Green Initiative at IIT Kharagpur: A Concept Note

Green Core Committee

A core committee is constituted that will supervise and monitor the activity components of this concept note and will report to the Director, IIT Kharagpur from time to time.

Proposed Components of the Green Initiative

1. The Green Master plan

A Master Plan is to be drawn on the basis of components identified in this note and on any other components that may be added subsequently for inclusive changes for modifications and new additions to the existing buildings, structures, campus, roads and infrastructures, the services and the upcoming structures and facilities to make them energy efficient, minimizing waste generation, optimizing consumption of power, water and supplies. A detailed study of all relevant aspects by the Core Committee and external experts will be done to prepare the Master Plan and that will be at least compliant to GRIHA or equivalent.

Action taken:

> Green core committee is currently developing the master plan with the help of internal resources, and external experts from Indian Green Building Council, Hyderabad and West Bengal Pollution Control Board.

2. Green Audit

A comprehensive green audit of the existing structures and all operations will be undertaken with a goal of improving energy and water usage efficiency and all round management and development of the campus in environment friendly manner for sustainable future. Incorporations of the green norms and practices will reduce dependence on fossil fuels, better waste management and conservation of natural resources and surroundings. The report of green audit will provide major inputs for preparation of the Master Plan.

Action Taken:

> A comprehensive plan for green baseline audit is under formulation with specific scope and extent of such exercise.

3. Energy conservation

The goal is to identify all points of energy wastage and leakage and to take appropriate steps setting a target of attain 15-30 % energy saving by appropriate modifications and adopting green and best practices. Consumption of electrical energy of the grid may be reduced by installing solar panels on rooftops as well as suitable open spaces.

Action taken:

a) A few energy conservation initiatives are underway, like replacement of the fluorescent light with the LED in the existing buildings and street lights across the campus.

b) A 100 kW rooftop solar power plant is being installed in the main institute building.

4. Water Management Plan for optimum usage of water

The goal is to prevent wastage of water as well as to recycle and reuse the wastewater in the Institute and in the campus. A sustainable water management plan will be adopted based on the local water table and geo-hydrological characteristics of the aquifer. Critical components of the plan will include: reduction of potable water usage by efficient monitoring, using efficient fixtures, and restricting usage for irrigation. Rainwater harvesting units will be installed at suitable locations. Similarly ground water recharging arrangements will be done to serve as a model of this area.

Action taken:

a) Rain water harvesting plan for the existing buildings are finalized and implementation will start soon.

b) All new constructions will be equipped with rainwater harversting components. Porous paver blocks are being used in the academic campus to augment rainwater recharging.

c) Renovation of ponds has been taken up in three places in the campus for storing surface run-off water.

d) Work is planned across the campus for Deep aquifer recharging through borewells.

e) Design of drainage system and multi-purpose detention pond for storm water management of IIT Kharagpur campus (A write-up is enclosed at the end of this document).

5. Solid Waste Management

Disposal of the degradable wastes (food wastes, kitchen wastes, vegetable and fish) and non degradable wastes has been a big problem all over the country and we can make a model facility for management of wastes generated in the Institute and in the campus. This will basically involve segregation of the wastes at source into recyclable, non-degradable and degradable components. A model biomethanation unit may be established at a suitable place in the campus for generation of biogas from market wastes, etc. A gas engine will be run on the biogas to generate electrical power.

Action taken:

a) The plan for Segregation of the solid waste in the campus into biodegradable and non degradable component has been formulated.

b) The downstream processing of the components is in the design phase.

6. Biodiversity, Ecological Management & Water Bodies

Local natural ecological characteristics will be preserved by minimizing disruption due to building and construction activities. The existing microclimate will be utilized for energy efficient site planning. An eco-park showing biodiversity of the region and its conservation will be established. It will include water bodies with solar powered fountain, butterfly enclosure, vegetable garden and medicinal plants and exotic flora and fauna within the framework of the laws. A local 'Peoples Biodiversity Registrar' (PBR) will be compiled for authentic documentation of the local species and its preservation.

Action taken:

a) A complete plan for compiling the local People Biodiversity Register (PBR) has been initiated with the West Bengal Biodiversity Board.

b) Planning is underway to develop a eco-park showing the local biodiversity and its protection.

c) Fly ash bricks are being used in all non-primary masonry structural members.

d) Blanket ban is imposed on plastic cup and thermocol plates and bowls w.e.f 01.04.2014.

7. Plantation and Landscaping

There is enough scope of plantation of many more trees in the campus in a planned manner. This should be done in a scientific way with expert advice to add both green cover and beauty to the campus. Landscaping of different sizes may be done on the roadside and at suitable open spaces with flowering plants, grass and small fountains targeting to be the most beautiful green campus among the IIT's.

Action taken:

a) A forestation drive all across the campus has been planned for implementation in the coming monsoon.

b) Tree plantation pilot project has been initiated.

8. Reduction of Carbon Foot print

A methodology of calculating the carbon footprint of the whole institute should be developed and its improvement should be monitored.

Action taken:

All current and future construction activity in the campus have been brought under the purview of Green standard.

9. Innovation & Outreach

A number of projects directly related to environment and promotion of green and sustainable development will be launched and will be a part of academic curriculum. Two lists of projects initiated are enclosed in the appendices.

Action taken:

Decision has been taken to offer projects for UG and PG students dealing with promotion of green and sustainable development.

10. Green Rating and Green Awards

A methodology may be developed to assess the performance of the different departments and communities of the campus in this respect and their contributions towards implementation of the Green Initiative. "Green Awards" may be announced to recognize laudable performances.

Action taken:

Goal has been set to achieve Griha 4 or equivalent rating.

11. Implementation of Kakodkar Committee Report

Recommendation of Dr Anil Kakodkar Committee Report on "Taking IITs to Excellence and Greater Relevance" (Page.: 25) is given below:

> "**IITs and Society:** The IITs must engage much more with the society through, among other things, local governments and NGOs, in local and regional issues such as sanitation, water management, road safety and environmental issues like pollution control technologies - green technologies - and adopt initiatives similar to the "corporate social responsibility" of companies (teaching in the villages, helping other colleges and universities, compulsory NSS, helping SMEs, etc.)."

Action taken:

The implementation Kakodkar Committee Report process has started.

a) Through NSS programme of IIT Kharagpur.

b) IIT Kharagpur has introduced Faculty Challenge Grants-Service to the Society (SGFSS) (see Appendix 1). The faculty members of the institute will come up with solutions to some of the key societal problems of the marginalized/ deprived people of the society living immediate surroundings of IIT Kharagpur. The project will be demonstrable in the institute (or nearby places and at the possible end-user site.

c) IIT Kharagpur has started Innovation Challenge Grant for Green Technological Solutions (see Appendix 1). This will be executed by the student community.

APPENDIX -1.

