Journal of Construction Engineering and Technology

Volume No. 12

Issue No. 1

January - April 2024

ENRICHED PUBLICATIONS PVT. LTD

S-9, IInd FLOOR, MLU POCKET,
MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR-5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-47026006

Journal of Construction Engineering and Technology

Aims and Scope

Journal of Construction Engineering, and Technology is focused towards the rapid publication of fundamental research papers on all areas of Construction Engineering,
Focus and Scope Covers

- Planning and Management of the Construction of Structures
- Design of Temporary Structures
- Quality Assurance and Quality Control
- Building and Site Layout Surveys
- On Site Material Testing,
- Safety Engineering, Materials Procurement, Budgeting & Cost Engineering
- Concrete Mix Design

Journal of Construction Engineering and Technology

Journal of Construction Engineering and Technology

(Volume No. 12, Issue No. 1, Jan - Apr 2024)

Contents

Offshore Wind Resource Evaluation of Four Locations in Indian Ocean

Garlapati Nagababu‡, Surendra Singh Kachhwaha[2], Vimal Savsani[3]

[1]Department of Mechanical Engineering, School of Technology,
Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India,
garlapatinagu@gmail.com,

[2]Department of Mechanical Engineering, School of Technology,
Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India,
Surendra.Singh@sot.pdpu.ac.in,

[2]Department of Mechanical Engineering, School of Technology,
Pandit Deendayal Petroleum University, Gandhinagar, Gujarat, India,
vimal.savsani@gmail.com

‡ Corresponding Author; Tel: +91 9724013948

ABSTRACT

This paper presents an assessment of wind resource of four offshore locations (coded as AD04, BD11, CALVAL, and CB02) in Indian Ocean near southern India, by using four years (2011-2014) wind speed data and was subjected to two-parameter Weibull analysis. The results showed that maximum annual mean wind speed of 7.66 m/s is obtained at BD11 while the minimum value of 5.09 m/s is obtained at CB02 amongst all the locations considered. At the hub height of 80 m, the annual wind power density and energy variation ranges from 146.36 W/m^2 and 1287.25 kWh/m^2/year respectively at CB02 to 443.34 W/m^2 and 3908.24 kWh/m^2/year at BD11. The annual mean wind speed and wind power density were found to be equal to or more than 5.09 m/s and 146.36 W/m^2 respectively, at the hub height of 80 m, suggesting the suitability of all the sites for offshore wind power development.

***Keywords:** offshore wind energy; moored buoy; Indian Ocean; two-parameter Weibull distribution, wind turbine.*

1. INTRODUCTION

The environmental risks due to climate change caused by the greenhouse gases[1]. In view of this and also to achieve energy security, robust steps are being taken by the concerned governments to encourage the utilization of renewable energy sources as an alternative to the fossil fuels [2], [3]. Involvement of multiple stakeholders in the development of commercial onshore wind power plants has led to various challenges including the Not-In-My-Back-Yard (NIMBY) attitude and other environmental impacts like deforestation, land acquisition, bird hits, adverse effects on marine and wildlife, noise and flicker generated by the wind turbines, etc. [4], [5]. Offshore wind resources are abundant compared to onshore ones. Factors like stronger and more consistent offshore winds, relatively easier offshore land access, ease in transportation of wind turbines to the offshore locations, etc. draw interest towards the development of offshore wind power[1].

Table 1. Targeted and achieved capacity of grid – interactive power in India through renewable sources of energy[7].

Renewable Source of Energy	Target Capacity for FY 2015-2016 (in MW) (% of Total)	Installed Capacity for FY 2015-2016 (in MW)	Cumulative Installed capacity achieved (in MW) (% of Total)
Wind Power	2400 (53.81%)	421.3	23864.91 (65.13%)
Solar Energy	1400 (31.39%)	357.68	4101.68 (11.19%)
Small Scale Hydro Power	250 (5.61%)	75.20	4130.55 (11.27%)
Bio Power	400 (8.97%)	-	4418.55 (12.06%)
Waste-to-power	10 (0.22%)	12	127.08 (0.35%)
Total	**4460**	**866.18**	**36642.77**

The total installed wind power capacity across the globe is around 369.6 GW, and indicates a cumulative annual market growth of more than 16% at the end of year 2014[6]. At present, India has emerged as the second largest wind market in Asia, thus opening a wide range of opportunities for both the national as well as the international investors. For the financial year 2015 – 2016, the government of India has set the target to achieve total grid – interactive power of 4460 MW capacity by developing it's renewable sources, as shown in Table 1 [7], which indicates the dominance of wind power sector over other renewable sources in India.

Unlike onshore applications, direct measurement of wind data for the offshore locations is relatively difficult and involves heavy expenditure. In most of the cases, assessment of the available offshore wind resources depends on the long term measurements recorded at the nearby land sites rather than the on-site moored buoy or ship data. However, the marine meteorological stations or moored buoys directly measures real time wind data with high time resolution[8]. Wind speed frequency distributions can be modelled by using various probability density functions (pdf) [9], [10]. According to the studies –[11][14] available in literature,the Weibull function has been frequently used to model the wind speed distribution due to its ability to fit a wide variety of measured wind speed data with relatively better accuracy.

Main objective of present study is to perform the statistical analysis of the available measured wind data obtained from four offshore locations in Indian Ocean near the southern coast of India. Here, measured wind data has been subjected to the best fit of 2-parameter Weibull distribution to study the wind speed frequency distribution. Wind characteristics has been estimated for each offshore location along with the seasonal variation.

2. METHODOLOGY AND MATHEMATICAL MODEL

The present study deals with wind speed calculation at turbine hub height; which usually ranges between 70 m and 120 m for most of the wind turbines commercially available in the market. The variants with hub height of 80 meter above the sea level (asl) are common for most of the wind turbine original equipment manufacturers (OEM) in India. Hence, in this study, the hub height of 80 m asl has been selected and log-law has been used to extrapolate wind speed data measured at 3 m height. The atmosphere was assumed to be neutrally stable and a surface roughness factor of $z_o = 0.2\,mm$ was used [8], [14]. As per the log-law, at any given height z the wind velocity V is given by

$$V = V_{ref} \frac{\ln(z / z_o)}{\ln(z_{ref} / z_o)} \qquad (1)$$

Where z_{ref} is the height at which the wind speed V_{ref} has been measured by the moored buoys.
The wind power density indicates the amount of power generated at a particular wind speed, per unit area swept by the wind turbine rotor (W/m^2) and calculated by

$$P = \frac{1}{2} \rho \frac{\sum_{i=1}^{N} V_i^3}{N} \qquad (2)$$

Where a constant value 1.225 kg/m^3 has been assumed for wind density $()\rho$ [8], [14].
Weibull function has been used in order to study the wind speed frequency distribution at each location [13]. In terms of Weibull distribution, the probability density function is given by

$$f(V) = \left(\frac{k}{c}\right)\left(\frac{V}{c}\right)^{k-1} \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \qquad (3)$$

where k and c are the Weibull shape and scale parameters respectively. The corresponding cumulative distribution function is given by

$$F(V) = 1 - \exp\left[-\left(\frac{V}{c}\right)^{k}\right] \qquad (4)$$

Various analytical or empirical methods are available to evaluate Weibull parameters which provide quite similar results. Some of the commonly used methods are the graphical method, moment estimation and quartiles, maximum likelihood method, standard deviation method, modified maximum likelihood and energy pattern factor method amongst others. The maximum likelihood method has been adopted in this study, where Weibull parameters k and c can be evaluated by the following approximations.

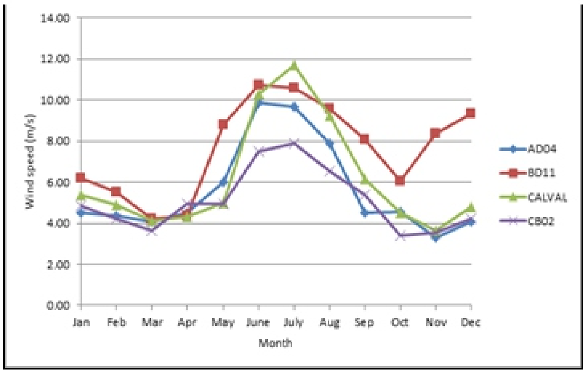

Fig. 1. Variation of monthly mean wind speed

$$k = \left(\frac{\sum_{i=1}^{N} V_i^k \ln(V_i)}{\sum_{i=1}^{N} V_i^k} - \frac{\sum_{i=1}^{N} \ln(V_i)}{N} \right)^{-1} \qquad (5)$$

$$c = \left(\frac{1}{N} \sum_{i=1}^{N} V_i^k \right)^{1/k} \qquad (6)$$

Based on the wind power density (WPD), annual energy (E_a) indicates the maximum (i.e. ideal amount of) of electricity that can be extracted from each location has been calculated using the following expression[13], [14].

$$E_a = \sum_{n=1}^{12} E_{avg} \left(kWh/m^2/year \right) \qquad (7)$$

where $E_{avg} \left(= 24 \times 10^{-3} dP_{avg} \right)$ is the mean monthly extractible energy, d is the number of days in the month and P_{avg} is the monthly mean WPD (W/m^2).

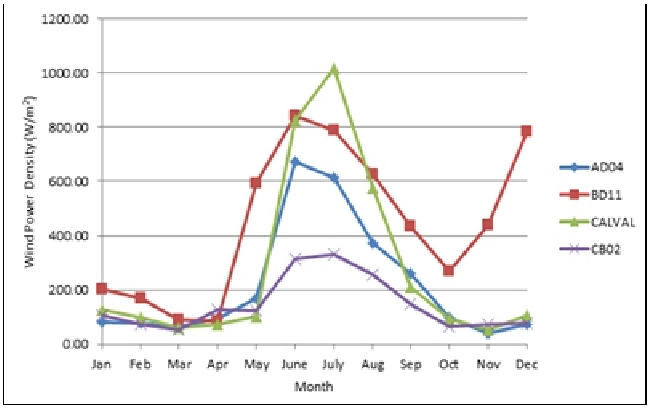

Fig. 2. Variation of monthly average wind power density

Table 2. Monthly variations of average wind speed, power densities and energies for the four locations

Buoy		Months											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
AD04	Average wind speed (m/s)	4.5	4.4	4	4.5	5.9	9.9	9.7	7.8	7.3	4.6	3.3	4.1
	Average wind power density (W/m^2)	83.4	75.2	61.9	93.3	161.9	672.4	621	372	312.6	98.3	38.2	74.9
	Average energy (kWh/m^2)	61.6	51.7	47.6	67.2	127	484.1	456.2	278.7	188.3	73.7	27.5	55.4
BD11	Average wind speed (m/s)	6.2	5.5	4.2	4.3	8.8	10.7	10.6	9.6	8.2	6	8.4	9.3
	Average wind power density (W/m^2)	201.5	167.1	90.4	86.6	592.5	843.3	788.1	627.8	433	268.2	436.3	785.3
	Average energy (kWh/m^2)	149.9	112.3	67.3	62.4	440.8	607.2	586.4	467.1	314.5	199.5	316.8	584.3
CALVAL	Average wind speed (m/s)	5.1	4.6	4	4	4.5	9.4	11.7	9.2	7.2	4.5	3.7	4.8
	Average wind power density (W/m^2)	126.9	98.4	61.7	71.6	103.4	827.6	1020	577.6	281.4	95	52.1	107.2
	Average energy (kWh/m^2)	94.4	66.1	45.9	52.1	76.9	595.9	758.9	429.7	152.3	70.7	37.5	79.8
CB02	Average wind speed (m/s)	4.8	4.2	3.6	4.9	4.9	7.5	7.9	6.5	5.4	3.4	3.6	4.2
	Average wind power density (W/m^2)	107.7	75.2	53.1	128.2	124.6	312.4	332.7	256.9	149.8	66.3	71.7	77.8
	Average energy (kWh/m^2)	80.1	50.5	39.5	92.3	92.7	226.8	247.6	191.2	107.8	49.3	51.6	57.9

3. RESULTS & DISCUSSION

3.1. Wind resource analysis

Monthly variations of average wind speed, power densities and energies of four moored buoys at 80 m height are tabulated in Table 2. It can be inferred from table, the mean annual wind speed for all locations are greater than 5 m/s which is fairly higher than the cut-in speed of 3 m/s specified for most of the commercially available wind turbines. Figs 1 and 2 depicts the monthly variations of mean wind speeds and average power densities of four moored buoys and it further corroborated the fact that CALVAL and BD11 locations are very windy. The monthly mean wind speed is maximum (11.6 m/s) in July at CALVAL having a corresponding mean WPD of 1019.9 W/m^2. However, the maximum annual mean wind speed and corresponding annual mean WPD is 7.6 m/s and 443.3 W/m^2 respectively, at the moored buoy BD11. The minimum monthly mean wind speed and the corresponding WPD is 3.3 m/s and 38.2 W/m^2 respectively in the month of November at moored buoy AD04. The minimum annual mean wind speed and annual mean WPD are found to be 5.0 m/s and 146.3 W/m^2 at the moored buoy Cb02.

Table 3. Variation in seasonal mean wind speed and seasonal average wind power density at the extrapolated hub height of 80m for the four locations

	Season	Wind speed (m/s)	Wind power density (W/m^2)
AD04	Winter	4.4	79.9
	Pre-Monsoon	4.8	104.9
	Monsoon	8.5	482.9
	Post Monsoon	4.0	70.1
BD11	Winter	5.9	186.0
	Pre-Monsoon	5.8	259.0
	Monsoon	9.6	662.4
	Post Monsoon	7.8	484.3
CALVAL	Winter	5.1	113.1
	Pre-Monsoon	4.5	79.2
	Monsoon	9.0	608.8
	Post Monsoon	4.3	84.5
CB02	Winter	4.5	92.1
	Pre-Monsoon	4.5	101.6
	Monsoon	6.9	269.6
	Post Monsoon	3.8	72.5

Moreover, the minimum and maximum monthly energy values are 27.51 and 758.86 $kWh/m^2/year$ respectively, at AD04 (in November) and CALVAL (in July), while the minimum and maximum annual values are 1287.25 and 3908.24 $kWh/m^2/year$ respectively at CB02 and BD11.

3.2. Seasonal variability

The span from January to December in India is generally classified into following four seasons

1. Winter: January to February (59 days)
2. Pre-Monsoon: March to May (92 days)
3. Monsoon: June to September (122 days)
4. Post-Monsoon: October to December (92 days)

Variation of seasonal mean wind speed and corresponding WPD are given in Table 3. From table it can be inferred that seasonal mean wind speed and WPD are highest during the monsoon season. The mean wind speed and WPD for monsoon season are 8.5, 9.6, 8.9, 6.9 m/s and 482.9, 662.4, 608.8, 269.6 W/m^2 respectively for the locations of AD04, BD11, CALVAL and CB02. A second peak in wind speed and WPD is encountered during the post-monsoon period for moored buoy BD11. The WPD during post monsoon is more than two times greater for BD11 as compared to other locations.

For the remaining three sites at the locations of moored buoys AD04, CALVAL and CB02; apart from monsoon, the seasonal mean wind speed and WPD in the remaining three seasons are between 3.8 to 5.1 m/s and 70.1 to 113.1 W/m^2 respectively. These three sites exhibit similar variations in the seasonal mean wind speed and WPD because all three are located in the Arabian Sea, off the south-western coast of India, unlike the moored buoy BD11 which is located in the Bay of Bengal, off the south-eastern coasts of India. As shown in Figs. 1 and 2, the wind speeds at all the four locations follow a similar pattern for the duration of January to October, however from October to December, the wind speed pattern observed at the location of BD11 is different because, in the north Bay of Bengal a continental high-pressure system produces north-eastern winds (the north-eastern monsoon) from November to April; and also during the months of April-May and October-November, intense tropical storms having high wind speeds occur accompanied with torrential rains.

