UNIVERSITY OF JOHANNESBURG

PROGRAM	:	BACHELOR OF ENGINEERING TECHNOLOGY: *ENGINEERING : CIVIL*
SUBJECT	:	**WATER RETICULATION DESIGN 3A**
CODE	:	**WRDCIA3**
ASSESSMENT	:	WINTER EXAMINATION (MAIN PAPER)
DATE		3rd JUNE 2019
DURATION	:	(SESSION 1) 08:30 - 11:30
WEIGHT	:	40:60
TOTAL MARKS	:	100

ASSESSOR	:	G.K. NKHONJERA
MODERATOR	:	DR EDNAH ONYARI
NUMBER OF PAGES:		PAGES: 20 including the cover page and Annexures.

INSTRUCTIONS :

1. This paper contains 3 questions in Section A and 3 questions in Section B
2. Section A: ANSWER **ALL** QUESTIONS
3. Section B: ANSWER **TWO** QUESTIONS ONLY
4. Make sure that you understand what the question requires before attempting it.
5. Any additional material is to be placed in the answer book and must indicate clearly the question number, your name, and Student number.
5. Where necessary, answers without calculations will not be considered.

SECTION A
ANSWER ALL QUESTIONS

QUESTION 1 [15]

1.1 With respect to water supply, describe how the following may affect water demand in an area:

a) Climate. (2)
b) Introduction of water-metering programs. (2)

1.2 In water distribution network design, sometimes calculations may be done manually using either the Head or Flow balancing methods. Explain any TWO general principles that govern the Flow Balancing Method. (2)

1.3 A municipality in the Eastern Cape treats and distributes a total of 25 x 10^6 cubic metres of water per annum to a residential location with a population of 150 000 people. It is discovered that with a present water tariff of R11.17/m^3, the municipality only manages to collect revenue of R206.64 million. Under these conditions, determine the following:

a) Water delivery on a typical consumption day. (2)
b) Unaccounted-for water in (%). (4)
c) Daily per capita consumption, assuming 60% of the total delivery is for domestic use. (3)

QUESTION 2 [15]

2.1 Discuss how the concepts of health, environment and development, impact on each other in as far as stormwater management is concerned. (2)

2.2 In your own words, describe how urbanization impact negatively on the following environmental features:

a) Hydrologic cycle. (2)
b) Channel of the receiving stream. (2)

2.3 A stormwater drain channel is to be constructed in a location which is predominantly residential. The drain should be able to carry a peak flow of 300 m^3/min when flowing under normal flow. The drain, which should be unlined, will be covered with grass in order to stabilize its banks. For this stormwater drain, therefore, the Manning's coefficient, $n = 0.030$. The side slopes are 1: 3 (*z or m = 3*) while the longitudinal slope of the channel is 0.36 %. If the bed width of the channel is taken as 3 m and that the maximum allowable velocity in the channel is 1.12 m/s,

a) Calculate the flow depth (6)
b) Check whether your design meets the required standards in terms of its velocity. (3)

QUESTION 3 [20]

The diagram (**Fig. 3.2**) shows part of a layout of a proposed sewer reticulation system. The area is demarcated according to the potential levels of income of the people in the area. All the manholes on the layout are labeled with letters starting from A to N. The sewage from this area eventually drains out at P, as shown in the layout. The job at hand here is basically to estimate the sewage flow from this area. All the information you may need is provided in Table 3.1 below. Taking into account 15 % for infiltration and inflows, determine the Peak Wet Weather Flow (PWWF) discharging out of the sewer pipe at P.

Table 3.1: Sewage contribution of each development.

Income group	General residential	Lower	Middle	Upper
No. of units		2500	1500	900
Average flow *(L/unit/day)*	400 *L/100 m²/day*	550	750	1000
No. of people per unit.	10 *per 100 m²*	7	6	4

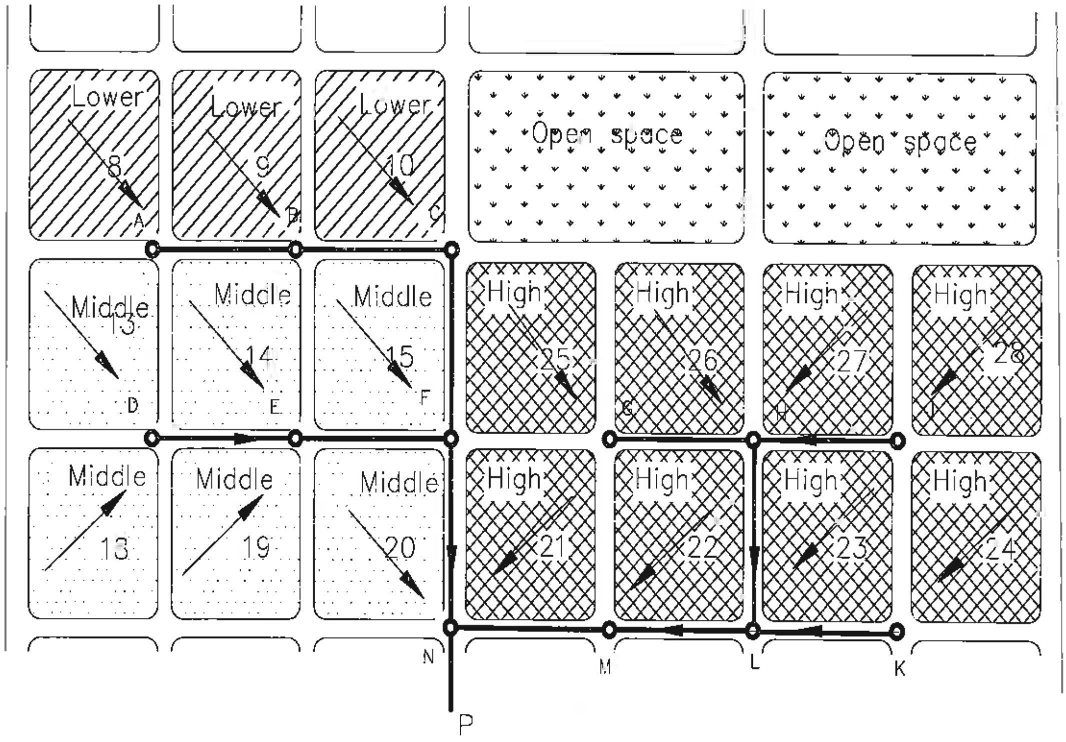

Fig. 3.2

SECTION B
ANSWER TWO QUESTIONS ONLY

QUESTION 4 [25]

