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Performance Evaluation of Nala Bund

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Abstract : The study was undertaken during 2002-03 in Dadegaon waters in Paithan Taluka of Aurangabad District -and executed by Shikshan Prasarak Mandal, Aurangabad, to evaluate the performance of nala bund and to observe the effect of nala bund on ground water recharge. The results indicated that selection of site for nala bund was correct. The storage capacity of the nala bund as determined by organization is found insufficient with respect to the expected runoff volume trom the catchment area of nala bund. The storage capacity of nala bund was 19.60 TCM as against storage requirement from hydrologic analysis of 24.60 TCM. The upstream side slopes of the earthen embankment considered by the organization was found steeper 2.5:1 against the standard requirement of 3: 1. The gross height of nala bund was found over designed. The bottom width of nala bund was found under designed. The amount of silt deposited in nala bund was 178.14 tonnes over a period of three years. The rate of erosion observed in the catchment was found to be well below the permissible limit of soil erosion. On an average the water table in the wells in the zone of influence of nala bund was found higher by 1.54 m than the water table in the wells located in out of zone of influence.

Introduction

Soil and water are the basic resources essential for survival of human kind. Ironically speaking, very few people rely the importance of conserving and judiciously utilizing the soil, the greatest gift of nature. Soil without water is desert and water without useable land and living being is useless. In fact, every kind of farm activity, connected with land and prosperity of nation, depends on the prospect of land resources. Efficient management and utilization of these resources are very important to increase the crop production and productivity per unit area.

Water harvesting system consists of collecting and storing the excess runoff from the catchment area of a watershed in a suitable reservoir and its subsequent use for irrigation of crops. It can be achieved by gully plugging, construction of structures like farm ponds, small check dams, nala bunds, percolation tank etc. These structures are integral part of soil and water conservation activity and are important components of watershed development and management programme.

Nala bunding is comprehensive activity. Nala bunds are embankments constructed across nalas for checking velocity of runoff, increasing water percolation and improving soil moisture regime. In fact nala bunds and percolation tanks both terms are synonymous but still they are being called differently at different places. However the structures costing Rs. 5 lakh or more are mostly called as percolation tanks. Main objectives of nala bunding are to impound surface runoff coming from the catchments and stabilise the nala grade to facilitate percolation of stored water into the soil sub-strata with a view to raise ground water level in the zone of influence of the nala bund and to hold the silt flow which would otherwise reach the multipurpose reservoirs and reduce their live storage capacity.

The Department of Agriculture, Maharashtra State has constructed number of earthen embankments, commonly called as nala bunds, in order to conserve surface runoff under various soil and water conservation programmes. The department has its own norms for design to suit the field conditions and administrative procedures. However, such simplifications in the design may lead to improper design which may result in improper functioning, or some times failure. Therefore, the present study on evaluation of Nala bund in Dadegaon watershed was undertaken to verify the design of nala bund and to evaluate its performance.

Material and Methods

The study was undertaken during the year 2002-03 in Dadegaon watershed in Paithan Taluka of Aurangabad District which was executed by Lokshikshan Prasarak Mandal, Aurangabad during the year 1998-99. The watershed is located in the periphery of 70km to the east of Aurangabad. The Khandala watershed is of 622.76 hectares in size with the catchement area of nala bund of about 100.22 ha. The average annual rainfall of the area is 857 mm. The expected runoff volume during the life of structure, required to be stored in nala bunds, was determined from the estimated runoff depth from the catchment and catchment area of the nala bund. The expected rainfall was determined from frequency curve developed for the purpose. The design runoff volume was calculated by multiplying runoff depth and catchement area of nala bund. The expected runoff depth was estimated by using Inglis and Desouza's formula as

Where,

R = Runoff (m)

P = Precipitation (m)

Expected storage volume of nala bund

$$R = \left[\frac{p - 17.8}{254} \right] xp$$

was selected such that the storage losses should be minimum. Evaporation is one of the major source of storage losses. To reduce evaporation losses storage ratio was taken as 6:1(Tiwari, 1991). The storage ratio is ratio of sum of runoff volume and reservoir volume to the storage volume.

The net height of the embankment was selected such that the storage volume provided by the embankment is greater than or equal to volume of storage calculated. The gross height of the embankment was then calculated as, Gross height = Height of impounding water + free board + Consolidation height. Free board should be 15 per cent of high flood level or greater than height of waves. Freeboard for earthen embankment was then considered as 0.80m.Consolidation or settlement allowances were considered as 5 per cent of dam height (Singh *et al*., 1990).

