Improvement of Drainage System in Cuttack-Bhubaneswar Twin City, Odisha

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Abstract- **The type of diversity of drainage problems requires a clear understanding of the purpose for designing a drainage scheme. Various factors confronted and some may be opposite to each other as regards to their merits are concerned. It is difficult to accommodate all factors in final design. The combination of various factors depending upon their suitability of a particular drainage area gives the design to its final shape. The benefit cost factor is a major criterion since a perfect technical solution will cost very high. The main aim of this study is to devise an effective drainage system of least cost. Before designing it is necessary to decide the rate at which excess water should be removed from the agricultural field. If the rate is too low, crops may sustain injury due to submergence and if too high, the cost of drainage scheme will go up. Therefore, evaluation of design run-off is most important in any drainage scheme. In this regard Mahanadi-Chitrotpala-Luna DOAB has been studied to assess the effective run-off. Its basic aim is to indicate how to obtain the highest benefits from the given resources. Economic evaluation of this project calls for a comparison of benefits and costs. In the field, it is very difficult to get a stable section of a drain which can carry a design discharge. It is observed that, the drain of bigger size tends to deteriorate fast as they do not carry design discharge in the study area. On the other hand, the drains of the smaller size, than the design section remain in better condition and can carry occasionally higher discharge. As per Mc. Maths formula the discharge for smaller catchments is restricted to 6 km^2 and the design discharge is 40 % of 15 km^2 whereas for larger catchments, Cypress-Creek formula with coefficient (C) 55 gives the result more realistic and is recommended for acceptance in the study area. This absolutely clears the benefit of doubt regarding cost factor and other technical implications.**

Keywords- DOAB; Drainage; Mc. Maths Formula; Cypress-Creek Formula; Water Logging

I. INTRODUCTION

Water is important component of all living beings. It also performs unique and indispensable activities in earth ecosystem, biosphere and biogeochemical cycles [1]. Drainage system of any region depends on DOAB of the flow path of river. DOAB is a compilation of a couple of words-'DO' meaning two and 'AB' meaning water. DOAB is a term used in India and Pakistan for a "tongue" or tract of land (strip of land) lying between two confluent rivers. To mitigate any disaster by virtue of natural drainage system, well calculated system has been developed by proper check dams, reservoirs and irrigation system to divert the huge volume of water i.e. drained in river system. The purpose of such investigation complies with the study of various causes, limitations, residues and design aspects to overcome from any such instants. Improvement of adequate drainage system resists the rise in flood level to avoid the spilling of overflowed water. Odisha which has a long coastal boundary is always under the threat of devastation. This coastal area is under the turmoil of huge sediment deposits that creates a siltation by virtue of fluvial environment (i.e. channel deposits, channel marginal deposits, over-bank deposits). Backwash of sea waves also creates the similar type of problem in this coastal region. As far as the velocity of the river current exists the problem still remains vulnerable. The surface runoff which is a seasonal phenomenon is largely affected by climate in the basins of Odisha [3]. The state of Odisha has a poor drainage system, huge water logging either due to surface ponding or rise of ground water table creates an extensive marshy land in the region. The research has been undertaken to have a general preview of the drainage in the DOAB of Mahanadi and Kuakhai River (Fig. 1) which extends two watershed zones of the twin city Cuttack-Bhubaneswar. In this circumstance the watershed management has also been studied and an outcome has been declared with some suitable suggestions.

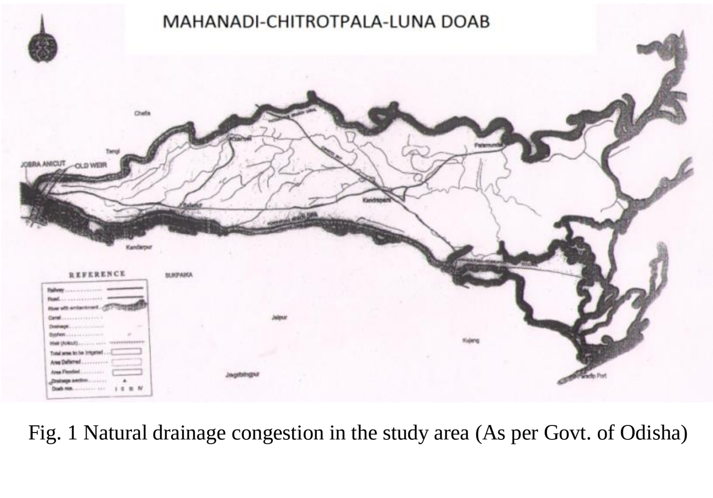

Fig. 1 Natural drainage congestion in the study area (As per Govt. of Odisha)