Table 4. Monthly variation of Weibull parameters (*k* and *c*) at the selected sites

	AD04		BD11		CALVAL		CB02	
	c	*k*	*c*	*k*	*c*	*k*	*c*	*k*
Jan	5.1	2.7	6.9	3.1	6.0	3.3	5.5	2.6
Feb	4.9	2.6	6.3	2.5	5.5	3.1	4.8	2.5
Mar	4.6	2.6	4.7	1.9	4.6	2.9	4.1	2.1
Apr	5.1	2.3	4.9	2.2	4.9	2.8	5.6	2.2
May	6.7	3.5	9.9	3.0	5.6	3.2	5.6	2.3
June	10.7	5.2	11.5	6.1	11.4	4.2	8.3	4.3
July	10.4	5.8	11.3	6.9	12.3	8.4	8.5	5.9
Aug	8.7	3.9	10.5	4.7	10.1	4.5	7.4	2.7
Sep	7.4	2.6	9.0	3.2	7.0	2.8	6.1	2.6
Oct	5.2	2.2	6.8	1.8	5.1	2.2	3.8	1.5
Nov	3.8	2.2	9.2	4.0	4.1	2.2	4.0	1.6
Dec	4.5	1.9	10.5	2.5	5.4	2.5	4.8	2.3

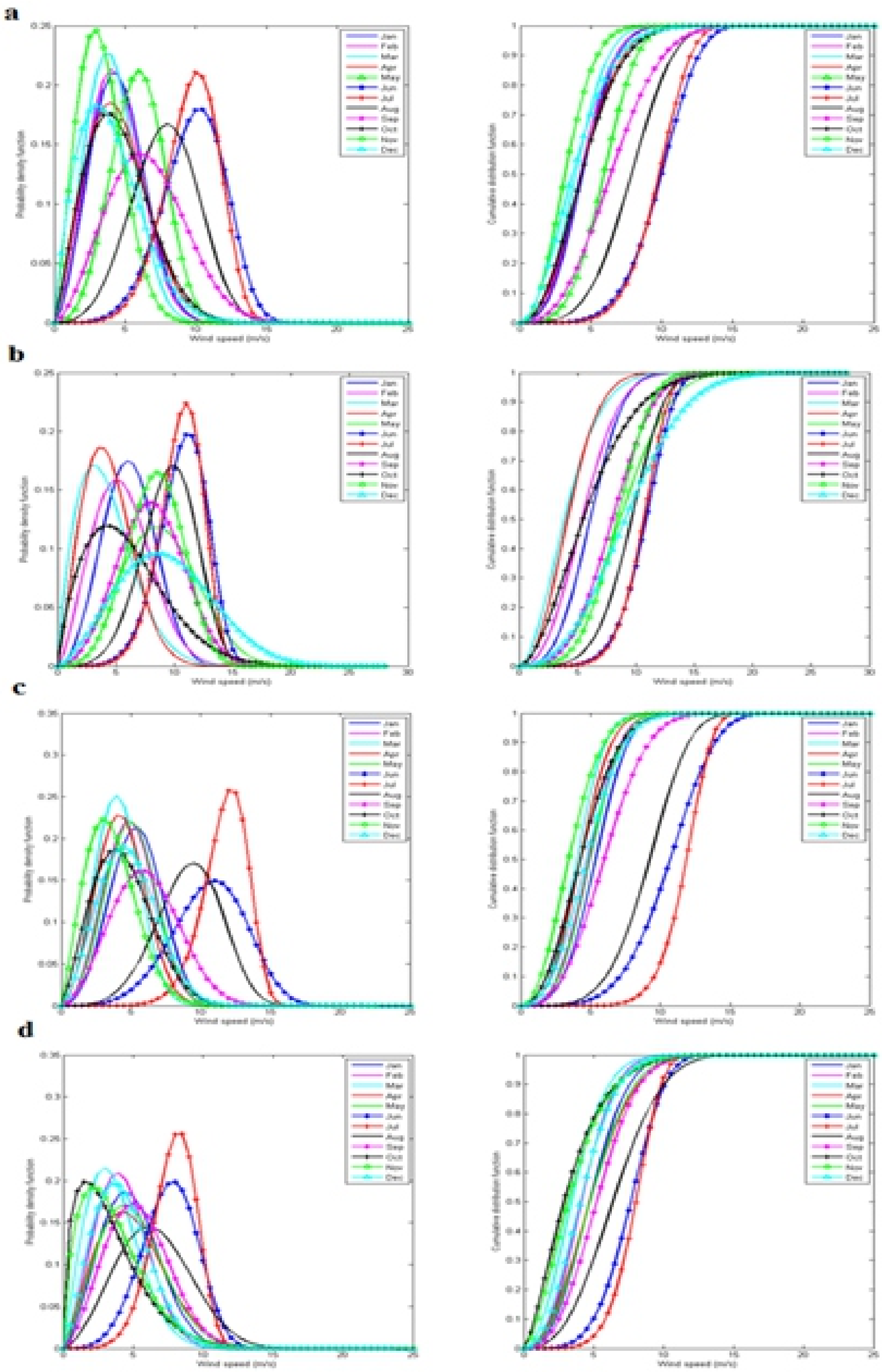

Fig. 3.Weibull probability density function and Cumulative distribution function of monthly wind speeds at 80m, averaged on Daily basis, for (a) Buoy AD04 (b) Buoy B11 (c) Buoy CALVAL (d) Buoy CB02

3.3. Wind speed probability distributions

The monthly variation of the Weibull shape and scale parameters (*k* and *c*) has been listed in Table 4. It has been observed that the Weibull parameter *k* varies between 1.5 at CB02 (October) to 8.4 at CALVAL in July. Hence, amongst the four sites the wind speed is most uniform at CALVAL in July while least uniform in October at CB02. However, the scale parameter c ranges from a minimum value of 3.7 m/s in October at CB02 to 12.4 m/s in July at CALVAL which indicates that amongst the four locations, the plot of the Weibull probability density function (pdf) has maximum span at CALVAL and minimum at CB02. This means that the pdf spreads over a wide range of velocities at CALVAL and a relatively narrow range of velocities at CB02, thereby indicating the possibility of encountering highest and lowest wind speeds at CALVAL and CB02, respectively. However, it should be noted that the location with the possibility of the highest wind speed need not be the one having highest annual mean wind speed (Table 2). Weibull pdf and Cumulative distribution function (cdf) of monthly wind speeds determined at 80 m height for the four sites are shown in Fig 3.

The plots of pdf, provide information about the possibility or chances of obtaining wind speeds equal to or greater than a particular value. However, plots of cdf provie information about the percentage of time for which the winds can be expected to blow at speeds greater than a specific value. Fig. 3 shows that most of the peaks are skewed towards the higher values of mean wind speeds along-with indicating that how the respective sites are expected to behave within the speed limits of turbine operation. Wind speeds equal to or above 6.5 m/s are observed for certain fraction of all the months at all the locations under consideration. Further, the wind turbines are expected to run at or above the cut-in speed of 3 m/s for at least 45% of the time during every month for all the sites. For the rated speed of 11 m/s and above the wind turbines are expected to run for an average 7%, 20.54%, 12.95% and 2.95% of the time per month at AD04, BD11, CALVAL and CB02 respectively.

Monthly peak frequencies indicate wind speed with highest probability of occurrence. For all the sites, the monthly peak frequencies range from 23.5% to 26 % (i.e. 23.5% for BD11, 24.5% for AD04, and 26% for both CALVAL and CB02). Moreover, around 10% of the time duration in every month, the wind turbines are expected to run for the wind speed greater than or equal to 5 m/s for all the sites. Fig. 3 further shows that the turbines having lowest possible cut-in speeds and rated speeds should be selected to increase the total duration of turbine operation and rated power generation respectively, across the year.

4. CONCLUSIONS

From the statistical data and computations, the following facts can be drawn from present study:

- All the locations under consideration have mean annual wind speeds above 5 m/s. The maximum and minimum monthly mean wind speeds and WPDs are 11.7 m/s and 1019.9 W/m^2, and 3.3 m/s and 38.2 W/m^2, respectively at CALVAL (in July) and AD04 (in November). However, the maximum and minimum annual mean wind speeds and WPDs are 7.7 m/s and 443.3 W/m^2, and 5.1 m/s and 146.4 W/m^2 respectively at BD11 and CB02.
- Weibull parameter k varies between 1.5 in October at CB02 to 8.4 in July at CALVAL. Moreover, the scale parameter c ranges from a minimum 3.7 m/s in October at CB02 to a maximum of 12.4 m/s in July at CALVAL.
- Amongst the four locations, classification based on WPD, AD04 and CB02 are of class 1, CALVAL is of class 2 and BD11 is of class 3. The maximum and minimum values of extractable energy are 3908.2 kWh/m^2/year at BD11 and 1287.2 kWh/m^2/year at CB02 respectively.

ACKNOWLEDGEMENT

We are thankful to the Indian National Centre for Ocean Information Services (INCOIS) for providing the measured moored buoy data for the present research study.

REFERENCES

[1] A. Tabassum, M. Premalatha, T. Abbasi, and S. A. Abbasi, "Wind energy: Increasing deployment, rising environmental concerns," Renew. Sustain. Energy Rev., vol. 31, pp. 270–288, 2014.

[2] Ministry of New and Renewable Energy, "Strategic Plan for New and Renewable Energy Sector Government of India," 2011.

[3] United Nations, "Kyoto Protocol To the United Nations Framework Kyoto Protocol To the United Nations Framework," 1998.

[4] K.-Y. Oh, J.-Y. Kim, J.-S. Lee, and K.-W. Ryu, "Wind resource assessment around Korean Peninsula for feasibility study on 100 MW class offshore wind farm," Renew. Energy, vol. 42, pp. 217–226, 2012.

[5] D. Y. C. Leung and Y. Yang, "Wind energy development and its environmental impact: A review," Renew. Sustain. Energy Rev., vol. 16, no. 1, pp. 1031–1039, Jan. 2012.

[6] Global Wind Energy Council, "Global Wind Report: 2014 Annual market update," 2015.

[7] Ministry of New and Renewable Energy, "Physical progress: Tentative State-wise break-up of Renewable Power target to be achieved by the year 2022," 2015. [Online]. Available: http://mnre.gov.in/mission-and-vision-2/achievements/. [Accessed: 31-Jul-2016].

[8] F. Pimenta, W. Kempton, and R. Garvine, "Combining meteorological stations and satellite data to evaluate the offshore wind power resource of Southeastern Brazil," Renew. Energy, vol. 33, no. 11, pp. 2375–2387, 2008.
[9] N. Salvação, M. Bernardino, and C. G. Soares, "Assessing the offshore wind energy potential along the coasts of Portugal and Galicia," no. 2006, pp. 995–1002, 2014.
[10] W. G. Früh, "Long-term wind resource and uncertainty estimation using wind records from Scotland as example," Renew. Energy, vol. 50, pp. 1014–1026, 2013.
[11] P. Beaucage, G. Lafrance, J. Lafrance, J. Choisnard, and M. Bernier, "Synthetic aperture radar satellite data for offshore wind assessment A strategic sampling approach," J. Wind Eng. Ind. Aerodyn., vol. 99, pp. 27–36, 2011.
[12] F. Onea and E. Rusu, "An Evaluation of the Wind Energy in the North-West of the Black Sea," Int. J. Green Energy, vol. 11, no. 5, pp. 465–487, 2014.
[13] O. S. Ohunakin, "Wind resource evaluation in six selected high altitude locations in Nigeria," Renew. Energy, vol. 36, no. 12, pp. 3273–3281, 2011.
[14] G. Nagababu, B. Dharmil, K. Surendra Singh, and S. Vimal, "Evaluation of Wind Resource in Selected Locations in Gujarat," Energy Procedia, vol. 79, pp. 212–219, 2015.

Studies For Hydrodynamics And Siltation For Deepening Of Approach Channel At Mormugao Port, Mormugao

V B Sharma[1], Prabhat Chandra[2], M.D. Sawant[3], T Nagendra[4]
[1,2,3,4]Central Water and Power Research Station,
P.O. Khadakwasla, Pune – 411024, India.
Email: pchandra_2003@yahoo.co.in, Tel.: 91-020-24103450

ABSTRACT

The rise in the traffic of bigger sized vessels at the Ports requires deepening of channel and harbor area. The accurate assessment of the maintenance dredging quantities and the judicious location of its disposal grounds, are very vital for economical feasibility of the project. Mathematical modeling is a convenient tool to simulate sediment transport and to identify suitable dumping ground for dredged material involving complex interactions of waves, currents, and the suspended materials. The Mormugao port proposes to deepen the approach channel and harbor areas to (-) 19.8m from the existing (-) 14.1m. In this present study, river discharges and both tidal and wave forces have been considered for carrying out the studies to predict the sedimentation and disposal grounds for the proposed deepening proposal using the 2-D numerical model MIKE -21. The model was well calibrated for the morphological parameters using the earlier data of maintenance dredging for the existing approach channel. Against the capital dredging of about 14.0 Mcum, an additional annual maintenance dredging quantity of about 2.70 Mcum was predicted and the disposal grounds were also suitably recommended.

Keywords: Approach Channel, Mormugoa port, Tide, Wave, Sedimentation, wave induced currents, MIKE-21

1. INTRODUCTION

Mormugao port, one of the major ports, is located at the entrance of River Zuari on the west coast of the India (Figure 1). The port is exposed to the waves and tides from the Arabian sea. The existing 250m wide approach channel is dredged to a depth of -14.4m and harbor area and turning circle to a depth of -14.1m for catering to 60,000 DWT size ships. In order to boost commercial trade in the region on Public – Private – Partnership basis, the Mormugao Port Trust (MPT) has proposed to deepen the existing approach channel to a depth of -19.8m and harbor areas to -19.5m covering a total plan area of about 2.90 sqkm and increasing the channel length by about 3.5 km involving an additional capital dredging quantity of about 14 Mcum (Figure 2) on the next page.

As per the previous dredging records of the Mormugao port, the average annual maintenance dredging is about 3.0 Mcum. The maintenance dredging activity at the Mormugao port normally takes place during the post monsoon season for a period of about two months. The existing disposal grounds are located north of approach channel at -14.2m depth contour.

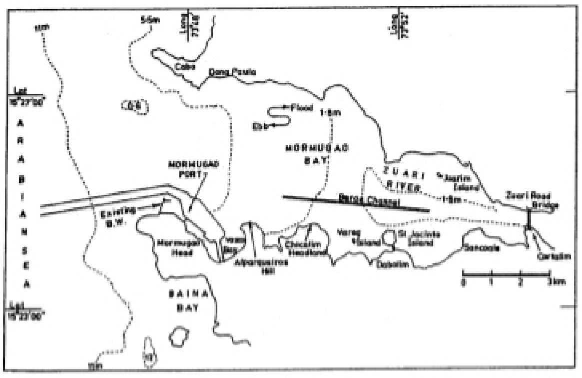

Figure 1. Layout of Mormugao bay

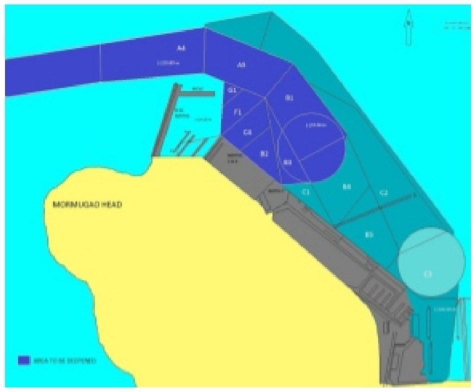

Figure 2. Proposed Deeepening in Harbour Area

In the present paper, the studies carried out by using 2-D mathematical model MIKE – 21 for assessment of the annual maintenance dredging requirement and for recommending the disposal grounds for the deepening proposal of Mormugao port, have been described.