Top width of Nala bund was calculated by using the equation $T = \frac{H}{5} + 1.5$

Where,

T = Top width of dam, m.

H = Gross maximum height of dam, m.

Top width was kept constant throughout the length of dam

On structures having height less than 15 m with average materials of construction, the side slopes should not be steeper than 3:1 on upstream sides and 2:1 on downstream sides (Schwab *et al*., 1981). The maximum base width was at maximum height of dam. Thus, the equation of base width used, for 3:1U/S slope and 2:1 D/S side slopes, is

B=5H+W

where,

B = Maximum base width of dam, m.

H = Gross height of dam, m.

W = Top width of dam, m.

The cross-sectional area of dam was calculated by using formula (Singh *et al.*,1990).

$$A = \frac{(W + B)}{(2)} \times H$$

Where,

A = Cross-sectional area of embankment, m^2.

W= Top width of embankment, m.

B = Bottom width of embankment, m.

H = Gross height of embankment, m.

Emergency spillway was designed to pass safely the peak flow of runoff. The peak runoff rate from the catchment area of nala bund was estimated by using Rational method

$$Q = \frac{CxIxA}{360}$$

Where,

Q = Peak runoff rate, m^3/s.

C = Coefficient of runoff.

I = Average intensity of precipitation for a duration equal to time of concentration, mm/hr.

A = Drainage area (ha).

Co-efficient of runoff 'C' was computed by taking into consideration the soil texture, vegetative cover and slope (Singh *et al.*, 1990). Average intensity of precipitation for duration to time of concentration was calculated by using intensity-duration-return period relationship.

$$I = \frac{KT^a}{(t_a+b)_a}$$

Where,

I = Average intensity of precipitation cm/hr.

T = Return period, years.

t_c = Storm duration, hrs.

k, a, b and n are constants.

The values of these constant for Aurangabad region were selected as recommended by Singh *et al.* (1990) as K=6.081,a=0.1459,b=0.5 and n=1.0923.

Time of concentration of the catchment area of nala bund was estimated by Kirpich's equation (Suresh, 1998).

$t_c = (0.00032) \times L^{0.77} X S^{-0.385}$

Where,

t = Time of concentration, hours.

L = Length of channel reach, m and

S = Average slope of channel reach, m/m.

The dimensions of emergency spillways, considering rectangular section, were determined using,

$Q = C \times L X h^3/_2$

Where,

Q = Discharge, m^3/s

C = A coefficient, dependent on the nature of crest and approach condition (C= 1.77)

L = Length of crest, m.

h = Height of water above the crest, m.

The dimensions of spillway were selected such that the discharge through spillway is greater than or equal to peak flow of runoff estimated.

The present dimensions of the structure i.e. top width, bottom width, height and cross-sectional area were recorded and compared with the initial dimensions for determining the per cent change in different dimensions of the structures. The data on silt deposition i.e. depth of silt deposited in the storage area and area of silt deposition were collected. Volume and weight of the silt deposited were determined for evaluating the efficiency of the structures with respect to retention of soil loss from the area. To evaluate the influence of earthen nala bund on ground water recharge levels in the wells were recorded. Some open wells were selected in the zone of influence and some in out of zone of influence of nala bund.

Water levels in each well were recorded monthly from the month of June to March during the year 2002-03, with respect to fixed point marked on the top of each well with the help of tape.

Results and Discussion

The details about present dimensions of Nala bund, dimensions as per standard requirement were collected and compared. Stability analysis and performance evaluation were also carried out. The information on location, catchment area, nala bed slope, width and depth of nala, spillway dimensions and wells in the zone of influence and out of zone of influence was collected from project report of respective watershed development project. Data regarding the site conditions of nala bund in watershed have been presented in table 1.

It is seen from table that the catchment area of nala bund was greater than 40 ha and average nala bed slope was less than 2 per cent, nala width was between 5 to 15m and depth of nala was more than 1 m similar to the conditions stated by Singh *et al*.(1990). Hence, it can be concluded that the selection of site for nala bund was correct. The storage volume required as per hydraulic analysis of the catchment and storage ratio was worked out as 24.60 TCM as against the stored volume of the existing Nala bund of 19.60 TCM. Thus, the designed nala bund was found to have insufficient storage capacity. The overall dimensions of the nala bund at maximum depth are presented in table 2. For an earthen embankment of nala bund of watershed Khandala, gross height was determined as 2.70 m after considering full supply level of stored water, freeboard and consolidation. However, the gross height determined and considered for construction by organization of the project is 3.80m. The organization has considered a catchment area of 100.22 ha and the actual runoff contributing area is also 100.22 ha. The FSL of 1.1 m was considered by the organization whereas FSL by 6: 1 storage ratio was worked out to be 1.90 m. Top width for Nala bund was worked out as 2.00 m, whereas existing top width is 1.30 m., i.e. top width is under estimated. For the embankment under consideration, the side slopes of 3:1 on upstream and 2:1 on downstream side were proposed. However, the existing slopes were 2.5:1 on upstream and 2.5: 1 on downstream side. Maximum bottom width was worked out as 15.54 m, whereas, the existing one was 10.80 m. The bottom width as per standard requirement was more due to more design height and upstream side flatter slope as compared to existing nala bund.

