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Introduction

This report is prepared for the solutions of the assigned problems in the Homework 5.

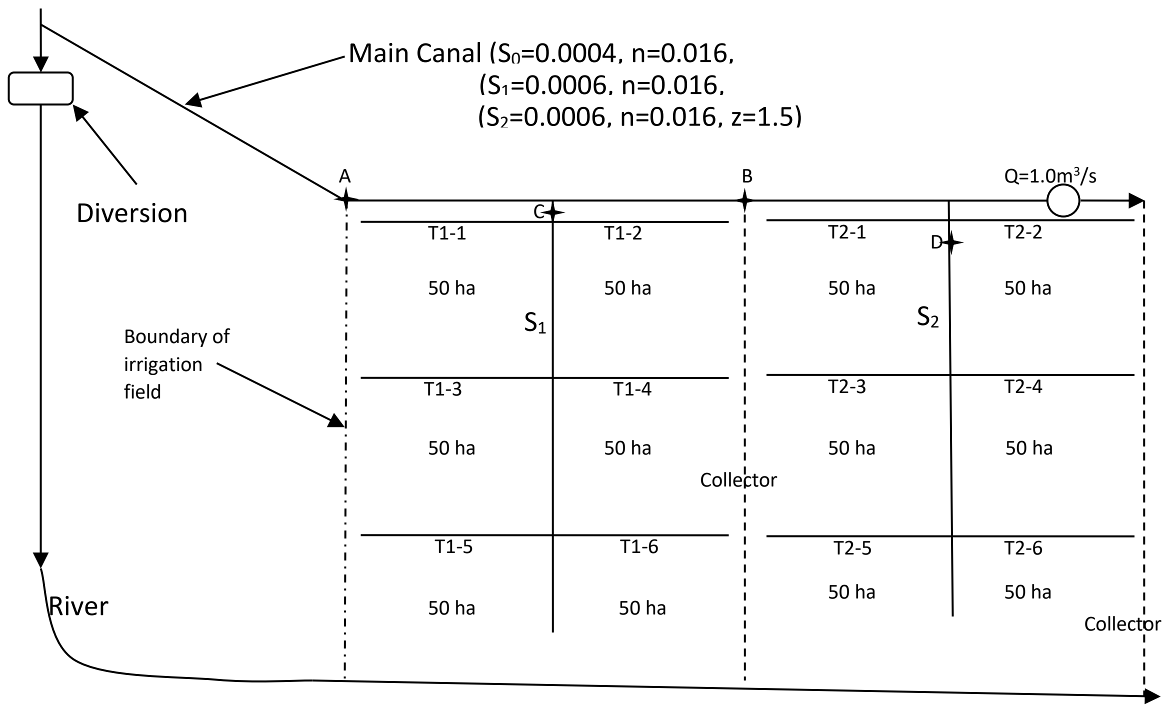

Figure 1:Layout of the Irrigation Area

Layout in Figure 1 is given for the irrigation network. Capacity of irrigation canals at points A, B and D are asked by using Demand Method. Before starting to use Demand Method, by Blaney-Criddle method, consumptive water requirement calculation is needed. After obtaining the discharges, optimum canal dimensions should be calculated and checked for minimum and maximum flow velocities. Also critical depths inside the channels should be checked. Then irrigation frequency and duration of irrigation also asked. The aerial crop distribution in the project area is 50% tomatoes and 50% potatoes. The area lies at a latitude 36^0 in the northern hemisphere. The overall efficiency is 60% and average root zone depth is 1.0 m and conventional root distribution can be used. Effective precipitation during June, July and August are, 15 mm, 10 mm and 5 mm. Mean temperatures are 20°C, 25°C and 28°C. The capacity of the main canal after distributing the irrigation water requirements of secondary canals S_1 and S_2 is 1 m^3/s. Field Capacity (FC) is 0.32 and the permanent wilting point (PWP) is 0.12. Percolation losses is 25% and infiltration capacity is equal to the 90% of the maximum daily average value of consumptive use determined by Blaney-Criddle method.

Calculations

Canal Capacities by Demand Method

Table 1: P Values

Month	Latitudes (in northern hemisphere)							
	24^0	26^0	28^0	30^0	32^0	34^0	36^0	38^0
January	7.58	7.49	7.4	7.3	7.2	7.1	6.99	6.87
February	7.17	7.12	7.07	7.03	6.06	6.91	6.86	6.76
March	8.4	8.4	8.39	8.38	8.37	8.36	8.35	8.34
April	8.6	8.64	9.68	8.72	8.75	8.8	8.85	8.9
May	9.3	9.38	9.46	9.53	9.63	9.72	9.81	9.92
June	9.2	9.3	9.38	9.49	9.6	9.7	9.83	9.95
July	9.41	9.49	9.58	9.67	9.77	9.88	9.99	10.1
August	9.05	9.1	9.16	9.22	9.28	9.33	9.4	9.47
September	8.31	8.31	8.32	8.34	8.34	8.36	8.36	8.38
October	8.09	8.06	8.02	7.99	7.93	7.9	7.85	7.8
November	7.43	7.36	7.27	7.19	7.11	7.02	6.92	6.82
December	7.46	7.35	7.27	7.14	7.05	6.92	6.79	6.66