2. ANALYSIS OF PROTOTYPE DATA

The basic inputs for hydrodynamic and sedimentation studies are bathymetry, tidal data, current data, wave data, sediment characteristics, suspended sediment concentration etc. Bathymetry was obtained from available hydrographic charts as supplied by the MPT and from MIKE-21 C map data as shown in Figure 2. Tides in the estuary are semidiurnal with pronounced diurnal inequality having considerable difference in the tidal ranges and the elevation of low waters and high waters in the successive tidal cycles. The spring tidal range in the Zuari estuary is about 2.4 m. A typical observed tide at Mormugao is shown in Figure 3

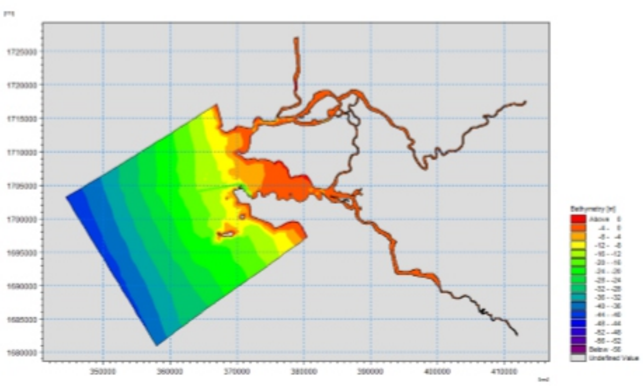

Figure 2. Bathymetry of model area

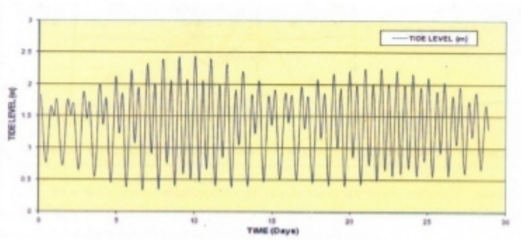

Figure 3. Observed Tide at Mormugoa Port

The prototype data for the currents, suspended sediments, salinity etc. were collected for a period of about 10 years in September 1977 at the time of stage-1 development of the Mormugao port and the same were used for the present studies. The maximum currents in the channel was observed to be about 0.40m/s during spring tide while during average tide it was about 0.20m/s. Observed currents in the harbor area varies from 0.05- 0.15m/s.

In the Mormugao bay, there are considerable spatial and seasonal variations in the values of the sediment concentration due to the exposure of varied hydraulic and physiographic conditions. The average values of the sediment concentration in the Mormugao port and bay area are shown in the Figure 4. On the basis of the analysis of water sample data, the average suspended sediment concentration has been considered as 0.040 ppt during the monsoon season and 0.012 ppt during the nonmonsoon season in the port and channel areas. The grain size distribution of bed samples collected in the approach channel show that sediment is about 0.002mm under dispersed state and the bed material may be classified a soft – silty and clayey type (Figure 5).

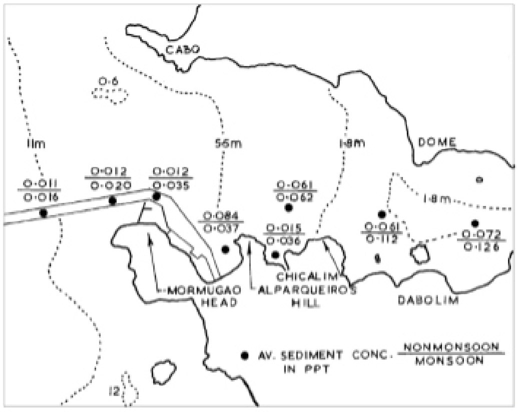

Figure 4. Suspended sediment concentration during monsoon and non- monsoon

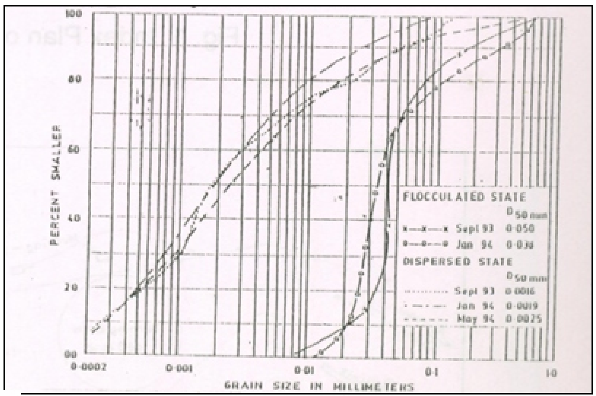

Figure 5. Grain size distribution of bed samples

The river hydrographs of the Mandovi and Zuari rivers show that the flood discharge in Mandovi river is about 4-5 times high as compared to the Zuari river .The maximum river discharges in Mandovi and Zuari rivers have been observed as about 4000m3/s and 970m3/s respectively. The average discharges in Mandovi and Zuari river are about 1000 m3/ s and 250 m3/s respectively.

The hydrographic surveys of Mormugao Port during different years and different seasons were analyzed (Purandare, U.V. et al., 1994) to find siltation trends zone wise and seasonal wise namely pre-monsoon (April/May), post-monsoon/ pre-dredging (December/January) as shown in Figure 6. The graphical representation of siltation at two sections i.e. in the approach channel (section A-A) and in the turning circle area (section C-C) have been shown in Figure 7 for the typical year 1987-88 and the plots of other years confirm the repetitive trends. It could be seen from figure that sedimentation in the approach channel mainly occurs during monsoon period. The average annual siltation in the western portion of the channel is quite less of about 0.50m and in the harbor area near turning circle, it is more than 2.0m.

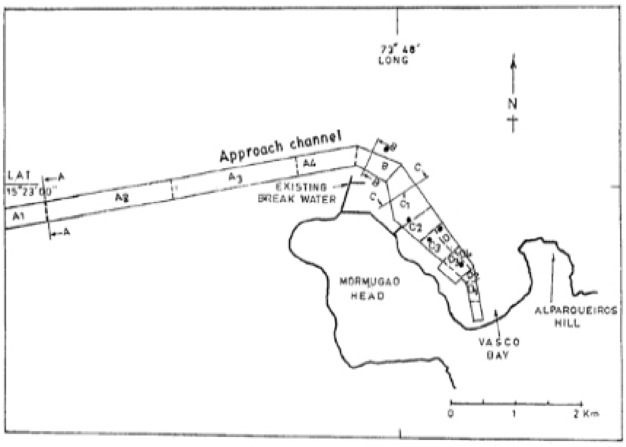

Figure 6. Locations of zones and sections in approach channel and harbour area

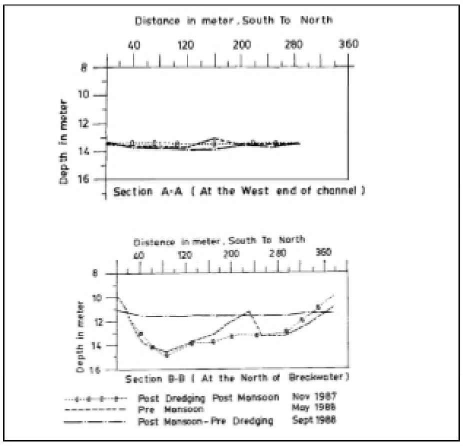

Figure 7. Typical cross sections at Mormugao port during 1987-88

Offshore wave data reported in Indian daily weather chart reports published by Indian Metrological Department (IMD) the same have been used to generate wave induced stresses.

From the analysis of the wave data, it was observed that the Mormugao port region is subjected to incident short period waves of significant height of 2.0m from the directions north to northwest during the nonmonsoon season (October to May) and from the directions between southwest and west of significant height of about 4.0m during the southwest monsoon season i.e. from June to September.

3. MODELING APPROACH

In order to simulate dynamics of cohesive sediment, it is necessary to initially compute the hydrodynamics of water body in terms of velocity and water level fluctuations. MIKE-21HD model has been used for simulating hydrodynamics while MIKE-21 NSW (Short wave) model has been used to simulate wave induced stress which is input to MIKE -21 HD Model. MIKE-21HD model is based on the numerical solution of the two- dimensional incompressible Reynolds averaged Navier-Stokes equations invoking the assumptions of Boussinesq and of hydrostatic pressure. The spatial discretization of the primitive equations is performed using a cell-centred finite volume method.

Further for simulating sediment transport, Mud Transport Model (MIKE-21MT) which is based on advection-dispersion equation was used which describes erosion and deposition of mud or sand/mud mixtures under the action of currents and waves. The two dimensional depth averaged sediment transport model (MIKE- 21-MT) takes into account conservation of mass of sediment, depth averaged velocities, longitudinal dispersion coefficient, lateral diffusivity, settling velocity, critical deposition stress, and critical erosion stress for the given sediment. The numerical values of these parameters were modified within their range such that the prevailing sedimentation in the existing approach channel is achieved.

4. MODEL SIMULATION AND CALIBRATION IN EXISTING CONDITION

The computational model considered for tidal flow simulation covered an area of 70 km x 40 km. The model area covers the entire proposed port area upto (-) 56 m depth contour. Mesh and bathymetry files were generated using MIKE-21 tools. In the vicinity of harbor area and approach channel, fine mesh was generated while in the remaining model area, coarse mesh was generated to reduce the simulation time.

MIKE-21 NSW model was simulated for significant wave height of 3.0 m for the waves coming from west direction corresponding to the southwest monsoon. The radiation stresses derived from NSW model were used as input to MIKE-21-HD model. The Hydrodynamic model consists of 5 open boundaries; two river boundaries and three sea boundaries. Predicted tidal levels obtained from C-map were supplied at north and south boundaries with appropriate level differences. As the flow is almost parallel to the contours along western boundary, no cross flow condition was provided at this boundary. At remaining two open boundaries, hydrographs of Mandovi and Zuari River were provided. The model parameters like bottom roughness coefficient, surface elevation etc. were adjusted realistically within the respective ranges to match the required prototype conditions in the model. The changes in flow fields were computed every time step of 30 sec and results are recorded at every 30 minutes time interval. The time history of velocities at 8 locations along the channel (Ch-1 to Ch-4) and in the harbor area (H1 to H4) as shown in Figure 9, were monitored. Typical plots of current in approach channel and harbor area are shown in Figure 10. These velocities match well with the observed data.

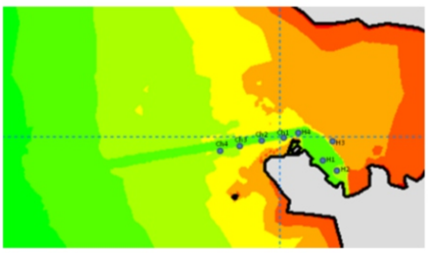

Figure 9. Location of current data

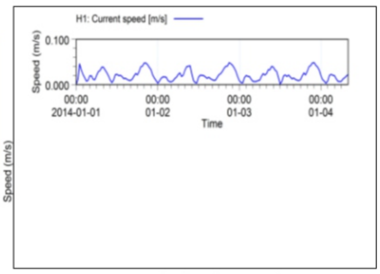

Figure 10. Magnitude of current in approach channel and harbour

Velocity vectors plots in the vicinity of port area during flooding phase of tide and during ebbing phase of tide is shown in Figure 11. Flow circulations could be observed in the vicinity of harbor during flooding phase while during ebbing phase of tide there is no circulation. These circulations may not have significant impact on the maneuvering of ships as these circulations are very weak. The figure also shows that ebb strength is more than the flood strength at the entrance of Zuari river.

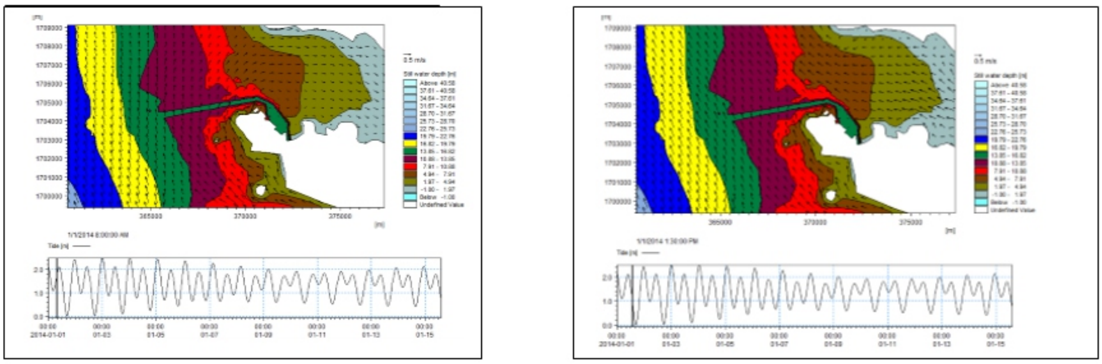

Figure 11. Flow patterns during flood and ebb phases of tide in the model area

After calibrating the flow pattern in existing condition, MIKE-21MT was used to simulate sedimentation in the model area. Model was simulated for a period of one month during monsoon period considering observed suspended sediment concentration. As per the previous dredging records, about 3.0 Million m3 is being dredged every year in existing approach channel and harbor area. It is observed that the siltation occurs during the four months of the southwest monsoon season. This quantity was considered for calibrating the sediment model. The model parameters like critical shear stresses of erosion and deposition were fine tuned to arrive at prevailing sedimentation in the approach channel and harbor. The parameters were found within their permissible limits. A typical plot of sedimentation after one month model simulation in existing condition is shown in Figure 12. The approach channel is divided in five zones from A1 to A5 as shown in this figure. Annual sedimentation in each zone is shown in Table 1. It could be seen from the table maximum siltation occurs in harbor area and minimum sedimentation at entrance of the channel. It is due to the fact that wave induced currents are prevalent in the harbor area and difference in depth in harbor is also maximum with respect to surrounding area. Weak circulation can also be observed in the harbor area during flooding. All these factors are responsible for more sedimentation in the harbor area. These sedimentation quantities matches well with the prevailing sedimentation in existing channel dredged to -14.4m below chart datum (Purandare, et al., (1994).

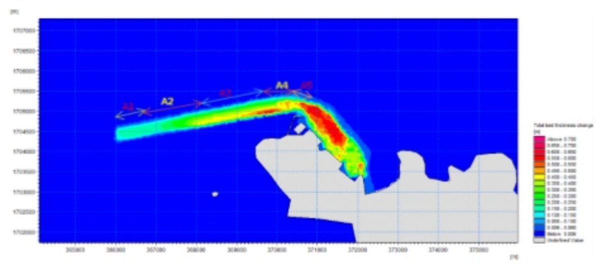

Figure12. Sedimentation in approach channel and in harbour (one month) (existing condition)

Table 1. Annual Sedimentation Zonewise

Zone	Sedimentation per Annum (m)
A1	0.54
A2	0.65
A3	1.40
A4	1.80
A5	1.95
Harbour	2.00

5. MODEL SIMULATION FOR PROPOSED CONDITION

After calibrating the model for the observed currents and sedimentation in the approach channel and harbor area, proposed deepening was incorporated in the bathymetry and hydrodynamic and sediment model were simulated for a period of one month without changing the calibrated parameters.

The typical flow fields during different tidal phases are shown in the Figure 13. It is observed that magnitude of flow drops in the channel and harbor as compared to prevailing currents in the channel and harbour. The maximum currents are of the order of the order of 0.32 m/s in the approach channel while in the harbor area currents are of 0.12 m/s.

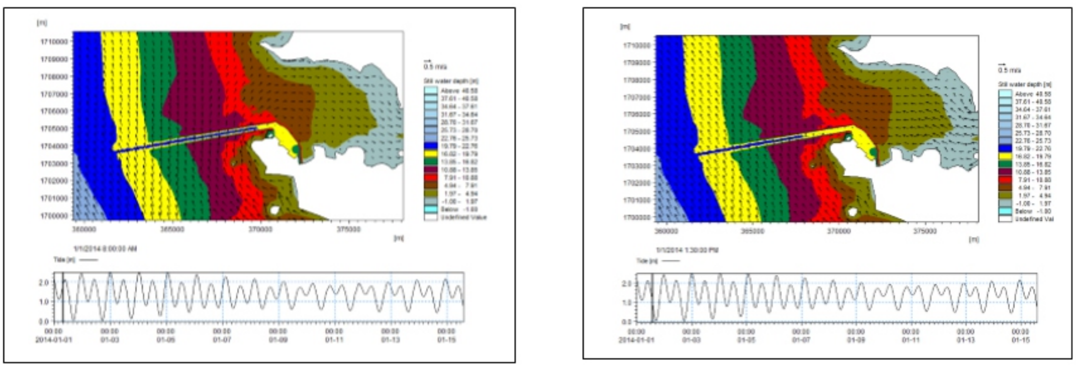

Figure 13. Flow patterns during flood and ebb phases in model area

Model was simulated for mud transport for a period of one month for SW monsoon conditions. A typical plot of sedimentation in the harbour and approach channel is shown in Figure 14. Annual zone wise sedimentation in the channel and harbour is shown in Table 2. It could be seen from figure and table that sedimentation pattern almost remains same but quantity of sedimentation changes. The total annual sedimentation in the harbour and approach channel including the areas which are not proposed to be deepened would be about 6.0 Million m3. It could be seen from table maximum siltation occurs in harbor area and minimum sedimentation at entrance of the channel. With proposed condition of deepening, the annual sedimentation would increase to about 1.5m in the approach channel region and to about 3.5m in the Harbour area.

