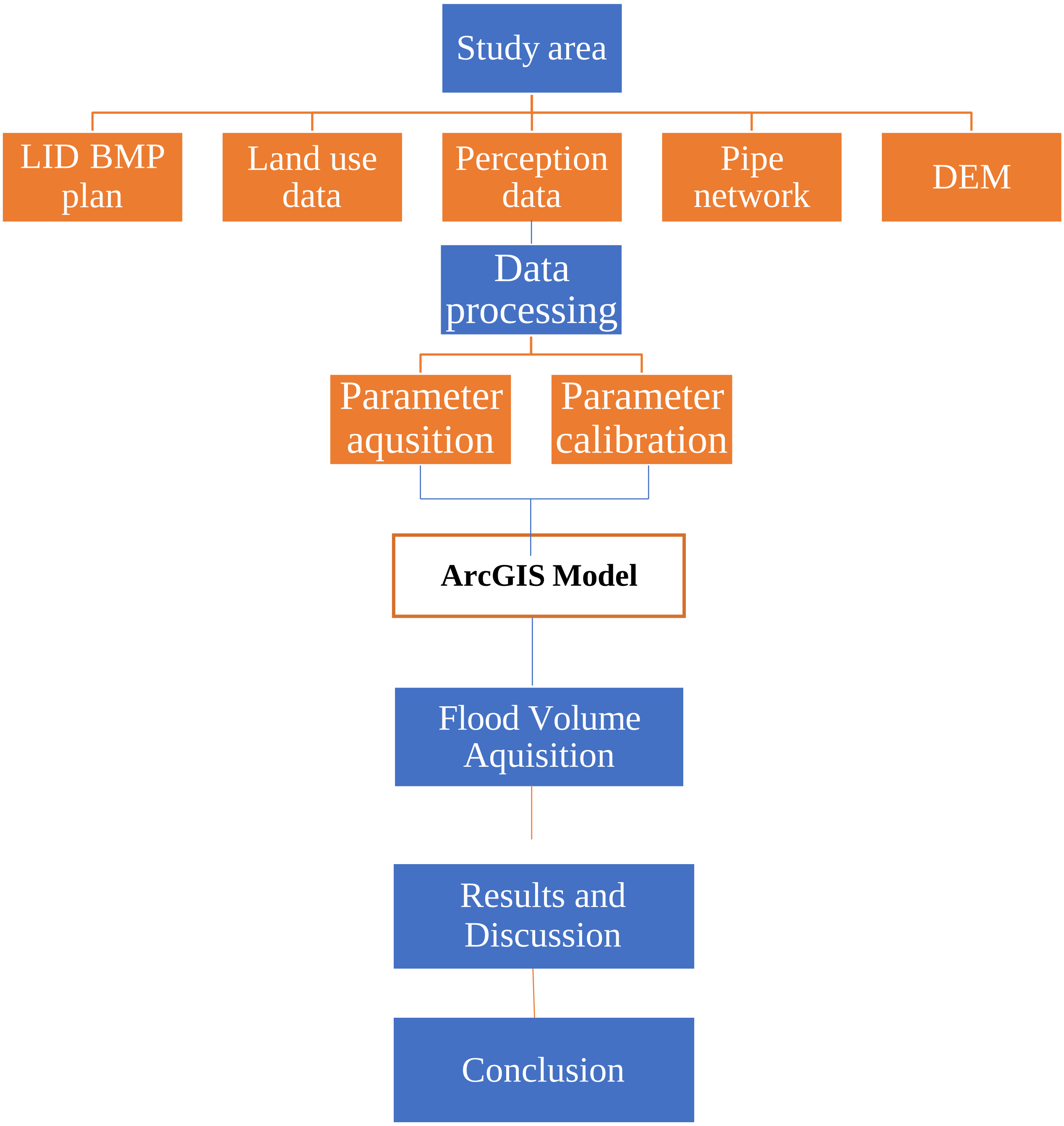

Fig. 2 Methodology Chart

In this study, ArcGIS software is used to plan, design and generate a storm water model for the following study area, SAID UL AJAIB, near Saket metro station, Delhi, India. Different data required is gathered from various agencies for the study area like the data for DEM (Digital Elevation Model) map were extracted from Cartosat 30 m DEM from Bhuvan and the study area's land use/cover map is derived from Landsat-8 satellite imagery. Rainfall data required is procured from Irrigation and Flood Control Department, Delhi.

Following steps were followed to process GIS data:

a) **Modifying existing GIS layers Converting Polylines to Polygons**:

Since the land cover GIS data were not collected solely for the stormwater management purposes (catchments need to be represented by closed polygons), some of the layers, for example: driveway layer, was represented by polylines inoriginal GIS layer. Such layers were converted to polygons.

b) **Removing Overlapped Areas:**

Moreover, some of the overlapping areas, for instance: between sidewalk and driveway layers, was removed in one of the layers in order to avoid double counting impervious areas.

c) **Adding Missing Topographic Features:**

To reduce the impact of data being collected a couple of years ago, some of the GIS layers need to be modified. For example, a few buildings may be built any time after collecting GIS data or due to human errors, some omission errors could happen in GIS data. Therefore, some missing topographic features were updatedby on-screen digitization.

d) **Processing existing GIS layers to produce Grass layer:**

The original GIS data did not have a layer that represents grass. Hence, all the existing GIS layers were merged into one layer. Then, grass area within each parcel was defined by using *Erase* function in ArcGIS, where Input Features = parcel boundary; Erase Features = merged layer; Output feature = grass.

e) Generating land cover information:

After processing GIS layers, land cover types were presented by the following five layers: 1) wooded area (tree), 2) building, 3) road, 4) driveway, and 5) grass. After producing these five land cover types in order to improve data quality, firstly, polygons were integrated if the area is smaller than 0.15 m, which removed smaller gaps between land cover types.

3.1 ArcGIS SOFTWARE

The Environmental Systems Research Institute maintains a geographic information system (GIS) system used to deal with maps and geographical information (Esri). The following are the main features of this software:

1.) to develop and use maps

2.) compiling location data.

3.) analyzes map information.

4.) sharing and receiving location information.

5.) the use of maps and accommodation information in other programs.

6.) to manage location data in a database.

Most varieties have been released so far when 10.6, 10.7, 10.8. In July 2020 Esri released ArcGIS 10.8.1 On October 21, 2020 Esri publicly announced that this will be the final release of ArcGIS Desktop. Its products will be licensed there till March 1, 2026, along with ArcMap. This announcement has confirmed the prediction that ArcGIS Pro (and related products) are scheduled to become a full-fledged ArcMap site. ArcGIS encompasses of the following Windows desktop software:

- Arc Reader is a program that lets you browse and query maps made with other ArcGIS products.;
- ArcGIS Desktop (sometimes known as "ArcMap" to distinguish it from

ArcGIS Pro) is a set of four apps that work together to create a map:

- ✓ ArcMap is a two-dimensional mapping program that allows you to examine and modify geographical data in two dimensions.
- ✓ Arc Scene, a local projected view for viewing and manipulating three-dimensional geographical data;
- ✓ Arc Globe is a graphical interface for big, global 3D information.
- ✓ ArcCatalog is a tool for managing and controlling and manipulating GIS data.

This new integrated GIS program, is slated to eventually replace ArcMap and its companion apps. ArcGIS Pro is a mapping and visualization program that uses Artificial Intelligence and works in 2D and 3D. (AI). The ArcGIS Enterprise bundle contains both server-based ArcGIS software and ArcGIS mobile applications for phones and tablets. Extensions for ArcGIS can be purchased separately to increase the software's functionality.

3.2 ORIGIN OF ArcGIS:

Prior to the release of the ArcGIS suite, Esri had created a variety of software for diverse components, including the command line Arc/INFO workstation, several graphical user interface-based products, such as the ArcView GIS 3.x desktop programme, Map Objects, a programming library for developers, and Arc SDE, a relational database management system. The products and services had branched out into several source trees and did not interface effectively with one another, necessitating the redesign of a single integrated programme that included all of the functionality.

3.3 DATA FORMATS

Data in the shapefile format was used in older Esri products. Advanced versions came with some restrictions on how data was handled. Spatial data in

ArcGIS is stored using a database architecture which stores data in object form and is based on a geodatabase. A geodatabase serves as a "container" for datasets. Geodatabases in ArcGIS can be saved in three distinct ways: as a file, as a folder, or as a database "the document.

