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ANALYSIS OF STORM WATER DRAIN IN 1410 ACRES, PALASAMUDRAM SITE

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Abstract –*The present study is aimed to explore the analysis of storm water drain in 1410 acres at Palasamudram Site. In this site, many branch nallahs are running and it has been connected together and lead to properly designed pond. Many rainwater recharge pits are considered for natural ground recharge to follow the statutory norms. Artificial pumpings were not used in this layout. The full layout is analysed properly for economical drain sections. Three artificial ponds are considered for collecting storm water at several locations. This design reduces the impact of flood to great extent and the maximum rainwater can be sent to the ground.*

Key Words: **Environment, Rain Waste Disposal, Rainwater Harvesting, Saving Nature, Location; Palasamudram.**

1. INTRODUCTION

1.1 Description of the Site:

The Site is having an area of 1410 acres and shares its northern boundary with ISRO. State Highway runs along the western boundary of the site. There is private agricultural land on eastern and southern side of the site.

1.2 Topographical features of the site

The existing ground level of the site varies from 544.0m to 575.0m R.L. The natural slope of the ground tends towards north east corner of the site. The highest elevation is observed on the south west and southern corner of the site. The external boundary wall, peripheral security patrolling roads and external fencing are constructed on existing contour levels. An inner security double fence is proposed inside the external boundary wall. Inside the inner double fence, the plant is proposed to be developed. The plant area will be graded in stepped manner from 552.0m to 564.0m R.L., with each step being 2.0m.

1.3 Hydro-meteorological features of the site.

The site is located in Anantapur district. Rainfall data is collected from Department of Statistics (Bangalore office) for Palasamudram village. The normal monthly rainfall for Palasamudram and it is observed that the rainfall is bi-modal peaking in months of May and October with maximum rain occurring in the month of October. The average yearly rainfall at Palasamudram village is 475.6 mm (1971 to 2000). Daily maximum rainfall over for the period 1955 to 2012.

It is observed that the streamlines get generated inside the two-sub watershed with a minor branch of external flow from the North West entering the site at one corner and which goes out. For the larger part of the left sub watershed also the streamlines are generated inside the site. Due to the two prominent streams in the site area, the runoff generated in the site area will accumulate at two different points (unless flows from one stream are diverted to another). In the present natural condition, the streams passing through the site area finally join together outside the site area to finally release in the Palasamudram lake on the north-east part of the site.

1.4 Scope & Composition of the Report

The objective of the report is to lay down the design basis for design of storm water drainage system for efficient and safe disposal of the storm water. The scope of this DBR comprises of planning and design of storm water drainage system. The storm water plant site will be disposed through streams joining outside the plant boundary to Palasamudram Lake.

1. The study covers the general introduction of the site and background information.
2. Covers the analysis of rainfall data and derivation of design rainfall intensity.
3. The study is on planning of the drainage system and proposed outfall level with design cases.
4. The study covers the estimated design discharges of different zone and hydraulic design of the sections.
5. The Study also covers the recommended maintenance aspects of the drainage system.

2. DESIGN BASIS RAINFALL INTENSITY

Hourly intensity of design precipitation is the most critical parameter for the storm water drainage design. The "expected extreme precipitation" associated with an appropriate reference interval is used in designing the drainage system. Indian Meteorological Department (IMD) provides isohyetal curves for different return periods (Mean Recurrence Interval - MRI). Such values, as suggested by IMD, are 35 mm/hr for 2 - year return period, 50 mm/hr for 5-year return period and in between 60 mm/hr for 50-year return period for Palasamudram area.

However relevant AERB codes (Ref.12) suggest that extreme value analysis should be carried out to arrive at design intensity value. It is recommended that the analysis should preferably use data from those stations equipped with continuously recording rain gauge such as a weighing or tipping bucket type. However, if the network of continuously recording stations is too sparse, the use of data from network of non-recording should be considered (Ref.12). It is further recommended in AERB siting code (Ref.9) that total precipitation depth for running 24 hours shall be collected for a period of at least 30 years at the site. Where such data is not available, the daily rainfall measured from non-recording stations shall be used.

