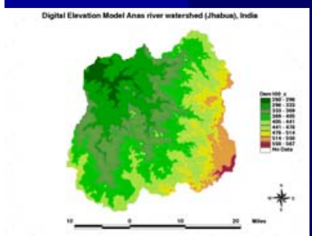
Module 8 – (L31 – L34): "Storm Water & Flood Management":

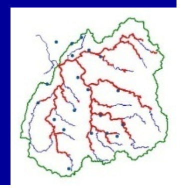
Storm water management, design of drainage system, flood routing through channels and reservoir, flood control and reservoir operation, case studies.

Storm Water Management

L31– Storm Water Management

- **Topics Covered**
- Stormwater runoff; Harvesting, Stormwater system, Integrated storm water management, separate system, combined system, Urban flooding
- Keywords: Stormwater runoff, system, harvesting, management, Urban flooding.





Stormwater Runoff

- Stormwater is rainwater & melted snow that runs off streets, lawns, & other sites.
- When stormwater is absorbed into the ground, it is filtered & replenishes aquifers or flows into streams/ rivers.
- In urbanized areas, impervious areas like pavement & roofs prevent water from naturally soaking into ground.
- Water runs rapidly into storm drains, sewer systems, & drainage ditches and can cause: D/s flooding ; Stream bank erosion; Increased turbidity, Habitat destruction; Changes in the stream flow hydrograph; Combined sewer overflows; Infrastructure damage & Contaminated streams, rivers, & coastal water

Stormwater Harvesting

- Stormwater - concern for the volume and timing of runoff water (flood control & water supplies) & other related water pollution.
- Stormwater is also a resource of readily available water.
- Techniques of stormwater harvesting with point source water management & purification, can potentially make urban environments self sustaining in terms of water.
- **Stormwater harvesting** is the collection, accumulation, treatment or purification, & storing for its eventual reuse.
- It can also include other catchment areas from man made surfaces, such as roads, or other urban environments such as parks, gardens & playing fields.

Stormwater Management

- Managing the quantity & quality - "Stormwater Management”
- "The term *Best Management Practice* (BMP) is often used to refer to both structural or engineered control devices & systems (e.g. retention ponds) to treat polluted stormwater, as well as operational or procedural practices.
- There are many forms of stormwater management & BMPs, including:
  - manage stormwater to control flooding and erosion;
  - manage & control hazardous materials to prevent release of pollutants to environment (source control);
  - plan and construct stormwater systems so that contaminants are removed before they pollute surface waters or groundwater resources;

Stormwater Management…

- Acquire and protect natural waterways where they still exist or can be rehabilitated;
- Build "soft" structures such as ponds, swales or wetlands to work with existing or "hard" drainage structures, such as pipes and concrete channels;
- Revise current stormwater regulations to address comprehensive stormwater needs;
- Enhance and enforce existing ordinances to make sure property owners consider the effects of stormwater before, during & after development of their land;
- Educate a community about how its actions affect water quality, & what it can do to improve it; and
- Plan carefully to create solutions before problems become too great.

Why Manage Stormwater?

- Urbanized areas: More impervious areas -Effects of stormwater
- Road flooding: accidents, washouts, driver delays.
- Building & property flooding: structural & property damage, sewer backup, foundation settlement, devalued properties.
- Environmental damage.
- Utility service interruptions.
- Increased clean-up costs, health hazards, personal inconvenience, increased insurance costs.
- **Solutions:** Concrete, Steel & HDPE pipe, Concrete structures, Swales and ponds

Why Manage Stormwater?

- Manage large amount of storm water to avoid flooding & other inconveniences.
- Traditional stormwater management design - focused on collecting stormwater in piped networks & transporting it off site as quickly as possible, either directly to a stream or river, to a large stormwater management facility (basin), or to a combined sewer system flowing to a wastewater treatment plant.
- Low impact development (LID) & wet weather green infrastructure address these concerns through a variety of techniques, including strategic site design, measures to control sources of runoff, & thoughtful landscape planning.