"Enterprise geodatabase," "personal geodatabase," or "geodatabase" " (formerly known as an SDE or ArcSDE geodatabase). The information in a geodatabase file is saved in a folder with the. gdb suffix. The personal geodatabase format is not supported by ArcGIS Pro (which is a 64-bit programme), but it may be converted to supported formats using geoprocessing tools.

3.4 ABOUT GIS AND RS

The area of RS and GIS has grown fascinating in recent years, with fast growing prospects. Many organizations invest a significant amount of money in these areas. The issue therefore becomes, why have these disciplines become so significant in recent years? There are two primary causes behind this. 1) Nowadays, scientists, researchers, students, and even ordinary people are very interested in learning more about our surroundings. Environment here is the meaning of physical spacing and happenings around the research area. In other words, we've realized that physical space, as well as the data that describes it, is a part of our daily lives; nearly every decision we make is impacted or driven by some geographical fact. 2) Advances in cosmopolitan space technology (that provides enormous volumes of spatio technical imagery and data) combined with affordable computers and their respective softwares (which can process these data) have made Remote Sensing and GIS accessible to a growing number of people.

3.5 REMOTE SENSING

Gather facts about things, places and its features without any possible physical contact is termed as remote sensing. If we use this definition of Remote Sensing, a variety of devices, such as seismographs and fathometers, would be considered Remote Sensors. Seismographs can assess earthquake strength without coming into close touch with the epicenter. Fathometer can also measure without coming into contact with the ocean floor its breadth.

Modern Remote Sensing, on the other hand, refers to the use of reflected or emitted electromagnetic radiation to gather information about the earth's land and ocean surfaces. We may have a better grasp of Remote Sensing by looking at the definitions below: Remote sensing, according to **White (1977)**, encompasses all means for acquiring images or other kinds of electromagnetic recordings of the Earth's surface from a distance, as well as the treatment and processing of the image data.

The detection of EMR obtained from the target sources is the main concern of RS, inside the sensor instrument's range of view. This radiation might have come directly from the target area's many components, or it could have been solar energy reflected from them, or it could have been reflections of energy sent to the target area from the sensor itself. This radiation might have come from the various components of the target area, renewable radiation reflected from them, or reflections of radiation supplied to the target region by the sensing element itself. And per the American Culture of Motion capture, Satellite Imagery illustrations is created using a sensor other than (or in addition to) a customary camera to interpret a scene, such as digital scanning, and using radiations outside the perfectly natural radar range of the film and camera, such as microwave, radar, thermodynamic, infrared, ultraviolet, and hyperspectral, as well as special techniques. Agriculture, archaeology, forestry, geography, geology, and other fields are only a few examples.

Remote sensing is the science of perceiving the planet's surface from space using the parcels of land of electrical signals radiated, meant to reflect, or diffracted by the sensors particles in order to improve biodiversity conservation, land use, and environmental legislation, based on the current United Nations (95th Plenary Meeting, 3 December 1986). The practice of generating insights about the earth's sustainable resources layers from images acquired from an overhead standpoint, using electromagnetic energy reflected or emitted from the earth's surface in one or more part of the electromagnetic spectrum, according to **James B. Campbell (1996)**. As a result, the Remote Sensing stage entails:

- EMR source
- Energy transmission between the source and earth's surface.
- The impact of EMR on the environment.
- The Remote Sensor receives the energy transmitted from the surface via atmosphere.
- The sensor helps in the identification of energy.
- Sensor information transmission to ground station – Sensor data processing and analytics.
- Final available data for various sorts of applications

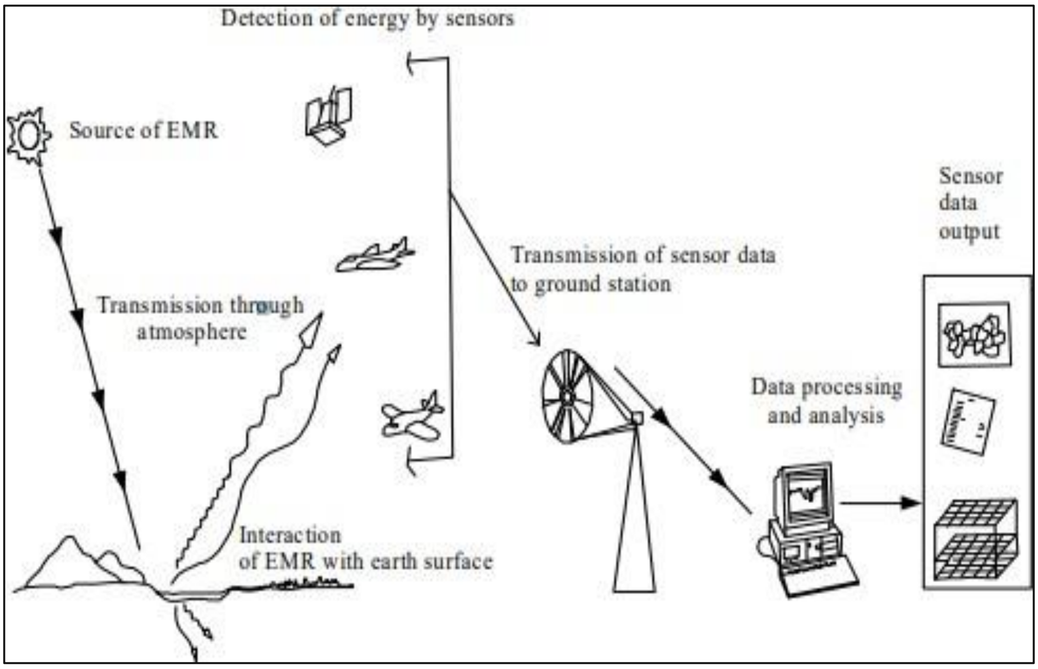

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Fig.3 Stages of remote sensing

3.5.1 Remote Sensors

Remote sensors are equipment that use electromagnetic energy reflected or transmitted from various things on the earth's surface to detect them. The sensors are mounted on the previously stated bases. Different spectral bands of electromagnetic radiation emanating from the planet's surface are recorded by different sensors. The most popular type of remote sensor that uses visual electromagnetic radiation is an ordinary camera.

3.6 GEOGRAPHICAL INFORMATION SYSTEM (GIS)

Geographic Information System (GIS) is a three-word acronym that stands for geographic information system, information system, and system. Geographical things or characteristics are those that can be related to a central location on the earth's surface. The item might be physical, natural, or cultural, created by humans. Similarly, the term "information" refers to a huge amount of data on a certain thing on the earth's surface. The data is made up of a variety of qualitative and quantitative characteristics that real-world items acquire. To invoke understanding and mode of handling a complex environment is broken down into fragments which are called as systems and the approach is known as systems approach. This approach aids in managing and making decisions. With the advent of powerful computer technology and software, this is now feasible in a relatively short period of time. As a result it is, a computer-based ariel and surface information system that associates various traits and features with geographic locations and aids in having forethought and liable decision-building. The term "geographic information system" (GIS) can be defined in a variety of ways. Geographic Information System (GIS) is a computerized system that streamlines the stages of data input, data analysis, and data presentation, especially when dealing with geo referenced data, according to the International

Training Centre (ITC) in Holland. GIS is described by the Indian Society of Geomatics (ISG) and the Indian Space Application Centre (ISRO) as a computerized system for integrating and analyzing diverse geoinformation data sets in order to create information relevant to planning needs in a context. GIS is a computer-based technique for mapping and analyzing objects that exist and events that occur on Earth, according to the Centre for Spatial Database Management and Solutions (CSDMS).