List of Projects under Faculty Challenge Grant - Service to the Society (SGFSS):

1) Estimation of Potential Health Hazardous Materials in Drinking Water collected from Tribal Villages nearby IIT Kharagpur
2) Organic Farming for sustainable food Production at Pariapara
3) Empowerment of Village Youth Through Improved Mud Block Making
4) Technology Transfer of Puffed-Rice Making to Sholadhar : A Drive to Make Women Self Sufficient in Sholadhar
5) Enrichment of Rural Education at Kharagpur
6) Pilot Program for Nutritional Intervention Amongst Primary School Children at Kashijora
7) Development of Solar Assisted Vapour Absorption Refrigeration System for Rural storage Needs
8) Investigation of Groundwater Zones for Agricultural and Drinking Water in Various Villages Around IIT Kharagpur
9) Toxic & Non Edible Food Colors in Food Chain Creating Public Health Menace
10) Exploration, Testing and Supply of Safe Drinking Groundwater to School Children of Soladahar and Balarampur Village, West Medinipur
11) Ferro-Cement as a Cost Effective building Material
12) Wind-turbine for Domestic Power Generation
13) Heptic Torch for Mobility of Visually Impaired and Blind People
14) Development of a geospatial Data Infrastucture for Mapping and Management of Information Around IIT Kharagpur
15) Improvement of Class Room Acoustic with Murals on vetiver Grass Screen Through Engagements of Local Artisans.

APPENDIX -2.

List of Projects under Innovation Challenge Grant for Students:

1) Comprehensive Solid Waste Management and Recycling Plan
2) Recycling plastic (pet) for construction use along with waste management
3) Portable Electricity Generator from Organic Waste
4) Development of Jute based noise suppressors for portable powered devices to reduce environmental noise pollution
5) Recycling of kitchen waste into Vermicompost and its utilization in roof-gardening for organic crop production
6) Smart Card based Energy Meter (SCEM)
7) Development of a hybrid energy source for electric vehicles consisting of batteries and ultra-capacitors and its charger
8) Development of self-rejuvenating biocement slabs as a construction material for boundary walls, roads and pavements
9) Design, Development and Prototyping of a robust, secure modern trash collector with salient features like trash compaction, modular assembly & ease of operation
10) 135 LD Project: Art and illusion technique to reduce water usage in hostels
11) Demonstration of zero discharge model to process sewage using green technology

Design of Drainage System and Multi-purpose Detention Pond for Storm Water Management of IIT Kharagpur Campus

By

Deepak Singh Bisht, Pawan Upadhyay, Manaswinee Sahoo

(M.Tech., Land and Water Resources Engineering)

Under the supervision of

Dr. Chandranath Chatterjee

Agricultural and Food Engineering Department

Indian Institute of Technology Kharagpur

Design of Drainage System and Multi-purpose Detention Pond for Storm Water Management of IIT Kharagpur Campus

1. INTRODUCTION

It has been observed in recent years that IIT Kharagpur campus is facing a drainage congestion problem with the stagnation of rainwater at different locations causing inconvenience to the locality. Apart from improper storm water management, other causes could be attributed to the change in land use obstructing the natural infiltration capacity of the soil, increased intensities and frequencies of rainfall due to global climate change, improper assessment of design storm and design flood, improper drainage system design, insufficient surface water and groundwater flow monitoring system, improper futuristic structural planning for peak flood alteration, lack of groundwater recharge facilities such as rain gardens, increased quantity of domestic waste water due to increase in total population and lack of sufficient avenues for waste water disposal and its reuse.

Land use modifications associated with urbanization includes removal of vegetation, replacement of pervious areas with impervious surfaces which result in changes in the characteristics of the surface runoff hydrograph (Goonetilleke et al., 2005), increasing storm water runoff volumes and peak flows. Due to the development of infrastructure like residential apartments, hostels, laboratories, lecture complexes etc. impervious area is increased in recent years, which is resulting in higher runoff creating flooding problems in the low lying areas in IIT Kharagpur campus. Hence, there is a need to scientifically assess, monitor, and predict the rainfall-runoff characteristics of the IIT Kharagpur campus to estimate the design storm and design flood under the current trend of land use/land cover change and global climate change scenarios.

Rational method which is widely used for the design of storm drainage system is simple to use, but it allows only the determination of the peak of discharge hydrograph. It is inadequate to account large catchment for pipe routing or variations in rainfall intensity, contributing area and rate of contribution. The further drawback in the method is the lumping of all physical factors into two parameters (runoff coefficient and time of concentration) which makes parameter estimation subjective (Sevalingam et al., 1987). At present, several efficient urban catchment simulation models are available. In this study, EPA Storm Water Management Model (SWMM) is used. SWMM tracks the quantity and quality of runoff generated within each subcatchment and the flow rate, flow depth, and quality of water in each pipe and channel during a simulation period comprising of multiple time steps (Baffaut and Delleur, 1989 and 1990). This model was primarily developed for urban areas and is capable of modeling water quantity and quality through the catchment for both short- and long-term.

The drainage design of urban area depends not only on the pervious and impervious land distribution over the area but also on the characteristic and conditions of the natural water boundary- “the watershed” in which the settlement area falls (contributing watershed). As the water does not confine to the settlement area and quite a good amount of runoff generated from the areas of contributing watershed may cause flooding in the settlement area too, a holistic assessment of the drainage requirement becomes necessary. To model this storm affected area the input conditions and model parameters used are always crucial. Rainfall has been advocated as one of the most important inputs to develop the runoff response. Various models have been used to design the drainage system of such an area. Some of these models are the (i) MIKE 11 (DHI, 2007a), (ii) MIKE 21 (DHI, 2007b), (iii) MIKE FLOOD (DHI, 2007c), (iv) MIKE URBAN (DHI, 2012), and (v) Arc SWAT (Arnold et al., 1994).

In some cases, flood flows in channel systems can be efficiently simulated by one-dimensional, MIKE 11 Hydrodynamic (HD) module which is used to perform hydraulic analysis for the floods, using an implicit, finite difference scheme for the computation of unsteady flows in rivers and estuaries.

However, when modeling floodplain flows, where the one-dimensional assumption is in question, the accuracy of one-dimensional models may be inadequate. The interaction between the channel and the floodplain makes two-dimensional models more attractive, since they are capable of coupling the two processes. While MIKE 11 fails to provide detailed information regarding the flow field, MIKE 21 hydrodynamic module simulates water level variations and flows in response to a variety of forcing functions.

2. OBJECTIVES

In the light of above discussion, the present study is taken up with the following objectives:

i) To analyze trends of extreme rainfall at IIT Kharagpur campus,
ii) To estimate design storms for IIT Kharagpur campus,
iii) To simulate and analyze the flooding in the southern region of IIT Kharagpur campus due to recent extreme rainfall events using SWMM, MIKE21 and MIKE FLOOD models,
iv) To assess the adequacy of existing drainage system of IIT Kharagpur campus to handle flows resulting from design storms using SWMM, and
v) To design the drainage system and a multi-purpose detention pond for IIT Kharagpur campus using SWMM.

3. STUDY AREA AND DATA USED

The campus of IIT Kharagpur lies between 22˚18′ to 22˚19′ North latitudes and 87˚17′ to 87˚19′ East longitudes spread in an area of 466.82 ha (Fig. 1). It is situated about 120 km west of Kolkata, West Bengal, India. IIT Kharagpur receives an average annual rainfall of 1564 mm and the mean annual temperature is around 26°C (Kumar, 2013).