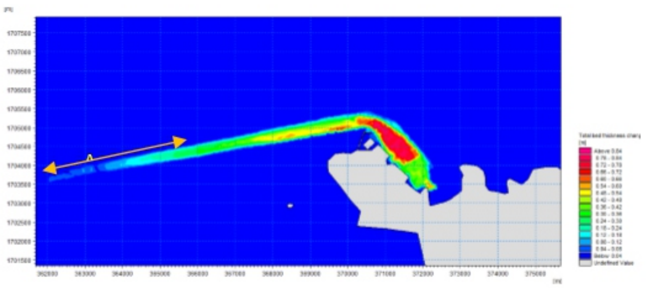

Figure 14. Sedimentation in approach channel and in harbour (one month) (proposed condition)

Table 2. Annual Sedimentaion zonewise

Zone	**Sedimentation per Annum (m)**
A0	0.56
A1	1.64
A2	1.85
A3	2.55
A4	2.90
A5	3.40
Harbour	3.50

6. DISPOSAL GROUND IDENTIFICATION

It is proposed to dredge 0.1 Million m3 of dredged material per day for the total estimated capital dredging quantity of about 14 Million m3 using two dredgers. MIKE -21 AD (Advection and Dispersion) model was used to study the sediment behavior after dumping the dredged material. Model was simulated for a period of one month considering 2500 cum of hopper material being dumped at an interval of one hour at (-) 27m depth contour (UTM 356000 E and 1705000 N) north of the approach channel. The location of dumping ground and simulation of results are shown in Figure 15 and Figure 16 respectively.

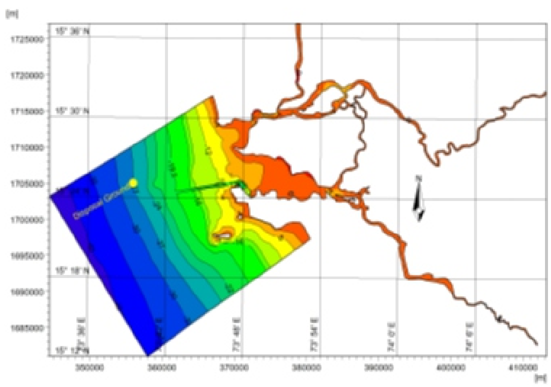

Figure 15. Dumping location location

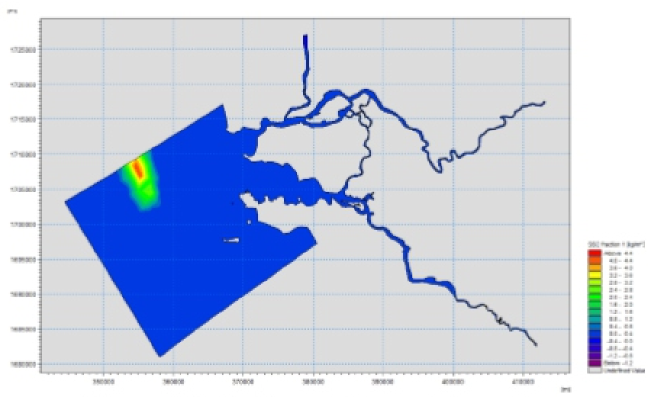

Figure 16, Sediment plume at dumping after one month of simulation

It could be seen from figure that sediment plume moves towards north and it spreads in 4 km wide area. Further, the Plume would cross the north boundary of model and it could be seen from the sediment plume pattern that it may move another 5 km towards north before it attains ambient conditions. The dredging would take place during month of August-September when the offshore currents are northward.

7. DISCUSSION OF THE RESULTS

The sedimentation in the channel and harbor areas is caused mainly due to the trapping of the suspended materials in the deepened portions while being transported with the tidal currents. The sedimentation increases gradually from the western end of the approach channel to the harbor areas with the difference in ambient and dredged depths. Wave induced bed shears have a big role in bringing the sediments into suspension. The river discharges have no significant effect in effecting the flow conditions in the channel and harbor areas. The source of sedimentation in the port areas is sea bed and river bed material deposit much in the upstream portions of the Mormugao bay. The suspended sediment concentration is about 5-6 times more in the upstream reaches of the Mormugao bay during the nonmonsoon season and about 2-3 times during the southwest monsoon season. This is basically due to the difference in the wave induced bed shear which is much higher in the shallow depths. The dredged material which is of soft – silty- clayey type is likely to move in the north after being disposed at (-) 27.0 m contour north of approach channel.

8. CONCLUSIONS

The main findings of the study are summarized as below:

- The main sediment transport mechanism in the Mormugao Port area and near the upstream reaches of Mormugao bay is due to the suspended sediment transport. The wave induced bed shear stress is mainly responsible for bringing bed material into suspension which is further transported in suspension with prevailing tidal currents to other areas.
- For the deepening proposal at Mormugao port development, the total annual maintenance dredging quantity is predicted to be about 6.0 Million cum against the 3.0 Million cum at present. More than 90% of the siltation would take place during the four months of the southwest monsoon season.
- The disposal grounds for the proposed deepening proposal are recommended to be located at UTM 356000 E and 1705000 N in an area of 2.0 km x 2.0 km at (-) 27.0 m contour north of approach channel.

REFERENCES

MIKE 21 Scientific background - Flow Model FM, DHI, Denmark

Purandare, U.V. and Prabhat Chandra (1994). Suspended sediment and siltation trends at Mormugao Port. Proc. IX Congress of APD-IAHR at Singapore

Evaluation Of Horizontal Layouts Of An Urban Storm Drainage System Based On Graph Theory And Geospatial Network Analysis

S.V.Kanitkar [1], Dr.R.N.Sankhua [2]

[1] *Research scholar, Civil Engg. Department, Govt. College of Engg. Pune 411001, India*

[2] *Director, National Water Academy, Pune 411024, India.*

sandeepvkanitkar@gmail.com

ABSTRACT

Design of an urban storm drainage system involves selection of the best alternatives amongst various alternatives having combination of horizontal and vertical layouts. Horizontal layout is function of number of man hole and outfall/s location, digital elevation model slope and aspect as well as road network alignments. This paper focuses on directed spanning tree type horizontal layout generation from a maximally connected directed storm pipe network by using attribute criteria as deflection angle made by individual pipe with respect to mean slope direction of digital elevation model for a given micro catchment as a weight and then applying algorithm for directed spanning tree. Layouts generated are then further evaluated using graph theory metrics depicting structural properties of the network. Using Multi Criteria Decision Analysis (MCDA) techniques alternatives generated for the individual network are ranked based on criteria related to structural properties. Two different networks each with four feasible layouts from a sub catchment of Pune City, India are analyzed and comparative network performance results are documented herein the paper.

Keywords: Graph theory; MCDA; Directed spanning tree; urban storm drainage design

1. INTRODUCTION

Optimal design of storm water network is studied by various researchers either focusing on explicit design of horizontal layout and vertical layout fulfilling multiple objectives separately or by implicit simultaneous design. This paper focuses on selection of a horizontal layout from available discrete set of alternatives using graph theory and MCDA. Selected alternative then can be analyzed functionally using hydraulic as well as hydrological characteristics of the network and an optimal solution can be obtained. Scope of this paper is restricted to structural analysis only. Various researchers have taken help of graph theory to analyze horizontal layouts of the either water or waste water pipe network. Minieka (1978) used Dijkstra method of graph theory to generate the shortest spanning tree of a graph, Tekel et al. (1986) focused on computerized horizontal layouts of network generation for sanitary sewers. Walters et al. (1995) applied evolutionary algorithms to optimize tree type networks. Dunn et al. (2012), Lhomme et al. (2013), have applied network topology theory to analyze, design and manage infrastructure systems. Simultaneously optimizing horizontal as well as vertical layouts by developing an iterative model has been studied by Li and Matthew (1990), Diogo et al. (2000) developing a global optimization model, Haghighi et al. (2013) adopted a loop by loop cutting algorithm to generate multiple horizontal layouts.

The three objectives are considered in this paper are, first one being generation of degree constrained directed spanning tree network generation from maximally connected storm water pipe network for fixed manhole and outfall positions and then analyze structural properties of the generated tree type network network using network metrics. Further analyze the generated alternatives using distance based, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), MCDA technique to select the best possible network from the given alternatives.

1.1 The study area

Two pipe networks from micro catchment of Kothrud sub-basin of city of Pune, Maharashtra, India are selected. Pune city is situated between 180 22' 30.00" to 180 37' 30.00" North latitude and 730 45' 00.00" to 730 58' 7.50" East longitude at an average altitude of 560 m above mean sea level .Location of Pune city along with Kothrud sub basin is shown in Figure 1.

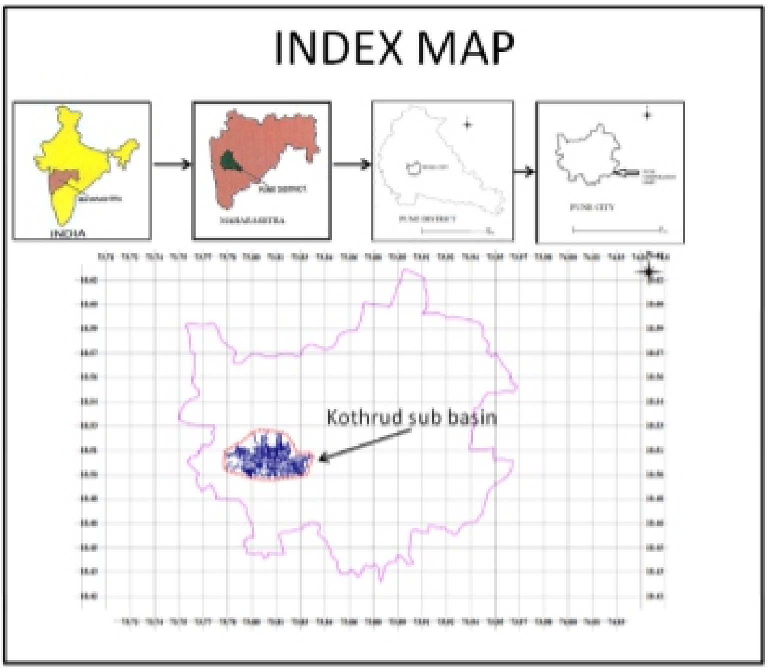

Figure 1 The study area

Two pipe networks named as G and M are selected from Kothrud sub basin, which are generated first by fixing number and position of design manholes taking into account road layouts, digital elevation model, slopes, natural streams and feasible outfall location and then connecting manholes by directed pipe networks with maximum possible connectivity. Resulting two networks are shown in Figure 2 and Figure 3.

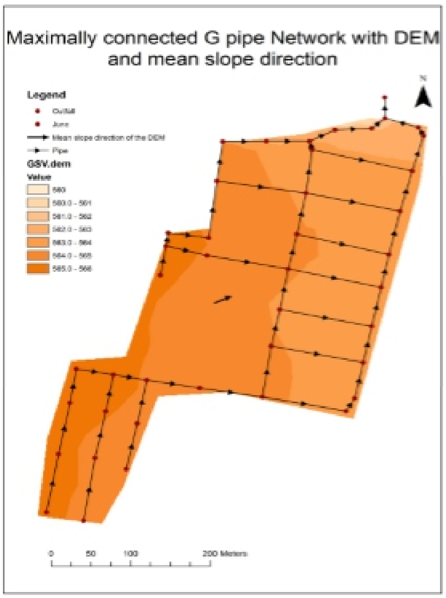

Figure 2 G pipe network.

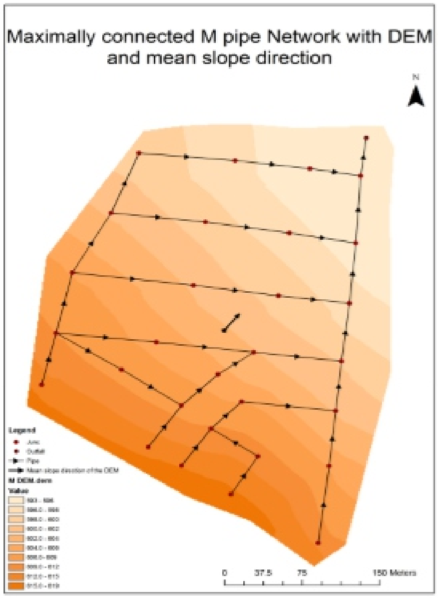

Figure 3 M pipe network.

2. METHODOLOGY

2.1 Generation of storm water network using CIVIL 3D an Autodesk® product.

For the Kothrud sub catchment with the available Digital elevation model (DEM) , LISS IV satellite imagery , topo-sheet and Pune Muncipal Corporation data ,two micro catchments M and G are considered and surfaces, road network ,stream network and land use land cover files are extracted. Then using CIVIL 3D an Autodesk® product, manholes and a single outfall positions are fixed along the road network for the two micro catchments. This is followed by generating storm pipe network connecting manhole taking into account terrain slopes as well as property boundaries resulting in maximally connected directed storm water pipe network which is practically possible.

2.2 Generation of spanning tree network from maximally connected storm pipe network.

Generating a spanning tree problem is a well-known problem in the area of network optimization. A spanning tree is a connected acyclic sub-graph that spans all nodes. There are various applications of finding degree constrained spanning tree, namely in the design of road systems, where a limit is imposed on the number of roads that are allowed to meet at any crossing, Savelsbergh and Volgenant (1985) and in the design of computer communication networks, Gavish (1995), as well as VLSI layouts, electrical circuits, details can be referred to Ahuja et al. (1993).

For the predefined locations of the manhole, and outfall/s, considering road network topology, ground slopes and accessibility of outfall near natural stream, treatment plant or storage node, directed pipe network can be generated which can be either tree or grid network, directing towards the outfall with maximum possible edges. New layout can be generated; keeping manhole position and number fixed and deleting maximum possible edges without creating sub graphs at the same time maintaining the connectivity till the grid network is converted to spanning tree. This will reduce the cost of pipe network to be provided at the same time draining the required contributory area to the specified outfall. While deleting edges two criteria are considered. First is included angle between angle made by each pipe due north and angle made by mean slope directional vector due north of the DEM of the contributory area named as "A". Second criteria can be set to length "L" as weight of each individual pipe in the network and then setting criterion to maximum L or minimum L condition. Deletion of the edge is based on whether criterion is set to maximum A\L or minimum A\L condition. Thus four spanning tree layouts are generated.

An algorithm is developed in Python language which will read shape file of storm water network as input and generate spanning tree network shape file based on set criteria as minimum or maximum attribute (angle "A", or length "L") as output. Figure 4 and Figure 5 show resulting spanning tree networks of network G an M.

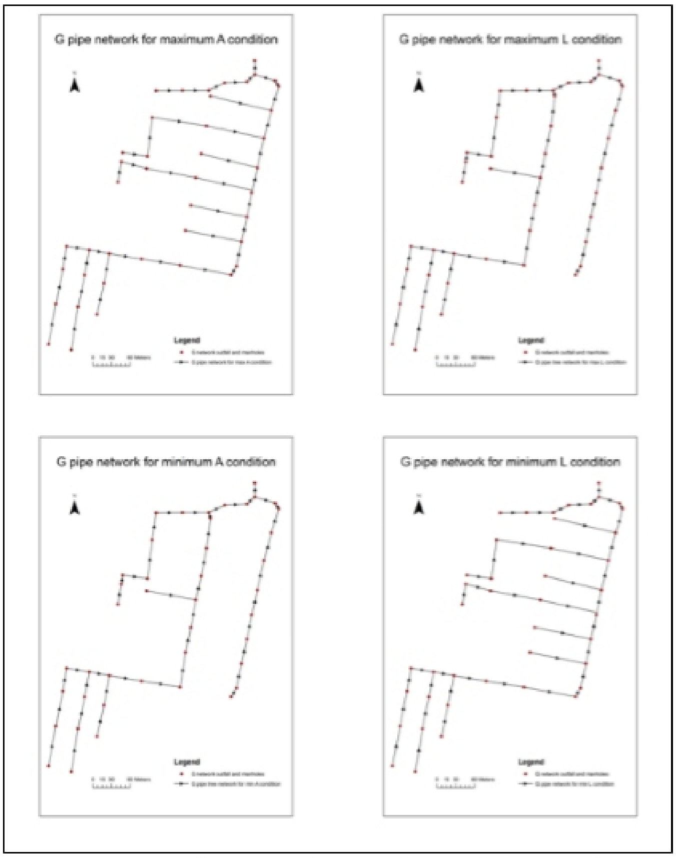

Figure 4 Four spanning tree alternatives of the G pipe network.