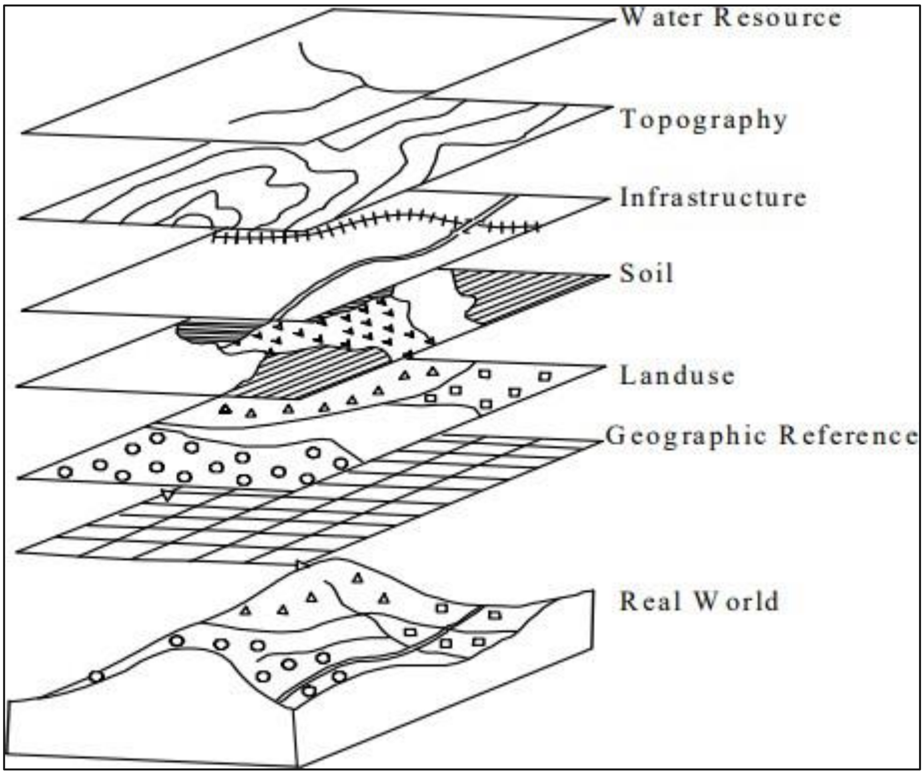

Image downloaded: https://wellesleyma.gov/224/GIS

Fig.4 GIS data- Thematic layers of a spatial features

GIS was described by **Burrough (1986)** as a set of tools for gathering, storing, accessing at will, manipulating, and presenting geographical data from the actual world for a certain set of purposes. GIS, according to **Aronoff (1989)**, is a computer-based system that handles geo-referenced data in four ways: data input, data management (data storage and retrieval), manipulation analysis, and data output. We may deduce from the preceding descriptions that a GIS user expects the system to assist them in entering geo-referenced data, analyzing it in various ways, and producing output (maps and other) from the data. Cartography, cognitive science, computer science, engineering, environmental sciences, geodesy, landscape architecture, law, photogrammetry, public policy, remote sensing, statistics, and surveying all contribute concepts and ideas to GIS. As a result, it studies not only the basic challenges that arise from the generation, management, storage, and use of geographic information, but also the effects of GIS on individuals and society, as well as the influences of society on GIS.

3.7 DEVELOPING URBAN DRAINAGE MODELS

Sub catchment Parameterization:

Once sub catchments were created from GIS data and WorldView-2 data, hydrologic and hydraulic parameters are to be assigned based on the resultant of the land cover information. With reference to Rossman (2010), % Imperviousness, Manning's n, depression storage, % Zero-impervious parameters were assigned accordingly. Then, a set of rules was developed to identify an outlet for each sub catchment.

Urban drainage modelling:

The primary data requirement of urban drainage models, land cover information to parameterize specific Manning's n and depression storage values, was collected from two sources: GIS data and the classification results of the WorldView-2 images. 1) soil type to determine the infiltration rate, 2) average monthly evapotranspiration rate, 3) storm drainage infrastructure information that convey runoff, 4) digital elevation model (DEM) to identify the elevation values of all hydraulic elements, 5) rainfall data for the period of analyses, and 6) monitored runoff data to validate the model performance. With all these described data, two detailed distributed homogeneous-area models using land cover information from two different sources, but the same model structure and sub catchment parameterization, were developed to simulate the rainfall – runoff process. Using the GIS data, lumped models were also developed.

Models Analysis:

The developed models were analyzed by comparing total simulated vs. observed surface runoff volume, simulated vs. observed peak flow rate, flow duration exceedance and water balance for three different drainage system. This comparison highlighted the benefits of implementing LIDs.

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CHAPTER 4

CHAPTER 4

STUDY AREA

4.1 GENERAL

Our country's capital is in the heart of India's political hub and a historically significant location. It is also a vital commercial, transportation, and cultural hub. Raja Dhilu, according to mythology, was a monarch who ruled this territory in the first century BCE. The region, which is located in the Indo-Gangetic plains, has a total size of 42.7km^2.

Delhi region is vulnerable to seismic activities and it falls under the seismic zone-IV, making it vulnerable to earthquakes. This zone is encompassed with many fault lines which results in frequent mild intensity earthquakes.

The climatic state of this zone is a hot semi-arid climate in New Delhi, verging on a dry winter and a scorching summer. The climate ranges between a humid subtropical climate and a considerable fluctuation in temperature and rainfall between summer and winter. Summer temperatures fluctuate from 46 degrees Celsius (115 degrees Fahrenheit) to about 0 degrees Celsius (32 degrees Fahrenheit) in the winter.

In 2014, the World Health Organization classified New Delhi as the most polluted city in the world, out of roughly 1,600 communities tracked by the entity. Every year, pollution levels continue to rise.

4.2 STORMWATER MANAGEMENT AT DELHI

The Rajdhani of India faces adverse climatic fluctuations and increased urban population every year as discussed earlier. Migrations happen in a large scale resulting in over population. This results in irregularities in the rainfall intensity, uncontrolled pollution, congestions, storm and sewage water drainage network issues. Due to the mix of a multitude of natural and man-made drainage systems, Delhi's storm water drainage is a complicated issue. Five drainage basins, huge natural drains, roadside storm water drains, and combined sewer cum storm water drains are all included. However, the majority of the water collected through various drainage systems is eventually released into the Yamuna River.

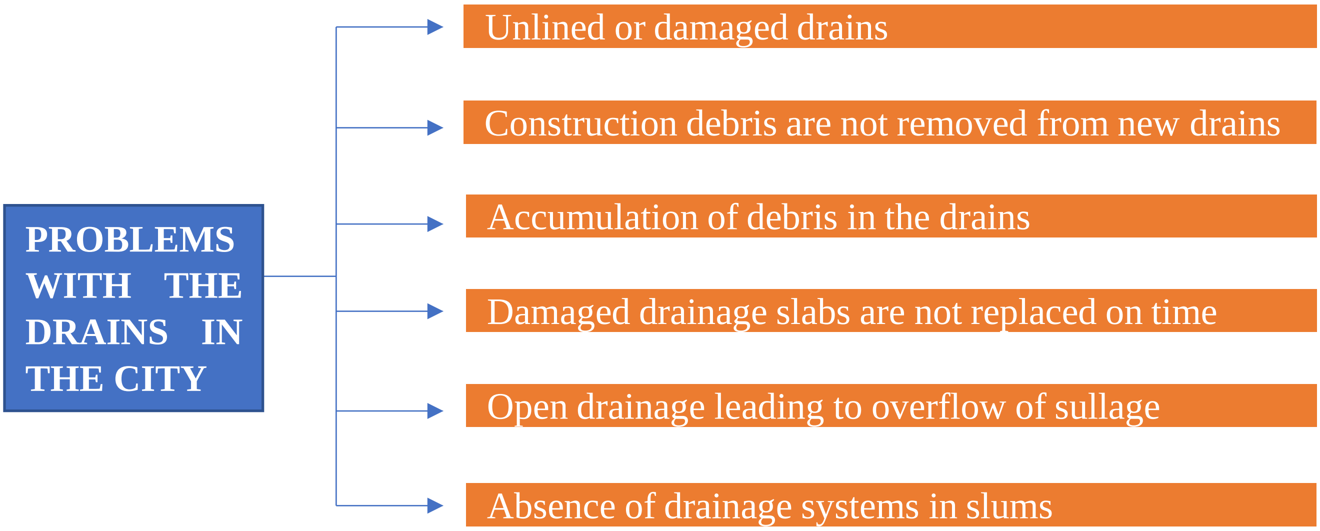

Fig.5 Problems associated with drains

Malaria, filaria, dengue fever, and yearly recurrences of gastroenteric illnesses are all symptoms of a clogged drainage system. A detailed evaluation of the problem is likely to be missing, and only fragmentary remedies have been tried at various stages of the city's growth.