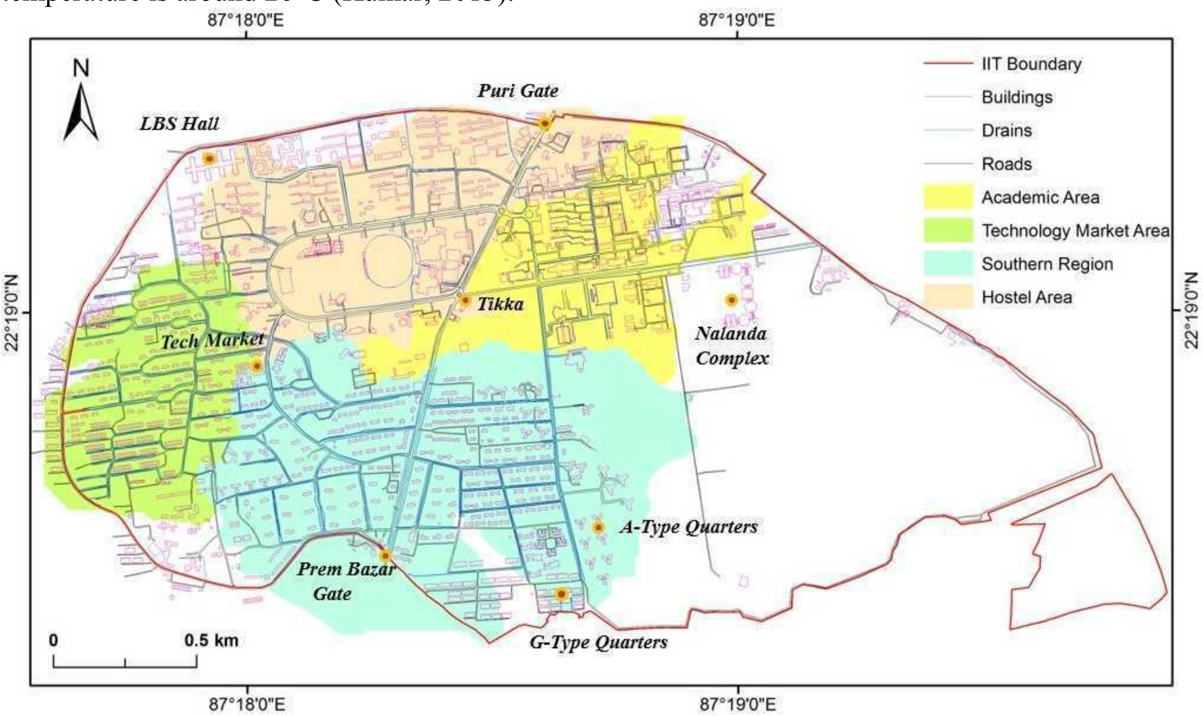

Fig. 1. IIT Kharagpur campus layout

The drainage network in IIT Kharagpur campus for stormwater is mostly an open drainage system. Majority of the drains in southern region of IIT Kharagpur campus are earthen while most of the drains in hostel area are concrete lined and have culverts of different dimensions. In general, the water in the campus moves in all the directions as the drainage system of the campus has multiple outlets. Channels of smaller dimensions carry the runoff from the residential houses, other buildings and green areas to the main channel. In the absence of adequate carrying capacity, even during short duration medium intensity rainfall people often face water stagnation and flooding problems at various locations in the campus. Figure 2 shows the flooding which occurred in the hostels and main academic building due to the rainfall of 187.5 mm on 29 July 2013.

Fig. 2. Flooded areas in IIT campus on 29 July 2013

For the present study, we have used the extreme rainfall data of 29 July 2013, i.e., 187.5 mm and 16 June 2008, i.e., 543 mm (Fig. 3). In addition, we have used the rainfall data of 2 October 2013, i.e., 29.5 mm for calibration of SWMM model.

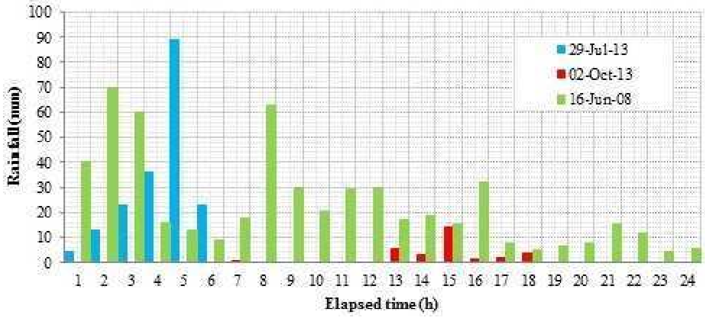

Fig. 3. Hourly rainfall measured at IIT Kharagpur used in model simulation

To estimate the design storms of 2, 5 and 10 year return period, daily annual maximum rainfall data of IIT Kharagpur (1975-2013) is used for carrying out the frequency analysis. A computer aided design (CAD) drawing map of the campus showing elevation contour lines (at 20 cm interval), roads, buildings, drains and other IIT Kharagpur properties was obtained from Civil Works Department, IIT Kharagpur. This drawing was used to generate the digital elevation model (DEM) of the campus (Fig. 4) and to extract other required information such as drainage network, buildings etc. in ArcGIS 9.3. In order to simulate the runoff from the contributing watershed of IIT Kharagpur, SRTM DEM of 90 m resolution was used.

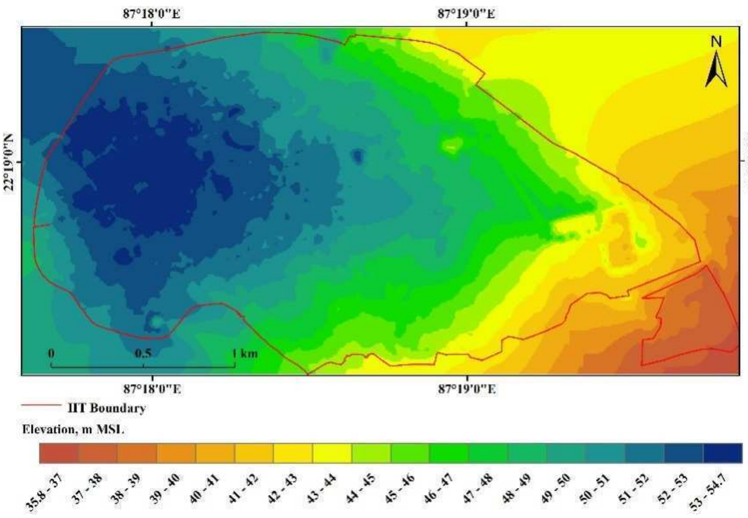

Fig. 4. Digital elevation model of IIT Kharagpur campus

Soil classification was done based on the soil sampling done at 42 locations within the campus. International pipette method was used to determine the soil textural classes. A thiessen polygon based soil map was then developed in ArcGIS 9.3 (Fig. 5) and respective soil properties were assigned from the standard literature.

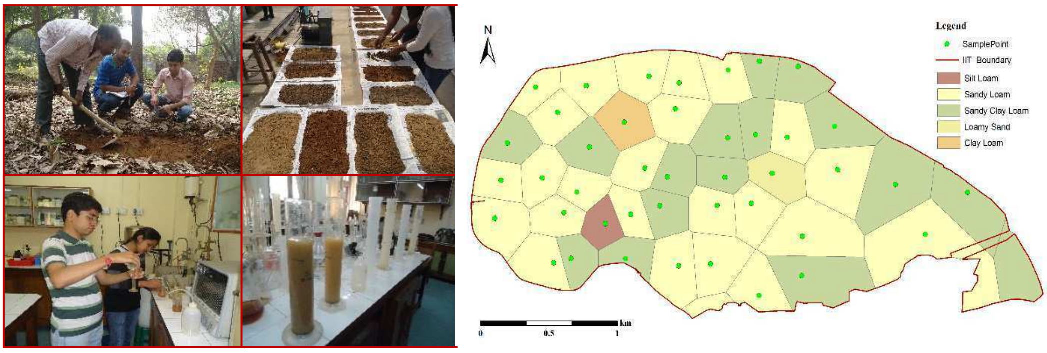

Fig. 5. Soil testing and thiessen polygon based soil map of IIT Kharagpur campus

4. METHODOLOGY

Based on daily rainfall data of IIT Kharagpur (1956-2012) trends of different extreme rainfall were analyzed. Two non-parametric tests, Mann-Kendall test and Sen's slope test are performed to detect any existing trends in rainfall data. Extreme rainfalls are categorized as follows:

i) 1-, 2- and 3-day annual maximum rainfall.
ii) Number of events exceeding 95th percentile value of the period 1956-2012 for each year.
iii) Number of events exceeding 95th percentile value of the period 1956-2012 for each 25 year moving window. The moving windows are from 1956-1980, 1958-1982, 1960-1984 …. 1988-2012.
iv) Threshold extreme rainfall as 99th percentile of 25 year moving window data.
v) In addition to above extreme rainfalls, the trends of cumulative rainfall of monsoon season i.e. June to September are analyzed.

