Karachi Rain Water Drainage Issues and Recommendations

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Nov, 2020

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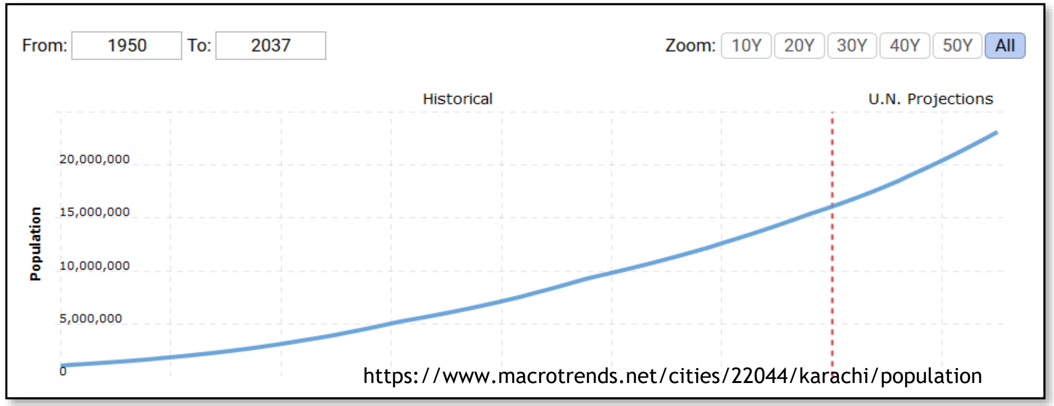
City History and Background

- Modern Karachi was reputedly founded in 1729 as the settlement of *Kolachi-jo-Goth*. The new settlement is said to have been named in honour of *Mai Kolachi*, whose son is said to have slain a man-eating crocodile in the village after his elder brothers had already been killed by it. The name *Karachee*, a shortened and corrupted version the original name Kolachi-jo-Goth, was used for the first time in a Dutch report from 1742 about a shipwreck near the settlement.
- The British East India Company captured Karachi on 3 February 1839 after HMS Wellesley opened fire and quickly destroyed Manora Fort, which guarded Karachi Harbour at Manora Point.
- In 1843, Karachi was annexed to the British Empire, the entire province was amalgamated into the Bombay Presidency for the next 93 years.
- With the completion of the Suez Canal in 1869, Karachi's position as a major port increased even further. In 1878, the British Raj connected Karachi with the network of British India's vast railway system. In 1887, Karachi Port underwent radical improvements with connection to the railways, along with expansion and dredging of the port, and construction of a breakwater.
- Public building works were undertaken at this time in Gothic and Indo-Saracenic styles, including the construction of Frere Hall in 1865 and the later Empress Market in 1889.
- After Independence, Karachi was selected as the first capital of Pakistan, and was administered as a federal district separate from Sindh beginning in 1948, until the capital was shifted to Rawalpindi in 1958.

Source: https://en.wikipedia.org/wiki/Karachi



Karachi Population increased at the rate of 5% from 1952 to 1980, and then at the rate of 2.5% from 2000 to 2020.

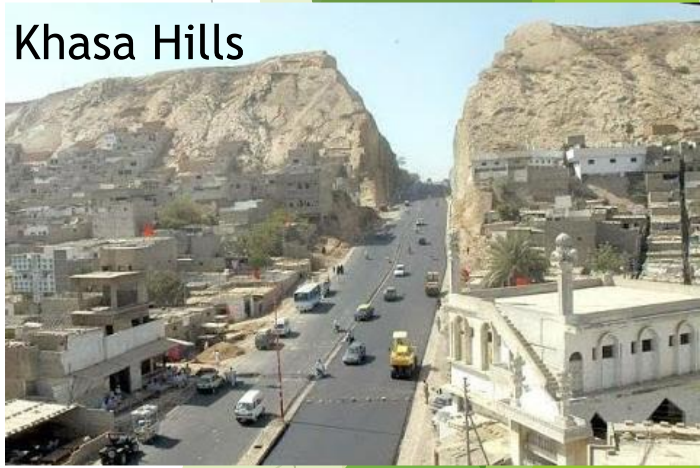
From 1950 to 2020, the population increased from 1.1m to 18m

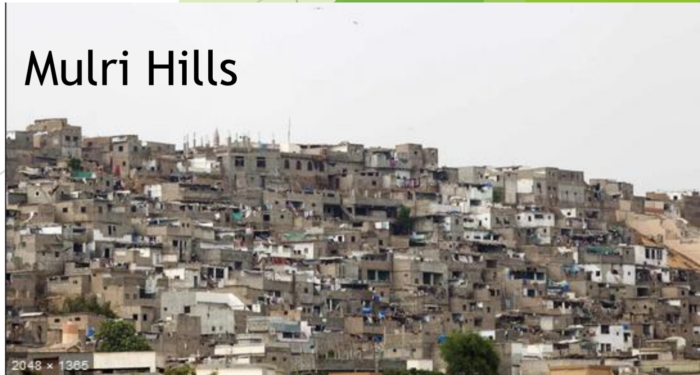
Karachi Land Geography

- Karachi is located on the coastline of Sindh province in southern Pakistan, along a natural harbor on the Arabian Sea. Karachi is built on a coastal plain with scattered rocky outcroppings, hills and marshlands. Mangrove forests grow in the brackish waters around the Karachi Harbor, and farther southeast towards the expansive Indus River Delta. West of Karachi city is the Cape Monze, locally known as Ras Muari, which is an area characterized by sea cliffs, rocky sandstone promontories and undeveloped beaches.

- Within the city of Karachi are two small ranges: the Khasa Hills and Mulri Hills, which lie in the northwest and act as a barrier between North Nazimabad and Orangi. Karachi's hills are barren and are part of the larger Kirthar Range, and have a maximum elevation of 528 meters (1,732 feet).

- The city is divided by two non-perennial river streams namely Rivers Lyari and Malir. The River Malir flows from the east towards the south and center, and the River Lyari flows from north to the southwest. The main tributaries of the River Lyari are Gujjar nullah and Orangi nullah, while Thaddo and Chakalo are the main tributaries of the River Malir.





Water Resources

- Most of the supply comes from the Indus River, and 90 MGD from the Hub Dam.
- Keenjhar Lake is situated about 36 kilometers (22 mi) from the city of Thatta. It is the second-largest fresh water lake in Pakistan and an important source of drinking water for Thatta District and Karachi city.
- The three main sources of the city's water supply are Lake Hāleji, 55 miles (90 km) away, fed by the Indus River; wells that have been sunk in the dry bed of the Malīr River, 18 miles away; and Lake Kalri, 60 miles away, also fed by the Indus waters.
- Karachi gets about 78% drinking water from Keenjher Lake thru 2 canals specially built for this purpose
- Karachi's water supply is transported to the city through a complex network of canals, conduits, and siphons, with the aid of pumping and filtration stations.
- 76% of Karachi households have access to piped water as of 2015, with private water tankers supplying much of the water required in informal settlements.
- 18% of residents in a 2015 survey rated their water supply as "bad" or "very bad", while 44% expressed concern at the stability of water supply.
- The K-IV water project is under development at a cost of $876 million. It is expected to supply 650 million gallons daily of potable water to the city, the first phase 260 million gallons upon completion

K-IV Project; Part of Greater Karachi Water Supply Scheme, Indus Water from Keenjhar Lake to Karachi City		
Phase	**Capacity**	**Proposed Completion Year**
K-IV Phase-1	260 MGD	Year 2018
K-IV Phase-2	260 MGD	Year 2022
K-IV Phase-3	130 MGD	Year 2025
Total Cost	Rs. 25.6 billion	

