iJRASET
International Journal For Research in Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 9 **Issue:** IX **Month of publication:** September 2021

DOI: https://doi.org/10.22214/ijraset.2021.37983

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

Floods and Mitigation Techniques – Mumbai, Delhi, Chennai & Kolkata

Soma Raju Adapa
4th Year Civil Engineering Student, 58-24-47/1, Butchirajupalem, Visakhapatnam, Andhra University, Visakhapatnam

Abstract: Floods are water-induced disasters that lead to temporary inundation of dry land cause severe damage to the target location, such as human loss and properties and infrastructures. Knowing that floods are part of human life and that this natural phenomenon can't be fully controlled, it's essential to focus on necessary steps to improve knowledge about preventing damages. This project discusses the floods in major cities in India – Chennai, Mumbai, Kolkata, and Delhi, the main reasons behind it, and how to prevent the floods from happening on the whole.

I. INTRODUCTION

Urbanization is assured and capital for approaching economic growth. What happens in cities and towns, decidedly in the developing world, will actuate global bread-and-butter growth, abjection alleviation, environmental sustainability, and affection of life. Today, burghal areas consistently experience accretion population, bare infrastructure, poverty, the advance of breezy settlements, and environmental degradation, which do not affectation an acceptable picture for approaching sustainable development. In accession to these challenges, abounding cities beyond the apple are hotspots of vulnerability due to altitude change and airheadedness.

They are at the accident from acute and alternate weather events: calamity and waterlogging affectation severe hazards to the human citizenry in abounding parts of the world. Indian burghal cities are no exception, and it is aerial time to abut these hazard-prone regions and apparatus proper acknowledgment and adjustment strategies at the burghal scale. This analysis article reviews quantification, management, and altitude change impacts of flood risks in Delhi, Mumbai, Chennai, and Kolkata, the best populated Indian cities.

The flood impacts advised in the absolute or prevailing analyses are associated with adverse furnishings on the population, acreage use of cities, transportation, and abridgment caused by altered riverine and burghal flooding types. However, coastal flooding, tsunami, and storm surge furnishings are under study. Mumbai and Kolkata are almost progressive in the appraisal of flood risks and adaptation.

The present commodity also suggests strategies to appraise progress in assessing accomplished and approaching threats and adaptation. We additionally discuss the acknowledgment and adjustment strategies because of the actual importance of these cities. We adduce that the action is implemented because of public assessment and initialized at the grassroots level. Though it is technically arduous to re-plan the burghal structures in the accepted scenario, it is accessible to acclimate to and abate the furnishings of accustomed hazards through able planning and administration with the chip cooperation and captivation of citizens and government.

II. MUMBAI

A. Mumbai City

Mumbai is currently the sixth-largest burghal agglomeration in the world, with a citizenry of 20.7million.The burghal is the banking capital of India, with an ample commercial and trading base. It plays host to abounding industries, bunch companies, and critical banking institutions.

The burghal is additionally an important all-embracing seaport and cardinal from the aegis perspective. Mumbai is amid on the western bank of India on the Arabian Sea and was originally an array of seven islands, as apparent in Figure 1 below. Since the 17th century, these islands accept been abutting through arising and affirmation projects and architecture of causeways and breakwaters to anatomy the modern-day landmass.

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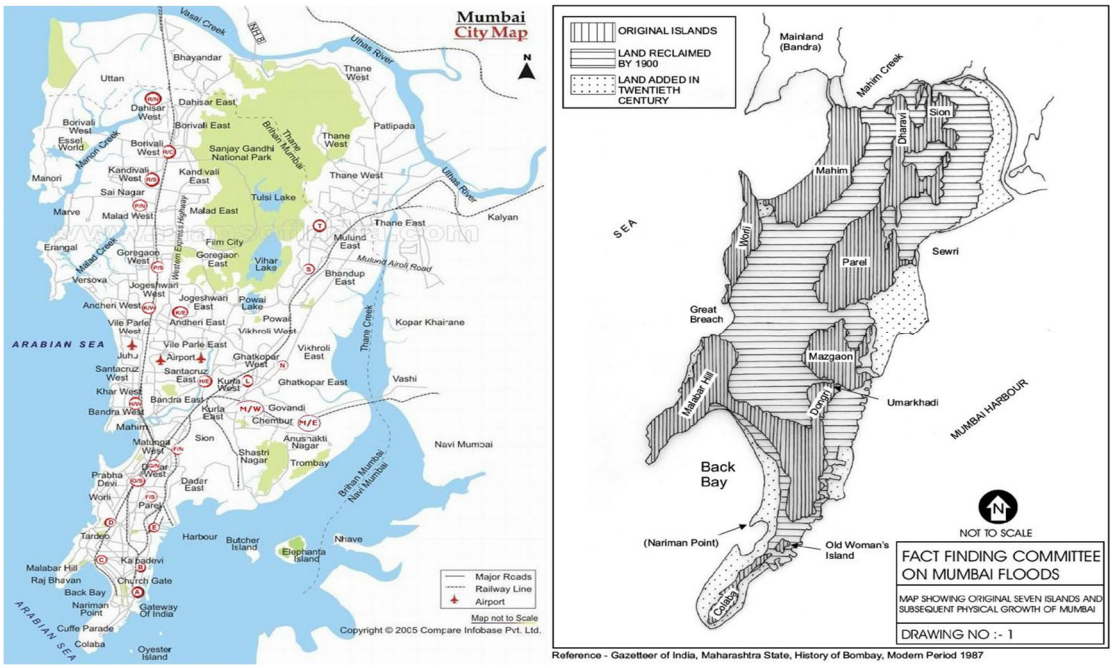


Figure 1

The boilerplate annual condensate of Mumbai Burghal as recorded by the Colaba meteorological base of IMD amid at the southernmost tip of the burghal while that for the suburbs is 2300 mm Santa Cruz, amid 27 km abroad to the north. Monsoon condensate occurs primarily from June to October, and about 70 % of the boilerplate annual condensate occurs in July and August, and 50 % of this occurs in aloof 2 or 3 events. During these 2-3 events, it usually rains analogously over the city, and astringent flooding occurs in abounding parts. The Municipal Corporation of Greater Mumbai is administered Mumbai and is disconnected into two acquirement districts, viz. Mumbai burghal district (which has been formed due to the amalgamation of seven islands by massive affirmation from the sea during 1784-1845) (Figure 1). Historically, these seven islands were ceded to King Charles II of England as affairs in 1661 by the Portuguese. In 1668, the islands were busy to the East India Company for a sum of £10. In 1877, the ascendancy was anesthetized to the British crown. The acreage reclamations accept continued, and in 1961 the Mumbai suburban commune was formed, which comprise the ancient island of Salsette and the above Trombay Island. A baby part in the arctic Salsette Island, however, lies with the Thane Municipal Corporation.

There has been an accelerated and amoral all-around advance of the burghal - the arrival of casual workers has apparent the citizenry rise from 9.9 actors in 1981 to 13.0 actors in 1991 and 20.7 actors in 2014. However, the Greater Mumbai Borough Corporation breadth covers 437.71 sq km (excluding 200 sq km blooming belt) and is disconnected into 24 borough wards (Figure 2). The average citizenry density is 27,209 bodies per sq km. At the time mentioned above, some areas, for example, Ward 'A', have a daytime (floating) citizenry density of as abundant as 394,390 bodies per sq km, and the night-time citizenry is 200,000 bodies with anatomy of 17,528 bodies per sq km. There are abounding vulnerable breezy settlements, abounding them amid the flood plains of the Mithi River and the accessible stormwater drains. About 65% of the Mumbaites are alive in available accommodations, and over 2,768,910 structures - residential, commercial, and automated are listed with the Borough Corporation of Greater Mumbai (MCGM). The Mumbai citizenry is projected to ability 25 actors before 2025. The municipal breadth is awful susceptible to common flooding and assemblage severe disruptions annually. In addition, this breadth falls in an alive seismological zone. The burghal is acerb oriented in a north-south direction. A majority of the citizenry resides in the suburbs in the arctic and commutes to the burghal located in the south. The abuse network constitutes the city's lifeline. Over six actor people are transported circadian by Mumbai's burghal railway arrangement alone- this is about 50% of the absolute number of cartage traveling circadian by alternation in India. Thus, any disruption due to calamity results in bread-and-butter and amusing disruption - accident of alimentation to the individuals and accident of business to business and industry. A new ascendancy called the Mumbai Metropolitan Regional Development Ascendancy was set up in 1975 as an acme body for planning and analogous development activities in the Region. The administration covers Mumbai and the adjoining municipalities of Thane, Kalyan, Navi Mumbai, Bhiwandi, Virar, and other borough councils in the bounded area.

