

A draft report on
Cement nala bund planning protocol



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Introduction

Palghar region, which is the area of our study, receives an average annual rainfall of around 2500 mm and is simultaneously subjected to water scarcity every year from the month of February. The reasons behind this scarcity are topographical and hydrogeological. The area has several hilly regions, regions with high slopes, and a predominant basaltic geological substrate which causes around 70% runoff and limits the water conservation interventions. While several attempts are being made and planned to address this situation (dams, pipe water schemes, regional water schemes, tanker supply, rain water harvesting), an important activity for water conservation at the village and block level is that of watershed management.

A definition of a watershed is that it is the area from which surface water and groundwater flows in to a stream, with streams in turn merging to form large flows. The extent of the area, coupled with the rainfall and geology of the area determines the capacity of water available for the region. Watershed management implies the proper use of all land and water resources through set of interventions. Watershed interventions are aimed at reducing the flow of water (and hence control erosion), storing water for recharge and later use, improve groundwater infiltration etc.

An important watershed intervention is the cement nala bund which is built on the mainstream/nala. A cement nala bund (CNB) is a bund/obstruction across the nala or stream constructed by using cement concrete to obstruct and store the flowing water.

Cement nala bunds are also referred to a few other names---pukka bund, check dam, weir.

A CNB serves two important purposes,

I. Recharge and source strengthening

Surface water stored in a CNB can act as recharge resource for wells in close proximity and downstream to the CNB. The infiltration and groundwater flow of the stored water keeps the base flow of the wells available for longer.

II. Surface water storage

CNBs impound water, and in turn can also control the speed (in local regions) of water flow through a nala during the monsoon season. The stored water is a critical surface water resource for several irrigation-based livelihood activities, for domestic needs and for livestock.

This document discuss details about the important steps that are required towards planning the CNB intervention.

Structural Components of a CNB

Cement nala bund is the intervention which has numerous types based on site location, implementation agency and funding available. There is standard-traditional components of the bund which is followed by all government officials without gates or vents, where cost is the limiting factor.

A cement nala bund has the following main structural components,

- **Main body**
To obstruct the water flow, carry water pressure
- **Flank wall**
To ensure stability of the nala side embankments.
- **Wing wall**
To prevent the water entry into farmlands.
- **Apron & cushion**
To prevent the nala erosion at the upstream side when water overflows

A typical section view and top view of a CNB are as show in the following figures.

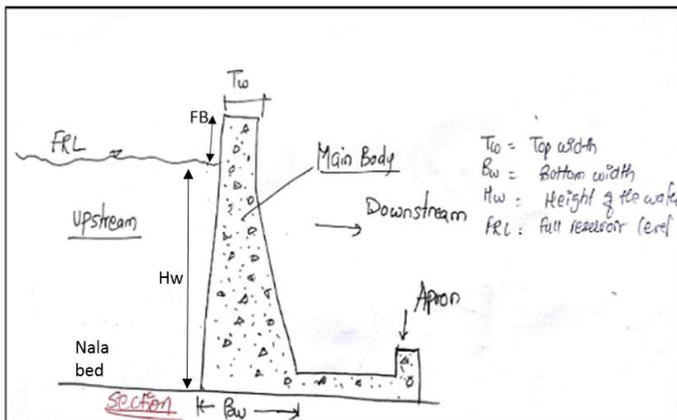


Figure 1. Section of the bund

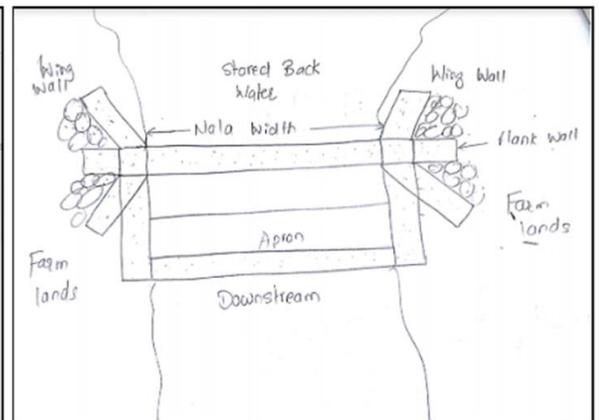


Figure 2. Top view of the bund

Note the following points from the figures,

- A typical section of the bund is having design components like main body of the bund with top width (Tw), bottom width (Bw) and desirable water height (Hw) as shown in Figure 1.
- While designing the bund capacity, the height from the nala bed to which water can be stored is the Fill Reservoir Level (FRL). A buffer height to account for sudden and rapid changes in water levels is maintained between the FRL and the height of the bund and is