Table 2: k1 and k2 values

Crop	k_1	k_2 values: Monthly consumptive use coefficient as % of seasonal coefficient k1								
		March	April	May	June	July	Aug.	Sept.	Oct.	Nov.
Alfalfa	0.85	70	120	108	114	125	113	108	68	70
Corn	0.8				46	146	162	100	38	
Cotton	0.65			45	75	100	130	150		
Beans	0.65				37	70	165	127		
Potatoes	0.7				75	85	140	110		
Grass, Hay	0.75	44	100	116	132	124	128	128	88	56
Pasture	0.6	93	182	100	98	100	93	93	145	93
Citrus tree										
Deciduous t.	0.65	29	94	102	154	148	114	90	75	65
Cereals	0.8	102	153	118	24					
Small grain	0.75	102	153	118	24					
Sugar beet	0.7	53	75	153	242	192	100	42	38	8
Rice	1.1		30	125	133	131	135	48		
Tomatoes	0.6				32	70	122	115	140	

- **June**

- **For Potatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \ where \ P = 9.83 \ from \ Table \ 1$$

$$k_1 = 0.7 \ and \ k_2 = 0.75 \ from \ Table \ 2$$

$$u = 25.4 * 0.7 * 0.75 * \left(\frac{1.8 * 20 + 32}{100} * 9.83\right) = 89.1 \ mm/month$$

$$\%A = 50 \ \%$$

- **For Tomatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \ where \ P = 9.83 \ from \ Table \ 1$$

$$k_1 = 0.6 \ and \ k_2 = 0.32 \ from \ Table \ 2$$

$$u = 25.4 * 0.7 * 0.75 * \left(\frac{1.8 * 20 + 32}{100} * 9.83\right) = 32.6 \ \ mm/month$$

$$\%A = 50 \ \%$$

$$\sum CIR = 0.5 * \left(U_{potatoes} - P_{eff}\right) + 0.5 * \left(U_{tomatoes} - P_{eff}\right) = 0.5 * \left((89.1 - 15) + (32.6 - 15)\right)$$

$$\sum CIR = 45.85 \ \ mm/month$$

After calculating CIR, TDR (Total Delivery Requirement) calculation is needed;

$$TDR = \frac{\sum CIR}{e} = \frac{45.85}{0.6} = 76.45 \quad mm/month$$

$$q_{max} = \frac{(76.4 * 10000)}{(30 * 86400)} = 0.29 \ \ lt/s/ha$$

- ## July

- **For Potatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \; where \; P = 9.99 \; from \; Table \; 1$$

$$k_1 = 0.7 \; and \; k_2 = 0.85 \; from \; Table \; 2$$

$$u = 25.4 * 0.7 * 0.75 * \left(\frac{1.8 * 25 + 32}{100} * 9.99\right) = 116.25 \quad mm/month$$

$$\%A = 50 \; \%$$

- **For Tomatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \; where \; P = 9.99 \; from \; Table \; 1$$

$$k_1 = 0.6 \; and \; k_2 = 0.7 \; from \; Table \; 2$$

$$u = 25.4 * 0.7 * 0.75 * \left(\frac{1.8 * 25 + 32}{100} * 9.99\right) = 82.06 \quad mm/month$$

$$\%A = 50 \; \%$$

$$\sum CIR = 0.5 * \left(U_{potatoes} - P_{eff}\right) + 0.5 * \left(U_{tomatoes} - P_{eff}\right)$$
$$= 0.5 * \left((82.06 - 10) + (116.25 - 10)\right)$$

$$\sum CIR = 89.155 \quad mm/month$$

After calculating CIR, TDR (Total Delivery Requirement) calculation is needed;

$$TDR = \frac{\sum CIR}{e} = \frac{89.155}{0.6} = 148.6 \quad mm/month$$

$$q_{max} = \frac{(148.6 * 10000)}{(31 * 86400)} = 0.55 \;\; lt/s/ha$$

August

- **For Potatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \; where \; P = 9.40 \; from \; Table \; 1$$

$$k_1 = 0.7 \; and \; k_2 = 1.40 \; from \; Table \; 2$$

$$u = 25.4 * 0.7 * 1.40 * \left(\frac{1.8 * 28 + 32}{100} * 9.40\right) = 192.8 \quad mm/month$$