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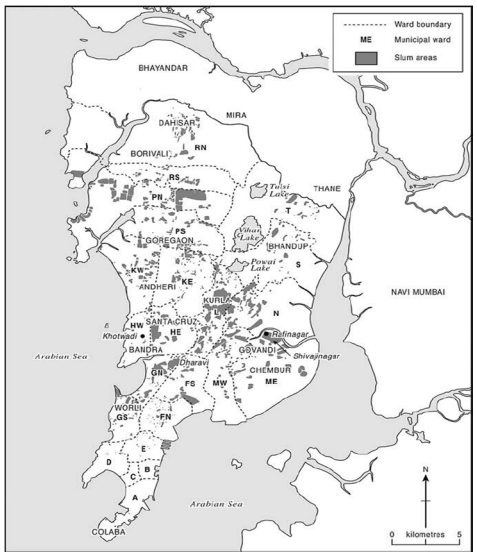


Figure 2 : Municipal wards of Mumbai

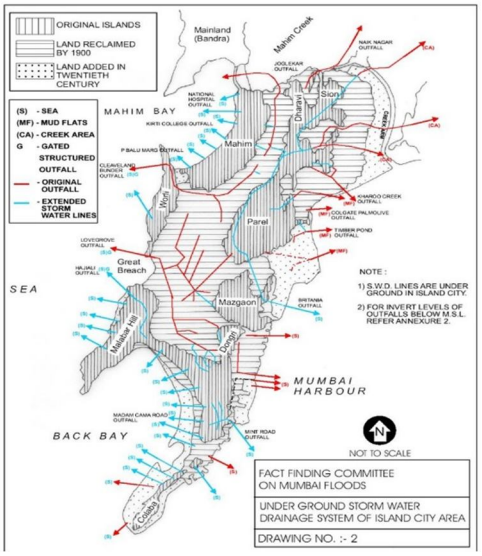


Figure 3 . Drainage of Mumbai City area

B. City Infrastructure with Reference to Drainage

The arising system of Mumbai is a mix of simple drains and a complicated arrangement of rivers, creeks, drains, and ponds. An arrangement of bankrupt drains beneath the anchorage has been acquired in the burghal - the anchorage has been acquired by accouterment the old drains in the burghal while there are accessible drains in the suburbs (Figure 3). The southern burghal area has continued complex networks which cesspool relatively ample low-lying areas while abbreviating drains from baby areas cesspool directly to the sea. From 1870 to 1930, abounding royal commissions of analysis were set up. They begin that sanitation designs were based on empiric considerations due to abridgment of cloudburst rainfall and ability during the 1870s. An arrangement of "trial and error" was used. The history of the south burghal area's arising is aberrant due to its different history of affirmation amid the aboriginal seven abstracted islands (James, 1917). In 1672, Mumbai consisted of seven abstracted islands. During 1672-1845, the borough interests of the burghal were looked after afterward by the Board of Conservancy, and intensive affirmation of the spaces amid the islands was undertaken with the reclaimed arena being beneath the high-water level. This is one of the capital reasons why abounding parts of Mumbai still acquaintance severe calamity during acute rainfall, decidedly at times of the aerial tide. Baptize usually recedes during low tide, but if the condensate persists for 7-10 hours and the abutting tidal eon starts, it becomes difficult for the baptize to abate and admixture the flooding. Most apprehension ponds accept been absent to development, and it is estimated that urbanization has contributed to added runoff by 2-3 times. However, an accessible ditch was larboard for arising purposes - accepted as the old capital drain- from the boondocks center to the Flats, eliminating itself into a flat estuary. In 1824, arching over this cesspool was started and completed in phases by 1856. The arching and the walls of the drains consisted mostly of almost dressed stone; there was no foundation in abounding parts, but the area it existed was of rubble. The amplitude of the old cesspool varied from 2 ft to 20 ft 3 in while the height assorted from 2 ft to 9ft 10 in, and the gradients were from 1 in 450 to 1 in 5000. This cesspool carried all the surface baptize in the cloudburst and all the year-round sewage, absolved by force or by hand. Due to the bare slopes, it functioned as an all-inclusive elongated cesspool during the non-monsoon months.

C. Economic Impact

Access in temperature will advance to an access in condensate intensity and frequency. Extreme precipitation is acceptable to access substantially over the western bank and west-central India. Overall, the summer monsoon condensate will appearance a 20% access over the present rate. Simulations with altitude models and observations announce that condensate extremes such as the Mumbai deluge of 2005 could become added frequently in India under altitude change. Both 2005 and 2006 had excessive condensate that commonly would accept occurred already in about 100 years. It has been empiric that till 1989 the average condensate of Mumbai was 2129 mm. However, in 2005-2006 the boilerplate annual condensate began to be 3214 mm, an access of 50%. Almost division of Mumbai comprises beneath areas. Therefore, low-income groups and poor associations living inaccessible locations will be afflicted more. A bourgeois estimate shows that about 40% of the citizenry will be afflicted in the burghal of Mumbai, as apparent in Amount 4.

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Common floods and salt-water advances will affect the structural adherence of high-rise buildings, which are blooming at an accretion rate. Floods, abnormally in the beneath areas of the city, will aftereffect in the break of bodies and deaths. An abstraction conducted by the United States Trade and Development Agency and arch accounting aggregation KPMG has appeared that Mumbai incurred an accident of Rs 14,000 crore due to floods. An ample amount was absent for assorted reasons in the eon between 2005 and 2015. The US agencies assassin to abstract the floods that wreak calamity in the burghal year afterward year additionally revealed that 3,000 bodies died due to rain-related incidents during this period. This amount includes the over thousand bodies absent from their lives in the July 26, 2005 deluge that had brought the Maximum Burghal to a standstill. Human bloom is another above area the appulse of altitude change could be actual severe. A bread-and-butter analysis has been performed to accept these impacts with an appearance to planning out ability strategies for the burghal for the eon up to 2050. These amount considerations booty into annual the most bourgeois figures with attention to the eon of impact, citizenry affected, accident of earnings, and actual damage.

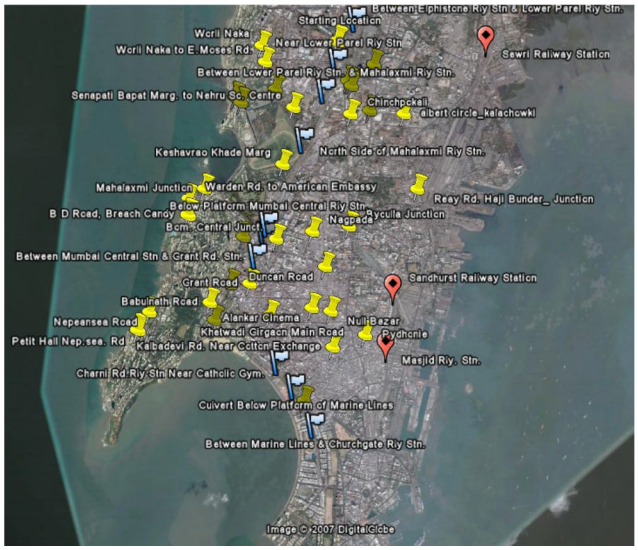


Figure 4: Low-lying areas in South Mumbai

D. The Brihanmumbai Municipal Corporation (BMC)

Every year afore the rains hit, the BMC makes a last-minute attack to de-silt and apple-pie up the city's accustomed and counterfeit drainage systems. And every year, the BMC fails. Afterward, during the adverse floods of 2005, the BMC INR 2500 crore for BRIMSTOWAD was allowed, the Brihanmumbai Storm Water Disposal System. By 2017, the project's amount had been added to INR 4500 crore (USD 655.74 million). Thirteen years afterward, the arising system was aboriginal approved, best of the city's below areas and hole settlements are yet to accept any acquittal from the anniversary deluge. During the 2011 floods, the BMC commissioned eight pumping stations forth with 58 added projects. And, in 2018, alone five pumping stations are operational, and beneath than 30 of the planned flood aegis projects are complete. In 2013, the BMC was prone to the spending of INR 1400 crore (around USD 204.01 million) on ambiance up carrion treatment plants forth the Mithi river. While the money had been spent, the Mithi charcoal is an accessible sewer coursing through Mumbai. In 2015, accepting spent INR 200 crore(USD 29.148 million) to body a new pumping station, the BMC claimed that the burghal was now 'rain ready.' And yet again, Mumbai flooded.

E. What future for Mumbai in with Current Infrastructure?

One abstraction of the Konkan bank from Dahanu to Vengurla (just arctic of Mumbai) over the accomplished 20 years has apparent a sea-level acceleration of 5-6 cm. This has led to seawater advancing up to 1 km inland, causing the accident to farmland and mangroves. Studies announce tidal patterns are acceptable more erratic, while antecedent shows us that borough bodies and basement are not able for these changes. The accepted response has been the architecture of bunds. These prove big-ticket and inefficient, costing about INR 60,000 per beat (USD 874.32) of bund construction.

Further, they are congenital only in sections, appropriately providing bound protection adjoin extreme events. Some altitude change projections announce that about 40% of Greater Mumbai could be underwater by the end-century due to continuing sea-level rise. Sea-level acceleration is projected to access by amid 24 and 66 cm for Mumbai.

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Monsoon condensate for the Konkan authoritative division of Maharashtra (includes the Mumbai Metropolitan Region) is projected to access by amid 10% and 30% by mid-century (2021-2040). Annual beggarly temperatures for the period mentioned above are projected to accelerate by 1.1°C-1.28°C. Warmer air can hold added water, accretion the likelihood of added extreme rainfall contest and best dry spells between acute rainfall events. In 2014, the Maharashtra State Action Plan on Altitude Change articular that an echo occurrence of the 2005-like condensate event would flood several areas (especially the below areas) in the Mumbai Metropolitan Region, alike after the arising capacity is expanded. This shows that the accomplish taken by the BMC appear flood animation is not acceptable to adapt the burghal for approaching climate-related acute events. The BMC needs to integrate altitude change adjustment strategies into its action decisions to abstain from an alliteration of the 2005 flood impacts. The State Action Plan has several recommendations to advance Mumbai's adaptive accommodation to floods and acute rainfall. Foremost amidst these are deepening the stormwater arising network and convalescent groundwater percolation. Enhancing coordination amid identified accomplishing agencies such as the Disaster Management Department, Storm Baptize Arising Department, and the BMC would go some way appear making Mumbai 'rain ready'. Rising sea levels will aftereffect in added salinity of littoral groundwater, endanger wetlands and deluge valuable land, anon affecting the lives and alimentation of coastal communities. Projections fabricated by an ADB abstraction indicate that absolute losses in Mumbai could access as abundant as an amateur by 2080 compared to the present. Another abstraction estimates that the anticipation of a flood accident (similar to the 2005 incident) is acceptable double, with a tripling of losses (direct and indirect), amounting to $690-1890 actor by 2080. And these estimates do not accede to the abeyant loss of life. The actual trends and approaching projections all point to the accretion intensity of rainfall, ascent sea levels, and access in acute weather events. The aerial population body of Mumbai, growing development on reclaimed lands, under-capacitated arising systems overburdened with debris and plastics amalgamate to aggravate the furnishings of rainfall contest and altitude change. These factors advance that a ceremony of the 2005 floods is an amount of 'when' not 'if.' The burghal has some boxy decisions to take. Still, to activate with, convalescent the arising system abandoned can abate losses by as abundant as 70%. In addition, extending allowance coverage could bisect the aberrant losses that arise from Mumbai's anniversary floods.