Fig. 4.3 below represents a schematic layout of a distribution network with inflow at node A and demands at nodes B, H, N, G and D, as indicated in the layout. The initial estimated flows in pipes AB, CG and GN are 17 l/s, 14 l/s and 12 l/s respectively. The pressure head (piezometric head) at node A is registered as 55 m. All the pipes are assumed to have a Darcy's friction factor, $f = 0.022$. For any other information, refer to **Table 4.4** below. Using the Head Balance (Hardy Cross) method to perform **only 1 (one) iteration (for each loop),**

a) Determine discharge in each pipe. *(Calculation sheet (Appendix E) provided may be used).* (23)

b) Comment on the limitation of this method. (2)

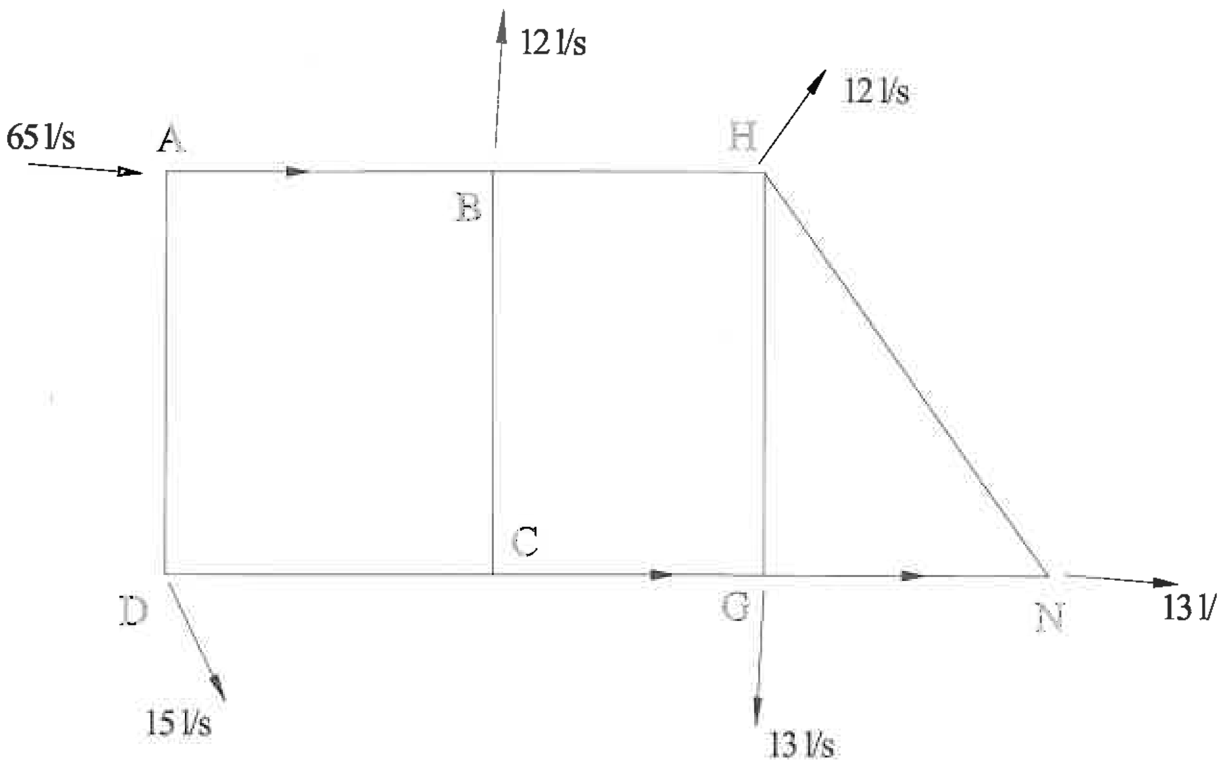

Fig. 4.3

Table 4.4: Pipe lengths and sizes

No.	Pipe name	Pipe length (m)	Pipe diameter (mm)	Estimated flow (l/s)
1	AB	500	150	17
2	BC	600	110	
3	CD	500	125	
4	AD	600	150	
5	BH	450	125	
6	HG	600	110	
7	CG	450	125	14
8	HN	750	110	
9	GN	450	125	12

QUESTION 5 [25]

Design a gravity sewer line that will drain sewage from areas P, Q, R, S and T and discharge it into an existing sewer line at manhole MH_475. The plan view of the proposed sewer is shown in **Fig 5.5** in **Appendix B**. Data on pipes, manholes and sewer flow is given in **Table 5.4** below. The minimum pipe size available is 300 mm and all the other sizes are in increment of 50 mm. Assume that the minimum and maximum velocities in the pipes are 0.7 m/s and 2.5 m/s respectively. *You may use the nomogram and calculation sheet provided in the Appendices K and F respectively.*

Table 5.6: Pipe and manhole information

Pipe name	Length, L (m)	Sewage flow, Q (l/s)	Invert levels (m)	
			Upstream manhole	Downstream manhole
MH_32 - MH_31	100	60.13	301.99	300.34
MH_31 – MH_30	95	74.15	299.69	298.49
MH_30 – MH_29	110	111.23	298.49	297.74
MH_29 – MH_28	105	167.84	297.14	296.54
MH_28 - MH_475	91	201.21	294.81	293.99

QUESTION 6 [25]