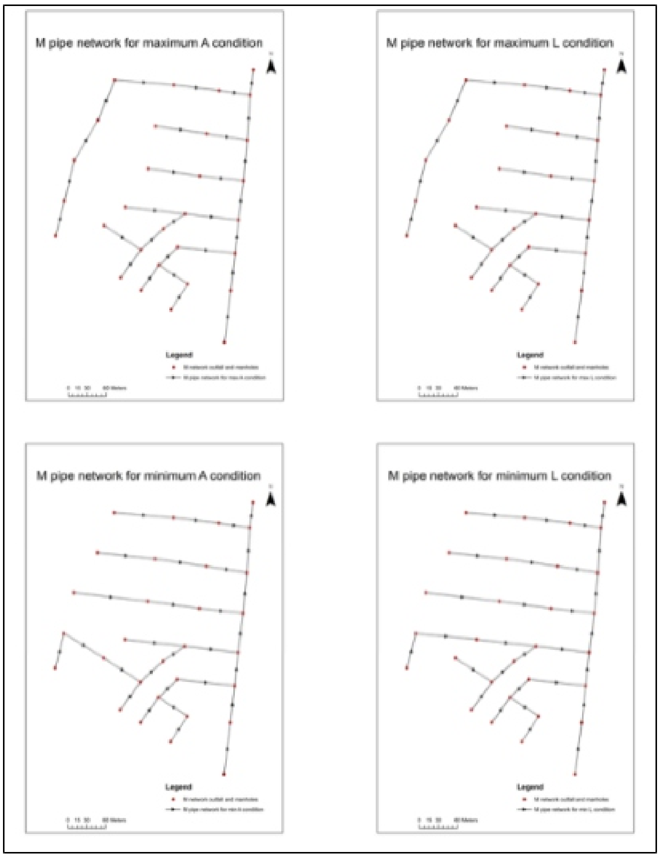

Figure 5 Four spanning tree alternatives of the M pipe network.

2.3 Defining criteria related to structural properties of the network using graph theory and graph metrics

Using the mathematics of graph theory, storm pipe networks can be described as network of interconnected manholes, or vertices, and pipes, or edges, with characteristics of connectivity, flow, and accessibility. Graph-theory based network measures and indices summarize the topological properties of pipe networks, thus enabling comparison of structural and functional characteristics of different layouts. The fundamentals of graph theory provide that any given network can be described as a graph, *G*, consisting of three elements: *E* or the edge set of a graph; *V* vertex set; and, the relation between edges and vertices, where the edges of *E* are defined by two vertices in *V*. The indices used to describe graphs of the networks consider them to be "planar" graphs i.e. they exist in two-dimensional space.

The cumulative characteristics of graphs can be measured with indices of connectivity and circuitry by index alpha (α). Alpha (α), a measure of the circuitry of a graph, is a ratio of the number of actual circuits in the graph, expressed as $e-(v-p)$ and the maximum number of circuits possible in a planar graph, given as $2v-5$. The theoretical upper limit of α is one, and its lower limit is zero. Alpha (α) increases as a network becomes more connected.

$$\alpha = \frac{e - v + p}{2v - 5} \quad (1)$$

Where, e is number of edges, v is number of nodes present in the network and p is number of sub-graphs. In case of maximally connected pipe network G, and M as shown in Fig 2 and 3, α is greater than zero while for spanning trees of G and M networks which are considered in analysis value will be zero.

Network performance measures are most commonly expressed by two measures, shortest average path length or Characteristic path length (CPL) and diameter (D).The CPL of a network captures the concept of efficiency in a network and is defined as the average number of steps along the shortest path between all pairs of nodes in a network.

$$CPL = \frac{1}{v(v-1)} \sum_{i,j \in v, i \neq 1} d_{ij} \quad (2)$$

Where, CPL is the shortest average path length of the network, v is the total number of nodes and d_{ij} is the shortest path considering length as weight between node i and node j. A "high" CPL indicates that the nodes are distant, implying little network graph compactness. The diameter is the maximal distance (shortest path) amongst all the distances calculated between each couple of vertexes in graph. The diameter indicates how much distant are the two most distant nodes. It can be a first and simple general parameter of graph "compactness", meaning with that the overall proximity between nodes. A "high" graph diameter indicates that the two nodes determining that diameter are very distant, implying little graph compactness. Being an average, CPL can be more informative than the diameter and can be also considered a general indicator of network “navigability", and is also included as a criterion of network performance. The stress is a node centrality index. Stress is calculated by measuring the number of shortest paths passing through a node considering length as weight. To calculate the stress of a node v, all shortest paths in a graph is calculated and then the number of shortest paths passing through v is counted. A "stressed" node is a node traversed by a high number of shortest paths indicating that the node v is critical to maintain the connection between nodes whose paths are passing through it. Average stress value of the graph is calculated by averaging the stress values of all nodes in the graph. Details regarding network measures can be referred to Kansky et al. (1989). Similarly pipe length provided to road network length (PL/RL) ratio for the given sub- network which is service level benchmarking criteria is considered which should be of maximum value as far as possible. Thus total four network measures are selected for measuring performance of the network layout of which diameter, CPL and stress criteria are of minimization function while PL/RL is of maximization function.

2.4 Multi criterion analysis using TOPSIS method.

MCDA technique have been applied to storm water management by Azzout et al.(1995),Ellis et al.(2004), Kolsky et al.(2002) ,Lee et al.(2009) , Mccuen et al.(1988) and Sun et al.(2011). Distance based, Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a MCDA technique which was first proposed by Hwang and Yoon (1993). TOPSIS compares and ranks alternatives based on two set of solutions known as the positive and negative ideal solutions. The positive ideal solution contains data that is the most desirable from among all the alternatives and negative ideal solution contains data points that are the least desirable from among all the alternatives. The ranking is determined by calculating the Euclidean distance of an alternative from these two ideal solutions. The alternative which has the largest distance from the negative solution and least distance from the positive solution is termed as the best. The TOPSIS method involves the following steps for a decision matrix having *m* alternatives and *n* criteria.

Step 1: Construction of normalized decision matrix.

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} (a_{ij})^2}} ; \forall j \qquad (3)$$

Step 2: Construction of weighted normalized decision matrix.

$$V_{ij} = (r_{ij})_{m \times n} \times \left((w_j)_{n \times n}^{diagonal} \right) \qquad (4)$$

Step 3: Determination of the positive ideal and negative ideal solution. The positive ideal solution V^+_j and the negative ideal solution V^-_j are given by

$$V_j^+ = \{(\max V_{ij}, j \in J_1), (\min V_{ij}, j \in J_2), i = 1,2,3.....,m\} \forall j \qquad (5)$$

$$V_j^- = \{(\min V_{ij}, j \in J_1), (\max V_{ij}, j \in J_2), i = 1,2,3.....,m\} \forall j \qquad (6)$$

Where, J_1 corresponds to benefit criteria and J_2 corresponds to cost criteria. V_{ij}= Weighted normalized values of decision matrix;

Step 4: Calculate the distances d^+_i and d^-_i from the positive ideal and negative ideal solution respectively.

$$d_i^+ = \left\{ \sum_{j=1}^{n} (V_{ij} - V_j^+)^2 \right\}^{\frac{1}{2}} ; \forall i \qquad (7)$$

$$d_i^- = \left\{ \sum_{j=1}^{n} (V_{ij} - V_j^-)^2 \right\}^{\frac{1}{2}} ; \forall i \tag{8}$$

Step 5: Determine relative closeness of alternatives to the ideal solution

$$cl_i^+ = \frac{d_i^-}{d_i^+ + d_i^+} \tag{9}$$

Where, $0 \leq cl^{+}_{-} \leq 1$, Alternatives with higher magnitude of closeness are preferred. Equal weights have been assigned to each criterion in order to generate weighted normalized decision matrix.

Using TOPSIS method, from a matrix of four alternatives and four criteria, an alternative is selected as layout which can be further analyzed for vertical layout taking into account various implicit and explicit constraints, hydraulic and hydrological parameters fulfilling number of objectives like minimum flooding, cost minimization and maximum hydraulic performance.

3 RESULTS AND CONCLUSIONS

Decomposition of maximally connected G and M network to spanning tree networks using an algorithm and attribute criteria of angle or length, leads to four alternatives for the each network as shown Fig. 4 and Fig. 5.

For the G network layout generated for maximum angle and minimum length have same horizontal configuration, while layouts generated using minimum angle and maximum length have same horizontal configurations.

From the maximally connected M network, layouts generated using maximum angle and maximum length are having same horizontal configuration while other two differ in layouts.

For the layout with maximum angle, pipes with orientation across the average slope vector of the DEM are selected and with minimum angle criteria, layout is selected where most of the pipes are selected with orientation along the average slope of the DEM. These layouts generated will certainly differ in hydraulic performance, for the given hydrological parameters which can be analyzed by hydrologic and hydraulically routing the network. Using graph theory and graph metrics, both G and M type networks generate four different alternatives each, and matrix of alternatives and criteria for each network type is documented in Table 1 and Table 2.

Table 1 Matrix of alternatives v/s criteria for spanning tree layouts of G network

Criteria Alternatives	DIAMETER	CPL	STRESS	PL/RL
G maximum A	1041.00	68.51	63.42	0.926
G maximum L	1041.00	67.71	62.33	0.921
G minimum A	945.00	56.09	50.16	0.894
G minimum L	1052.00	66.45	57.91	0.872

Table 2 Matrix of alternatives v/s criteria for spanning tree layouts of M network

Criteria/ Alternatives	DIAMETER	CPL	STRESS	PL/RL
M maximum A	528.00	41.77	13.67	0.730
M maximum L	528.00	41.77	13.67	0.730
M minimum A	618.00	44.30	14.73	0.759
M minimum L	575.00	42.85	13.67	0.768

From Table 1, diameter as well as CPL for (G minimum A) alternative is the least indicating that network is more compact and more effective from flow navigation point of view. Also the average stress value of the network considering length as weight is also least which indicates that impact of failure of nodes to function will affect lesser than other alternatives. Similarly in case of M type network, alternative (M minimum A), shows highest values for diameter, CPL, and stress indicating that the spanning tree network generated is less compact .Also from node criticality point of view it is more critical as it shows highest stress amongst the available alternatives as shown in Table 2. After analyzing the alternatives for the G and M network using TOPSIS method, results of the analysis are tabulated in Table 3 and Table 4.

Table 3 Ranking of alternatives based on TOPSIS method for G type network

Ranking	Alternative	Closeness
1	G minimum L	0.94612
2	G minimum A	0.55842
3	G maximum L	0.17622
4	G maximum A	0.15262

Table 4 Ranking of alternatives based on TOPSIS method for M type network

Ranking	Alternative	Closeness
1-2	M maximum L	0.97767
1-2	M maximum A	0.97767
3	M minimum L	0.62939
4	M minimum A	0.01713

From above Table 3 and 4, alternative (G minimum L) and M maximum L/A is selected as a final layout for analyzing the network for the vertical layout analysis. The methodology used in this paper analyzes horizontal layouts separately only for the structural properties and using MCDA technique, a better alternative is selected for further functional analysis. Other approach can be to analyze the networks simultaneously for both structural as well as functional requirements. Also the analysis does not consider maximally connected network which will have more pipes compared to spanning networks making network more robust as well as resilient but at the same time will increase cost of the network. Equal importance is given to each criterion by assigning equal weight to each criterion. Sensitivity of variation in weights applied to the criteria on the results of the outcome can also be analyzed Algorithm developed to decompose maximally connected pipe network into spanning tree network considering attribute criteria related to angle can be used to any network with any number of nodes as well as outfall/s. Resultant spanning tree network can be more economical draining designed discharge from the basin.

REFERENCES

Ahuja, R.K., Magnanti, T.L., Orlin, J.B.(1993), Network Flows: Theory, Algorithms, and Applications. Prentice Hall.

Ali Haghighi (2013), Loop-by-Loop Cutting Algorithm to Generate Layouts for Urban Drainage Systems DOI: 10.1061/ (ASCE) WR.1943-5452.0000294.

Autodesk® CIVIL 3D (2012), User guide Published By: Autodesk, Inc.111 Mclnnis Parkway San Rafael, CA 94903, USA.

Azzout, Y., Barraud,S., Cres, F.N. and AlFakih, E.(1995), Decision Aids for Alternative Techniques in Urban Storm water Management. Water Science and Technology, 32(1), 41-48.

Diogo, A. F., and Graveto, V. M. (2006), Optimal layout of sewer systems: A deterministic versus a stochastic model. J. Hydraul. Eng.,132(9).

Dunn S and Wilkinson S (2012), Identifying critical components in infrastructure networks using network topology .Journal of Infrastructure Systems 19(2):157–165, http://dx.doi.org/10.1061/ (ASCE) IS.1943-555X.0000120.

Ellis J.B., Deutsch J.C., Mouchel J.M., Scholes L. & Revitt D.M. (2004),Multi criteria decision approaches to support sustainable drainage options for the treatment of highway and urban runoff, Science of the Total Environment, 334-335, (2004) 251-260.

Gavish B, Topological design of centralized computer networks: Formulations and algorithms, Networks, 12: 355-377, 1982.

Hwang, Ching-Lai,Young-Jou Lai, and Ting-Yun Liu. (1993),A new approach for multiple objective decisions making. Computers & operations research 20.8: 889-899.

Kansky Karl, Danscoine Pascal, (1989), Measures of network structure. Flux, numéro spécial,. pp. 89-121. doi : 10.3406/flux.1989.913

Kolsky,P. and Butler, D. (2002), Performance indicators for urban storm drainage in developing countries. Urban Water 4, pp. 137-144.

Lee, J.H., Baek, C.W., Kim, J.H., Jun, H.D., Jo, D.J. (2009), Development of a decision making support system for efficient rehabilitation of sewer systems. Water Resour. Manag. 23, 1725–1742.

Li, G., and Matthew, R. G. S. (1990), New approach for optimization of urban drainage system. J. Environ. Eng., 116(5), 927–944.

Lhomme S , D. Serre, Y. Diab and R. Laganier (2013), Analyzing resilience of urban networks: a preliminary step towards more flood resilient cities. Nat. Hazards Earth Syst. Sci., 13, 221–230 doi:10.5194/nhess-13-221-2013

McCuen, R. H and Moglen, G. E.. (1988), Multi criterion storm water management methods. Journal of Water Resources Planning and Management, ASCE, 114(4), 414-431.

Minieka, E. (1978), Optimization algorithms for network and graphs, Dekker Marcel, New York.

Savelsbergh M and Volgenant T, Edge exchanges in the degree-constrained minimum spanning tree problem, Computers and Operations Research, 12: 341-348, 1985.

Sun, S. A., S. Djordjevic, and S. T. Khu, (2011), Decision Making in Flood Risk-Based Storm Sewer Network Design. Water Science and Technology 64 (1): 247–254.

Tekel, S., and Belkaya, H. (1986), Computerized layout generation for sanitary sewers. J.Environ. Eng., 112(4), 500–515.

Walters, G. A., and Smith, D. K. (1995), Evolutionary design algorithm for optimal layout of tree networks. Eng. Optim., 24(4),261–281.

Use of Waste Scaling in Construction Industry: an Emerging trend in Technology

K. M. Chacko[1], Laxmi Rawat[1], R.K.Singh[1]

[1]Director
Shriram Institute For Industrial Research , Delhi -110007
[2]Assistant Director
Shriram Institute For Industrial Research , Delhi -110007
[3]Scientist
Shriram Institute For Industrial Research , Delhi -110007

A B S T R A C T

Construction industry is growing at an alarming rate in order to meet the needs of the ever growing population globally. Generally most of the population in the society maintains a very close relationship with the built environment. To meet materials required for construction, natural resources are indiscriminately exploited. Energy is also spent in processing and transportation of construction materials. This has led to the environmental degradation contributing to the climate change. In order to mitigate such serious problems, resources need to be judiciously used. "Reduce, Reuse – Recycle" is proving to be the only way to handle these problems. There have been successful attempts to use industrial, agricultural and mining waste in construction industry.

