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FARM PONDS : A Climate Resilient Technology for Rainfed Agriculture

Planning, Design and Construction

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FOREWORD

Water harvesting is one of the key components of successful rainfed farming in semi-arid regions. Harvesting surplus runoff in dug out ponds and recycling the same for providing supplemental irrigation to kharif crops or pre-sowing irrigation to rabi crops has proved to be the most successful technologies for adoption. CRIDA and many its partner institutions have demonstrated the potential of this technology across India for several years. Water harvesting becomes all the more relevant now in view of the recent increase in the extreme events wherein heavy rainfall is occurring in few days followed by long dry spells. Under such circumstances, the only answer is harvesting the surplus runoff during high rainfall events and using the same during dry spells for critical irrigation.

Although the farm pond technology is well known in the country, its adoption has been quite low due to number of constraints like high initial cost, short life of the lining materials, lack of suitable lifting systems and above all low awareness among farmers about its utility and cost benefit analysis. There is also lack of authentic literature on the design and performance of farm ponds in different agro ecological zones and soil types. Several programs of the Government of India like RADP (Rainfed Area Development Program), NHM, MGNREGS and IWMP have farm pond as one of the important components. The field staff involved in the implementation of such schemes often face difficulties in designing these structures at a given site considering the rainfall, slope and soil characteristics. Considering this critical gap, this bulletin on farm ponds has been prepared covering all aspects of the design, utilization and cost economics. It is based on practical observations and study at Gunegal Research Farm of CRIDA for more than 2 years. It also provides information on catchment and cultivable area ratios and methods of construction and lining of farm ponds.

I hope the bulletin will be very useful to the engineers and other field staff involved in the above programs. I compliment Dr.K.S.Reddy and his team for coming out with such a useful publication. The feed back from all stakeholders will be most welcome for improving the contents and bringing out a second edition.

B. Venkateswarlu

B.VENKATESWARLU
Director, CRIDA

PREFACE

Rainfed agriculture constitutes 55% of net sown area in the country. The annual average rainfall of the country varies from 400 to more than 2000mm varying in both space and time. In low to medium rainfall rainfed regions, the occurrence of high intense rainfall events with the short duration are very common causing the soil erosion. Hence, the efficient rain water management is necessary to improve water productivity and protect the natural resource base in rainfed regions. Farm pond technology has very good potential for implementation in different schemes of state or central government. The present technical bulletin addresses the issues based on practical experiences with respect to planning, design and construction of farm ponds.

The authors are indeed grateful to Dr. A. K. Singh, DDG (NRM), ICAR, New Delhi, for his constructive suggestions during his visit to GRF. We are also thankful to Dr G. R. Korwar, Head, Division of Resource Management, CRIDA, Hyderabad for his guidance and cooperation for undertaking the construction of farm ponds at Gunegal Research Farm. Some of the Scientists namely Dr. V. Maruthi, PS (Agronomy), Dr. Gopal Krishna Reddy, Scientist (Horticulture), Dr. P. K. Mishra, Director, CSWCRTI, Dehradun, have provided data related to critical stages and rainfall for whom we are thankful and grateful. We also acknowledge the support and suggestions in pond lining given by Er. G. V. Ramana Reddy, M/s Sagar Agro Services Centre, Nalgonda.

We are also indebted to the field personal working at Gunegal Research Farm, namely Sri V. Sreeramulu, Farm Superintendent (T9), A. Chandraiah, (T3), Sri B. Kurmaiah, Field Technician (T1), K. Rajeshwar, (T1), P. Ramakrishna, Skilled worker and other staff like SSGs, Temporary staffs labours etc for their whole hearted support and cooperation in the execution and lining of farm ponds at GRF.

Lastly, the authors acknowledge the support and encouragement given by the Director, CRIDA and Principal Investigator, NICRA project. The support and help rendered by the administrative staff and finance departmental staff for publication of the present bulletin is fully acknowledged.

- Authors

Farm Ponds : Design, Planning and Construction

Introduction

Rainfall is a basic resource for all the forms of water in semi arid tropics of India. Though the annual average rainfall of the country is 1200 mm, it varies in both space and time affecting the availability of water for different sectors. India uses 80% of the available water in agriculture keeping the remaining 20% for drinking, industry and energy sectors. The growing population puts tremendous pressure on the water resources. The annual per capita water availability has decreased from 5000 m^3 in 1950 to 1300 m^3 in 2010 and projected to decrease further to below 1000 m^3 by 2025 (MOWR,2011). Added to this, the country may face climate change in future predicting more frequent floods, droughts, extreme events of rainfall etc. with increased temperature (IPCC, 2007). The food grain production in India is contributed by irrigated and rainfed areas by 60% and 40% respectively. Irrigated areas have reached plateau in the yield but rainfed areas are considered to offer future scope for increasing food production. Rainfed area with 55% net cultivated area contribute 40% of food grains and support 60% of livestock population (NRAA,2011). Most of the pulse and oil seeds production (80%) comes from rainfed areas. Rainfed areas suffer from severe land degradation and poor socio economic base of farmers.

Several management options are available at the farm scale to increase rainfall use efficiency. Some of these are management of crop residues to improve infiltration and reduce sediment levels, construction of farm ponds for collection of excess rainfall flowing from the farm area, crop rotations and soil amendments (Freebairn *et al.,* 1986). Several researchers have shown that on-farm runoff collection into dugout farm ponds and supplemental irrigation can increase and stabilize the crop production (Krishna *et al.,* 1987). There is an abundant scope and opportunity for harvesting excess runoff in the rainfed region in different states of the country (Wani, et al., 2003, Sharma et al, 2009).

Government of India has introduced several schemes to improve the surface water availability in irrigated and rainfed areas for enhancing the productivity

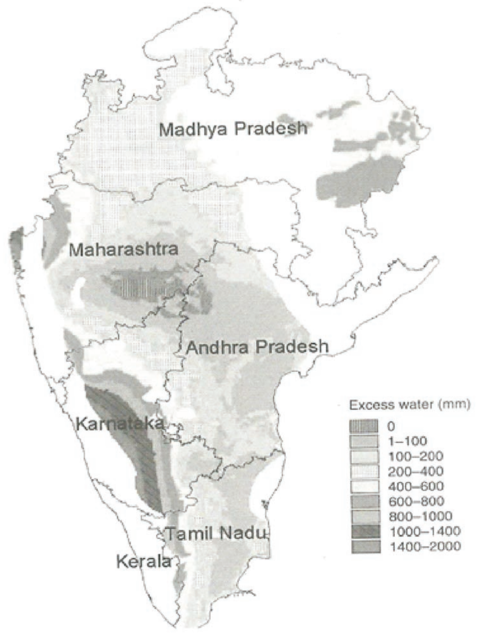
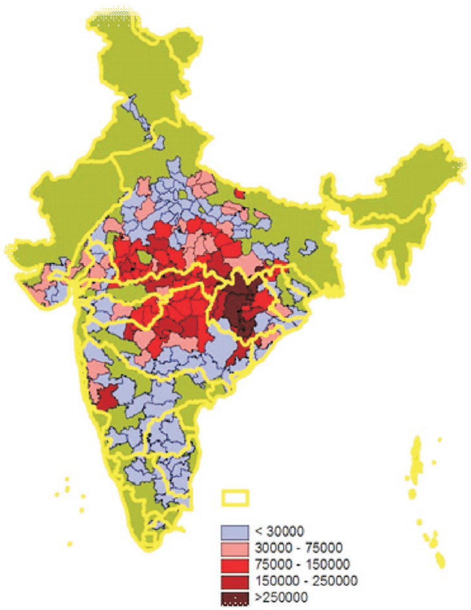


Fig. 1(a) : Excess water available for harvesting as runoff in the states of the semi arid tropics, India (June-October) (Sources: S. P. Wani, et al., 2003)



(b) : Spatial distribution of surplus runoff (ha-m) across districts and river basins (Source: Sharma et al, 2009)

and ground water recharge. Integrated Watershed Management Programme (IWMP) has been implemented successfully in most of the rainfed regions of the country with major objective of the stabilizing crop production by controlling soil erosion in arable and non-arable lands. Among several interventions, farm pond is the most important and promissing technology in the integrated water shed management program with other environmental benefits. Farm ponds would help the farmers for on farm water management by using stored water for tackling the drought or dryspells during the season which are common as given in Table1.

Considering the need and the current emphasis on on-farm rain water harvesting for enhancing water productivity in rainfed regions by the Govt of India, the present technical bulletin on Farm Ponds: Planning, design and construction is brought out based on field experiences by CRIDA for the benefit of the implementing agencies working in IWMP, State Govt depts, NGO's, SAU's. The bulletin describes a practical approach for designing and construction of a farm pond.

Table 1 : Types of water stress and underlying causes in semiarid and dry sub humid regions

	Dry spell	Drought
Meteorological		
Frequency	Two out of three years	One out of ten years
Impact	Yield reduction	Complete crop failure
Cause	Rainfall deficit of 2 to 5 week during crop growth periods	Seasonal rainfall below minimum seasonal plant water requirement
Agricultural		
Frequency	More than two out of three years	One out of ten years
Impact	Yield reduction or complete crop failure	Complete crop failure
Cause	Low plant water availability and poor plant water uptake capacity	Poor rainfall partitioning, leading to seasonal soil moisture deficit for producing harvest (where poor partitioning refers to a high proportion of runoff and nonproductive evaporation relative to soil water infiltration at the surface)

Source: (Falkenmark and Rockström, 2004)

Planning of Farm Pond

Farm pond

Farm Pond is a dug out structure with definite shape and size having proper inlet and outlet structures for collecting the surface runoff flowing from the farm area. It is one of the most important rain water harvesting structures constructed at the lowest portion of the farm area. The stored water must be used for irrigation only. Inadvertently, some people use the farm ponds as ground water recharge structures which is not correct as per the definition. For recharging the ground water, the structures require high capacity and are generally located in the soils having high infiltration rates and are called percolation tanks. Percolation tank is meant for only recharge purpose and not for irrigation. Such structures conceptually differ in their hydrology and physical location. A farm pond must be located within a farm drawing the maximum runoff possible in a given rainfall event. A percolation pond can be dug out in any area where the land is not utilized for agriculture.

Farm ponds have a significant role in rainfed regions where annual rainfall is more than or equal to 500 mm. If average annual rainfall (AAR) varies between 500 to 750 mm, the farm ponds with capacity of 250 to 500 m^3 can be constructed. If AAR is more than 750 mm, the farm ponds with capacity more than 500 m^3 can be planned particularly in black soil regions without lining. It was observed from the field experience and if present rainfall pattern changes; atleast two to three rainfall events producing considerable runoff are possible in a season making farm ponds an attractive proposition.

In high rainfall semi arid regions, these structures can be made as multiple use enterprises like protective/supplemental irrigation, fish culture or duck farming integrated with poultry. These structures provide localised water and food security by enhancing the crop productivity and climate resilience. Moreover, farm ponds conserve the natural resources like soil and nutrients apart from water and acts as flood control structure by reducing peak flows in the watersheds or given area of catchment.

Depending on the source of water and their location, farm ponds are grouped into four types:

1) Excavated or Dug out ponds
2) Surface ponds
3) Spring or creek fed ponds and
4) Off stream storage ponds.

Selection of site

Selection of the site for farm pond depends on local soil condition, topography of area, drainage capacity, infiltration, rainfall pattern and distribution. Selecting the suitable site is considered as one of the most important steps in planning for farm ponds. The following points may be considered for site selection within farm area:

Dugout ponds:

1. Observe the average slope direction in the farm area in which farm pond is to be planned for construction
2. If the slope is towards left bottom corner of the field (Fig.2a), a farm pond must be constructed in the left corner of the plot.
3. If the slope is towards bottom right corner of the field (Fig.2b), a farm pond must be constructed in the right hand corner

4. If the slope is towards the bottom of the field (Fig.2c), a farm pond must be constructed to the corner of either side with proper field channel at the bottom of the field connecting to the inlet of the structure.

5. If the farm area has multiple slopes in different directions (Fig.2d), a farm pond must be located in a portion of area in which water is drained into the structure, may be at centre of the field or near to it.

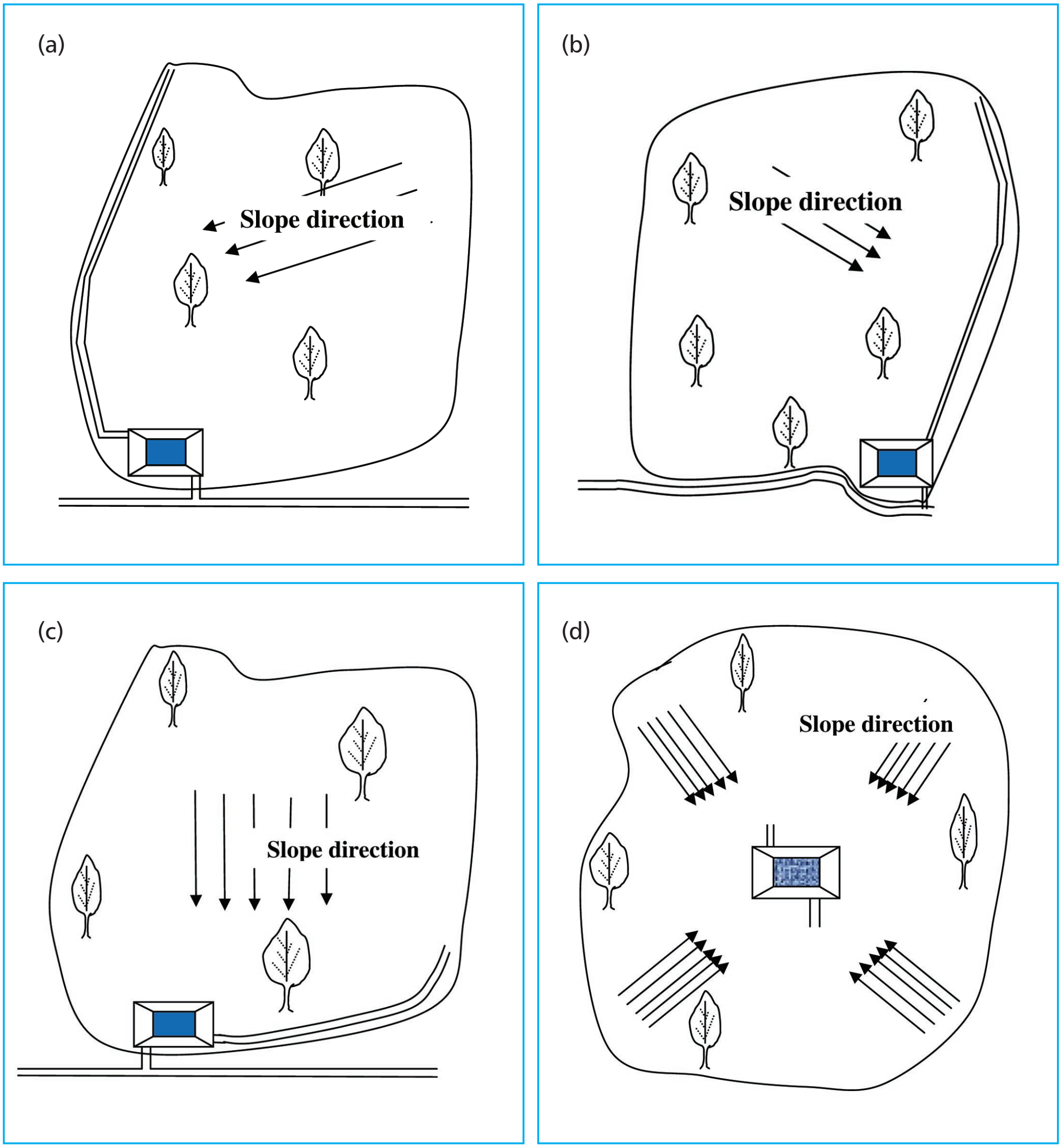


Fig. 2 (a,b,c,.& d) : Planning and selection of site for farm pond location in farm catchment areas with different slopes

Surface Pond

Surface ponds are considered to collect surface runoff from farm area into a local depression or the lowest portion of the farm so that the excavation is minimum except to construct the earthen bund surrounding the water body (Fig. 3a). These are possible in highly eroded farm areas with undulating topography. Such farm ponds do not require inlet provision but it should have outlet provision in the earthen bund to remove the excess flow.

Spring or Creek Fed Ponds

In the ridge portions of the farm area, particularly hilly catchments, after saturation of the soil, there will be a flow from the subsurface layers drawing water into the pond (Fig. 3b). The sub surface flow is called base flow. It may be a perennial source for water within a farm.

Off stream storage ponds

The streams are seasonal from which water is drawn into the farm pond by diversion (Fig. 3c). When the stream flows are the source of storage, the farm ponds should never be constructed across the streams and the structure must be located off the stream with proper diversion of water through pipe or channel.

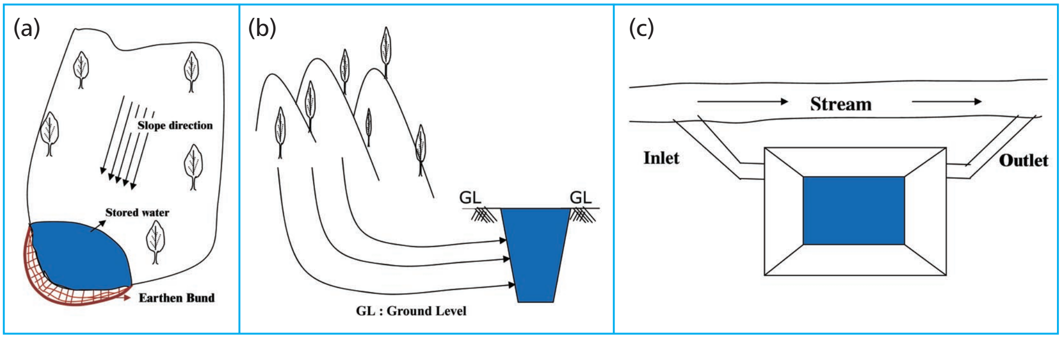


Fig. 3 (a, b& c) : Different types of farm ponds : surface (a), spring (b) and offstream (c) and their location in the catchment

Soil type

India has 30% alfisols, 35% vertisols and 35% of other soils including alluvial, laterite, etc., in rainfed areas (Virmani, 1991). The distribution of different soils of India is given in Fig.4. For construction of farm pond, the soils must have low hydraulic conductivity with minimum seepage and percolation so that water can be retained for longer time in a farm pond. Soils with a low infiltration rate are most suitable for construction of pond. Table 2 shows the infiltration rate of different soils. The black soils have good potential for rain water harvesting without lining as the seepage losses are minimum. The seepage losses are more in sandy soils and their mixed textures and they require lining for storing water for more time.