Integrated Stormwater Management

- Integrated water management (IWM) of stormwater - address many of the issues affecting the health of waterways & water supply challenges facing the modern urban city.
- IWM-S known as low impact development in USA, or Water Sensitive Urban Design (WSUD) in Australia.
- IWM has the potential to improve runoff quality, reduce the risk & impact of flooding & deliver an additional water resource to augment potable supply.
- Development of modern city often results in increased demands for water supply due to population growth
- Altered runoff predicted by climate change has potential to increase the volume of stormwater that can contribute to drainage & flooding problems.

Integrated Stormwater Management

- IWM offers several techniques including: stormwater harvest (reduce amount of water causing flooding),
- infiltration (to restore the natural recharge of groundwater),
- biofiltration or bioretention (e.g., rain gardens) to store & treat runoff & release it at a controlled rate to reduce impact on streams & wetland treatments (to store, control runoff & provide habitat in urban areas).
- IWM - in its infancy & brings together elements of drainage science, ecology & a realization that traditional drainage solutions transfer problems further d/s to the detriment of our environment & precious water resources.

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Low Impact Development (LID):

- LID: aims to restore natural watershed functions through small-scale treatment at the source of runoff. The goal is to design a hydrologically functional site that mimics pre-development conditions.
- LID – Land development – works with nature to manage stormwater as close to its source as possible.
- LID principles – preserve & recreate natural landscape features, minimize effective imperviousness to create functional & appealing site drainage that treat stormwater as source.
- Practices – bioretention facilities, rain gardens, vegetated rooftops, rain barrels & permeable pavements.
- LID – water managed in a way that reduces impact of built area & promotes natural water movement

LID & Green Infrastructure

- LID restore a watershed's hydrologic ecological functions
- LID – a sustainable stormwater practice
- Green Infrastructure - refer to systems & practices that use or mimic natural processes to infiltrate, evapo-transpirate (return of water to the atmosphere either through evaporation or by plants), or reuse stormwater on the site where it is generated.
- Green infrastructure- used at a wide range of landscape scales in place of, or in addition to, more traditional stormwater control elements to support principles of LID.
- Wet Weather Green Infrastructure: encompasses approaches & technologies to infiltrate, evapotranspire, capture, & reuse stormwater to maintain or restore natural hydrology

Benefits of LID & Green Infrastructure

- Social, economic & environmental benefits include:
- **Social**: Reduction in urban heat island effect , Provides "green jobs'/"green business" opportunities; Educational information provided through street kiosks; Crime reduction ; Health benefits through walking, biking, running trails
- **Economic:** Energy cost reduction using wind powered LED lighting; Water conservation ; Green Enterprise Business Opportunities
- **Environmental**: Carbon sequestration; Improved water quality through 90% capture of stormwater; Carbon footprint reduction; Recycling & beneficial use.

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Watershed Based Stormwater Management.

- **Goals:** Reduction of flood damage to life & property.
- Minimization of stormwater runoff from new development.
- Reduction of soil erosion from construction activities.
- Insurance of adequate stormwater facilities, including culverts, bridges, & other in-stream structures.
- Maintenance of groundwater recharge.
- Prevention/ reduce of non-point stormwater pollution.
- Maintenance of surface waters to ensure their biological & stormwater management functions,
- Protection of public health & welfare, through operation & maintenance of stormwater systems.

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Watershed Based Stormwater Management

- **Principles:**
- 1. Views regulatory compliance as a minimum requirement for acceptance.
- 2. Requires a stormwater management plan considering watershed-wide needs
- 3. Focuses on achieving good environmental results for the watershed in a cost-effective manner
- 4. Integrates stormwater plans into project development and project features.
- 5. Uses collaborative partnerships to leverage and deliver a combination of watershed improvements.
- 6. A coordinated mitigation/enhancement strategy.