Source: Frontier Work Organization (2019)

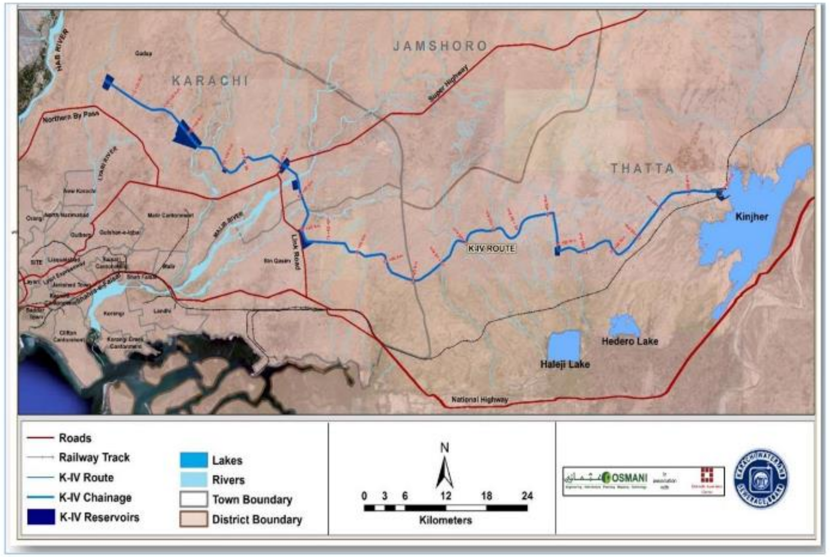


Figure 8: K-IV Bulk Water Supply Schemes Karachi

Source: Osmani & Co. (Pvt). Ltd. (2015)

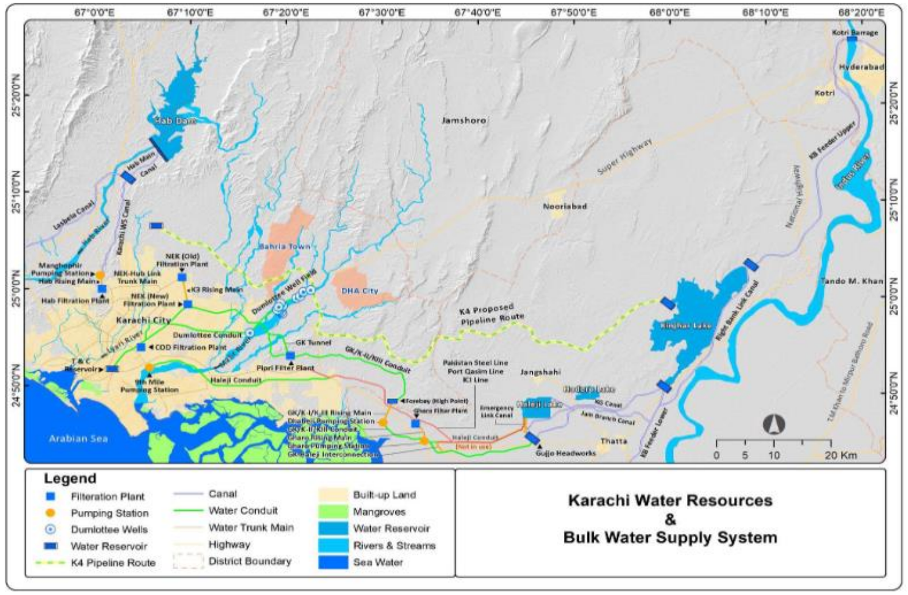


Figure 10: Karachi Water Resources and Bulk Water Supply System

Drainage and Sanitation

- 98% of Karachi's households are connected to the city's underground public sewerage system, largely operated by the Karachi Water and Sewerage Board (KW&SB)
- The KW&SB operates 150 pumping stations, 25 bulk reservoirs, over 10,000 kilometers of pipes, and 250,000 manholes.
- The city generates approximately 472 million gallons daily (MGD) of sewage, of which 417 MGD are discharged without treatment.
- There are three sewer districts in Karachi city, namely TP-1 (SITE), TP-2 (Mahmoodabad) and TP-3 (Mauripur). A system of six large scale and 16 smaller scale pumping stations convey the generated sewage directly or indirectly to one of three sewage treatment plants. Out of the 151.5 MGD of installed capacity of wastewater treatment only 55 MGD of wastewater is treated
- 72% reported in 2015 that Karachi's drainage system overflows or backs up, the highest percentage of all major Pakistani cities.
- Parts of the city's drainage system overflow on average 2–7 times per month, flooding some city streets