$$\%A = 50 \;\%$$

- **For Tomatoes**

$$u = 25.4 * k_1 * k_2 * f$$

$$f = \frac{(1.8t + 32)}{100} * P \; where \; P = 9.4 \; from \; Table \; 1$$

$$k_1 = 0.6 \; and \; k_2 = 1.22 \; from \; Table \; 2$$

$$u = 25.4 * 0.7 * 0.75 * \left(\frac{1.8 * 28 + 32}{100} * 9.83\right) = 144.01 \quad mm/month$$

$$\%A = 50 \;\%$$

$$\sum CIR = 0.5 * \left(U_{potatoes} - P_{eff}\right) + 0.5 * \left(U_{tomatoes} - P_{eff}\right)$$
$$= 0.5 * \left((82.06 - 5) + (116.25 - 5)\right)$$

$$\sum CIR = 163.4 \quad mm/month$$

After calculating CIR, TDR (Total Delivery Requirement) calculation is needed;

$$TDR = \frac{\sum CIR}{e} = \frac{89.155}{0.6} = 272.35 \quad mm/month$$

$$q_{max} = \frac{(148.6 * 10000)}{(31 * 86400)} = 1.02 \;\; lt/s/ha$$

Table 3: Results of the calculations

	June		July		August	
	Potatoes	Tomatoes	Potatoes	Tomatoes	Potatoes	Tomatoes
k1	0.7	0.6	0.7	0.6	0.7	0.6
k2	0.75	0.32	0.85	0.7	1.4	1.22
k	0.53	0.19	0.60	0.42	0.98	0.73
P	9.83	9.83	9.99	9.99	9.40	9.40
t (C)	20	20	25	25	28	28
f	6.68	6.68	7.69	7.69	7.75	7.75
U (mm/m)	89.14	32.60	116.25	82.06	192.80	144.01
%A	50	50	50	50	50	50
P_{eff} (mm)	15	15	10	10	5	5
CIR (mm/m)	37.07	8.80	53.13	36.03	93.90	69.51
TDR=CIR/E	61.78	14.67	88.54	60.05	156.50	115.84
TDR (mm/m)	76.45		148.60		272.35	
q_{max} (lt/s/ha)	**0.29**		**0.55**		**1.02**	

Since the maximum q value for provided irrigation area is 1.02 lt/s/ha, 1.02 lt/s/ha must be used in discharge calculations.

Table 4:Flexibility Coefficients (F)

Area (ha)	**q_{max} (lt/s/ha)**						
	0.5	**0.6**	**0.7**	**0.8**	**1**	**1.2**	**1.5**
20	4.62	4.28	4	3.77	3.41	3.72	2.77
30	3.9	3.63	3.42	3.24	2.97	2.73	2.47
40	3.44	3.22	3.04	2.39	2.95	2.47	2.25
50	3.11	2.91	2.75	2.88	2.65	2.27	2.09
60	2.95	2.58	2.54	2.43	2.43	2.11	1.95
70	2.64	2.49	2.36	2.25	2.25	1.98	1.84
…	…	….	…	…	…	…	…
200	1.84	1.75	1.69	1.63	1.55	1.48	1.40
300	1.68	1.62	1.56	1.52	1.45	1.39	1.33
600	1.48	1.44	1.40	1.36	1.31	1.28	1.23
…	…	…	…	…	…	…	…
…	…	…	…	…	…	…	…
2000	1.08	1.08	1.07	1.06	1.05	1.05	1.04
3000	1.07	1.06	1.06	1.05	1.04	1.04	1.03

$$Q_A = A * F * q_{max} \; where \; A = 600 \; ha, and \; F = 1.31 \; from \; Table \; 4$$

$$Q_A = 600 * 1.31 * 1.02 + Q_{remaining} = 801.72 \frac{lt}{s} + 1.0 \frac{m^3}{s} = 1.802 \quad m^3/s$$

$$Q_B = A * F * q_{max} \; where \; A = 300 \; ha, and \; F = 1.45 \; from \; Table \; 4$$

$$Q_B = 300 * 1.45 * 1.02 + Q_{remaining} = 443.7 \frac{lt}{s} + 1.0 \frac{m^3}{s} = 1.444 \quad m^3/s$$

$$Q_D = A * F * q_{max} \; where \; A = 200 \; ha, and \; F = 1.55 \; from \; Table \; 4$$

$$Q_D = 200 * 1.55 * 1.02 = 316.2 \frac{lt}{s} = 0.316 \quad m^3/s$$

Optimum Canal Dimensions

By using Figure 3 below, optimum canal dimensions and canal velocities can be determined.