The Delhi government created the latest Drainage Master Plan in 1976. The city has changed a lot since then: new roads have been built, people have grown older, but the pipeline system is still the same as it was 42 years ago. IIT Delhi has been tasked by the Department of Irrigation and Flood Management led by Smt. Sheila Dixit (former Chief Minister of Delhi) to develop a new system in 2012, the draft was approved in 2016. The final plan was finalized in June 2018, but the government has yet to approve it. As a result, the drains are still the same as they were in 1976.

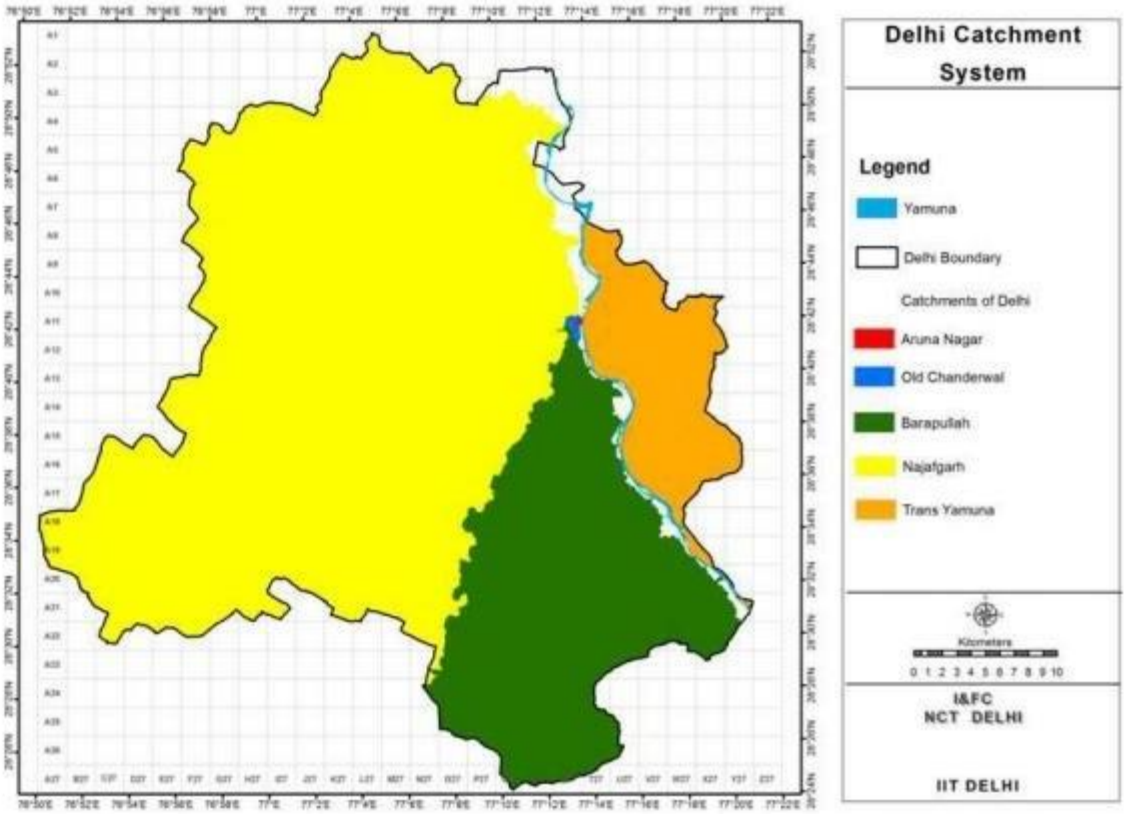

Fig.6 Delhi catchment system by NCT

Fig.7 Barapullah basin

4.3 GROUND WORK AND EXPERIMENTAL FINDINGS

The major problems that are observed through the ground study are discussed in next paragraph and these reasons makes it essential to collect data analyze and find a suitable way to prevent runoff disasters in the urban areas.

Stormwater drains from the city's three main drainage basins, the Trans Yamuna, Barapullah, and Najafgarh, with incorrect slopes, diverting the water away from its natural flow of the river, preventing excess rainfall from flowing into main sewage drains. It has to be pumped back. Pumps should be installed at each major flooded junction. Usually, the pumps fail from time to time and as a result, the extra water flows causing flooding.

Many of the pumps in areas prone to high water pressure, including the Moolchand subway, the Nizamuddin subway, and Badarpur, were found to be faulty or out of order in a report released by the Department of Public Works entitled "PWD Flood Control Order 2019." In addition, Delhi's rapid population growth over the past few decades has contributed to the city's poor water supply infrastructure. Another major issue in the city is the lack of proper sewers. Excess sewage overflows into stormwater drains, choking and clogging them which results in waterlogging due to siltation of drains.

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CHAPTER 5

CHAPTER 5
RESULTS & DISCUSSION

5.1 LAND USE/COVER

Landsat-8 satellite imagery was used to validate the area's land use/cover map. Iso cluster unsupervised classification was used to generate LULC maps. Clusters of pixels with comparable morphological features are formed in unsupervised categorization. The generated clusters have no particular significance, and the user must classify them. For picture categorization, thirty spectral classifications are developed. This is because, while there are five land cover classes to define, each class may have a variety of spectral identities. The colors for the thirty spectral classes are altered to fall into one of the five colors, and the five cover classes are color coded. That pixel is now tied with that characteristic. Because training regions established under supervised classification categorized certain characteristics in the wrong class, unsupervised classification was utilized for land use categorization. Fig. 8 & 9 shows the LULC maps that were generated.