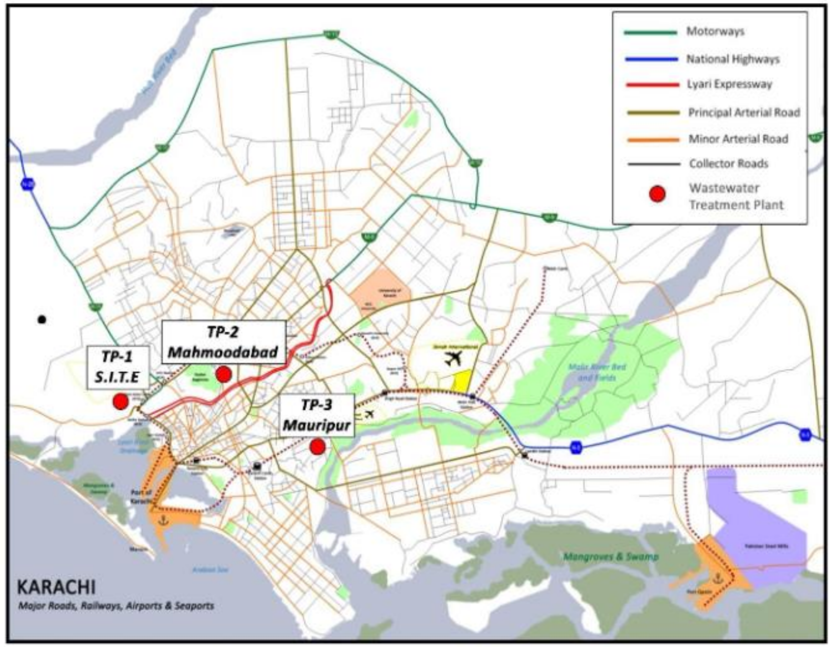


Figure 13: Wastewater Treatment Plant Locations in Karachi

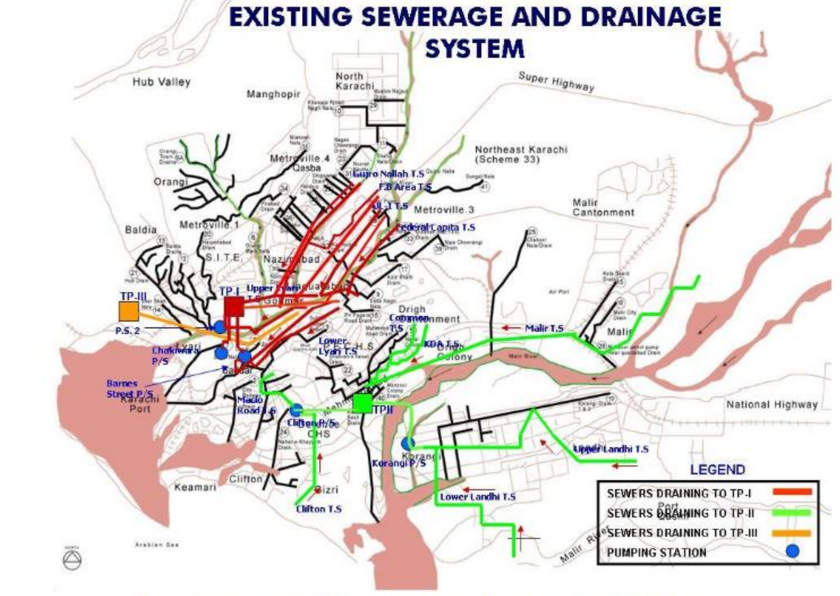
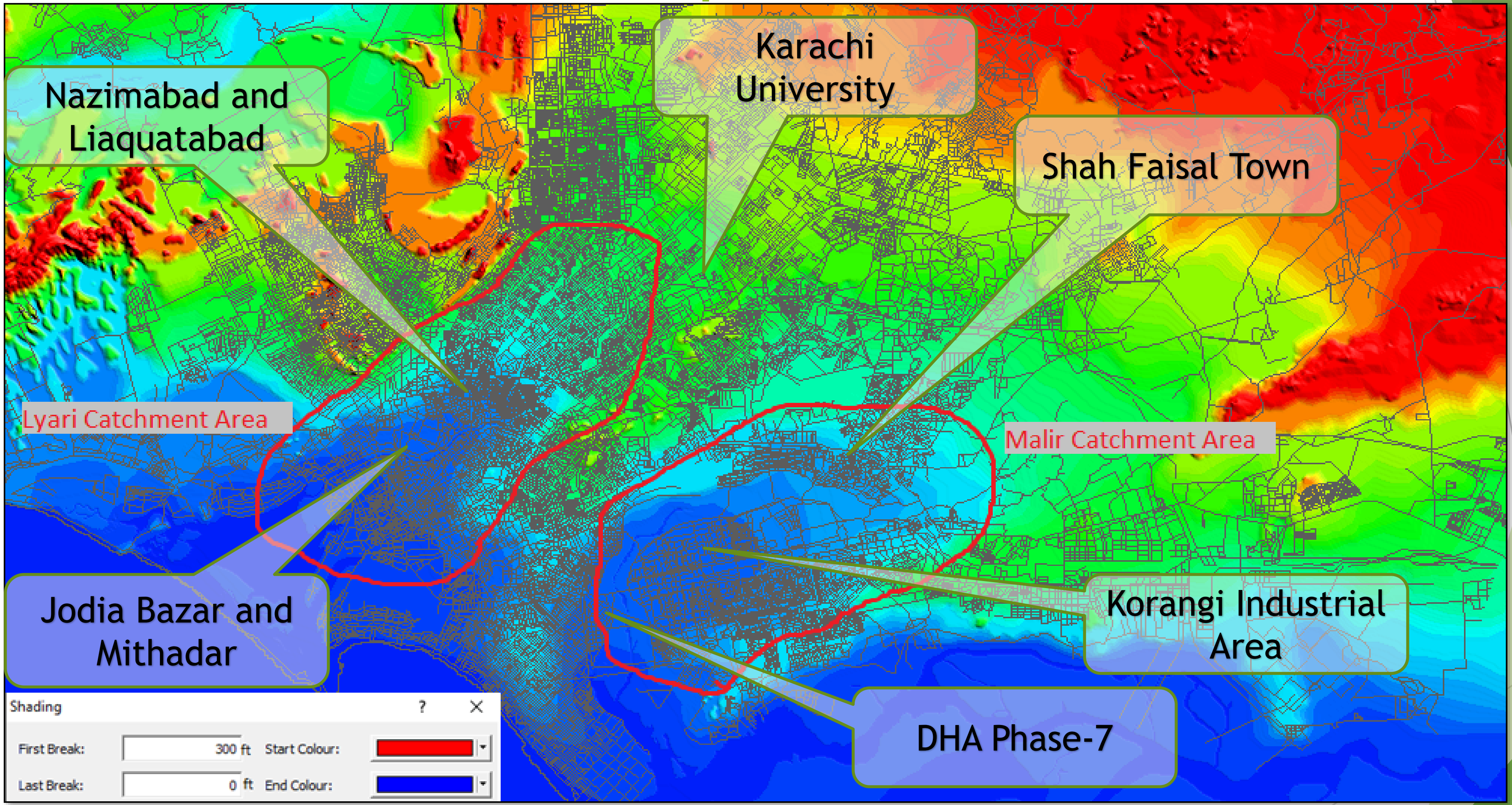


Figure 12: Sewerage and drainage system of Karachi showing Treatment plant's network

Source: KWSB, Sewage Disposal System, (2019)

Karachi Elevation Map

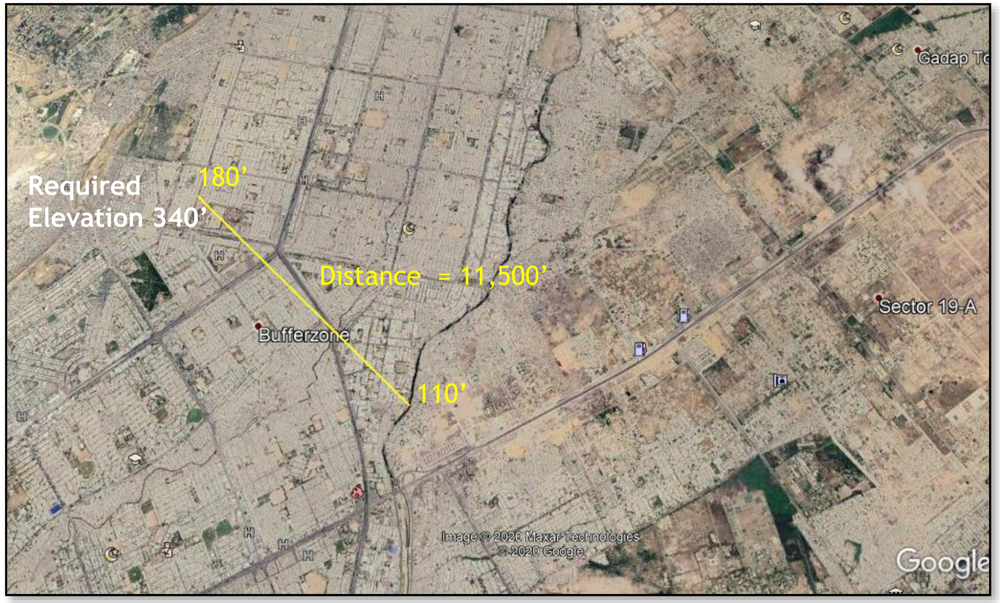


- Many notable parts of the city are actually under the Water Catchment Area, which means by geographical point of view, these are depression areas where water is stored naturally.