A. Land Drainage

The average annual rainfall in the study area is 1572 mm, of which 70% [7] is precipitated during the southeast monsoon from mid-June to mid-October. Land drainage is the removal by artificial means of excess water from soil or from the land surface, whose objective is to make the land suitable for human use. As far as agricultural land is concerned, its purpose is to increase production, sustain yield and reduce the cost of production. All these factors help the farmers to maximize the economic return. The sources of this excess water may be due to precipitation, irrigation water applied, land flow or under-ground seepage from an adjacent area or flood water of the rivers entering the fields. The excess water adversely affects the production of the crop by reducing the soil volume accessible to roots. Seepage is the major source of water in places where irrigation is practised. Manmade seepage usually stems from irrigation development works such as canals, reservoirs or similar structures. Comparison of fluctuations in ground water levels and fluctuations in water levels in canals or reservoirs indicates whether the structures are leaking. The main aspect of drainage is to remove that quantity of water which is being supplied in excess of the crop water requirements. This discharge capacity consists of two components, the surface run-off and the sub surface discharge which have been considered for the drainage improvement. The coastal belt of Odisha is worse affected due to ill-drainage and water logging problems.

B. Causes of Poor Drainage

Various causes contribute to the poor drainage conditions. The main factors are:

- The command being a flat land with slope less than 0.02%, it does not permit easy drainage;
- Low capacity disposal channel within the area;
- Outlet conditions which hold the water surface above ground level such as high lake or river stages and tide water;
- Excessive use of irrigation water;
- Seepage from canals;
- The inherent stratification of irrigated soils in the command areas causes poor condition. The coastal area is a broad, flat, alluvial plain. Because of the way the soil materials are deposited in these areas, the internal natural drainage is often poor;
- Low channel slopes (without cleaning velocity);
- The ground slope being very flat the channels do not get adequate gradient to develop self-cleansing velocity in delta command;

The deterioration of the drainage channels due to silting, encroachment, putting cross bunds, lack of maintenance.

The norms for maintenance of different types of drainage works set up by the government of India that up to date the expenditure(year 2002)for maintenance of drainage channel at 82.23 prices for 1982-1983 with increased rates for the subsequent years at 10% per year are as follows:

Drainage channels with discharge up to 5 cumecs = Rs.12230 per km

Discharge between 5-15 cumecs = Rs.15290 per km

Discharge above 15 cumec = Rs. 30580 per km

Otherwise inefficient channels:

The drainage channel slopes vary from 0.007 to 0.03 which would induce a velocity of approximately 0.2 mtr per sec.

Weed growth: Chemical control of weed is discouraged due to many disadvantages. Nowadays mechanical and manual methods are preferred.

Meanders: The meanders in the channels and drains are caused by excess of total changes (bed and suspended) during flood when excess turbulence is developed.

Insufficient water ways in road crossing and sluice.

Coincidence of DOAB rainfall with river flood: The storm tracks causing rainfalls in river basins travel from its mouth towards the upstream of rivers. Thus the command areas get rainfall when the rivers are in Spate. This coinciding effect of the river prevents flow of drainage water into river through the outfall.

Outfall condition: Some of the drains in the coastal belts outfall into the river in its tail reach. The slopes of the rivers are always flat in these locations and during rainy season their own discharge into the sea is difficult. Hence the drain out-falling into them is emptied with much difficulty and keeps large area submerged for long periods.

C. Classification of Problems and Extent of Areas Suffering

Drainage is the major constraint to agricultural development in the command. Out of the total area about 8% to 10% suffer from poor drainage conditions of varying degrees.

Three major categories of drain problems exist. These are:

- Drainage conditions inside the DOAB: Lack of excess of fields and field drains to the drainage network (lack of link drains), inefficient transport of drainage water inside the DOAB and inadequate outfall structures;
- River system: Lack of free flow discharge of flood water from the rivers to the sea through the coastal belt interferes with the possibility for good drainage;
- Coastal phenomena: Coastal process like littoral drift which tends to block the natural river outlets has an adverse effect on the free flow of rivers and drainage to the sea.

D. Drainage in the DOABs

Drainage situations exhibit substantial diversity in terms of the multiple crops and soils served, the many resources system functions affected, the scale of the systems, the development environment, the social and economic circumstances, and the ecological factors involved. The wide diversity encountered in drainage situations across the world and the variety of factors causing it show that "drainage" is a container concept. Talking about drainage in general is therefore almost meaningless—at both the analytical and intervention levels. A context-specific approach is required for both analysis and intervention [6].

The general conditions inside the DOABs are favourable for the good drainage. In general, for each DOAB, the land along the river is highest and slopes down towards the centre of the DOABs. The drainage channels are therefore situated in the DOAB interiors. However, variation in the ground level of a few feet occurs locally, the village being on the highest ridges. Occasionally bigger areas 200-300 ha may be affected, but mainly the water logged areas are dispersed throughout the DOAB and are relatively small. The Water Resources Department has developed a set of design for the purpose of designing drainage channels and improving existing primary and secondary drains, especially in the lower reaches. The drain patterns are determined by the differential tide levels at the outfall structure. The maximum head appears just before the low water at sea. Therefore the flow is intermittent with high peak during maximum discharge.

