A draft report on

Solar-based micro irrigation system

A case study in Tulyachapada, Mokhada Taluka, Palghar

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March 2019

1. Introduction

In Palghar district agriculture is a primary source of livelihood activity, lack of water availability leads to limited farming leading to migration during dry seasons from many parts of district. The area receives an annual rainfall of more than 2500 mm, but steep slopes and rocky terrain results in poor water retention. According to 2011 Census the Land use pattern indicates that 41.93% is the net sown area and only 1.9% of the total area is sown more than once. Community irrigation solution can be an attractive way to improve employment in agriculture and reduce migration. Considering the agricultural potential, favorable climate for vegetable farming and socio cultural acceptance and enthusiasm for new technology like drip irrigation, the NGO is willing to implement drip irrigation. Drip irrigation is widely practiced and established method of irrigation in developed countries and is slowly gaining popularity in India. It is most suited for horticulture crops, vegetables etc. and finds applicability in hard rock areas where groundwater is scarce and helps in optimization of the limited water resources. The system has its advantages and limitations. Its advantages are in terms of savings of water (50-60%) of that required for flow irrigation, effective use of fertilizers, less labour and energy cost. The limitation for adopting of this method is its high initial cost.

Pragati Pratishthan is an NGO based in Jawhar that works in sectors like agriculture development, school, water and solar energy. Pragati Pratishthan is continuously working to provide sustainable solutions to water crisis and farming solution. Solar powered micro irrigation systems are one such project of the NGO. To get basic idea about the existing solar based micro irrigation systems, field visit was made to Tulyachapada in Mokhada block.

2. Scheme details

Source for scheme is a Tulyachapada small dam constructed by minor irrigation department in year 1995. This dam is situated near Tulyachapada habitation in Morhanda village of Mokhada Taluka in Palghar district. This solar based irrigation scheme is designed for three habitations (Tulyacahapada, Kelichapada and Koldyachapad) which are approximately 2-3 km from dam. Pragati Prathishthan had implemented 10 solar based drip irrigation systems in this area. Out of 10 total setups 4 on dam and 6 on seepage water line. On seepage line gunny check dams were constructed for impounding and from there water is lifted till farm. They form 10 groups of farmers and each group has 10-11 farmers whose farms are in same area. Half acre land of each farmer is being irrigated. These setups are installed this year, first time farmers are using this. According to NGO approximately 50-60% household get benefited from this scheme. The total population of these three habitations is 632 souls (as per NRDWP website).

The main components of drip system are tank, filter, mainline, submain, laterals and emitters are shown in figure 1. In this system, water lifted from reservoir then it pass through sand filter of Netafim with the help of 7.5 Hp pump. Just beside filter there were 48 solar panels installed. From filter there are 2 main lines which serve 4 zones as shown in figure 2. One mainline served 3 zones and other mainline served 1 zone. Zones were prepared based on water schedules. From

these mainlines separate sublines were provided to each farm land. Submains have laterals of polyethylene material at 1.22 m having diameter of 16 mm and length varies from 35-56 m as per land dimension. Each lateral served each row of crop and emitter spacing is such that each emitter served each plant. Total length of submain is 640 m having diameter 63 mm. The mainline having diameter from 90mm to 63mm with length of 1376 m. The layout of existing system is as shown in figure 2.

