INDEX

A P P E N D I X

BROADLAWN ESTATES

The site is located on the north side of Heinlein Road, approximately 2000 feet east of Baumgart Road, in Center Township.

Existing conditions at the 20 acre site consist of flat to rolling pasture which has not been cultivated recently. Storm water from this area is presently conveyed past the recently developed Edinborough Subdivision to the west through existing ditches.

The proposed development requires that the drainage channel which crosses the south end of the site will be reshaped and moved slightly north to align with lot property lines. Runoff from the 42 acre watershed upstream of the site will enter the channel directly or be intercepted by a drainage swale along the east side of the site and be conveyed to the channel.

All storm water within the development will be detained on-site, except for two small areas totalling 0.23 acres. Storm detention will be provided in two separate areas: Detention Swale 'A' near the northwest corner of the site; and Detention Swale 'B' near the southwest corner. Both detention swales will release the stored storm water at controlled rates not to exceed the undeveloped runoff rates. Detention Swale'A' will provide 4219 cubic feet of storage at a maximum depth of 2.5 feet, while Detention Swale 'B' will provide 14,400 cubic feet of storage at a maximum depth of 2.5 feet. Both detention swales will have adequate freeboard capacity for storing runoff from the 100 year storm.

All on-site storm runoff will be conveyed to the retention basin by a combination of pipes and swales.

II(a) DETERMINATION OF A RUNOFF COEFFICIENT

Values of the runoff coefficient are given in Table 3.1 for rural areas and Table 3.2 for urban area. Table 3.2(a) presents runoff coefficients for particular types of urban areas and Table 3.2(b) gives coefficients which can be used to compute a weighted C based on the actual percentage of lawns, streets, roofs, etc.

Table 3.1
Rural Runoff Coefficients (Schwab et al., 1971)

Vegetation and Topography	Soil Texture: Open Sandy Loam	Soil Texture: Clay and Silt Loam	Soil Texture: Tight Clay
Woodland			
Flat 0-5% slope	0.10	0.30	0.40
Rolling 5-10% slope	0.25	0.35	0.50
Hilly 10-30% slope	0.30	0.50	0.60
Pasture			
Flat	0.10	0.30	0.40
Rolling	0.16	0.36	0.55
Hilly	0.22	0.42	0.60
Cultivated			
Flat	0.30	0.50	0.60
Rolling	0.40	0.60	0.70
Hilly	0.52	0.72	0.82

As mentioned before, this coefficient represents the runoff-rainfall ratio and includes many factors such as type of cover, soil types, infiltration, evaporation, evapo-transpiration, and any antecedent moisture condition. It has also been shown that C actually does not remain constant during the storm duration (Horner, 1910). The strong dependence on "engineering judgement" in selecting a runoff coefficient is one of the main weaknesses of the rational method.