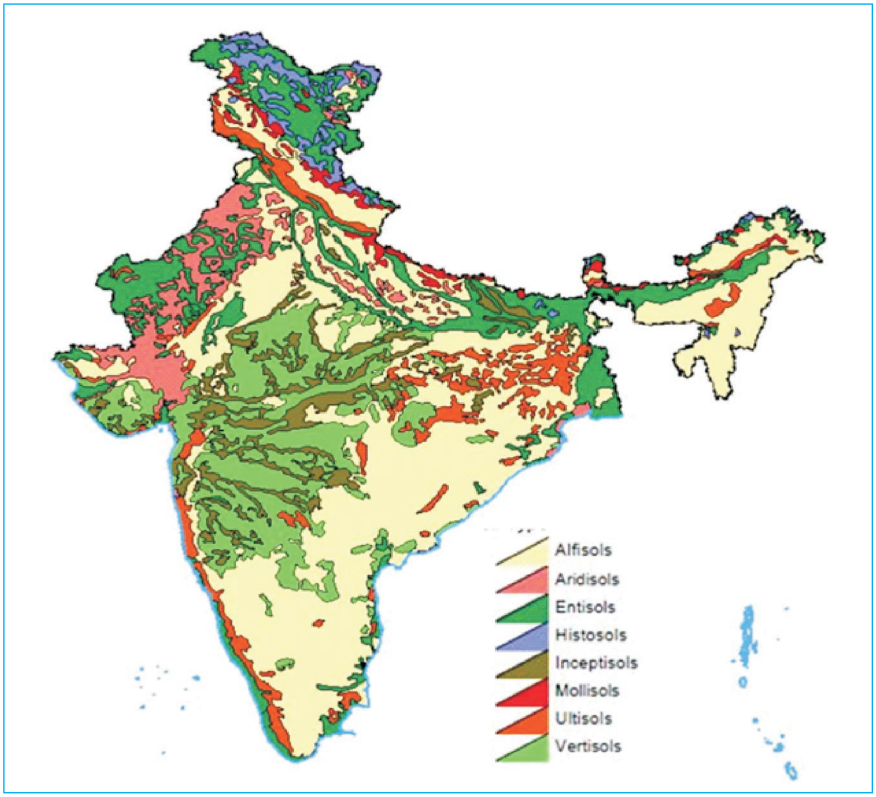


Fig. 4 : Distribution of different types of soils in India
Source : (National Atlas and Thematic Mapping Organization)

Table 2 : Infiltration rates of different types of soil

Sl. No.	Soil type	Infiltration rate (cm/hr)
1	Coarse sand	2.0-2.5
2	Fine sand	1.2-2.0
3	Fine sandy loam	1.2
4	Silty loam	1.0
5	Clay loam	0.8
6	Clay	0.5

Source: (www.nabard.org)

The soils having outcrops and stones must be avoided for digging farm ponds. The soil profile depth must be investigated before digging of the pond. The soils having good depth of >1 m, free of stones, low Ph, Ec and ground water level may be chosen for site selection for farm pond. Peat soils have special problems, since they are usually very acidic in nature and need sufficient liming. Soils rich in limestone create special problems of precipitating phosphate and iron.

Soil depth

The depth of soil is important where rain water harvesting systems are proposed. Deep soils have the capacity to store harvested water for longer duration. Soils having more than 1m are ideal for construction of farm ponds. More the depth of soil, the depth of farm pond will be more and reduces the evaporation losses.

Topography

The topographic features of the farm catchment area may vary from place to place and proposed land for pond construction must have minimum earth excavation so that cost can be reduced with increased storage. Depending upon the capacity of the farm pond, the contour survey is conducted to determine the slope, drainage pattern within farm. However, for small catchments of 1-5 ha land, a reconnaissance is sufficient to identify the location for farm pond. The contour survey can be done by using dumpy level with staff or a total survey station which gives the digital map of the farm with contours. The farm pond must be located within farm itself looking into the slope and drainage flow pattern to the convenience of the farmer. A sample contour map at GRF, CRIDA, with location of farm ponds is given in (Fig. 5)

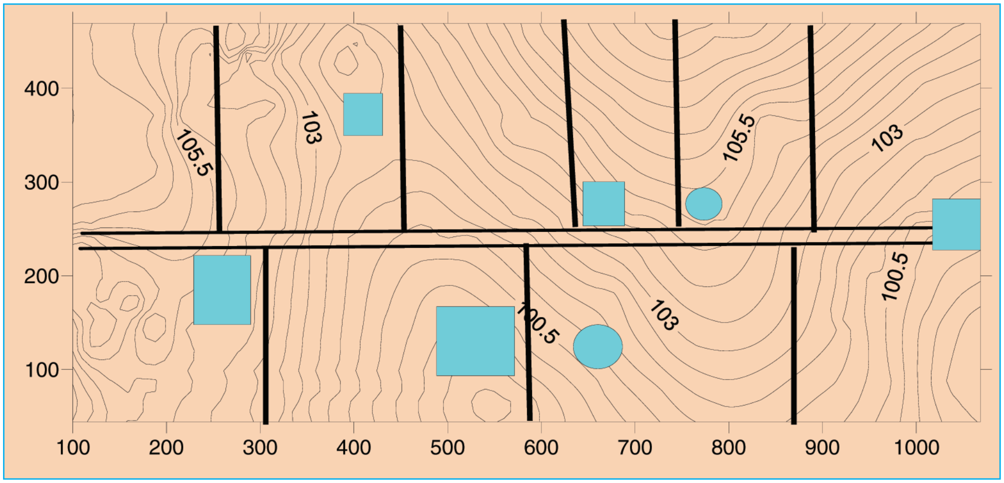


Fig. 5 : Contour map of the Gunegal Research Farm along with location of farm ponds

Drainage / Catchment area

The drainage/catchments area which produces surface runoff for storage in farm ponds, is very important from hydrology point of view. The structure must get filled at least once in the season so that the farmers can use the water for critical irrigation during dry spells. The characteristics of a catchment that directly affect the runoff yield are the slope of the area, infiltration of the soil, vegetation, land use and shape of the catchment. These interrelated factors are variable and site-specific. If the drainage area is too small in relation to the pond size, the pond may not adequately fill, or the water level may drop too low during extended periods of hot, dry weather. The high intense rainfall events would cause soil erosion and the runoff carries the silt load into the farm pond. These problems can be solved through proper soil and water conservation treatments. In order to achieve the desired depth and capacity of a pond to be proposed, the inflow must be reasonably free of silt from an eroding catchment. The best protection is adequate erosion control through in situ moisture conservation or land management practices (Ridge and furrow, Broad bed furrow, Compartmental bunds, Contour bund and Graded bund etc) on the drainage contributing area. Land under permanent cover of trees or grasses are the most desirable drainage area. If such land is not available, treat the watershed with proper conservation practices to control erosion before constructing the pond. The catchments must be selected in such a way that, the drainage from farmsteads, feedlots, sewage lines, dumps, industrial and urban sites and other similar areas does not reach the pond.

Design of Farm Pond

Rainfall analysis

Rainfall is one of the most important and critical hydrological input parameter for the design of farm ponds. Its distribution varies both spatially and temporally in semi arid regions of the country. The quantity of surface runoff depends mainly on the rainfall characteristics like intensity, frequency and duration of its occurrence. The high intense rainfall exceeding infiltration capacity of soil can produce more runoff than the event with low intensity for longer duration. Apart from the physical characteristics of the catchment area contributing to produce surface runoff, the rainfall analysis is very critical for optimal economic design of farm pond. But long term data on rainfall intensity is seldom available in the country. A case of seasonal rainfall analysis is presented in this bullettin for the design of farm ponds.

Design rainfall

It is defined as the total amount of rain during the cropping season at or above which the catchment area will provide sufficient runoff to satisfy the crop water requirements. If the actual rainfall in the cropping season is below the design rainfall, there will be moisture stress for crop. If the actual rainfall exceeds the design rainfall, there will be surplus runoff which may cause damage to the structures. The design rainfall is calculated from the probability analysis. It is assigned some probability level of occurrence or exceedance. Suppose the probability of 67% is given to rainfall, it indicates that the seasonal rainfall may occurre or exceed 2 years out of 3 and therefore, the crop water requirements would also be met two years out of three in a crop season. More the probability of the rainfall, it is more reliable for getting assured runoff into the farm ponds.

Probability analysis

A simple graphical method can be used for probability analysis and frequency of occurrence of annual or seasonal rainfall for the design of ponds. There are several analytical methods by selecting a suitable probability distribution function. Weibulls distribution is commonly used for its simplicity and easy to adaptation for such field situations. The first step is to get the seasonal rainfall(June to September) for the cropping season from the area of concern. It is important to obtain long term data for at least 20 years for the probability analysis. Short term data for 5 to 10 years may not be sufficient to represent the realistic rainfall pattern in the region. For the collected seasonal rainfall, each value has to be given ranks based on their amounts arranged in descending order. The occurrence of probability for each of the ranked observation can be calculated from the below equation (Critchley and Siegert, 1991) for the period N=10 to 100.

$$\mathbf{P}\ (\%) = \frac{m-0.375}{\mathrm{N}+0.25} \times \mathbf{100} \qquad ---\ (1)$$

Where,

P = probability in % of the observation of the rank m

m = rank of the observation

N = total number of observations used.

Steps in probability analysis

1) Annual or seasonal rainfall for a period of 20-30 years may be collected from nearby weather station of either govt (or) research station or IMD for selected area.
2) All the above data may be entered into MS excel sheet.

3) Arrange the annual/ seasonal rainfall data in descending order and rank them, having maximum rainfall as 1 and the minimum value with maximum rank.
4) If two rainfall events are equal consecutively, the same rank must be given to both the quantities.
5) Calculate the probability of each rainfall by using the equation 1.
6) Plot the probability vs rainfall on normal probability paper.
7) Determine the rainfall for 50%, 67% and 75% from the plotting curve.

An example for probability analysis of annual and seasonal rainfall for 30 years at Gunegal Research Farm near Ibrahimpatnam of CRIDA representing Southern Telengana is given below. Thirty years (1981-2010) annual and seasonal rainfall at GRF are given in Table 4. From the above calculations, it is observed that the annual rainfall analysis gives more rainfall than the seasonal rainfall at all probabilities. Generally, farm ponds are more likely to be filled during seasonal rainfall than during other periods in a year. Therefore, annual rainfall analysis may give over estimated designs of farm pond than seasonal rainfall. Therefore, seasonal design rainfall is considered for further calculations.

Table 4 : Annual and seasonal rainfall at Gunegal Research Farm (1981-2010)

Year	Annual Rainfall mm	Year	Annual Rainfall mm	Year	Seasonal rainfall mm	Year	Seasonal rainfall mm
1981	762	1996	590.6	1981	555.4	1996	341.3
1982	1022.5	1997	710.1	1982	621.9	1997	439.1
1983	850.5	1998	977.7	1983	621.7	1998	731.6
1984	534.2	1999	476.3	1984	395.9	1999	370.8
1985	553.5	2000	523.6	1985	399.6	2000	459.9
1986	602.3	2001	625.2	1986	377.7	2001	490.3
1987	911.9	2002	426.6	1987	453.7	2002	241.3
1988	570.1	2003	869	1988	485.5	2003	651.9
1989	769.5	2004	764.5	1989	710.9	2004	381.5
1990	1001.9	2005	1154.6	1990	549.8	2005	683.6
1991	883.2	2006	741.5	1991	676.1	2006	515
1992	507.4	2007	880.8	1992	249.9	2007	716
1993	584	2008	763.8	1993	349.2	2008	431.8
1994	790.5	2009	743.2	1994	338.5	2009	496.2
1995	1019.7	2010	780.8	1995	578.9	2010	550.8

On normal probability paper, the plot of annual/seasonal rainfall against corresponding probabilities is drawn as shown in Fig 6(a,b). The finally fitted curve would show the probability of occurrence or exceedance of rainfall value of a specific magnitude. It means that a seasonal rainfall of 500 mm with probability of 50% may exceed or equal once in two years of period. With 67% probability, 425mm rainfall may exceed or equal twice in three years period. Similarly, it is three times in 4 years for 75% probability of 375mm seasonal rainfall as seen from the plotted graph (Fig 6(b)). On average, in case of annual rainfall, 760mm, 650mm and 600mm can be expected for 50, 67, and 75% probability respectively Fig 6(a).

Table 5 : Rank and Probabilities of annual and seasonal rainfall at GRF

Year	Annual rainfall, mm	Rank (m)	Probability p(%)	Year	Seasonal rainfall, mm	Rank (m)	Probability p(%)
2005	1154.6	1	2.1	1998	731.6	1	2.1
1982	1022.5	2	5.4	2007	716	2	5.4
1995	1019.7	3	8.7	1989	710.9	3	8.7
1990	1001.9	4	12.0	2005	683.6	4	12.0
1998	977.7	5	15.3	1991	676.1	5	15.3
1987	911.9	6	18.6	2003	651.9	6	18.6
1991	883.2	7	21.9	1982	621.9	7	21.9
2007	880.8	8	25.2	1983	621.7	8	25.2
2003	869	9	28.5	1995	578.9	9	28.5
1983	850.5	10	31.8	1981	555.4	10	31.8
1994	790.5	11	35.1	2010	550.8	11	35.1
2010	780.8	12	38.4	1990	549.8	12	38.4
1989	769.5	13	41.7	2006	515	13	41.7
2004	764.5	14	45.0	2009	496.2	14	45.0
2008	763.8	15	48.3	2001	490.3	15	48.3
1981	762	16	51.7	1988	485.5	16	51.7
2009	743.2	17	55.0	2000	459.9	17	55.0
2006	741.5	18	58.3	1987	453.7	18	58.3
1997	710.1	19	61.6	1997	439.1	19	61.6
2001	625.2	20	64.9	2008	431.8	20	64.9
1986	602.3	21	68.2	1985	399.6	21	68.2
1996	590.6	22	71.5	1984	395.9	22	71.5
1993	584	23	74.8	2004	381.5	23	74.8

Year	Annual rainfall, mm	Rank (m)	Probability p(%)
1988	570.1	24	78.1
1985	553.5	25	81.4
1984	534.2	26	84.7
2000	523.6	27	88.0
1992	507.4	28	91.3
1999	476.3	29	94.6
2002	426.6	30	97.9

Year	Seasonal rainfall, mm	Rank (m)	Probability p(%)
1986	377.7	24	78.1
1999	370.8	25	81.4
1993	349.2	26	84.7
1996	341.3	27	88.0
1994	338.5	28	91.3
1992	249.9	29	94.6
2002	241.3	30	97.9

The return period T (in years) can easily be determined once the exceedance probability P (%) is known.

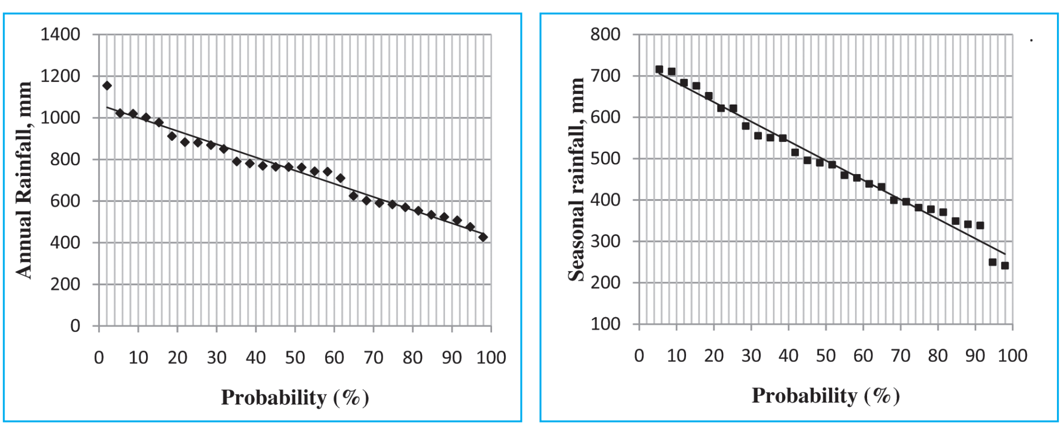
$$\mathbf{T} = \frac{\mathbf{100}}{\mathbf{P}} \qquad \text{--- (2)}$$

From the above example, the return period for annual and seasonal rainfall can be calculated as below:

$$T_{50} = \frac{100}{50} = 2 \text{ years}$$

$$T_{67} = \frac{100}{67} = 1.5 \text{ years}$$

$$T_{75} = \frac{100}{75} = 1.3 \text{ years}$$



(a) Annual **(b) Seasonal**

Fig. 6 (a,b) : Probability plotting for an observed series of annual and seasonal rainfall at GRF

Similar rainfall analysis is done for 25 centres of All India Co-ordinated Research Project on Dryland Agriculture representing different rainfed regions in the country. These centres are regrouped into three rainfall zones namely low rainfall areas in which annual average rainfall(AAR) of 30 years is in the range of 0-500mm; medium rainfall areas in which AAR is between 500-1000mm and high rainfall areas in which AAR is >1000mm. The average annual rainfall of 25 AICRPDA centres is given in Fig 7. The results of the rainfall analysis for 25 centres are given in Fig 8(a, b and c). From the probability graphs, the design rainfall of different centres is taken for two probabilities of 67 and 75(%) and presented in Table 6.