known as the free board (FB). Typically, the free board is 0.3 to 0.5m, depending on the upstream topology for storing the backwater.

- The main body and the apron of the bund is are a monolithic construction. The water cushion upto the apron protects the bund from seepage and erosion of the nala on the upstream side.
- The portion of the side embankments where wing wall and flank wall joins is filled with impervious strata like loose boulders and sandy soil to avoid the water entry into adjacent farm lands as shown in Figure 2.

Stepwise procedure for determining location a cement nala bund

Following is a sequence of steps for determining a possible location for constructing a CNB,

Step 1: Procuring the recharge priority map to understand location and characteristics of stream flows

Step 2: Identification and classification of streams

Step 3: Identification of existing assets within village boundary

Step 4: Verification of drainage map markings with intended purpose of storage

Step 5: Determining potential location of the bund

Step 6: Validating the tentative bund location based on design principles

Details of each step are as follows.

Step 1

Procuring the recharge priority map to understand location and characteristics of Stream flows

The objective of this step is to develop an understanding of the drainage pattern of the working area. The recharge priority map on which the small drainage streams with farmer's land plot number and plot boundary is available

Following is a recharge priority map of the Pathardi village in Mokhada.

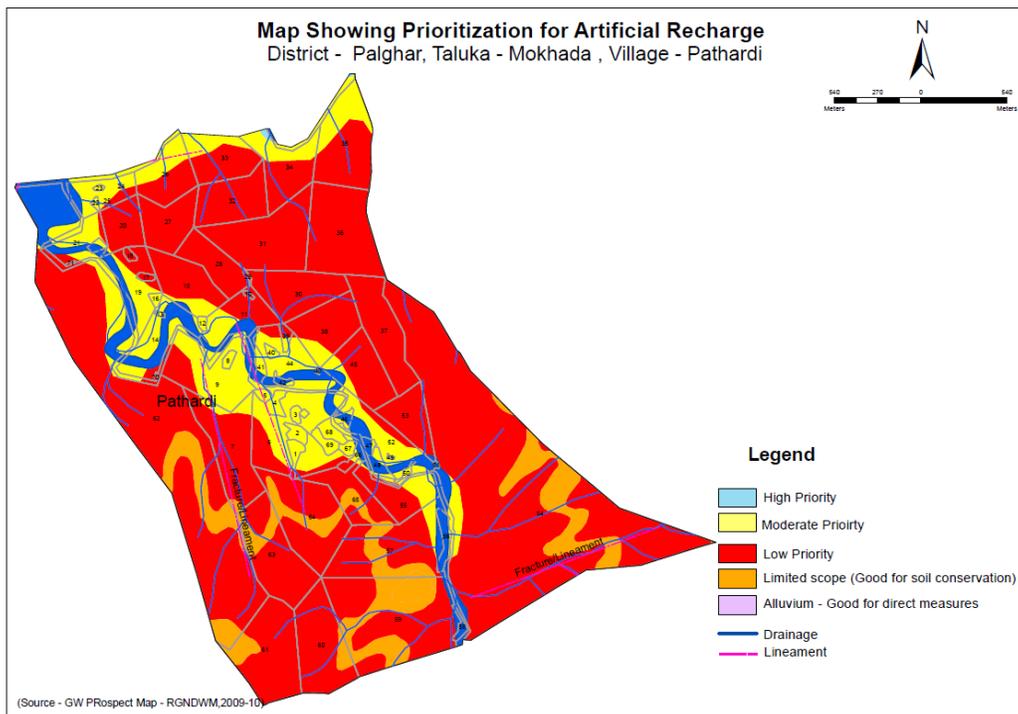


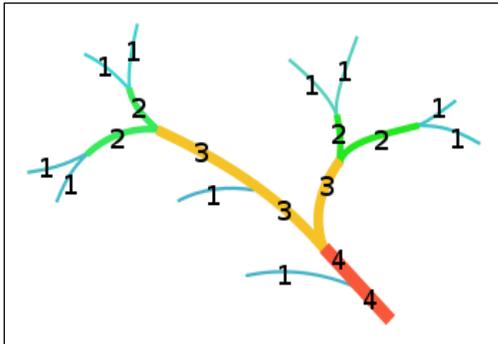
Figure 3. Recharge priority map for Pathardi village