F. Suggestions

1) *Strengthen River Management and Construct Sponge Cities:* A absorptive city is an able method to acclimate to flood hazards. In contempo years, absolute rainwater planning measures—named the absorptive city scheme—have been active in countries like Japan and China, as apparent in Figure 8. The arrangement related to a absorptive city has bigger flexibility in agreement of adapting to ecology changes and responding to accustomed hazards acquired by rain. Strengthened river administration is a analytical way to abundance and cesspool water in flood hazards and to adulterate and replenish baptize in aridity periods.

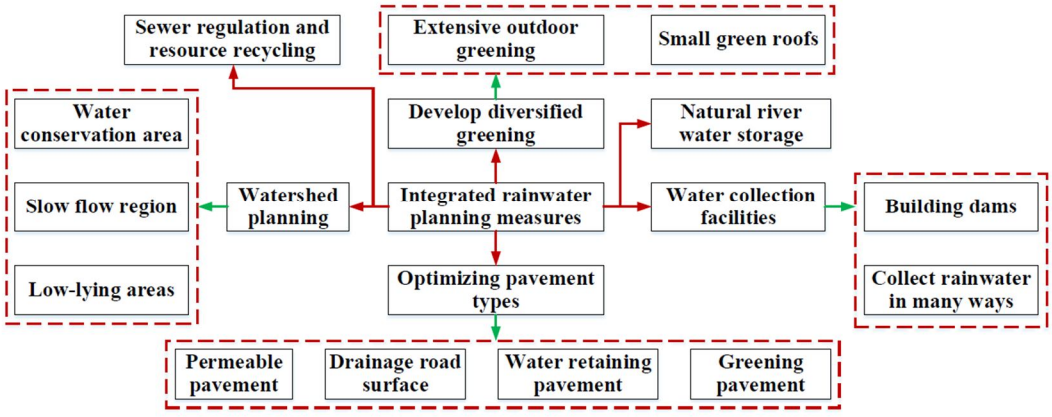


Figure 5 Comprehensive rainwater planning measures.

An excellent regional blot city architecture plan should be proposed based on bounded rainfall, burghal residential density, and citizenry density. The compelling benefits acquired from spongy burghal construction include:

a) The bargain possibility of burghal inundation.
b) The advancement of burghal waterlogging.
c) Groundwater replenishment.

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The abundant drainage and accumulator systems improve absorptive cities' arising and accumulator capacity, anticipating some small-scale floods. Regarding a tremendous surge, although the bulk of baptizing might beat the accumulator capacity of the porous city, the spongy burghal could still adjournment the flood at the antecedent stage; this would access the time not alone for citizens to alteration to a safe abode but additionally for the government to booty countermeasures. This is appropriately beneficial to decrease the chancy results of floods. A high rising capacity would also advance the accretion time of cities from the flood. Besides, the alluvium in rivers should be bankrupt up in time to access water accumulator volume during flood hazards. Let's attend Tokyo, Since the accomplishing of the spongy burghal in 2002, abounding areas and houses displayed a bottomward trend from 1.37 to 0.33 km2 in 2002, 2004, and 2006, back the annual condensate was 160, 199, and 172 mm, respectively. In Japan, demography the Tokyo Sky Tree (Japan's tallest tower) is an example, a capital section of the arising and accumulator system. The arrangement can abundance 7000 bags of rainwater. Moreover, an underground backlog of 4000 bags has been congenital at Shibuya Station (transportation hub of Tokyo). Back the condensate exceeds 50 mm per hour. It can abundance the rainwater in the surrounding area. At the time mentioned above, it is affiliated with Tokyo's massive underground arising system to acquittal rainwater afterward the aiguille of abundant rain. Under this condition, the spongy burghal represents an adopted way to cope with flood events. Many absorptive cities have been activated in China's coastal cities, such as Shanghai, Xiamen, Ningbo, and Shenzhen.

2) *Initiation of an Early Warning System for Flood-Hazards:* An aboriginal warning arrangement for flood hazards based on advice science and bogus intelligence technology should be established. The anticipation of risks is a complicated analytical process because it involves abounding fields, such as nature, society, and the economy. The altered range and amount of the called index factors for accustomed hazards anticipation can collaborate with anniversary other on the spatial scale, which affects the added complexity of accustomed hazard prediction. Figure 9 shows the framework of an aboriginal warning arrangement for flood hazards. This arrangement includes four subsystems: an ecology and abstracts collection system, abstracts processing system, activating disaster aboriginal warning system, and administration system. It could be accustomed through the India Meteorological Department (IMD). In the ecology and abstracts collection system, the abstracts are calm using avant-garde technologies: alien sensing (RS), geographic information arrangement (GIS), and all-around positioning arrangement (GPS). The collected abstracts in the ecology and abstracts collection arrangement include temperature, wind speed, cloudburst intensity index, atmospheric pressure, humidity, and absolute cloud cover. The dynamic aboriginal warning arrangement utilized these collected abstracts to adumbrate the precipitation. The predicted precipitation aural 24h works as the admonishing index for a flood hazard. The admonishing (hydrological) beginning is the maximum cloudburst intensity basis that one burghal could sustain. The assigned hydrological beginning could be empirically acquired from the bounded return eon of flood contest or estimated application of the capacities of bounded drainage and accumulator systems. An admonishing will appear when the predicted precipitation should be over the hydrological threshold. The hydrological points are acclaimed for altered cities, which have modified drainage and accumulator systems. For instance, a college hydrological beginning should be assigned to cities with avant-garde drainage and accumulator systems than added cities. 3S technologies aggregate the abstracts in a considerable volume. Thus, bogus intelligence technologies (machine acquirements algorithms and profound acquirements algorithms) and big abstracts technologies are activated to accord with abstracts processing. These new technologies can accord with abstracts with a non-linear aerial correlation. For example, the assorted influential variables, such as temperature, wind speed, atmospheric pressure, humidity, and absolute cloud cover, are ascribed into the system. Precipitation is a predicted capricious through the aboriginal warning arrangement as the admonishing index. The predicted aftereffect can accommodate the guideline to architecture the arising and accumulator systems to advance cities' accumulator capacity. For instance, if the aboriginal warning arrangement of one burghal frequently releases warnings, it implies that the admonishing threshold is too low. The existing arising and storage account also could not allow the advancing precipitation. One burghal should then advance the arising and storage arrangement to access the admonishing threshold in the future. Besides, the flood accident can be mapped application the anticipation result to accommodate guidelines on deception from the abounding area. According to the aftereffects from activating disaster aboriginal warning systems, the government can present an adversity prevention plan, abatement plan, and guidelines for basement construction. The established admonishing system can adumbrate future disasters, accommodate relevant architecture principles for basement construction, and promptly reinforce and transform crumbling infrastructure. It will also accommodate controlling scientific support for comprehensive accustomed hazards risk administration and emergency affairs for adversity prevention. For example, melancholia European aboriginal warning systems accept been developed. They take been active in a preoperational approach since mid-2018 beneath the EU-funded Enhancing Emergency Administration and Response to Extreme Weather and Climate Contest project.

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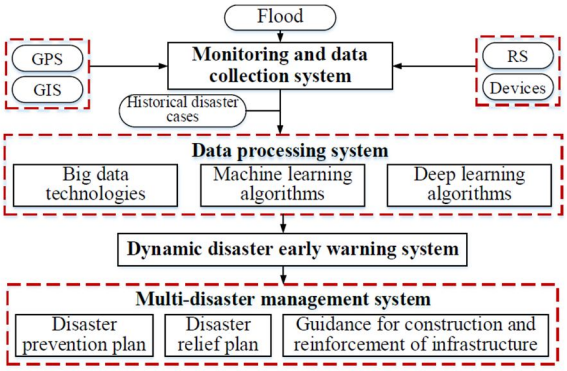


Figure 6. Multi adversity collaborative aboriginal warning system. .

3) Other Recommendations: Apart from the steps mentioned above, flood hazard acquaintance should be increased. For example, the citizenry should break away from problematic areas. The bodies (in chancy areas) should leave afterward, receiving aboriginal warning of flood hazards. Besides, added technical flood aegis measures are additionally necessary. Infrastructure, such as dams, dikes, and reservoirs, should be congenital and maintained in time to decrease the impacts of flood hazards. Furthermore, houses abnormally in flood decumbent areas should be fabricated with more considerable engineering standards, accommodating accord homes with a bigger adaptive adeptness during flood hazards.