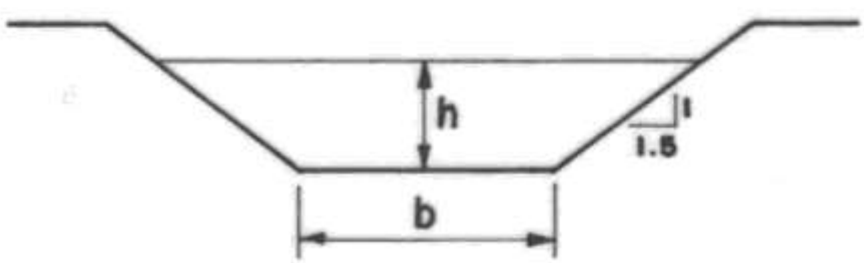

Figure 2: Irrigation Canal Section View

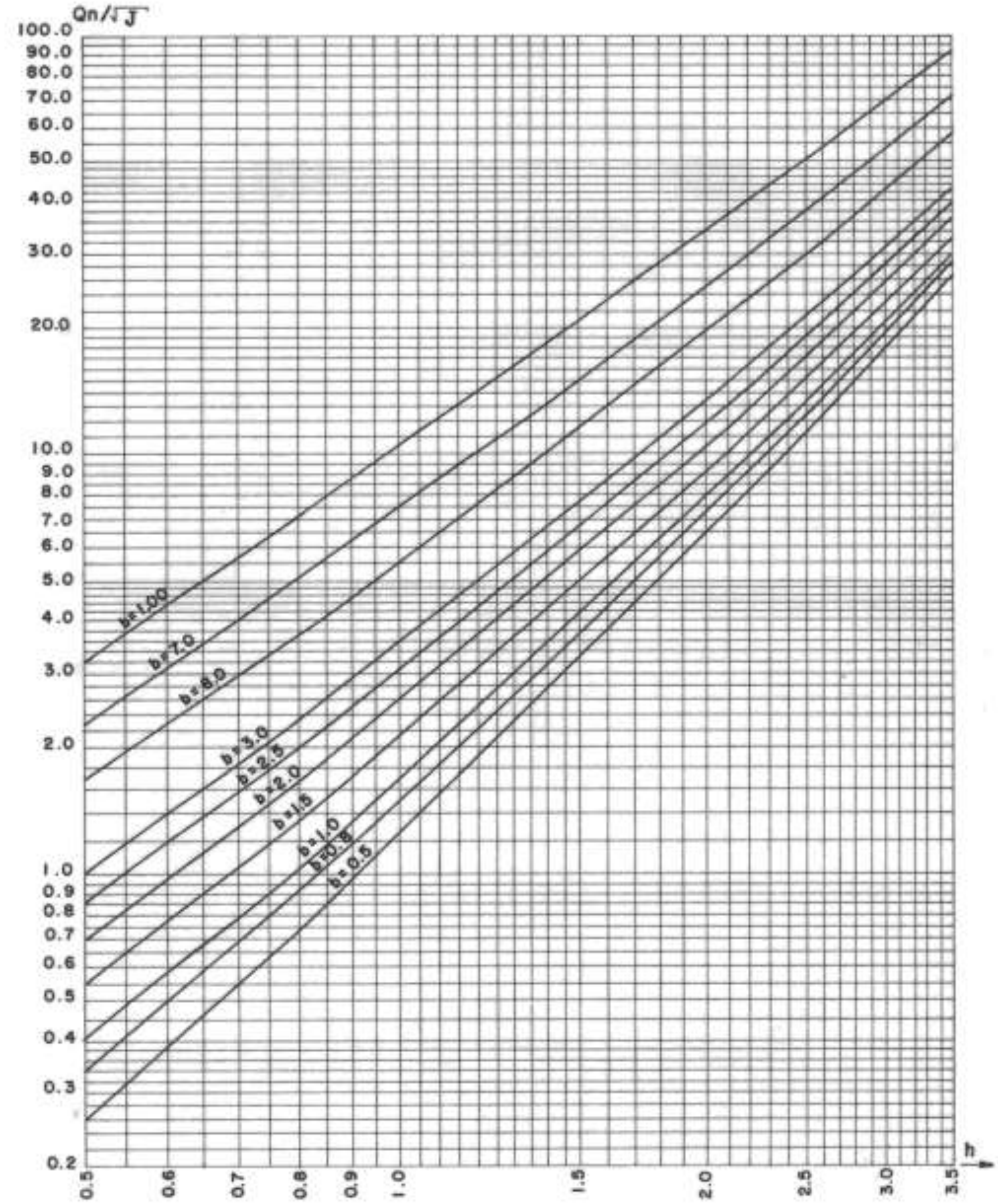

Figure 3: Dimensionless Chart showing the relationship between section factor with water depth and bottom width

- **For Point A**

$$Q_A = \frac{A * R^{\frac{2}{3}} * S_0^{0.5}}{n} \; when; R = \frac{A}{P}, and \; A = by + 1.5y^2, P = b + 2 * y * (1 + z^2)^{1/2}$$

$$\frac{Q_A * n}{S_0^{0.5}} = 1.802 * \frac{0.016}{0.0004^{0.5}} = 1.44$$

For this point, choose y=0.93 and b=1 from Figure 3.