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Stormwater Control Measures

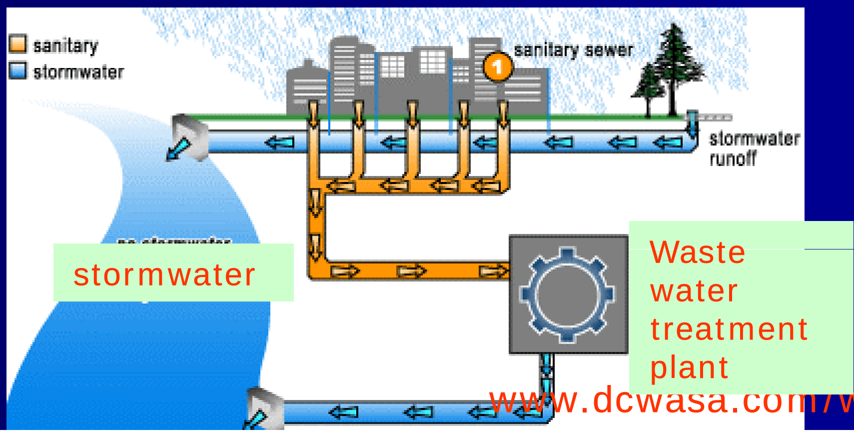
Category	Common approaches	Structural vs. Nonstructural
Policies and source controls	Public education, land use planning, material management and spill prevention, street and stormwater control facilities maintenance, prevention of illicit connections and dumping	Non-structural
Lot-level source controls	Green roofs, local storage/detention, stormwater harvesting, local infiltration, impervious cover reduction	Structural
Community level stormwater control measures	Community infiltration facilities, stormwater management ponds, constructed wetlands or natural wetland enhancement, extended detention (dry basins) treatment trains	Structural
Watershed level measures	Manages water on a natural versus political boundaries, establishes water quality goals and use designation protection, considers cumulative impacts, protects resources valuable in controlling runoff, supports and directs land use decisions, and assists in siting of stormwater control measures, employ the ecosystem approach, assists in the development of more detailed plans	Structural and Non-structural

Source: ASCE and WEF 1998; Marsalek and Chocat 2002; NRC 2008.

http://vwrrc.vt.edu/

Stormwater Management – Separate System

- Polluted stormwater runoff - transported through Municipal Separate Storm Sewer Systems, from which it is often discharged untreated into local water bodies.
- To prevent harmful pollutants from being washed or dumped into water bodies, appropriate pollution control measures should be developed.
- Separate systems are comprised of two independent piping systems: one system for "sanitary" sewage (i.e., sewage from homes & businesses) and one system for storm water



www.dcwasa.com/wastewater_collection/css/

Stormwater Management – Combined System

- A combined sewer system conveys both sanitary sewage & storm water in one piping system
- During normal dry weather conditions, sanitary wastes collected in the combined sewer system are diverted to the Wastewater Treatment Plant.
- During periods of significant rainfall, the capacity of a combined sewer may be exceeded - let the excess flow, (mixture of storm water & sanitary wastes), discharged directly into large water bodies - excess flow is called Combined Sewer Overflow (CSO).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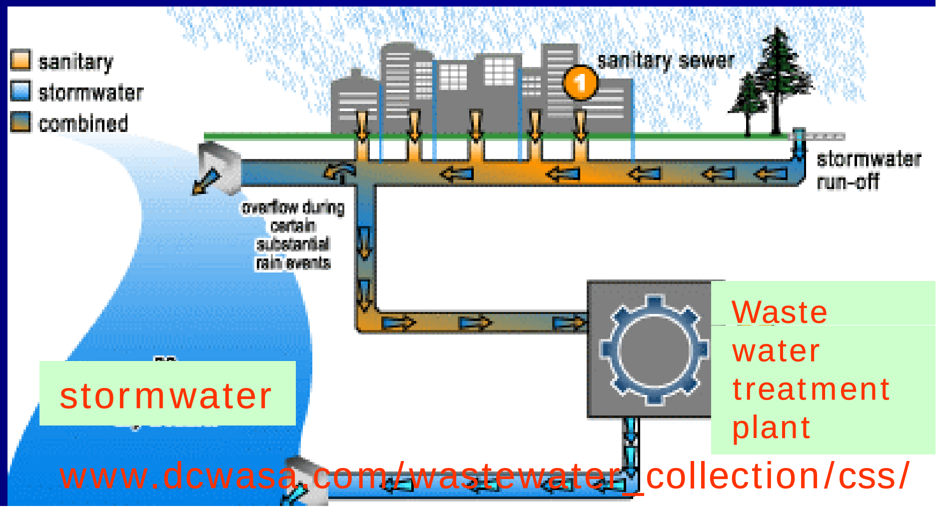