This map is color coded based on different recharge capacity of the soil strata. A list of legend is always provided in the map which is self-explanatory, as can be seen in the figure 3. For example, the red color shows low recharge capacity zone, which is usually, area of high elevation where most of the small streams originate. Thin blue lines are the small streams/nalas which become thicker as more and more small streams join to become major streams. Yellow portion, which is of moderate recharge capacity are generally a transition from the hilly region to low lying near river area. Mostly these are cultivable lands.

- Activity: download the recharge priority map from the web link <https://gsda.maharashtra.gov.in/english/index.php/GWRechargePriorityMap>
- Output: Recharge priority map with village boundary.

Step 2

Identification and classification of streams and its order on the drainage map



Streams are classified into different orders based on their flows, width from ridge to valley. The stream originating in the ridge area is termed as 1st order stream. This smaller stream meets to other smaller streams and becomes a 2nd order stream of the stream. Two streams of the same order merge to create the next order stream, e.g., two 1st order stream merge to form a 2nd order stream. A first order stream and a second order stream merge to remain a second order stream.

For a bund to be constructed, sufficient quantity of runoff is required for impounding. Second order and third order streams usually meet this criteria.

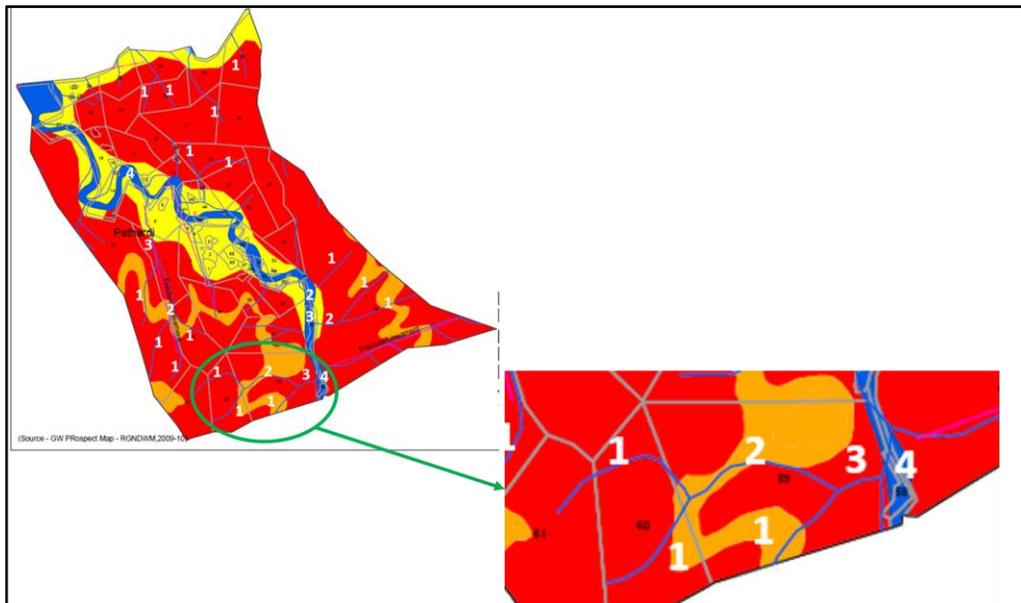


Figure 4. Mapped stream order

Figure 4 is the marked stream orders on the recharge priority map. The stream originating from the hilly area is marked as 1st order streams. Meeting of these two 1st order small streams joins to form a 2nd order of the stream and so on. The all above are meeting to the mainstream which of 4th order. In the same manner, Identify and mark for the entire map.