The farmers have the tendency to use the drains for irrigation purpose by temporarily putting cross bunds across them. This practice, however, is in serious conflicts with the purpose of drain system. Therefore, precautions should be taken so that such misuse of drainage system will not occur.

E. Degree and Extent of Poor Drainage

Drainage is poor in nearly 35%-40% of the coastal command areas of Odisha. These areas suffer from drainage congestion of two different degrees. The degrees vary from year to year depending upon the depth of duration of rainfall, extent of cultivation in different seasons and release of water in the canals. The poor drainage areas can be broadly classified into different categories.

1) Area Unsuitable for Cultivation Throughout the Year:

These areas are marshy and swampy and remain submerged throughout the year. The extent of such areas in all the doab is 0.247 lakh ha. After making provisions or surface drainage it is expected most of these areas retrieved.

2) Unsuitable for Cultivation in Kharif:

These are low lying lands where land grading and land shaping are poor. They remain water logged for most part of the kharif season. The extent of such land in the command is 0.733 lakh ha. Due to lack of drainage facility during kharif season, no crop is possible.

3) Areas Suitable for Cultivation in Both Season but with Low Yield:

In these areas the high water table interferes with the production and reduces the same through it is possible to raise the crop in both the seasons. The extent of such areas in the command is 0.922 lakh ha.

4) Areas Which Cannot Be Economically Retrieved:

These areas suffer from the most serious type of drainage congestion. They cannot get drained out by the surface drainage system, as the surface level is lower than the bed level of the adjacent drains. The extent of such areas is 0.276 lakh ha.

F. Improvement Measures:

The existing drainage channels insides the DOABs have aggraded, silted up, cross bonded, full of weeds and sometimes considerable anchored upon. Therefore their carrying capacity is deteriorated to a great extent. Very inadequate provision of water ways in the construction of bridges and other cross-drainage structures have resulted in unexpected afflux. Non availability of field drains and link drains aggravate the situation by prolonging the retention of water in the fields. Once the river water enters the doabs it does not get drained out easily and results in substantial damage to the crops, to the distribution system, public and private properties and utility services [4].

Improving drainage is a key objective of the proposed drainage project. Without improvement of drainage, investments in improved irrigation service will have relatively limited impact. Crop yield and production will continue to stagnate or decline. Project design and improvement should be therefore largely developed around the requirements of the drainage components which would be considered as an entire system rather than a series of individual engineering works.

1) Link Drains:

Link drains connect to field drainage network with the secondary and main drainage system. Without such linked drains flooding problems would be severe despite improvement in the macro drainage facilities.

2) Outfall and Secondary Drains:

They have been neglected over the years and are generally in the state of substantial disrepair. Most are simply wide or stream beds with little or no improvement and most are badly clogged with sediment and water borne plants. Immediate attentions should be given to the design of cross sections and embankments as required, particularly in the lower reaches.

3) Control Structure:

Control structures are designed and are to be operated in such a way that benefits for multiple objectives (both irrigation and drainage) can be obtained. As the river system is very complicated and with change in sea level it is very difficult to predict past experience on influencing major design and operational changes.

4) Field Drains and Laterals to Be Constructed After Consolidation:

This project is presently in progress in the coastal belt of Odisha. After this phase is over the collector drains and the field drains will be excavated to the required section and grading.

5) Providing Sweet Wateron the Land Side up to Structure Point:

The sweet water of the drain will travel up to the tidal structure. As there is a large area in between the present irrigation boundary and the tidal structures in case of stage-1 delta, the area can be suitably irrigated by recycle of drainage water through low head lift.

6) Availability of Water for Recycling:

Due to poor maintenance, canals and branches have been 36.3% and in distributaries and minors 23% of the discharge of head. After the modernization and lining, the losses are expected to be as follows:

The main conveyance losses in the system assumed for the month of July (after modernization)

- In main canals 11% of the discharge canal head;
- In distributaries 11% of the distributaries head discharge which is about 9.8% canal head discharge;
- In minor and sub-minor land percent of minor head discharge, which is about 8.7% percent of canal head discharge.

The total conveyance loss amounts to about 29.5% of the discharge released through head regulator of the main canals.

G. Operation and Maintenance

1) Operation:

The operation mainly consists of regulation of sluice, wherever the water level is high in the parents' channel [5]. Drainage facility provided under the project requires a much higher degree of precision maintenance over the present state of maintenance for effective control from water logging and flooding. The most important operations will be the control and regulations of the tidal operations. Depending on the relative tide and drainage levels, that the full length of the ebb tide period is availed for the discharge accumulated drainage water. The types of works to be undertaken can be broadly divided into following categories:

- Improvement to drainage channels;
- Construction of cross drainage works and regulating structures;
- Construction of outfall structures;
- Construction of secondary and linked drains;
- Sluice or other regulating structures provided at all in let points to the outfall drains.