A planned subdivision of a location is sketched in **Fig. 6.7** in **Appendix C**. The stormwater pipes are laid along the Baloyi and Kapata Avenues in such a way that the stormwater collected drain into the main pipe located along the Tsapane Street which eventually drains out at P. The areas to the south of Kapata Avenue between Moeketsi and Chirwa Streets (shaded area) will not be served now, hence, not part of the design. And so will be the area to the south of Baloyi Avenue between Tsapane and Nyambi Streets. For the served area, the plan is to let the water run along the street gutters and only enter the pipe drain at the specified inlet points. In this area, the Municipal regulations specify a 5-year return period for the design of all stormwater facilities. Again, in this part of the area, the local IDF curves can be approximated functionally as:

$$I = \frac{a}{b + T_c}$$

Where:

I = Rainfall intensity (*mm/hr*).
T_c = Time of concentration (minutes).
a, b = constants for different return periods.
And, for this hypothetical location, $a = 2500$ and $b = 20$, for a return period of 5 years.

Now, with all this information duly available to you and:

a) Using the stormwater calculation sheet and the nomogram provided in the Appendices K and H respectively, calculate the quantity of stormwater in (m^3/min) that is draining out at P. (11)

b) As you work through, determine the slopes and sizes of all the stormwater pipes in the layout. (11)

c) If the runoff drained from this area before development was 60.39 m^3/min, and that for environmental protection, the Municipal regulations dictate that the post-development runoff from the area must NOT be more than the pre-development runoff, would you consider this stormwater system environmentally viable? Explain your answer. (3)

Table 6.8: Specified velocities in pipes (m/s)

Pipe	Length (m)	V (m/s)
AB	60	1.5
BC	60	1.5
CD	60	1.5
DE	60	1.5
FG	60	1.5
GH	60	1.5
HJ	60	1.5
JK	60	1.5
RQ	60	1.5
QP	60	1.5
PE	60	1.5
EK	65	1.5
KL	65	1.5
LP	50	1.5

Table 6.9: Catchment characteristics of the area.

Catch-ment Name	Catch-ment Area, A, (ha)	Runoff Coeff. C	Time of entry (minutes)
6	1.25	0.40	15
7	1.25	0.40	15
8	1.25	0.40	15
9	1.25	0.40	15
10	1.25	0.40	15
11	1.25	0.40	15
12	1.25	0.40	15
13	1.25	0.40	15
14	1.25	0.40	15
15	1.25	0.40	15
20	1.25	0.40	15
51	1.25	0.40	15
52	1.25	0.40	15
53	1.25	0.40	15

Table 6.10: Suggested minimum slopes for standard pipe sizes

Pipe Diameter (mm)	Minimum gradient (1 in ....)
300	80
375	110
450	140
525	170
600	200
675	240
750	280
825	320
900	350
1050	440
1200	520
1375	610

HAPPY WINTER HOLIDAY TO YOU ALL !!!!!!!!

APPENDIX A

FORMULAS

1.0 Rational Formula:

$$Q = 0.278CIA\,, \qquad T_c = 0.0195L^{0.77}S^{-0.385}$$

Where:

I = intensity (mm/hr).
A = catchment area (km^2).
L = hydraulic length of the catchment (m).

2.0 Pipe Friction:

General Formula: $h_L = h_f = rQ^m$;

Darcy-Weisbach: $h_f = \dfrac{fLQ^2}{12.1d^5}$

Resistance, $r = \dfrac{fL}{12.1d^5}$

Hazen-William formula: $h_f = 10.67LD^{-4.87}\left(\dfrac{Q}{C}\right)^{1.85}$

3.0 Pipe capacity:

$$Q = AV$$

4.0 Manning's Equation:

$$V = \frac{1}{n}R^{2/3}S^{1/2}$$

5.0 Chezy Formula:

$V = CR^{1/2}S^{1/2}$; where C = Chezy coefficient.

6.0 Hydraulic radius:

$R = \dfrac{A}{P}$; where P = Wetted perimeter in the channel.

7.0 Hydraulic Depth:

$D = \dfrac{A}{T}$; where T = Top width of the water surface in the channel.

8.0 Froude Number:

$$N_F = \frac{V}{\sqrt{gD}}$$

9.0 Darcy-Weisbach Head Balance Method spreadsheet:

Trial No.	Loop No.	Pipe	Diameter	f	L	m	r	Flow rate Q	Friction loss (h_f)	h_f/Q	ΔQ	$\Delta Q'$	Revised flow (Q)	Velocity

Where $\Delta Q = \frac{\sum h_f}{-m\sum \frac{h_f}{Q}}$

$$r = \frac{fL}{3.03d^5}$$

$$NewQ = Q + \Delta Q + \Delta Q'$$

10.0 Harmon's formula

$$PF = 1 + \frac{14}{4 + \sqrt{p}}$$

Where:

P = population per a thousand.