The present paper is an attempt to use one of an important industrial waste i.e. Scaling produced in the steel industry. Scaling or Mill scale is a nuisance when the steel is to be processed. Mill scale has a rich amount of Iron oxide which is useful to be used in the construction industry as replacement of sand. Since aggregate is the major part of concrete , billions of tons of this natural material is mined from rocks and processed every year to be used in concrete, leaving a substantial impact on the environment. By the replacement of aggregate with Mill scale upto 50 % inConcrete, we can conserve and protect our natural wealth . The Compressive behavior of Concrete has been studied after replacing aggregate with mill scale in this present paper.

1. INTRODUCTION

Billions of tons of concrete is manufactured every year globally and such bulk volumes requireenormous amounts of natural resources for aggregate production. The concrete industry can enhance its environmental compliance by using large volumes of recycled materials from industry. Fine Aggregate (Sand) has the biggest contribution in the Concrete (approximately 75 %) and it has the most important role in deciding the major properties of concrete i.e. strength, workability, durability etc. Replacement of sand with Millscale will lessen the demand for virgin materials. It is also evident in the current situations, that good quality of aggregate (Sand) is depleting. Existing natural deposits are being exhausted at a faster rate and new deposits arelocated either underground or very close to already built up areas or too far away from the areas where it is required adding to the cost of transportation.

Environmental concerns are also being raised against uncontrolled extraction ofnatural sand. Erosion of river beds is also a big concern. Therefore, there is an urgent need for some products which can replace the natural sand.

Mill scale is a flaky hazardous solidwaste formed on the outer surfaces of steel plates or sheets, when they are being produced by rolling red hot iron or steel billetsin steel mills. Initially this scaling acts as a protection layer to the steel, but since it is electro chemically cathodic to the steel, any break in the mill scale starts causing corroding the steel and creates problem in the processing of steel .In general one steel plant produces approximately 7000 tons of scaling causing problem affecting environment too. Currently the major use of mill scale is in the making Flux for welding electrode and as a source of Ferro alloys.

This work aims toevaluate the optimum use of mill scale in concrete, as a replacement for natural fineaggregates.

2. LITERATURE REVIEW:

During the processing of steel, iron oxides are formed on the metal surface. These oxides occur during continuous casting, reheating and hot rolling operations. The formation of mill scale is a continuous process through the alternate formation and reduction of oxides of iron. Fe_2O_3 is reduced to Fe_3O_4 and FeO. The final result is a scale composed of layers of richer in oxygen at the scale surface and richest in iron at the metal surface. Mill scale is generally dark blue in colour, irregular in shape and is very abrasive.

Mill scale is a layer of iron oxide which forms on ferrous materials during continuous casting, reheating and hot rolling operations. It contains both iron in elemental form and three other types of iron oxides: Wustite (FeO), hematite (Fe_2O_3) and magnetite (Fe_3O_4). The iron content is typically around 70% with traces of non-ferrous metals and alkaline compounds.

Approximately, 90% of mill scale is directly recycled within steelmaking industry and small amounts are used for ferroalloys, in cement plants and in the petrochemical industries. However, finer mill scale which is heavily contaminated with oils, went to landfills in general and this residue is classified as hazardous waste by the Environmental Protection Agency.

This paper presents the findings of a study that investigates the use for mill scale into concrete. The composition of steel mill scale was determined by chemical analysis. For concrete cubes, the replacement was done for 50%. Compressive strength was measured for different specimens of the concrete samples. The results are promising and encourage further study in applications in concrete.

3. EXPERIMENTAL :

Mix designing of M 25 grade of Concrete was done using the guidelines of IS: 12062 and Compressive strength was assessed for the qualifying criteria

Preparation of Concrete cubes

Cement Used	:	OPC , 43 grade
Mould size	:	150mm x 150mm x 150mm
No. of Cubes cast	:	06 each (03 for 7 days & 3 for 28 days)
Characteristic Strength(f'ck)	:	25 N/mm2
Standard deviation	:	4
Statistical Constant	:	1.65
Target Mean Strength	:	31.6 N/mm2
Coarse Aggregate used	:	20 mm graded
Fine aggregate)	:	Sand + Mill scale

Durability requirements :-

Exposure	:	Moderate
Cement Content	:	400 kg/m3
Maximum Water Cement Ratio	:	0.50
Workability	:	50-75 mm

4. TEST DATA FOR MATERIALS :

Testing of Fine aggregate and Mill scale was done for its physical properties i.e. specific gravity, water absorption and chemical composition i.e. Silica , iron oxide and calcium oxide .

	Results	
Material	**Fine Aggregate**	**Mill Scale**
Specific Gravity	2.64	2.13
Water absorption	0.80%	0.90%
Silica	99.3%	1.37%
Iron Oxide	0.10%	94.6%
Calcium Oxide	0.05%	0.10%

Raw materials analysis:

Parameter	Cement	Coarse aggregate	Fine aggregate (Sand + Mill Scale)
Specific Gravity	2.88	2.66	2.59
Water Absorption	--	0.00%	0.02%
Surface Moisture	--	1.00%	1.78%

Gradation of Fine aggregate (Sand + Mill scale)

IS Sieve size	Wt. retained (g)	Wt. Retained , %	Passing , %
10.0 mm	0.0	500.0	100
4.75 mm	6.0	494.0	99
2.36 mm	22.0	472.0	94
1.18 mm	114.5	375.5	72
0.600 mm	185.5	172.0	34
0.300 mm	145.5	26.5	5
0.150 mm	24.5	2.0	0

Experimental Data :

W/C = 0.46
Water content = 179.4 kg / m3
Cement = 390 kg /m3
Density of Cement = 2.88
Water absorption of Graded Aggregate = 0.003%
Water absorption of Sand + Mill Scale = 0.018
% of Graded Aggregate = 0.57
% of Sand + Mill Scale = 0.43
Coarse aggregate = (1000-(390/2.88) + 179.4) x 0.57 x 2.66 = 763.09
Mill Scale + Sand = (1000-(390/2.88) + 179.4) x 0.43 x 2.59 = 1038.87
Water Correction = 196.25

Ratio by Weight :-

Water	Cement	Sand + Mill Scale	20 mm aggregate	10 mm aggregate
0.46	1.000	1.957	1.332	1.332

Ratio , kg/m3 :-

Water	Cement	Sand + Mill Scale	20 mm aggregate	10 mm aggregate
179.4	390	763.09	519.43	519.43

Slump Observed : 55 mm

Compressive strength at 7 days(Average of 3 cubes) : 25.5 N/mm2

Compressive strength at 28 days (Average of 3 cubes) : 36.0 N/mm2

5. CONCLUSION :

The major conclusions of the study are :

- Steel industry has a huge amount of fine Mill scale which is not being used in general and can be used in construction industry.
- The trend of compressive strength is positive i.e. the strength is achieved with substitution of mill scale for sand.
- Replacing 50 % of Fine aggregate (Sand) with Mill Scale gave a satisfactory compressive strength at 7 and 28 days as required by the criteria.
- The use of Mill scale as fine aggregate would result in reducing the construction cost considerably as it is readily available industrial waste.

6. REFERENCES:

1. IS: 383 : 1970 (RA 2002): Indian Standard on Aggregates
1. IS: 456 : 2000 : Indian Standard on Plain & Reinforced Concrete
2. IS: 516 : Indian Standard on Method for Concrete Strength
3. IS: 2386 : 1963 (RA 2002) : Indian Standard on Test methods for Aggregate analysis
4. IS: 4031 : 1996 : Indian Standard on Test Methods for Cement analysis
5. IS: 12062 : 2009 : Indian Standard on Concrete Mix Designing
6. Neville A .& Brooks J. (2002) , Concrete Technology , 2nd Edition , Longman, UK
7. Neville A . M. & (1996) , Properties of Concrete , 4th Edition , Longman, UK
8. Cory Peter Mcdermott , Lowa State University, "The Future of the Construction industry and the implications for construction project management and education" (2009)
9. Daiga, V.R. Horne, D.A. Thronton, J.A. (2002)" Steel Mill waste processing on a rotary hearth furnace to recover valuable iron units"- Proceedings – Iron making Conference , p 655-665
10. N. A. El-Hussiny, F. M. Mohamed, and M. E. H. Shalabi (CMRDI), Recycling of Mill Scale in Sintering Process
11. European Journal of Scientific Research ISSN 1450-216X , Vol 24 , No. 3 (2008) p332-338 , Eurojournals publishing Inc. 2008
12. R. Farahat, M. Eissa, G. Megahed, and A. Baraka, "Reduction of mill scale generated by steel processing," Steel Grips, vol. 8, pp. 88–92, 2010
13. Viktors Mironovs, Jānis Broņka, Aleksandrs Korjakins, Jānis Kazjonovs, Possibilities of Application of Iron containing waste materials in manufacturing of Heavy concrete .
14. O. Benchiheub, S. Mechachti, S. Serrai, and M. G. Khalifa, "Elaboration of iron powder from mill scale," Journal of Materials and Environmental Science, vol. 1, no. 4, pp. 267–276, 2010
15. Bairagi, N.K. Kishore, R &Pareek, V .K. " Behaviour of Concrete with different proportions of natural and recycled aggregates", Resources, Conservation and Recycling, Vol ***9 (1993) p 109-****126*
16. L. Camci, S. Aydin, and C. Arslan, "Reduction of iron oxide in solid wastes generated by steelworks," Turkish Journal of Engineering and Environmental Sciences, vol. 26, pp. 37–44, 2002

A Comparative Study for Evaluation of Evapotranspiration Methods and Finding out Irrigation Scheduling for Chaskaman Command Area

Mr. Ankit K. Kulkarni[1], Mr. Ravichandra Masuti[2]

[1]*Research Scholar, Sinhgad College Of Engineering, Pune, India.*
[2]*Assistant Professor, Sinhgad College Of Engineering, Pune, India.*
Email: ankitkoolkarni@gmail.com

ABSTRACT

Accurate estimation of evapotranspiration is very necessary step in the field of water resource management. Evapotranspiration varies spatially and temporally. Recently, the Food and Agricultural Organization (FAO) has suggested FAO-56 Penman Monteith method (modified PM method) as a standard method for calculating reference evapotranspiration (ETo). FAO-56 PM requires very large amount of meteorological data, which is not available at full climate stations. So there is need to find out next best suitable method after FAO-56 PM method, which will give ETo results nearer to FAO-56 PM method. Here six different methods are considered for present study, which are radiation based (FAO-56 Hargreaves, Turc, Priestley-Taylor), temperature based (Thornthwaite, Blaney-Criddle) and combine parameters based (FAO-56 modified Penman Monteith method). Chaskaman dam and its left bank canal is selected for this project.. Comparative study of five methods with standard method FAO-56 PM method on monthly basis showed that PT method yielded highest R2=0.92 and BC method yielded lowest error values as 1.33 for percent deviation and 0.08 for SEE. Comparison on seasonal scale showed that, for summer season BC method is the best which yielded lowest error values hence it ranked as the best after FAO-56. For rainy and winter season, on the basis of errors estimation PT method performed best among all methods and yielded values close to that of FAO-56 PM method. Further ETc (crop evapotranspiration/ crop water requirements) will be calculated for that command area. With reference to crop pattern, an Irrigation requirement is calculated, followed by Irrigation scheduling.

Keywords: Evapotranspiration, crop water requirements, irrigation scheduling

1. INTRODUCTION

Evaporation is the process in which water is lost from soil surface and wet vegetation. It is denoted as E. In this process liquid water is get converted to water vapors and removed from the surface. Evaporation is affected by climatic factors such as solar radiations, air temperature, air humidity and wind speed. Transpiration is the second process of water loss, in this process water vaporizes into the atmosphere through small openings in plant leaf (stomata) and it is denoted as T. Transpiration is dependent on the energy supply, vapor pressure gradient, and wind. Environmental aspects, cultivation practice and crop characteristics also influence transpiration.

Now, evapotranspiration is the combine process of both evaporation and transpiration. In this process water vaporizes from soil surface on one hand by evaporation and on other hand by transpiration from plant leaf and it is denoted as ET. When height of crop is small, main process is evaporation and when crop is fully grown then dominant process is transpiration. There is no easy way to distinguish between evaporation and transpiration, because both the process occurs simultaneously. Reference crop evapotranspiration is an evapotranspiration calculated on reference crop for which adequate amount of water is available and denoted by ETo. Reference surface is a hypothetical grass having specific characteristics. Evapotranspiration of reference crop is calculated and then the value is related to other surfaces. So there is no need to calculate separate evapotranspiration for each crop and stage of growth. It is independent of crop type crop development stage and management practices. When ETo multiplied by particular crop factor (K) it will give ET for that crop.

Crop water requirement (CWR) is the amount of water that is used by the crop for evapotranspiration. FAO (1984) had defined crop water as 'the depth of water needed to meet the water loss through evapotranspiration of a crop, being disease free, growing in large fields under non restricting conditions and achieving full production under given growing environment'. The value of CWR is equal to ETc. Irrigation requirements (IR) can be defined as the amount of water supplied to the crop through irrigation system to complete its crop water requirements. Irrigation scheduling is very important step after calculating CWR and IR. Three main parameters that should be considered during irrigation scheduling are i) the daily crop water requirements. ii) total moisture content and water holding capacity of soil. iii) root zone depth of crop. Soil properties such as condition of soil, texture, topography, depth, bulk density, salinity, acidity, fertility, drainage affect the plant root zone up to which it penetrates into the soil and uses available moisture. To match all this conditions irrigation system used should be perfect and hence scheduling is required.

2. INFORMATION OF STUDY AREA

The Chas Kaman Dam is one of the important dams of Maharashtra and is built on the Bhima River at Rajgurunagar in Pune district. The main purpose of Planning Commission in approving the project, was to improve irrigation and supply of electricity to the nearby villages. The reservoir holds about 241 MCM of water of which 214 MCM is approved for use for irrigation purpose. It is estimated that the Chas Kaman Dam can irrigate about 32824 ha of land of the villages nearby.

The dam and the surrounding areas receive rainfall from southwest monsoon from the month of June to September. Rajgurunagar is located at the north side end of Pune district in Maharashtra on the bank of the Bhima River about 40 kilometers from Pune. The Chas Kaman dam was built on 1977 at Bibi village.

The dam has water throughout the year which offers major benefits to the farmers of the region in terms of irrigation and crops rotation. During the time of monsoons, it will be having 250 MCM storage capacities. In fact, this is being used for drinking as well as irrigation. Its Coordinates are 18°57'39"N - 73°47'8"E. All the hydro meteorological data (historical as well as present) which is required for calculation will be collected from Irrigation Department, Pune and from Indian Meteorological Department (IMD), Pune. Chaskaman dam and its left bank canal are selected for present study, so data required for that canal will be collected from rain-gauge station at Chaskaman dam. The description, year and data type of the data collected is as shown in the table 1and the Details of canal are as below (source: report by National remote sensing agency) in table 2.

Table 1- List of available meteorological data

Description	**Year**	**Data type**
Pan evaporation	2003-2009	Daily
Temperature	2003-2009	Daily
Relative humidity	2003-2009	Daily
Wind speed	2003-2009	Daily
Net radiations	2003-2009	Daily

Table 2- Details of canal

Canal	**Left bank**
Length	144 km
Design discharge	26.33 cumec
Villages in command area	73
Type of lining	Lined

3. NEED FOR CALCULATION OF STANDARDIZED ET_o

Calculation of ET_o is done with the help of meteorological data. Over the last 50 years there were so many methods have been developed (empirical as well as semi empirical) to calculate ET_o from climatic variables. Methods which were developed are radiation based, Blaney-Criddle, pan evaporation, Penman and Modified Penman method; Thornthwaite etc., each of these methods require different data as per their parameters. Some old methods require less data for calculation, hence this old methods fail to give proper or exact value of ET_o. Many researchers have done the comparative study between all these methods in different area and for different cropping pattern. They found that value of ET_o varies spatially and temporally. But the main outcome of conclusion of researchers is that, FAO -56 PENMAN-MONTEITH method is the sole standard method for calculation of ET_o. Thevalues provided by PM method are more accurate and consistent and hence the use of old methods is no longer advisable.

4. METHODOLOGY

4.1. Calculation of ET_o **-** After collecting required hydro-meteorological data of dam site, reference evapotranspiration is calculated with the help of all the six methods on daily, monthly and seasonal basis.