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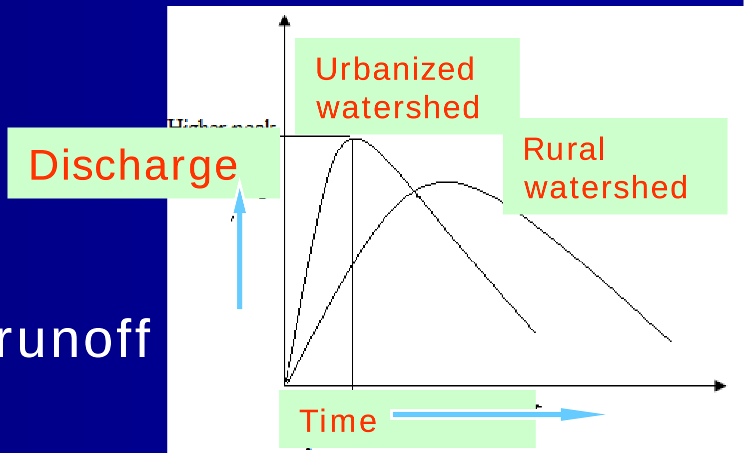
Urbanization Effects & Flooding

- Natural surface is covered by artificial structures
- It increases impervious areas
- Channel characteristics of shape, slope, & roughness- better known
- Changes flow pattern & quality of runoff is also influenced
- Estimation of losses is simplified
- It leads to higher peak flow and shorter time to peak and causes the inundation problem at the low-lying areas and undesirable load to the downstream areas



Urban Flooding - Causes

- Meteorological factors: Rainfall; Cyclonic storms; Small-scale storms; Temperature; Snowfall and snowmelt
- Hydrological factors: Soil moisture level; Groundwater conditions; infiltration; impervious cover; Channel conditions; Tidal effects etc.
- Human factors: Land use/ land cover changes; in appropriate drainage systems; occupation of flood plain areas; sudden release of water from dams; climate change; urban micro climate; indiscriminate waste disposal etc.

Urban Flood Problems

- The impacts may include loss of money, temporary disruption to transportation systems.
- Inconvenience to city life
- It can also cause erosion and instability of soils on steep slopes threatening houses.
- The extreme events result in inundation for a prolonged duration
- Heavy rainfall, tidal influences and lack of adequate drainage system is a serious problem affecting on many coastal cities.
- Due to the complexity of the problem, advanced modeling tools are required.

Urbanization Impacts

- Modification of flooding characteristics – by introducing storm drains
- Rapid removal of water from the drained area decreases the time and infiltration
- To delay the Peak rate of runoff – increasing an area's storage capacity and delaying outflow
- Runoff from streets to drainage system

Flooding due to: Limited intake capacity of the drainage system; Insufficient capacity of the pipe system

Approaches in Urban Hydrology

- Empirical Lumped-Parameter Approach
- Consideration of the entire drainage area as a single unit
- Estimation of flow at only the most downstream point
- Assumption of the rainfall is uniformly distributed in time and space over the watershed
- Apply techniques such as unit hydrograph techniques

Approaches in Urban Hydrology

Physical – Process Approach: Involves following steps

- Determine a design storm
- Deduct losses from the design storm to arrive at an excess rainfall rate
- Determine the flow to a gutter or some defined channel by overland flow equations
- Route these gutter flow to main channel flow
- Route the flow through the principal conveyance system
- Determine the outflow hydrograph