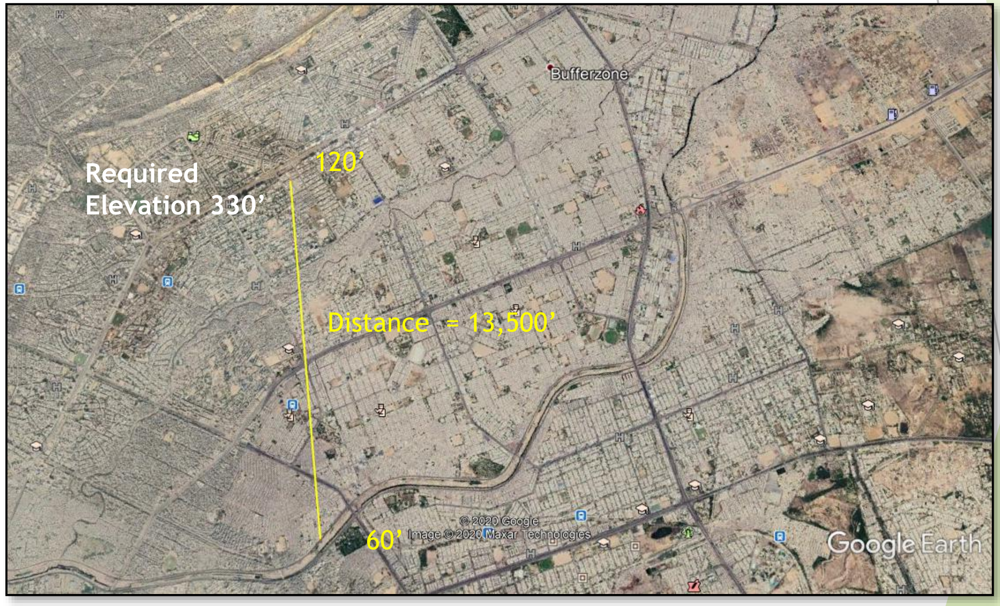
Waste Water Minimum Inclination Requirement

- Large sewer lines and canals (including Nullahs) are required be designed to have an inclination slope of 2% to 5%.
- This means for a 100ft length, if the lower end is at 0ft, then the higher end should be between 102 to 105ft for the proper drainage of water.
- Based on the above criteria, following slides shows the actual and the required height of some notable areas (w.r.t. to the nearby Nullahs) in Karachi to have a natural flow of rain water and drainage.

Inclination Requirement for Waste Water Drainage with 2% Inclination

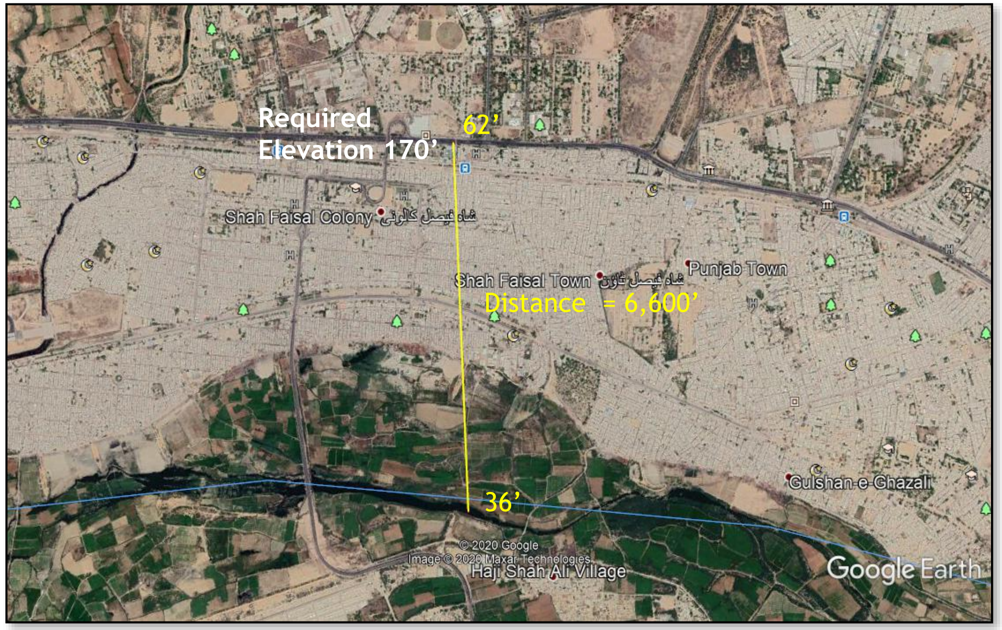


The Required Height at North Nazimabad should be 340' instead of 180'

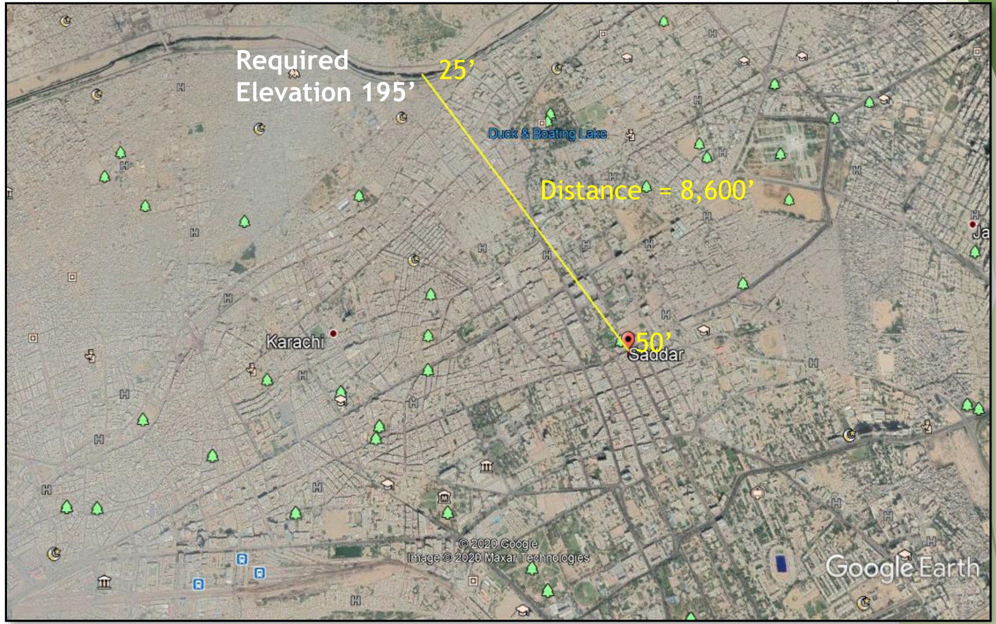


The Required Height at Hydari should be 330' instead of 120'

Inclination Requirement for Waste Water Drainage with 2% Inclination



The Required Height at Shahrah e Faisal, should be 170' instead of 62'



The Required Height at Saddar, should be 195' instead of 50'

Future of Wastewater Treatment

- Greater Karachi Sewerage Plan (S-III)
  - To improve the sewerage system of Karachi and reduce the pollution load on natural water bodies, KWSBis working on Greater Karachi Sewerage Plan (S-III).
  - This project, through a well-integrated system of collection, treatment and sewage of wastewater from municipal and industrial sources, aims to improve the environmental conditions of Karachi.
  - In this project, sewage will be transmitted to the River Lyari and Malir via a RCC before finally being disposed off in the sea.
  - Following initiatives will be taken under this project
    - Malir Trunk Sewer: 05 Contract Packages with overall length of 22.74 km
    - Lyari Trunk Sewer: 08 Contract Packages with overall length of 33.32 km
    - Upgradation and Capacity Enhancement of Sewage Treatment Plant from 51 to 100 MGD at Haroonabad SITE
    - Upgradation and Capacity Enhancement of Sewage Treatment Plant from 54 to 180 MGD at Muaripur
    - Construction of New Sewage Treatment Plant at Korangi of 180 MGD

Upcoming Projects by KW&SB

- To address the issues of Water Shortages and Drainage in the city, following projects are in pipeline.
  - K-III Textile City and CETP
  - Greater Karachi Water Supply Project K-IV
  - Rehabilitation of Dhabeji Pump House Phase-I
  - Rehabilitation of Clifton Pumping Station (CPS)
  - Greater Karachi Sewerage Plan S-III