- Input: drainage map downloaded from the site
- Output: drainage map marked with major stream classified in order

Step 3

Identification of existing assets within village boundary

Village specific assets related to drinking water and watershed includes existing wells, bunds, stream location with these interventions, village road, agricultural and forest land area distribution. This is to understand the number and type of interventions spread within the village. It is also important to consider the land ownership based on the revenue map available at the Talathi office. Currently, there is no availability of consistent records of the existing drinking water and watershed assets within the village.

Before going to the village, it is possible to identify and find these assets using a satellite image (via Google Earth or similar software tools). For finding and locating these interventions, few simple steps are to be done. The shapefile of the village boundary is to be superimposed on google earth pro. Mark the points of these assets as shown in Figure 5. Shapefile of villages in Palghar district are available and can be requested on the following email address tdsc.iitb@gmail.com.

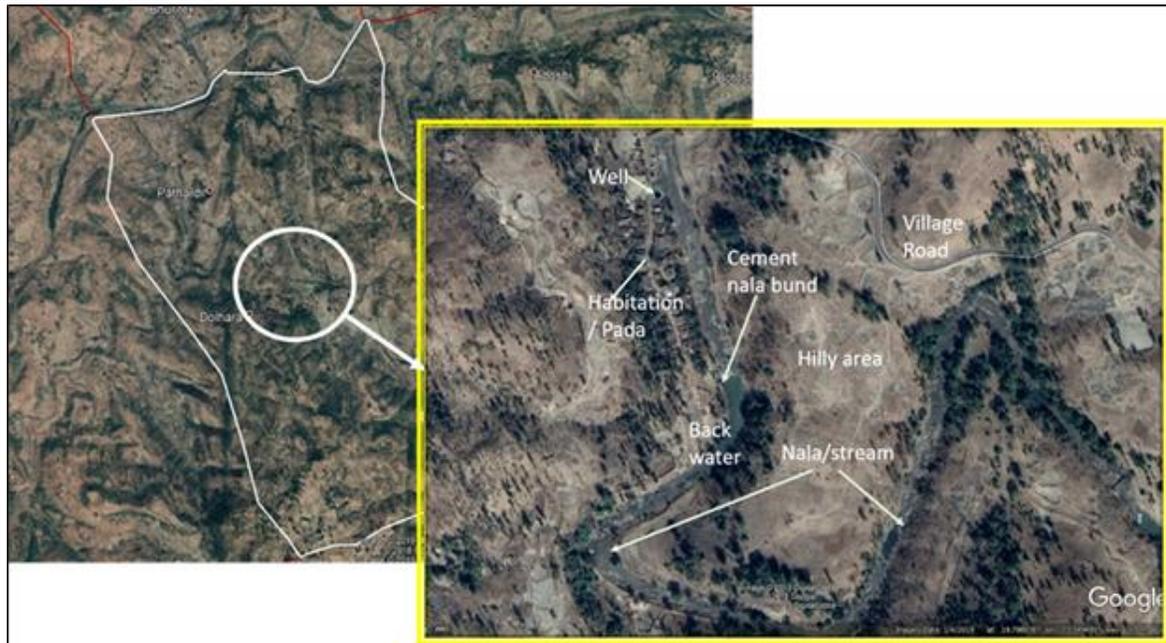


Figure 5. Drinking water and watershed assets identification on a satellite image.

The above image is a satellite image (via the Google Earth software) which shows village boundary and the zoomed out area show the nala (it's direction) with the assets marked on the map. Habitation layout, well, cement nala bund, back water storage, village roads etc. can be seen from the satellite image.