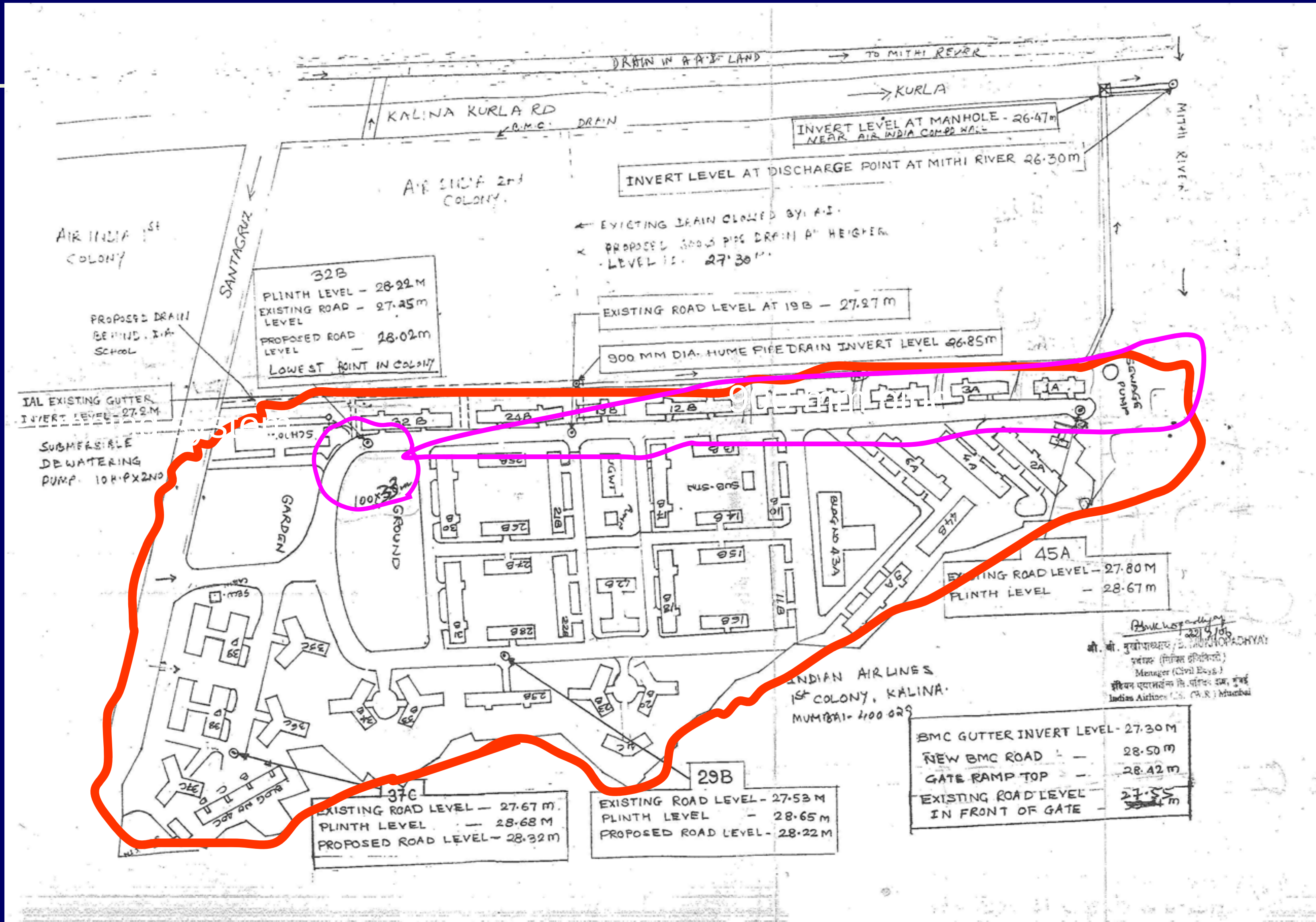
Measures for Reducing/ Delaying Storm Runoff

- Large flat roofs
- Porous parking lots
- Increase recharge
- Planting a high delaying grass
- Increase forest cover
- Detention basins
- Grassed waterways
- Porous sidewalks
- Roof top gardens
- Fountain storage

Case Study: Stormwater Drainage for an Urban Area:

- Study area: A Housing Colony – Santacruz Mumbai
- To study the actual situation of the flooding problem in a low lying urban area subjected to tidal effects and suggest measures.
- Presently the area is affected by frequent flooding in most of the monsoon season as this area is low-lying compared to the nearby areas.
- **Present status of the drainage system**
- Two submersible pumps (capacity of 10 HP each) pumping the storm water to the road drainage system
- A 900 mm diameter pipe (slope of 1 in 1000) draining directly to the Mithi River.

Topographic features of the Area



Present Drainage System Capacity

- The Mithi River is passing nearby and the drainage system drains into the river, which is subjected to tidal effect.
- When the water level rises in the river and high tide occurs the outfall of drain is subjected to tidal effects and consequent flooding.
- During the year 2004 a new 900 mm diameter pipeline was laid to solve the flooding problem and that year the area was not subjected to flooding.
- But in 2005, highest ever recorded rainfall occurred during the monsoon and the area was severely affected by floods.