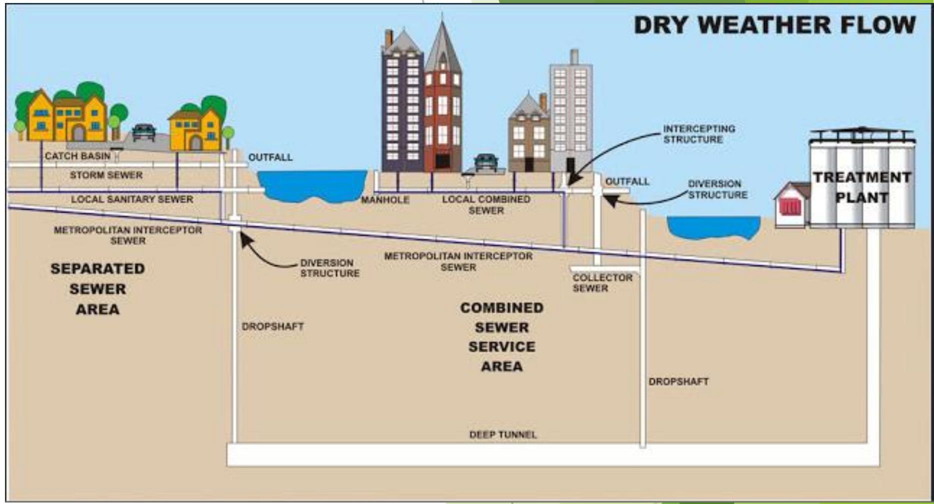
Recommendations and Solution Proposals

Hypothetical Solutions

- Deepening of the Drainage Canals and Nullah
  - The Nullah Drainage into the sea at shoreline is barely 10’ above sea level. Any further deepening will create reverse salt water flow from the sea into the Drainage Nullahs.
- Increasing the Elevation of the City
  - Although such solutions were adapted to raise the cities of New York, London, Amsterdam in the early years of settlements, to avoid flooding from the nearby river, such a solution is not feasibly both technically and financially for the current length and breadth of Karachi.

Construction of Ponds and Wetlands

- Strong and effective Storm Water Management plan is needed for the city. Currently both major drain for the city namely Rivers Lyari and Malir as well as major nullahs including their outfall points in the city are badly affected due to dumping of solid waste and encroachments. It needs special attention in order to improve the sewerage flow and reduce the urban flooding situation in rainy season.
- Most appropriate recommendations for treating domestic wastewater are:
  - (a) Waste Stabilization Ponds (WSPs)
  - (b) Constructed wetlands (CWs) (phyto-technology).
- WSPs have already been successfully set up in many urban areas, while CWs are quite sustainable, aesthetically pleasing and cost-effective green wastewater treatment technology, particularly for developing countries including Pakistan. CWs innovatively optimize the wastewater treatment process with zero or very low energy consumption. Similarly, WSPs is an algal-based inexpensive and effective substitute for wastewater treatment option which may also be adopted for wastewater treatment of Karachi.

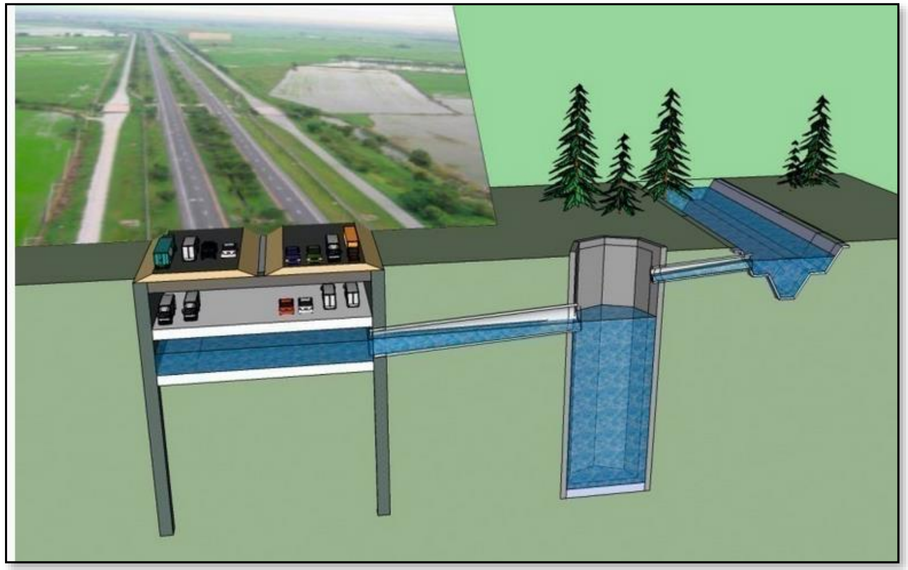


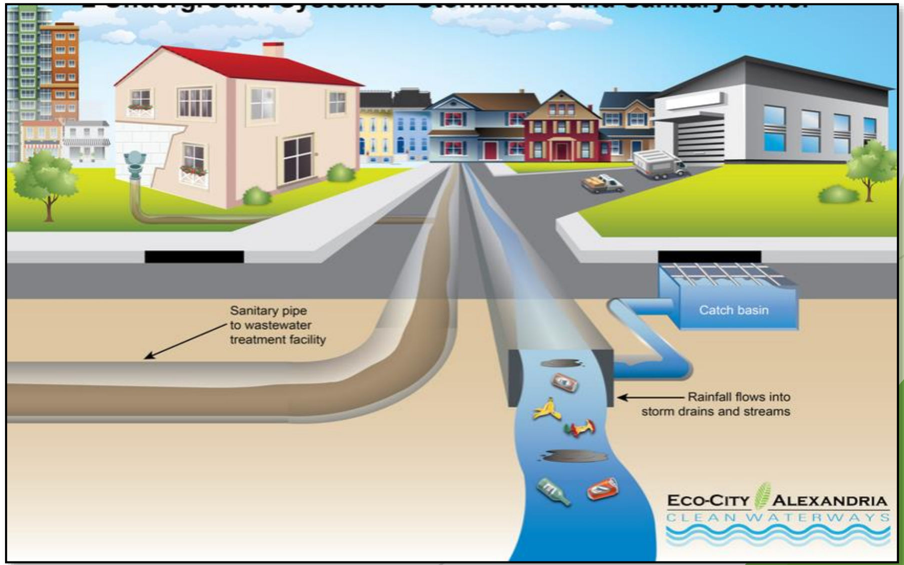
Small Reservoirs and Check Dams

- Small Reservoirs and check dams for water storage
  - Construction of small reservoirs around Karachi can reduce the rate of rain water wastage and store water for use.
  - Malir River and its tributaries discharge the highest amount of flood water from land area to the Arabian Sea.
  - Check dams should be constructed on the streams like Jarando, Langheji, and Watanwari for flood control and groundwater recharge. The purpose of check dams is to stop the movement of sediment in streams, thus mitigating erosion while also replenishing aquifers.
  - Check Dams have also been constructed in DHA City Karachi for accumulation/storage of rain water and for the constant recharging of aquifer to maintain the underground water level.
  - The city government needs to build small reservoirs and check dams in Karachi on priority basis in order to store water, harvest rain water in light of water policy 2018, and to protect the agricultural and residential lands in Malir. It is also suggested to develop strategy to use local ponds, wetlands, lakes as natural expanded storages.