- Input: Marked streams with their orders on the map
- Output: Identified village assets on the map with reference to the river/nala source

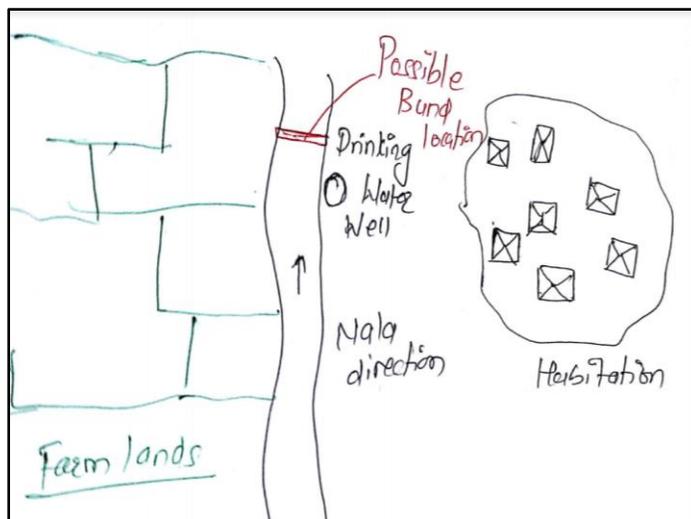
Step 4

Verification of drainage map markings and intended purpose of usage

Location of the bund is to be fixed with consideration of possible utility to the nearby villagers/farmers/ such as wells on upstream or impounded water. The identified streams over the map is to be verified on the field. Ground truthing is very much important as they might not be exactly as shown in the map. For the confirmation and verification of the streams on the map, it is suggested to conduct a transect walk across the village (Shivarpheri). This is to be done with conducting the basic introduction of yourself to the village group at gavthan. This meeting should clearly specify the intention and purpose of the visit. Shivar pheri (a transect walk) is to be conducted to mark following on a village map and also using a GPS tool.

1. The existing drinking water and watershed assets
2. Streams
3. Agricultural and forest areas of land
4. Water based demand and purpose
5. Interventions in upper reaches on the nala etc.

While mapping the streams it is important to understand the purpose of the bandhara will fulfill after construction within the village. Bandhara is to be constructed to obstruct the runoff and it is expected to have its possible utilization to nearby farmers. The impounded water percolates depending on the strata available at its storage zone. Further, siltation in the nala can be understood based on the number and type of existing interventions on the upper reaches. Silt trapping interventions such as loose boulder structure, contour trenches, terracing etc. usually constructed at the upper reaches.



It is important to identify the drinking water well near to the habitation as shown in the Figure 6 as well as farm lands adjacent to the bund. Bund construction near to well and farm land will directly help to increase the well water level and water usage for agricultural crops.

Considering such points into consideration and understanding villagers' demand, 4-5 possible locations are to be marked on the map for the further reference.

Figure 6. Purpose identified location of possible bund

As you can see in the Figure 6, there is a well at the upstream portion of the bund. And there is a habitation, locating near to the bund. Thus in above case, identification of the existing well water got recharged due to impounded water and this well is the primary well for the drinking water purpose which is near to the habitation. These important aspects are considered as shown in the figure while selecting the bund location with respect to its purpose.

- Input: Marked streams and land areas on map
- Output: Selection of suitable nala according to the purpose

Step 5

Determining potential location of the bund

There are few important technical design principles of the bund location to be fixed on the nala relative to well and farming plots. Those are listed below

1. Nala width should be between 5m to 50m, relative narrow width in particular
2. The slope of the nala bed should be less than 3% (refer to Annexure for nala bed slope measurement procedure)
3. Nala section height should be 3m-4m, minimum top width should be 0.45m
4. Side embankment of the nala should be strong enough and not loose material to ensure the stability
5. Identify the point for the maximum backwater length of the stored water (where slope becomes zero with the nala bed) (refer to Annexure for the explanation)
6. Do not select the nala site which has curvature
7. Soil strata should not be highly permeable
8. Locate the material and transportation is possible easily
9. Distance between two bunds should be more than 500m

Considering this above factors, fix best locations and take GPS location and photographs of the site from all the sides (upstream, downstream). Format of this is attached in the annexure.



Figure 7. Nala selection showing the curve and width criteria to be taken care of (Source: watershed development booklet under MGNREGS)

Bund construction on sharp curve will cause heavy nala erosion as shown in the left side of the Figure 7 and the right image is the selection of the narrow nala width rather than broader nala width.