Present drainage system capacity

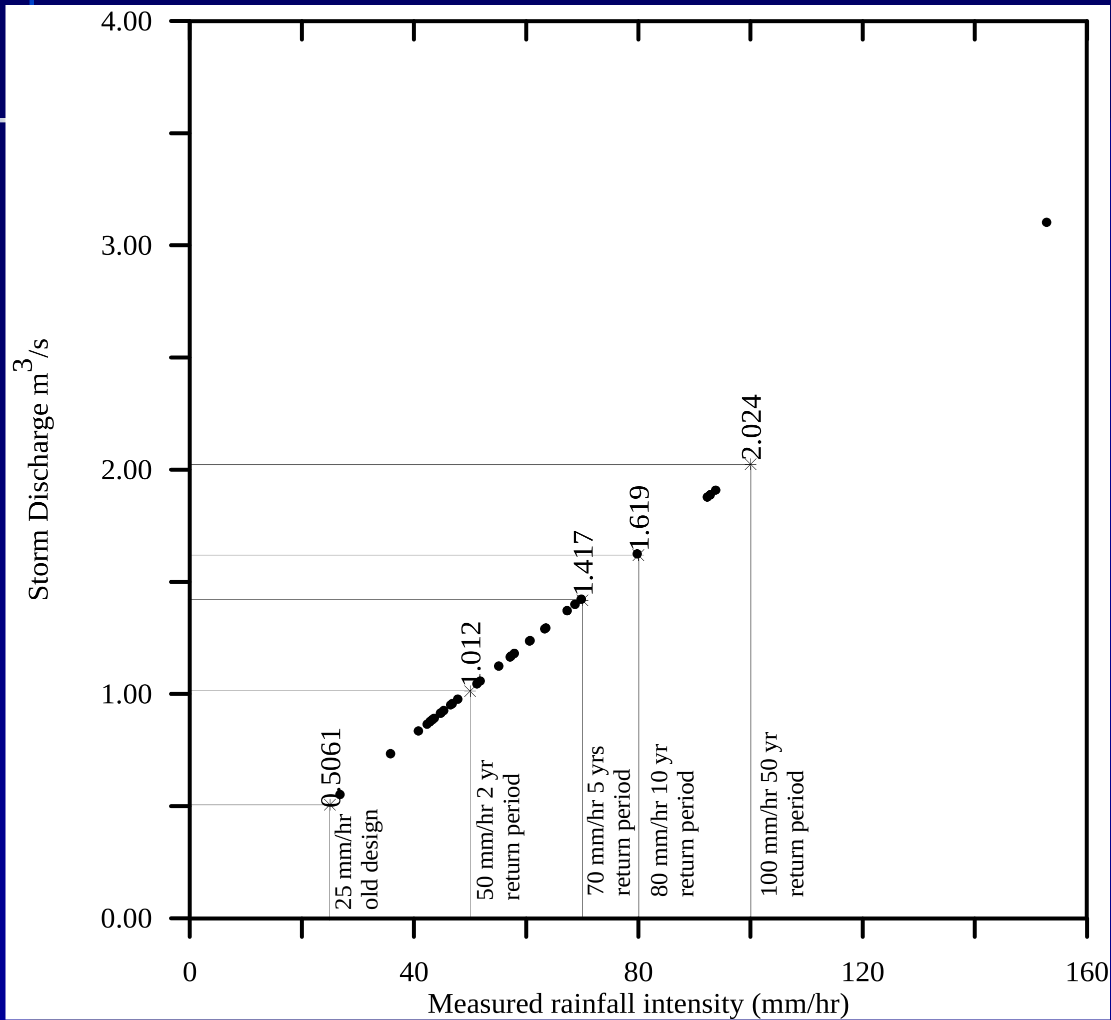
- Storm water discharge through the pumping system $Q = 0.051\ m^3/s$
- Storm water discharge through the 900 mm diameter pipe drain $Q = 0.492\ m^3/s$.
- Total drainage capacity of the present system $0.543\ m^3/s$.
- Rational formula: $Q = CiA$; C – runoff coefficient = 1.0; Q – 0.543 m3/s; A – area to be drained = 18 acres = 7.28 ha = 72875 m^2; i - rainfall intensity = ?? mm/hr.

From the above calculation it is found that the system is capable of discharging only 25 mm/hr rainfall

Drainage Problem..