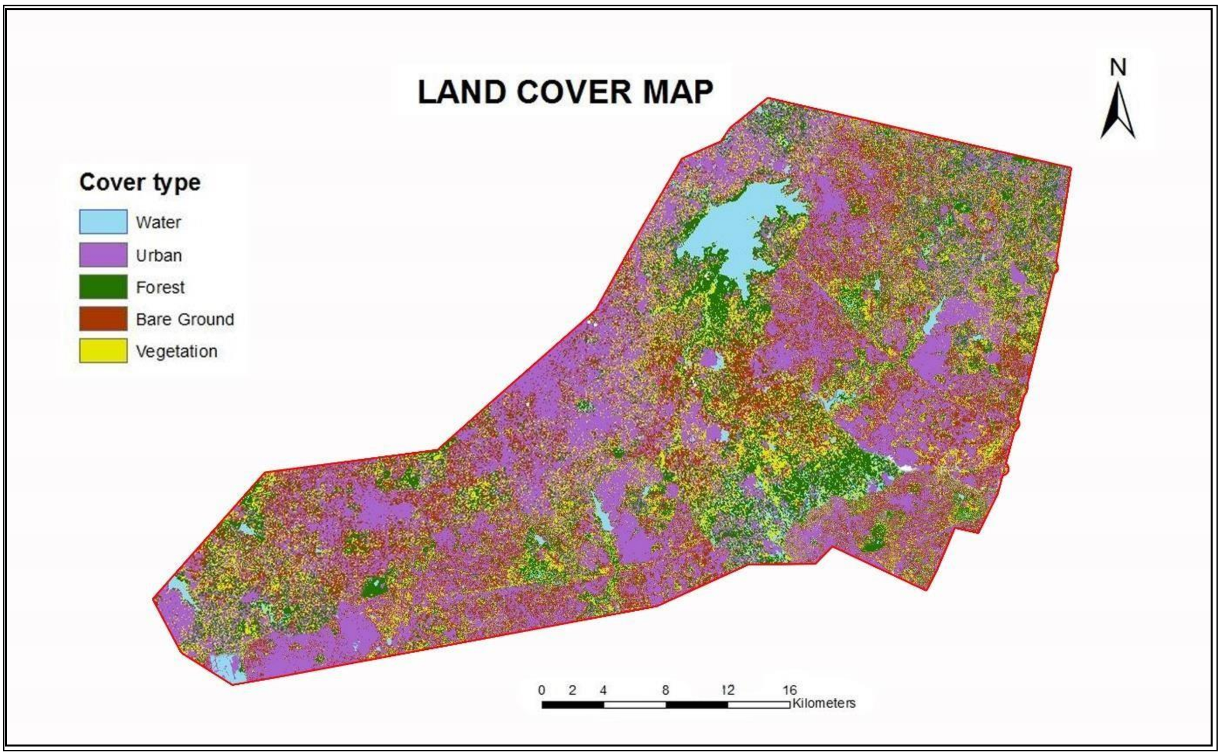

Fig.8 LULC Map

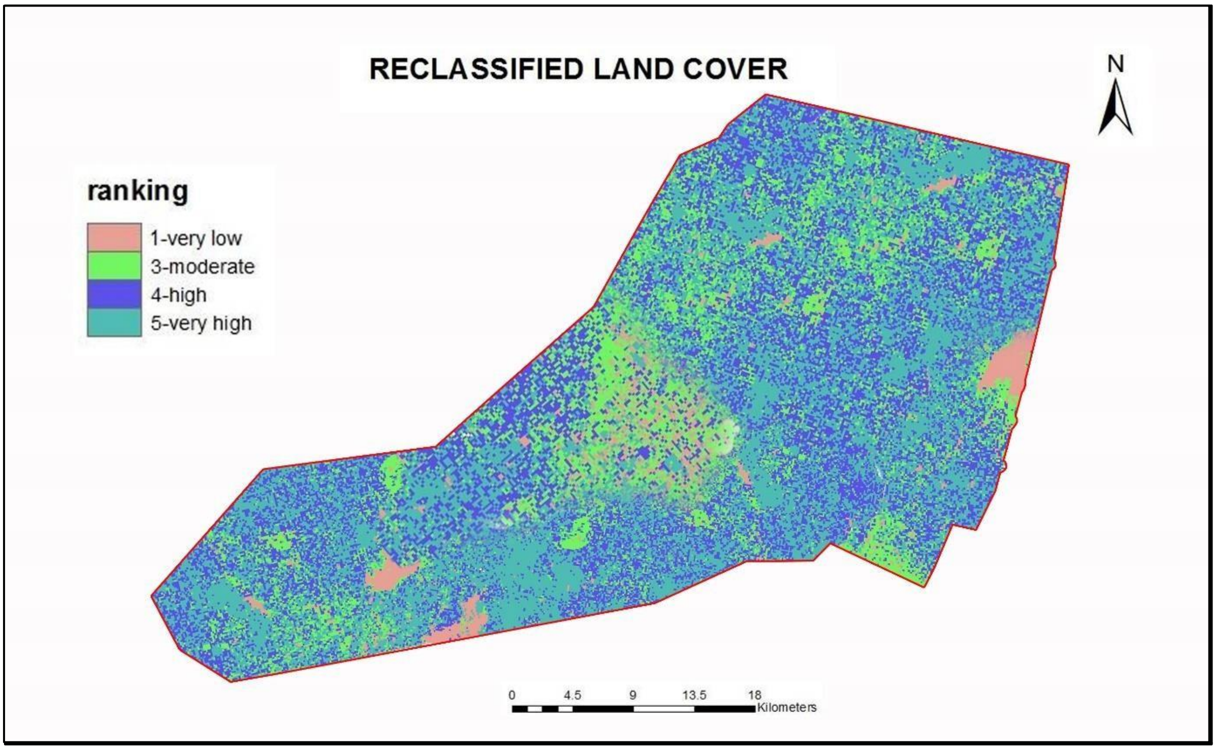

Fig.9 Reclassified LULC map

Forest, water, urban, vegetation, and barren terrain were all included in the LULC map that was developed. It was then reclassified for the overlay analysis. Because of all the impermeable surfaces, the urban land cover is judged to be the most vulnerable to floods and is hence ranked as ‘very high.' Because of their compressed nature, vegetation and bare ground land coverings are regarded to be the next most vulnerable to floods and are given the classification of ‘high.' The land cover types of forest and water have moderate and low ranks, respectively. This ranking is represented in Table 1 below. According to the LULC data (form Fig.8), it can be clearly seen that major part of the study region is covered by urban land.

Table1 Land cover ranking

Land use/cover	**Ranking**
Forested	Moderate
Water	Low
Urban	Very high
Vegetation	High
Ground	High

5.2 DEVELOPING OF DEM

DEM currently stands for Digital Elevation Model, which is used to estimate the storage volume of surface flooding. Additionally, using ArcView and the DEM, the results are represented in the form of a flood inundation map. Fig. 10 & 11 shows the DEM and reclassified DEM respectively.

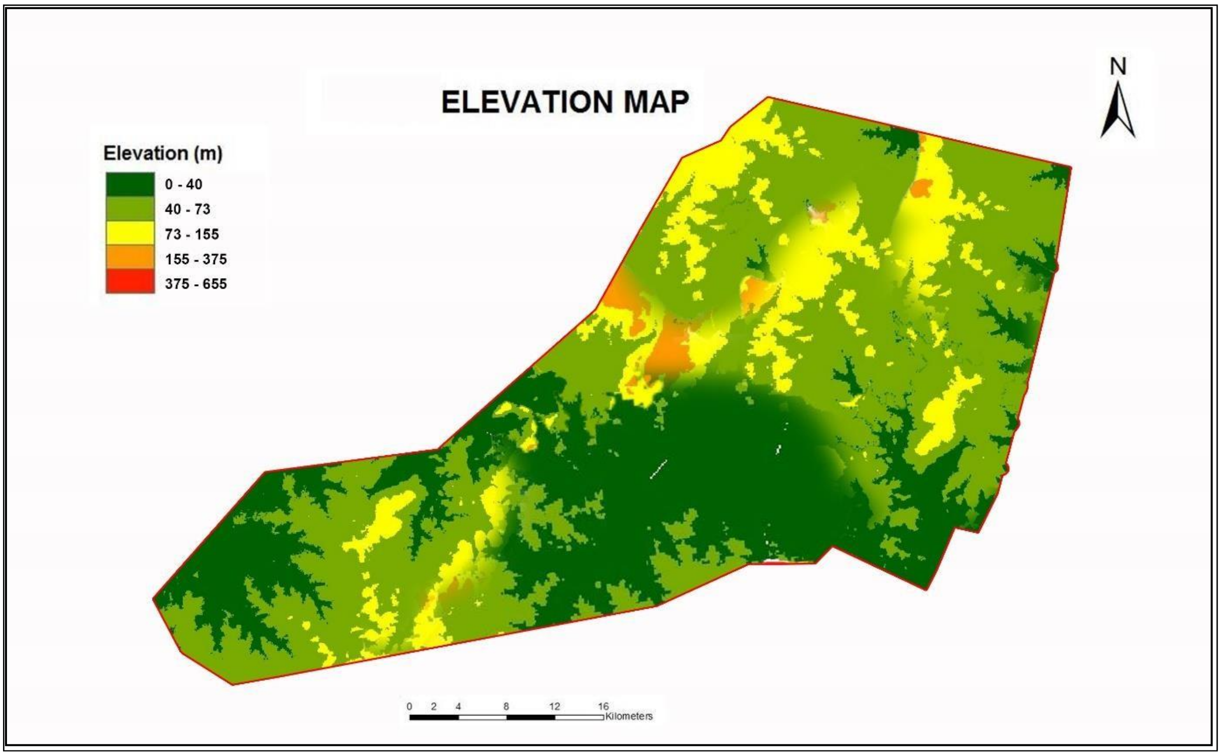

Fig.10 Elevation Map

Surface analysis tools under the spatial analyst tool bar in ArcGIS are used to estimate the elevation and slope from the ASTER DEM. The DEM is utilized to extract the research area's contours, which are then used to produce the slope and elevation maps. The flow and flooding of a certain region are affected by the slope's steepness. During floods, low-lying regions with moderate slope angles are more likely to be flooded than those with high slope angles.