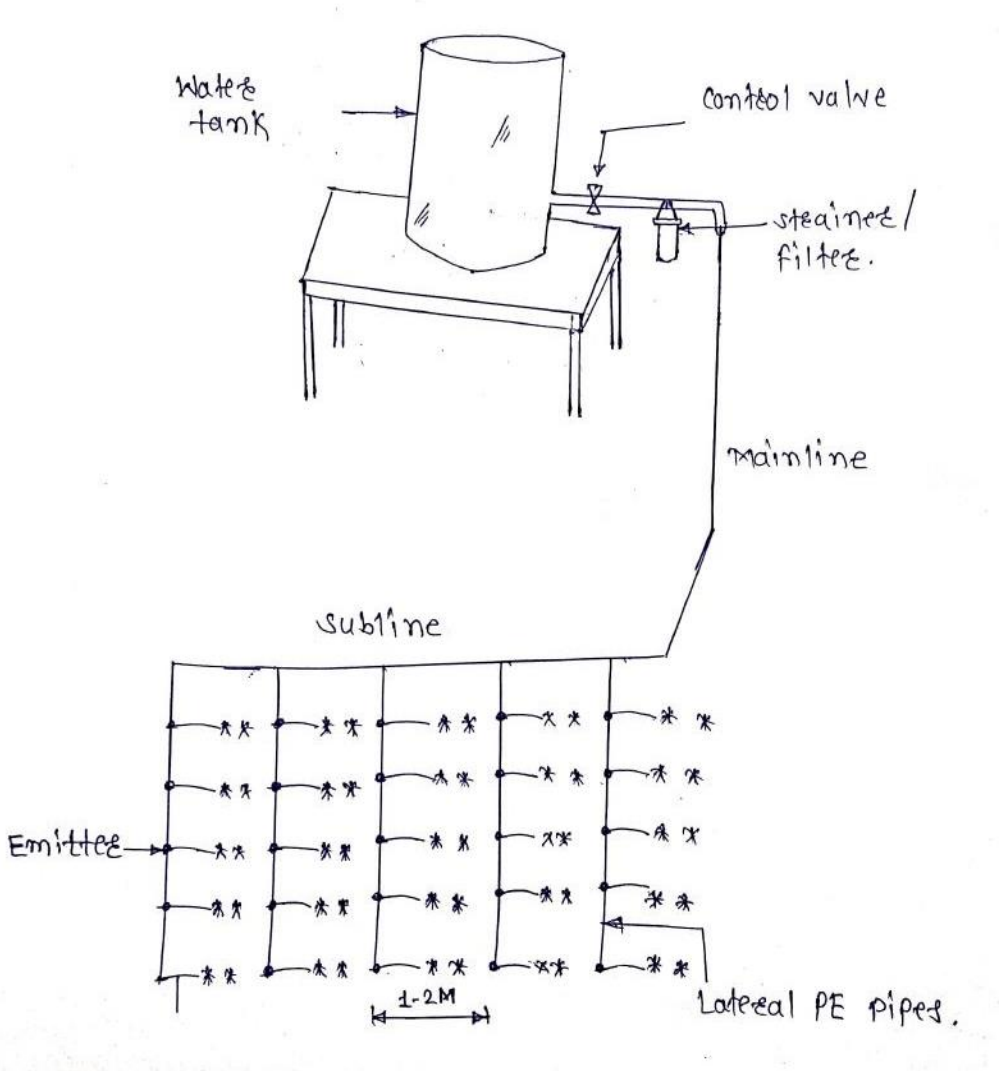


Figure 1: Main components of the drip-based solar-powered irrigation system.