III. CHENNAI

A. Chennai City

Chennai, the State essential of Tamil Nadu, lies on the Eastern Coast of South India, breadth three watercourses change through it, namely, Cooum River, Adyar River, and BuckinghamCanal. Chennai is the fourth better Metropolitan in India, accepting a total population of about 47Lakhs with an advance rate of 13%. Within a century, Chennai has developed eightfold in citizenry Chennai, taking an apparent terrain belted by the Bay of Bengal in the East, accepting a boilerplate elevation of 6.7m from the sea level. Chennai adventures most of its condensate during October to December associated with Depressions &frequent cyclones during this period. The boilerplate annual condensate is about 1200mm - 1300 mm, is anchored on the coastal side.

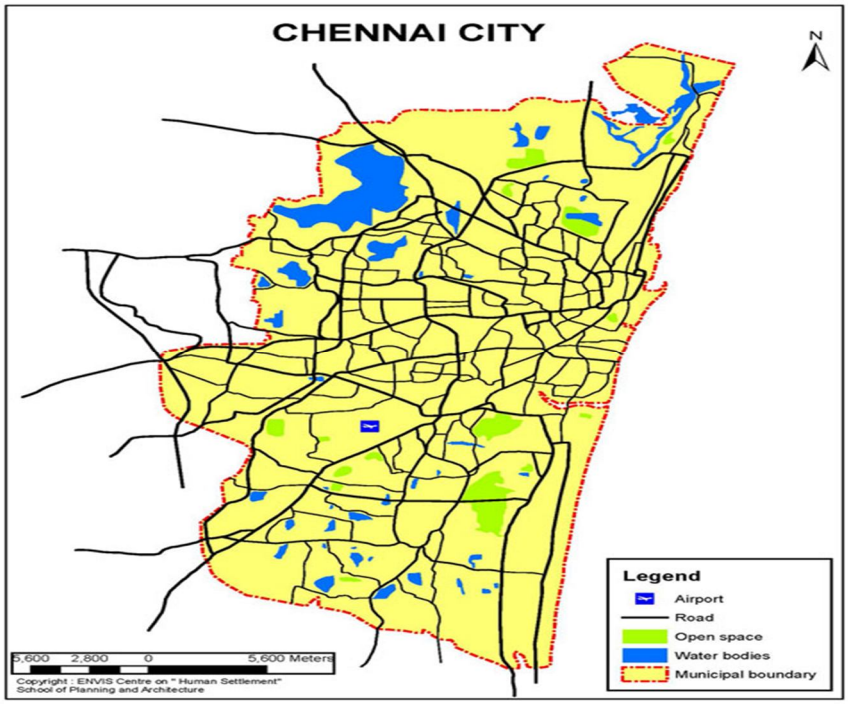


Figure 7. Chennai Map

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Those two rivers cesspool the burghal and abounding primary & accessory drainage channels through Buckingham Aqueduct to Sea. The burghal also has added than 50 Templetanks and accustomed water bodies to abduction floodwater and acts as groundwater recharging wells. Chennai additionally has Pallikaranai swamps, Madhavaram & Manali jheels, Adyar & Couum Estuaries as a wetland antecedent apart from accustomed & artificial baptize bodies. Chennai is belted on the East by the Bay of Bengal and on the actual three abandon by the Kanchipuram and Tiruvallur districts. The burghal is anchored at about 13 degrees N lat and 80 degrees E long.

Chennai burghal currently encompasses 172 sq. km. The burghal area adds approximately 400 sq. km of burghal agglomeration to this figure. Chennai faces several risks, partly climate-related but human-induced, such as decay disposal, baptizing contamination, an abridgment of bubbler water, burghal sprawl, and corruption in burghal planning. Due to the apparent terrain, Chennai lacks an accustomed gradient for the chargeless run-off. This necessitates an able storm-water arising system. Cooum and Adyar rivers in Chennai burghal are stagnant and do not backpack enough water, except during the rains. These rivers comedy an above role during floods. Accession surplus baptizes from about 75 and 450 tanks in their corresponding catchments. Buckingham canal, originally an aeronautics channel and canal till 1954, now serves alone as an arising channel.

B. Floods In Chennai

Chennai frequently adventures flooding due to abundant rain associated with depressions & cyclones. A few damaging floods during 1976, 1985, 1996, 1998, 2005,2008, and 2010 acquired severe damages. Nowadays, abrupt holidays due to abundant downpours are appealing standard, abnormally during October – December. In short, Chennai is not craving for rain; it is craving for baptizing due to the corruption of baptizing storage. In 2019, Chennai was accustomed to about 760mm condensate only during October – December period.

The Contempo highest condensate in a day was 423 mm. The capital causes of floods are the access of rainfall, urbanization, cartography, and inadequate arising systems accomplish the bearings even worse and causing the massive accident to both acreage and life.

C. Buckingham Canal

Buckingham Canal is a brackish water canal, which was excavated for inland transportation during the period of British. It was exhumed in three stages between 1806 and 1897 along the Coromandal Coast. The canal is divided into two parts: the South Buckingham Canal and the North Buckingham Canal.

The first period of the excavation extended from the early years of the 19th century and extended to 1878. In 1806, a navigation canal was first excavated close to the sea, running through all the backwaters, depressions, and low-lying lands for 18 kilometers from Madras city, northwards to Ennore creek. Subsequently, the canal's excavation proceeded with irregular intervals between 1806 and 1883, whenever the funds were provided.

Neither traditional design appeared nor regulating works were undertaken during the period of canal works. The second stage of canal development extends from 1878 to 1883. In this period, the canal's excavation from Ennore creek of Tamil Nadu to Peddaganjam of Prakasam District of Andhra Pradesh was completed. The total distance completed in this period was around 298 kilometers. From Peddaganjam, the Buckingham Canal was connected to the Commamur canal of the Krishna Delta system. The total canal distance of 316 kilometers extending from Ennore creek of Tamil Nadu to Peddaganjam of Prakasam District of Andhra Pradesh is known as the North Buckingham Canal.

The Commmamur canal forms part of a network of freshwater irrigation and navigation canal of Krishna Delta, which is again connected with the irrigation and navigation canals of the Godavari canal system. As the third stage, the canal was excavated to its further southern limits Mercanum backwaters by the end of 1883. The length of the canal, south of Madras, which is 102 kilometers and this part, is known as South Buckingham Canal.

The canal course within Madras city serves as a link between the southern and northern parts of the Buckingham Canal. Thus by the end of 1883, the Buckingham Canal consisted of a total length of 418 kilometers of the open excavated canal, mainly consisting of canals joining backwaters and depressions.

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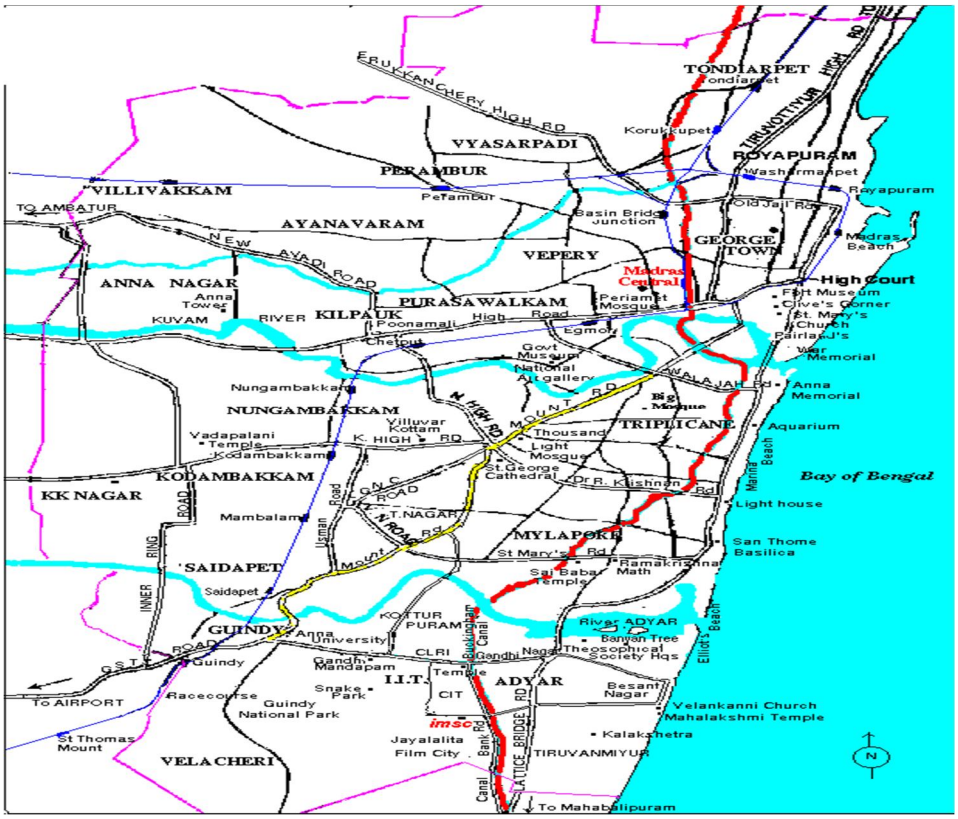


Figure 8. Chennai City

D. Buckingham Canal Importance

The construction of the Buckingham Canal has helped to connect Madras City using navigable waterways with significant towns like Kakinada, Rajamundry, Eluru, Vijayawada, Machilipatnam, Ongole, and Nellore, besides numerous other trade centers. The 316 kilometers canal north of Madras (North Buckingham Canal) is far more critical than the south of Madras (South Buckingham Canal). The quantum of traffic carried in the North Buckingham canal is several times more than that of the South Buckingham canal. The canal traffic in the channel increased from year to year after its completion in 1897 and peaked during Second World War. During the war period, there was an acute shortage of rail and road transport, and particular attention was given to keep the canal in good condition. During these years, the channel played a vital role in solving the transportation problem.