APPENDIX B: SANITARY SEWER DESIGN

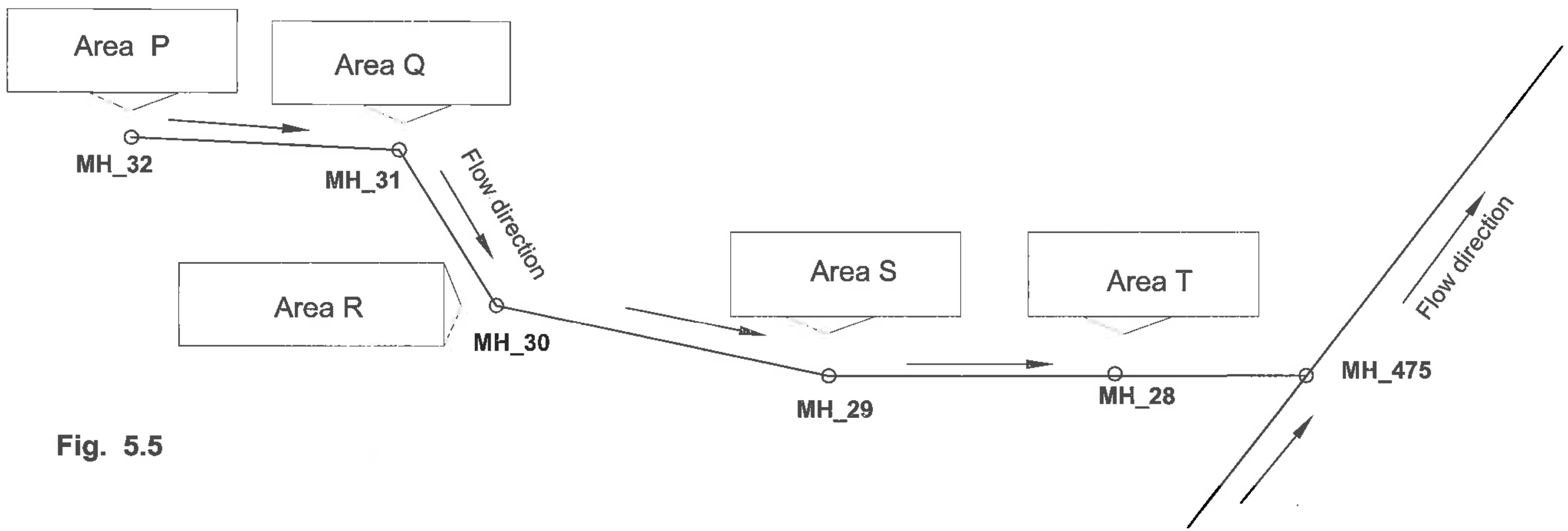

Fig. 5.5

APPENDIX C: DRAINAGE AREA IN A LOCATION

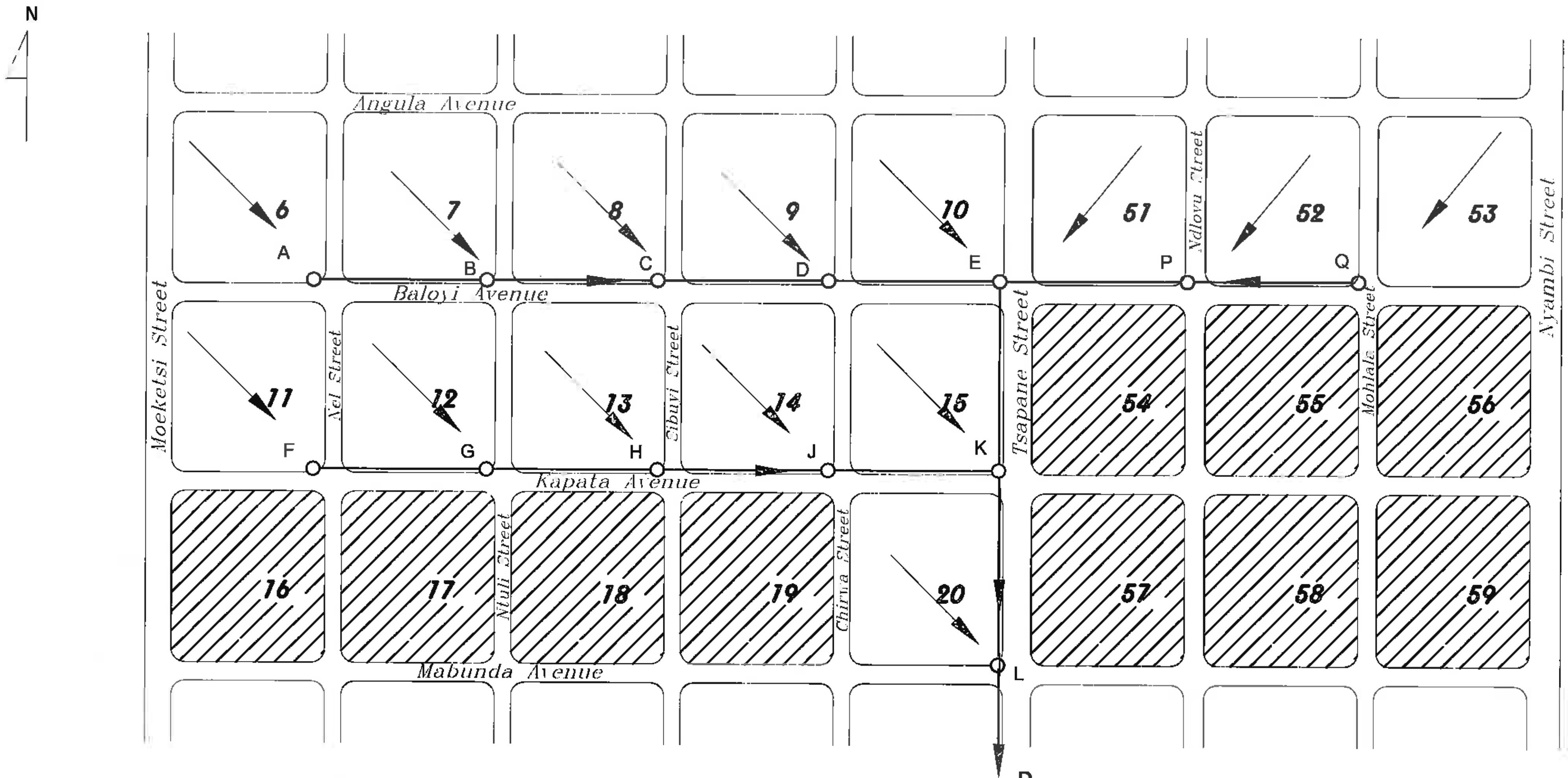

Fig. 6.7

APPENDIX D

DEPARTMENT OF CIVIL ENGINEERING
DOORNFONTEIN CAMPUS

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SEWAGE FLOW CALCULATION SHEET