2.1 Data and Checks

The daily maximum annual rainfall data for the period 1955 – 2012 has been converted hourly maximum rainfall by using conversion ratio proposed by CWC.

2.2 Statistical Checks

The non- parametric tests are done when any information about the underlying population is unknown, and hence the application of parametric tests may result in erroneous results. The following checks were performed for this report:

I. Wald-Wolfowitz's test.

II. Box – Whisker plot.

I. Wald-Wolfowitz' Test (Runs Test)

The Wald-Wolfowitz's test also popularly known as the Run's test gives us whether the set of data produced is from a random process or not. In any random data set, the probability that the (i+1)th value is greater than the ithvalue follows a binomial distribution, this forms the basis of Run's Test. Run signifies the number of group of binary value that represent the data. The first step in the runs test involves in defining the data in a dichotomous format. Having done so, the next step involves the statistical analysis that needs to be done, as has been discussed below to reach upon two hypotheses:

$H_O =$ This implies that the set of data obtained is random

$H_1 =$ Given set of data is non-random in nature.

The importance of the Run's Test lies in the fact that it determines whether a univariate process is in control. If yes, then it can be modelled linearly, or else it needs non-linear or time series modelling. The following study involves the use of the P - Value approach.

This approach consists of calculation of a test statistic and considering it to be normally distributed we calculate the p-value. The p-value signifies how well the sample data supports the argument of null hypothesis. If the p-value turns out to be greater than the α value (significance level: i.e the probability of making TYPE 1 error), then we cannot reject the null hypothesis. However, if p-value is less than the α value null hypothesis is rejected in favour of alternative hypothesis.

The time series plot of maximum hourly rainfall is shown in

Figure 1 below.

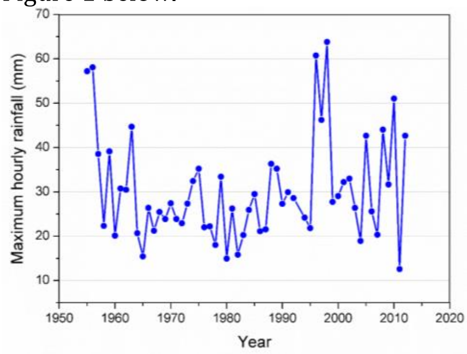

Figure 1: Time series plot of maximum hourly rainfall from 1955 to 2012

To determine the number of runs, first it is necessary to establish the criteria. It is considered that any value greater than mean value is one, less than mean is zero and if it is equal to mean the value should be omitted.

$$\text{Mean} = \frac{1}{N}\sum_{i=1}^{N} x_i = 30.3 \text{ mm}$$

II. Box-Whisker plot

This test is used in the estimation of outliers in data. Many statistical data can get distorted due to the presence of an outlier. The greatest being that of mean and standard deviation. This plot will let us know whether any outliers are present in data. The Box-whisker plot of the data is shown in Figure 2.

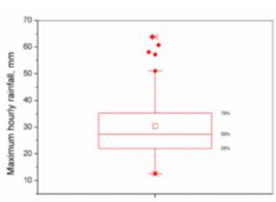

Figure - 2

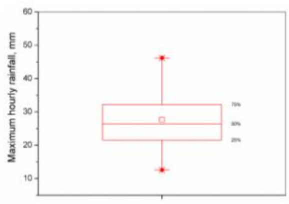

Figure - 3

From the fig. it can be seen that outliers are exist in the data considered. The outliers are removed from the data and proceeded with further analysis. The Box-Whisker plot of the data after omission of outliers is shown in Figure 3

2.3 Extreme Value Analysis of Maximum Hourly Rainfall Data

The maximum hourly data was subjected to extreme value analysis (Gumbel & Frechetdistributions) in accordance with AERB safety guide no. AERB/SG/S-3 'Extreme value analysis of meteorological parameters' (Ref.12). The Probable Maximum Precipitation (PMP) values obtained from EVA and from Isohyet maps given by IMD for different MRI

Higher of the values obtained from Gumbel and Fréchet distributions is considered as probable maximum precipitation (PMP) value. The probable maximum precipitation (PMP) values arrived from this analysis are:
Probable maximum hourly intensity for Mean Recurrence Interval (MRI) of 50 years = 59.83 mm

Probable maximum hourly intensity for Mean Recurrence Interval (MRI) of 100 years = 70.90 mm

Probable maximum hourly intensity for Mean Recurrence Interval (MRI) of 1000 years = 124.26 mm

From the rainfall data, it is seen that the site has recorded maximum hourly intensity of 63.8 mm in year 1998. From the adopted rainfall distribution, the return period of this rainfall intensity comes out be 65 years.