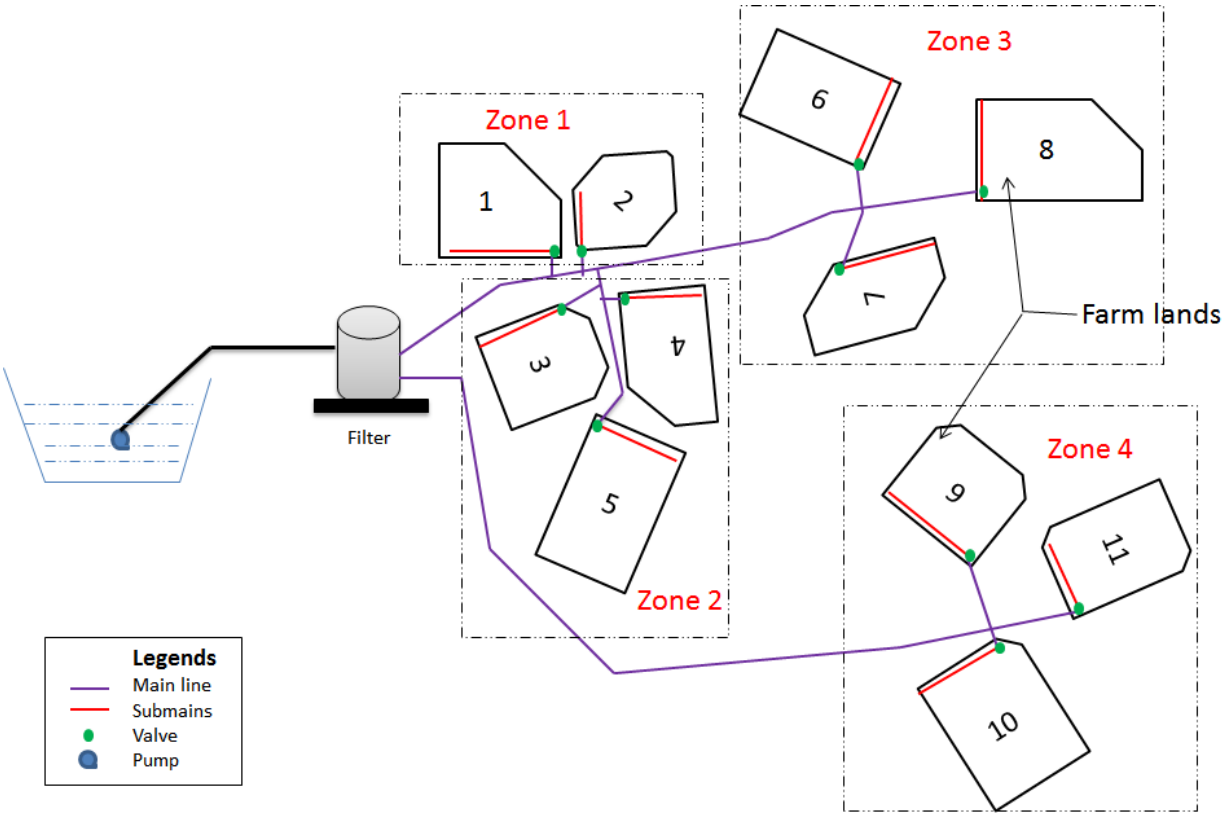


Figure 2: Layout of existing system and the cluster of farm lands (zones) covered in each shift (operation slot).

3. Existing system

Out of 10 systems we will discussed here one system in details which is near to dam. Total area irrigated is 6.07 acres (2.46 hectare) of 11 farmers.

a) **Site information**

Reservoir of Tulyachapada dam is a source for this scheme. The ground elevation of reservoir is 415 m. The ground elevation of filter is 418 m. Measurement of dimensions and elevation of each farmer's farm land was carried out by technical team. Detailed map attached in annexure 3.

b) **Calculation of water requirement**

The crop taken by all farmers is groundnut. In general, designers consider 6 mm as the standard peak water requirement for any vegetable crop. Here also designer considers 6 mm as crop water requirement.

Total daily water requirement during peak period = peak crop water requirement*Area

= (6mm x 2.46 ha*10)

= 148 cu.m/day

c) Selection of drippers and calculation of irrigation time

Designer selected emitter having flow rate 2 lit/hr based on water requirement and soil type. The emitter spacing is 0.4 m. The spacing between lateral is equal to distance between rows of crop i.e., 1.22 m (4 feet). Application rate can be calculated as,

Application rate = Emitter discharge/ lateral spacing/ emitter spacing
= 2 l/h/ 1.22 m/0.4 m = 4.1 mm/hr

Total area is divided into 4 zones and operations were carried out as per zone. Duration of one operation is depending on peak water requirement and application rate.

Duration of one operation = Water requirement/ application rate
= 6 mm/4.1 mm/hr= 1.46 hr

Designer considered the number of hours available for solar irradiation is 8 and hence all four shift operations could be carried out in one day. But in general solar PV based system 6 hours are considered as irrigation hours. Shift wise water demand and total area is given in Table 1

Table 1: Zone wise water demand and total area

Zones	**Farm number**	**Area, (m^2)**	**Area (ha)**	**Application rate (mm/hr)**	**Valve Flow (cu.m/h)**	**Zone area (Ha)**	**Shift Flow (cu.m/h)**
1	1	1846	0.18	4.10	7.6	0.43	17.8
	2	2494	0.25	4.10	10.2		
2	3	2559	0.26	4.10	10.5	0.71	29.2
	4	2149	0.21	4.10	8.8		
	5	2412	0.24	4.10	9.9		
3	6	2025	0.20	4.10	8.3	0.66	26.9
	7	2199	0.22	4.10	9.0		
	8	2344	0.23	4.10	9.6		
4	9	2450	0.25	4.10	10.0	0.66	26.9
	10	2119	0.21	4.10	8.7		
	11	1985	0.20	4.10	8.1		
Total		**24582 m^2**	**2.46 ha**		**100.8 (cu.m/h)**	**2.46 ha**	**100.8 (cu.m/h)**

d) Selection and design of pipes (Laterals, submains and main lines)