Flood Tunnel System

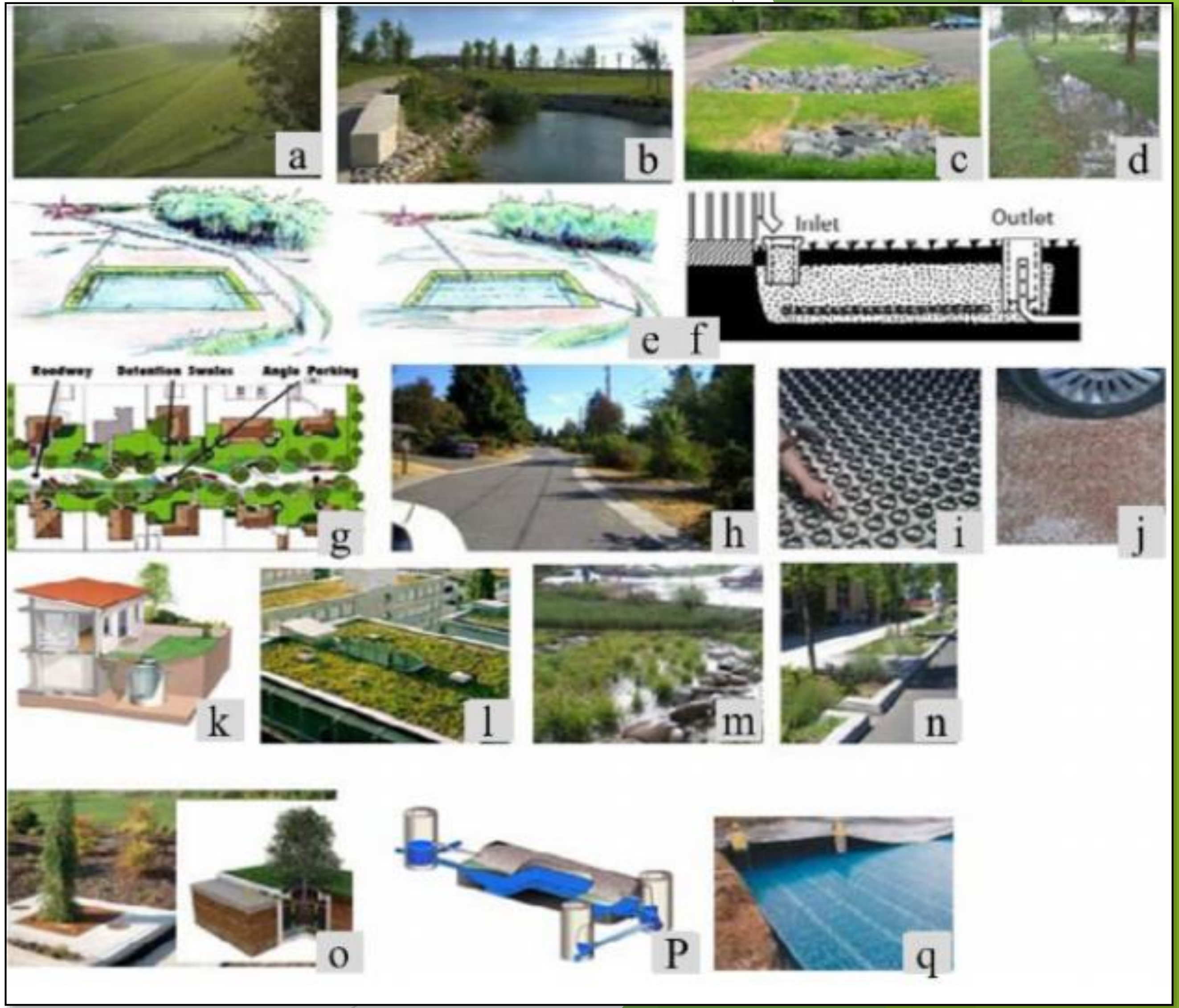
- Multipurpose Underground Service Flood Tunnel System (MUSTS)
- A system of arteries for the flood water tunnels can be developed along the major highways with storage tanks.
- These systems will keep major highways such as Shahrah e Faisal, National Highway, University Road, Shahrah e Pakistan and Rashid Minhas Road clear from flood water.
- Separate Sewer Systems for Storm water and Sanitary Sewer
- Rainwater is comparatively easy to filter and clean compared to sewer water.
- Storm water, wherever possible, should have separate piping system for each housing schemes to cater for, and connected to garden and green belt watering system.





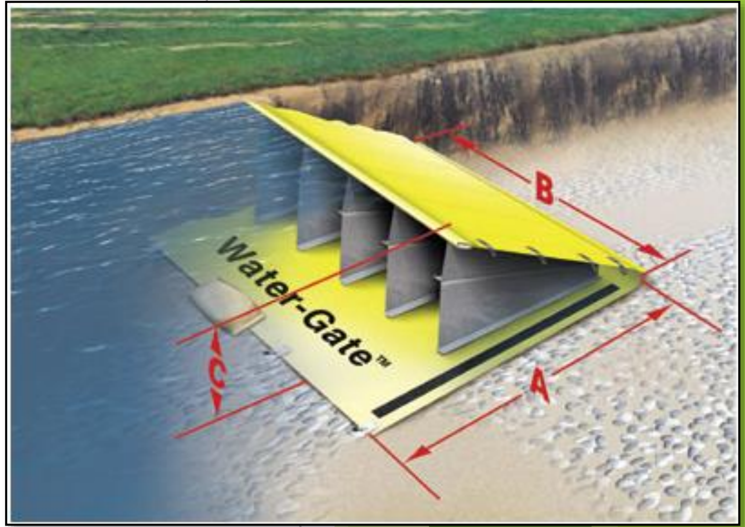
Small Scale Flood Mitigation Measures

- Small Scale Flood Mitigation System can be installed / constructed at the very local level of houses and gated community.
- These Mitigation Measures include:
  a. Retention Basins
  b. Detention Ponds
  c. Infiltration Ponds
  d. Drainage Ditches
  e. Flow Discharge and Flow Energy Control System
  f. Infiltration Trenches
  g. Detention Swales
  h. Plantation to tolerate flooding and erosion
  i. Permeable Spaces and Parking
  j. Permeable Paving
  k. Micro Reservoirs
  l. Green Roofs
  m. Rain Gardens
  n. Pluvial Seedbeds
  o. Individual Infiltration
  p. Underground Storage Tanks
  q. Modular Storage of Ground Water Runoff