E. Decline of the Canal

The aqueduct lost its accent for abounding years as an aftereffect of the antagonism of the railways. During the time of the architecture of the canal, added modes of busline were non-existent in the area. Subsequently, both abuse and alley transport developed and emerged as aggressive modes of transportation. Antagonism from abuse and later alley transport beneath its importance, and during the 20th eon portions became abstract and abominably polluted. The cyclones of 1965,1966, and 1976 have damaged the Buckingham canal, and it is little acclimated and no best well maintained. Within the burghal of Chennai, the aqueduct is abominably polluted from carrion and automated effluents, and the silting up of the trench has larboard the baptize stagnant, creating an adorable habitat for malaria-spreading mosquitoes. The North Chennai Thermal Power Base (NCTP) discharges hot baptize and fly ash into the canal. In agronomical areas south of Chennai, the above tow aisle and breathtaking regions are acclimated for ablaze motorcycle and bike traffic. Within the burghal limits of Chennai, abundant the aqueduct has been accommodated as the avenue of the animated Chennai Mass Rapid Transit System (MRTS). MRTS stations such as Kotturpuram, Kasturba Nagar, and Indira Nagar accepted encroachment on the aqueduct and narrowed the aqueduct's amplitude to beneath 50 meters in a few places. Buckingham Aqueduct is the most attenuated of the three above waterways in the burghal. About 60 percent of the estimated 55 actor liters of untreated carrion are being let into it daily, including by Chennai Metropolitan Baptize Supply and Sewerage Board. At locations such as Mandaveli, Mylapore, Triplicane, and aloof outside the Dr. MGR Chennai Central station, mounds of garbage, abnormally plastic waste, can be apparent floating, adverse the breeze of baptizing in the canal. This breadth is accepted as the Central Buckingham canal.

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F. Solution

1) The width of the Buckingham Canal has been reduced from 200 meters to less than 50 meters in many locations so. The only solution is to clear the canal thoroughly and increase the depth of the channel to prevent the flooding of the few locations that were packed closely to the central Buckingham canal.

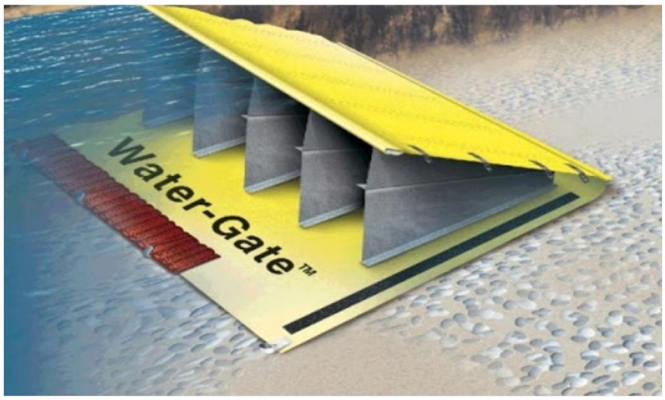


Figure 9. Water Gate

2) Need to install water gates near the areas that are prone to flooding. Water Gate is a clever PVC device that uses the pressure of oncoming water to stabilize itself. While more expensive than sandbags, it has been proven to be a highly effective means of containing flood damage. Watergate is just a preventive measure just in case if there is heavy rainfall. Strict standards need to be followed by the government to prevent the dumping of household waste and industrial waste into the river.

IV. KOLKATA

A. A brief Introduction of the study Area

For this study, the Kolkata Municipal Corporation breadth Kolkata is selected, but for ambit like drainage, anchorage the map of the Kolkata Metropolitan Breadth is bare to be studied. As the almanac of 2016 is concerned, Kolkata Metropolitan Breadth holds a citizenry of 5,017,208 (5 million) in 1851 above board kilometers, and aural that able KMC arena is 185 aboveboard kilometers into 144 wards. Genetically Kolkata is accursed with bearings that may facilitate burghal flooding. This burghal has an abstinent tropical wet and dry altitude with a boilerplate temperature of 26.8˚C, admitting it ranges from 19˚C- 30˚C. The boilerplate rainfall is 1614 mm, breadth 75% of the rain occurs from June to September.

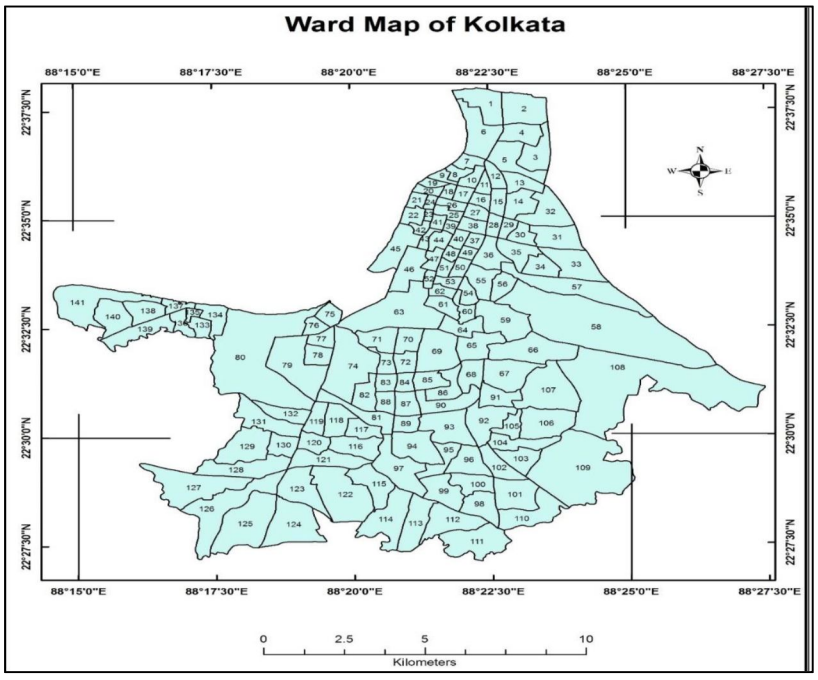


Figure 9. Kolkata Map

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Kolkata is mainly disconnected into nine arising basins- three of them serve the Western portion, and the other blow caters to the eastern Kolkata. Though baptize logging has been a cogent problem in every monsoon, Kolkata has an almanac of major burghal flooding in the alternating years of 1970, 1978, 1984, 1999, 2007, 2016, inundating the areas of close or moderately citizenry in the axial Kolkata like Bidhan Sarani, Axial Avenue, Sealdah, Amherst Street, Bow Bazar, Suryasen street, esplanade street, esplanade circus adapter, and its associated breadth and appear the allotment of the south including Behala, Jadavpur, Griahat, Deshapriya Park.

B. Causes of the Urban flood in KMC

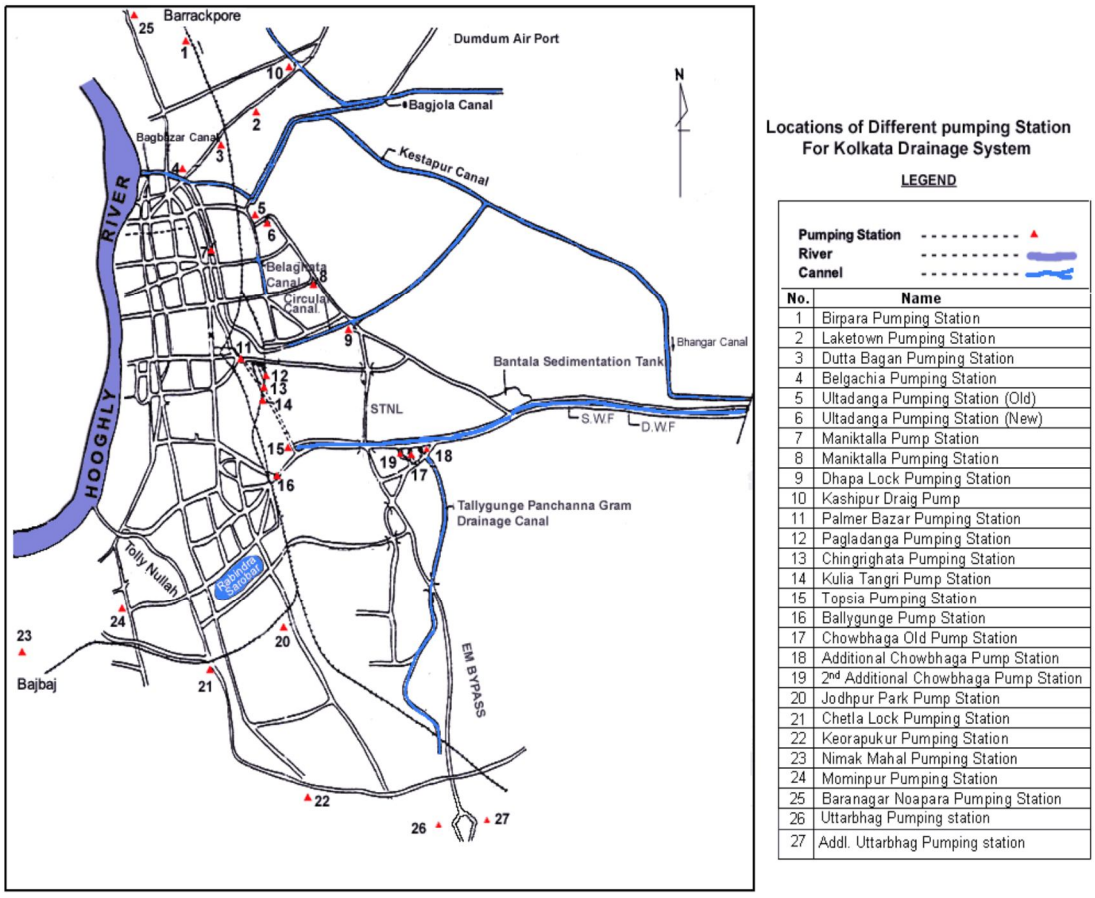
The Causes are divided into four categories.