L-moments based frequency analysis method was used to estimate the design storms of 2, 5 and 10 year return period. These storms were further distributed in 24 hours using the time distribution coefficients given in "Flood Estimation Report for Lower Ganga Plains Subzone 1(g), 1994" of "Central Water Commission."

DEM of the campus generated from surveyed data was used for watershed delineation using ArcSWAT while slope of the catchment was determined using 3D Analyst tool in ArcGIS 9.3. Gross impervious cover of the sub-catchments were estimated using the campus layout map while the invert elevation of the drains at the junctions were extracted from the DEM. SWMM was used to assess the carrying capacity of existing drainage system and to design an efficient drainage system to carry a 10 year return period storm safely. Input parameters for SWMM like manning's n for overland flow and drains, depression storage for impervious and pervious area are taken from the literature while the initial estimates of the width of the sub-catchments were obtained by calculating the square root of the sub-catchment areas.

MIKE FLOOD model was used to simulate the surface flooding conditions and depth of inundation near G-type quarters in the southern region of campus for extreme rainfall events of 29 July 2013 (187.5 mm) and 16 June 2008 (543 mm). Apart from this, MIKE 21 model was also used to simulate the surface flooding scenario inside IIT Kharagpur campus taking into account the area outside IIT campus which contributes to the floods. The MIKE 21 model is also used to simulate flooding conditions with and without IIT boundary wall. CWC synthetic unit hydrograph approach is used to develop flood hydrographs to obtain the peak runoff contribution of the outside area.

5. RESULTS AND DISCUSSION

Results obtained from the trend analysis of extreme rainfall and frequency analysis using L-moments approach for IIT Kharagpur, as well as model simulation runs for SWMM, MIKE FLOOD and MIKE 21, are presented in this section.

5.1 Trend Analysis of Extreme Rainfall at IIT Kharagpur Campus

There is no significant trend in 1-, 2-, and 3-day annual maximum rainfall of IIT Kharagpur. The number of extreme events is calculated based on 95th percentile value. The 95th percentile threshold value is found to be 26.5 mm for the entire data period of 1956-2012. Number of extreme events show significant increasing trends in both cases, i.e, number of events in each year and number of events in 25 year windows (Figs. 6 and 7). Threshold value as 99th percentile value of each 25 year window has no significant trend. The cumulative seasonal monsoon rainfall also does not show any significant trend.

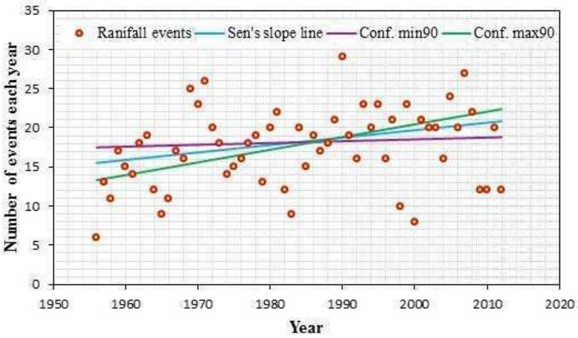

Fig. 6. Sen's slope line with confidence interval at 10% significance level for number of extreme events in each year exceeding the 95th percentile value for the period 1956-2012.

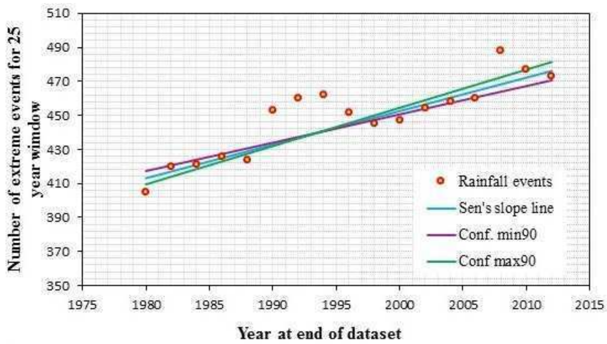

Fig. 7. Sen's slope line with confidence interval at 10% significance level for number of extreme events in different 25 year moving windows exceeding the 95th percentile value for the period 1956-2012.

5.2 At-Site Rainfall Frequency Analysis

Thirty nine years of daily annual maximum rainfall data (1975 to 2013) obtained from Department of Physics and Meteorology, IIT Kharagpur is used for frequency analysis. Various distributions namely Generalized logistic distribution (GLO), Generalized extreme-value distribution (GEV), Generalized Normal (lognormal) distribution (GNO), Pearson type III distribution (PE3), Generalized Pareto distribution (GPA) and Wakeby distribution (WAK) are used. In this study, the L-moment ratio diagram and Z_{dist} -statistic are used as goodness of fit measures for identifying the robust frequency distribution. In order to analyze the effect of extreme rainfall event received on 16 June 2008 (543 mm), a separate frequency analysis was carried out excluding this event and it was found that this rainfall was greater than that of 10000 year return period. Therefore, results obtained from the frequency analysis excluding this extreme event were used in the present study. Estimated 1-day design storms of 2, 5 and 10 year return period were found to be 126, 192 and 230 mm, respectively.

5.3 Time Distribution Curve for 24 Hour Rainfall

To simulate the rainfall-response of the catchment, a time series of rainfall distributed in 24 hours duration was required for the study. Hence, for distributing the daily annual maximum rainfall of 2, 5 and 10 year return periods obtained through L-moment based frequency analysis, a time distribution curve was developed using the hourly data of 23 storms (since May 2011) of greater than 50 mm depth recorded by "Automatic Weather Station" at Department of Agricultural and Food Engineering, IIT Kharagpur. Hourly percentage of each storm against their respective cumulative values was calculated. These values were distributed in 24 hours duration assuming the maximum depth of rainfall occurring at 4th hour to avoid any trend (either continuous increment or decrement in rainfall intensity).

Once all the 23 storms were distributed as stated, the time distribution coefficients were calculated by averaging the distribution in each hour for all the 23 storms (Fig. 8). As IIT Kharagpur falls in the Lower Ganga Plain Subzone, time distribution coefficient given in "Flood Estimation Report for Lower Ganga Plain Subzone" published by Central Water Commission, New Delhi was compared with the locally derived coefficients (Fig. 8). CWC developed these coefficients based on hourly rainfall data of 29 self-recording raingauge stations having at least 5 years of record. Unlike our study which used only 23 storms, a total of 4258 rainstorms of duration ranging from 2 hours to 24 hours were analyzed by CWC.