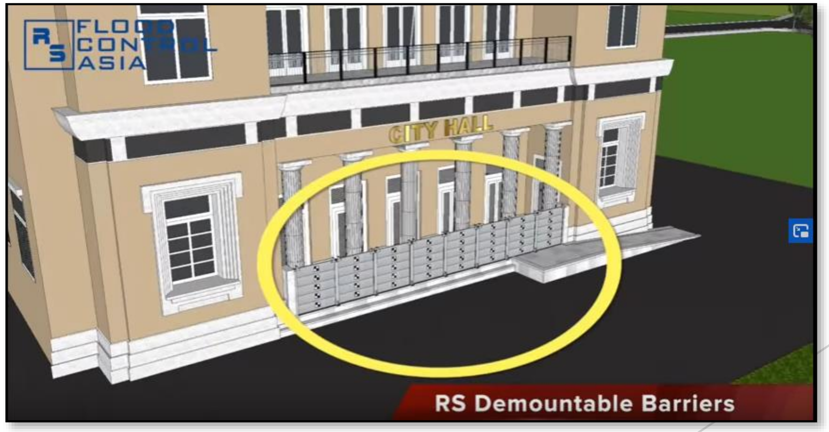
Water Gate and Water Barriers

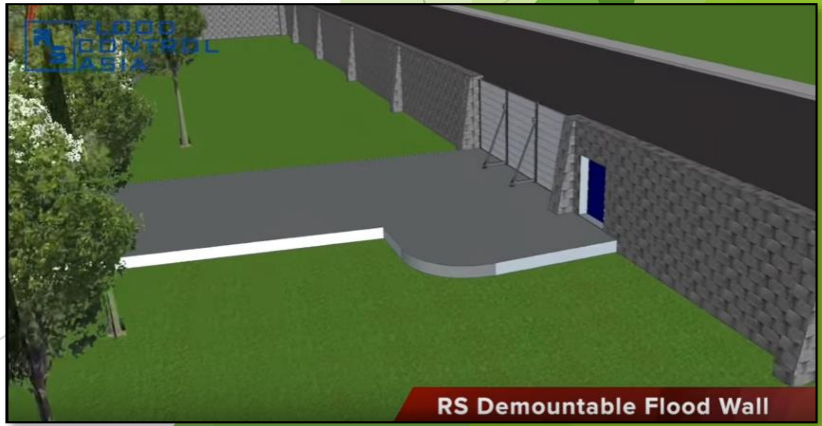
- Portable and Inflatable Water Barriers are easy and cost efficient temporary solution during Heavy Rain or Flooding Season.
- Water Gates and Barriers can be installed at entry points of low-laying areas to avoid water runoff and stagnation.
- These solutions can also be used on Roads and Highways to avoid flooding.
- Most beneficial will be to use at roads leading to Underpass and Tunnels.



Demountable Flood Walls and Barriers

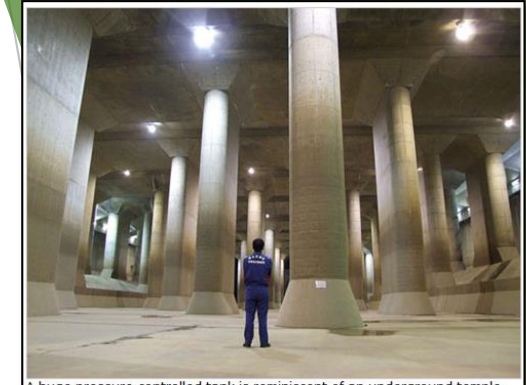
- Demountable Flood Walls and Barriers along with Water Tight Windows and Doors provide excellent solution to small and large buildings, including Malls, Banks, Govt. Offices, Schools, etc.
- These temporary walls and barriers can be installed as per requirement during the rainy season or flooding.
- These work best with Water Resistant walls and water tight windows and doors.





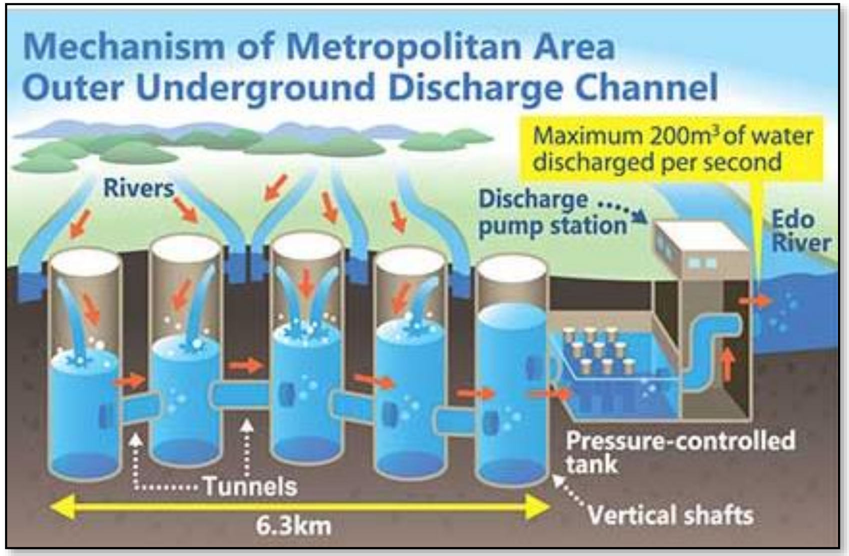
Underground Water Storage Reservoir

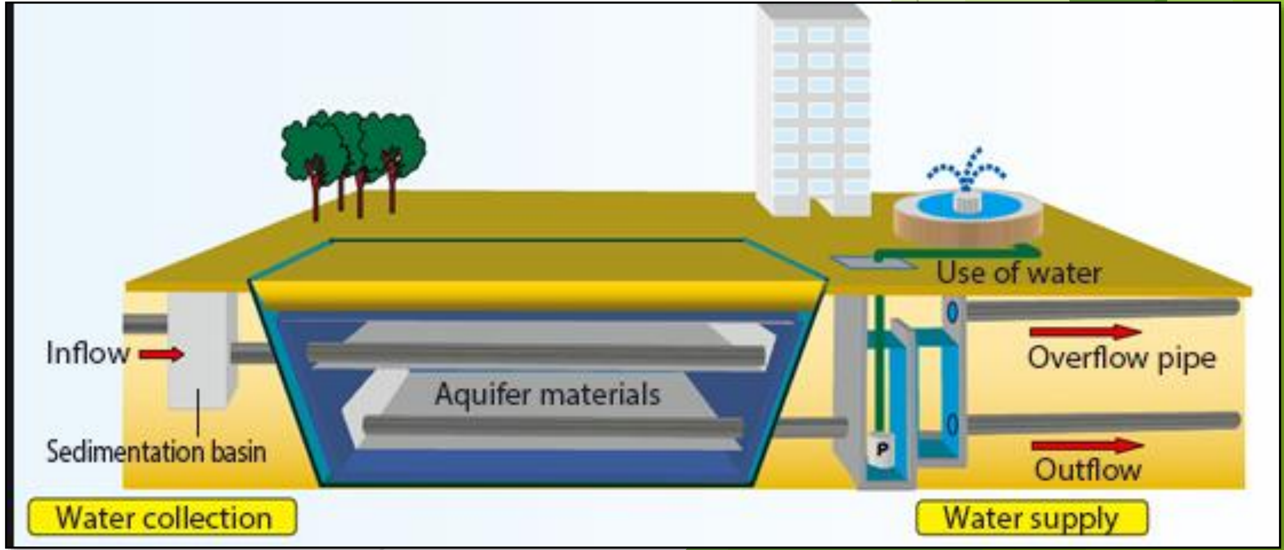
- Large Scale Underwater Storage Reservoirs are permanent solutions for Rainwater and Flash Flooding.
- These Underwater Reservoirs need to be carefully planned on the paths of flooding and water runoffs and need to be isolated from Drainage and Sewer System.
- These reservoirs could be used for both drinking and plantation purposes.
- Pakistan’s first such project has been initiated in Lahore and similar constructions are expected in other cities as well.
- One of the largest flood tunnel and storage tank systems is found on the northern outskirts of Tokyo, Japan. The Metropolitan Area Outer Underground Discharge Channel, also known as the G-cans project commenced in 1993 and the project was fully completed in 2006, at a cost of US$2.6bn.