The lesser base width of earthen embankment of nala bund has resulted in intersecting the downstream face by seepage line and consequent scouring of soil from the toe of the downstream face. The cross section of earthen embankement of Nala bund are shown in fig. 1. The expected peak runoff rate for the catchment of nala bund was worked out as 10.25, m3/sec. Where as that reported by organization was 6.94 m^3/sec. This is because the organization has considered the catchement area of 100 ha, rainfall intensity of 50mm/hr and coefficient of runoff as 0.50. Using rectangular weir formula, the length of crest and height of spillway were worked out and presented in table 3. The capacity of spillway was found less (8.32m^3/s) estimated (9.52 m^3/s) than the peak flow rate and therefore the design dimensions of the spillway are insufficient. The velocities of flow were within the limit of non-erodible velocity i.e. 0.75 to 1.8 m/s (Chow Ven Te, 1985). The length of crest and height of flow over the crest are shown in table 3. The designed

Table 1. Details about site condition of nala bund

Watershed	Catchment area(ha)	Average slope of nala bed	Number of wells	Width of nala(m)	Depth of nala (m)
Dadegaon	100.22	1.0	2	13	3

Table 2.Dimensions of nala bund designed by organization and as per standard requirement

	Dimensions of Nala bunds designed by organization and by standard requirement									
Dimen-sions	Height FSL	Free board (m)	Height of dam (m)	Consoli dation(m) (m)	Gross height (m)	Top width (m)	U/S Slope H:V)	D/S Slope (H:V)	Bottom Width (m)	C/S area (m^2)
Org.**	1.1	1.0	2.10	0.70	3.80	1.30	2.5:1	2.5:1	10.80	22.99
Std. Reqd.*	1.9	0.80	2.70	0.13	2.70	2.0	3:1	2:1	15.54	23.75

*As per standard requirement. ** Organization

flow depth for the nala bund was worked out as 0.80 m and flow depth as per organization is 0.70 m. This has resulted in lesser depth available to flow of water. The carrying capacity of spillway by organization is less than the peak flow rate calculated from Dadegaon nala bund. This has resulted in spilling over of water from top of sides of spillway and sub sequent collapse of the sides and widening of the spillway crest.

The dimensions of nala bund and spillway have been presented in table 4 and table 5, respectively. It is found from table that, the cross-sectional area of earthen embankment was reduced by 8.00 percent within three years period due to shrinkage and consolidation. The height of the earthen embankment was reduced by 21.05 per cent over three-year period. The average settlement of this embankment thus worked out as 21.05 per cent. At this stage the consolidation of the embankment has completed and attended a stable height. Thus for the soils of Aurangabad region, an allowance for settlement more than 21.05 per cent may be recommended. The data on silt deposited at earthen nala bunds during three years period have been presented in table 5. The data reveals that the nala bund constructed in Dadegaon watershed has arrested 178.14 tonnes silt, indicating that the watershed development activities i.e. earthen water harvesting structures (nala bunds) are found to be effective with respect to prevention of soil in the watershed rather than to go out with runoff water. The rate of erosion observed in catchment is found to be well below the permissible. limit of soil erosion. (4.5 -11.2 tonnes/ha/year). The water levels in the wells were measured monthly during the period of June-2002 to March-2003. The well observations are presented in table 6. It is seen from the fig.2 that the ground water level was rising from June to September and thereafter falling gradually, in case of all observation wells in the zone of influence and outside influence area. It is observed that the ground water level is highest during the month of September. The data on silt deposited at earthen nala bunds during three years period have been presented in table 5. The data reveals that the nala bund constructed in Dadegaon watershed has arrested 178.14 tonnes silt, indicating that the watershed development activities i.e.earthen water harvesting structures (nala bunds) are found to be effective with respect to prevention of soil in the watershed rather than to go out with runoff water. The rate of erosion observed in catchment is found to be well below the permissible. limit of soil erosion. (4.5 -11.2 tonnes/ha/year). The water levels in the wells were measured monthly during the period of June-2002 to March-2003. The well observations are presented in table 6.