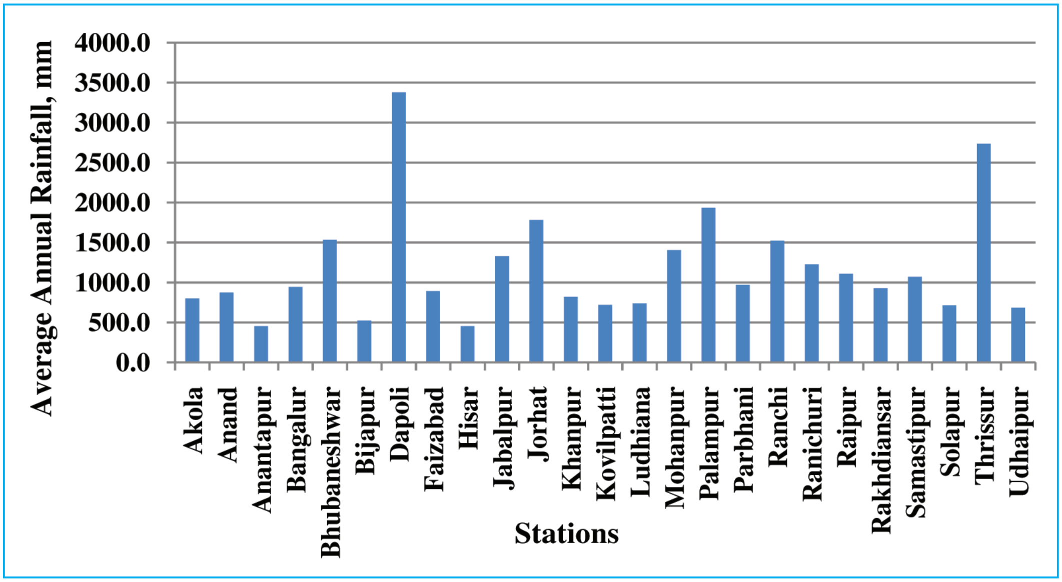
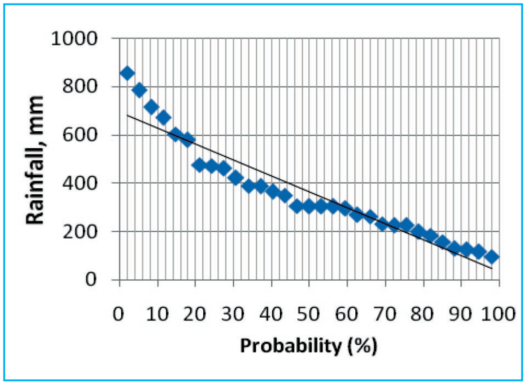
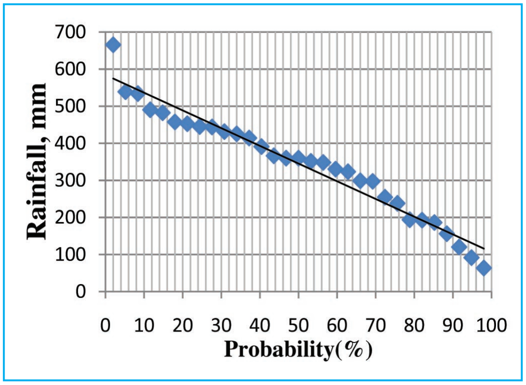


Fig. 7 : Average Annual Rainfall(AAR) of different rainfed regions in the country

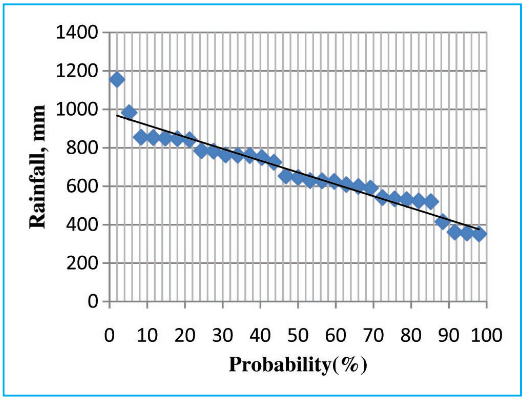


Anantapur

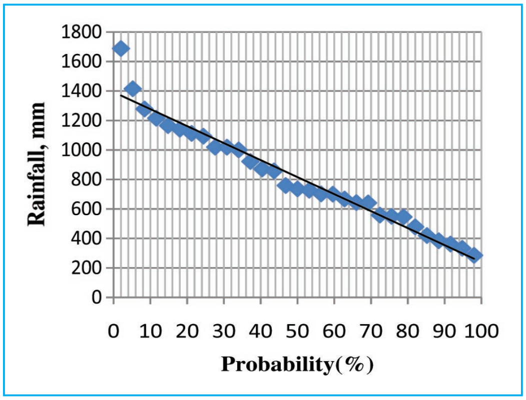


Hissar

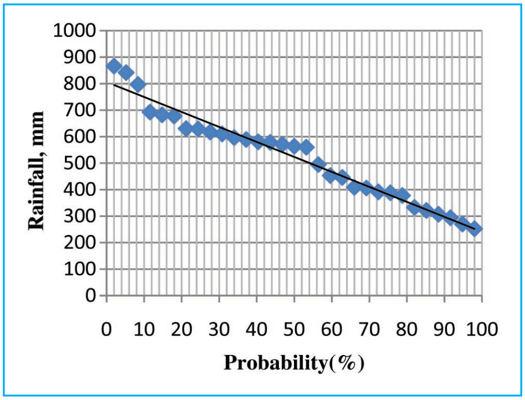
Fig. 8(a) : Probability vs Seasonal rainfall of low rainfall centres



Akola



Anand



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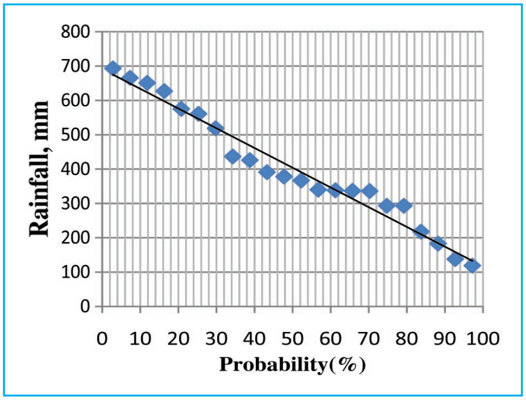

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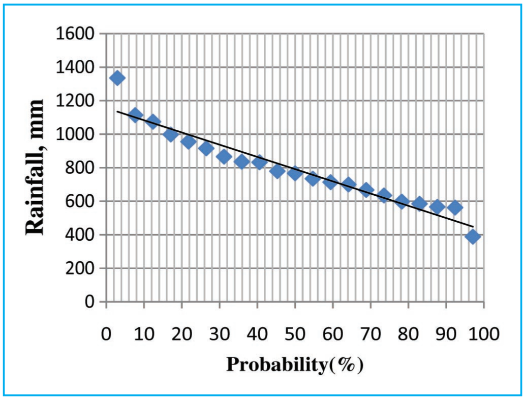
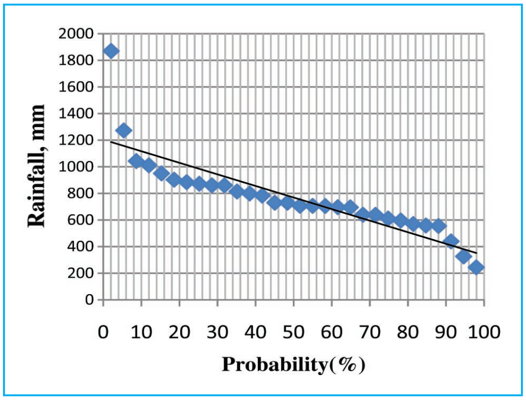
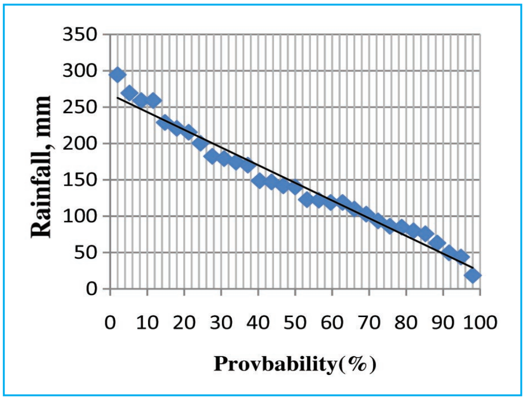


Faziabad

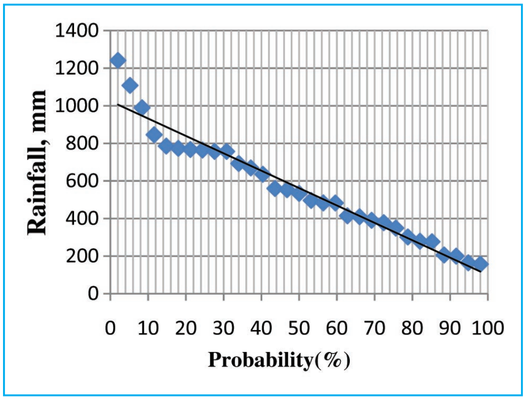


Kanpur

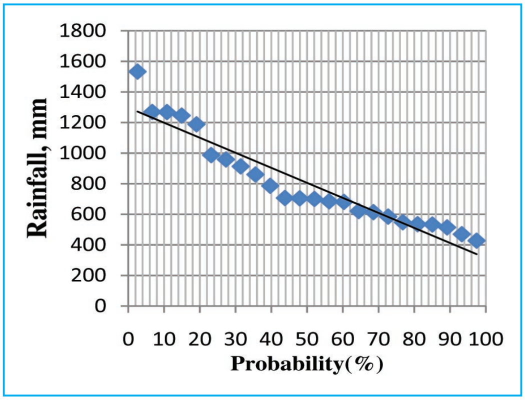
Fig. 8(b) : Probability vs Seasonal rainfall for medium rainfall centres



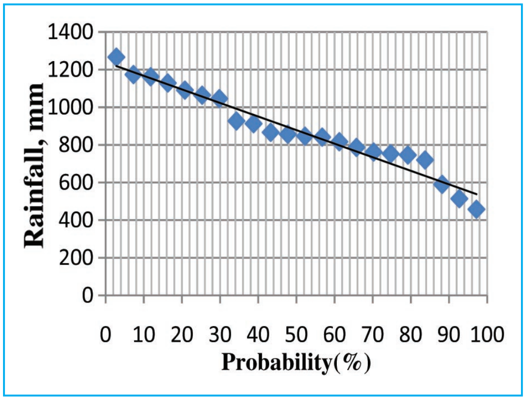
Kovilpatti



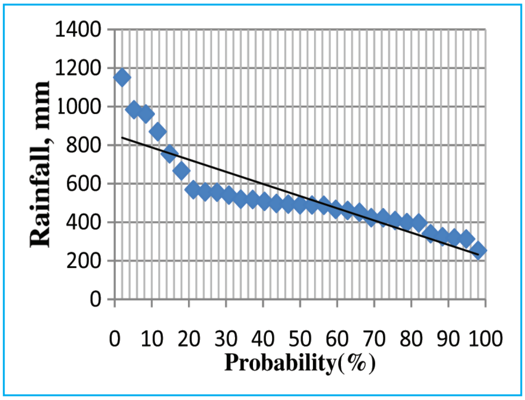
Ludhiana



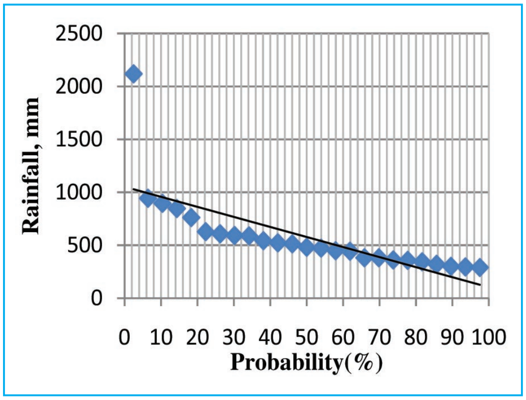
Parbhani



Rakhdiasar

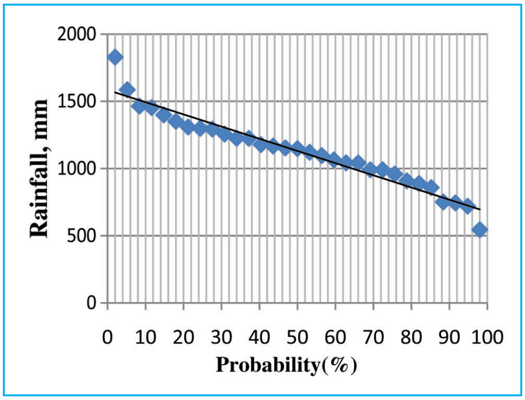


Solapur

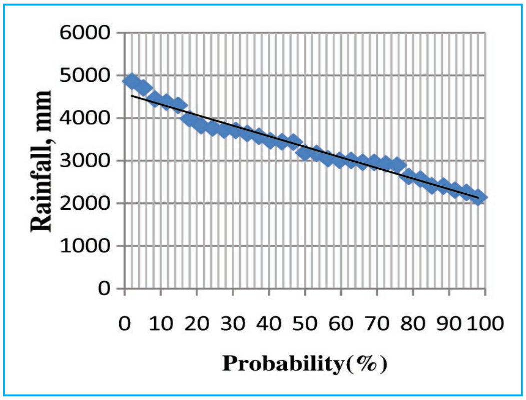


Udaipur

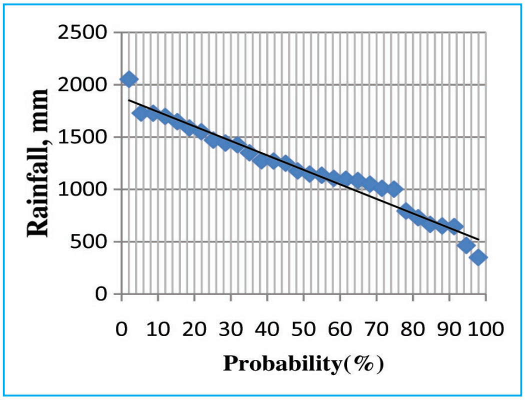
Fig. 8(b) : Probability vs Seasonal rainfall for medium rainfall centres



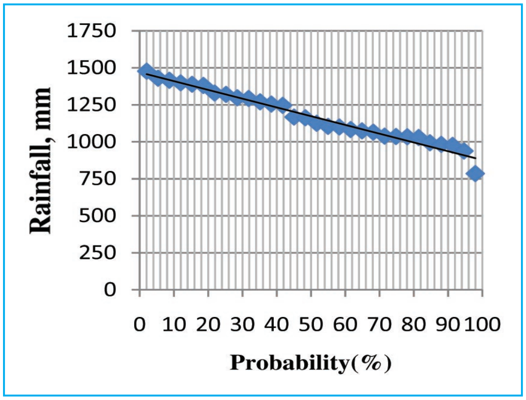
Bhubaneshwar



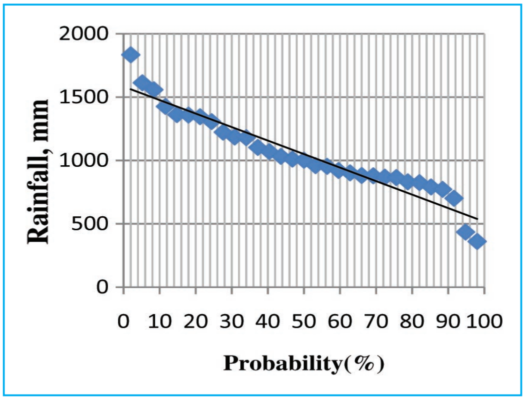
Dapoli



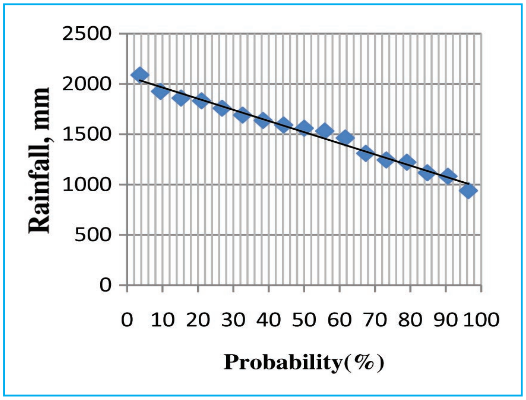
Jabalpur



Jorhat

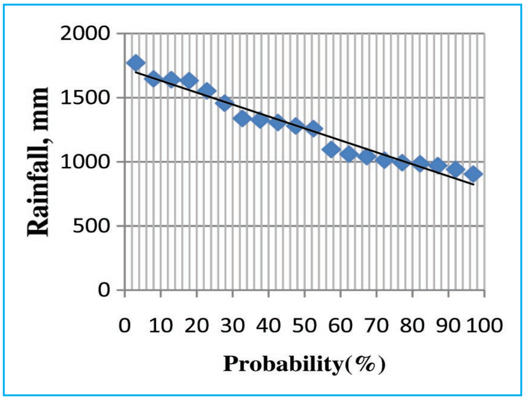


Mohanpur

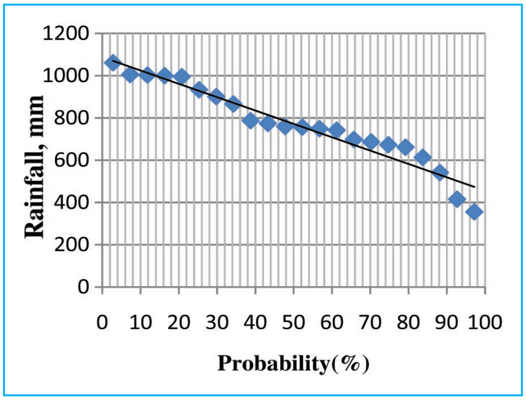


Palampur

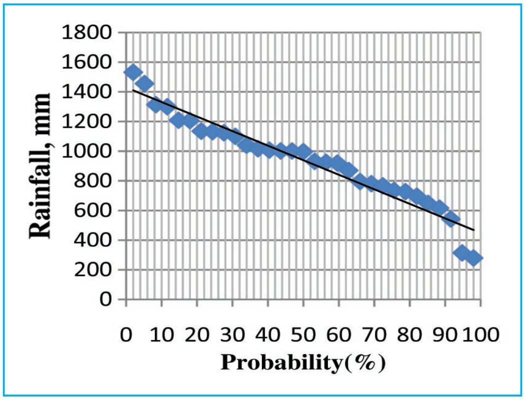
Fig. 8(c) : Probability vs Seasonal rainfall of high rainfall centers



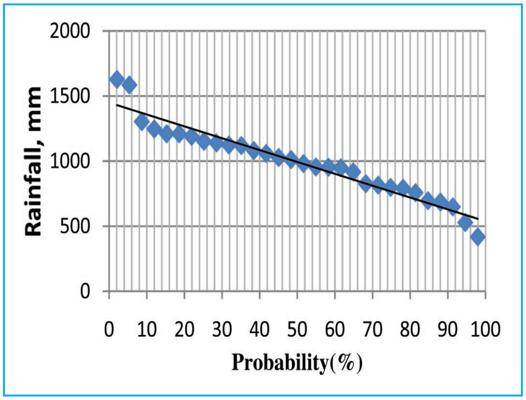
Ranchi



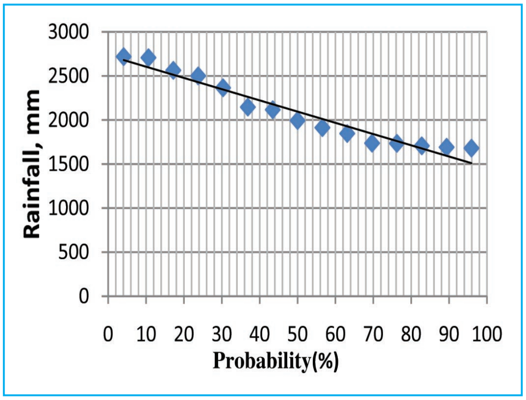
Ranichuri



Raipur



Samastipur



Thrissur

Fig. 8(c) : Probability vs Seasonal rainfall of high rainfall centers

Table 6 : Average Seasonal Rainfall (ASR) of different rainfed centres in the country and their expected design rainfall at different probabilities.