On field 16 mm diameter laterals, 63 mm diameter submains and 63,75,90 mm diameter main line were placed. Pipes are generally selected from calculated flow rate and constraint on flow velocity by using Nomogram (the figure of Nomogram attached to annexure 2). The flow nomogram can be used only if, at least two values out of A, B, C, D are known. Joining the two values on lines and extending the line henceforth will give the desired values. The velocity of system limited to 1.5 m/s and laterals around 0.2 m/s. Flow rate in each submain is given in table 1 (valve flow). Flow rate in main line consider as maximum flow rate in submains so flow rate of mainline consider as 29.2 cu.m/hr. Flow rate in lateral is varied by length of lateral, in this case it varies from 35 to 56 m, for calculation purpose assumes average value (45 m).

Flow rate of lateral = (Lateral length/emitter spacing)*emitter flow rate
= (45 m /0.4 m)*2 l/hr = 0.225 cu/hr= 0.06 l/s

Flow rate in lateral is 0.06 lps and velocity is constraint to 0.2 m/s if we draw a straight line joining these two points on Nomogram we get diameter of lateral 16 mm and hydraulic gradient of 0.45 m per 100 m. Similarly diameter of all pipes can be measured.

e) Selection of pumps

In a drip Irrigation system, the selection of pump depends on two parameters, which are the required flow rate and the total head it has to overcome for proper operation of system. On field 7.5 Hp pump were used to pump water. Designer calculated separately pump capacity required for each zone and highest among them used in system. Generally head loss in lateral and submains consider as 2 m. Head loss in main line is calculated Hazen Williams head loss formula.

$hf = \text{length} \times (v/(4.567 \times 0.001 \times c' \times d^{0.63}))^{1/0.54}$
$= 171*(0.77/ (4.567*0.001*140*90^{0.63}))^{1/0.54}$
$= 1.26$ m

Total head = Static head + Submain headloss + lateral head loss + Mainline head loss + Emitter operating pressure head loss + head loss in filter + fitting head loss + valve head loss

=15m + 1.26m +2m +2m +5m + 5m +2m +1 = 34.26 m

Power of pump required can be calculated as given below

$P= (Q*\rho*g*H)/(3600*746*\eta)$
$= 17.6*1000*9.81*34.26/ (3600*746*0.65)$
$= 5.2$ HP

Table 2: Shift wise total head and pump requirement

Head	Zone 1	Zone 2	Zone 3	Zone 4
Emitter Min. operating pressure (m)	5 m	5 m	5 m	5 m
Submain head loss (m)	2 m	2 m	2 m	2 m
Lateral dripline head loss (m)	2 m	2 m	2 m	2 m
Main line head loss (m)	1.26 m	5.12 m	9.04 m	22.54 m
Static head (m)	15 m	23 m	14 m	-16 m
Head loss in filter (m)	5 m	5 m	5 m	5 m
Fitting head loss (m)	2 m	2 m	2 m	2 m
Head loss in valves (m)	1 m	1 m	1 m	1 m
Total head (m)	**34.26 m**	**47.12 m**	**43.04 m**	**27.54 m**
Q (cu.m/hr)	17.8m^3/hr	29.3 m^3/hr	26.9 m3/hr	26.9 m3/hr
Pump (Hp)	**5.2 Hp**	**7.1 Hp**	**7.1 Hp**	**2.8 Hp**

- 7.5 Hp (7.1 Hp) maximum of above calculated pump capacity was used on field. Solar panel requirement is calculated as follow.
- Average daily sun hours are 8 hours for Mumbai location, assuming similar average daily sun hours for Mokhada location.
- Power required by pump: 5.595 kW
- Energy used by pump running for 7 hrs: 39.16kWh
- Assuming avg. daily sun hours of 5.5, peak watt rating of modules required: 39.16/8 = 4.89 kWp ~ 4.90 kWp.
- 48 panels in series and parallel combination is attached, each of 345W capacity are installed. Total installed system capacity: 5.52 kW

4. Cost estimation

All farmers sown groundnut this year. This project was supported by CSR fund of Bank of America and technical partner was Gram Oorja. Solar pump setup, seed cost was provided by Bank of America. Drip setup's 60% cost were provided by funder and 40% government subsidy. Land preparation work and sowing were done by farmers. Seeds were provided by NGO. The cost of breakup is given in Table 3. The cost of single system around Rs.10,30,000 which is very high. The next step of this project to explore how much more area can be irrigated with existing system.