PROJECT NAME: ____________ **SHEET No.** ____________ **DESIGNED BY:** ____________ **DATE:** ____________

Line No.	Line Description	From Manhole	To Manhole	Sub Area Name	Income Level	No. of Units/ Area Size	Average flow (l/unit/day) or (l/area/day)	ADWF (L/s)	Cummulative ADWF (l/s)	No. of people per unit	Total tributary population	PF	PDWF (L/s)	PWWF (L/s)

APPENDIX E

DEPARTMENT OF CIVIL ENGINEERING
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HEAD-BALANCE METHOD ANAYLSIS

UNIVERSITY OF JOHANNESBURG

PROJECT NAME:_______________ SHEET No. ________ DESIGNED BY: _______________ DATE: ________

Trial No.	Loop No.	Pipe Name	Diameter (mm)	Length, L (m)	Pipe roughness size, k (mm)	*Friction Coef. "f"*	r **	Flow, Q (L/s)	m	Friction loss, hf (m)	hf/Q	Change in Q, ΔQ	Change in Q', ΔQ'	New Q

* This table is developed for the Darcy-Weisbach formula, but some columns can be added or replaced to suit other formulas

** For Darcy-Weisbach Formula, r = (fL)/(12.1*D^5)

APPENDIX F

DEPARTMENT OF CIVIL ENGINEERING
DOORNFONTEIN CAMPUS

SEWER DESIGN CALCULATION SHEET

UNIVERSITY OF JOHANNESBURG

PROJECT NAME: ________ **SHEET No.** ____ **DESIGNED BY:** ________ **DATE:** ________

														Ground Elevation		Invert Elevation	
Line No.	Sewer Description	From Manhole	To Manhole	Length (m)	Sewage Flow, PWWF, (m^3/min)	Pipe Diameter (mm)	Grade of Sewer	Fall of Sewer (m)	Velocity flowing full (m/s)	Capacity flowing full (m^3/min)	Q/Q_{full}	V/V_{full}	Velocity (m/s)	Upper End, (m)	Lower End, (m)	Upper End, (m)	Lower End, (m)

APPENDIX G

UNIVERSITY OF JOHANNESBURG

DEPARTMENT OF CIVIL ENGINEERING
DOORNFONTEIN CAMPUS

STORMWATER DRAINAGE CALCULATION SHEET

PROJECT NAME: ____________ SHEET No. ______ DESIGNED BY: ____________ DATE: ____________

															Ground Elevation		Invert Elevation	
Line No.	Area Name	Area, A (ha)	Runoff Coefficient, C	Imp Area (CxA)	Cummulative Imp Area $\Sigma(CA)$	Time of concentration, Tc (min)	Rainfall Intensity, I (mm/hr)	Runoff, Q, (m^3/min)	Slope/ Grade	Pipe Dia. (mm)	Velocity Flowing full, (m/s)	Length, L, (m)	Time of flow, t, (min)	Capacity of Pipe, (m^3/min)	Upper End, (m)	Lower End, (m)	Upper End, (m)	Lower End, (m)

APPENDIX H

OPEN CHANNEL DESIGN, NORMAL DEPTH

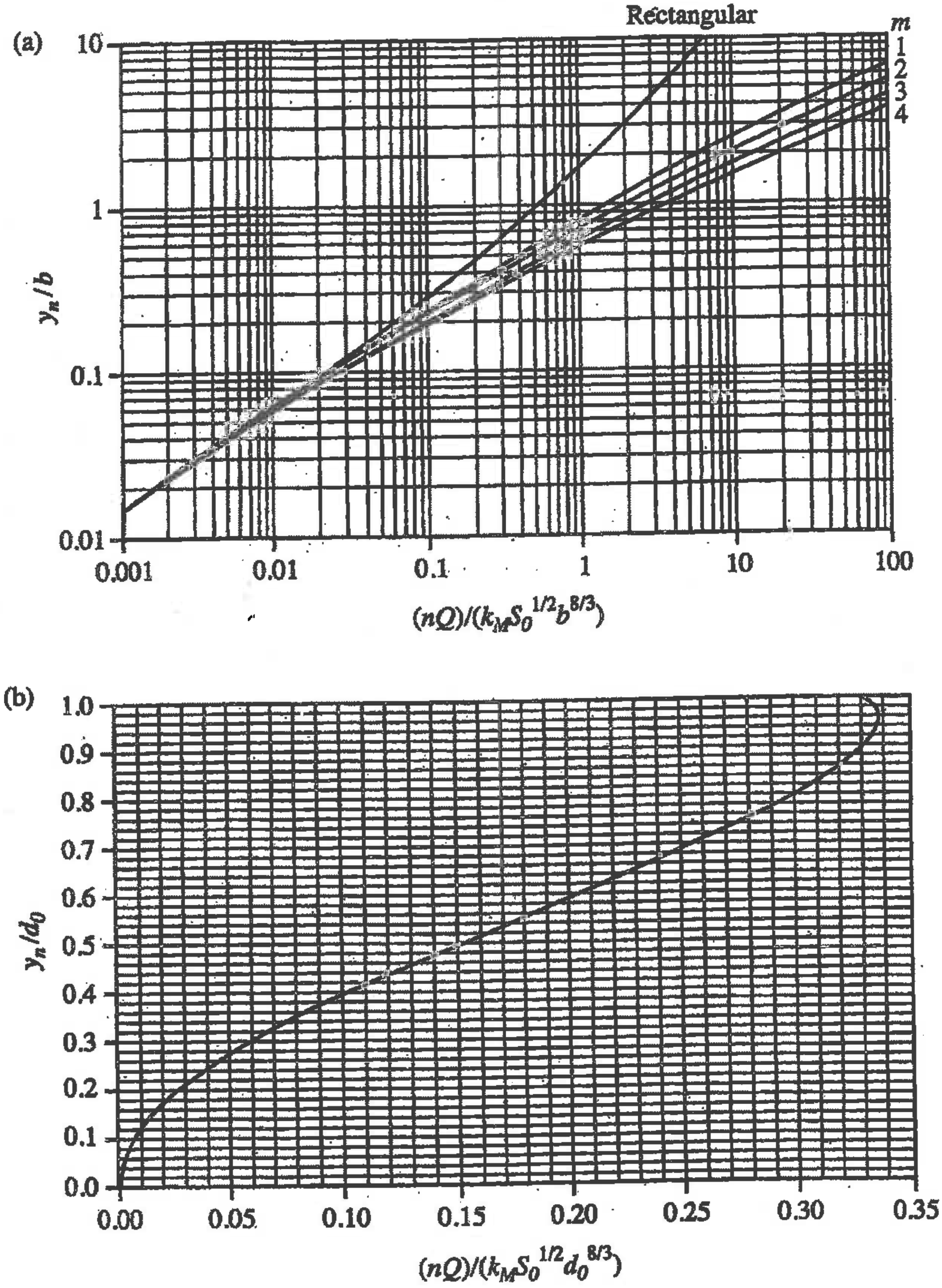
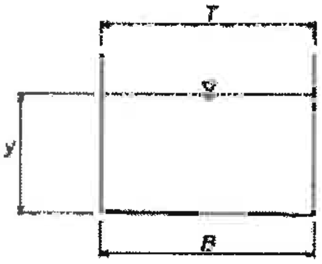