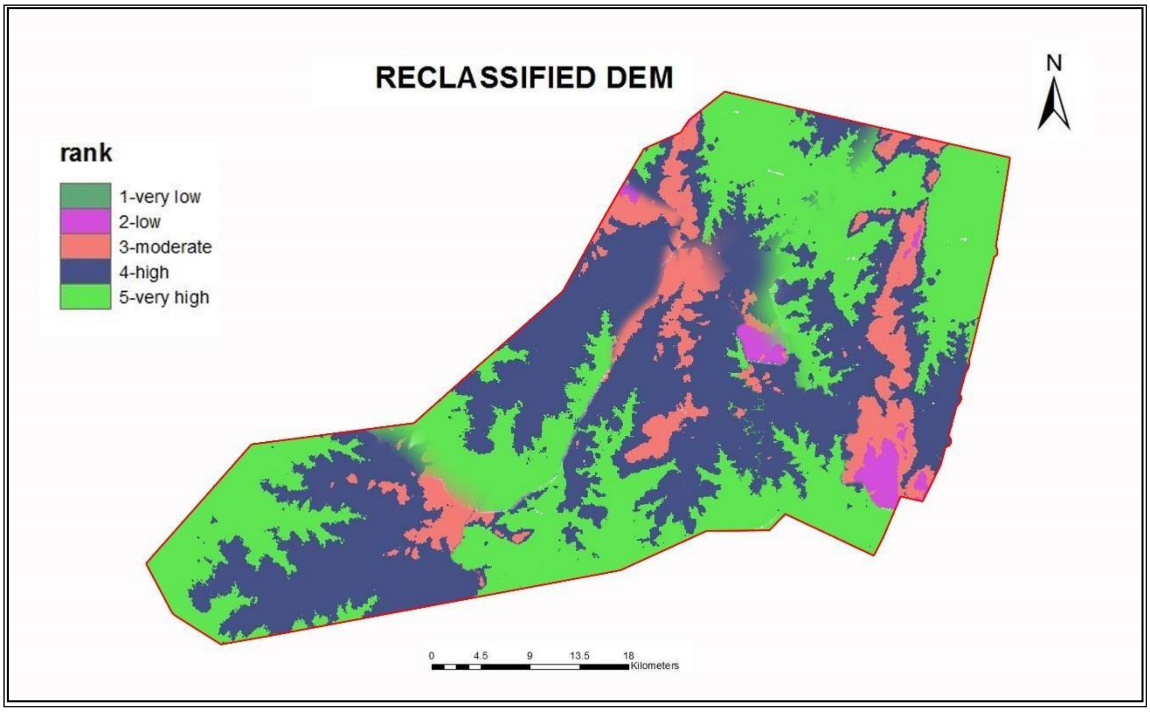

Fig.11 Reclassified DEM Map

Using the Natural Breaks (Jenks) distribution, the elevation map is divided into five groups as it identifies real classes within data. The five groups are shown below in Table 2.

Table2 DEM ranking

DEM (m)	Ranking
0 – 39	Very high
39 – 75	High
75 – 156	Moderate
156 – 377	Low
377 – 65535	Very low

5.3 GEOLOGY AND SOILS

5.3.1 Geology

Precambrian Dahomeyan schists, granodiorites, granite gneiss, amphibolite, and Precambrian Togo series, primarily Quartzite, phillite, phyllitones, and quartz breccia, underlie the plains. Paleozoic Accraian sediments-sandstone, shales interbedded with gypsum lenses are among the other formations discovered.

The Accraian sandstones are prone to earthquakes because to significant faulting and jointing. Seismological activity is highest in the unconsolidated sand and clay in the Sakumono, Densu delta, and Nyanyanu. The ground is found to be highly stable if the underlying rock is hard Togo quartzite and schist or hard Dahomeyan schist and gneiss.

5.3.2 Soil

Drift materials resulting from windblown erosion; bed rock shale deposits results in alluvial sand and oceanic snarled clays; gneiss, schist, and quartzite rocks produces remnant clays and gravels; weathering of accraian sand stone leads to the formation of sandy lateritic clays, Patches of alluvial ‘black cotton' soils may be found in several of the municipality's poorly drained low-lying regions. These substrates have a huge impact on the environment, producing foundation and footing difficulties. Lateritic soils, which can be found in some places, are very acidic and, when saturated, can cause honeycombing in concrete foundations.

Table 3 Soil rankings

Geology	Ranking
Sericite Quartz Schist	High
Water	low
Middle Shale Formation	High
Lower Sandstone Formation	High
Phyllite And Phyllonite	High
Marine Fluvial or Lacustrine Sediments	Very high
Red Continental Deposits	High
Fine Grained Quartz Schist	High
Quartzose And Impure Sandstone	High
Orthogneiss And Augen Gneiss	High
Weathered Granitoid-Pegmatite Complex	High

5.4 RAINFALL DATA

The yearly rainfall point data is represented in Fig. 12 & 13 and this data was used to build a rainfall interpolation surface for the study region. We need to interpolate the rainfall because we know that India is a tropical country, and its agricultural planning and water use are heavily reliant on monsoon rainfall, with the monsoon season accounting for more than 75% of total rainfall. Rainfall during the monsoon season is unequal in both time and place, thus this is an essential aspect to consider as the rainfall analysis. The most important component is the rainfall distribution pattern; because rainfall distribution changes across space and time, it is necessary to analyze data collected over extended periods of time and at numerous places in order to obtain reliable information. Severe storms occur mostly during monsoon season, and when rainfall is uneven in time and space throughout the monsoon season, it is important to examine rainfall variance. The interpolated rainfall surface is shown in Fig. 14.

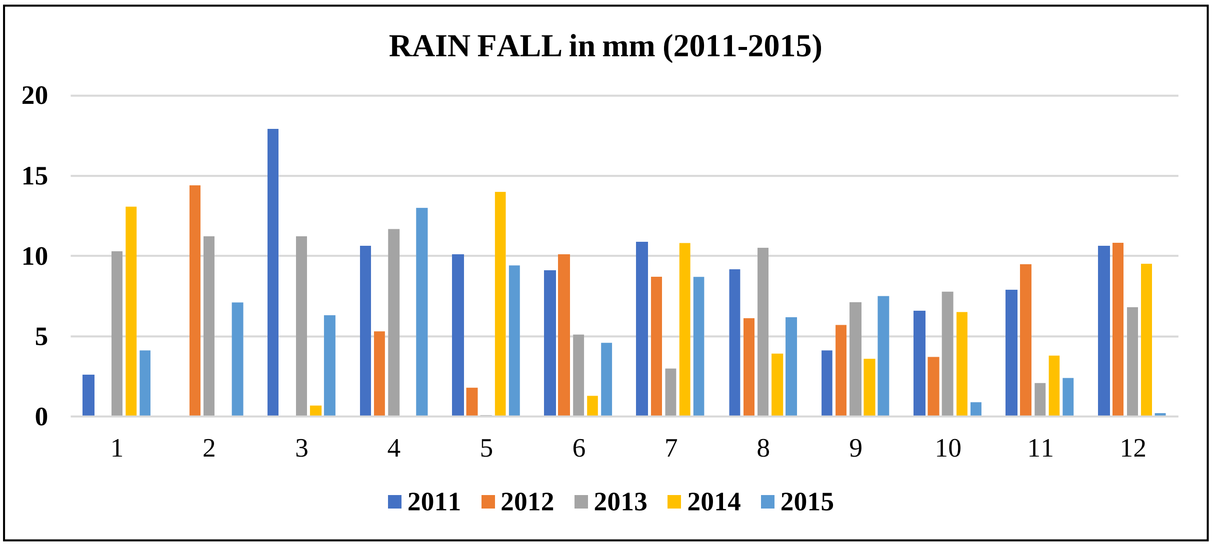

Fig.12 Rainfall Data (2011-2015)