These control structures will be made to function automatically so that the operation cost is reduced to the minimum and no time will be lost for their working. Alternately manually operated arrangements will be made for regulating structures.

2) Maintenance:

The question of maintenance is clearly a problem of management as well as economics, perhaps basically it is also a matter of responsibility.

Physical maintenance: Open drains require maintenance to keep them functioning as designed. Shallow surface drains in stable materials generally require spot cleaning only annually and a complete cleaning in about every five years. Removal of weeds is the next major feature requiring constant attention throughout the year. In more stable soil and deep drains chemicals used periodically will prevent or kill weeds etc.

H. Types of Earthwork

The following types of earth works in excavation are expected to be met with during the renovation of the drains:

- In case of linked drains, ordinary soil and hard soil without involving any extra lead or lift will be encountered;
- In the downstream reaches of the secondary drains; the earth work will require one extra lift;
- As one goes down stream, the earth work will involve provision for diversion arrangements for flow;
- In the reaches downstream of the tidal control structure, earth work can only be done mechanically.

II. METHODOLOGY

- Studying the geology, geomorphology, soil characteristics, topography and hydrological surveyed data collection;
- Feasibility study of the coastal drainage system;
- Preparing drainage map of the study area;
- Preparing rainfall map;
- Flood routing of the study area;
- Preparing S-curve of different zones;
- Design of cross drainage works;
- Design of sluices and other regulating structures in the inlet points to the out fall drains;
- Design of drainage channels to prevent flood and land use.

A. Statement of the Problem

The type of diversity of drainage problems requires a clear understanding of the purpose for designing a drainage scheme. Various factors confronted and some may be opposite to each other as regards to their merits are concerned. It is difficult to accommodate all factors in final design. The combination of various factors in view since a perfect technical solution will be highly costly.

There are many formulas to estimate the maximum run-off discharges based on the characteristics for the water shed, the land views and the maximum rainfall intensities. Design criteria are developed in two general ways:

- From empirical data collected through evaporation of existing drainage problems.
- From a theoretical analysis of the problem, applying known physical laws and testing the theory through evaporation of existing drainage systems.

B. Empirical Methods

There are many formulas based on the characteristics of water shed, land use, maximum rainfall intensity for the duration.

They are as follows:

- Mc. Math’s formula;
- Boston formula or Punjab-Boston formula;
- S.C.S. curve number method;
- Rainfall excess straight line method;
- Cypress creek formula;
- 20-40 rule.

C. Rational Method

This method is simple and has practical use, however, this formula tends to over-estimate the run off value and hence water shed greater than 500 Ha should not be calculated using this method. Areas greater than 500 Ha should be subdivided into sub areas.

D. Design of Channels

For the optimum output from a hydraulic design of the drainage system, it is required to design a suitable drainage system for its capacity and its strength. For the design of a drainage channel, the following parameters are computed:

1) Velocity:

The drain section shall be adequate to carry the design discharge and the velocity shall be non-silting, non-scouring to be determined by Manning's formulae.

2) Design of the Drain:

In order to open the discharge in a drain, it is necessary to know the mean velocity of flow obtained above which when multiplied by area of cross section of the drain will give the discharge.

3) Side Slopes:

Although deeper sections of the drains are desirable, the width/depth ratio is so selected that the section is both hydraulically efficient as well as economically excavation. A minimum of 1 meter should be provided between the top of the embankment and the section of the drain.

4) Fixation of HFL at Outfall:

Whenever a drain is out falling into river, the HFL should be slightly higher than the dominant flood level. In cases where the topography permits, the HFL can be above the highest flood level. However if such a level results in flatter slopes or HFL becomes higher than the natural ground level, the out fall should be kept slightly above the dominant flood level.

III. DESIGN REQUIREMENTS

A. Rainfall

It is always desirable to assess the amount of water that has to be discharged through the drains of drainage schemes by direct measurements. But at the time of designing a drainage scheme, very often adequate discharge data are not made available to the design engineers and therefore indirect methods such as the calculations of discharge from rainfall data will have to be used.

B. Frequency of Distribution over Space and Time

The higher the design rainfall is, the more the cost of project is and therefore there is less risk of failure. There is however a certain point at which the cost of ensuring more safety outweighs the benefits of a further reduction in the number of failures. Therefore, the choice of a design frequency is an optimization problem.

C. Intensity and Duration of Rainfall

The rainfall intensity is expressed as a depth per unit of time. This unit can be an hour, a day, a month or a year. The type of problem will decide the duration to be selected to analyse. As per IS: 8833-1978 the duration of the storm is about three days but the drainage is decided to be carried out for a period of 7 days since the rice, the predominate crop in Mahanadi Delta Command Area sustain a submergence of 7 days. Considering the accumulation of water in watershed will start after one day of the starting of storm their rain fall in 8 consecutive days is considered for drainage.