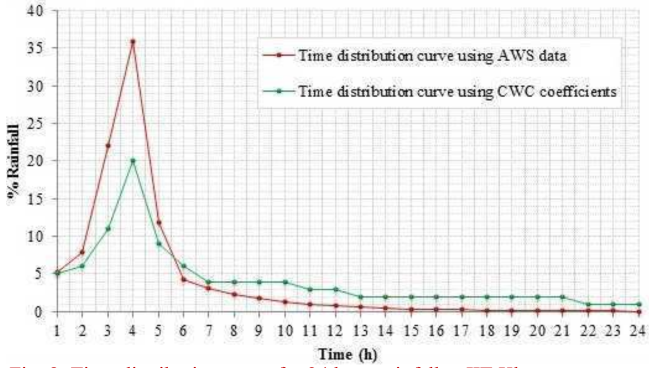

Fig. 8. Time distribution curve for 24 hour rainfall at IIT Kharagpur

From Fig. 8 it can be said that the time distribution coefficients developed by CWC are not in good agreement with the calculated coefficients. As stated above, CWC time distribution coefficients were developed by analyzing larger numbers of events, hence, in the present study they have been used for further analysis.

5.4 Calibration of SWMM

SWMM run was carried out for the southern region of the campus using a 24 hour rainfall recorded by Automatic Weather Station (AWS) at Agricultural and Food Engineering Department in IIT Kharagpur. In the absence of time series data of flow at the outlet for calibration of model, flow was measured at a few locations in the drains for the rainfall received on 2 Oct 2013 (Fig. 9). These observed point values were used for calibrating the model. It is observed that the model is reasonably well calibrated.

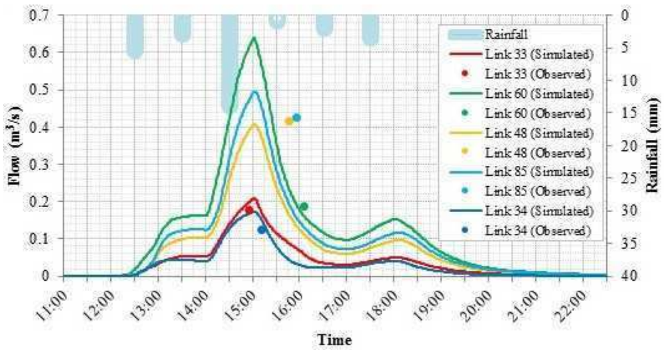

Fig. 9. Simulated and observed flows in links for the southern region of IIT campus for rainfall received on 02 Oct 2013

5.5 Flooding Scenario in Southern Region of IIT Campus for Extreme Rainfall Events

IIT Kharagpur usually receives a good amount of rainfall but in the recent past the high rainfall events are found to be more frequent. SWMM and MIKE FLOOD models were used to simulate the flooding scenarios in southern region due to two extreme rainfall events of 16 June 2008 and 29 July 2013.

System Response for Extreme Rainfall Events using SWMM

Two extreme rainfall events of 543 mm received on 16 June 2008 and 187.5 mm (89 mm of rainfall occurred in one hour) received on 29 July 2013 were used for simulating the system response under existing drainage system. Extreme rainfall intensity coupled with inadequate drainage system design resulted in heavy flooding. For 16 June 2008, maximum total inflow was found to be to the tune of 18.28 m^3/s, while the maximum flooding peak was 14.54 m^3/s, which infers that 79.5% of the runoff generated from the system got lost as flooding from the nodes (Fig. 10). Whereas for 29 July 2013, SWMM simulated maximum total inflow was 24.55 m^3/s, while the maximum flooding peak was

21.11 m^3/s, which infers that 85.9% of the runoff generated from the system got lost as flooding from the nodes (Fig. 11).

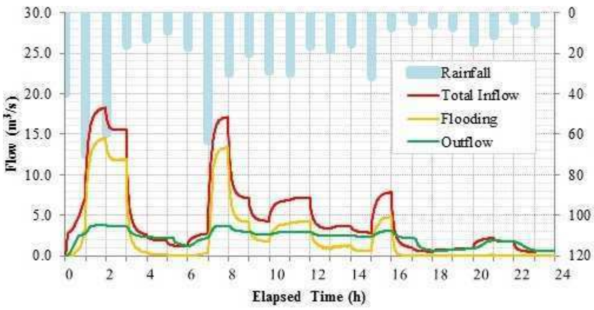

Fig. 10. System response for 543 mm of rainfall received on 16 June 2008

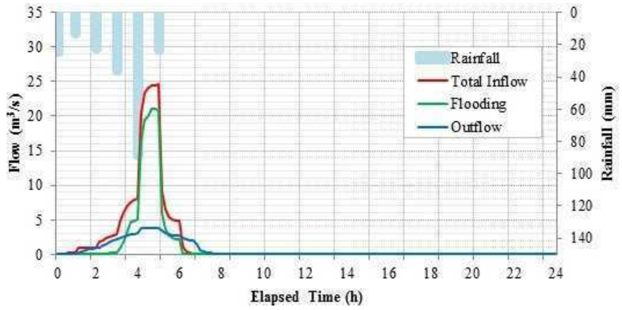

Fig. 11. System response for 187.5 mm of rainfall received on 29 July 2013

MIKE FLOOD Model Simulation for Southern Region

Surface flooding conditions cannot be simulated using SWMM. Hence, MIKE FLOOD model was used for this purpose. Depth of inundation and surface flooding for the same extreme rainfall events near G-type quarters in southern region were simulated using MIKE FLOOD (Fig. 12). Here, the water depth obtained from the simulation (i.e., 1.45 m) is compared with the observed water depth (as narrated by the residents of G-Type quarters). The simulated values are found to be closer to the observed ones. Result of the simulations cannot tally exactly with the observed ones because we do not have much information about the various locations in the IIT boundary from where the water flows inside and outside the campus boundary. We are considering only the major openings in the boundary. In addition to that we also do not have discharge and stage data of the drain which is entering the IIT campus at Prembazar gate. Results of MIKE FLOOD in this case provide a general idea about the situation inside the campus for these particular events which gives us very useful information about the characteristics of flooding in the IIT Kharagpur campus.

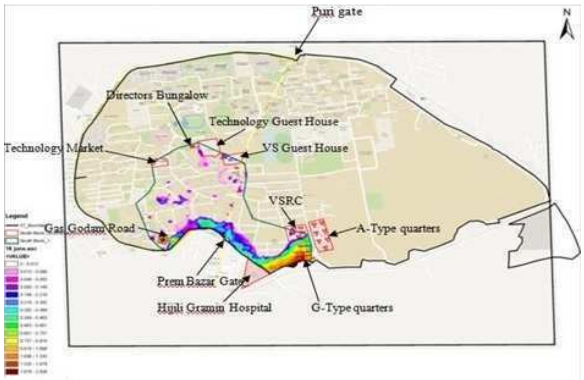

Fig. 12. Inundation in south part of IIT Kharagpur campus on 16 June 2008

5.6 MIKE 21 Model Simulations using SRTM DEM

Initially, model was set up for the entire catchment of which IIT Kharagpur campus is a part. Bathymetry for this catchment was created using SRTM DEM of 90 m resolution. Bathymetry and time series rainfall data are the primary requirements for setting up a MIKE 21 model. It is seen that an area outside IIT campus contributes flow to the southern part of IIT Kharagpur campus. The entire catchment which contributes flow to the South block region of IIT Kharagpur campus including the portion which lies outside IIT campus is shown in Fig. 13.