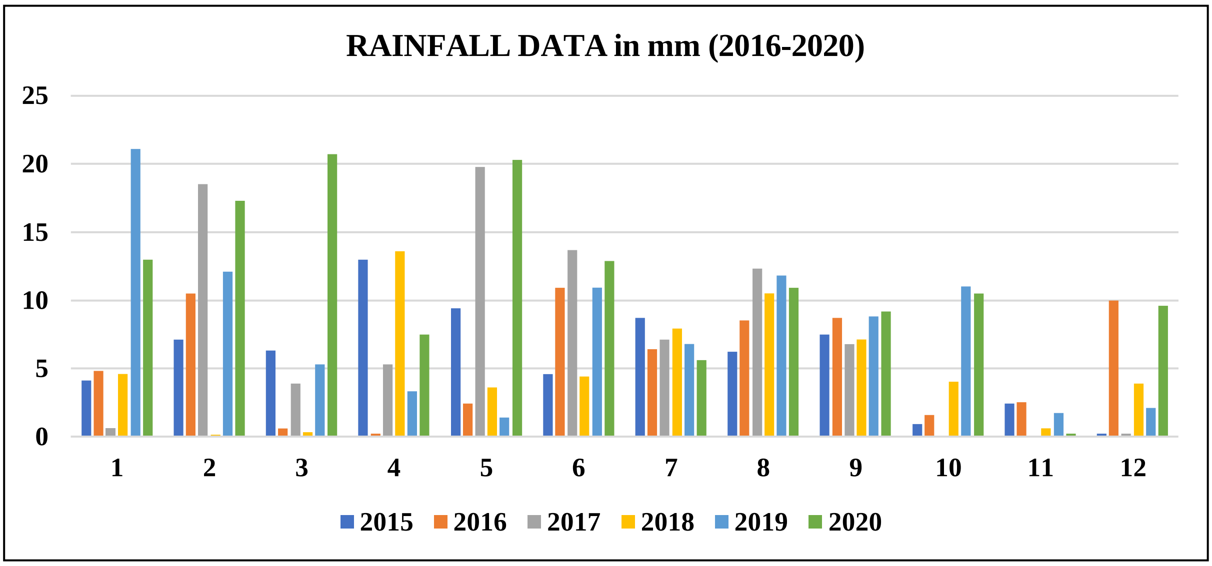

Fig.13 Rainfall Data (2016-2020)

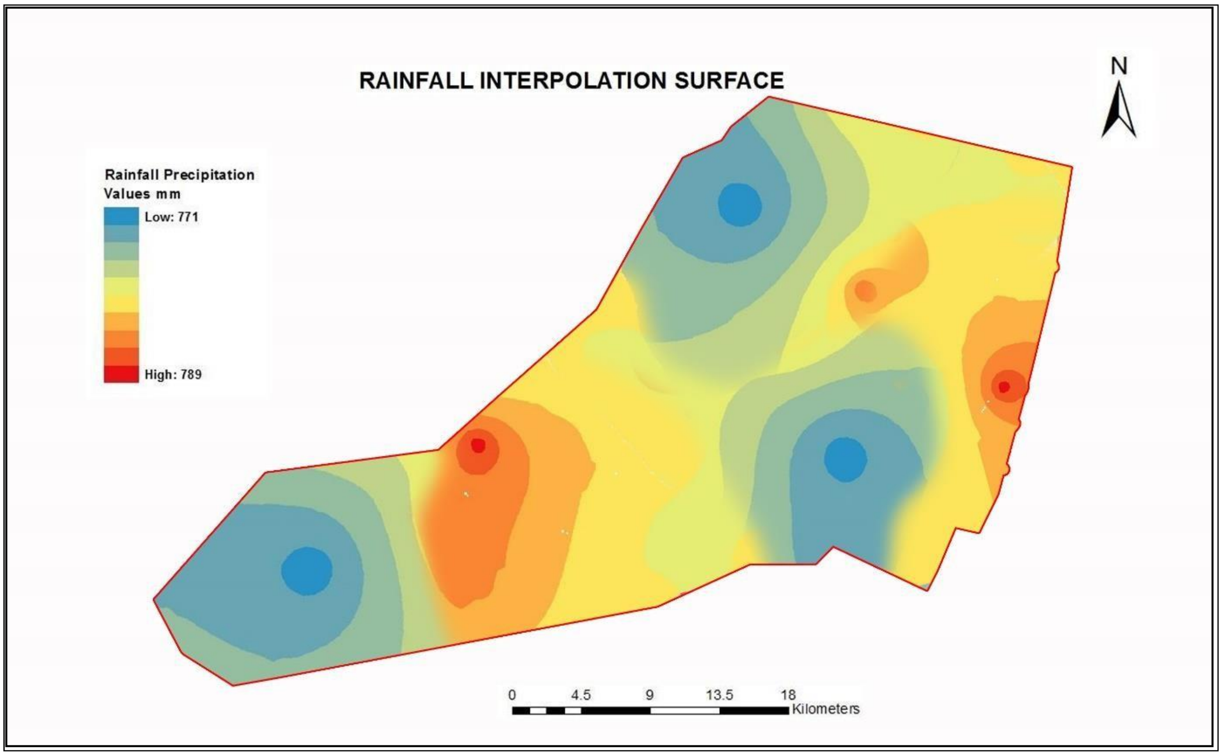

Fig.14 Rainfall Map

5.5 EXISTING DRAINAGE NETWORK

Multiple entities are responsible for the region's storm drains. In the Said ul Ajaib area, storm drains from several agencies are joined to make a comprehensive storm network. To transport storm water to the outfalls, a dense drainage network length (GIS) is installed. Fig.15 depicts a map of the storm drainage network (four feet and above) under the authority of several authorities.

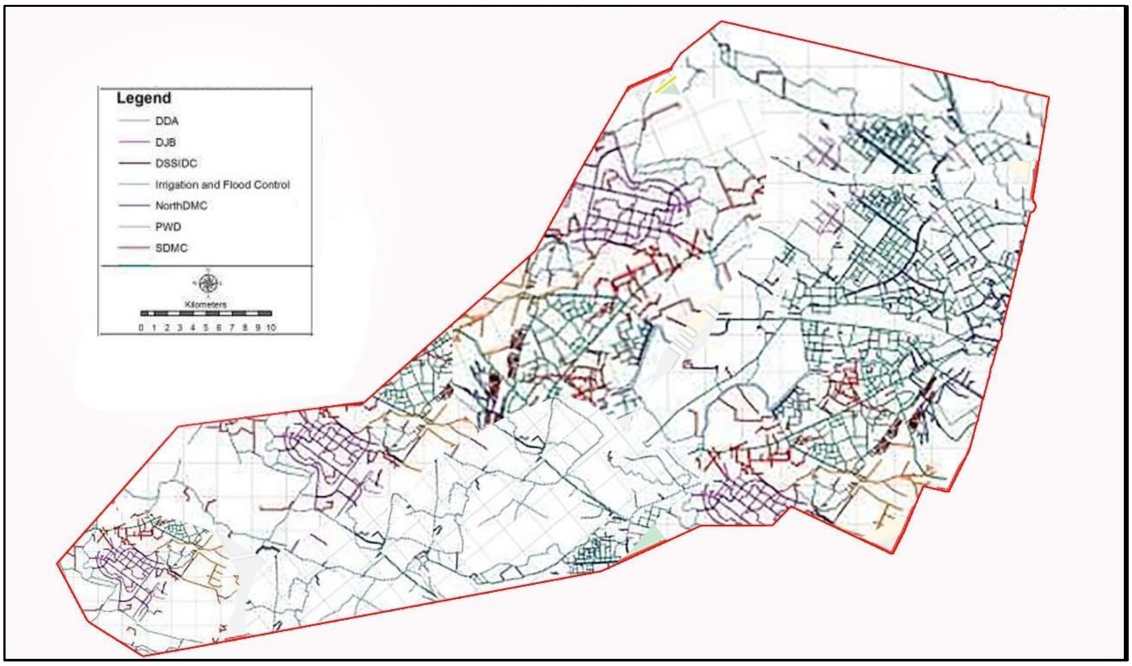

Fig.15 Drainage map for Said ul Ajaib

5.6 MAJOR DRAINAGE PROBLEMS IN THE SAID UL AJAIB REGION

As previously stated, the region's fast unplanned development, shallow groundwater levels, and low to medium elevation have resulted in regular flooding issues. The most serious issues are listed below.

- Increased paved area, decreased water percolation, and increased runoff.
- Reversal of flow direction and pumping inadequacy/failure: Chirag Delhi drain is the basin's longest drain, carrying all runoff and sewage from the basin's south area and outfalling into the drain.
- Construction debris in new drains is frequently not emptied, and litter is thrown in roadside drains. There is no separation of sewage and storm water infrastructure.
- Drainage congestion is severe in low-lying regions.

During major flood seasons, authorities have installed several pumps at various sites across this region to pump away surplus water. The location of the installed pumps is seen in Fig.16. Mobile pumps are utilized to push excess water into adjacent drains, resulting in flooding in the downstream areas.