Hence, as per AERB approved practice, hourly rainfall intensity of 100 years return period i.e. 71 mm has been adopted as design basis intensity for storm water drainage system.

3. PLANNING OF DRAINAGE SYSTEM, ALTERNATE ROUTES AND DESIGN CASES

3.1 Planning & Alternate Routes for Storm Water Disposal

Figure 5 shows the location of plant site in Palasamudram. In the present natural condition, the streams passing through the site area finally join together outside the site area to finally release in the Palasamudram lake on the north-east part of the site after the development of the plant site, the surface runoff will get channelized and concentrated and hence, will have to be given a passage to the tank.

Keeping in view of the Master Plan, Contour of existing site and drainage pattern, it is proposed to develop the nallah as shown in drawing attached in Figure - 4. Internal branch storm water drainage network will be developed within the plant area. These branch drains will release the storm water in either of the main drains. the surface runoff will get channelized and concentrated and hence, will have to give a safe passage to Palasamudram lake.

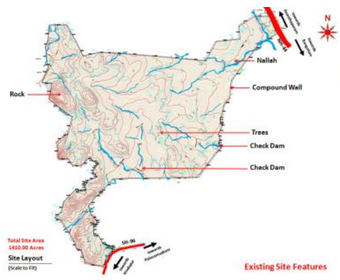

Figure - 4

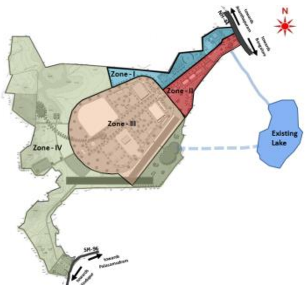

Figure - 5

The topography shows (based on toposheet D43K11 of Survey of India) that two sub watersheds enclose the Plant site areaand the areas of these sub watersheds extending only inside the Plant site boundary are taken into consideration for determination of runoff. The two sub watersheds are designated as Left WS and Right WS (and having their individual streams). The design storm water layout is kept similar to the naturally occurring pattern as much as possible.

3.1 Terrain Analysis and Formation of Drainage Zones

The proposed layout drains. The Major features of the terrain have already been described. Based upon the topographical features, contour details, built-up areas, area grading and engineering considerations, site has been divided into 25 drainage zones. Drainage zones are indicated. Storm water under left zone as indicated Figure 1 will be diverted to left main nallah and detention tank and area under right zone are diverted to main drain in right area and finally left and right nallah are combined in Zone 22 & Zone 23 before discharged to main nallah connecting to Palasamudram Lake.

4 .PEAK DISCHARGE ESTIMATE & HYDRAULIC DESIGN OF DRAIN SECTIONS

4.1 Introduction

The main objectives are to estimate daily runoff/yield for the site for pre-construction and post construction scenarios. SCS-CN method is used to determine the runoff from the two sub watersheds enclosing the Plant site area.

4.2 Methodology

4.2.1 SCS-CN method:

A good runoff model includes spatially variable parameters such as rainfall, soil types and land use /land cover etc. In this study the Soil Conservation Service Curve number (SCS CN method as also outlined in TR 55) also known as hydrologic soil group method is used to determine daily runoff. This method is a versatile and popular approach for quick runoff estimation and is relatively easy to use with minimum data and it gives adequate results.

The SCS runoff equation is

$$Q=\frac{(P-I_a)^2}{(P-I_a)+S}$$

where

Q = runoff (mm)

P = rainfall (mm)

S = potential maximum retention after runoff begins (mm) and

Ia = initial abstraction (mm)

Taking Ia = 0.2S, Equation simplifies to:

$$Q=\frac{(P-0.2S)^2}{(P+0.8S)}$$

S is related to the soil and cover conditions of the watershed through the CN. CN has a range of 0 to 100, and S is related to CN by:

$$S=\frac{25400}{CN}-254$$

The CN values adopted in this work are given below and these pertain to the Group A soil (Soil group is selected based on the infiltration rates of the soil).