S No.	Rainfed centres	Average seasonal rainfall, mm	Probabilities	
			67(%)	75(%)
Low Rainfall Areas (AAR:0-500mm)				
1	Anantapur	353.6	263	224.8
2	Hisar	345.4	299.1	238.2
Medium Rainfall Areas (AAR:500-1000mm)				
1	Akola	671.7	598.8	534.3
2	Anand	815.5	643.1	549.5
3	Bangalur	523.5	408.7	388.3
4	Bijapur	403.9	336.6	293.3
5	Faizabad	791.6	667.1	597.7
6	Khanpur	714.5	639.4	611.1
7	Kovilpatti	145.8	109.8	86.2
8	Ludhiana	593.1	409.5	349
9	Parbhani	834.1	618	545
10	Rakhdiansar	878.4	786.4	753
11	Solapur	533.0	451.8	408.5
12	Udhaipur	604.5	381	350
High Rainfall Areas (AAR:>1000mm)				
1	Bhubaneshwar	1116.1	1042.1	959.2
2	Dapoli	3259.5	2962.4	2894.3
3	Jabalpur	1174.5	1050	793.8
4	Jorhat	1173.3	1065.4	1034
5	Mohanpur	1050.2	881.35	865
6	Palampur	1521.3	1310.7	1222.5
7	Ranchi	1260.7	1040.7	990
8	Ranichuri	771.8	698.3	673.1
9	Raipur	951.1	795.4	734.9
10	Samastipur	993.6	830	798
11	Thrissur	2094.7	1720	1734

Surface runoff / Water yield

The surface runoff is generated in the catchment area after fulfilling the soil infiltration, interception and local depressions. It depends on the soil physical characteristics, land use characteristics, antecedent soil moisture, topography, shape and size of the catchment besides rainfall characteristics of intensity, frequency and duration.

Rainfall-Runoff relationship

There are several methods to estimate runoff. However, SCS curve number (USDA, 1967) is the most popular for the field engineers of soil and water conservation. It requires minimum data set of daily rainfall data , details of land use and its distribution, hydrologic groups of soils based on infiltration rate of the catchment area and antecedent moisture condition (AMC) of the watershed based on the previous 5 days consecutive total rainfall preceding the rainfall considered.

Curve Number method

It estimates the direct runoff (depth) or rainfall excess, storm wise. This method is based on the potential maximum retention(S) of the watershed, which is determined by wetness of the watershed i.e. the antecedent moisture condition (AMC) and physical characteristics of the watershed.

$$Q = \frac{(P - Ia)^2}{P - Ia + S} \qquad --- (3)$$

Where,

Q = runoff depth, mm.
P = daily rainfall, mm.
S = potential maximum retention of soil, mm.
Ia = initial abstraction, mm

Ia is related to S for different soil types. For black soils, Ia= 0.2S, and For red soils, Ia = 0.3S.

For black soils, the equation (3) becomes,

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad --- (3a)$$

For red soils, the equation (3) becomes,

$$Q = \frac{(P - 0.3S)^2}{P + 0.7S} \qquad --- (3b)$$

The potential maximum retention of the soil is determined by selecting the curve number for different land uses in a catchment (Table 7). The CN and S are related by the equation 4, if 'S' has units mm.

$$CN = \frac{25400}{254+S} \qquad ---(4)$$

Antecedent Moisture Content (AMC) : It is defined as the wetness index of soil. The AMC is determined on the basis of 5 days antecedent consecutive rainfall amounts. The AMC limits are given in Table 7.

Table 7 : Seasonal rainfall limits to determine antecedent moisture condition

AMC Group	Total 5-day antecedent rainfall, mm.	
	Dormant season	Growing season
I	<12.7	<35.6
II	12.7-27.9	35.6-53.3
III	>27.9	>53.3

Source: (Anonymous, 1972)

There are three levels of AMC, as discussed below:

AMC I : Defines the lowest runoff potential, because the soils are in dry condition with more infiltration.

AMC II : Defines the average condition of the catchment to produce runoff'

AMC III : Defines the highest runoff potential of the soil, when areas of catchment saturated from antecedent rains.

Curve number varies from minimum zero for most permeable surface or fully saturated to the maximum as 100 for impervious (Concrete) surface. However, the values of curve number for different land use conditions and hydrologic soil groups are given in Table 8. These values are applied to antecedent moisture condition (AMC) II only *i.e.* for average condition. The correction factors are applied to get the CN values for other AMCs (i.e. I & III). The correction factors for other AMCs are given in Table 9.

Once the runoff depth (Q) is estimated, the volume (m^3) of the particular event can be calculated from the given equation.

Where,

$$\text{Runoff volume to be harvested (Vq)} = \frac{Q \times Ac}{1000} \qquad --(5)$$

Q= runoff depth, mm. Ac= catchment area, m^2 1 ha=10000m^2 1 acre = 4047m^2

Table 8 : Curve numbers for different hydrologic soil groups and land uses for AMC II

Land use pattern	Treatment/ practices adopted	Hydrologic condition	Hydrologic soil group			
			A	B	C	D
Fallow-row crops	Straight row	—	77	86	91	94
		Poor	72	81	88	91
		Good	67	78	85	89
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured+Terrace	Poor	66	74	80	82
Small Grain	Straight row	Poor	65	76	84	88
		Good	63	75	83	87
	Contoured	Poor	63	74	82	85
		Good	63	75	83	87
	Contoured+Terrace	Poor	61	72	79	82
Seeded Legumes	Straight row	Good	59	70	78	81
		Poor	66	77	85	89
	Contoured	Good	58	72	81	85
		Poor	64	75	83	85
	Contoured+Terrace	Good	55	69	78	83
		Poor	63	73	80	83
Pasture Land	Contoured	Good	61	67	76	80
		Poor	47	67	81	88
		Fair	25	59	75	83
		Good	60	35	70	79
		Poor	45	66	77	83
Farm Woodland		Fair	36	60	73	79
		Good	25	55	70	79
Hard surface			74	84	90	92
Farmsteads			59	74	82	86
Meadow			30	58	71	78

Source: (SCS, USDA, 1964)

Table 9 : Multiplying factor for converting AMC II to I or III condition in curve number method

S. No.	Curve number / weighted curve number for AMC II	Factors to convert from AMC II to AMC I	AMC III
1	10	0.40	2.22
2	20	0.45	1.85
3	30	0.5	1.67
4	40	0.55	1.50
5	50	0.62	1.40
6	60	0.67	1.30
7	70	0.73	1.21
8	80	0.79	1.14
9	90	0.87	1.07
10	100	1.00	1.00

Source: (Anonymous, 1972)

Example: A catchment of 75 ha area having 12 ha in fair wood land and remaining is under fair pasture. The soils are related to hydrologic group B. The 6hours duration rainfalls for 2, 10, and 100 years return periods are 51.8mm, 86.4mm and 130 mm respectively. Compute the runoff for all three return periods. Ia=0.2S (Black soil).

Solution :

1. Calculation of weighted curve number (WCN)
   Using the Table 7, the WCN from soil hydrological group B for fair wood land and fair pasture cover can be taken as 60 and 59.

$$\text{WCN} = (12\times60+63\times59)/(12+63) \qquad =60$$

2. Computation of 'S'
   For 2 years return period

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

$$60 = \frac{25400}{254+S}$$

$$60\,(254+S) = 25400$$

$$S = \frac{25400-15240}{60}$$

$$S = 169.33\text{ mm}$$

3. Computation of runoff
   For 2 years return period

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

$$Q = \frac{(51.8-0.2\times169.33)^2}{(51.8+0.8\times169.33)} = 1.71\text{mm}$$

For 10 years return period

$$Q = \frac{(86.4-0.2\times169.33)^2}{(86.4+0.8\times169.33)} = 12.4\text{mm}$$

For 100 years return period

$$Q = \frac{(130-0.2\times169.33)^2}{(130+0.8\times169.33)} = 34.81\text{mm}$$

From runoff depths, the runoff co-efficients can be caliculated as ratio of runoff to rainfall.

Catchment and Cultivable Area ratio

The water harvesting systems consist of catchment (collection) and a cultivable (concentration) area. The relationship between the two, in terms of size, determines by what factor the rainfall will be multiplied. For an appropriate design of a system, it is recommended to determine the ratio between catchment (Aca) and cultivable area(Acu) based on information available on runoff coefficients and efficiency factor for the selected location.

The calculation of (Aca): (Acu) ratio is primarily useful for rain water harvesting systems where crops are intended to be grown and it can be related by the equation 6 (Critchley and Siegert, 1991) as given below:

$$\frac{\text{Crop water requirement - Design rainfall}}{\text{Design rainfall} \times \text{Runoff coefficient} \times \text{Efficiency factor}} = \frac{\text{Catchment Area}}{\text{Cultivable Area}}$$

Crop water requirement

Crop water requirement depends on the type of crop and the climate of the location where it is grown. It can be estimated from the climate data by using CROPWAT (FAO, 2011) model.

Design rainfall

The design rainfall has to be calculated as suggested in section rainfall analysis. A conservative design would be based on a higher probability in order to make the system more reliable and thus to meet the crop water requirement more frequently.

Runoff coefficient

Runoff coefficient is the ratio of runoff to rainfall which flows along the ground. Degree of slope, soil type, vegetative cover, antecedent soil moisture, rainfall intensity, frequency and duration of the rainfall are the major factors which influence the runoff coefficient. The coefficient usually ranges between 10 to 50% (Critchley and Siegert, 1991). A reasonable runoff coefficient must be selected based on the experience and physical characteristics of the catchment. Larger catchments will have low runoff coefficients with varying slopes. Black soils with mini catchments of 1 to 5 ha will have on an average the runoff coefficient of 10 to 20 % with mild to medium slopes (1-10%) (Adhikari et al, 2009). Higher runoff coefficients may be taken for slopes >10%. However, the red soils with high infiltration rates have runoff coefficients varying from 5 to 15% for the mild to medium slopes (1to 10%) and the catchment area varying from 1 to 14 ha for the design of farm ponds in semi arid regions. However, the runoff co efficients are site specific and they must be obtained from the research organizations near by the area.

Efficiency factor

This factor takes into account the inefficiency of uneven distribution of the water with in the field as well as losses due to infiltration, surface depressions, evaporation and deep percolation. Where the cultivated area is levelled and smooth, the efficiency is higher. Micro catchment systems have higher efficiency as water is usually less deeply ponded. Selection of the factor is left to the discretion of the designer based on his experience and of the actual technique selected. Normally the factor ranges between 0.5 to 0.75. A factor of 0.5 is selected for larger catchments and 0.75 is taken for micro catchments. The factor decreases with increasing catchment area (Aca) Fig 9.

The ratios of catchment to cultivable area for southern Telengana region are calculated for different crops with design seasonal rainfall at probability of 75% with different runoff coefficients varying from 5 to 20% and efficiency factor of 0.5 for alfisols. The design rainfall of 375 mm at 75% probability was used in calculating the Aca : Acu.

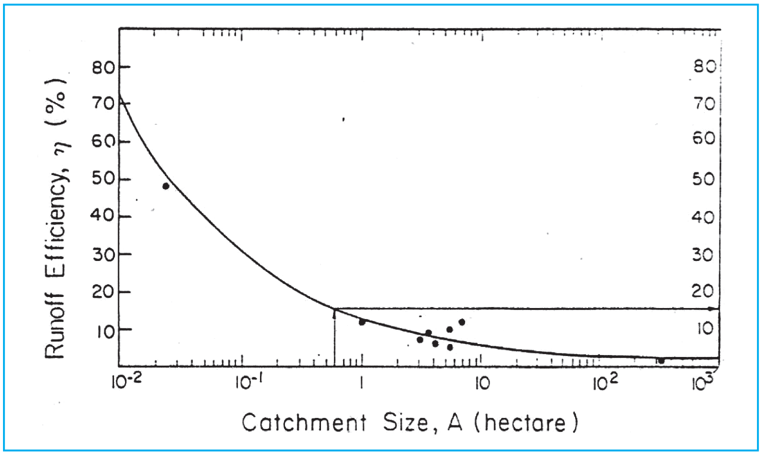


Fig. 9 : Relationship between runoff efficiency and catchment area.
Source : (Ben Asher., 1998)

Farm ponds can be designed for three strategies of irrigation in rainfed regions as given below:

i) Meeting the crop water requirement of growing season

ii) Meeting water requirement of critical irrigation(CRI) during the critical stages of crop growth

iii) Meeting water requirement in cropping system approach(Irrigation during critical stages of kharif crop plus the water requirement of rabi vegetable)

In Southern Telengana rainfed region, the cereals like sorghum and maize; pulses like Pigeon pea, green gram and black gram; Oil seeds like castor, groundnut, sunflower, cotton and soybean; and vegetables like onion, cabbage, tomato, chillies, potato, beans , carrot and Okra are grown. For these crops, the information on crop water requirement in rainfed regions are taken from literature and two irrigation depths of 30 and 50 mm were considered for critical irrigation. The data related to crop water requirements of rainfed crops and critical irrigation water requirement are given in Table 10. Similarly the water requirements in combination of either cereal or pulse or oil seed in kharif with critical irrigation of 30 and 50mm depths and water requirement of vegetable in rabi are given in Fig10.

Based on the water requirement calculated for different options of the irrigation strategies from farm ponds, the ratio of catchment area (Aca) to cultivable area (Acu) is calculated by using equation 6. Here, the design seasonal rainfall of 375mm at 75% probability is considered for calculating the ratio for Southern Telengana region. The

Table 10 : Details of different crops with their critical stages, crop water requirement (CWR) and water requirement for critical irrigation in kharif.

Category	Crops	CWR* (mm)	Critical stages	DAS	Water requirement(mm) for critical irrigation in kharif	
					30mm	50mm
Cereals	Sorghum	450	Booting,	40-55	90	150
			Blooming	55-65		
			Milky Dough Stage	65-80		
	Maize	450	Tasseling	40-65	90	150
			Silking	66-95		
			Grain development	96-105		
Pulses	Redgram	200	Flowering	35-40	60	100
			Pod setting	55-65		
	Chickpea	200	Late vegetative phage	35-40	30	50
	Black gram	200	Flowering	35-40	60	100
			Pod setting	55-65		
	Green gram	200	Flowering	35-40	60	100
			Pod setting	55-65		
Oil seed crops	Ground nut	400	Flowering,	30-45	90	150
			Peg Formation	45-55		
			Pod Development	60-80		
	Sunflower	350	Pre-flowering	25-35	60	100
			Post-flowering	55-65		
	Soybean	450	Blooming	25-35	60	100
			Seed Formation	55-65		
	Castor	500	Flowering	35-40	60	100
			Seed development	40-65		
	Cotton	600	Flowering	60-80	60	100
			Fruiting period	110-130		
Vegeta-bles	Onion	550	Bulb Formation	30-40	60	100
			Pre-maturity	75-80		
	Tomato	600	Flowering	45-50	60	100
			Fruit Setting	50-55		
	Potato	550	Tuber Initiation	30-35	60	100
			Maturity	50-60		
	Cabbage	500	Head Formation	50-70	30	50
	Okra	500	Flowering	50-60	60	100
			Fruit Setting	60-80		
	Carrot	500	Root initiation	40-45	60	100
			Root Enlargement	60-70		
	Beans	500	Flowering	45-50	60	100
			pod setting	50-60		
	Chilies	500	Flowering	40-45	60	100
			Fruit Setting	50-55		

*CWR data is taken from (Reddi and Reddy, 2003) and lower values are considered for rainfed regions.