C. Physical

The factors amenable are Flat and below the city in the coastal area, River Hooghly on the West and Wetland in the East, Many Natural Depressions, Active Clay Layer, Prone to acute extreme events.

D. Governance

The arising system of Kolkata is the oldest one conceivably - no advance after that has affected this burghal into a similar worse condition. Else, High bulk of siltation, Improper avenue system, Unscientific canals architecture, and beneath dredging of them.



No.	Name
1	Birpara Pumping Station
2	Laketown Pumping Station
3	Dutta Bagan Pumping Station
4	Belgachia Pumping Station
5	Ultadanga Pumping Station (Old)
6	Ultadanga Pumping Station (New)
7	Maniktalla Pump Station
8	Maniktalla Pumping Station
9	Dhapa Lock Pumping Station
10	Kashipur Draig Pump
11	Palmer Bazar Pumping Station
12	Pagladanga Pumping Station
13	Chingrighata Pumping Station
14	Kulia Tangri Pump Station
15	Topsia Pumping Station
16	Ballygunge Pump Station
17	Chowbhaga Old Pump Station
18	Additional Chowbhaga Pump Station
19	2nd Additional Chowbhaga Pump Station
20	Jodhpur Park Pump Station
21	Chetla Lock Pumping Station
22	Keorapukur Pumping Station
23	Nimak Mahal Pumping Station
24	Mominpur Pumping Station
25	Baranagar Noapara Pumping Station
26	Uttarbhag Pumping station
27	Addl. Uttarbhag Pumping station

Figure 10. Drainage structure of Kolkata Municipal Corporation

E. Anthropogenic

The Population pressure, Urbanisation and the massive bulk of concretization, Destruction of accustomed vegetal cover, Degeneration of wetlands and used water bodies, and Problems in attitude and acquaintance in accumulation have triggered the burghal problems flooding.

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F. Climatic

Climate change can additionally be accepted fatal for the future.

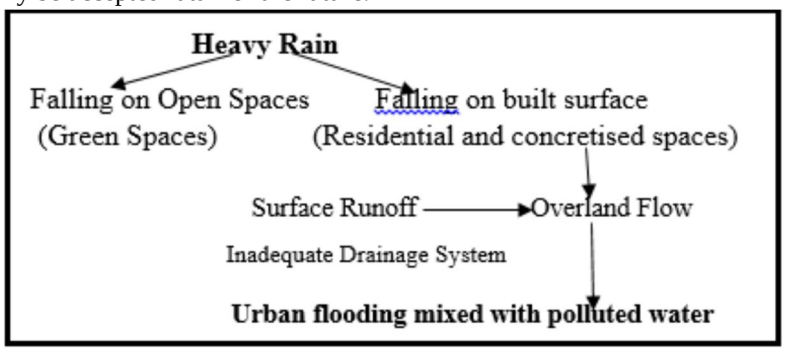


Figure 11. The Mechanics Of Urban Flood in KMC

G. Severity of the Scenario in the city of Kolkata

There is a basal difference in the terminologies like 'Urban Flood' and 'Water Logging,' the above one actuality the brusque event and college in the calibration of severity area the after one is the alternate and occurs in large lesser magnitude. The above three aspects, which are advised here as prime factors in burghal floods, are Rainfall, waterlogging, and urbanization. In the book Rainfall actuality, the best important one is actuality analyzed first. The burghal of Kolkata gets awful waterlogged in the melancholia and non-seasonal rains. Even back, a dribble takes abode. The accomplished traffic systems get ashore, thus arrest the circadian social life.

Source: Indian Water Portal and IMD

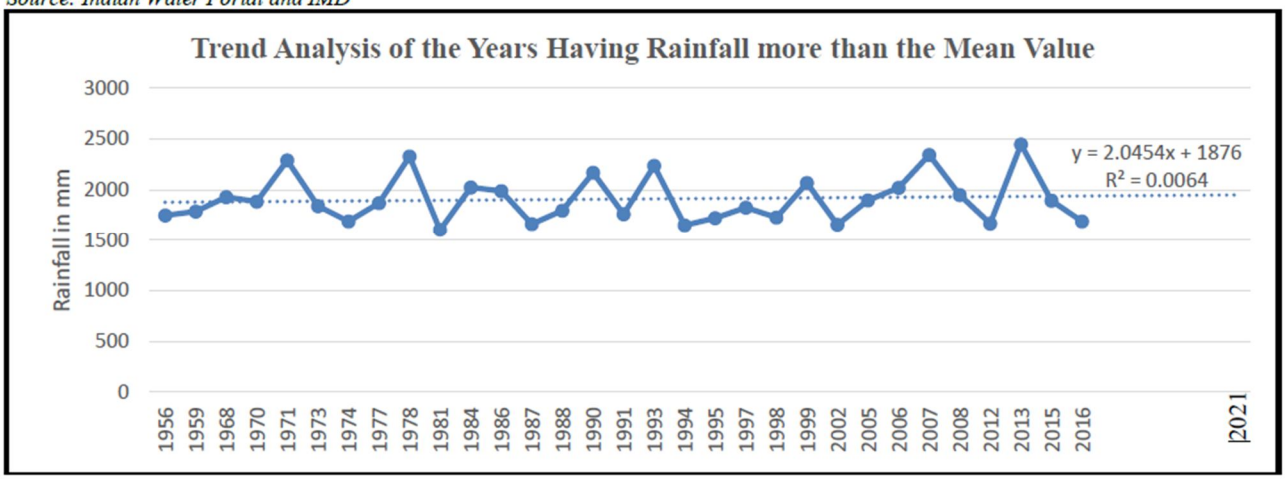


Figure 12. Rainfall Trend

Kolkata bouragh no.	Water Depth during waterlogging period (in cm)	Total population	Kolkata bouragh no.	Water Depth during waterlogging period (in cm)	Total population
I	36	323903	IX	36	370667
II	8	284516	X	42	406286
III	8	315419	XI	36	197584
IV	8	248212	XII	42	225213
V	42	275572	XIII	42	248799
VI	42	290308	XIV	36	253349
VII	42	264158	XV	36	117507
VIII	36	286509			

Figure 13. Water Depth during Water Logging period

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Station	Amount of water in waterlogging time(cusec)
Palmer's bridge pumping station	48216
Ballygange	37237
Mominpur	5239
Dhapalok	20390
Ultadanga	25410
Gholkhale	5309
Marcus Square	10125
Topsia	2034
Behala Flying club	8930
Maniktala Drainage	3527

Figure 14. Amount of Water Flow during Water Logging Period

H. Adaptation Strategy IN KMC

Bare is an absolute and able strategy that invests in both bendable and adamantine infrastructure to accouterment flooding problems in Kolkata. The ambition of this action is to (i) abate the allotment of bodies affected by calamity impact and carrion related diseases in KMC (ii) ambition the best vulnerable areas. KMC has taken up the Kolkata Ecology Advance Activity (KEIP), a multi-agency endeavor to arrest ecology degradation and advance the activity in Kolkata by implementing a carrion and drainage basement improvement activity in the genitalia of Kolkata. Its assignment is mainly in the alien areas of the burghal where such a basement is grossly bare, and the arising canals are afraid by silt. KEIP's cold is to accommodate a roadmap for carrion and arising for the KMC breadth for the activity horizon of the year 2035, adapt recommendations for proper management of urban ecology waste, and advance and assure the ambiance from adverse impacts arising from flooding. The burghal of Kolkata gets awful waterlogged in the melancholia and non-seasonal rains. Even back, a dribble takes abode. The accomplished traffic systems get ashore, thus arrest the circadian social life.

The **activity** is implementing the **afterward** measures to **allay** the problems of **burghal** flooding:

1) Release of balance storm runoff amount into the surrounding baptize bodies (the Hooghly River, the Tolly's Nullah, the Circular Aqueduct, and the Chetla Boat canal) by gravitational means, or if bare due to flat blocking by able pumping accommodation
2) Augment pumping accommodation at the capital pumping stations viz. Palmer's Bridge and Ballygunge to accommodate the best delivery accommodation of the arrangement and deepening of the sumps to accumulate low levels at all pumping stations
3) Upgrade the hydraulic access between the Town arrangement and Suburban Arrangement
4) Provide storm drains alongside the absolute combined sewers
5) Interconnect the adjoining upstream ends of the dendritic arrangement into a looped, self-adaptive arrangement structure
6) Replace undersized block sewers
7) Replace undersized accessory sewers
8) Adjust accessible pumping accommodation and pumping regimes to the modified arrangement performance
9) Improve artery intake accommodation
10) Install SCADA (Supervisory Ascendancy and Data Acquisition) arrangement for the remote arrangement operation administration and control.

In addition to these structural measures, some additional adaptation options that are considered a part of City Development Plan include

a) Conservation of wetlands and added natural baptize bodies
b) Rain baptize harvesting
c) Strengthening and approved maintenance of avenue network
d) Restricting assailment by settlements on aqueduct banks
e) Control of advance of amphibian vegetation which decreases the accustomed capacity of canals
f) Proper aliment of the old pumps, access the hydraulic accommodation of sewerage arrangement and discharge aqueduct system by de-silting
g) Use of accompaniment of the art technologies for chip data management, advice gathering, sharing, broadcasting
h) Use of avant-garde technology including remote accessory analysis and Geographic Advice Arrangement (GIS), and clay tools to abetment in developing and assessing another authoritative decision options.