4.2. ***Comparison of all the methods*** **-** After calculation of ET_o, all the six methods are compared with standard method (i.e. FAO-56 PM method). The regression analysis, Standard Errors of Estimation (SEE), and positive percent Deviation is calculated for the same.

4.2.1 ***Methods used-***

For the comparison of evapotranspiration value, six methods were used which are radiation based, temperature based and combine parameters based. Calculation and comparison is done after collecting the required meteorological parameters for the dam site. Method's name and its formula are mentioned below.

- **FAO-56 Penman-Monteith**

$$ET_0 = \frac{0.408\,\Delta(R_n - G) + \gamma \frac{900}{T + 273} u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \qquad (1)$$

- **Hargreaves**

$$ET_o = 0.0135 \times \frac{R_n}{\lambda} \times (T + 17.8) \qquad (2)$$

- **Turc**

$$ET_o = 0.013\left(\frac{T_{mean}}{(T_{mean} + 15)}\right)(23.9R_n + 50) \qquad (3)$$

When RH>50%

$$ET_o = 0.013\left(\frac{T_{mean}}{(T_{mean} + 15)}\right)(23.9R_n + 50)\left(1 + \frac{(50 - RH)}{70}\right) \qquad (4)$$

When RH<50%

- **Blaney-Criddle**

$$ET_o = a + b \times [P(0.46 \times T_{mean} + 8.13)] \quad (5)$$

- **Priestley-Taylor**

$$ET_o = 1.26 \times \frac{\Delta}{\Delta + \gamma} \times \frac{R_n}{\lambda} \quad (6)$$

- **Thornthwaite**

$$ET_o = 16(\frac{10T}{I})^a * \frac{\mu N}{360} \quad (7)$$

4.2.2 *Notations*:-

ρa = air density in kg m-3,
Cp = specific heat of dry air [~1.013 x 10-3 MJ kg-1 °C-1]
Es = mean saturated vapor pressure in kPa computed as the mean eo at the daily minimum and maximum air temperature in °C
ra = bulk surface aerodynamic resistance for water vapor in s m-1
ea = mean daily ambient vapor pressure in kPa
rs = canopy surface resistance in s m-1
ETo = Reference evapotranspiration (mm/day)
Rn = Net radiation at the crop surface (MJ/m2 per day)
G = Soil heat flux density (MJ/m2 per day)
T = Mean daily air temperature at 2 m height (°C)
u2 = Wind speed at 2 m height (m/sec)
(es – ea) = Saturation vapour pressure deficit(kPa)
Δ = Slope of saturation vapour pressure curve at temperature T (kPa/°C)
γ = Psychometric constant (kPa/°C)
λ =Latent heat of vaporizations, [MJ/kg] [2.45 MJ/kg],
R_s =Solar radiation, [MJ/m^2 d^{-1}]
T =Mean air temperature, [°C]
I = for each month is derived from mean monthly temperatures according to the formula i_i = 0.09*(Tj) 1.5, where subscript j indicates the specific month under investigation
a = empirically derived exponent which is a function of I, and is 0.016*I + 0.5. (for Thornthwaite method).
N = mean number of daylight hours in a particular month
μ = number of days in the month
R_S = Daily global solar radiation, [KJ/ m^2 d^{-1}]
α = Priestley Taylor coefficient (1.26)

4.3. *Calculation of crop water requirements* - CWR for crop is equal to the value of actual crop evapotranspiration. Hence K_c value is multiplied with ET_o to get water requirement of each crop.

4.4. *Estimating irrigation requirement* - Irrigation requirements are calculated with the help of crop water requirement of each crop. That is nothing but the water required for that crop to fulfill their need. Water required for that crop from sowing process to harvesting process.

4.5. ***Irrigation scheduling –*** At the final stage irrigation scheduling is done for the left bank canal of Chaskaman dam. Proper water will be provided to the crop as per their requirements.

4.5.1 ***Irrigation frequency***

Irrigation frequency is defined as the frequency of applying water to a particular crop at a certain stage of growth and is expressed in days. The equation is

$$\mathbf{IF = \frac{SM_{ra}}{ET_c} = \frac{SM_{ta} * P * RZD}{ET_c}} \qquad (8)$$

Where,

IF = irrigation frequency in days

SM_{ra} = radially available soil moisture (= SM_{ta} * P* RZD) in (mm)

SM_{ta} = total available soil moisture (= FC – PWP) in (mm/m)

P = allowable depletion

RZD = root zone depth (m)

ET_c = crop evapotranspiration or crop water requirements (mm/day)

4.5.2 ***Irrigation Requirements***

For manual calculations of irrigation requirements of crop, it is calculated by following formula.

$$\mathbf{IR_n = IF * ET_c} \qquad (9)$$

Where,

IR_n = irrigation requirements.

Once the frequency of irrigation in days and irrigation requirements of that crop is calculated, it is easy to plot a table for complete schedule of that crop depending upon its stage.

5. RESULTS.

Evapotranspiration values by all five methods are calculated and are compared with FAO-56 PM Method. This study is done to find out the alternate best method for Chaskaman command area after FAO-56 PM method. So as to find out the results, calculated values are divided on monthly, seasonally and yearly basis. Their regression equations are calculated and error estimation is also done with the help of SEE, percent Deviation and ARE.

Daily values of ET_o are calculated first, then this values are converted into monthly values. Average monthly values of ET_o are tabulated in Table 3. Graphical representation of monthly values of ET_o is shown in Figure 3. The graph showed that values of ET_o goes on increasing from month of January-May. This is just because there is increase in the temperature up to month of May and again it goes on decreasing from May to December.

5.1 *Monthly Basis*-

In comparative calculation by regression and error analysis results indicated that Priestley Taylor method gave high coefficient of determination value (R^2= 0.9298) and lowest ARE (0.1471). After that Blaney-Criddle method showed the lowest errors such as 1.33 and 0.08 for percent deviation and SEE. Turc method found to be closely following Priestley Taylor method having high R^2 value as 0.91 and 0.30, 0.21, 0.93 for ARE, percentage deviation and SEE. Hargreaves method also performed well after Turc, showing values 0.90, 0.15, 12.12 and 0.69 for R^2, ARE, percent deviation and SEE.

Here more weightage is given to the results from error analysis in present since the coefficient of correlation (R^2) in regression analysis is only an indicator of how well the line of regression fits with the original data and do not consider the actual closeness/ error of each estimated record with respect to actual standard record. Hargreaves method also follows Priestley Taylor method closely in error as well as regression analysis. But as HR method requires less data than Pristley Taylor method it has given third rank. Turc and Thornthwaite performed low in ARE, Percent deviation as well as SEE, so their rank is low. The comparison calculation of all methods is shown in table no-5.

5.2 *Seasonal Basis*-

In India there are lots of variations in the climate conditions. It contains all types of region such as humid, sub humid, arid, and semiarid. Chaskaman dam and its command area come under semiarid region, although it is having average amount of rainfall in its area. Monthly average values of ET0 are divided into main three seasons.

from February – May -- Summer

from June – September -- Rainy

from October –January -- Winter

In this region the intensity of solar radiation and temperature is more is summer seasons. This results in high evapotranspiration value. In the present research work, comparative evaluation for seasonal basis is done with the help of linear regression and error estimation.

For summer season (from February – May) results showed that Priestley Taylor method gave highest value of (R^2= 0.993) after that Hargreaves method gave (R^2= 9876), percent deviation, SEE and ARE values given by Blaney-Criddle method was lowest. Hence for summer season the results proved that Blaney-Criddle method is the best method to estimate ET_0 which yielded ET_0 value closer to that of FAO-56 PM method.

In rainy season Blaney-Criddle gave R^2 = 0.9739 as highest value. But in errors estimation Priestley Taylor gave values as 0.3481, 0.799, 0.088 for SEE, percent deviations and ARE. Turc method also found to be closely following Blaney-Criddle method in case of regression analysis. But on the basis of the results shown by errors estimation Priestley Taylor is stated as the best alternate method for rainy season when compared with FAO-56 PM method.

Now for the winter season Priestley Taylor gave good results among all the methods. It showed the highest R^2 value as R^2 =0.8287 with lowest SEE, ARE and % deviation as 0.13, 0.04, 4.22 respectively and hence the study concluded that for winter season Priestley Taylor is the best method after FAO-56 PM method. Hargreaves method also showed results nearer to Priestley Taylor method so it has given second rank.

5.3 *Irrigation scheduling*

Irrigation schedule for the crops based on Crop Water Requirements is as shown below. Bajra, Maka, Jowar, Onion and Wheat are major crops in this region. Soil parameters are finalized first.

Type of soil in this area is Black Cotton Soil. Total available moisture content in the soil is considered as 140 mm/day; initial soil moisture depletion is 50% and finally, initial available moisture for crop for its complete growth is 50 mm/meter. This values are shown in table – 6. Crop data is imparted in table – 7 and calculation of irrigation scheduling is shown in table - 8.

Calculation of irrigation scheduling for Bajra (Millet) is shown in results section. Irrigation scheduling for remaining crops is calculated with same soil parameters.

6. SUMMARY AND CONCLUSION

Six methods FAO-56 PM, Priestley Taylor, Blaney-Criddle, Turc, Hargreaves and Thornthwaite are applied to estimate the reference evapotranspiration using weather data of metrological station of Pune region. For evaluation of other five methods, FAO-56 PM method is taken as standard to calculate ET_0, as per the recommendation of Food and Agricultural Organization (FAO) experts consultation panel.

The regression analysis and error analysis of all these methods on monthly basis shows that the Priestley Taylor performed best amongst all the method with highest R^2 =0.92 and ARE= 0.14 which is lowest. In case of errors estimation Blaney-Criddle shows relatively lowest value for % deviation and SEE that is 1.33 and 0.081 respectively.

Turc and Hargreaves also gave high values for regression that is 0.91 and 0.90 with low ARE 0.30 and 0.15 respectively.

On seasonal scale PT method followed by HR method gave highest R^2 value as 0.993 and 0.989 for summer season. But in errors estimation Blaney-Criddle Method gave less result than all other methods, so here in this study there is more concentration on the values of error estimated. Hence Blaney-Criddle stood best among all the methods. Also less data required for Turc holds lost rank in comparison. Similarly in rainy season Priestley Taylor showed good results and holds first rank among all the methods. For winter Priestley Taylor method is the best because it gave highest R^2 values as 0.8287 as well as lowest error that is SEE= 0.13, % deviation= 4.22, ARE= 0.040. There is quite more difference between the values provide by all other methods. Hence Priestley Taylor stood as the first and yielded results closer to that of FAO-56PM method.

The comparative evaluation of five ET_o estimation techniques done in this study is site specific and the results may vary from site to site. This study will surely help the decision maker to select the best alternate ET_o estimation technique with data or accuracy constraints. Also the same kind of study on large scale for each agro-climate zone will help to complete the best possible ET estimation Technique in accordance with data availability.

Estimation of accurate irrigation scheduling is very much required for proper management of water as per the requirements and to minimize the water losses. Proper scheduling is plotted for the crops coming under that area, considering all the parameters related to it. Developing accurate irrigation schedules will help for the agricultural extension service to support better irrigation practices.

7. DISCUSSION AND FUTURE SCOPE

In the present study, calculation of evapotranspiration, crop water and irrigation requirement followed by irrigation scheduling of left bank canal Chaskaman dam command area will be very beneficial for the farmers as well as people in that area. Now-a-days proper scheduling of irrigation system plays vital role. So Irrigation scheduling will enable farmers to schedule watering to minimize crop water stress and maximize their yields. It will also reduce farmer's costs of water and labor through less irrigation, and also making maximum use of soil moisture storage for growth of crop. Now considering the point of economy it will increase net returns of that farmer by increasing crop yields and crop quality. Scheduling will minimize water-logging problems in the field. Finally irrigation scheduling will be advantageous in future also by boosting the crop production in small fields.

ACKNOWLEDGMENT

I would like to thank my Principal of institute Dr. S. D. Lokhande, HOD Dr. S. S. Shastri, M.E. coordinator Prof. Nishad Patki, my guide Mrs. V. S. Limaye, co- guide Prof. Ravichandra Masuti, Er. Bagde sir from Irrigation department, M.E. staff and all my dear friends for their support.

REFERENCES

Adeboye, O. B. Osunbitan J. A. Adekalu K. O. Okunade D. A. (2009): "Evaluation of FAO-56 Penman-Monteith and Temperature Based Models in Estimating Reference Evapotranspiration Using Complete and Limited Data, Application to Nigeria." Agricultural Engineering International: CIGR Journal. Vol 11, pp-1–25.

Andreas P. Savva, Karen Frenken, "Crop Water And Irrigation Scheduling", FAO irrigation manual module 4, 2002.

Ankit K. Kulkarni, Ravichandra Masuti, Mrs. Vaishali Limaye, "Comparative Study Of Evaluation Of Evapotranspiration Methods And Calculation Of Crop Water Requirements At Chaskaman Command Area In Pune Region, India" in 'International Journal of Research in Engineering and Technology' (IJRET), volume-04, issue-03, Mar-2015.

Bhaskar R. Nikam, Pradeep Kumar, Vaibhav Garg, Praveen K. Thakur and S. P. Aggarwal, "Comparative Evaluation Of Different Potential Evapotranspiration Estimation Approaches", IJRET: International Journal of Research in Engineering and Technology, Volume: 03 Issue: 06, Jun-2014

Csaba Racz, János Nagy, Attila Csaba Dobos "Comparison of Several Methods for Calculation of Reference Evapotranspiration" Acta Silv. Lign. Hung., Vol. 9 (2013), pp- 9–24.

Dr. M. V. S. S. Giridhar and Dr. G. K. Viswanadh, "Comparison of Radiation Based Reference Evapotranspiration Equations with FAO-56 Penman Monteith Method" International Journal of Computer Science and System Analysis1(2) July-December 2007; PP. 149-158.

Hari Datta Paudel and Ashish Pandey, "Comparative study of ETo estimation methods for the water balance estimation–a case study of Sikta irrigation project, Nepal" Journal of Indian Water Resources Society, Vol 33, No.4, October, 2013Vol 33, No.4, October, 2013.

J. Doorenbos and W.O. Pruitt, FAO. Crop water requirements. FAO Irrigation and Drainage Paper 24, 1984.

Jitendrasinh D. Raol, Prof. S.A.Trivedi "Managing irrigation canal system with optimum irrigation scheduling for watrak irrigation scheme of North Gujarat, India" Journal of Engineering Research and Studies, JERS/Vol. III/ Issue II/April-June, 2012/25-27.

Kavish S. Mehta, Rutvij J. Sonecha, Parth D. Daxini, Parth B. Ratanpara, Miss Kapilani S. Gaikwad," Analysis of Engineering Properties of Black Cotton Soil & Stabilization Using By Lime." Int. Journal of Engineering Research and Applications,ISSN : 2248-9622, Vol. 4, Issue 5(Version 3), May 2014, pp.25-32.

L.C. Tollefson and M.N.J. Wahab, " Better Research-Extension-Farmer Interaction can Improve the Impact of Irrigation Scheduling Techniques" Canada-Saskatchewan Irrigation Diversification Centre.

Laxman Nandagiri and Gicy Kavoor, "Performance Evaluation of Reference Evapotranspiration Equations across a Range of Indian Climates", American Society of Civil Engineers, 01 June 2006.

M. G. Mardikis, D. P. Kalivas, V. J. Kollias "Comparison of Interpolation Methods for the Prediction of Reference Evapotranspiration- An Application in Greece" Water Resources Management (2005) Vol.19, pp 251–278 1 July 2004.

M. Shekhar, B. Simhadri Rao, Dr. V. Venkateshwar Rao, "Assessment of Irrigation Potential Created in AIBP funded Irrigation Projects in India using Cartosat Satellite Data : CHASKAMAN Irrigation Project, Maharashtra State" NRSA–RS&GISAA-WRD-Final Report -PC1307 –AIBP53-Chaskaman Project–R01-dt.23.05.2008

R. E. Yoder, L. O. Odhiambo, W. C. Wright "Evaluation of methods for estimating daily reference crop evapotranspiration at a site in the humid southeast United States".

Richard Allen, Luis Pereira, Dirk Raes and Martin Smith "Crop evapotranspiration: Guidelines for computing crop water requirements." FAO Irrigation and Drainage Paper 56, 1998a.

S. K. Himanshu, A. K. Singh, S. Kumar, P. Kalura, "Response of Broccolli to Irrigation Scheduling and Methods under Drip, Sprinkler and Surface Irrigation", International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-2, Issue-4, April 2013.