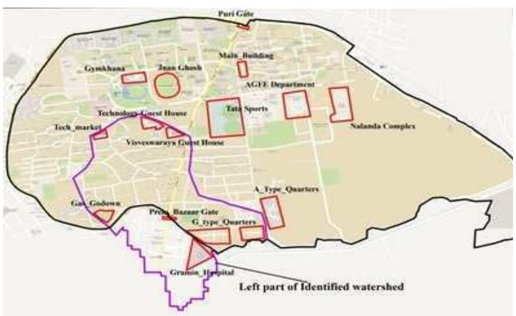

Fig. 13. The entire catchment which contributes flow to the South Block region of IIT Kharagpur campus – the left part of the identified catchment is outside IIT.

DEM of the identified watershed (Left South Block) consisting of an area of about 1.024 km^2, was used to create bathymetry for MIKE 21 model set up. Time series of two extreme rainfall events of 16 June 2008, i.e., 543 mm and 29 July 2013, i.e., 187.5 mm were used for the calculation of excess rainfall with phi-index value of 2.7 mm/h (CWC, 1994). Time series of excess rainfall values for both the events were given as input to the model. There is a maximum inundation depth of 2.44 m due to 16 June rainfall event and 2.22 m due to 29 July 2013 rainfall. Model result shows maximum inundation occurs near G-type quarters. MIKE 21 model has been setup and run by including the Gramin Hospital area present outside the campus with no boundary wall. It results in less or almost no inundation inside the campus area. So, it can be said that boundary may be a reason for increasing flood inundation inside the campus. Flood inundation depth near G-type quarters has been extracted to compare the model results with boundary wall and without boundary wall conditions (Fig. 14). Results show that inundation depth is nearly 1.43 m with boundary wall and almost zero when there is no boundary wall. Removing the entire boundary wall may cause security issues and hence, openings may be provided in the boundary wall.

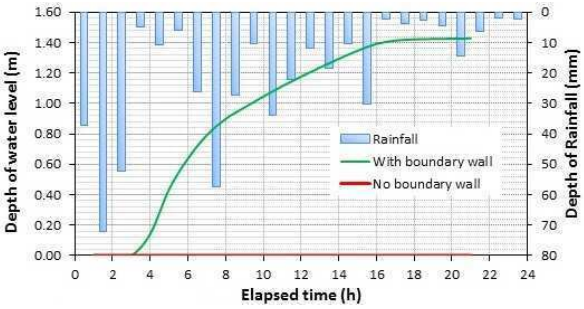

Fig. 14. Flood inundation depth near G-type quarters with and without boundary wall due to 16/06/2008 rainfall event

5.7 Development of Flood Hydrographs using CWC Synthetic Unit Hydrograph Approach

To estimate the peak flow contribution from the portion of the catchment outside IIT Kharagpur campus, synthetic unit hydrograph approach (CWC, 1994) was used. Two flood hydrographs were prepared by considering (i) the entire catchment/watershed (an area of 1.024 km^2) (ii) the entire catchment/watershed excluding the portion outside IIT campus (an area of 0.716 km^2).

Design initial losses of 0.27 cm/h and base flow of 0.05 m^3/s/km^2 are adopted for all the catchments in lower Ganga plain subzone 1(g). Flood hydrograph developed for the entire catchment for two extreme rainfall events of 16 June 2008 of 543 mm and 29 July 2013 of 187.5 mm resulted in a peak of 12.02 m^3/s and 11.96 m^3/s, respectively.Excluding the portion of catchment outside IIT campus, the peak discharge reduces to 7.794 m^3/s and 8.469 m^3/s for 2008 and 2013 events, respectively. It is observed that excluding portion of catchment outside IIT campus, peak discharge is reduced by about 35%. Hence, it can be concluded that outside campus area is contributing about one third of the peak flow which leads to a flooding condition near G-type quarters.

5.8 SWMM based Rainfall-Runoff Modeling to Assess the Adequacy of Existing Drainage System of IIT Kharagpur Campus

SWMM runs are carried out to simulate the rainfall runoff response of the catchment with existing drainage network to assess the carrying capacity of drains for 2, 5 and 10 year return period storms. Based on the results obtained, the new cross sections are proposed to avoid flooding and water stagnation problem due to inadequate carrying capacity. It has been found from the model runs that the existing drainage system is inadequate to carry the storm of 5 year return period safely to the outlet (Figs. 15 and 16). Flooding at various nodes were observed in the southern region, hostel area, academic area and technology market area.

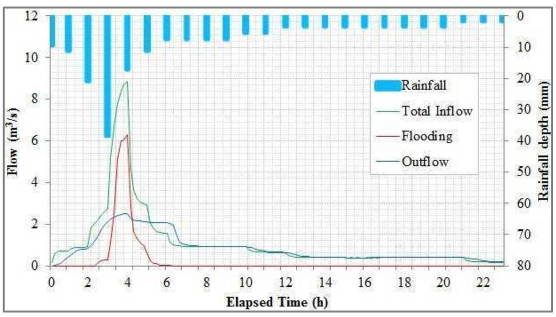

Fig. 15. Rainfall-runoff response of Southern region for 5 year return period rainfall

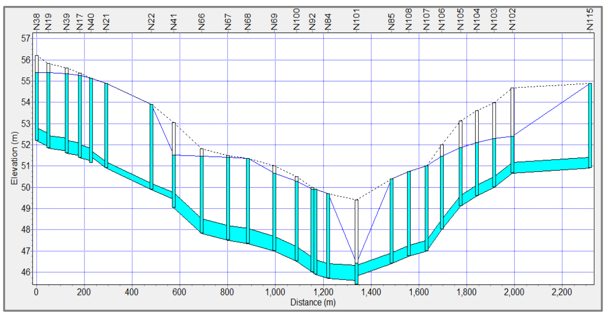

Fig. 16. Water elevation profile: Node N38 to N115 for 5 year return period rainfall in existing drainage system – Southern region

5.9 SWMM based Rainfall-Runoff Modeling for Design of Drainage System of IIT Kharagpur Campus

In order to prevent the flooding in the campus due to inadequate carrying capacity of the drainage system, number of model runs was carried out using different combinations of drain dimensions. Drainage network was modified from its existing conditions to the extent where it can carry a runoff generated from a rainfall of 10 year return period safely to the outlet without causing any flooding or water stagnation inthe upstream areas (Fig. 17). Figure 18 shows the water elevation profile in the drain network starting from Sahara restaurant and Tata sports complex joining near SB-type quarters, for 10 year return period design storm with modified drainage system. The design drain dimensions of IIT Kharagpur campus are shown in the Appendix-I.

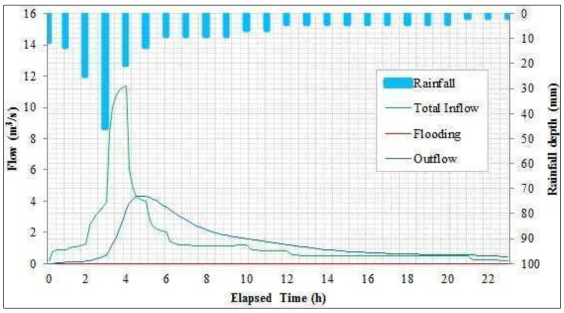

Fig. 17. Rainfall-runoff response of Southern region for 10 year return period rainfall

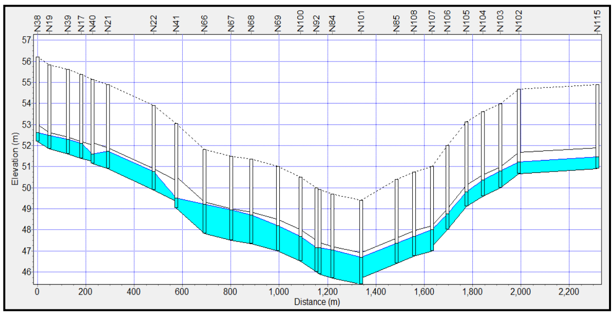

Fig. 18. Water elevation profile: Node N38 to N115 for 10 year return period rainfall in modified drainage system – Southern region.