D. Critical Rainfall

For determination of critical rainfall in command area, all the 13 rainfall stations are considered. Expected rainfall in the projected area during the months of June to October station wise has been computed for 1 days, 2 days, 3 days, 4 days, 7 days, 8 days durations and for 5 years, 10 years, 15 years, 50 years retain periods. Weighted average of all the 13 stations (Table 1) is calculated for designed purposes.

TABLE 1 WEIGHTED AVERAGE RAINFALL FOR 8 DAYS

Months	8 years return periods @ 8 days rainfall
June	380
July	421
August	400
September	308
October	338

"The maximum weighted average rainfall occurring during July being 421 mm is considered for the design of drainage system".

E. Crop Type and Conditions

Paddy is the predominant crop in the Mahanadi Delta Command area grown during monsoon period from June to October.

Hence the condition for paddy crop during the different periods of growth has been taken into consideration. Showing operation starts in the month of June. Where transplantation operation is carried out in the month of July and August when the crop height is 150-200 mm.

F. Depth of Water Retained with Field

The project area is situated almost flat, low lying alluvial delta and having quite a high rainfall during the main growth season and occasional run-off from river floods. Rice, which is the principal crop, can withstand certain height without detrimental effect. Depth of watering for paddy generally varies from 50-75mm. Hence for calculating drainage index a depth of 50mm during early part of crop season i.e. June & July is taken.

G. Period of No-Damage Submergence

As the crop can withstand a certain amount of standing water, it can stand for a certain period beyond which damage to the crop will occur. This period is known as "period of no-damage submergence". Crops like paddy can generally stand submersion for a period of 7-10 days. The extent of coverage is more than 90% of the cropped area.

H. Irrigation Water Supply

The project area is well irrigated by canal system. These canals and water sources are maintained by a group of irrigation engineers stationed at different places. However, these field officers are not connected by efficient communication systems. Therefore, there is always a time lag between the requirements in the fields and water supply at head regulators.

I. Storm Warning

Even though the forecast of a storm reaches the field level some hours before its commencement, canal closer cannot be affected until the rainfall actually takes place in the command area.

J. Minimum Time Required for Operation

When the storm starts, immediately its duration and intensity cannot be ascertained. After knowing the nature of the storm and talking steps for canal closer, it will take at least 2 days for complete stoppage of water supply through canals.

IV. COMPUTATION OF RUNOFF OR DESIGN DISCHARGE - COMPARISON OF DIFFERENT RESULTS

Runoff is the portion of precipitation that makes its way out of the water shed. There are many formulas developed to estimate the maximum runoff discharge, based on the characteristics of the water shed, the land use and the maximum rainfall intensities for the duration and recurrence selected. The methodology adopted for estimation of runoff by using different formulae has been briefly discussed.

A. Computation of Runoff or Design Discharge Comparison of Different Results

Runoff is the portion of precipitation that makes its way out of the water shed. There are many formulas developed to estimate the maximum runoff discharge, based on the characteristics of the water shed, the land use and the maximum rainfall intensities for the duration and recurrence selected. The methodology adopted for estimation of runoff by using different formulae has been briefly discussed. A case study is made to estimate the runoff in Hansua drainage basin (Pilot DOAB area) by using different empirical formulae and the results so obtained are compared to establish the design runoff to be accepted for designing most efficient drainage system. For estimation of runoff by using different formulae are discussed as below.

B. Mc. Maths Formula

It provides an analytical method or estimating surface runoff for small water sheds. The Mc. Math's formula gives results which are considered fairly reliable for planning purposes. In F.P.S unit the formula can be written as

When $Q = 1/5CA^{4/5}$

Q = Discharge in cusecs

C = Runoff co-efficient representing the basic characteristics.

I = Rate of rainfall in inches per hour for the time of concentration and frequency.

S = Average slope of the water shed in ft/1000 ft.

A = Area of the basin in acres.

The formula can be expressed in the metric unit as $Q = 0.0091\ CA^{4/5}$.

When Q = Discharge in cusecs.

C = Mc. Math Runoff co-efficient.

I = Intensity of rains in mm/hour.

S = Average slope of the watershed in meter/meter.

A = Area of the water shed in Ha.

This formula is based on the same principles as the rational formula. The values of rainfall intensities are obtained the same way as the rational formula.