Table 3: Cost of each particular and a system

Sr. No.	Particulars	Cost (Rs.)
1	Head unit	80872
2	Submain	69647
3	Main line	125134
4	Drip lateral	223576
5	Drip fitting accessories	3423
6	Solar pump*	141750
7	PV panel*	384000
	Total cost	**Rs.1028402**

* These costs are not provided by NGO, we had taken current market cost of these particulars.

Annexure 1: Design step for design of drip irrigation scheme

Design criterion for drip irrigation system:

A drip system layout is designed for the selected scheduling alternative, consisting of mainline, submain, manifolds and laterals.

Steps in designing drip irrigation system:

The design of drip irrigation differs from crop to crop, plot to plot, soil to soil and climatic conditions. In general, following steps are involved in design of drip irrigation system.

1. Obtaining site information

Obtaining site information is a very important step in the design procedure. Complete and accurate survey with other field information is essential for designing an efficient irrigation system.

2. Calculation of water requirement

While designing the irrigation system, highest water required for the plant throughout its lifecycle is considered for calculation of water requirement. While calculating peak water requirement, peak rate of evapo-transpiration is taken into consideration. The total water requirements for different crops are as shown in Table 4.

Table 4: Crop water requirement

Crop	Duration (days)	Total water requirement (mm)
Brinjal	150	400 - 600
Chilly	150	400 - 600
Okra	150	380 - 510
Bitter gourd	150	410 - 460
Radish	45	130 - 260
Cucumber	105	380 - 510
French bean	90	250-500
Groundnut	105	500-700

(Source: http://www.fao.org/3/s2022e/s2022e02.htm and http://extension.missouri.edu/sare/documents/estimatedwaterrequirementsvegetable2012.pdf)

The water requirement specified above is for shallow rooting crops with similar water and spacing requirements. Drip designers consider 6 mm as the standard peak water requirement for any vegetable crop. The peak water requirement of small vegetable crops is much is much lower than 6 mm.

3. Selection of drippers and calculation of irrigation time

Selection of drippers is based on water requirement, soil type, water availability, electricity availability etc. Drippers should be selected such that it should emit enough water to fulfill water requirement within predefined time.

Flow rate of emitter

Clayey soil has low infiltration rate and hence water spreads more laterally than vertically in this type of soil as compared to other types. Similarly, in loamy soil water spreads more laterally compared to sandy soil, because sandy soil has the highest infiltration rate and highest depth of water percolation.) Emitter discharge is always in the range of 1-15 l/hr form manufacturers standards based on the type of soil and the frequency with which the irrigation is to be carried out. Commonly available emitters flow rate are 2lph, 4lph, 8lph. The spacing of later is based on cropping pattern and emitters flow rate

4. Selection and design of lateral:

Lateral design is based on maximum 7.5 - 10% discharge variation and up to 15% pressure variation. Laterals come in the range of 12-32 mm according to manufacturer's standards. Calculate the average dripper spacing on laterals

5. Selection and design of manifold:

The placement of manifolds is decided by the maximum permissible length of lateral on less than 1% slope. The manifolds here are placed at a distance of 40 m and sub mains are placed at a distance of 100 m thus allowing the irrigation of minimum area of approximately 1 acre. A distance of 1.2 m is left between any two one acre subunits for operation and maintenance needs. All the lines have been laid along the direction of slope. The elevation steeply falls along the length of manifolds thus introducing head gain.

6. Selection and design of submain:

After finalizing drippers and laterals or in-lines, we have to decide the no of sections, for the entire area, so that irrigation cycle can be completed in the available time for operation. Design of sub main for the particular section is based on both capacity and uniformity. Sub main size should be large enough to deliver the required amount of water to irrigate subsequent part of the field. The size of the sub main is optimized at maximum 2 m head loss.