- The maximum hourly rainfall intensity in most of the year is more than 25 mm/hr
- During the monsoon, River overflows and in addition if the heavy rainfall happens simultaneously with the rising tide a reverse flow occurs leading to heavy flooding situation in the area.
- Problem in selecting the Design Criteria
  - Unavailability of adequate natural slope to facilitate gravity flow
  - Tidal effects encountered at the exit point
  - Lack of space to provide appropriate drainage arrangements since the ground levels of surrounding area had been raised much higher than those of this colony.

Discharge to be drained by the system for various rainfall intensities



- **Hydraulic analysis using Manning's formula**
- $Q = AR^{2/3}S^{1/2}/n$

Plot of measured hourly rainfall intensity and its runoff

Recommendations

- The present existing ground level has to be increased at least 60 cm in the lower levels of the low lying area, so that an adequate slope is available for the proposed new drain.
- A small gutter all along the internal road of the area leading to the lowest point. Since the existing 900 mm pipe is almost at ground level, it is advisable not to have cross connection inlets other than the existing inlets to this existing 900 mm diameter pipe drain.
- Entry of storm water from the surrounding areas needs to be prevented
- The cross connections to the nearby Draining Nullah has to be cut off as the latter has a high invert level, which would give rise to a reverse flow.

References

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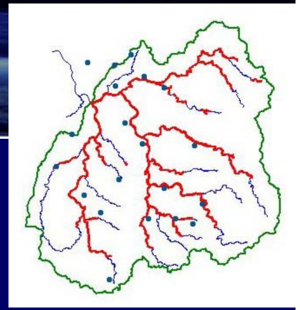
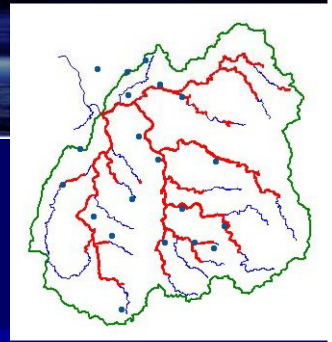


Tutorials - Question!.?.

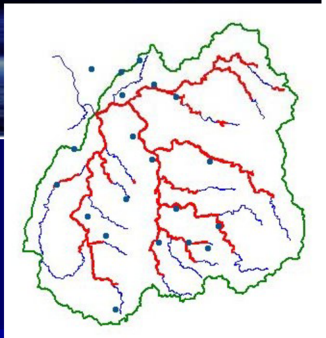
- Critically study the stormwater management issues in India. What are the major problems in implementing appropriate stormwater management systems in Indian cities like Mumbai/ Kolkotta?. ***http://ndma.gov.in/ndma/guidelines.html***

- Compare the stormwater management practices in USA, UK and India and propose better management practices for Indian Cities.



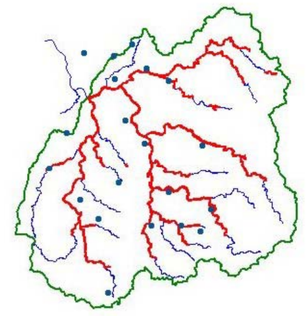
Self Evaluation - Questions!.

- Discuss stormwater runoff & parameters influencing on watershed basis.
- What is the “Best Management Practices” related to “Stormwater Management”?.
- Discuss Integrated Stormwater Management practices.
- What are the goals & principles of watershed based Stormwater Management?.
- Differentiate between “Separate” & “Combined” stormwater management system.
- What are important measures for delaying storm runoff?



Assignment- Questions?.

- Illustrate various stormwater harvesting techniques.
- Why we have to manage stormwater?.
- Discuss the features of "Low Impact Development & Green Infrastructure" within the perspective of stormwater management.
- Illustrate important stormwater control measures.
- What are the important effects of urbanization on runoff?.
- Discuss the important causes of urban flooding.
- Differentiate between "empirical lumped parameter approach" and "physical process approach" in urban hydrology.



Unsolved Problem!.

- What are the important stormwater management problems in your watershed area?.
- Collect the necessary data for the stormwater design in your area.
- With the help of rainfall data, topo-sheet and other maps such as drainage network maps, LU/LC map, road network, design an effective stormwater management plan for your study area.

THANK YOU

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