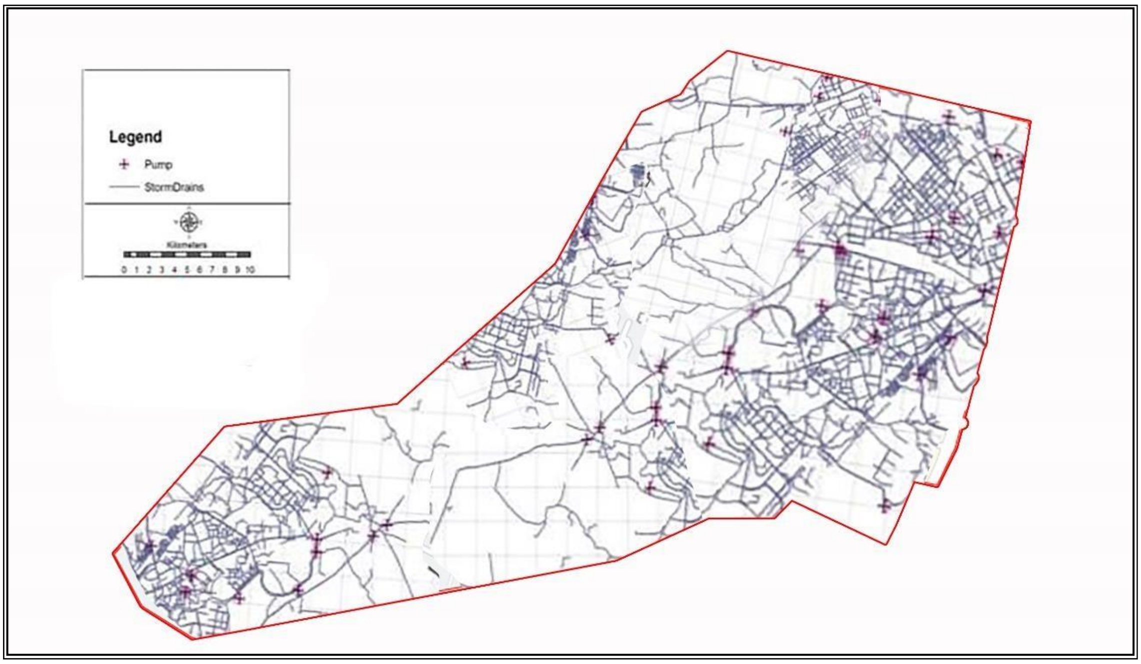

Fig. 16 Location details of pumps installed in Said ul Ajaib

The Delhi Traffic Police discovered 160 water logging sites, which are shown in Fig.17. Apart from this, water logging has been observed in inner built-up areas, particularly during the monsoon season.

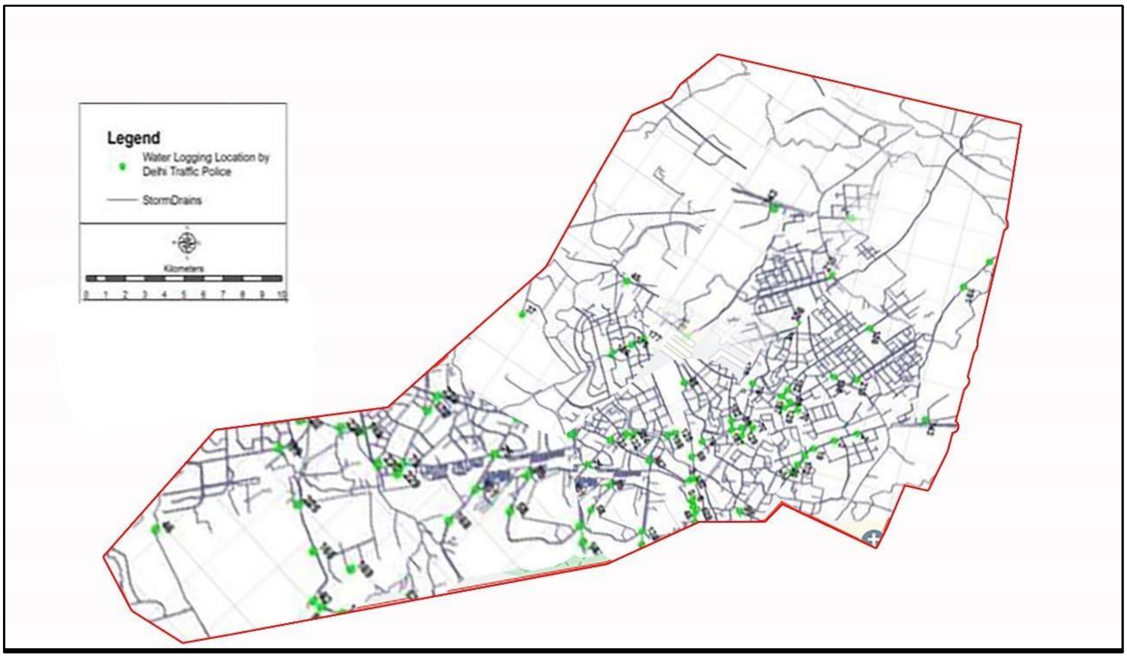

Fig.17 Areas facing frequent water logging

The rainfall data for 10 years was collected and used to run an exhaustive simulation of the stormwater drainage network. Fig.18 depicts the flooded intersections based on rainfall occurrences during a 10-year period.

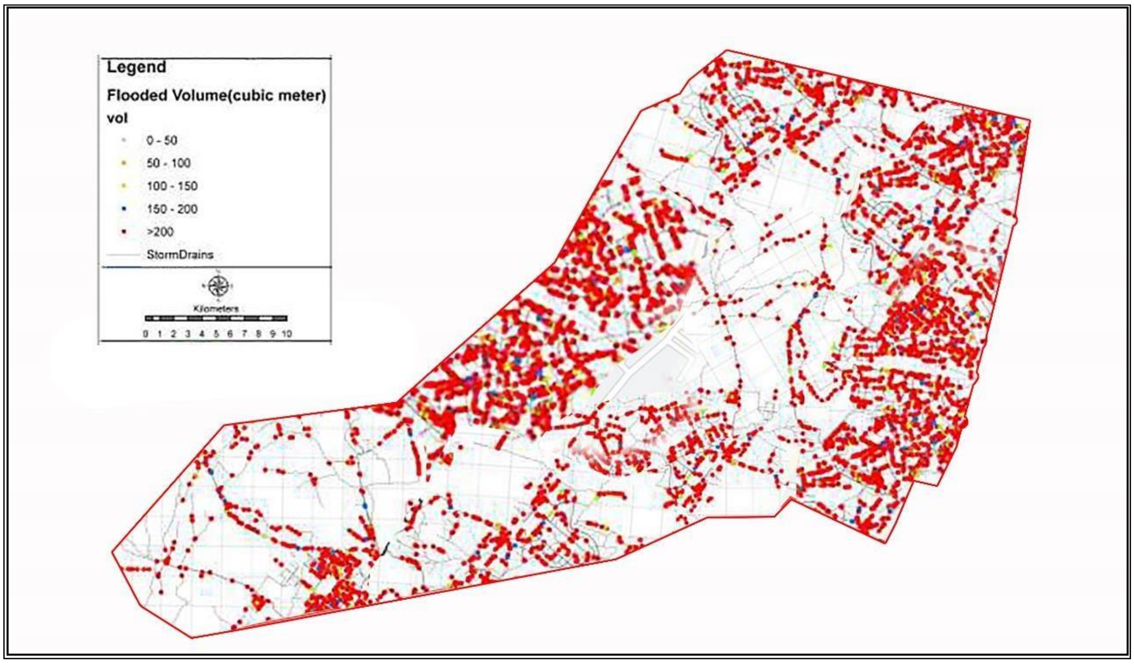

Fig.18 Flooded volume in Said ul Ajaib

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CHAPTER 6

CHAPTER 6

CONCLUSION

The present study employs ArcGIS software to simulate the urban drainage systems of Delhi city in the rapidly urbanized Sail ul Ajaib area. The simulation was based on the DEM, digital map, rainfall data and underground pipeline network. Rainfall data required for the study was collected from Irrigation and Flood Control Department, Delhi. The findings show that existing drainage routes are insufficient to absorb rainwater from the Said ul Ajaib region and hence some parts of the area are frequently affected by flooding. This situation of flooded junctions can be reduced by increasing the size of drainage system. It is also concluded that using ArcGIS software is a very valuable and accessible method for assessment of stormwater drainage impacts of urbanization.

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CHAPTER 7

CHAPTER 7

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