Values of *C* ranges from 0.20 for low runoff conditions to 0.75 for high runoff conditions depending principally on vegetation, soils, topography and runoff conditions. The *C* value increases as the vegetation cover becomes less dense, as the soil becomes heavier and as the slope of the ground increases. Mc. Math formula tends to give higher values for the smaller catchments which tend to have lower time of concentration. However, it seems that, there will be little difference to costs whether works in small catchment areas are designed in Mc. Math or any other formula. The USBR Manual also confirms that Mc. Math is more appropriate for small catchments though no guidance is given to the upper limits of applicability. A suggested approach would be limit use of Mc. Math to catchments served by a single drain. The following table as given in the USBR Drainage Manual shows the drainage basin factors for determining *C* (Table 2).

TABLE 2 WEIGHTED DRAINAGE BASIN FACTORS FOR DETERMINING MC. MATH'S CO-EFFICIENT 'C'

Runoff conditions	Vegetation	Soils	Topography
1	2	3	4
Low	Well grassed 0.08	Sandy 0.08	Flat 0.04
Moderate	Good coverage 0.12	Light 0.12	Gentle slope 0.06
Average	Good to fair 0.16	Medium 0.16	Slopping to hilly 0.08
High	Fair to sparse 0.22	Heavy 0.22	Hilly to slope 0.11
Extreme	Sparse to bare 0.30	Heavy to rocky 0.30	Step 0.15

Computation of value of n: A 5 year return period 1 hour rainfall value is found out. For this the rainfall intensity map of 10 year period 1 hour rainfall from IMD, Bhubaneswar is made use of the value coming to 90 mm. Now to convert 10 year return period to 5 year return period value 90 mm is divided by 1.2 per USDI Drainage Manual. Hence i = 90/1.2 = 75 mm/hour.

As per actual observation is 41.5 mm at Cuttack and since the value of 75 mm is quite high, an intermediate value of 60 mm is taken for design purpose. Thus i = 60 mm/hour = 2.36"/hour.

The Mc. Math formula takes into account the slope area and the intensity and frequency of rainfall and the time of concentration to provide the peak flow.

Therefore, the values obtained are higher than required for designing characteristics of drainage as it does not take into consideration the following facts which are realistic in our drainage concept.

- It does not consider the detention and retention which occur in flat rice lands.
- It does not consider the routing that will enter when a 7 day rainfall will be discharge in 7 days and not a peak discharge.

Taking the retention of about 3 inches in a rainfall of 76 inches, it is evident that the retention is about 20% assuming a peak flow hydrograph to be triangular, the peak of which corresponds to remaining 80% value of the rainfall, the average flow of the same hydrograph volume would be ½ of 80% i.e. equal to 40% of the peak flow has been taken as the corresponding designed discharge for the small catchments. It has been suggested that the No. Math formula is applicable to small catchments but the limit is not defined. It is further suggested that the use of Mc. Math formula may be limited to catchment served by single drain. In some project reports this area has been recommended to be 15 sq. Miles. Under the above circumstances, the use of Mc. Math formula is restricted to catchment of about 6 sq. Miles and the design discharge equal to 40% of the original No. Math discharge.

C. Boston Formula and Punjab Boston Formula

$$C = CA\ 1/2$$

Where *Q* = Discharge area in cusecs.

A = Catchment area in sq. Mile.

C = Co-efficient based on Hydro-meteorological characteristics of the catchment.

The value of "*C*" is generally taken as follows.

a) Area with rainfall less than 20 inches, *C* = 200

b) Area with rainfall 20 inches to 30 inches, *C* = 400

c) Sub-mountainous area with rainfall over 30 inches, *C* = 2000

d) For hilly area having about 30 inches rainfall every case based on actual study. For flat land with rainfall more than 30 inches we have assumed C = 1000. In the Boston/Punjab formula, the design discharge of the drains is taken to be one-sixth of the original Boston discharge.

The Boston type empirical formula has been adopted in many parts of the country and is used to estimate maximum or catastrophic floods in areas where data are not available for use of any better methods. Its major drawback is not the absence of any exploit frequency or return period of the flood which it represents nor does it refer to any intensity or duration of flood storm. But drainage in agriculture land is unlikely to be economic if agreed to such extreme event. Therefore, the use of this formula is not recommended in our study, but the values are provided just for the sake of comparison. A definite economic values and their justification has been adopted.

D. SCS (USDA CURVE NUMBER METHOD, Cn = 40 & 45)

The SCB curve number method was developed by the soil conservation services of the USDA can be adopted for computation of runoff for a comparative study. This gives an approximate discharge and can be adopted only for preliminary study. The above method based on observation of runoff from water shed upto 2000 acres in size. The preliminary need of field data in this method is infiltration rate, moisture condition of the grounds at the time of storm and the land use. The discharges are computed on a basic of free discharge. But the conditions to such hydrological condition, we find that about 3 inches of direct rainfall is impounded in the rice fields and does not come to runoff within the design period at all. Besides free over land flow does not occur in the flat rice fields. Here the water flows from plot to plot after inundating each plot almost to its bunch level or through a small orifice or cut made in the bunch. Therefore, the most appropriate curve number for use should be CN 40 & 45 instead of CN 90 obtained from the graph. Again this method is shown for a comparison only.