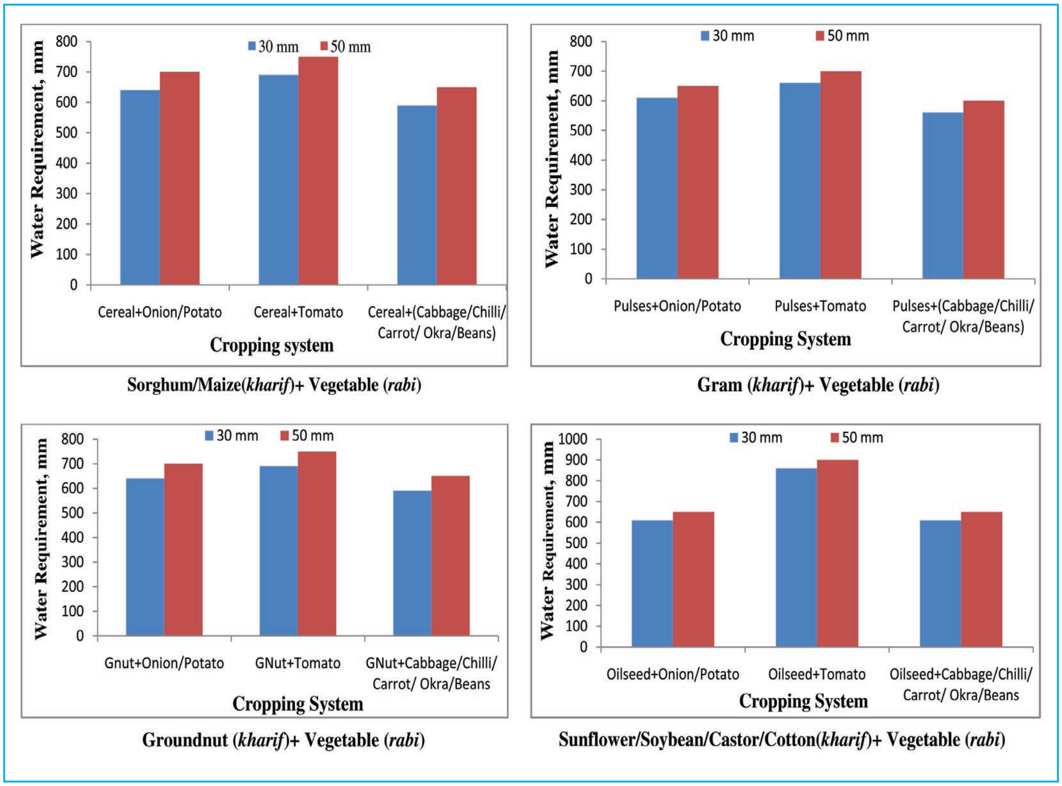


Fig. 10 : Crop water requirements for cropping systems considering critical irrigation in kharif plus the water requirement of rabi vegetable for water harvesting

ratio of Aca:Acu for different rainfed crops is presented in Table 11(a) considering seasonal crop water requirement. From the Table, it is seen that, the pulses don't require any additional water as the design seasonal rainfall is more than crop water requirement. Same is the case in sunflower under oilseeds. Similarly, the ratios of Aca:Acu are presented in Table 11(b) for different rainfed crops considering only critical irrigation during the critical crop growth stages as given in Table 10 for two irrigation depths of 30 and 50mm.

The ratios of Aca:Acu for different combination of rainfed cropping systems considering critical irrigation in kharif and water requirement of rabi vegetable, are worked out and presented in Table 11(c). The rabi vegetable gives more profit to a farmer under farm ponds. It is observed from the Table that, the ratios are more in the lower range of runoff coefficients and they decrease as the runoff coefficients increases suggesting to have system approach for black soils in which the water harvesting potential is more.

Table 11(a) : Ratio of catchment area (A_{ca}) to cultivable area(A_{cu}) for different crops with varying runoff coefficients considering crop water requirement and design rainfall at 75% probability Southern Telengana region.

Crops	Runoff coefficients, %			
	5	10	15	20
Cereals				
Sorghum/ Maize	8.0	4.0	2.7	2.0
Pulses				
Redgram	NR	NR	NR	NR
Chickpea	NR	NR	NR	NR
Blackgram	NR	NR	NR	NR
Green gram	NR	NR	NR	NR
Oil seed				
Groundnut	2.7	1.3	0.9	0.7
Sunflower	NR	NR	NR	NR
Soybean	8.0	4.0	2.7	2.0
Castor	13.3	6.7	4.4	3.3
Cotton	24.0	12.0	8.0	6.0
Vegetables				
Onion/ Potato	18.7	9.3	6.2	4.7
Tomato	24.0	12.0	8.0	6.0
Chillies, Cabbage, Carrot, Okra, Beans	13.3	6.7	4.4	3.3

NR : Not required as the design rainfall is more than the crop water requirement

Based on the above information for different irrigation strategies with farm ponds, the cultivable area (Acu) for different crops can be estimated. However, this requires information on expected runoff volume collected from the farm catchments. Hence for different catchment areas, the runoff volumes are calculated for varying runoff coefficients (5-20%) and efficiency factor (EF) of 0.5 and 0.75. The results are presented in Fig 11(a and b) for different design seasonal rainfall at two probabilities of 67 and 75%. For unlined farm ponds, the collected runoff volumes have to be multiplied with a factor of 1.5 for accounting water losses through seepage and evaporation. For lined farm ponds, the volume may be multiplied by the factor of 1.05 to account for only evaporation losses. These volumes have to be considered for the design of farm ponds in a selected catchments.

Table 11(b) : Ratio of catchment area (A_{ca}) to cultivable area (A_{cu}) for different crops with varying runoff coefficients considering critical irrigation and design rainfall at 75% probability for Southern Telengana region.

Crops	Runoff coefficients (%)							
	5		10		15		20	
	30mm	50mm	30mm	50mm	30mm	50mm	30mm	50mm
Cereals								
Sorghum/ Maize	9.6	16	4.8	8.0	3.2	5.3	2.4	4.0
Pulses								
Redgram, Blackgram, and Green gram	6.4	10.7	3.2	5.3	2.1	3.6	1.6	2.7
Chickpea	3.2	5.3	1.6	2.7	1.1	1.8	0.8	1.3
Oil seed								
Groundnut	9.6	16.0	4.8	8.0	3.2	5.3	2.4	4.0
Sunflower, Soybean, Castor and Cotton	6.4	10.7	3.2	5.3	2.1	3.6	1.6	2.7
Vegetables								
Onion, Tomato, Chillies, Cabbage, Potato, Carrot, Okra, Beans	6.4	10.7	3.2	5.3	2.1	3.6	1.6	2.7

Pond Design

A well designed pond is a valuable asset for integrated farming system with minimum maintenance cost. Proper construction of a pond must be preceded by proper planning and design. To design a pond, careful study is required with respect to the hydrology of the catchment, rainfall–runoff relationship, requirement of water, expected seepage and evaporation losses. The main consideration in design is to provide enough water for agricultural operations at minimum cost. The analysis of these parameters will guide to decide the dimension of the ponds. Dimensions in designing a pond are the size, shape of the pond, side slopes and the water control structures (inlet, silt trap and outlet).

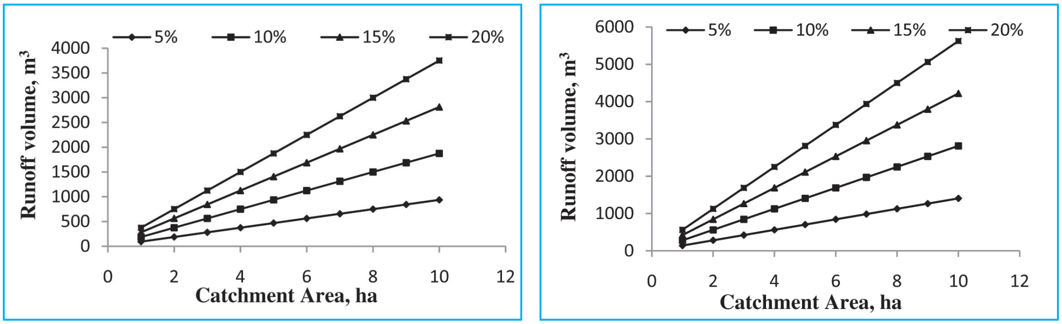
The design of a excavated or dugout pond include the determination of specifications for the following: (a) Pond capacity, (b) Shape of pond, (c) Dimensions (depth, top & bottom widths and side slopes), (d) Inlet channels and (e) Emergency spillway or Outlet.

Table 11(c) : Ratio of catchment area (A_{ca}) to cultivable area($A_{cu(}$) for different crops with varying runoff coefficients considering critical irrigation in khariff and vegetables in Rabi for design rainfall at 75% probability in Southern Telengana region.

Cropping System	Runoff Coefficients, %							
	5		10		15		20	
Cereals ***(kharif) plus vegetable (rabi)***								
Sorghum/Maize+Onion/Potato	68.3	74.7	34.1	37.3	22.8	24.9	17.1	18.7
Sorghum/Maize +Tomato	73.6	80.0	36.8	40.0	24.5	26.7	18.4	20.0
Sorghum/Maize +Cabbage/Chilli/ Carrot/Okra/Beans	62.9	69.3	31.5	34.7	21.0	23.1	15.7	17.3
Pulses ***(kharif) plus vegetable (rabi)***								
Gram+Onion/Potato	65.1	69.3	32.5	34.7	21.7	23.1	16.3	17.3
Gram +Tomato	70.4	74.7	35.2	37.3	23.5	24.9	17.6	18.7
Gram +Cabbage/Chilli/Carrot/ Okra/Beans	59.7	64.0	29.9	32.0	19.9	21.3	14.9	16.0
Oil seed ***(kharif) plus vegetable (rabi)***								
Groundnut+Onion/Potato	68.3	74.7	34.1	37.3	22.8	24.9	17.1	18.7
Groundnut+Tomato	73.6	80.0	36.8	40.0	24.5	26.7	18.4	20.0
Groundnut+Cabbage/Chilli/ Carrot/Okra/Beans	62.9	69.3	31.5	34.7	21.0	23.1	15.7	17.3
Other oilseed+Onion/Potato	65.1	69.3	32.5	34.7	21.7	23.1	16.3	17.3
Other oilseed+Tomato	91.7	96.0	45.9	48.0	30.6	32.0	22.9	24.0
Other oilseed+Cabbage/Chilli/ Carrot/Okra/Beans	59.7	64.0	29.9	32.0	19.9	21.3	14.9	16.0

Pond Capacity

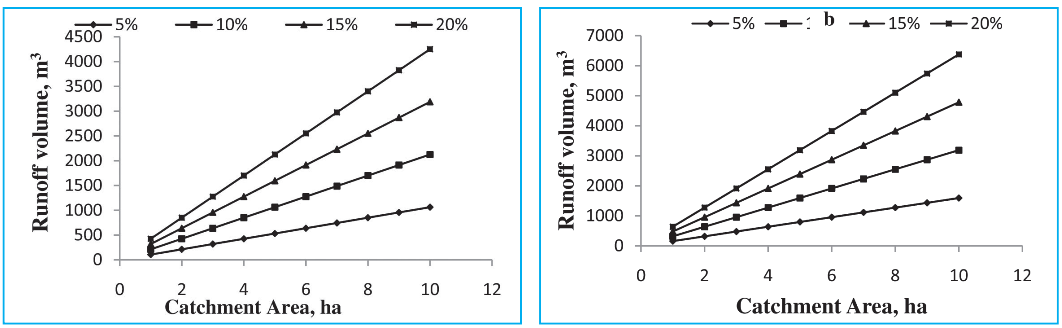
The capacity of the dugout pond depends on purpose for which water is needed and by the amount of inflow that can be expected in a given period. The seasonal water yield can be estimated using past historical weather data. The storage losses such as seepage and percolation losses would also influence the storage capacity of pond. The type of soil in the catchment area contributes to the siltation and this has to be considered as it affects the storage capacity of pond. The capacity of the pond depends upon the catchment size and factors affecting its water yield. On a conservative estimate, a dependable minimum value of 20% of the seasonal rainfall can be expected to go as runoff in case of black soils and 10% in case of red soils with mild to medium slopes. The pond should be of sufficient capacity to meet the demand of the crops or integrated farming system for which it is constructed. Generally, one or two



EF= 0.5

EF= 0.75

Fig. 11(a) : Expected runoff volume at design seasonal rainfall of 375mm (75% probability) for varying runoff coefficients, efficiency factor (EF) and catchment area.



EF= 0.5

EF= 0.75

Fig. 11(b) : Expected runoff volume at design seasonal rainfall 425mm (67% probability) for varying runoff coefficients, efficiency factor (EF) and catchment area.

supplemental irrigations with 50mm or less are planned for irrigating crops from such ponds. Barring summer months, the evaporation rate is fairly constant during the period of storage in the semi-arid regions. However, the seepage rate varies widely due to the variations in the sub-soil strata. A suitable provision should be made for the loss in storage capacity due to silting which is generally kept as 5-10 per cent. In sandy or light texture soils having high infiltration rate (>10cm/hr) will have a water loss of 50-60% in which seepage is predominant (40-50%). In such soils, the pond capacity must be designed for actual requirement of water for irrigation plus the seepage (40-50%) and evaporation losses (5%).

Shape of Pond

Excavated farm ponds may normally be of three shapes, viz; (a) square, (b) rectangular, and c) inverted cone. However, as curved shape offers difficulties in construction, either square or rectangular ponds are normally adopted. Inverted cone ponds with circular cross section are theoretically cheaper, but difficult to construct and manage.

Lining of such ponds would require more material for the same capacity of square or rectangular farm ponds. Therefore, the lining of inverted cone farm ponds is costlier. Square ponds are more economical than rectangular. Different shapes of farm ponds are given in Fig 12(a, b & c).

Fig. 12(a,b&c) : Different shapes of farm ponds with Silpaulin and HDPE lining

Dimensions of farm pond

The selection of dimensions for excavated pond depends on the required capacity, soil type, purpose and type of machine available for pond construction. The size of a pond should be relative to the size of the catchment area contributing surface runoff to the site. Ponds with too little catchment will have difficulty in filling up and remaining full during drought conditions. Ponds with too much watershed require expensive water control structures and are difficult to manage. Therefore, determination of optimum dimensions based on hydrological considerations is very important to keep the area loss to an extent of 10 to 12% in a farm catchment.

Depth and side slope of farm ponds

The depth of pond is generally determined by soil depth, kind of material excavated and type of equipment used. The selected pond depth should have a depth equal to or greater than the minimum required for the specific location as depth of pond is most important dimension among the three dimensions. In semi arid regions, the evaporation losses can be reduced by deepening the pond depth for the same volume of water stored as lesser is the area occupied by the pond. However, with increased depth, the seepage losses also increase. Seepage loss can be controlled by application of lining through LDPE/HDPE/Silpaulin plastic film. Water Technology Centre for eastern region reported that, when pond construction is done with labour, any increase in depth beyond 3.5 to 4.0 m becomes uneconomical. It also becomes uneconomical and difficult for lifting devices operated with human and animal power. Hence, a depth of 2.5 to 3.5 m may be suitable in general for the ponds.

The side slope of the pond are decided based on their angle of repose of the material being excavated and this angle of repose varies with type of soil. For the most cases, the side slopes of 1: 1 to 1.5:1 are recommended for practical purpose. Based on practical experience it is recommended that, selected side slopes are generally no steeper than the natural angle of repose of material. The recommended side slopes for different soil are given in Table 12.

The standing of water in a farm pond for a longer duration, may require relatively flatter side slopes to avoid slippage due to saturation. The area of the top and bottom for rectangular, square and inverted cone can be calculated from their dimensions in case of rectangular or square and diameter in case of inverted cone as per Fig 13(a&b).

Table 12 : Suitable side slopes for different soils

Soil type	Slope (horizontal:vertical)
Clay	1:1 to 2:1
Clay loam	1.5:1to 2:1
Sandy loam	2:1to 2.5:1
Sandy	3:1

(Source: FAO, 2011)

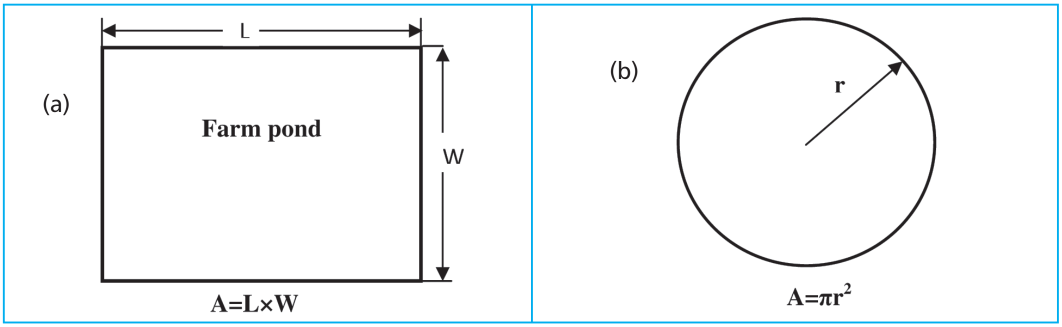


Fig. 13(a & b) : Plan view of rectangular and inverted cone farm pond for estimation of top, and bottom areas

Where,

A	=	area, m^2,	W	=	width of the pond,m. and
L	=	length of the pond,m.	r	=	radius of the pond, m.

Once the volume, depth and side slope are known, the dimensions of different shape of farm ponds can be calculated using the prismoidal formula as given below as per the definition sketch (Fig 14).

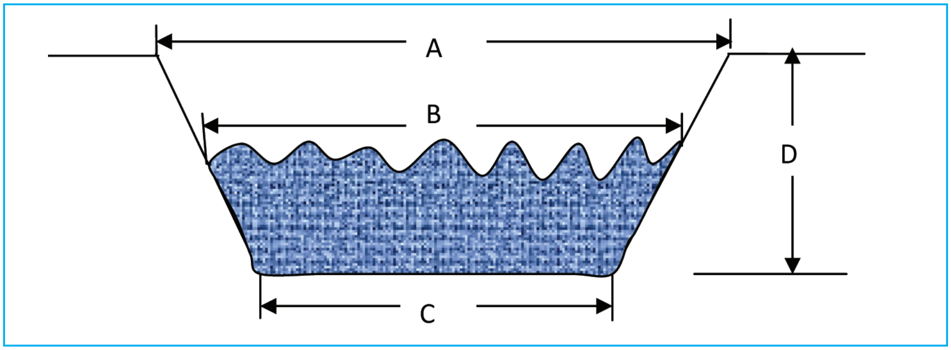


Fig. 14 : Definition sketch of farm pond for estimation of top and bottom areas

$$V = \frac{A+4B+C}{6} \times D \qquad \text{---- (7)}$$

Where,

V = volume of excavation (m^3)

A = area of excavation at the ground surface (m^3)

B = area of excavation at the mid- depth point (D/2) (m^3)

C = area of the excavation at the bottom of pond (m^3); and

D = average depth of the pond (m).

The plan and section views of rectanglar and inverted cone farm ponds are given in Fig. 15 (a&b).