Table 3. Spillway dimensions

Length of crest (m)		Height of water over crest (m)		Discharge (m^3/S)		Velocity of flow ways	
Std. Reqd.	Org.	Std.Reqd.	Org.	Std. Reqd.	Org.	Std. Reqd.	Org.
9	9	0.8	0.7	11.39	9.32	1.58	1.47

1) Cross-Section as per standard design

2) Cross- Section of Nala bund adopted by department of agriculture

Fig. 1. Cross sections o Nala bund at Dadegaon (W_1)

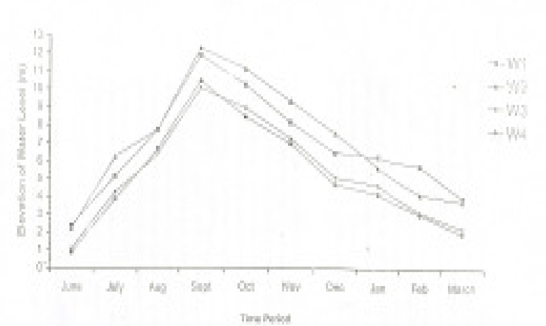

Fig.2.Typical well hydrographs showing fluctuations of water level in observation wells (1 &2)in the influece area and (3&4) outside the influence area at the experimental area (W1)

Table 4.Designed and Present dimensions of Nala bund

Water shed	Designed dimensions: Height (m)	Top width (m)	Bottom width (m)	C/S area (m^2)	Dimensions in year 2002-03: Height (m)	Top width (m)	Botton width (m)	C/S area (m^2)	Percent reduction in cross section	Per cent reduction in height
Dade gaon	3.80	1.30	10.80	22.99	3.00	0.40	13.20	21.15	8.00	21.05

Table 5. Silt depositions in earthen embankment

Average depth of siltation	Area of silt deposition	Volume of silt deposition	Bulk density	Weight of silt deposition	Erosion rate Tone/ha/year
(m)	(m^2)	(m^2)	(g/cc)	(tonnes)	
0.345	344;25	118.76	1.5	178.14	0.59

Table 6.Monthly water table in wells located in the area of influence and outside area of influence of Nala bund, Dadegaon during 2002-03

Area	In the influence		Outside the influence	
Well number	1	2	3	4
Well depth(m)	12.30	13.30	12.0	11.00
June	2.40	2.20	1.10	0.90
July	5.20	6.30	4.30	3.90
August	7.20	7.90	6.50	6.80
September	11.90	12.30	10.10	10.50
October	10.30	11.20	9.00	8.50
November	8.20	9.40	7.30	7.00
December	6.5	7.60	5.10	4.70
January-2003	6.30	5.70	4.70	4.20
February	5.80	4.20	3.20	3.10
March	4.00	3.80	2.30	2.00

It is seen from the fig.2 that the ground water level was rising from June to September and thereafter falling gradually, in case of all observation wells in the zone of influence and outside influence area. It is observed that the ground water level is highest during the month of September. This may be due to receipt of a considerable amount of rainfall during the period July to August. After September, the ground water level gradually decreased in all the observation wells. This may be due to withdrawl of monsoon towards end of September and withdrawal of water from groundwater table for irrigation and ground water flow also. It is also observed that in the influence area (observation wells i.e. 1 and 2) there is more ground water recharge than the outside influence area (observation wells i.e. 3 and 4). This is due to the impact of earthen embankment constructed above the observation wells 1 and 2.

Hence, it may be concluded that selection of site for earthen nala bund was correct. The storage capacity of the nala bund as determined by organization is found insufficient with respect to the expected runoff volume from the catchment area of nala bund. The storage capacity of 9.60 TCM was observed as against storage requirement from hydrologic analysis of 24.60TCM .The upstream side slopes of the earthen embankment (nala bunds) determined by organization were found steeper 2.5:1 against the standard requirement of 3: I.The gross height of nala bund determined by the organization was found over designed. The bottom width of nala bund determined by the organization was found under designed. This has resulted scouring of the soil from toe of the nala bund. The required carrying capacity of the spillway was found under designed. This has resulted in widening of the spillway and gully formation at the spillway. The amount of silt deposited in nala bund was 178.14 tonnes over a period of three years. The rate of erosion observed in catchment was found to be well below the permissible limit of soil erosion. (4.5 -11.2 tonnes/ha/year). On an average, the water table in the wells in the zone of influence of nala bund was found higher by 1.54 m than the water table in the wells located in out of zone of influence.

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