5.10 Design of Multi-purpose Detention Pond

Model runs with identified drainage network was carried out to visualize the flow pattern in drains. The simulation (Fig. 19) reveals that drain running from Prembazar gate to outfall meets another major drain running from Tata Sports Complex near SB-type quarters. A free flow condition at the outlet was assumed while modifying the drainage system neglecting any backwater effect and drainage congestion at downstream boundary. But in actual case the outlet of the catchment is a canal running outside the campus boundary which causes backwater effect during rainy season. Moreover there is a drainage congestion problem at the downstream area near G-type and SB-type quarters. In order to provide a solution for this, a new retention cum detention pond is proposed to divert the flow from the existing outfall. Flow carried by aforementioned drains is diverted to the designed pond while the outlet for the area draining from SB-type and G-type quarters is kept at its existing location as shown in Fig. 20.

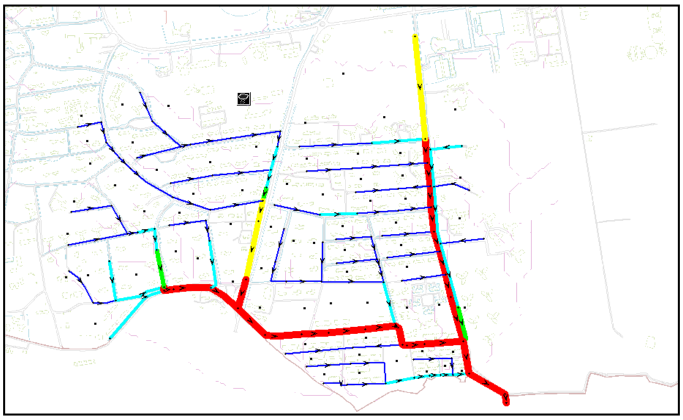

Fig. 19. Link flow in existing drainage network – southern region

In order to design the multi-purpose detention pond at the upstream of proposed new outfall, a seasonal rainfall analysis of the historical rainfall data of IIT Kharagpur was done. Annual rainfall data of 56 years from 1957 to 2012 is used for this purpose. Analysis of the 56 years of rainfall record revealed that on an average 75% of the rainfall occurred in monsoon season alone i.e., June to September.

Seasonal rainfall (June to September) analysis results were used to determine the minimum depth of water available in the retention pond when the design storm occurs. These seasonal rainfall data were used to perform a probability analysis using Weibull method, to approximate the available depth of accumulated water in the pond at different probability levels. Probable rainfall for different return periods (return period is inverse of probability) can be approximated by using the linear equation for fitted logarithmic trend line using Weibull method. At 50, 60, 70, 80 and 90% of probability level, seasonal rainfall for IIT Kharagpur was found to be 1104, 1046, 992, 948 and 909 mm, respectively.

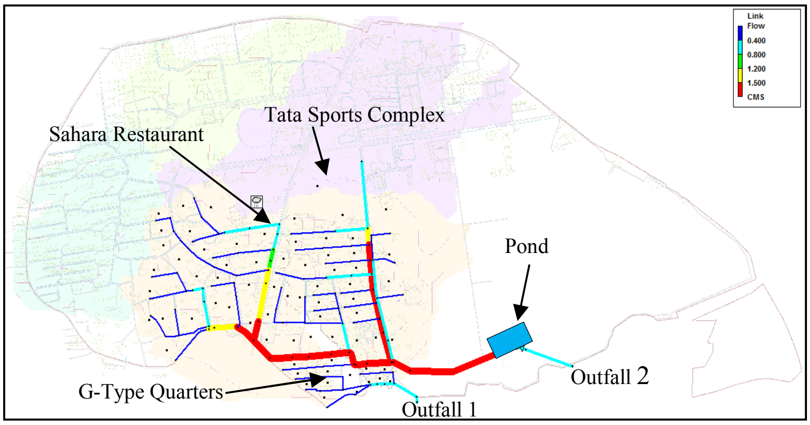

Fig. 20. Link flow in modified drainage network with multi-purpose detention pond

Fifty percent probability of seasonal rainfall depth is considered for designing dimension of the multi-purpose detention pond. Primary purpose of a retention pond is to retain the runoff and act as a rainwater harvesting structure by allowing the standing water to infiltrate for groundwater recharge. While the detention pond is designed to reduce the peak of outflow hydrograph at the downstream end by allowing a slower release of incoming flow by means of weirs or orifices.

Three outlets are proposed from the reservoir. Three transverse weirs of 1.0 m height and 3.0 m width are proposed at each outlet. These weirs allow water to discharge in case water level rises beyond the weir crest, thus converting the retention pond into a detention pond during high intensity rainfall event. Surface area of pond is kept as 3 ha (300 m length and 100 m breadth). While simulating the outflow hydrograph at the downstream of the pond, depth of standing water in the pond was assumed to be at same level as of crest of the weir due to the possible previous runoff from the system as well as direct rainfall into the pond.

Inflow-outflow hydrograph for 10 year return period rainfall of the pond reveals a slower discharge and reduction in peak of the outflow hydrograph at the outlet from 10.55 m^3/s to 6.12 m^3/s. This reduction of peak discharge is very significant in the present study as all the runoff generated from the chosen area is drained into a canal running outside the campus boundary. During high rainfall events this canal starts running at full flow, hence, discharge from the campus at higher rate encounters the backwater effect from the canal resulting in flooding at the adjacent upstream areas. This backwater effect can be avoided or reduced to a significant extent by reducing the discharge at the outlet.

6. CONCLUSIONS

Based on the study, following conclusions are drawn:

i) A trend analysis of the rainfall data at IIT Kharagpur campus reveals that the 1-day, 2-day, 3-day annual maximum rainfall as well as the cumulative monsoon season rainfall do not show any significant trends. Hence, they may be safely used to carry out frequency analysis. However, the number of extreme events (i.e. daily rainfall events exceeding the 95th percentile threshold value of 26.5 mm for the entire data period of 1956-2012) occurring each year shows a significant increasing trend.

ii) Frequency analysis of the daily annual maximum rainfall of IIT Kharagpur campus reveals that the rainfall of 16 June 2008 is an outlier. Daily annual maximum rainfall for 2, 5 and 10 year return period as obtained from the frequency analysis of IIT Kharagpur data are 126, 192 and

230 mm, respectively. The CWC time distribution coefficients for the region were used to distribute these rainfalls into hourly values for use in SWMM.

iii) The flooding scenarios near G-Type quarters simulated using MIKE FLOOD model for two high rainfall events of 16 June 2008 (543 mm with 70 mm occurring in 1 hour) and 29 July 2013 (187.5 mm with 89 mm occurring in 1 hour) revealed depths of inundations of 1.45 m and 1.2 m, respectively. These depths were in agreement with the observations narrated by the residents of the G-Type quarters. The areal extent of the contributing catchment for the floods near G-Type quarters is about 105 ha. Approximately 70 ha lies inside IIT and 35 ha lies outside.