The major factors that determine CN are the hydrologic soil group (HSG), cover type, treatment, hydrologic condition, and antecedent runoff condition (ARC).
ARC is given according to values shown below.

Based on the ARC, CN values are modified using the equations given below:

$$CN(I)=\frac{4.2*CN(II)}{10-(0.058*CN(II))}$$

$$CN(III)=\frac{23*CN(II)}{10+(0.13*CN(II)}$$

where, CN(II) is the curve number for normal condition, CN(I) is the curve number for dry condition, and CN(III) is the curve number for wet condition.
For scenario SC1, a single CN value is applicable for the complete Plant site.

Thus, for SC2, the model uses a CN value applied to the building area separately (and flow from roofs of buildings separately determined) and a composite CN number applied to the roads and open land (and flow from roads and open land separately determined). Hence, CN values applicable to SC2 for the two sub watersheds.

4.3 Determination of flood hydrograph and discharge

Basins in natural conditions absorb/collect storm water and slowly release it at a controlled rate so that downstream areas are not excessively flooded or eroded. They basically attenuate the flood hydrograph by reducing the peak and increasing the base. As areas become urbanized (with constructions), the impervious areas increase resulting in higher peaks in the hydrograph and shorter base of the hydrograph. This can adversely affect downstream areas causing flooding.

Flood hydrographs and peak discharges are determined for two scenarios: pre-construction scenario (SC1) and post-construction scenario (SC2). Further two cases are considered under SC2: a) SC2-PA with all constructions planned on the Plant site are completed b) SC2-P1 with constructions planned in Phase 3 completed.

The methodology used to determine the flood hydrograph is based on Tabular Hydrograph Method of TR 55 (TR 55, 1986). The Tabular method can develop partial composite flood hydrographs at any point in a watershed by dividing the watershed into homogeneous subareas. In this manner, the method can estimate runoff from non-homogeneous watersheds.

The method is especially applicable for estimating the effects of land use change in a portion of a watershed. It can also be used to estimate the effects of proposed structures.

Input data needed to develop a flood hydrograph using the Tabular Method include-

- 24-hour rainfall for the required return period (P)
- CN values
- time of concentration (Tc)
- drainage area (A)

For calculating Tc, in the case of pre-construction scenario SC1, the type of flow assumed is sheet flow for the first 100m, then shallow concentrated flow for 1/3 of the remaining length and channel flow for the 2/3 of remaining length of the stream. On the other hand, for calculating Tc, in the case of post-construction scenario SC2-PA, the type of flow assumed is sheet flow for the first 100m and channel flow for remaining length of the stream, and this is because much of the flow is carried in formed drains in the post-construction scenario when all constructions have been completed. The drain size adopted is with nominal cross-sectional area of 2 m2, surface width of 4m and a flow depth of 0.5m. In case of case SC2-P1, the type of flow assumed is sheet flow for the first 100m, then shallow concentrated flow for 1/3 of the remaining length and channel flow for the 2/3 of remaining length of the stream. Based on the above data and initial abstraction (Ia) and Type III rainfall distribution (Type III represents tropical rainfall with large 24- hours rainfall, more appropriately fitting for monsoon climate condition. Hence, same is generally adopted for Indian scenario), TR 55 gives the ordinates of hydrograph (qt) for different ratios of (Ia/P) and Tc. The final hydrograph is calculated based on the following equation-

q= qtAQ ....Eqn. 4.1

Where,

q = hydrograph coordinate at hydrograph time t

qt = tabular hydrograph unit discharge

A = drainage area of individual subarea

Q = runoff

4.3 Peak Discharge Estimation

Based on the methodology given in section 4.2 the ordinates of the flood hydrograph are determined (for pre-construction and post construction scenarios (SC1, SC2-PA and SC2-P1) and for the left and right sub-watersheds) and hydrographs.