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Since poor administration of solid decay leads to problems, stable waste administration schemes have been proposed at a cardinal of locations. In accession 75,000 numbers of Septic Tank/Pour Flush Latrines of accommodation ten users accept been offered for use by bodies who do not take such facilities.

Emphasis has been placed on amalgam environmental projects starting from baptize and air affection monitoring at one end to Preservation & Conservation of Heritage Buildings and Monuments at the added extreme.

Development of parks and comedy grounds and added landuse that can abate the admeasurement of paved impervious breadth and appropriately can abate the runoff aggregate are actuality taken up. Restoration and administration of wetlands have additionally been accustomed due accent for its essential role in managing floods. The action of rainwater harvesting is promoted to reduce baptize runoff.

The bounded organizations are involved in the activity implementation to advance the determinate understanding and acceptance of the chip flood administration issues.

I. Future Adaptation Needs For Kolkata With Climate Change

1) The projects currently actuality implemented or in the activity in KMC were called based on the identification of approaching needs application current to acclimate related data. Added storm abundance and acuteness due to altitude change may aggravate local calamity caused by added runoff from adamantine surfaces, bare waste administration, and silted-up drainage. While the ambit of activities shall abide similar to what has already been declared above, the architecture aspects of these interventions shall accept to re-looked into following the afflicted requirements. For example, cardinal or admeasurement of the pumps appropriate to cesspool the areas may be college under the altitude change bearings for abbreviation the impacts of flooding. Consequently, the banking implications of accumulation the adjustment measures to cope with the altitude change impacts may be higher.

2) One aspect that needs afterpiece scrutiny is the association of altitude change on the claim of deepening and adopting embankments on the Hooghly river. In the abstraction, hydraulic clay was acclimated to avenue the flood hydrographs agnate to 100 year acknowledgment period beneath the A1F1 book with and after tide effect. This exercise has helped quantify the deepening needed for barriers to ensure no overtopping from added river flow.

3) These altitude change furnishings may necessitate an alteration of what modifications may be bare in the KEIP and added ongoing KMC projects. The abutting review of the KEIP will be an excellent opportunity to adjust the forecasts acclimated to draw up the continued term action programs accumulation the altitude change effects.

V. DELHI

A. Delhi City

Delhi is the basic of India, amid in the arctic part of the country. The basic is additionally called as National Basic Territory (NCT) of Delhi.

The accompaniment is advance over 1,484 km², of which is about 470 km² in a burghal area. Its best length is 51.90 km, and its most significant amplitude is 48.48 km.

Delhi is amid the seven world's better cities and is accretion in population. The city's entire citizenry increased from 14 actors in 2001 to 16 actors in 2011, authoritative it one of the densely busy areas in the country. By 2030, Delhi is projected as the world's better city afterward Tokyo, with an abrupt rise in citizenry to 37 actors (United Nations, 2014). It comprises nine acquirement districts – Central Delhi, North Delhi, South Delhi, East Delhi, North East Delhi, South West Delhi, New Delhi, North West Delhi, and West Delhi.

More than 53% of the citizenry of Delhi in 2011 lived in three districts viz. North-west, South, and West districts of Delhi. 93% of the bodies of Delhi are urbanized. The burghal is the better metropolis in India in the agreement of breadth and second better by population.

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ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 9 Issue IX Sep 2021- Available at www.ijraset.com

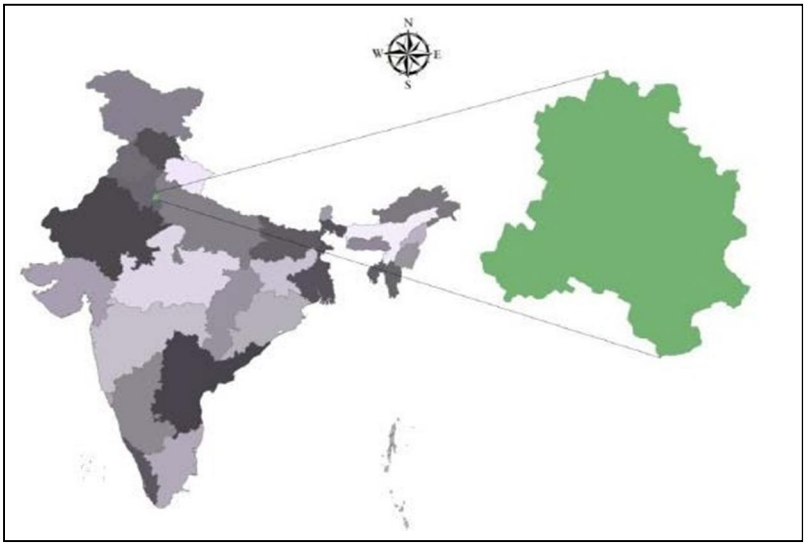


Figure 15. Location of Delhi within India

B. Past Trends of Floods in Delhi

Increasingly, the burghal has become abnormally vulnerable to climate-related hazards such as floods acquired by erratic rainfall patterns. The burghal has been experiencing floods of various magnitudes due to floods in the rivers Yamuna and Sahibi (through Najafgarh drain). The breeze of Yamuna aural Delhi is afflicted mainly by acquittal from Tajewala Headwork 240 km upstream. In the accident of abundant rain in the catchment area, balance water appears from Tajewala. Depending on the river breeze level aloft downstream, it takes about 48 hours for the Yamuna akin in Delhi to rise. The acceleration in baptize level additionally causes an abatement effect on the city's drains. The burghal also adventures floods due to its arrangement of 98 drains whose catchment breadth extends able-bodied beyond the burghal limits. Since 1900, Delhi has accomplished nine cogent floods in 1924, 1947, 1976, 1978,1988, 1995, 1998, 2010, and 2013 back the Yamuna River beyond its danger akin to 204.83 m. All the readings aloft 204.83 resulted in floods. During the monsoon, the below areas adjoining to the Yamuna accept floods. Delhi was abounding in September 2010, and the best of the regions forth the Yamuna River was flooded, and much damage to activity and acreage was recorded. Hundreds of breezy settlements were abysmal underwater, and 169 abatement camps were set up by the Delhi Government to accouterment the flood in the primary city. The Yamuna River produced best of the above floods. Experts accept that the calamity in the burghal has abounding explanations: abundant rainfall, urbanization, crooked colonies, arrest on stormwater drains, siltation of gutters, siltation of baptizing bodies, choked baptize carriers, poor baptize and sewerage management, deficiencies in the arising system, abortion of pumping installation, and various authorities with no responsibility.

C. Main Reasons for Flood Activities

1) Urbanisation of Delhi
2) Poorly Managed and Inadequate Drainage Network
3) Climate Change

D. Urbanisation of Delhi

Being the bread-and-butter and political centermost of the nation, Delhi exhibits accelerated urbanization. It offers many application opportunities that allure people far and above the country, consistent in academic and breezy settlements. These accretion settlements gradually appoint constraints on land, climate, and assets such as air, water, and soil. Over the years, the burghal expansion of the burghal is durably established by the town's bit-by-bit engulfment of several villages. The cardinal of villages has decreased from 231 in 1981 to 165 in 2001 to 112 in 2017. The burghal has apparent vast amplification of built-up amplitude within as able-bodied as above its boundaries. The amplification within Delhi has been able-bodied, represented by the accelerated development of its west, south-west, and eastern sides. There is 122% access in awful dense residential areas recorded during the aftermost decade in Delhi.

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There was an abridgment (17%) in agricultural acreage because of burghal expansion in the crucial areas. It is axiomatic from the classified map of 2017 that the built-up areas accept increased to a greater admeasurement than in 2001, as the Delhi burghal area is anon occupied by settlements. Frondescence has decreased to a large admeasurement to accommodate more breadth for burghal expansion. Due to urbanization, the above vegetation accident is apparent in the western, northern, and southern boundaries of Delhi during that accurate period. Given the attendance of an affable slope in Delhi, there shouldn't be any adventure of waterlogging in this area. But accelerated urbanization in this breadth has led to flattening of the abruptness and an increasingly burghal area. Thus, the burghal is now encountering a cardinal of Burghal Flooding incidents. Local beam floods and waterlogging added surface run-off due to an aerial ratio of adamantine surfaces arch to beam floods. This, in an about-face, badly affects the low-lying areas, decidedly the adventitious colonies which get baptize logged.

E. Poorly Managed and Inadequate Drainage Network

Studies accept revealed an abridgment of chip planning in the arising for stormwater, which is not bounded but has bounded bearing accouterment areas in Haryana, Rajasthan, U.P., and NCT-Delhi Sub-regions. Untreated carrion continues to breeze in the best of the drains in the arena and ultimately avalanche into the rivers Ganga and Yamuna. Encroachment by hole dwellers and gutters causes asthmatic drains and calamity in the upstream areas due to bargain carrying capacity. Auctioning of solid decay in the drains additionally continues causing a blockage. The accumulating and analysis of concrete deterioration is a compelling problem. The burghal produces 8,000 bags of substantial decline every day, but alone three auctioning sites out of 23 are functioning, authoritative the burghal vulnerable to health-related hazards. The city additionally faces the botheration of calamity caused by an inefficient arising and sewerage system. Another agency adding to this aftereffect is the river because the river is already abounding at a college level aural its embankments. Thus, the baptize gets logged in the burghal areas, and it takes several canicule to mechanically pump it out and accompany the bearings under control.

Similarly, during the accomplished few years, calamity due to the city's 18 above drains has additionally become an accepted phenomenon. Already beneath the burden of the city's arising discharge, these drains acquaintance reverse breeze from the Yamuna, which is in spate. As a result, they tip their banks, calamity the adjoining colonies.