(i) Rectangular farm pond

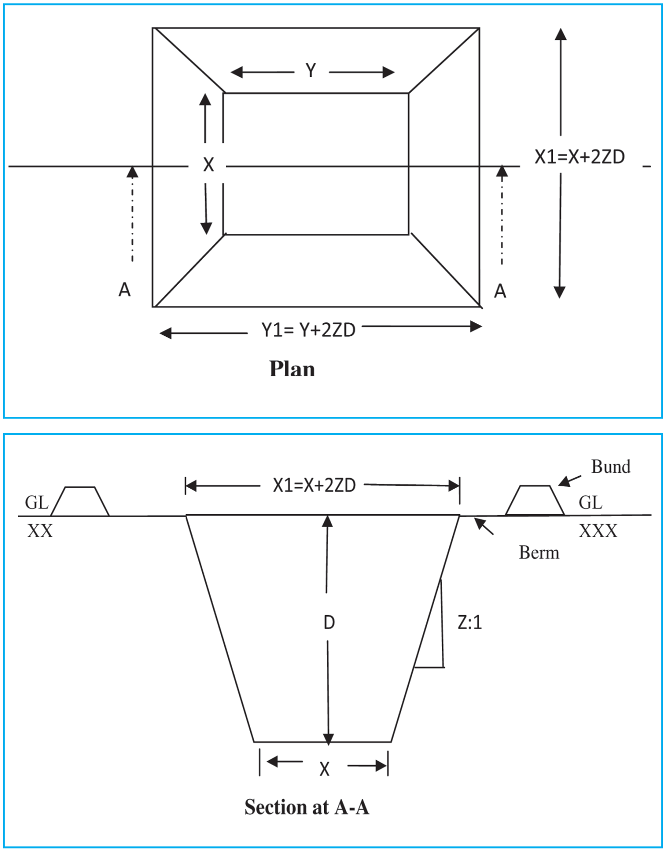


Fig. 15(a) : Plan and section view of square shaped dugout farm pond

From the equation (7) the bottom dimensions for rectangular is derived as given below:

$$X = (0.5/C)\left(\sqrt{Z^2D^2(1+C)^2 - 4C\{(4/3)Z^2D^2 - V/D\}} - ZD(1+C)\right) \quad ---\ (8)$$

Where, X, and Y are two sides of the dugout pond (rectangular) at the bottom and C= Y/X.

For a square section, C=1, i.e. X=Y, the equation (8) can be simplified as follows:

$$X = \sqrt{Z^2D^2 - (4/3\ Z^2D^2 - V/D\}} - ZD \quad ---\ (9)$$

(ii) Inverted cone

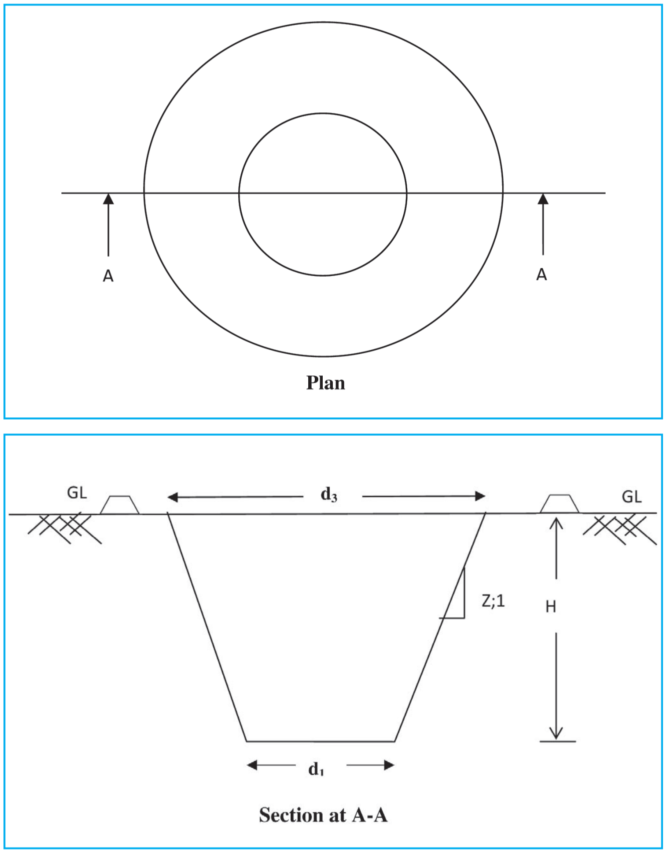


Fig. 15(b) : Plan and section view of inverted cone dugout farm pond

From the equation (7), the dimension for inverted cone is derived as follows:

$$d_1 = \sqrt{\{(4V/\pi H)-(1/3)Z^2H^2\}} - ZH \qquad \text{--- (10)}$$

$$d_3 = (d_1+2ZH) \qquad \text{--- (11)}$$

The dimensions of the bottom and top surface of farm ponds are worked out for different volume of farm ponds, depths and side slopes (Table 13, 14 (a,b) and 15).

Table 13 : Dimensions of square shaped dug out farm pond for different capacities (V), depths (D) and side slopes

Pond capacity, m^3	Side slope = 1:1								Side slope = 1.5:1							
	2		2.5		3		3.5		2		2.5		3		3.5	
	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top	Bottom	Top
250	9.1	13.1	7.4	12.4	6.0	12.0	4.7	11.7	8.0	14.0	6.0	13.5	4.3	13.3	2.6	13.1
500	13.8	17.8	11.6	16.6	9.8	15.8	8.3	15.3	12.7	18.7	10.2	17.7	8.1	17.1	6.3	16.8
750	17.3	21.3	14.8	19.8	12.7	18.7	11.0	18.0	16.3	22.3	13.4	20.9	11.1	20.1	9.1	19.6
1000	20.3	24.3	17.4	22.4	15.2	21.2	13.3	20.3	19.3	25.3	16.1	23.6	13.6	22.6	11.4	21.9
1250	23.0	27.0	19.8	24.8	17.3	23.3	15.3	22.3	21.9	27.9	18.5	26.0	15.7	24.7	13.4	23.9
1500	25.4	29.4	22.0	27.0	19.3	25.3	17.1	24.1	24.3	30.3	20.6	28.1	17.7	26.7	15.2	25.7
1750	27.6	31.6	23.9	28.9	21.1	27.1	18.8	25.8	26.5	32.5	22.6	30.1	19.5	28.5	16.9	27.4
2000	29.6	33.6	25.7	30.7	22.8	28.8	20.3	27.3	28.6	34.6	24.5	32.0	21.2	30.2	18.5	29.0
2250	31.5	35.5	27.5	32.5	24.3	30.3	21.8	28.8	30.5	36.5	26.2	33.7	22.8	31.8	19.9	30.4
2500	33.3	37.3	29.1	34.1	25.8	31.8	23.2	30.2	32.3	38.3	27.8	35.3	24.3	33.3	21.3	31.8
2750	35.1	39.1	30.6	35.6	27.2	33.2	24.5	31.5	34.0	40.0	29.3	36.8	25.7	34.7	22.6	33.1
3000	36.7	40.7	32.1	37.1	28.6	34.6	25.7	32.7	35.7	41.7	30.8	38.3	27.0	36.0	23.9	34.4
3250	38.3	42.3	33.5	38.5	29.9	35.9	26.9	33.9	37.3	43.3	32.2	39.7	28.3	37.3	25.1	35.6
3500	39.8	43.8	34.9	39.9	31.1	37.1	28.1	35.1	38.8	44.8	33.6	41.1	29.6	38.6	26.2	36.7
3750	41.3	45.3	36.2	41.2	32.3	38.3	29.2	36.2	40.3	46.3	34.9	42.4	30.8	39.8	27.3	37.8
4000	42.7	46.7	37.5	42.5	33.5	39.5	30.2	37.2	41.7	47.7	36.2	43.7	31.9	40.9	28.4	38.9
4250	44.1	48.1	38.7	43.7	34.6	40.6	31.3	38.3	43.1	49.1	37.4	44.9	33.0	42.0	29.5	40.0
4500	45.4	49.4	39.9	44.9	35.7	41.7	32.3	39.3	44.4	50.4	38.6	46.1	34.1	43.1	30.5	41.0
4750	46.7	50.7	41.1	46.1	36.8	42.8	33.3	40.3	45.7	51.7	39.8	47.3	35.2	44.2	31.5	42.0
5000	48.0	52.0	42.2	47.2	37.8	43.8	34.2	41.2	47.0	53.0	40.9	48.4	36.2	45.2	32.4	42.9
5250	49.2	53.2	43.3	48.3	38.8	44.8	35.2	42.2	48.2	54.2	42.0	49.5	37.3	46.3	33.4	43.9
5500	50.4	54.4	44.4	49.4	39.8	45.8	36.1	43.1	49.4	55.4	43.1	50.6	38.2	47.2	34.3	44.8
5750	51.6	55.6	45.4	50.4	40.7	46.7	37.0	44.0	50.6	56.6	44.2	51.7	39.2	48.2	35.2	45.7
6000	52.8	56.8	46.5	51.5	41.7	47.7	37.9	44.9	51.7	57.7	45.2	52.7	40.1	49.1	36.0	46.5
6250	53.9	57.9	47.5	52.5	42.6	48.6	38.7	45.7	52.9	58.9	46.2	53.7	41.1	50.1	36.9	47.4
6500	55.0	59.0	48.5	53.5	43.5	49.5	39.5	46.5	54.0	60.0	47.2	54.7	42.0	51.0	37.7	48.2
6750	56.1	60.1	49.4	54.4	44.4	50.4	40.4	47.4	55.1	61.1	48.2	55.7	42.9	51.9	38.6	49.1
7000	57.1	61.1	50.4	55.4	45.3	51.3	41.2	48.2	56.1	62.1	49.1	56.6	43.7	52.7	39.4	49.9

* All dimensions are in 'm'.

Table 14(a) : Dimensions of rectangular shaped dug out farm pond for different capacities (V), depths (D) and side slope of 1:1

Pond capacity, m^3	2				2.5				3				3.5			
	Y	X	Y_1	X_1	Y	X	Y_1	X_1	Y	X	Y_1	X_1	Y	X	Y_1	X_1
250	11.1	7.4	15.1	11.4	9.0	6.0	14.0	11.0	7.3	4.8	13.3	10.8	5.7	3.8	12.7	10.8
500	16.8	11.2	20.8	15.2	14.1	9.4	19.1	14.4	11.9	8.0	17.9	14.0	10.1	6.7	17.1	13.7
750	21.2	14.1	25.2	18.1	18.0	12.0	23.0	17.0	15.5	10.3	21.5	16.3	13.4	8.9	20.4	15.9
1000	24.9	16.6	28.9	20.6	21.3	14.2	26.3	19.2	18.5	12.3	24.5	18.3	16.2	10.8	23.2	17.8
1250	28.1	18.7	32.1	22.7	24.2	16.1	29.2	21.1	21.2	14.1	27.2	20.1	18.7	12.4	25.7	19.4
1500	31.0	20.7	35.0	24.7	26.8	17.9	31.8	22.9	23.6	15.7	29.6	21.7	20.9	13.9	27.9	20.9
1750	33.7	22.5	37.7	26.5	29.2	19.5	34.2	24.5	25.8	17.2	31.8	23.2	22.9	15.3	29.9	22.3
2000	36.2	24.1	40.2	28.1	31.5	21.0	36.5	26.0	27.8	18.5	33.8	24.5	24.8	16.5	31.8	23.5
2250	38.6	25.7	42.6	29.7	33.6	22.4	38.6	27.4	29.7	19.8	35.7	25.8	26.6	17.7	33.6	24.7
2500	40.8	27.2	44.8	31.2	35.6	23.7	40.6	28.7	31.6	21.0	37.6	27.0	28.3	18.9	35.3	25.9
2750	42.9	28.6	46.9	32.6	37.5	25.0	42.5	30.0	33.3	22.2	39.3	28.2	29.9	19.9	36.9	26.9
3000	44.9	29.9	48.9	33.9	39.3	26.2	44.3	31.2	34.9	23.3	40.9	29.3	31.4	20.9	38.4	27.9
3250	46.9	31.2	50.9	35.2	41.0	27.3	46.0	32.3	36.5	24.3	42.5	30.3	32.9	21.9	39.9	28.9
3500	48.7	32.5	52.7	36.5	42.7	28.4	47.7	33.4	38.0	25.4	44.0	31.4	34.3	22.9	41.3	29.9
3750	50.5	33.7	54.5	37.7	44.3	29.5	49.3	34.5	39.5	26.3	45.5	32.3	35.6	23.8	42.6	30.8
4000	52.3	34.8	56.3	38.8	45.8	30.6	50.8	35.6	40.9	27.3	46.9	33.3	37.0	24.6	44.0	31.6
4250	53.9	36.0	57.9	40.0	47.3	31.6	52.3	36.6	42.3	28.2	48.3	34.2	38.2	25.5	45.2	32.5
4500	55.6	37.1	59.6	41.1	48.8	32.5	53.8	37.5	43.6	29.1	49.6	35.1	39.5	26.3	46.5	33.3
4750	57.2	38.1	61.2	42.1	50.2	33.5	55.2	38.5	44.9	30.0	50.9	36.0	40.7	27.1	47.7	34.1
5000	58.7	39.1	62.7	43.1	51.6	34.4	56.6	39.4	46.2	30.8	52.2	36.8	41.9	27.9	48.9	34.9
5250	60.2	40.2	64.2	44.2	53.0	35.3	58.0	40.3	47.4	31.6	53.4	37.6	43.0	28.7	50.0	35.7
5500	61.7	41.1	65.7	45.1	54.3	36.2	59.3	41.2	48.7	32.4	54.7	38.4	44.1	29.4	51.1	36.4
5750	63.2	42.1	67.2	46.1	55.6	37.1	60.6	42.1	49.8	33.2	55.8	39.2	45.2	30.1	52.2	37.1
6000	64.6	43.0	68.6	47.0	56.9	37.9	61.9	42.9	51.0	34.0	57.0	40.0	46.3	30.9	53.3	37.9
6250	66.0	44.0	70.0	48.0	58.1	38.7	63.1	43.7	52.1	34.7	58.1	40.7	47.3	31.6	54.3	38.6
6500	67.3	44.9	71.3	48.9	59.3	39.5	64.3	44.5	53.2	35.5	59.2	41.5	48.4	32.2	55.4	39.2
6750	68.6	45.8	72.6	49.8	60.5	40.3	65.5	45.3	54.3	36.2	60.3	42.2	49.4	32.9	56.4	39.9
7000	69.9	46.6	73.9	50.6	61.7	41.1	66.7	46.1	55.4	36.9	61.4	42.9	50.3	33.6	57.3	40.6

Y=Bottom length, X=Bottom width, Y_1=Top length, X_1=Top width, Y/X=1.5, * All the dimensions are in ‘m’.

Table 14(b) : Dimensions of rectangular shaped dug out farm pond for different capacities (V), depths (D) and side slope 1.5:1

Pond capacity, m^3	2				2.5				3				3.5			
	Y	X	Y_1	X_1	Y	X	Y_1	X_1	Y	X	Y_1	X_1	Y	X	Y_1	X_1
250	9.8	6.5	15.8	12.5	7.3	4.9	14.8	12.4	5.2	3.4	14.2	12.4	3.2	2.1	13.7	12.6
500	15.5	10.3	21.5	16.3	12.5	8.3	20.0	15.8	9.9	6.6	18.9	15.6	7.7	5.1	18.2	15.6
750	19.9	13.3	25.9	19.3	16.4	10.9	23.9	18.4	13.5	9.0	22.5	18.0	11.0	7.4	21.5	17.9
1000	23.6	15.7	29.6	21.7	19.7	13.1	27.2	20.6	16.5	11.0	25.5	20.0	13.8	9.2	24.3	19.7
1250	26.8	17.9	32.8	23.9	22.6	15.1	30.1	22.6	19.2	12.8	28.2	21.8	16.3	10.9	26.8	21.4
1500	29.7	19.8	35.7	25.8	25.2	16.8	32.7	24.3	21.6	14.4	30.6	23.4	18.6	12.4	29.1	22.9
1750	32.4	21.6	38.4	27.6	27.6	18.4	35.1	25.9	23.8	15.9	32.8	24.9	20.6	13.7	31.1	24.2
2000	34.9	23.3	40.9	29.3	29.9	19.9	37.4	27.4	25.9	17.2	34.9	26.2	22.5	15.0	33.0	25.5
2250	37.3	24.9	43.3	30.9	32.0	21.3	39.5	28.8	27.8	18.5	36.8	27.5	24.3	16.2	34.8	26.7
2500	39.5	26.3	45.5	32.3	34.0	22.6	41.5	30.1	29.6	19.7	38.6	28.7	26.0	17.3	36.5	27.8
2750	41.6	27.7	47.6	33.7	35.9	23.9	43.4	31.4	31.3	20.9	40.3	29.9	27.6	18.4	38.1	28.9
3000	43.6	29.1	49.6	35.1	37.7	25.1	45.2	32.6	33.0	22.0	42.0	31.0	29.1	19.4	39.6	29.9
3250	45.6	30.4	51.6	36.4	39.4	26.3	46.9	33.8	34.6	23.1	43.6	32.1	30.6	20.4	41.1	30.9
3500	47.4	31.6	53.4	37.6	41.1	27.4	48.6	34.9	36.1	24.1	45.1	33.1	32.0	21.3	42.5	31.8
3750	49.2	32.8	55.2	38.8	42.7	28.5	50.2	36.0	37.6	25.1	46.6	34.1	33.4	22.3	43.9	32.8
4000	51.0	34.0	57.0	40.0	44.2	29.5	51.7	37.0	39.0	26.0	48.0	35.0	34.7	23.1	45.2	33.6
4250	52.7	35.1	58.7	41.1	45.7	30.5	53.2	38.0	40.4	26.9	49.4	35.9	36.0	24.0	46.5	34.5
4500	54.3	36.2	60.3	42.2	47.2	31.5	54.7	39.0	41.7	27.8	50.7	36.8	37.2	24.8	47.7	35.3
4750	55.9	37.3	61.9	43.3	48.6	32.4	56.1	39.9	43.0	28.7	52.0	37.7	38.4	25.6	48.9	36.1
5000	57.5	38.3	63.5	44.3	50.0	33.4	57.5	40.9	44.3	29.5	53.3	38.5	39.6	26.4	50.1	36.9
5250	59.0	39.3	65.0	45.3	51.4	34.3	58.9	41.8	45.5	30.3	54.5	39.3	40.7	27.2	51.2	37.7
5500	60.4	40.3	66.4	46.3	52.7	35.1	60.2	42.6	46.7	31.2	55.7	40.2	41.9	27.9	52.4	38.4
5750	61.9	41.3	67.9	47.3	54.0	36.0	61.5	43.5	47.9	31.9	56.9	40.9	43.0	28.6	53.5	39.1
6000	63.3	42.2	69.3	48.2	55.3	36.8	62.8	44.3	49.1	32.7	58.1	41.7	44.0	29.4	54.5	39.9
6250	64.7	43.1	70.7	49.1	56.5	37.7	64.0	45.2	50.2	33.5	59.2	42.5	45.1	30.1	55.6	40.6
6500	66.0	44.0	72.0	50.0	57.7	38.5	65.2	46.0	51.3	34.2	60.3	43.2	46.1	30.7	56.6	41.2
6750	67.4	44.9	73.4	50.9	58.9	39.3	66.4	46.8	52.4	34.9	61.4	43.9	47.1	31.4	57.6	41.9
7000	68.7	45.8	74.7	51.8	60.1	40.0	67.6	47.5	53.5	35.6	62.5	44.6	48.1	32.1	58.6	42.6

Y=Bottom length, X=Bottom width, Y_1=Top length, X_1=Top width, Y/X=1.5, * All the dimensions are in 'm'.