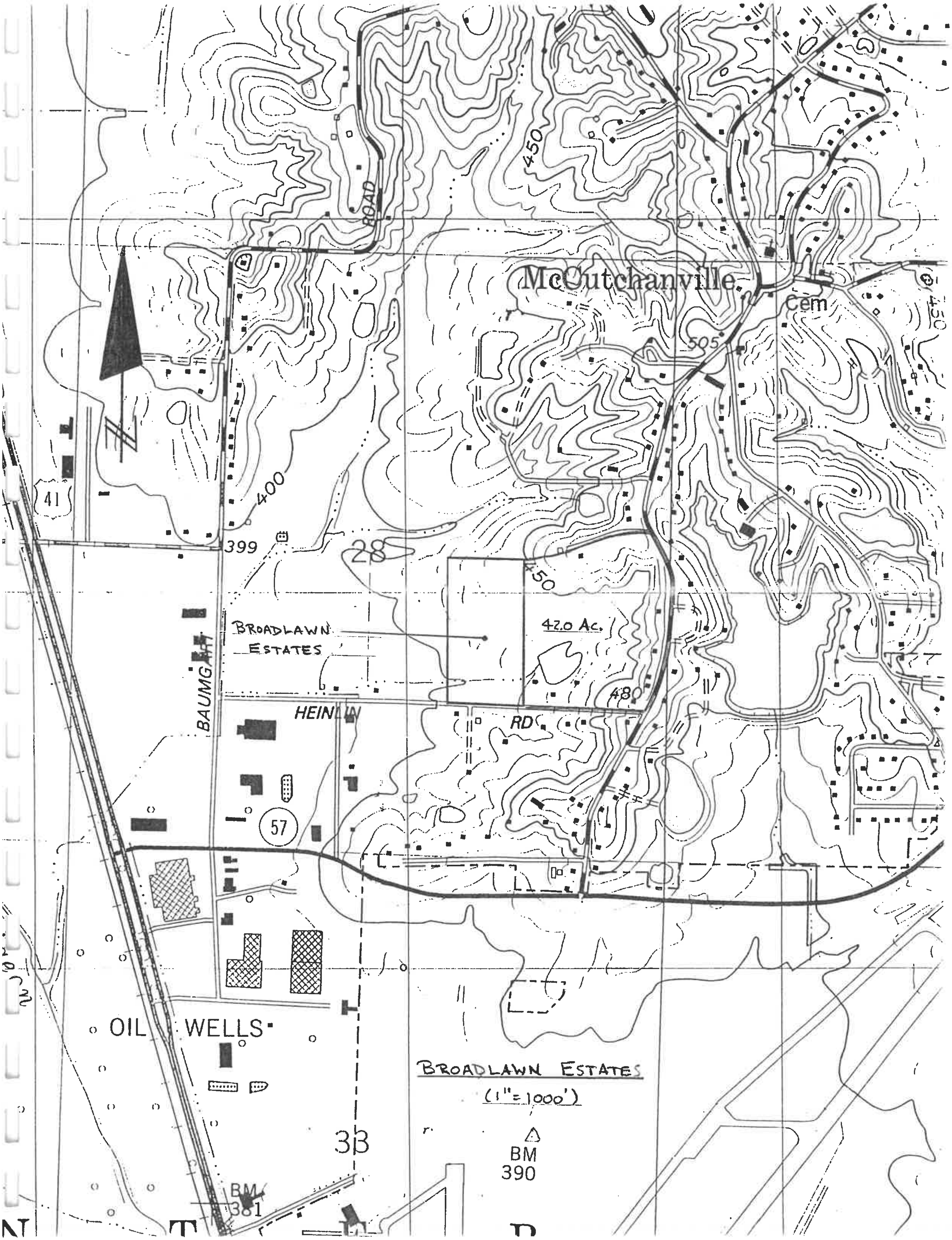
Table 3.2(a)
Urban Runoff Coefficients for the Rational Method (ASCE 1976)

Table 3.2(a) Runoff Coefficients for an Urban Area

Description of Area	Runoff Coefficients
Business	
Downtown	0.70 to 0.95
Neighborhood	0.50 to 0.70
Residential	
Single-family	0.30 to 0.50
Multi-units, detached	0.40 to 0.60
Multi-units, attached	0.60 to 0.75
Residential (suburban)	0.25 to 0.40
Apartment	0.50 to 0.70
Industrial	
Light	0.50 to 0.80
Heavy	0.60 to 0.90
Parks, cemeteries	0.10 to 0.25
Playgrounds	0.20 to 0.35
Railroad yard	0.20 to 0.35
Unimproved	0.10 to 0.30

Table 3.2(b)
Values Used to Determine a Composite Runoff Coefficient for an Urban Area

Character of Surface	Runoff Coefficients
Pavement	
Asphalt and Concrete	0.70 to 0.95
Brick	0.70 to 0.85
Roofs	0.75 to 0.95
Lawns, sandy soil	
Flat, 2 percent	0.05 to 0.10
Average, 2 to 7 percent	0.10 to 0.15
Steep, 7 percent	0.15 to 0.20
Lawns, heavy soil	
Flat, 2 percent	0.13 to 0.17
Average, 2 to 7 percent	0.18 to 0.22
Steep, 7 percent	0.25 to 0.35
Water Impoundment	1.00