- Input: Nala sites with possible purpose
- Output: Fixed and marked bund locations site which is technically sound.

Step 6

Validating the tentative bund location based on design principles

The data collected from the field visit for tentative location each bund has to transfer to excel sheet. Extract the locations from GPS device and locate those on google earth pro. Validate the slope, backwater length, bund surroundings, relative elevations etc. from the collected data from field visit also estimate the storage capacity by the relation explained here. Choose the best location of the bund based on all the design principles and storage capacity.

Bund storage capacity is calculated using following approximation,

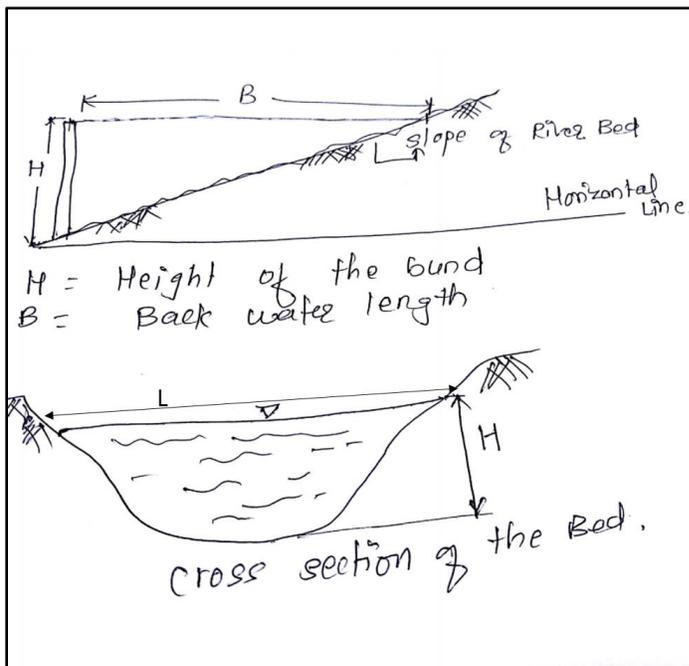


Figure 8. Storage capacity with backwater length

$$V = 0.5 \times B \times H \times L \times k$$

where,

B = Backwater length in meter
H = Height of the bund in meter
L = Length of the bund in meter
K = Factor of safety (0.4 to 0.8)

Out of this all fix the 2-3 locations and propose for the construction to the implementing agency.

- Input: Locations of few bund locations marked on map which are technically sound on site
- Output: Storage capacities at potential locations, and a short list of most likely locations of the bunds.

Issues with standard CNB in Jawhar-Mokhada region

There are bunds in the region which found with siltation frequently which causes reduction in the storage capacity and affects the life of the bund.

Vented CNB- solution

Gates or vents are the openings provided into the main body of the the bund. Vents to be opened during monsoon season to de-silt the structure. To be closed at the end of the monsoon season to enable storage to build up. While looking for the successful interventions in this area, we found that Vented CNB constructed by AROEHAN which sustains water in summer. The vents are to be operated by the appointed farmer/villager.

Observations regarding vented CNB constructed by AROEHAN

- Bunds with vents for semi-automatic de-silting
- These are best for impounding water within the stream area extending stream life
- These vents are flanged for ease of operation
- Requires vents depending upon the length and cost varies with it

Procedure to construct the vented CNB

- After fixing the location for the bund, next step is to level the ground. In this region of the basalt rock bed strata blasting leads to the seepage of water through cracks.
- If there is water accumulation in the stream then dewater and start the construction
- Cement slurry layer is to be laid over the length and width of the foundation.
- The next step is to reinforce the desired diameter of bars are specified distance and start concreting.
- The number of vents depends on the length and other location-specific characters
- Generally, 1m diameter of steel vent is placed at the bottom of foundation which is to be fixed in cement concrete layer
- The layer of cement slurry is to be laid for all part of the bund to avoid the leakage and to give stability
- Side walls and key walls are to be anchored into side embankments
- The vent is an opening into the main body of the bund it may reduce the structural stability if not constructed fixed correctly. Many times small trapezoidal key wall is constructed at some intermediate distance for ensuring the stability.