iv) The flooding problems near G-Type quarters was further analysed using SWMM, MIKE 21 and MIKE FLOOD models as well as field visits. Based on model studies and field visits, the major reasons identified for the flooding/drainage congestion problem in the area are (a) insufficient capacity of the existing drainage system including the culverts to handle design flows, (b) poor maintenance of the existing drainage system, (c) presence of boundary wall, (d) drainage congestion at the outlet as the main drain drains into a canal which runs full during monsoon season, and (e) an area outside IIT campus (to the tune of 35 ha) contributes flow to the IIT campus near the G-Type quarters. However, it should be noted that both the rainfall events of 16 June 2008 as well as 29 July 2013 are extremely high events which are much beyond the design storms and hence, it is not economically viable to design drains to handle runoff resulting from such storms.

v) In order to provide a solution to the flooding problem near G-Type quarters, a new multi-purpose detention pond (3 ha surface area and 3 m depth) is proposed to divert the flow of the drain behind VSRC to avoid drainage congestion at the G-type quarters (this drains enter from the Prembazar gate and eventually ends at the existing outlet near G-type quarters). The catchment of pond is 100 ha (i.e. approximately 30 ha from the Tata-Sports complex/A-type quarters and 70 ha from the contributing catchment for G-Type quarters). The primary purpose of the detention pond is to retain the runoff and act as a rainwater harvesting structure and allow the standing water to infiltrate for groundwater recharge. The detention pond is designed to reduce the peak of outflow hydrograph at the downstream end by allowing a slower release of incoming flow by means of weirs. This reduction of peak discharge from 10.55 m^3/s to 6.12 m^3/s will allow a fairly safe passage of flow to the canal outside IIT campus.

vi) The outlet for the area draining from South Block-type and G-type quarters (the high drain) is to be kept at its existing location. The catchment of this outlet (after the proposed modification stated above) lies mainly outside the IIT campus (areal extent of about 35 ha). The developed flood hydrographs using the CWC synthetic unit hydrograph approach revealed that the outside area contributes to nearly 35% of the peak flood discharge near the G-Type quarters. Currently, the topographic information for this outside area is not available and hence, a drainage solution for this area could not be provided. But this will be taken up soon. However, for the time being, openings may be provided in the boundary walls near the G-Type quarters.

vii) The 24 hour distributed rainfall of 2, 5 and 10 year return period were used to simulate the flows using SWMM in the existing drainage system to assess their carrying capacity in the (a) hostel area, (b) academic complex (c) southern region and (d) Technology market area. At many locations, the existing drain dimensions are found to be insufficient to handle the flows pertaining to even 5 year return period.

viii) Based on the above exercise, the drains have been designed using SWMM to handle flows corresponding to 10 year return period in the (a) hostel area, (b) academic complex (c) southern region and (d) technology market area. The design dimensions are provided in a map given in Appendix-I. The map also provides the dimensions of existing drains at some locations. Based on these dimensions, specific recommendations have been made to Civil Works Department to take up construction of some of the critical drains before the upcoming monsoon season.

ix) Based on field visits, it has been felt that it is very essential to clean the existing drains periodically and restore the critical missing links. Unless regularly maintained, the redesigned drain sections will not suffice beyond one season. Due to the disposal of waste from Hall Mess and other litter, drains gets clogged, therefore, frequent cleaning of the drain is required. Apart from this there are various pipes (of Water supply, Cable etc.) running through the drains which further restricts the free flow of water in drains.

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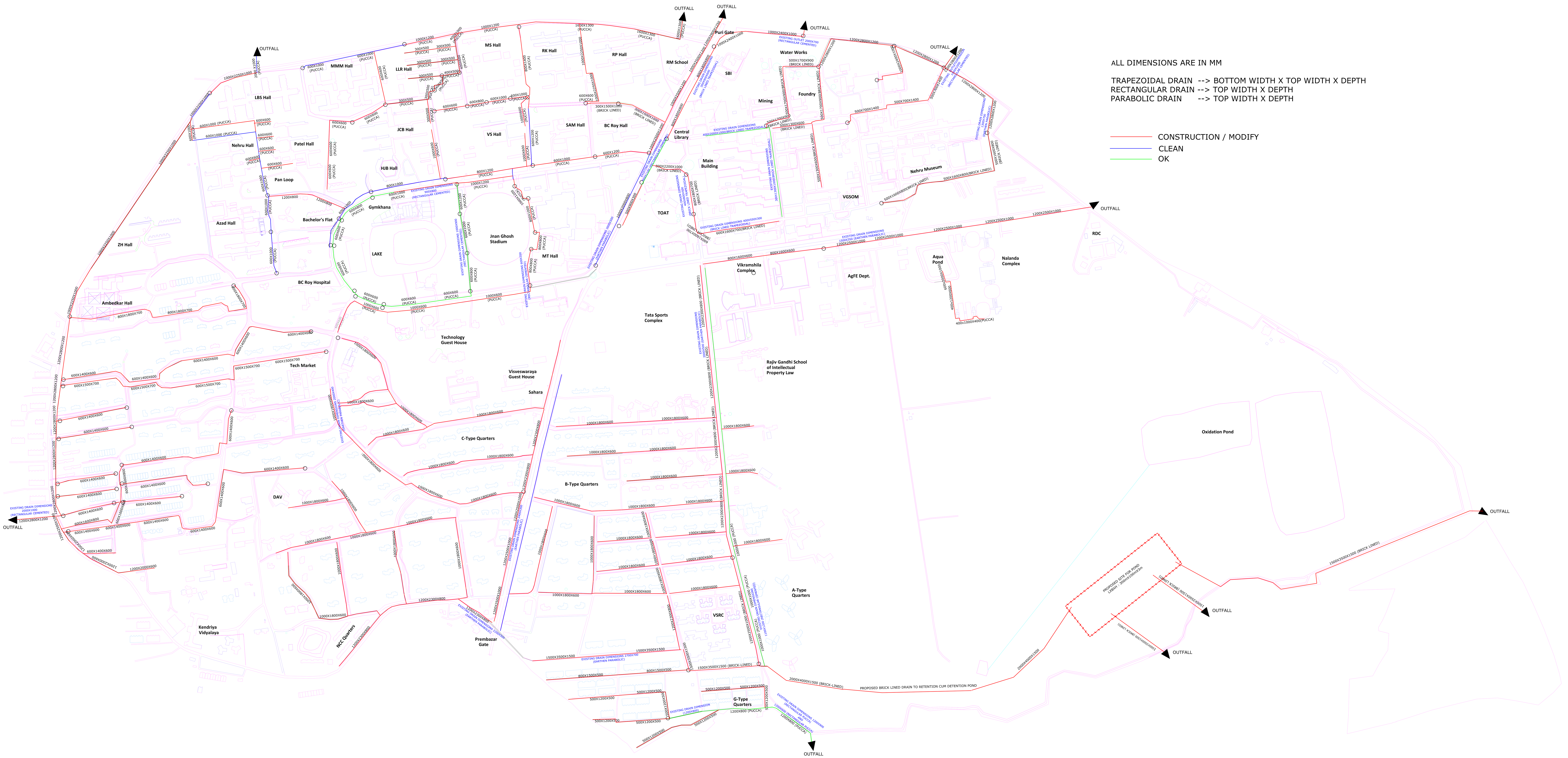
APPENDIX- I

See in the next page.



Design Drain Dimensions for IIT Kharagpur Campus for 10 Year Return Period Rainfall