Table 15 : Dimensions of inverted cone shaped dug out farm pond for different capacities (V), depths (D) with side slopes.

Pond capacity, m^3	Side slope = 1:1								Side slope = 1.5:1							
	2		2.5		3		3.5		2		2.5		3		3.5	
	d_1	d_3	d_1	d_3	d_1	d_3	d_1	d_3	d_1	d_3	d_1	d_3	d_1	d_3	d_1	d_3
250	10.6	14.6	8.7	13.7	7.2	13.2	5.8	12.8	9.5	15.5	7.3	14.8	5.5	14.5	3.8	14.3
500	15.8	19.8	13.4	18.4	11.5	17.5	9.8	16.8	14.8	20.8	12.1	19.6	9.8	18.8	7.9	18.4
750	19.8	23.8	17.0	22.0	14.8	20.8	12.9	19.9	18.8	24.8	15.7	23.2	13.1	22.1	11.0	21.5
1000	23.2	27.2	20.0	25.0	17.5	23.5	15.5	22.5	22.2	28.2	18.7	26.2	15.9	24.9	13.6	24.1
1250	26.2	30.2	22.7	27.7	20.0	26.0	17.7	24.7	25.2	31.2	21.4	28.9	18.4	27.4	15.9	26.4
1500	28.9	32.9	25.1	30.1	22.2	28.2	19.8	26.8	27.9	33.9	23.8	31.3	20.6	29.6	17.9	28.4
1750	31.4	35.4	27.3	32.3	24.2	30.2	21.6	28.6	30.3	36.3	26.0	33.5	22.6	31.6	19.8	30.3
2000	33.7	37.7	29.4	34.4	26.1	32.1	23.4	30.4	32.6	38.6	28.1	35.6	24.5	33.5	21.6	32.1
2250	35.8	39.8	31.3	36.3	27.9	33.9	25.0	32.0	34.8	40.8	30.0	37.5	26.3	35.3	23.2	33.7
2500	37.9	41.9	33.2	38.2	29.5	35.5	26.6	33.6	36.9	42.9	31.9	39.4	28.0	37.0	24.8	35.3
2750	39.8	43.8	34.9	39.9	31.1	37.1	28.1	35.1	38.8	44.8	33.6	41.1	29.6	38.6	26.2	36.7
3000	41.7	45.7	36.6	41.6	32.6	38.6	29.5	36.5	40.7	46.7	35.3	42.8	31.1	40.1	27.6	38.1
3250	43.5	47.5	38.2	43.2	34.1	40.1	30.8	37.8	42.5	48.5	36.9	44.4	32.5	41.5	29.0	39.5
3500	45.2	49.2	39.7	44.7	35.5	41.5	32.1	39.1	44.2	50.2	38.4	45.9	34.0	43.0	30.3	40.8
3750	46.8	50.8	41.2	46.2	36.9	42.9	33.4	40.4	45.8	51.8	39.9	47.4	35.3	44.3	31.6	42.1
4000	48.4	52.4	42.6	47.6	38.2	44.2	34.6	41.6	47.4	53.4	41.3	48.8	36.6	45.6	32.8	43.3
4250	50.0	54.0	44.0	49.0	39.4	45.4	35.8	42.8	49.0	55.0	42.7	50.2	37.9	46.9	34.0	44.5
4500	51.5	55.5	45.3	50.3	40.7	46.7	36.9	43.9	50.5	56.5	44.1	51.6	39.1	48.1	35.1	45.6
4750	53.0	57.0	46.7	51.7	41.9	47.9	38.0	45.0	52.0	58.0	45.4	52.9	40.3	49.3	36.2	46.7
5000	54.4	58.4	47.9	52.9	43.0	49.0	39.1	46.1	53.4	59.4	46.7	54.2	41.5	50.5	37.3	47.8
5250	55.8	59.8	49.2	54.2	44.2	50.2	40.2	47.2	54.8	60.8	47.9	55.4	42.6	51.6	38.3	48.8
5500	57.2	61.2	50.4	55.4	45.3	51.3	41.2	48.2	56.1	62.1	49.1	56.6	43.7	52.7	39.4	49.9
5750	58.5	62.5	51.6	56.6	46.4	52.4	42.2	49.2	57.5	63.5	50.3	57.8	44.8	53.8	40.4	50.9
6000	59.8	63.8	52.8	57.8	47.4	53.4	43.2	50.2	58.8	64.8	51.5	59.0	45.9	54.9	41.4	51.9
6250	61.1	65.1	53.9	58.9	48.5	54.5	44.1	51.1	60.1	66.1	52.6	60.1	46.9	55.9	42.3	52.8
6500	62.3	66.3	55.0	60.0	49.5	55.5	45.1	52.1	61.3	67.3	53.7	61.2	48.0	57.0	43.3	53.8
6750	63.5	67.5	56.1	61.1	50.5	56.5	46.0	53.0	62.5	68.5	54.8	62.3	49.0	58.0	44.2	54.7
7000	64.7	68.7	57.2	62.2	51.5	57.5	46.9	53.9	63.7	69.7	55.9	63.4	49.9	58.9	45.1	55.6

*d_1=bottom dia, and d_3=top dia, All dimensions are in 'm'.

Inlet channels and spillways

The inlet channels have to be constructed in such way that, all the surface runoff generated in catchment area should reach the pond. The inlet channels can be laid all along the slope but care should be taken that, it should be with safe velocity. The grasses can be grown on constructed channel to avoid the channel erosion.

Stone pitching can be done to reduce erosion. The channels are to be made on one side of the farm with a major slope of area contributing runoff without affecting the cultivation land. The length and width of the channel should be sufficient to carry the surface runoff (Fig 16). The inlet is designed as chute spillway for conducting the runoff into the pond in a controlled manner. The entry section can be designed as a rectangular broad crested weir. Since the velocity of runoff is accelerated along the side slope of the pond, the width is contracted at 1 m below the top level of pond and continued at the same width thereafter. The parabolic cross section with a depth of 0.3 to 0.5m and 1 to 1.5m width are preferred for channel dimensions so that the farm machinery can easily cross the channels during the field operations. However, a square or rectangular cross section field channels are common in the fields for the disposal of runoff. Grassed waterways would be more effective in safe disposal of runoff without erosion.

Fig 16. A view of inlet channels and stone picthing in spillway

Outlet/Waste weir

The outlet or waste weir for the pond is designed to remove the surplus runoff above the maximum capacity of the pond. Generally, outlet is located at one end of pond in undisturbed soil and should be well vegetated with grass to reduce erosion. The flow through the outlet should be shallow, slow, and uniform to minimize the possibility of the outlet eroding and causing failure of the pond. The outlet position will be a little lower (15 to 20 cm) than the elevation of the inlet to avoid backing up of the water. The discharge capacity of the outlet can be assumed to be half as that of the inlet capacity as peak rate of runoff. The stone pitching if locally available will be effective in controlling channel erosion.

Construction of farm pond

After the site selection and pond dimensions decided, the pond site should be cleared of all stones and woody vegetation. Before construction of farm pond, proper layout should be made for proper construction. The design drawings for farm pond with silt trap, inlet and outlet construction are given in Fig 17(a, b, c &d). Stakes are used to mark the limits of the excavation and spoil placement areas and the depth of cut from the ground surface to the pond bottom should be indicated on the stakes. Excavation and placement of the dugout material are the principal items of work required in the construction of pond.

Generally, the equipments used for pond construction are tractor pulled wheeled scrappers, draglines and bulldozers. The use of a bulldozer for excavation is usually limited to relatively small ponds due to its inefficiency in transporting the material. In semi arid regions, any type of equipment can be used but in high rainfall areas where a ground water table exists in shallow depth, the dragline excavator is most commonly used equipment. The excavated material should be placed as near to the pond and that can be used for making the berm on the pond. After excavating of the earth, compaction of the sub grade and banks should be done thoroughly for proper establishment of the structure.

Earth moving machinery for excavation

The selected site should be free from vegetation, bushes and other obstacles and it should be levelled so that demarcation line of the pond area can be drawn. The design dimensions of proposed pond can be drawn with the help of rope and lines for demarcation can be done with lime powder or making small cuts with spade so that the demarcation lines are visible for equipment operator to enabling to excavate soil form the pond area. A view of earth excavation of dugout farm pond is showed in (Fig 18). Initially digging of pond must be started at the central portion of layout to a designed depth indicated on stakes. There are two types of earth moving machinery like JCB with bucket volume of 0.1 m^3 with short boom and Tata-Hitachi Volvo 200 model with bucket capacity of 1m^3 with long boom of 4m. When the soil from the bottom of pond is completely removed, put the rope connecting to the corner of bottom area and outer top corner; give the required or desired slope at one corner of pond by cutting the soil. It is often suggested that shaping the pond must be done with cutting rather than filling of soil and this will facilitate better preparation of the sub grade, which is very important for stable pond boundary. Thereafter, the soil is removed from the sides according to the already maintained slope at previous point i.e. corner and give a perfect shape to the reservoir by cutting the soil according to the slope. The excavated soil must be placed in the portion of dotted lines as shown in Fig 17(a) after leaving the space for berm of 0.5m along the side length of farm pond. The excavation soil should be compacted for its regular shape of trapezoidal bund with bottom width at least 1.5 to 2.5m and top width 0.5m and height of bund as 0.5m. The side slopes may be kept as 1:1. The bunds after compaction to the dimensions may be well grassed for its stability.

Operation and maintenance of farm pond

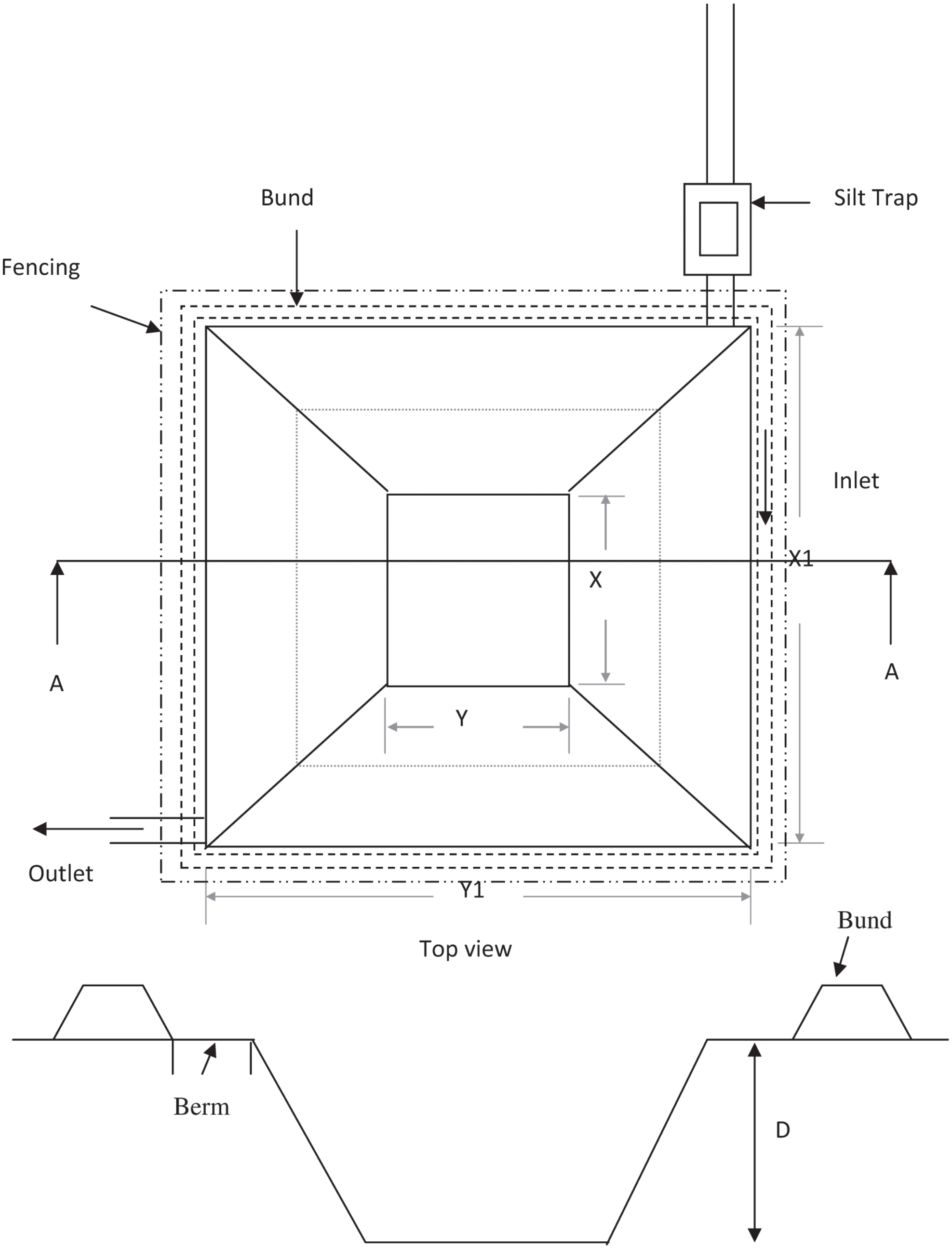
Proper maintenance of the pond can ensure good life and service as it prevents expensive repair costs. A pond, no matter how well planned and built, must be adequately maintained if its intended purpose are to be realized throughout its expected life. The pond should be inspected periodically. Care should be taken when heavy rains occur for the damages if any in farm pond. Initially damage may be small, but if neglected it may increase until repair becomes impractical. Any rills on the side slopes of the pond may be filled and any washes in the inlet spillway must be immediately filled with suitable material with thorough compaction. Care should be taken to keep the water in the pond as clean and unpolluted as possible. Trampling by livestock, particularly dogs and wild life must be prevented. The drainage from barn lots, feeding yards, bedding ground, or any other sources of contamination will have to be kept away from the pond. Storage of clean water is especially important in ponds which are used for irrigating crops, fish culture, and live stock drinking. Annually, the deposited silt at the bottom of the farm pond must be removed and applied to the nearby fields.

Fencing

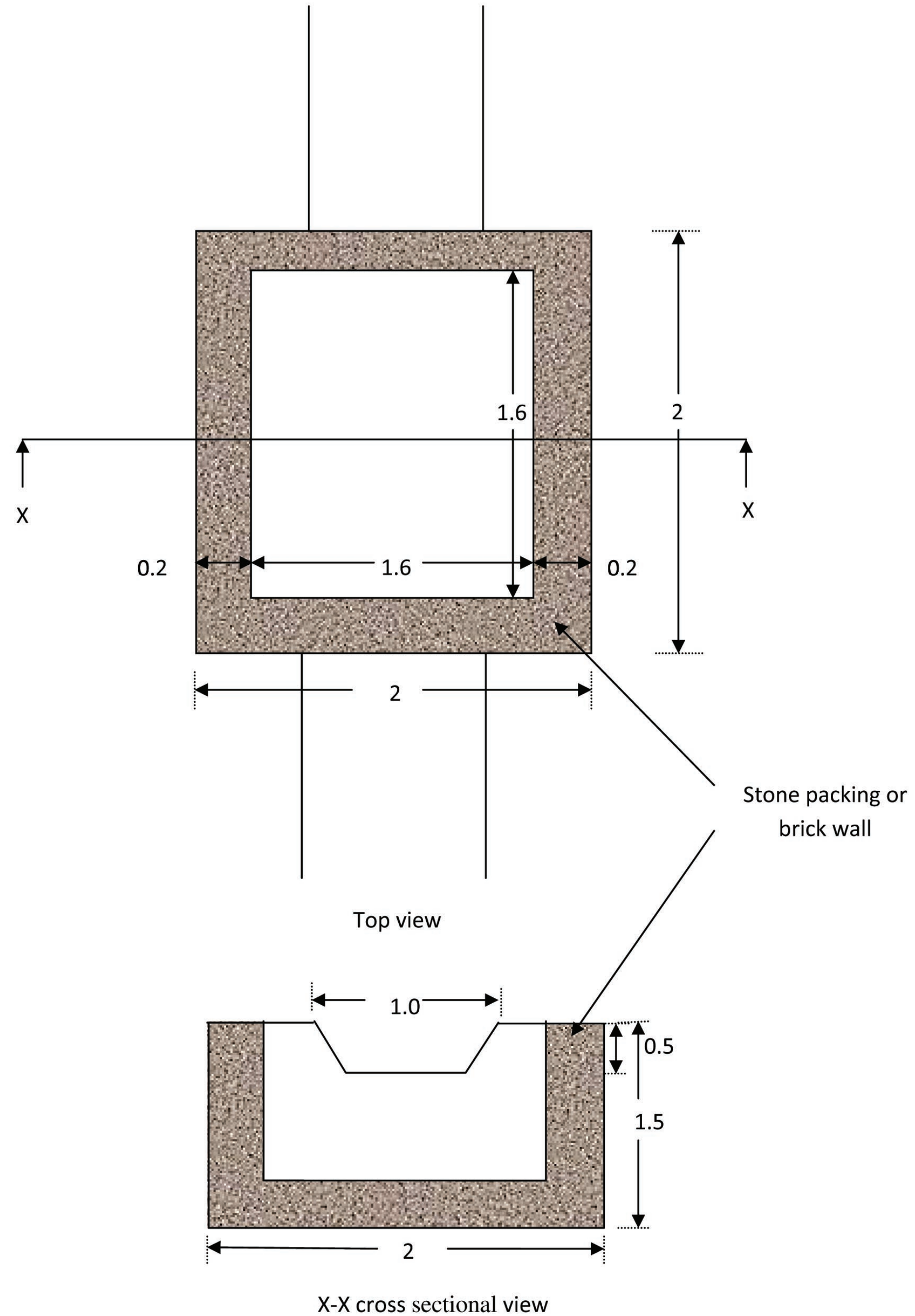
Fencing must be erected around the farm pond to prevent the entry of wildlife, stray dog etc. Fencing provides the protection from the damage and pollution by livestock. A view of tuflex fencing for dugout farm pond is shown in Fig 19. In farm field, cost effective vegetative hedges by using Henna, shallow rooted fruit trees, glyricidia etc., may be planned as protection to farm pond. Also, the barbed wire fencing with stones can also be preferred so as to reduce the cost of fencing.