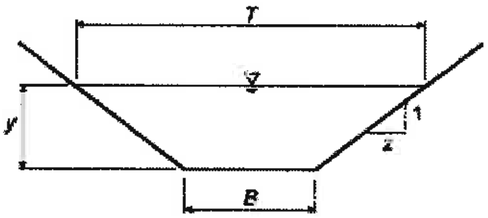
Figure 6.4 Normal depth solution procedure: (a) trapezoidal channels (m = side slope) and (b) circular channels (d_0 = diameter)

APPENDIX J

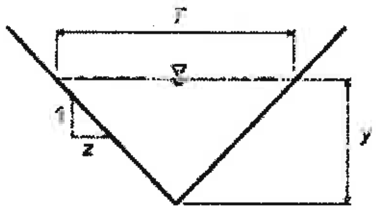
OPEN CHANNEL CROSS SECTIONS



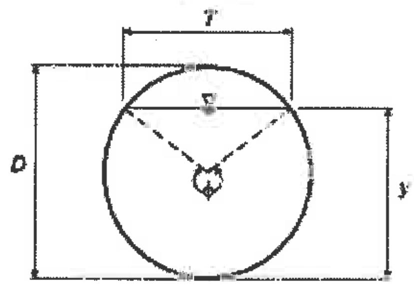
Rectangular



Trapezoidal



Triangular



Circular

Channel Shape	***Area, A***	***Wetted Perimeter, P***	***Hydraulic Radius, R***	***Top Width, T***	***Hydraulic depth, D***
Rectangular	By	$B+2y$	$\frac{By}{B+2y}$	B	y
Trapezoidal	$By+zy^2$	$B+2y\sqrt{1+z^2}$	$\frac{By+zy^2}{B+2y\sqrt{1+z^2}}$	$B+2zy$	$\frac{By+zy^2}{B+2zy}$
Triangular	zy^2	$2y\sqrt{1+z^2}$	$\frac{zy}{2\sqrt{1+z^2}}$	$2zy$	$\frac{y}{2}$
Circular *(ϕ in radians)*	$\frac{D^2(\phi-\sin\phi)}{8}$	$\frac{D\phi}{2}$	$\frac{D}{4}\left(1-\frac{\sin\phi}{\phi}\right)$	$D\frac{\sin\phi}{2}$	$\frac{D(\varphi-\sin\varphi)}{4\sin\varphi}$