Figure 9. Some images of vented CNB constructed by AROEHAN.

Some details of vented CNBs by AROEHAN

1. Bund details- Anchored Random Rubble Masonry (RRM) & mass concrete bund of dimensions (30x4.57x2.43)m, Wing wall (38.1x3.05x0.45)m
 - Vent details- 3ft diameter of total 6 number of vents
 - Cost - Rs. 20 lakhs
2. Bund details - Anchored Random Rubble Masonry(RRM) & mass concrete bund of (28.95x3x1.9)m, Wing wall (38.1x3.05x0.45)m
 - Vent details - 3ft diameter 4 number of vent
 - Cost- Rs. 12 lakhs

Annexure

A.1 Nala bed slope measurement procedure

Measuring slope of the stream/nala for the decision of fixing the possible intervention like CNB/ENB on the field to maximise the storage capacity and reduce the structure failure due to rapid water flows. There are few simple methods by using those we can measure the slope of ground. Few of them are explained here.

We know that,

Slope in % = $\frac{\text{Height (Vertical distance)}}{\text{Horizontal distance}} \times 100$

The pipe level

We need some locally available material to prepare the simple tool called Hydro marker to measure the slope. This is also called as the tube level or pipe level.

- Two wooden or aluminum planks/plates of 1.5 m height
- Thin, transparent pipe, about minimum 10 to 15 m long and 10mm thick
- Fine thread or transparent adhesive tape
- Fixtures etc.

It may take just two hours to prepare this. It will look like below image before ready to use.

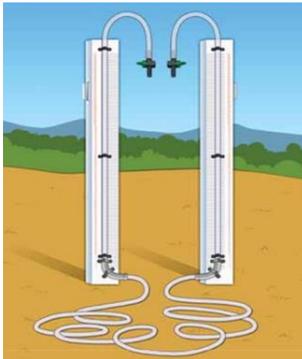


Figure 10. Hydro marker (source: Booklet of how to prepare hydro marker from Pani Foundation)

There are other surveying instruments that can also be used but not explained here.

Procedure:

1. Suppose we want to calculate the slope between two points A & B. Keep one plank/rod scale S1 of the pipe level at point A. Then move S2 to point B.
2. Take the water level readings in both scales. Remember that the readings have to be viewed from the bottom to the top and not from the top to the bottom. Also keep in mind that point B should not be higher than the height of scale S1 otherwise water will spill out of the pipe at S1.
3. This should be remembered particularly when we are trying to calculate the slope. Take down the water level readings on both the scales and calculate the difference between the two readings.
4. This is the vertical interval or elevation between points A and B. Also find out the horizontal distance between the two points.

- This is known as the horizontal interval between points A and B. Now keeping S2 where it is (i.e., at point B'), shift S1 to point C, is at a higher elevation than point B.
- Once again find out the difference in water level readings in S1 and S2. Also find out the horizontal interval between B and C. Repeat this procedure until you reach the desired point