Safety measures

A sign board of size 1m×0.5m must be installed near the farm pond. The board may be written with the material indicating prohibition of the structure for swimming and entry of animals. A danger signal with red color may also be displayed to the top left corner of the sign board. The writing should be properly visible.

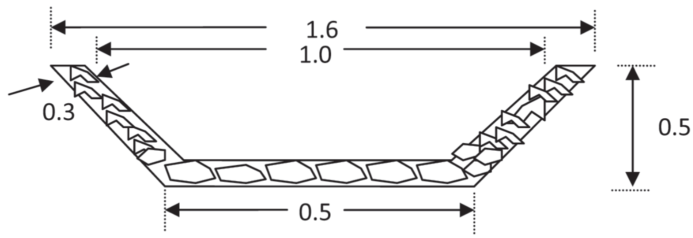


a. Layout of the dugout farm pond

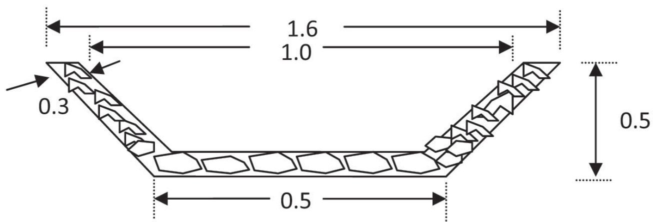


b. Plan and sectionof silt trap for the farm pond

All dimensions are in 'm'



c. Cross sectional and top view of the inlet channel with stone pitching



d. Cross sectional and top view of the outlet channel with stone pitching

All dimensions are in 'm'

Fig 17(a, b, c & d) Design drawings of farm pond with silt trap, inlet and outlet structures

Fig18. A view of earth excavation with V 200 model in dugout farm pond

Fig 19. A view of tuflex fencing for dugout farm pond at GRF

Lining of farm pond

Lining of farm pond to control seepage and percolation losses would be helpful in supplemental irrigation at crop critical stages, livestock rearing and domestic water supply. Lining is required in farm pond to control seepage from the wetted surface area. Seepage losses are predominant in case of light texture soils where sand percentile is more as compared to clay and silt particles. Particularly, the

farm ponds constructed in red soils require lining for long storage of water in the structures. Black cotton or vertislos or laterite soils do not require lining as the seepage losses are minimum because of more clay content. It is found that water losses through seepage varies from 1.21 to 10.54 cumecs/million sqm from heavy clay loam to porous gravelly soils in the earthen ponds, are the major constraints to its failure (Table 16) . In other words we can say that the drop in depth per day (cm) of ponded water via seepage and evaporation is 10.36 to 90.65 cm from heavy clay to porous gravelly soils. Several material options are available for lining of farm ponds.

The locally available material such as bricks and stones are used for hard surface lining of farm ponds. Such linings are constructed by using cement concrete and mortar. Asphaltic materials, paddy husk with cow dung. cement with soil mixture, fly ash mixture, bentonite have been tried to control seepage in farm ponds and their effectiveness are studied at different locations of the country (Table 17& 18) bricks, stones etc. The hard surface lining would positively reduce the seepage losses and of permanent type, if properly executed.

Table 16 : Seepage losses in different soils

Sl. No.	Type of soil	Water loss through seepage (Cumecs/million m^2 of wetted area)	Drop in depth per day (cm)
1	Heavy clay loam	1.21	10.36
2	Medium clay loam	1.96	16.84
3	Sandy clay loam	2.86	24.61
4	Sandy loam	5.12	44.03
5	Loose sandy soil	6.03	51.80
6	Porous gravelly soil	10.54	90.65

(Source: Agritech.tnau.ac.in)

The use of concrete with bricks and stones are costly as initial investment is more. But, they are of permanent type and effective in controlling seepage if properly laid. Pond and canals lining were done with LDPE film with brick overlaying the sheet to control the seepage. The life of such lining may vary from 15 to 20 years. But, organic materials mixed with cement and soils are purely temporary and do not long last for more years. Their life is very short varying from 1 to 2 years and seepage control is minimum. However, with the advent of new improved technology in the material science, the uses of polyethylene (PE) sheet have become popular among the farmers. It is required to select a proper thickness of the film for longer life. But the ecpected life for such film is 5-10 years. Presently, the HDPE films of 500 microns or cross layer reinforced silpaulin with 300 to 350 GSM are commonly used for lining of farm ponds

having 3-4 m depth of water storage. BIS has recommended the PE film as per code No. IS 15828:200 for design and construction of lined farm ponds. Important properties of various PE films are given in Table 19.

Advantages of pond lining with plastic film

- Reduction in water losses through percolation and seepage to the maximum extent (95%).
- Availability of water for a longer period of time.
- Lining with plastic film has benefits in porous soils where water retention in ponds and water harvesting tanks is minimal (Red soils).
- Prevents the lower area from the problem of water logging and prevents upward intrusion of salts in to stored water.
- Judicious utilization of stored water for the purpose of storage of drinking water, for fish culture and to provide supplementary irrigation during crop critical stages.
- Economical and effective method of storing water.

Method of laying Polyethylene films in farm ponds

For Laying of Polyethylene films, minimum of 500 micron thick as the best suited for longer life of film and the following steps are taken into consideration:

- Choose the film as per BIS/ISI mark
- Make the sides of the farm pond clean and smooth by removing vegetation and rills if any on the surface. A herbicide or weedicide may be applied on surface in advance so that there won't be any vegetation or root mass
- Make the trench of dimension 15 x 15 cm at the bottom along the sides for holding the plastic film firmly while laying
- Use minimum of 500 micron sheet or 300-350 gsm (g/m^2) cross reinforced silpaulin
- Calculate the film requirement for dugout pond.
- Plastic films manufactured in to panels of standard widths. Therefore convert the film into a single sheet as a desired either mechanically by heat-sealing machine like Hot Air fusion welding machine or manually (by overlapping 15 cm of the edge of two sheet and scrubbed lightly using emery paper or sand paper (120 grade) using bitumen/ Synthetic Rubber adhesive No-998 made by fevicol so that it fit exactly to fit in to the pond.
- Monitor the film in sun light for searching/puncture hole if any, and seal the hole with bitumen/adhesive or by heat – sealing procedure.

- The ends of the film at the surface have to be firmly buried in a trench at the bank of the pond to avoid sagging in the pond with proper anchoring of the sheet in a trench and filling with soil (Fig 20).
- Care should be taken to avoid the wrinkles and film must be pulled at the corner.

Table 17 : Effectiveness of different lining material for seepage control

S.No.	Lining material	seepage loss, lit/hr/m^2
1	Control (No lining)	18.56
2	Cowdung+ Paddy husk+Soil plaster (1:1:10)	16.98
3	Cement plaster at bottom (1:6)	12.99
4	Cement + Soil plaster (2:10)	0.85
5	Polythene sheet	0.32
6	Paddy husk ash plaster	11.60
7	Coastal saline soil plaster	5.47
8	Fly ash+ sand plaster (1:1)	2.5
9	Clay	12.07

(Source: Panigrahi, B. 2011)

Table 18 : Effectiveness of some sealants for seepage control in different research centres

S.No.	Research centre	Material used	Seepage as percentage of control
1	Bangalore	Clay +NaCl+$NaCO_3$(20:5:1) Soil cement(5:1) Soil cement(10:1)	19 30 42
2	Dantiwada	Plastic overlaid by brick work Lime mortor (1:6) with asphalt lining Cement+ sand(1:6)	9 11 19
3	Hyderabad	Plastic overlaid by brick work Brick lining overlaid by cement plastering Asphalt	0 0 13
4	Ludhiana	Bottom lined by polyethylene Sides lined by brick lining	2 6
5	Rajkot	Soil + cow dung+straw(7:2:1) Soil compaction to high bulk density	11 43
6	Ranchi	Coaltar Clay	44 56
7	Varanasi	Black polyethylene Soil cement(10:1)	4 24

(Source: Panigrahi, B. 2011)

Table 19 : Comparative properties of different PE films

Property	Test method ASTM coded	Unit	Values		
			LDPE film 0.5mm (500 microns)	HDPE film 0.5mm (500 microns)	Reinforced HDPE Geo-membrane 0.5mm (500 microns)
Material density	1505	Gm/cc	0.920	0.940	0.939
Breaking strength	6093, 638 Type IV	N/mm	12	14	28
Elongation	638	%	610	700	22+ for both MD and TD
Puncture Resistance	4833	N	120	176	491
Tear Resistance	1004	N	50	73	120
Bursting strength	751	kg/cm^2	4	4.3	8.5
Hydro static Resistance	751	kg/cm^2	Sample to be bursted at $2kg/cm^2$	Sample to be bursted at $3kg/cm^2$	No through leakage up to $6kg/cm^2$
Impact failure load		Gf	Load passed at 555gf	Load passed at 585gf	Passed more than 2000gf load

(Source: Agritech.tnau.ac.in)

Cost economics of construction of farm pond

Generally, the farm ponds are constructed with proper side slopes and inlet, silt trap and outlet structures to a recommended depth of 3 m. Presently, such structures are being done by using manual labour in the scheme of MNREGS implemented throughout the country by Govt. of India. But, they do not meet the design dimensions as required for meeting the crop water requirements and other uses. Therefore, it is recommended to use machinery particularly in hard soils where digging and earth removal becomes difficult by the human labour. Even in loose soils, the machinery is advisable for digging purpose and labor can be employed for making the side bunds and compacting soil. The earth moving machinery is available in the market with different bucket and boom sizes for

Inverted cone: Making trenches for anchoring lining plastic film

Square: Making trenches for anchoring lining plastic film

Spreading of silpaulin plastic film

Anchoring of the lining film on top and soil filling

A complete view of lined farm pond with silpaulin film

A complete view of lined farm pond with HDPE film

Fig. 20 : A complete procedure of lining of farm ponds with different plastic films

digging purpose. The size of bucket varies from 0.1 to 1 m^3 capacity with boom lengths varying from 2 to 4 m. A 4 m boom and 1 m^3 bucket capcity machine can remove the earth quickly and make the pond with capacity of 500 m^3 within 8 hrs of operation with proper side slopes and transport of the earth for bunding on the sides. The hiring charges with hagh capacity bucket machinery(TATA HITACHI V200 model) ranges from Rs1600-1700 in the market at present rates, which includes transport of the earth. On an average, the cost of digging becomes Rs26/ m^3 of soil in constructing farm pond. For the machinery like JCB, it takes more time atleast 2.5 times more than the bigger machine. Therefore, digging of farm pond must be done on cluster approach identifying the group of farmers for implementing the scheme in watersheds or Govt. schemes in rainfed areas. The details are given in Table 20.

Table 20 : Construction cost of the different capacities of the lined farm ponds by using machinery

S. No.	Work component	Square	Square	Square	Inverted cone	Inverted cone
1	Dimensions of the pond Top dimensions Bottom dimensions, m×m	 20 x 20 11x 11	 27.5x27.5 17 x 17	 17 x 17 8 x 8	 14 dia 5 dia	 20 dia 11 dia
2	Depth of pond , m.	3	3.5	3	3	3
3	Side slopes, Z:1	1.5 : 1	1.5 : 1	1.5 : 1	1.5 : 1	1.5 : 1
4	Capacity of the pond, m^3	741	1765	489	229	582
5	Cost for excavation of the soil, Rs.	19266	45890	12714	5954	15132
6	Surface area for lining, m^2	457	849	334	181	358
7	Required dimensions of the plastic sheet, m×m	24 x 24	32 x 32	21 x 21	18 x 18	24 x 24
8	Lining with 500 micron Plastic sheet, Rs.	57,600	1,02,400	44,100	32,400	57,600
9	Construction cost of inlet requirements and spillway, Rs.	10,000	15,000	10,000	10,000	10,000
10	Labour cost for anchoring the lining plastic sheet including trenching, Rs.	11,520	20,480	8,820	6,480	11,520
11	Total cost, Rs.	98,386	1,83,770	75,364	54,834	94,252
12	Cost per unit volume of stored water, Rs./m^3	133	104	154	239	162

The unit cost of expenditure for creating storage of 1m^3 of water decreases as the capacity of farm pond increases. The lining requirement is more in case of inverted cone farm ponds as the dimensions of the film are more for covering the pond surface area as it comes in square dimensions. In other dimensions of farm ponds with regular shape of square and rectangular, the lining requirement is less and easy to do the lining than the inverted cones.

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Appendix I

Cost of construction as per state Govt. rates.

Capacity of the farm pond, 741, cum						
S. No.	Particulars	dimensions		Quantity (Rs.)	Rate (Rs.)	Amount
1	**Earth work calculations**					
i	Farm pond Specifications					
	Top	20	20			
	Bottom	11	11			
	depth	3				
	side slope	1.5:1				
	Capacity (volume of earth work)			741		
ii	silt trap specifications					
	Length	2				
	width	2				
	depth	1.5				
	Capacity (volume of earth work)			6		
iii	Inlet specifications					
	Length	3				
	width	1				
	depth	0.5				
	Capacity (volume of earth work)			1.5		
iv	out let specifications					
	Length	3				
	width	1				
	depth	0.5				
	Capacity (volume of earth work)			1.5		
vi	Formation of bund around the pond					
	Length	80				
	Top width	1				
	Bottom width	2				
	depth	0.5				
	side slope	1:1				
	Capacity (volume of earth work)			60		
v	digging of trench for lining					
	Length	100				
	width	0.3				
	depth	0.3				
	Capacity (volume of earth work)			9		

S. No.	Particulars	dimensions		Quantity (Rs.)	Rate (Rs.)	Amount
vi	preparation of trench for waterways					
	Length	100				
	width	1				
	depth	0.5				
	Capacity (volume of earth work)			50		
vi	Filling of trench					
	Length	100				
	width	0.3				
	depth	0.3				
	Capacity (volume of earth work)			9		
	Total earthwork for excavation	809	cum			
	Total earthwork for embankment	60	cum			
	Total filing of trench	9	cum			
	Machinery excavation earth work			**741**	**21**	**15561**
	Manual excavation earth work			**68**	**56**	**3808**
	Manual embankment earth work			**60**	**28**	**1680**
	Manual filling of trench			**9**	**28**	**252**
2	**Civil works**					
i	Construction of the wall for silt trap					
	Length of the wall	8				
	Height of the wall	1.5				
	Area of the wall	12				
	Thickness of the wall	0.2				
	Volume of the wall	2.4	cum			
ii	Construction of the inlet					
a	Construction of wall					
	Length	3				
	Width	2				
	Depth	0.5				
	Perimeter of the section	3				
	Area of the wall	9				
	Thickness of the wall	0.2				
	Volume of the wall	1.8	cum			

S. No.	Particulars	dimensions		Quantity (Rs.)	Rate (Rs.)	Amount
b	Construction of steps					
	Length	5.41				
	Width	2				
	Thickness	0.5				
	Volume of the work	5.41	cum			
	Total volume of brick wall and steps			**9.61**	**800**	**7688**
3	**Rough stone dry packing**					
i	Before silt trap					
	Length	3				
	Top width	1				
	Bottom width	0.5				
	depth	0.5				
	side slope	1	:1			
	Perimeter of the channel	1.91				
	Area of the stone packing	5.74				
	Volume of the stones required	1.72	cum			
ii	Outlet					
	Length	3				
	Top width	1				
	Bottom width	0.5				
	depth	0.5				
	side slope	1	:1			
	Perimeter of the channel	1.91				
	Area of the stone packing	5.74				
	Volume of the stones required	1.72	cum			
	Total volume of the stones			**3.45**	**600**	**2070**
4	**Transportation of the soil with lead 2 km**					
	Volume of the soil	749	cum			
	Transport charges			**749**	**10**	**7490**
5	**Construction of the fencing around the pond**					
	Length	104				
	Height	1				
	Total area of the fence	104	sq.m			
	Cost of the fencing with mesh			**104**		

S. No.	Particulars	dimensions		Quantity (Rs.)	Rate (Rs.)	Amount
6	**Lining of the Farm pond with 500 microns plastic film for square cross section**					
	i) Top length	20	m			
	ii) Bottom length	11	m			
	iii) Side inclined length (SQRT $(d^2+z^2d^2)$)	5.38	m			
	iv) Total side length of film for two sides	10.76	m			
	v) Extra length required for anchoring considering 0.5 m one side	2	m			
	Total length of film required (ii+iv+v)	24	m			
	Size of the plastic film	24x 24	m^2			
	Cost of the film		**576m^2**	**100**	**57600**	

Shri Ashish Bahuguna, Secretary, DAC, Govt. of India and Dr. A.K. Singh, DDG (NRM), ICAR and K.Madhusudan Rao, IAS, CDA, Govt. of A.P. visiting the Farm Pond at Gunegal Research Farm (GRF), CRIDA

Dr. S. Ayyappan, Secretary, DARE and Director General, ICAR, New Delhi, Observing Maize Crop in Aqua Crop model experiment at Gunegal Research Farm (GRF), CRIDA

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