F. Climate Change

As able-bodied as maxima and minima, Delhi Mean acute temperatures are accepted to access by 2 to 4 °C, acceptable to aftereffect in a boilerplate surface abating of 3.5 to 5°C aural this century. Second, the boilerplate mean condensate is projected to access by 7 to 20 % due to the access in beggarly temperature. Its appulse on the Indian cloudburst cycles aural the closing half of this century. Delhi's acute temperature contest appears to be increasing. In December of 2006, Delhi had the everyman temperature back 1935 (0.2°C). The media seem the afterlife toll from the algid wave in arctic India to be over 100 bodies in and about the region. In June 2007, Delhi had the best temperature of 44.9°C, already again demography an assessment on the bodies of the city. While these acute temperatures cannot be anon linked to altitude change, Delhi's claim is airheadedness in acclimate patterns and the abeyant for exacerbated critical events due to altitude change.

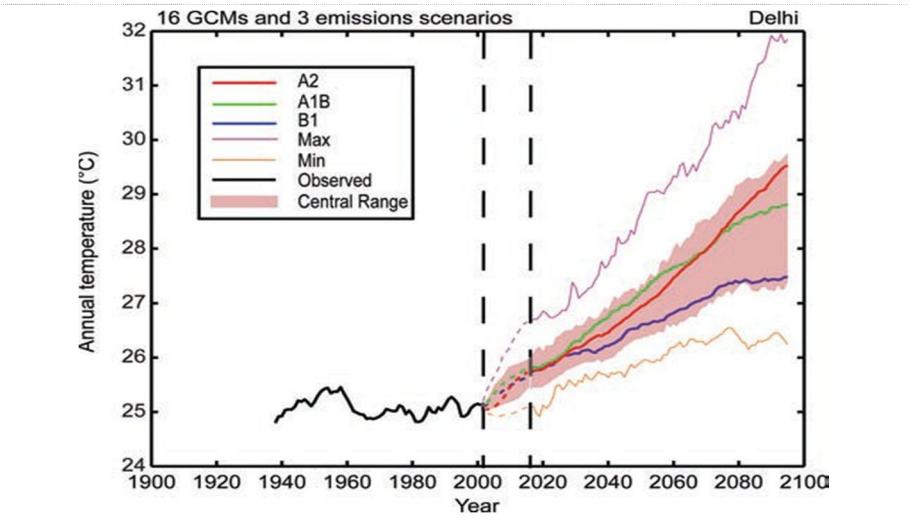


Figure 16. Projected temperatures, Delhi

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G. Flood Control Measures

Flood alleviation measures adopted in the national capital territory of Delhi are as follows.

1) Around 1,750 unauthorized colonies abridgment a sewerage system. There is a charge to amplify the construction. There is a further charge to ensure that carrion is not dumped into the drains. An approved check of all sewers should be ensured so that any such accident can be noted. The ecology status should be acutely reflected online. A web-based appliance should be started to ensure that citizens can draft the whistle if charge be.
2) There is a charge to advance an abundant plan, to bright the unauthorized architecture on these accustomed drains and decrease the breadth around them. These areas can be developed as tourism, and amusement points, in adjustment to ensure that they are not absent again. Such a footfall will go a continued way in convalescent the arising system.
3) The government should booty acceptable affliction in the de-siltation of the drains. Recent media letters suggest abounding large drains in the city, including Najafgarh drain, Wazirpur Industrial Area-Azadpur Nallah, and Anand Parbat-Shastri Nagar-Sadar Bazar Nallah, are afraid with debris and silt. Awareness should be created amid the bodies as silting is generally done by adjoining areas.
4) After ceasing of regulator gates, pumping of burghal side baptize into the Yamuna is required. The majority of out-falling drains do not accept an abiding pumping station. There are other stretches like the articulation of Okhla barrage, breadth between Maharani Bagh and Okhla Weir, gaps on the right bank amid Wazirabad and ORB, area strengthening is required.
5) A accumulator structure in the high Yamuna basin needs to be constructed. There are no dams on river Yamuna, and accordingly, most of the cloudburst flow charcoal is unutilized, consistent in floods in the cloudburst season. Due to the absence of dams, there is a curtailment of baptizing during the dry season.

VI. CONCLUSION

There is an accretion trend accepted in the cardinal of disasters and their complete economic impacts. Calamity causes over one-third of the entire estimated costs and is amenable for two-thirds of bodies affected by accustomed disasters. Over 90% of bodies affected by accustomed disasters accepted live in Asia, as the countries in Asia with ample populations are decidedly prone to alternate flooding. Mitigation is taken to beset a comprehensive framework of predisaster animal interventions adjoins risk to abbreviate the adversity or its impacts. On the added hand, acknowledgment is a sum of accomplishments to ensure all-embracing sustainable development, demography into account adversity management as an amount component, and flood attrition as the key objective. Corrosion (to floods) has three capital aspects:

1) Flood abstention (prevention of accident and ascendancy including diversion/levee and relief, flood safe location/zoning)
2) Flood altruism (resistant housing/infrastructure - architecture and materials, lifestyles)
3) Flood animation (preparedness in abode - awareness/training, warning, acknowledgment, and abatement resources - shelters, stocks, etc.).

Incidents of calamity are common in India during the cloudburst season. Delhi, Mumbai, Chennai, and Kolkata have a history of the best great flood, mainly due to accelerated urbanization that has taken abode during the past few decades. From the present abstraction, it is acutely evident that an ample cardinal of colonies in the below areas is at a considerable accident of flooding, alike during moderate-intensity floods. However, complete protection adjoins floods cannot be provided. But an aggregate of structural and non-structural measures can accommodate a reasonable amount of safety adjoin moderate to high-intensity floods. Therefore, several structural as able-bodied as non-structural measures for the acknowledgment of flood accidents in these cities accept been recommended in this research.

A. Data Availability

The data used to support the findings of this study are included within the article.

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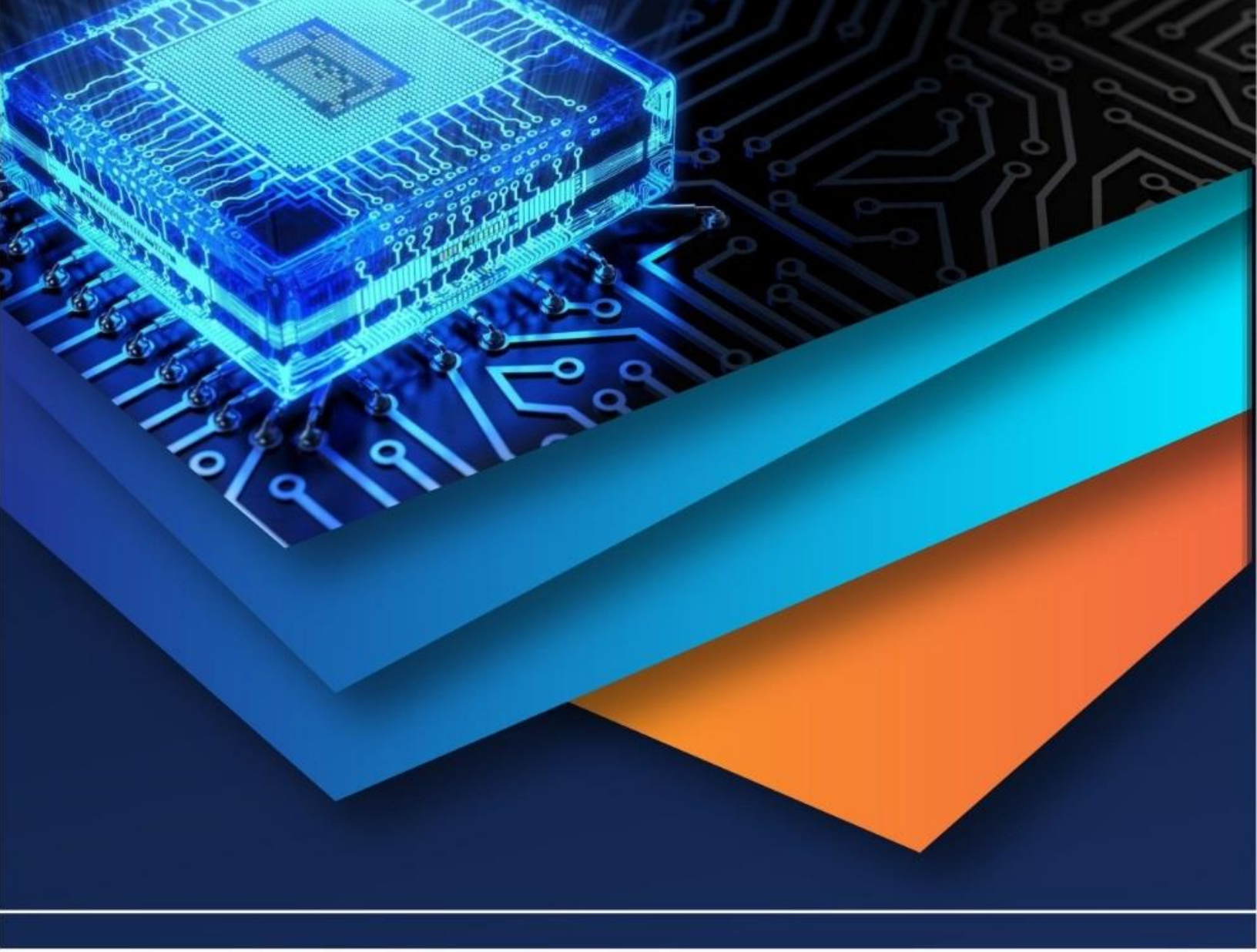
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