E. Practices Now Followed in Odisha as Per West Bengal Flood Committee

The present practice followed in the Irrigation Department, Odisha for drainage studies is 19 mm runoff to be drained from the entire area in 24 hours. This gives a straight line approach and does not show proportionate variation in the increased area. Given process is based on recommendations made by CWC for West Bengal Delta and which in turn is adopted by the Government of Odisha. This tends to provide low values for smaller areas. This gives a runoff of 0.21 cumec per sq. Km.

F. Rainfall Excess-Straight Line Method Directly Proportional to Area

The rainfall excess is computed by direct water accumulating in the field. The area same is directly multiplied by area and discharge for the drains is obtained. Though the determination of the rainfall excess on the actual field corresponding to the return period of the flood is more scientific, this method accepts the straight line method and it tends to give smaller values for smaller catchment. It gives a runoff contribution of 0.46 cumec per sq. Km.

G. Cypress-Creek Formula

This formula was developed in U.S.A. with average slopes less than 0.45%. The general empirical expression for the design discharge.

$$\text{(U.S.S.C.S 1971) is} = \text{CAp}. \tag{1}$$

When Q = Design discharge in efs.

C = Co-efficient depending on land use.

A = Area in Sq. Mile.

P = Co-efficient usually equal to 5/6.

But,

$$Q = CA^{5/6} \tag{2}$$

This value of ‘C’ can be obtained directly in the area to be drained or in this vicinity by actual water accounting in the fields. In metric units the cypress creek formula can be stated as follows.

$$Q = 0.00028 \times C = A^{5/6} \tag{3}$$

Where Q = Discharge in cumec.

C = Co-efficient which takes care of the characteristics of the soil vegetation, slope of the water shed and rainfall condition.

The Co-efficient ‘C’ can be computed from the CN curve of SCS hydrograph method and can relate to catchment conditions and the return period of storm.

Stephens and Mills (1965) have related the value of ‘C’ to the rainfall excess (Re in inches).

Besides, the value of rainfall excess of a storm event remains constant from the maximum 24 hours storm. Since the critical storm for flat areas may occur over an extended period of time, the analysis for determining Re should preferably be made by taking 7 days rainfall for return period of 8 years.

$$\text{Hence } C = 16.39 + 14.75 \text{ Re} = 16.39 + (14.75 \times 1.57) = 39.55 \quad (4)$$

Say = 40 in F.P.S. Units.

This value of '*C*' can be used in computing the runoff in the water shed up to secondary drains. For the tertiary drains the existing rule as prescribed SCS NEH section 16 may be followed.

Discharge based on prototype runoff model-based the actual rainfall and observed discharge.

From two of the discharge observation sites in Hansua drainage systems at Panchupalli and Nagarighat Pilot area (Mahanadi-Kathjodi-Devi DOABs) a co-relation between average discharge and no-damage rainfall has been developed. The observed discharge corresponding to this rainfall is thus increased corresponding to design rainfall by straight line method. These discharges are checked for their suitability to a formula like cypress creek formula. The data seem to fit reasonably into frame work of Cypress Creek Formula with Q = 55 for a return period of 8 years and a no-damage rainfall of 7 days.

H. Discharge Based on IS Specification No. 8885-1978

IS: 8835-1978 has prepared a guideline for planning and design of surface drains. The main recommendation is to provide capacity sufficient for draining 3 days rainfall of 5 years return period within 7 to 10 days if the principal crop is paddy as in the case.

V. RESULTS AND DISCUSSION

The Indian Standard Specification for computation of design runoff for cut sections considering 3 days rainfall with a return period of 5 years. The 3 days rainfall with 5 years return period has been determined for all the 13 rain gauge stations in the project area and shown in Table 5. The influence factors for each rain gauge station have been prepared by Theissian polygon.

A. Critical Rainfall

For determination of Mahanadi Delta Command area, all the 13 rain gauge stations have been considered. Expected rainfall in the project area during the months from June to October (Station wise) have been computed for 1 day, 2 days, 3 days, and up to 7 days with 5 year return period. Weighted average of all the 13 stations are calculated for design purpose and furnished in Table 3.

TABLE 3 WEIGHTED AVERAGE RAINFALL FOR 3 DAYS

Month	5 year return period 3 days rainfall in mm.
June	199
July	232
August	209
September	167
October	173

B. Infiltration Rate Accepted for Drainage Design

The rate of infiltration reduces appreciably during rainy season when the soil is fully saturated and sub-soil water level is considerably high. For safety-sake the minimum of the values are 0.118 cm/hr (by field observation) and 0.1015cm/hr (calculated as per recommendation of CWC). Twenty-five percent of the lowest of 0.1015cm/hr i.e. 254 mm/hr is taken as the design infiltration index.