BROADLAWN ESTATES
(1"=1000')

2/8/94, 2/25/94
DJH

BROADLAWN ESTATES SUBDIVISION

UNDEVELOPED CONDITIONS

Site Area = 20.0 Acres

Land Use – Pasture, flat (0-5%)

Soil Types:

MuB2 – Muren silt loam, 2-6%

St – Stendal silt loam

HoC2 – Hosmer silt loam, 6-12%

Avg. Slope:	Watershed A	Watershed B
ΔH	449 - 415 = 34'	441 - 397 = 44'
L	720'	1050'
S	0.0472	0.0419

Existing Runoff Coefficient & N Values

C = 0.30

N = 0.40

Return Period Coefficient – 25 Yr. Storm

k = 1.1

C_{25_u} = (1.1)(0.30) = 0.33

2/8/94, 2/25/94
DJH

BROADLAWN ESTATES SUBDIVISION

DEVELOPED CONDITIONS

Composite Developed Coefficient

59 Lots

Impervious - C = 0.95

House/Garage:	59 x 1450 SF	=	85,550 SF
Drive:	59 x 400 SF	=	23,600 SF
Patios:	59 x 150 SF	=	8850 SF
Street:	30' x 2450'	=	73,500 SF
Cul-de-Sacs:	$4 \times \pi \times (30')^2$	=	11,310 SF
Sidewalks:	2 x 5' x 2450'	=	24,500 SF
	$4 \times 2 \times \pi \times 30' \times 5'$	=	3770 SF
			231,080 SF
			= 5.305 Ac.

Lawn, heavy soil

Avg. slope: 2-7 %

C = 0.22

Area = 20.0 - 5.305 = 14.695 Ac.

Weighted $C = [(0.95)(5.305) + (0.22)(14.695)]/20.0$

$= 0.414 \times 1.1$

$= 0.455$

2/8/94
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BROADLAWN ESTATES

WATERSHED A

Area = 5.25 Acres

L = 720'

ΔH = 34'

S = 0.0472

$$t_c = 0.827 \left[\frac{(0.40)(720)}{(0.0472)^{1/2}} \right]^{0.467} = 23.75 \text{ min.}$$

$i_{25} = 3.95$ "/hr.

$i_{100} = 5.03$ "/hr.

Peak Flow Rates

Undeveloped $Q_{25} = (0.33)(3.95)(5.25) = 6.84$ cfs

Developed $Q_{25} = (0.455)(3.95)(5.25) = 9.44$ cfs

2/8/94
DJH

BROADLAWN ESTATES

WATERSHED B

Area = 14.75 Acres

$L = 1050'$

$\Delta H = 44'$

$S = 0.0419$

$$t_c = 0.827 \left[\frac{(0.40)(1050)}{(0.0419)^{1/2}} \right]^{0.467} = 29.13 \text{ min.}$$

$i_{25} = 3.39$ "/hr.

$i_{100} = 4.31$ "/hr.

Peak Flow Rates

Undeveloped $Q_{25} = (0.33)(3.39)(14.75) = 16.50$ cfs

Developed $Q_{25} = (0.455)(3.39)(14.75) = 22.75$ cfs

PROJECT: BROADLAWN ESTATES - WATERSHED A DATE: 94 02 28
ENGINEER:MORLEY AND ASSOCIATES,INC

DESIGN RETURN PERIOD:	5-25-100
RELEASE RATE PERIOD:	5-25-100
WATERSHED AREA (ACRES):	5.25
TIME OF CONCENTRATION(UNDEVELOPED):	23.75
RAINFALL INTENSITY (INCHES/HR):	3.95
UNDEVELOPED RUNOFF COEFFICIENT:	.33
UNDEVELOPED RUNOFF RATE (CFS):	6.84
DEVELOPED RUNOFF COEFFICIENT:	.455