Saskatchevan Ministry of Agriculture, Irrigation Scheduling Manual, November 2008.

Swati Pandey, Manoj Kumar, Soubhik Chakraborty and N.C. Mahanti, "A Statistical Comparison of Reference Evapotranspiration Methods: A Case Study from Jharkhand State of India" Vol. 3, Issue 1, January 2014.

T. A. Mcmohan, M. C. Peel, L. Lowe, R. Srikantan, and T. R. Mcvicar, "Estimating actual, potential, reference crop and pan evaporation using standard meteorological data: A pragmatic synthesis" Hydrology and earth system science, 17, pp-1331-1363, 2013.

T.A. Howell "Irrigation Scheduling Research And Its Impact on Water Use" pp. 21-33, In C.R. Camp, E.J. Sadler, and R.E. Yoder (eds.) Evapotranspiration and Irrigation Scheduling, Proceedings of the International Conference, Nov. 3-6, 1996, San Antonio, TX, American Society of Agricultural Engineers, St. Joseph, MI.

Results – Graphs and Tables of comparision.

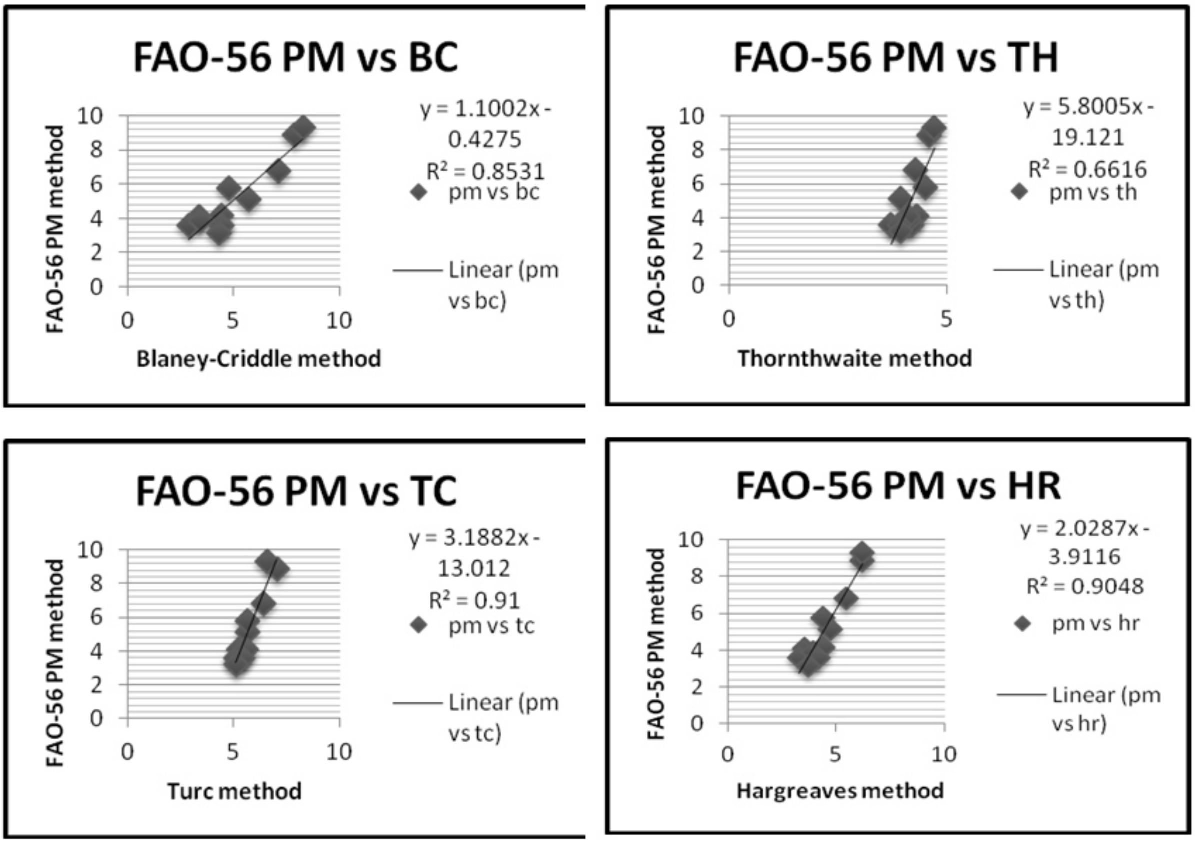

Figure 4- Comparison of daily evapotranspiration computed by five ET_o estimation methods vs. calculated ET_o by FAO-56 PM method

Table 3 - Monthly average ET_o values by all methods:-

Methods/Months	January	February	March	April	May	June	July	August	September	October	November	December
FAO-56 PM	3.59	5.11	6.81	8.88	9.29	5.77	4.07	3.61	3.88	4.13	3.56	3.18
PT	3.18	4.11	4.86	5.49	5.70	4.46	3.82	3.57	4.08	4.08	3.58	3.09
BC	4.41	5.73	7.09	7.86	8.24	4.77	3.37	2.88	3.41	4.44	4.43	4.31
TC	5.12	5.62	6.38	7.04	6.58	5.64	5.26	5.14	5.40	5.61	5.43	5.13
TH	3.71	3.93	4.25	4.58	4.69	4.49	4.30	4.17	4.13	4.10	3.90	3.93
HR	3.74	4.71	5.47	6.18	6.20	4.36	3.54	3.28	3.94	4.40	4.13	3.68

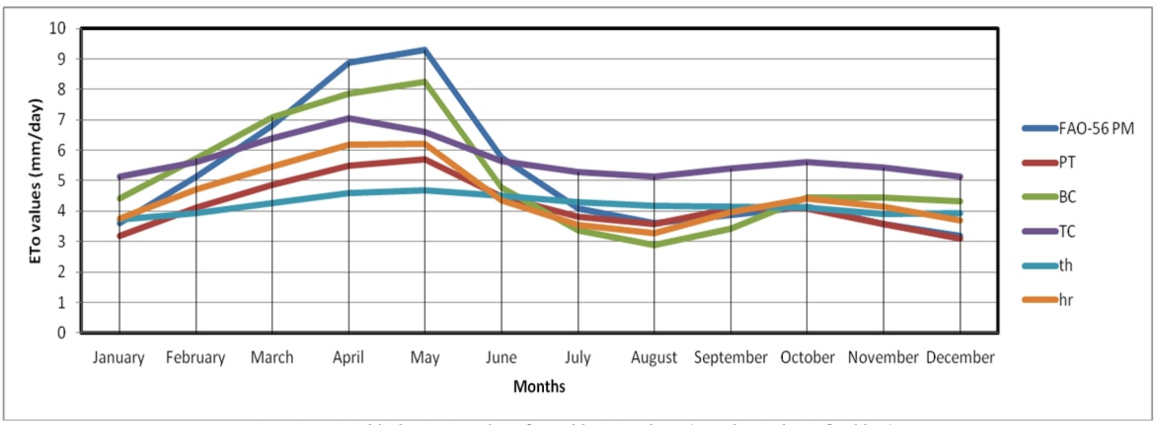

Figure 3- Graphical representation of monthly ET_o values. (Based on values of Table 3)

Table 4 – Regression and Error analysis between monthly values of calculated ET_o

Methods	Regression equation	R^2	ARE	% deviation	SEE
PT	2.4473x - 5.0498	**0.92**	**0.147**	19.859	0.990
BC	1.1002x - 0.4275	0.85	0.163	**1.330**	**0.081**
TC	3.1882x - 13.012	0.91	0.308	21.094	0.536
TH	5.8005x - 19.121	0.66	0.204	21.351	0.978
HR	2.0287x - 3.9116	0.90	0.151	12.125	0.690

Table 5- Error analysis between values of standard and estimated ET_o for three seasons

Season	Priestley-Taylor method				Blaney-Crridle method			
	SEE	% dev	ARE	R^2	SEE	% dev	ARE	R^2
Summer	2.487	47.352	0.312	**0.99**	**0.297**	**2.809**	**0.096**	0.97
Rainy	**0.348**	**7.997**	**0.088**	0.77	0.728	20.299	0.167	**0.97**
Winter	**0.136**	**4.228**	**0.040**	**0.82**	0.781	22.477	0.224	0.72

Season	Turc method				Hargreaves method			
	SEE	% dev	ARE	R^2	SEE	% dev	ARE	R^2
Summer	1.118	16.249	0.165	0.80	1.887	31.691	0.228	0.98
Rainy	1.027	27.074	0.281	0.82	0.5503	13.886	0.120	0.72
Winter	1.701	47.779	0.477	0.68	0.365	10.391	0.103	0.74

Season	Thornthwaite method			
	SEE	% dev	ARE	R^2
Summer	3.253	77.460	0.393	0.97
Rainy	0.060	0.919	0.124	0.88
Winter	-0.654	-15.412	0.187	0.70

Irrigation scheduling for Bajra (Millet)

Table 6- Soil details

Soil name	Black cotton soil
Total available soil moisture (fc-pwp)	100mm/day
Maximum infiltration rate	2mm/day
Maximum rooting depth	200 cm
Initial soil moisture depleation (as % tam)	50%
Initial soil moisture available	50mm/meter

Table 7- Crop data

		Bajra (millet)				
Growth stage		Initial	Development	Mid	Late	Total
Length stage	Days	20	30	50	35	135
Crop coefficient	Coeff	0.7	-	1	0.3	
Rooting depth	Meter	1		2		
Depletion level	Fraction	0.5		0.5	0.5	

Table 8- Irrigation scheduling program for millet-

Decade	ET_c	RZD	P	SMta	SMra	IF	IR_n
	(mm/day)	(m)	%	mm/m	mm/m	(days)	(mm)
01/11 - 10/11	3.92	0.15	0.4	100	8.4	2.14 (2)	7.84
11/11 - 20/11	3.92	0.2	0.4	100	11.2	2.86 (3)	11.76
21/11 - 30/11	4.08	0.3	0.4	100	16.8	4.12 (4)	16.32
01/12 - 10/12	4.68	0.4	0.45	100	25.2	5.38 (5)	23.4
11/12 - 20/12	5.48	0.45	0.45	100	28.35	5.17 (5)	27.4
21/12 - 30/12	6.3	0.5	0.5	100	35	5.56 (5)	31.5
01/01 - 10/01	6.7	0.5	0.5	100	35	5.22 (5)	33.5
11/01 - 20/01	6.87	0.5	0.5	100	35	5.09 (5)	34.35
21/01 - 30/01	6.67	0.5	0.5	100	35	5.24 (5)	33.35
01/02 - 10/02	6.14	0.5	0.5	100	35	5.70 (6)	36.84
11/02 - 20/02	5.36	0.5	0.5	100	35	6.53 (6)	32.16
21/02 - 30/02	4.5	0.5	0.5	100	35	7.55 (7)	31.5
01/03 - 10/03	3.71	0.5	0.5	100	35	9.43 (9)	33.39
11/03 - 15/03	2.92	0.5	0.5	100	35	11.98(12)	35.04

- Note – Irrigation scheduling for all the remaining crops is calculated with same steps considering same crop characteristics.

Instructions for Authors

Essentials for Publishing in this Journal

1 Submitted articles should not have been previously published or be currently under consideration for publication elsewhere.

2 Conference papers may only be submitted if the paper has been completely re-written (taken to mean more than 50%) and the author has cleared any necessary permission with the copyright owner if it has been previously copyrighted.

3 All our articles are refereed through a double-blind process.

4 All authors must declare they have read and agreed to the content of the submitted article and must sign a declaration correspond to the originality of the article.

Submission Process

All articles for this journal must be submitted using our online submissions system. http://enrichedpub.com/ . Please use the Submit Your Article link in the Author Service area.

Manuscript Guidelines

The instructions to authors about the article preparation for publication in the Manuscripts are submitted online, through the e-Ur (Electronic editing) system, developed by **Enriched Publications Pvt. Ltd**. The article should contain the abstract with keywords, introduction, body, conclusion, references and the summary in English language (without heading and subheading enumeration). The article length should not exceed 16 pages of A4 paper format.

Title

The title should be informative. It is in both Journal's and author's best interest to use terms suitable. For indexing and word search. If there are no such terms in the title, the author is strongly advised to add a subtitle. The title should be given in English as well. The titles precede the abstract and the summary in an appropriate language.

Letterhead Title

The letterhead title is given at a top of each page for easier identification of article copies in an Electronic form in particular. It contains the author's surname and first name initial .article title, journal title and collation (year, volume, and issue, first and last page). The journal and article titles can be given in a shortened form.

Author's Name

Full name(s) of author(s) should be used. It is advisable to give the middle initial. Names are given in their original form.

Contact Details

The postal address or the e-mail address of the author (usually of the first one if there are more Authors) is given in the footnote at the bottom of the first page.

Type of Articles

Classification of articles is a duty of the editorial staff and is of special importance. Referees and the members of the editorial staff, or section editors, can propose a category, but the editor-in-chief has the sole responsibility for their classification. Journal articles are classified as follows:

Scientific articles:

1. Original scientific paper (giving the previously unpublished results of the author's own research based on management methods).
2. Survey paper (giving an original, detailed and critical view of a research problem or an area to which the author has made a contribution visible through his self-citation);
3. Short or preliminary communication (original management paper of full format but of a smaller extent or of a preliminary character);
4. Scientific critique or forum (discussion on a particular scientific topic, based exclusively on management argumentation) and commentaries. Exceptionally, in particular areas, a scientific paper in the Journal can be in a form of a monograph or a critical edition of scientific data (historical, archival, lexicographic, bibliographic, data survey, etc.) which were unknown or hardly accessible for scientific research.

Professional articles:

1. Professional paper (contribution offering experience useful for improvement of professional practice but not necessarily based on scientific methods);
2. Informative contribution (editorial, commentary, etc.);
3. Review (of a book, software, case study, scientific event, etc.)

Language

The article should be in English. The grammar and style of the article should be of good quality. The systematized text should be without abbreviations (except standard ones). All measurements must be in SI units. The sequence of formulae is denoted in Arabic numerals in parentheses on the right-hand side.

Abstract and Summary

An abstract is a concise informative presentation of the article content for fast and accurate Evaluation of its relevance. It is both in the Editorial Office's and the author's best interest for an abstract to contain terms often used for indexing and article search. The abstract describes the purpose of the study and the methods, outlines the findings and state the conclusions. A 100- to 250-Word abstract should be placed between the title and the keywords with the body text to follow. Besides an abstract are advised to have a summary in English, at the end of the article, after the Reference list. The summary should be structured and long up to 1/10 of the article length (it is more extensive than the abstract).

Keywords

Keywords are terms or phrases showing adequately the article content for indexing and search purposes. They should be allocated heaving in mind widely accepted international sources (index, dictionary or thesaurus), such as the Web of Science keyword list for science in general. The higher their usage frequency is the better. Up to 10 keywords immediately follow the abstract and the summary, in respective languages.

Acknowledgements

The name and the number of the project or programmed within which the article was realized is given in a separate note at the bottom of the first page together with the name of the institution which financially supported the project or programmed.

Tables and Illustrations

All the captions should be in the original language as well as in English, together with the texts in illustrations if possible. Tables are typed in the same style as the text and are denoted by numerals at the top. Photographs and drawings, placed appropriately in the text, should be clear, precise and suitable for reproduction. Drawings should be created in Word or Corel.

Citation in the Text

Citation in the text must be uniform. When citing references in the text, use the reference number set in square brackets from the Reference list at the end of the article.

Footnotes

Footnotes are given at the bottom of the page with the text they refer to. They can contain less relevant details, additional explanations or used sources (e.g. scientific material, manuals). They cannot replace the cited literature.
The article should be accompanied with a cover letter with the information about the author(s): surname, middle initial, first name, and citizen personal number, rank, title, e-mail address, and affiliation address, home address including municipality, phone number in the office and at home (or a mobile phone number). The cover letter should state the type of the article and tell which illustrations are original and which are not.

<u>**Address of the Editorial Office:**</u>

Enriched Publications Pvt. Ltd.
S-9,IInd FLOOR, MLU POCKET,
MANISH ABHINAV PLAZA-II, ABOVE FEDERAL BANK,
PLOT NO-5, SECTOR -5, DWARKA, NEW DELHI, INDIA-110075,
PHONE: - + (91)-(11)-45525005