APPENDIX K

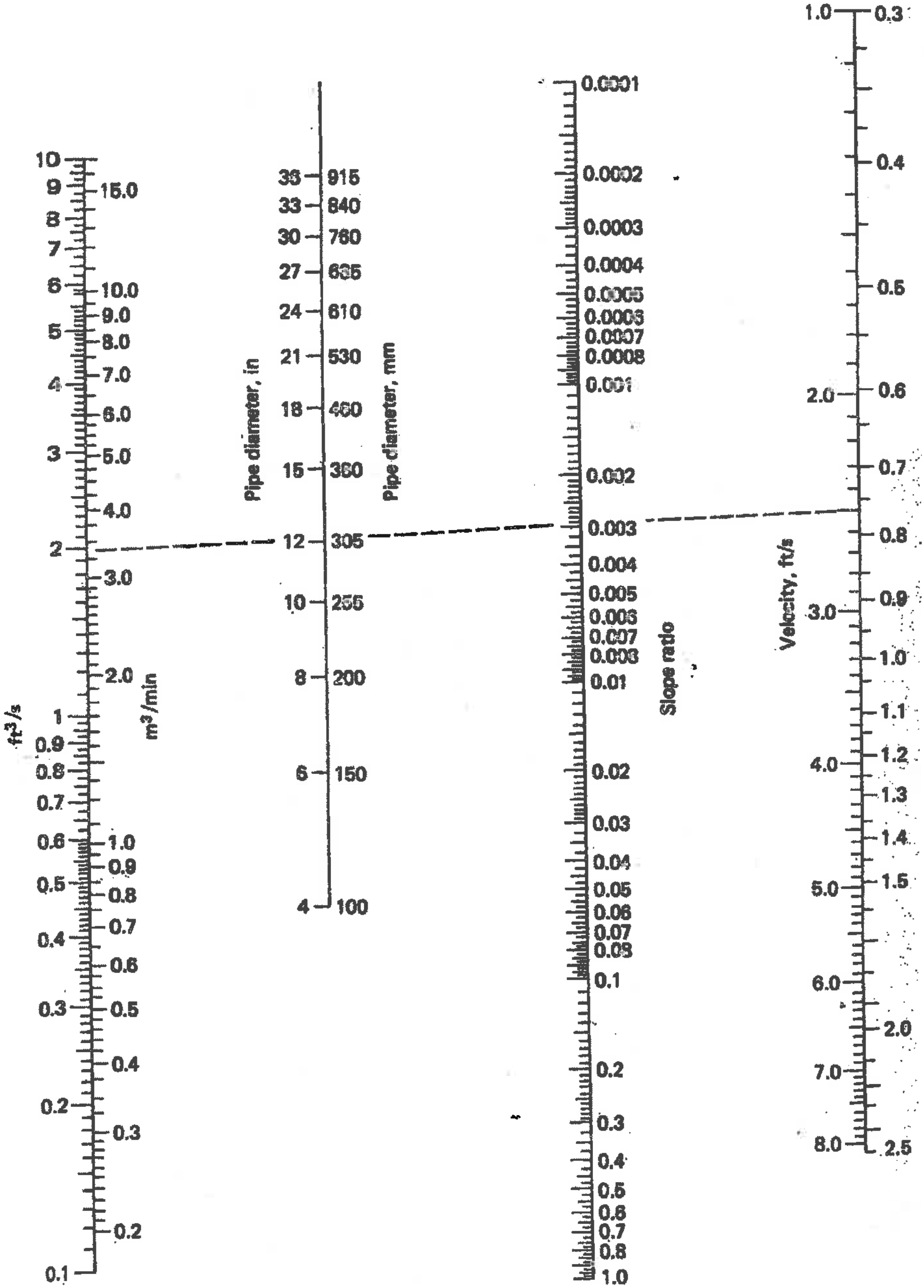


FIGURE 16-2
Nomogram for solution of Manning's equation for circular pipes flowing full (n = 0.013).

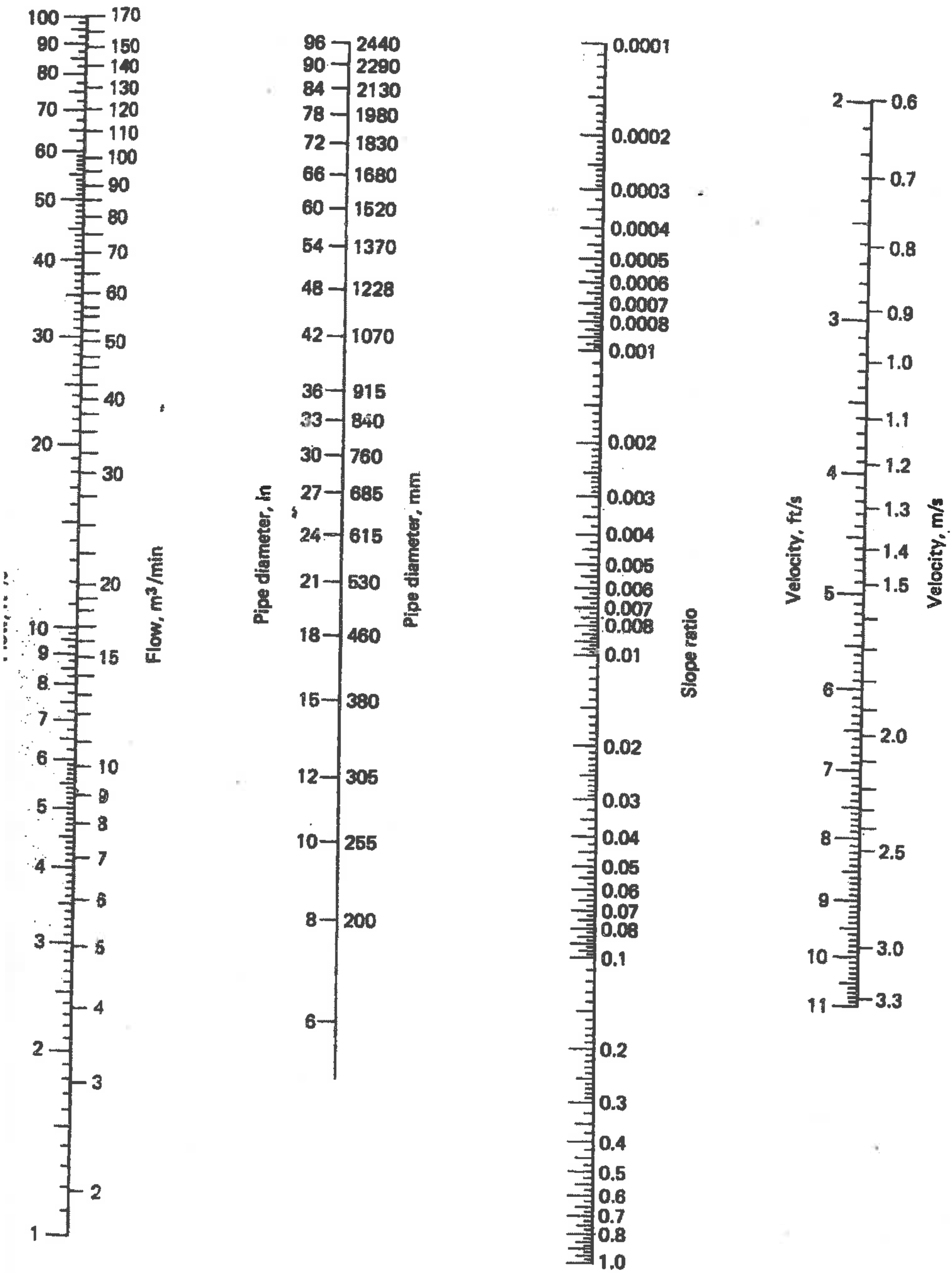


FIGURE 16-3
Nomogram for solution of Manning's equation for circular pipes flowing full ($n = 0.013$).