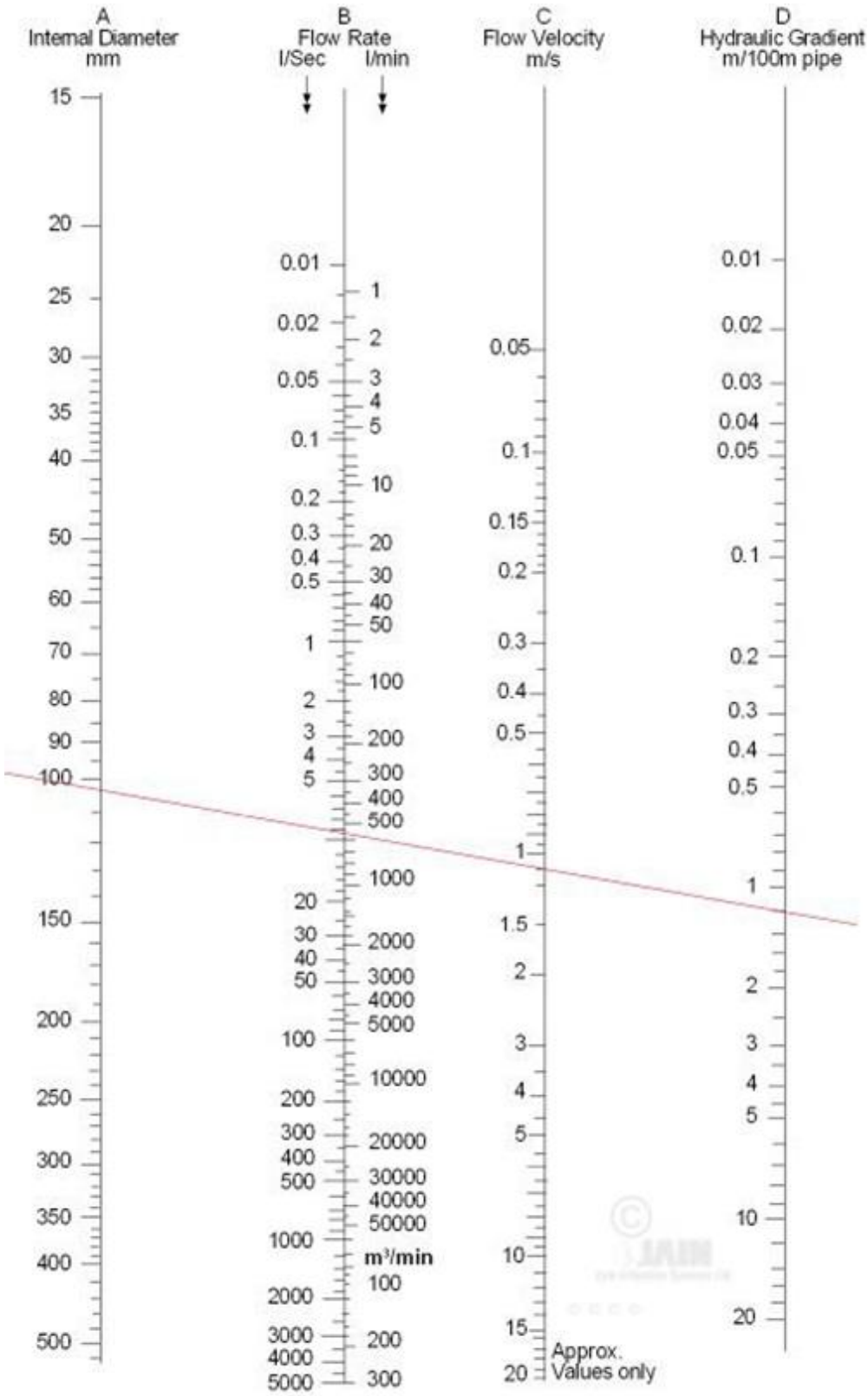
7. Selection and design of mainline:

After finalizing drippers, laterals/in-lines and sub main sizes and locations, we have to connect all the sub mains to the water source using the main line. Their sizes are determined by considering quantity of water flowing through the pipe, velocity required, ground elevation etc. Velocity recommended range is between 0.5 to 1.5m/s.

8. Selection of Pump:

Size of pump depends upon the flow of water required and total pressure required at the pump to operate the irrigation system efficiently. While designing the system from drippers to mainline, we have finalized the system flow (Q). The pump should have the capacity to deliver this flow. The required total head (H) of pump is the sum of static head, frictional head loss in main, submain and laterals, emitter operating pressure, valve fitting head etc.

Annexure 2: Flow Nomogram for Polyethylene pipes



(Source: http://www.jains.com/Pipefittings/hdpe%20pipe.htm)

For example : Flow 10 lps, Pipe size 110 mm OD (104mm ID), Velocity 1.2 m/s, Hydraulic Gradient 1.2 m/100m . The flow nomogram can be used only if, at least two values out of A, B, C, D are known. Joining the two values on lines and extending the line henceforth will give the desired values

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