C. Evapotranspiration

The design values of evapotranspiration for different months have been calculated. The same values are adopted for calculation and reproduced in Table 4 below.

TABLE 4 DESIGN VALUES OF EVAPOTRANSPIRATION (ETP)

Month	Design values of Etp mm/ month
June	81.00
July	57.97
August	49.00
September	52.00
October	53.63

The losses due to percolation and evaporation together for 3 days are calculated month-wise from June to October and furnished below.

1) For the month of June

Infiltration = 0.254 × 24 × 3 = 18.29 mm.

Evaporation = 81 × 3/30 = 8.10 mm.

26.39mm. say 26 mm.

2) For the month of July

Infiltration = 0.254 × 24 × 3 = 18.29mm.

Evaporation = 57.97 × 3/30 = 5.69 mm.

23.90 mm. say 24 mm.

3) For the month of July

Infiltration = 0.254 × 24 × 3 = 18.29 mm.

Evaporation = 49.00 × 3/81 = 5.61 mm.

23.03 mm. say 23 mm.

4) For the month of July

Infiltration = 0.254 × 24 × 3 = 18.29 mm.

Evaporation = 52.50 × 3/30 = 5.25 mm.

= 23.54 mm. say 24 mm.

5) For the month of July

Infiltration = 0.254 × 24 × 3 = 18.29 mm.

Evaporation = 53.63 × 3/30 = 5.19 mm.

23.48 mm. say 23 mm.

D. Computation of Rainfall Excess (Re)

The formula used in computing rainfall excess for each month from June to October for a return period of 5 years is given by

$Q_{SO} = Q_i + Q_n + P – S - Q_i$

Q_{SO} = Surface outflow (Rain excess)

Q_i = Irrigation water = 26 mm

Q_n = Standing water in the field prior to the advent of irrigation water is taking as 50 mm for the month of June & July and 75 mm for the month of August, September & October.

P = Precipitation (rainfall)

S = Amount of water in the field without causing damage which is taken as 125 mm for June, 150 mm for July & 175 mm for August, September & October

$Q_i = (E + Q_{ds})$ = Total Evaporation and Percolation loss.

For the month of June:

$Re = QSO/7$ = 1/7(26 + 50 + 199 -125 -26) = 18 mm/day.

For the month of July:

$Re = QSO/7$ = 1/7(26 + 50 + 232 -150 -24) = 19.14 =19 mm/day.

For the month of August:

$R_e = Q_{SO}/7$ = 1/7(26 + 75 + 200 -175 -23) = 16 mm/day.

For the month of September:

$R_e = Q_{SO}/7$ = 1/7(26 + 75 + 167 -175 -24) = 9.86 = 10 mm/day.

For the month of October:

$R_e = Q_{SO}/7$ = 1/7(26 + 75 + 173 -175 -23) =10.86 = 11mm/day.

Hence Rainfall excess (Re) adopted for design is 20 mm per day. This is also the drainage index of the basin.

VI. CONCLUSION

The design runoff has been calculated considering 3 days rainfall with 5 years return period as per the recommendation of the Indian Standards. The drainage module determined considering the ISI specification is 20 mm/day. But in the subsequent sections we have considered the determination of design runoff with 7 days rainfall and a return period of 5 years, which comes to 33mm/day. For the design of structure the 3 days 50 years, rainfall excess (Re) comes to 46 mm/day.

Discussion of formula of results:

Design discharge considering formulae mentioned in paragraph summarised for a unit area of 1 sq.km. (100 ha.) and are furnished in Table 5.

TABLE 5 COMPARISON OF DESIGN-DISCHARGE

Sl.No.	Formulae Used	Discharge From Sq. m. Catchment Area (Cumec)	Remarks
1	Rational formulae (para 2.3)	5.83	
2	40% Mc. Math formulae(para 4.2)	1.4	40% of Mc. Math discharge taken
3	1/6th of Boston and Punjab Boston Formulae (para 4.3)	2.94	1/6th of Punjab Bosten discharge taken.
4	S.C.S (U.S.D.A) curve number method (para 4.4)	0.14	
5	Present Practice followed in Odisha (Para 4.5)	0.21	
6	Rainfall excess and straight line method (para 4.6)	0.46	
7	Cypress Creek formulae (para 4.7)	0.52	
8	ISI Specification (para 4.8)	0.46	

It may be hence concluded that several methods are adopted in different parts of the world to calculate the actual drainage of a DOAB but the study area of Bhubaneswar-Cuttack twin area is restricted for two such formulae i.e. Mc. Math formula and Cypress Creek formula. From the above it may be seen that for small catchments below 13 sq.km. (5 m^2). Mc. Math formula and for larger catchments Cypress Creek Formula with C = 55 gives results more realistic and are recommended to be accepted.

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