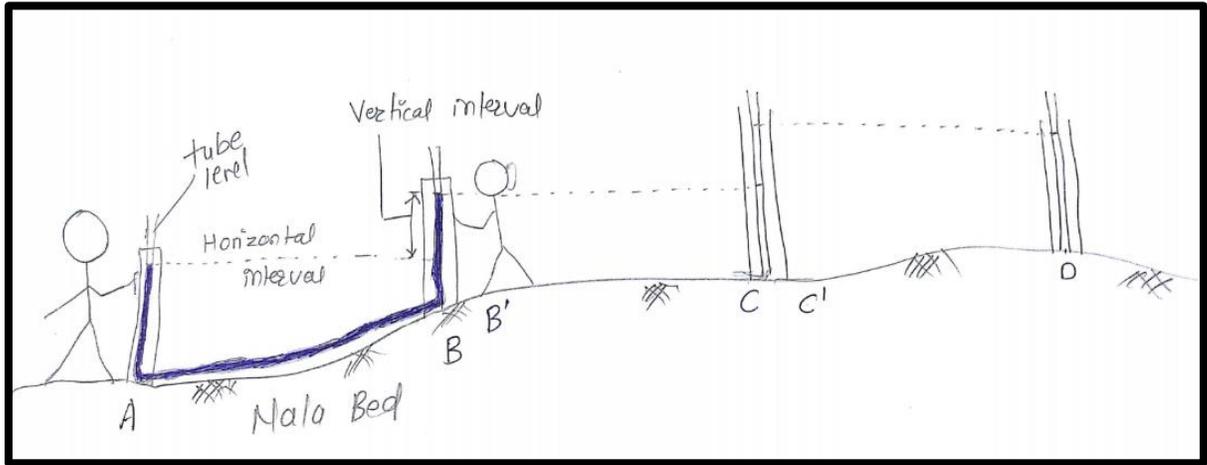


Figure 11. Calculating slopes with pipe level

Here is one example for estimation of the bund storage capacity at habitation with measured

X = Horizontal distance between two points

Y = Vertical distance from ground level upto water level of the pipe

Referring to the table, A, B, C, D are points observed on the field

B' and C' = readings on same point for next consecutive reading

Example field observation using pipe tube level						
Points	A	B	B'	C	C'	D
X (cm)	0	1080	0	1100	0	1090
Y (cm)	133	118	126	117	132.5	101.5
X2 -X1 (cm)	1080		1100		1090	
Y2 -Y1 (cm)	-15		-9		-31	
Slope (%)	-1.31		-0.8		-2.8	
Length of nala section (m)	11.5	8.4		7.3		8.5

Volume of water CNB can store = $0.5 \cdot L \cdot B \cdot H \cdot 0.5$ (Assuming H, vertical height of CNB as 2m)

Slope in (%) = $H/B \cdot 100$, A is the point where bund section is to be fixed

For the current nala be, average slope is 1.68%, B is backwater length in m, L is the length of bund

Thus, $1.68/100 = 2/B$, B = 119.04m,

Volume of water stored = $0.5 \cdot 11.5 \cdot 119.04 \cdot 2 \cdot 0.5 = 684.5 \text{ m}^3$

A.2 Some field photographs



Figure 12. Bund components (Source: Field visit to Wada taluka)



Figure 13. Nala slope measurement (Source: Field visit to Pathardi village Mokhada taluka)

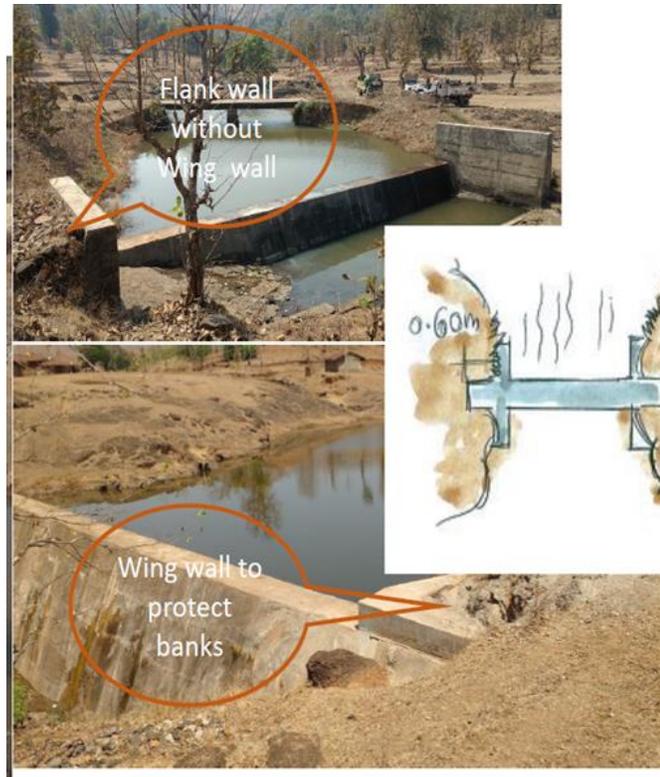


Figure 14. Flank wall and wing wall position of the bund (Source: field visit to some village of Mokhada taluka)