$$A = 1 * 0.93 + 1.5 * 0.93^2 = 2.23\ m^2\ and\ V_a = \frac{Q}{A} = \frac{1.802}{2.23} = 0.81\ m/s$$

2.5>0.81>0.5 **OK**

- **For Point B**

$$Q_A = \frac{A * R^{\frac{2}{3}} * S_0^{0.5}}{n}\ when; R = \frac{A}{P}, and\ A = by + 1.5y^2, P = b + 2 * y * (1 + z^2)^{1/2}$$

$$\frac{Q_A * n}{S_0^{0.5}} = 1.444 * \frac{0.016}{0.0004^{0.5}} = 1.155$$

For this point, choose y=0.84 and b=1.0 from Figure 3.

$$A = 1 * 0.84 + 1.5 * 0.84^2 = 1.898\ m^2\ and\ V_a = \frac{Q}{A} = \frac{1.444}{1.898} = 0.76\ m/s$$

2.5>0.76>0.5 **OK**

- **For Point C**

$$Q_A = \frac{A * R^{\frac{2}{3}} * S_0^{0.5}}{n}\ when; R = \frac{A}{P}, and\ A = by + 1.5y^2, P = b + 2 * y * (1 + z^2)^{1/2}$$

$$\frac{Q_A * n}{S_0^{0.5}} = 0.44 * \frac{0.016}{0.0006^{0.5}} = 0.29$$

For this point, choose y=0.54 and b=0.5 from Figure 3.

$$A = 0.5 * 0.54 + 1.5 * 0.54^2 = 0.71\ m^2\ and\ V_C = \frac{Q}{A} = \frac{0.44}{0.71} = 0.62\ m/s$$

2.5>0.6>0.5 **OK**

- **For Point D**

$$Q_A = \frac{A * R^{\frac{2}{3}} * S_0^{0.5}}{n}\ when; R = \frac{A}{P}, and\ A = by + 1.5y^2, P = b + 2 * y * (1 + z^2)^{1/2}$$

$$\frac{Q_A * n}{S_0^{0.5}} = 0.316 * \frac{0.016}{0.006^{0.5}} = 0.206$$

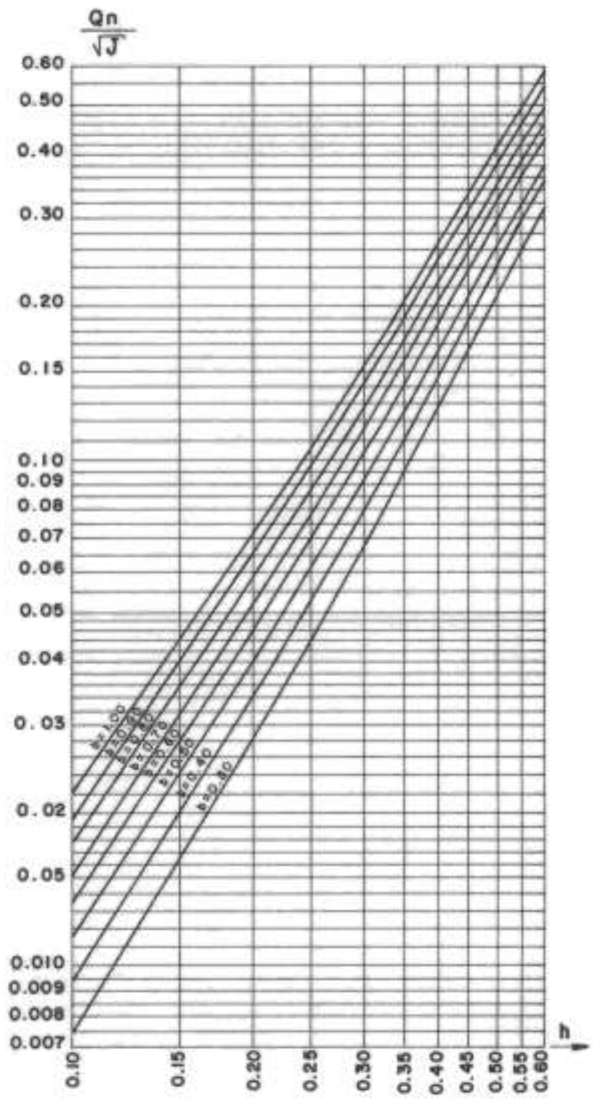

Figure 4: Dimensionless Chart showing the relationship between section factor with water depth and bottom width

For this point, choose y=0.35 and b=1 from Figure 4.