It is observed that for 100 years return period and for left sub watershed, the peak discharge for pre-construction scenario is 21.6 m3/s which increases to post-construction (SC2-PA) peak discharge of 47.6 m3/s. Further, for 100 years return period and for right sub watershed, the peak discharge for pre-construction scenario (SC2-PA) is 34.8 m3/s which increases to post-construction peak discharge of 79.4 m3/s.

Also, it is observed that for 100 years return period and for left sub watershed, the peak discharge for pre-construction scenario is 21.6 m3/s which increases to post-construction (SC2-P1) peak discharge of 31.3 m3/s. Further, for 100 years return period and for right sub watershed, the peak discharge for pre-construction scenario (SC2-P1) is 34.8 m3/s which increases to post-construction peak discharge of 48.3 m3/s.

4.4 Design of Storm Water Drain Section

Basic hydrodynamic equations are modified for application to open channel flow to include parameters of channel geometry by Saint - Venant and they assume the form:

$$\frac{1}{g}\frac{\partial V}{\partial t} + \left(\frac{V}{g}\right)\left(\frac{\partial V}{\partial x}\right) + \frac{\partial y}{\partial x} - \text{So} + \text{Sf} + \frac{[(V-Ux)q]}{gA} = 0$$

$$T\frac{\partial y}{\partial x} + \frac{\partial (VQ)}{\partial x}q=0$$

where,

g- acceleration due to gravity

V- velocity along the channel

Y- water depth

Ux -Component of velocity of the lateral inflow in direction of main flow

A- Area of the cross section

$T=\frac{dA}{dY}$ i.e. top width of the channel

q- lateral rate of inflow for unit length of channel

So - longitudinal slope of the channel

Sf- friction slope = n2VV/R4/3 in SI Units

where R is hydraulic radius and n is Manning's roughness coefficient

These equations are solved, as suggested by AERB codes, by numerical techniques using either finite difference method. However, for the free flow conditions, the equation is simplified by assuming steady uniform flow. Manning's equations for the gravity flow can be applied to arrive at design values. Government of India manuals (Ref 14) and others (Ref 8 & 13) approve the application of Manning's equation for design of Storm water drainage. Even for the unsteady uniform flow, generating gradually varied flow (GVF) regime, Manning's Equation of uniform flow can be applied with few assumptions & simplifications.

4.5 Manning's equation

Manning's equation states that

$V=\frac{1}{n}R^{2/3}S^{1/2}$...................(Ref 3,4,6,8, 13 & 14)

Where,

V- Velocity of the flow

n- Manning's Coefficient

S- Bed Slope

Then, Q= A*V

where, Q- Discharge

A- Flow Area

4.6 Design of the section

For the peak discharge value (QP), the respective sections have been arrived by choosing appropriate slope and geometry of channel. Trapezoidalstone pitching channel have been proposed for main drains within boundary. The branch drains within the plant area are proposed either of SS Masonry or RCC rectangular channel or RCC pipes, conforming to class NP3 (IS 458). The adopted slope in site varies from 1/500 to 1/800. Minimum velocity of 1.0 m/s in peak discharge condition has been ensured for non-silting condition of the drain. The maximum velocity has been kept less than 4.0 m/s to avoid scouring of the drain.

For the drain outside boundary, either stone pitched or earthen drains have been proposed. The Manning's coefficient for RCC section, stone pitched and earthen sections have been taken as 0.013, 0.020 and 0.025 respectively.

5. MAINTENANCE OF THE DRAINS

The storm water drains shall have to be periodically cleaned and maintained properly in order to have the smooth flow of the water. Immediately before and after monsoon, all the drains shall be de-silted and unclogged. There shall be provision of 'during monsoon' cleaning to ensure the smooth drain functioning in peak storm conditions. The CI cover of catch pits, storm water chambers, road gullies etc. shall be cleaned for free ingress of rainwater from the sub basins to main storm drains.

It shall be ensured that the detention tank outflow shall be kept open before the onset of monsoon and same may be closed only when there is confirmation of no rainfall is expected in the area.

CONCLUSION

Herewith conclude that the flow of natural Nallah should be maintained for the design of storm water drain. So, that the flow of rain water to the drain will drained easily and also the maintaining natural Nallah helps the project of the site for maintaining the storm water drain easier.

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