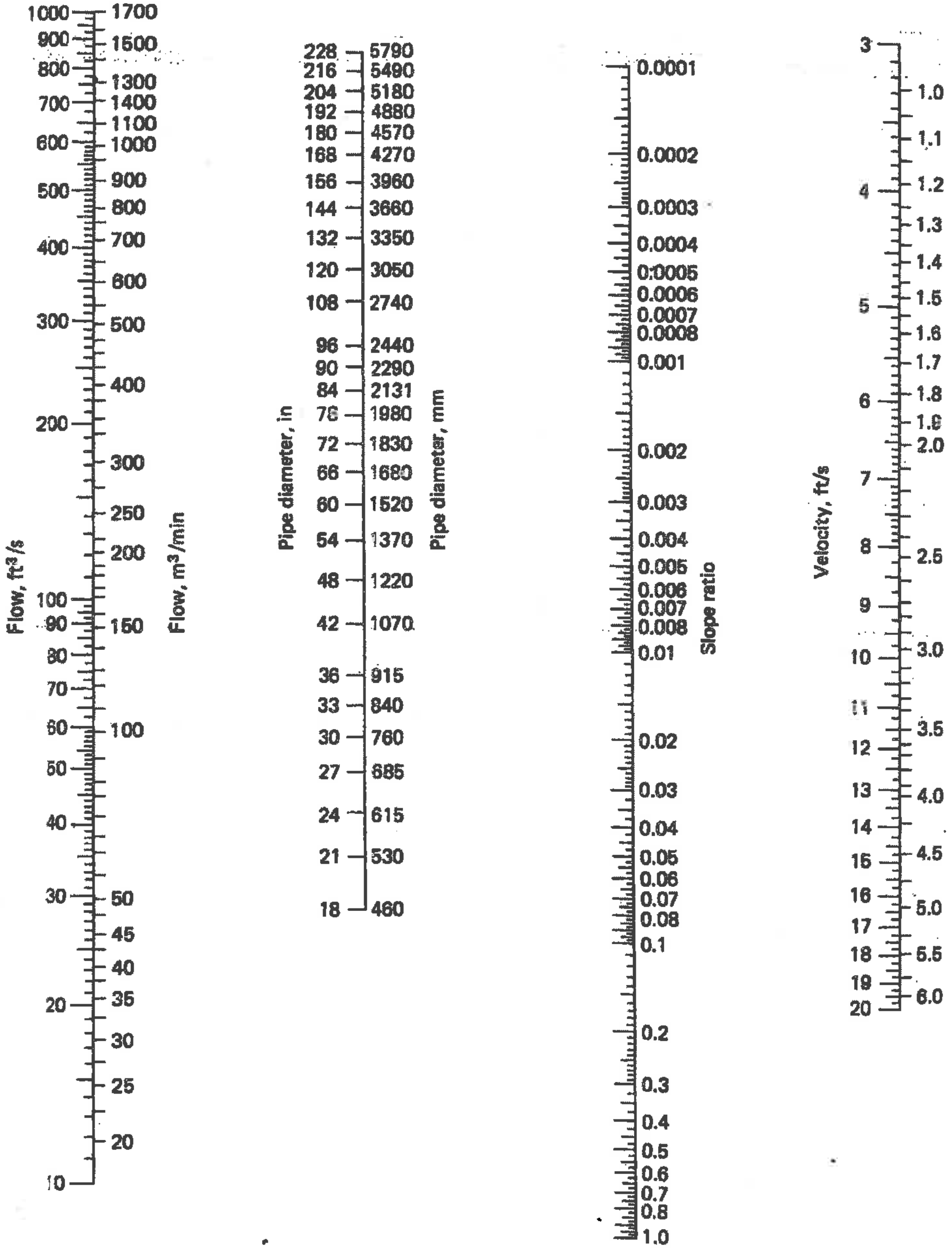


FIGURE 16-4
Nomogram for solution of Manning's equation for circular pipes flowing full ($n = 0.013$).

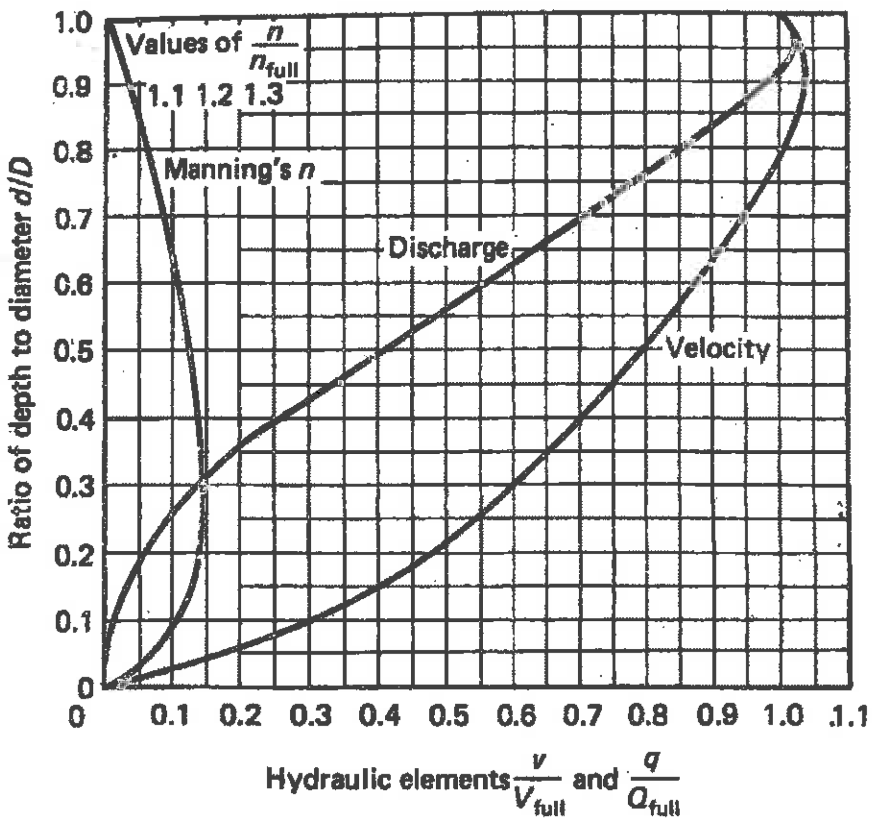


FIGURE 16-6
Variation of flow and velocity with depth in circular pipes.