$$A = 1 * 0.35 + 1.5 * 0.35^2 = 0.53\ m^2\ and\ V_D = \frac{Q}{A} = \frac{0.316}{0.53} = 0.60\ m/s$$

2.5>0.6>0.5 **OK**

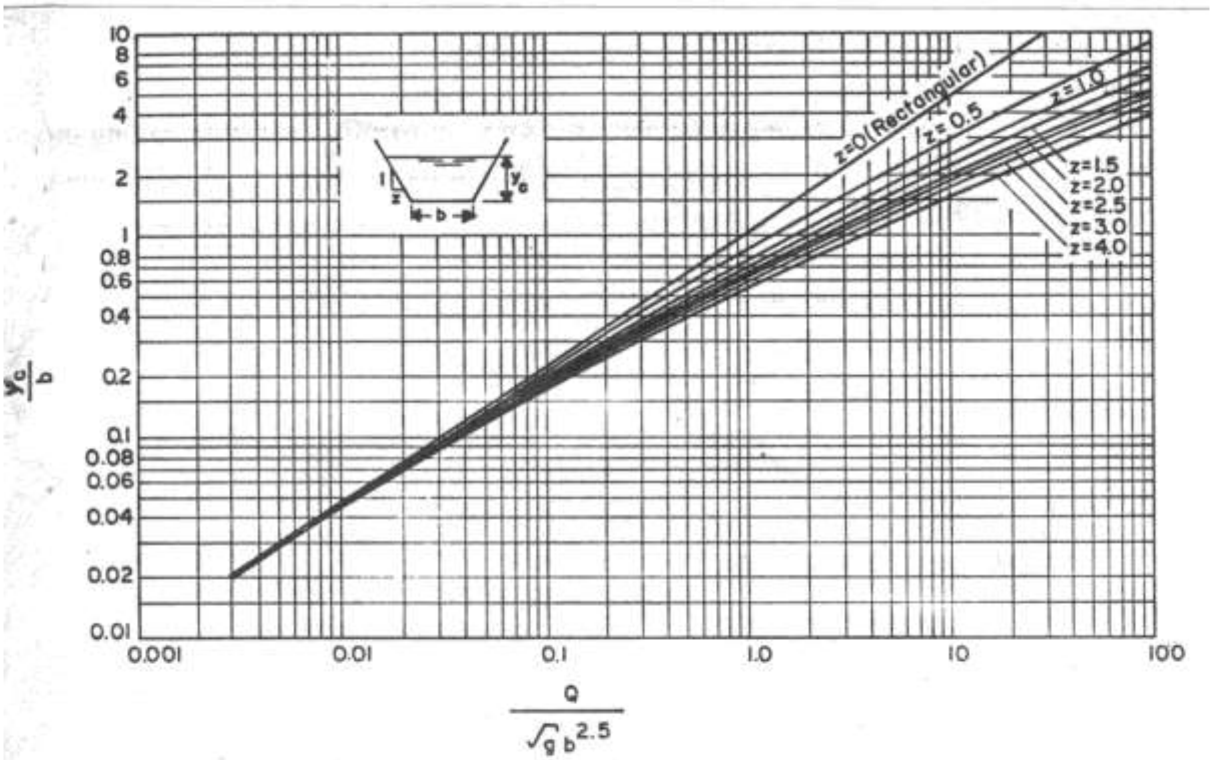

Figure 5: Critical Depth in a Trapezoidal Channel

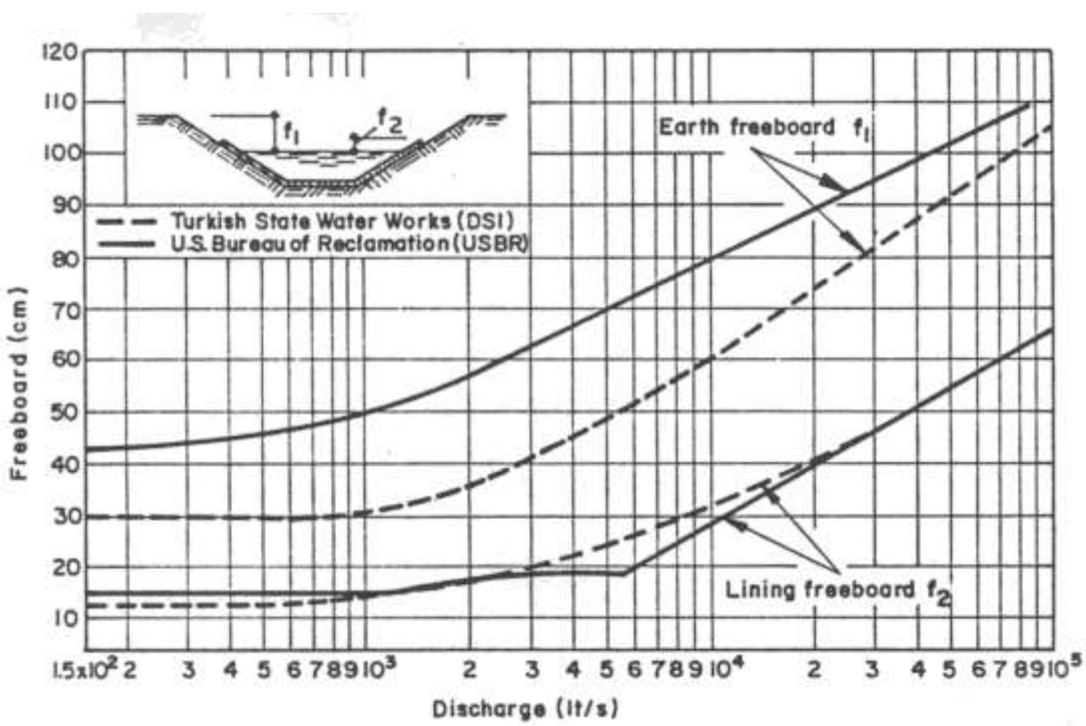

Figure 6:Recommended Freeboard for Canals

- **Point A**

<u>Freeboard</u>

$$Q_A = 600 * 1.31 * 1.02 + Q_{remaining} = 801.72\frac{lt}{s} + 1.0\frac{m^3}{s} = 1802\ lt/s$$

From Figure 6 (DSI), Earth freeboard is 38 cm

From Figure 6 (DSI), Lining freeboard is 18 cm

<u>Critical Depth</u> (From Figure 5)

$$y_c = 0.53\ m\ \ and\ y = 0.93\ m\ \ \ 0.93 > 1.1 * 0.53 = 0.58\ \ OK$$

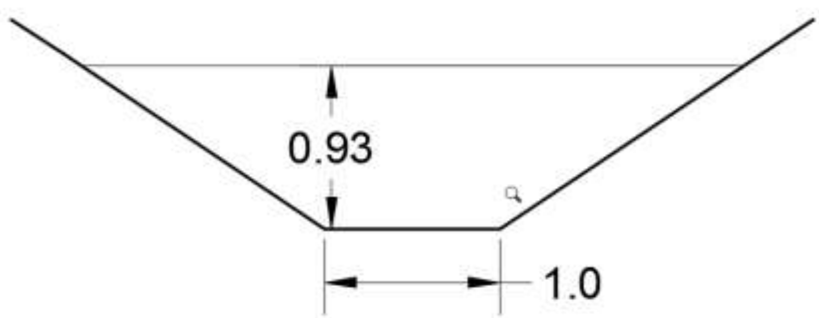