A huge pressure-controlled tank is reminiscent of an underground temple.
© EDOGAWA RIVER OFFICE

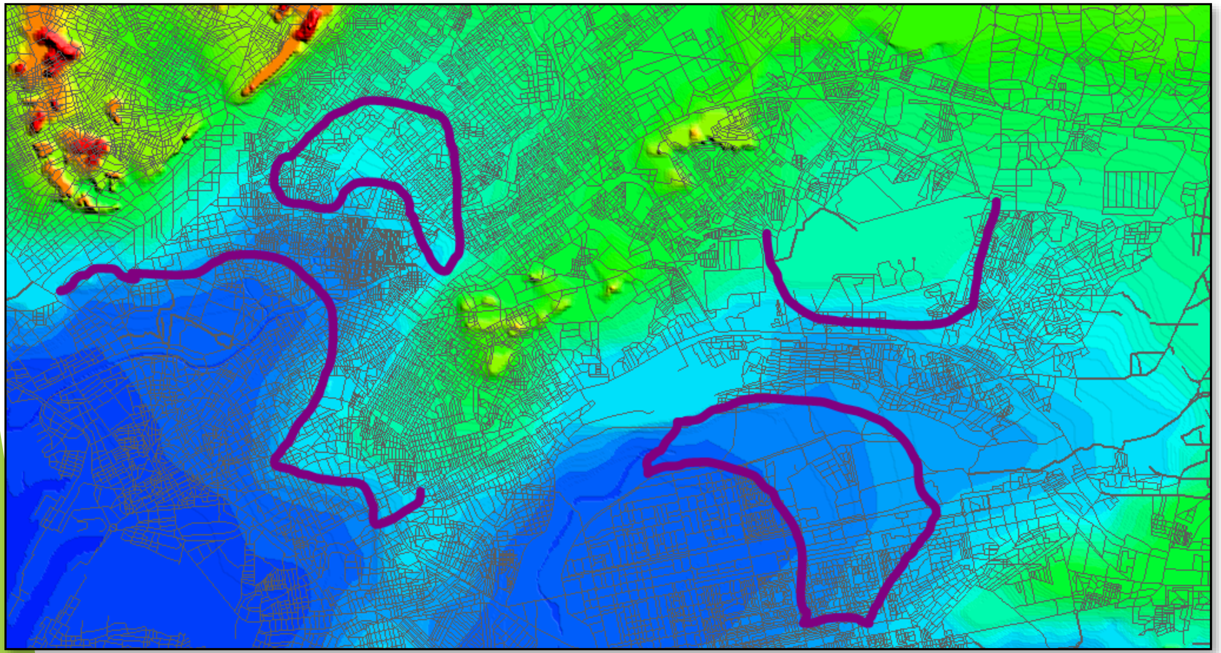
Visitors at the G-Cans Storm Tunnel – Photo: flickr.com/photos/technostan/





Dikes and Levees

- Dikes and Levees are another mega level project to divide the city into several circumferences based on the geography and land elevation.
- These system of Dikes and Levees will ease the control of water flow from one embankment to the other based on flooding level.
- Such a system require national and international level planning and execution.
- Example of Dikes outline to prevent flooding in specific areas of the city are as below:



Conclusion

- For a Mega City like Karachi, any one solution is not going to solve the issues of drainage and flooding.
- A number of large and small scale projects are required to be initiated in coordination with each other, to ease the load on existing drainage and relief the city from rainwater flooding.
- National and Provisional Govt. should take accelerated steps to complete the ongoing related projects and release funding and resources for the planned ones.
- The financial loss in damages and rehabilitation every monsoon exceeds than the installation of small scale prevention and mitigation systems for rainwater and flood.
- Plastic choking is the single major reason for the blocking of drain pipes and sewer system and should be banned from general purpose usage.
- Complete dependence on Govt. bodies be avoided and small scale flood mitigation system should be installed/constructed at the housing communities and housing schemes
- During the research of this topic, it was observed that there is almost zero study or research in this area. Civil Engineering and Urban Design Universities and Departments are encouraged to do research and provide solutions to the recurring issue of drainage and rainwater flooding in Karachi.
- Similar solutions can be sketched out for other flat-land cities such as Lahore, Faisalabad and Rawalpindi.

References

- NATIONAL WATER POLICY (2018) By MINISTRY OF WATER RESOURCES, GOVERNMENT OF PAKISTAN (https://ffc.gov.pk/wp-content/uploads/2018/12/National-Water-Policy-April-2018-FINAL_3.pdf)
- The Case of Karachi, Pakistan - By *Arif Hasan and Masooma Mohib*
- Karachi Water & Sewerage Board – Upcoming projects (http://www.kwsb.gos.pk/View.aspx?Page=95)
- Situational Analysis of Water Resources of Karachi (https://d2ouvy59p0dg6k.cloudfront.net/downloads/report___situational_analysis_of_water_resources_of_karachi.pdf)

  (https://wwfasia.awsassets.panda.org/downloads/final_karachi_brief.pdf)
- Karachi, Pakistan Metro Area Population 1950-2020 (https://www.macrotrends.net/cities/22044/karachi/population)
- Drainage and Sewer Pipe Slope (https://www.archtoolbox.com/materials-systems/plumbing/pipe-slope.html)
- Karachi - Encyclopedia Britannica (https://www.britannica.com/place/Karachi)
- Karachi – Wikipedia (https://en.wikipedia.org/wiki/Karachi)
- Keenjhar Lake – Wikipedia (https://en.wikipedia.org/wiki/Keenjhar_Lake)
- THE STUDY ON DRAINAGE AND SEWERAGE IMPROVEMENT PROJECT IN PHNOM PENH METROPOLITAN AREA (2016) (https://openjicareport.jica.go.jp/pdf/12270294_01.pdf)
- The Study On The Master Plan Of Greater Phnom Penh Water Supply (Phase 2) (https://www.fsmtoolbox.com/assets/pdf/184.pdf)
- Long Term Flood Prevention in Chaophaya Basin, Thailand (https://www.tunnel-online.info/en/artikel/tunnel_2012-03_Long_Term_Flood_Prevention_in_Chaophaya_Basin_Thailand_1419390.html)
- Two Types of Sewer Systems – Alexandria (Virginia) (https://www.alexandriava.gov/tes/stormwater/info/default.aspx?id=100183)
- Urban Floods Adaptation and Sustainable Drainage Measures (https://www.researchgate.net/publication/320914835_Urban_Floods_Adaptation_and_Sustainable_Drainage_Measures)
- Flash Flood Hazard Mapping Using Satellite Images and GIS Tools: A case study of Najran City, Kingdom of Saudi Arabia (KSA) (https://www.sciencedirect.com/science/article/pii/S1110982315000307)
- Water-Gate™ Instant Water Barrier (https://www.fs.fed.us/eng/pubs/html/02511306/02511306.html)
- Rainwater Harvesting Tanks (https://www.graf-water.com/rainwaterharvesting.html)
- Rainwater Harvesting Potential and Utilization for Artificial Recharge of Groundwater Using Recharge Wells (https://www.mdpi.com/2227-9717/7/9/623/htm)
- 5 Methods of Flood Protection - Flood Control Asia (https://www.youtube.com/watch?v=-0e2wZ32CAA)
- Water Sensitive Urban Design (https://www.youtube.com/watch?v=b_DTnOzYTR4)
- World-Class Underground Discharge Channel (https://web-japan.org/trends/11_tech-life/tec130312.html)
- G-Cans Project, Tokyo – Japan's $2.6 Billion Flood Tunnel (http://floodlist.com/protection/g-cans-project-tokyo-flood-tunnel)
- Deep Tunnel Jakarta (http://aksarafirdaus.blogspot.com/2013/02/perbandingan-deep-tunnel-jakarta-dengan.html)

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