Figure 7: Cross Section at Point A

- **Point B**

<u>Freeboard</u>

$$Q_B = 300 * 1.45 * 1.02 + Q_{remaining} = 443.7\frac{lt}{s} + 1.0\frac{m^3}{s} = 1444\ lt/s$$

From Figure 6 (DSI), Earth freeboard is 35 cm

From Figure 6 (DSI), Lining freeboard is 15 cm

<u>Critical Depth</u> (From Figure 5)

$$y_c = 0.469\ m\ \ and\ y = 0.84\ m\ \ \ 0.84 > 1.1 * 0.469 = 0.516\ \ OK$$

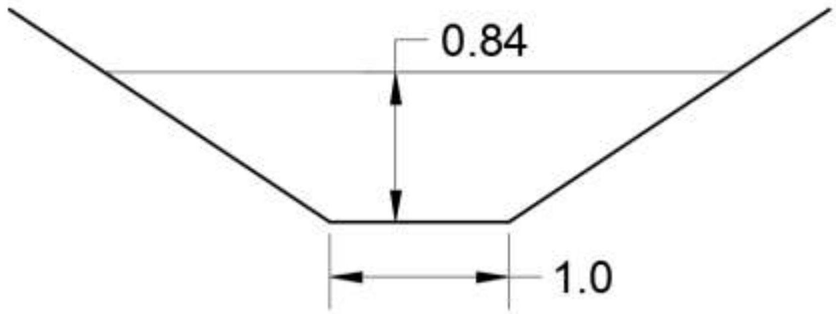

Figure 8:Cross Section at Point B

- **Point C**

<u>Freeboard</u>

$$Q_C = 440\ lt/s$$

From Figure 6 (DSI), Earth freeboard is 30 cm

From Figure 6 (DSI), Lining freeboard is 15 cm

<u>Critical Depth</u> (From Figure 5)

$$y_c = 0.238\ m\ \ and\ y = 0.54\ m\ \ \ 0.54 > 1.1 * 0.238 = 0.26\ \ OK$$

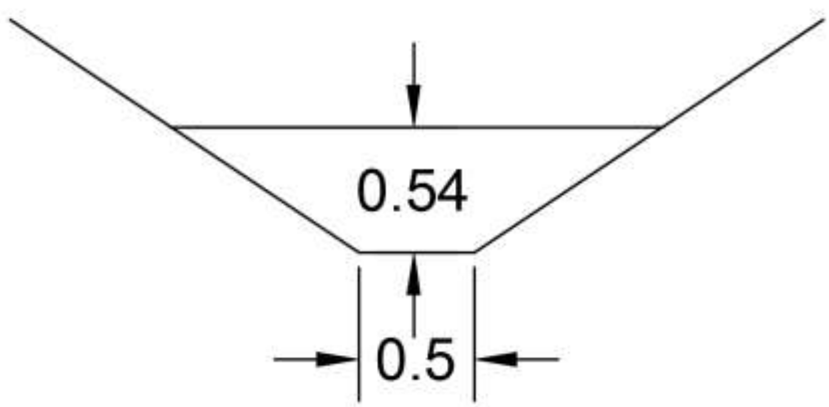

Figure 9:Cross Section at Point C

- **Point D**

  <u>Freeboard</u>

$$Q_D = 200 * 1.55 * 1.02 = 316.2\ lt/s$$

From Figure 6 (DSI), Earth freeboard is 30 cm

From Figure 6 (DSI), Lining freeboard is 15 cm

<u>Critical Depth</u> (From Figure 5)

$$y_c = 0.195\ m\ \ and\ y = 0.35\ m\ \ \ 0.35 > 1.1 * 0.195 = 0.215\ \ OK$$

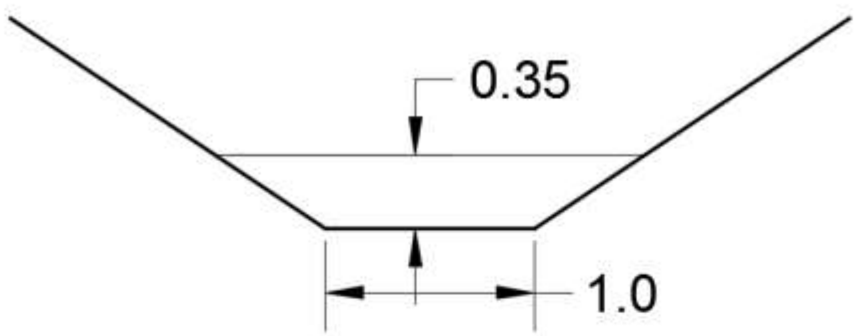

Figure 10:Cross Section at Point D

Irrigation Frequency(T) and Duration of Water Application (t_{1A})

$$RAW = \frac{(FC - PWP) * 0.75}{\%root}$$

$$T = \frac{RAW_{min}(mm)}{U_{c,daily}(mm)}$$

$$t_{1A} = \frac{U_{c,daily}(mm) * T(day)}{(1 - \%percolation) * f(mm/hr)}$$

$$AW = FC - PWP = 0.32 - 0.12 = 0.20 * 100 = 20\ cm$$

Root Zone	D(m)	%Root	Available Moisture (mm)	RAW (mm)
1	0.25	40	50	**93.75**
2	0.25	30	50	125
3	0.25	20	50	187.5
4	0.25	10	50	375

$$T = \frac{93.75}{\frac{37.07 + 8.80}{30} + \frac{53.13 + 36.03}{31} + \frac{93.90 + 69.51}{31}} = 9.6 \sim 9\ days$$

$$t_a = \frac{\left(\frac{37.07 + 8.80}{30} + \frac{53.13 + 36.03}{31} + \frac{93.90 + 69.51}{31}\right) * 9}{(1 - 0.25) * \left(\frac{0.9 * (144 + 192.8)}{31}\right)} = 11.87 \sim 12\ \ hours$$

Discussion and Conclusion

Several outputs are asked according to provided layout plan and information about the irrigation area. First of all, discharges at different points through the irrigation network is calculated. Points A, B, and D discharge values are calculated according to Blaney-Criddle method. Obviously, crop water requirement changes for different months. Different q_{max} values are obtained for different months and maximum came from August. q_{max} is calculated as 1.02 lt/s/ha and canal discharges are calculated accordingly. In the second part of the question, optimum canal dimensions are asked at points A, B, C, and D. By knowing discharges from the first part and using dimensionless charts provided in lecture notes, optimum canal dimensions are determined. After section dimensions determination, canals are checked for critical depth, maximum and minimum velocities. Then,, freeboard dimensions are determined according to Turkish State Water Works (DSI) and sections are plotted at those points. In the last part of the question, irrigation frequency and duration of water application during the irrigation season are calculated.

References

Darama, Y. (2009). *Introduction to Irrigation and Drainage Engineering*. METU Civil Engineering Department: ANKARA