25 YEAR STORM

STORM DURATION (HRS)	RAINFALL INTENSITY (INCH/HR)	INFLOW RATE (CFS)	OUTFLOW RATE (CFS)	STORAGE RATE (CFS)	REQUIRED STORAGE (ACRE-FT)
.08	6.85	16.36	6.84	9.52	.063
.17	5.45	13.02	6.84	6.18	.087
.25	4.65	11.11	6.84	4.26	.089
.33	4.15	9.91	6.84	3.07	.084
.42	3.80	9.08	6.84	2.23	.078
.50	3.40	8.12	6.84	1.28	.053
.58	3.20	7.64	6.84	.80	.039
.67	2.85	6.81	6.84	-.04	-.002
.75	2.75	6.57	6.84	-.27	-.017
.83	2.60	6.21	6.84	-.63	-.044
.92	2.45	5.85	6.84	-.99	-.076
1.00	2.30	5.49	6.84	-1.35	-.112
1.25	2.05	4.90	6.84	-1.95	-.203
1.50	1.85	4.42	6.84	-2.42	-.303
1.75	1.60	3.82	6.84	-3.02	-.441
2.00	1.40	3.34	6.84	-3.50	-.583
2.50	1.25	2.99	6.84	-3.86	-.804
3.00	1.10	2.63	6.84	-4.22	-1.054
4.00	.84	2.01	6.84	-4.84	-1.612

PEAK STORAGE (ACRE/FT): .09
PEAK STORAGE (CUBIC FT): 3869.86

BROADLAWN ESTATES

DETENTION SWALE 'A'

Req'd Vol. = 3870 cu. ft.

Dimensions: Bottom Width = 6'

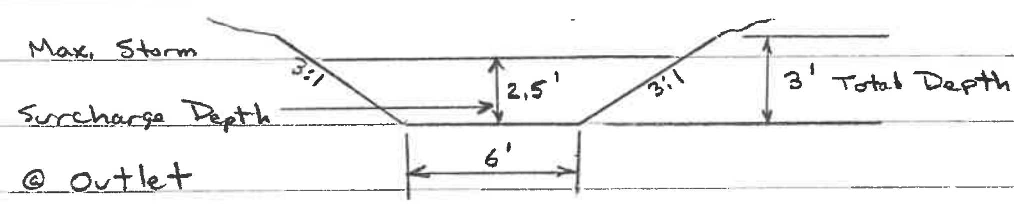
Side Slopes = 3:1

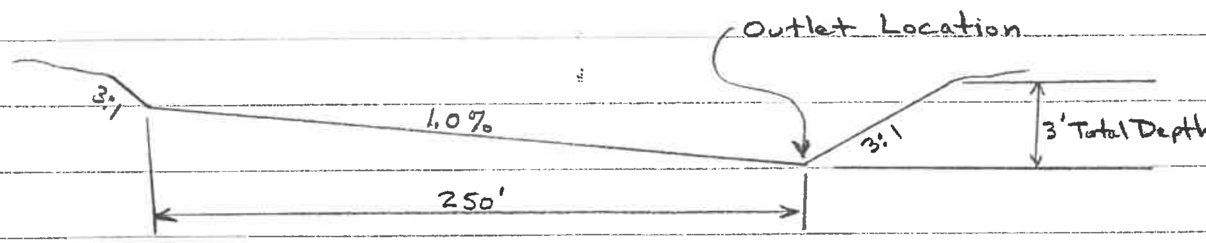
Depth @ Outlet = 3.0' (min.) @ outlet

Storage Depth = 2.5' (max.) @ outlet

Length (Bottom) = 250' @ 1.0% Slope

Typical Cross Sections





Storage Volume Provided

Cross Sectional Area @ 2.5' Depth

$= (2.5')(6') + (2.5')^2(3) = 33.75$ S.F.

Vol. $= \frac{1}{2}(0 + 33.75)(250') =$ 4219 cu. ft. > 3870

BROADLAWN ESTATES

Size Outlet Pipe

Undeveloped Q_{25} = 6.84 cfs

Sub-basins 2-7 & 2-8 uncontrolled

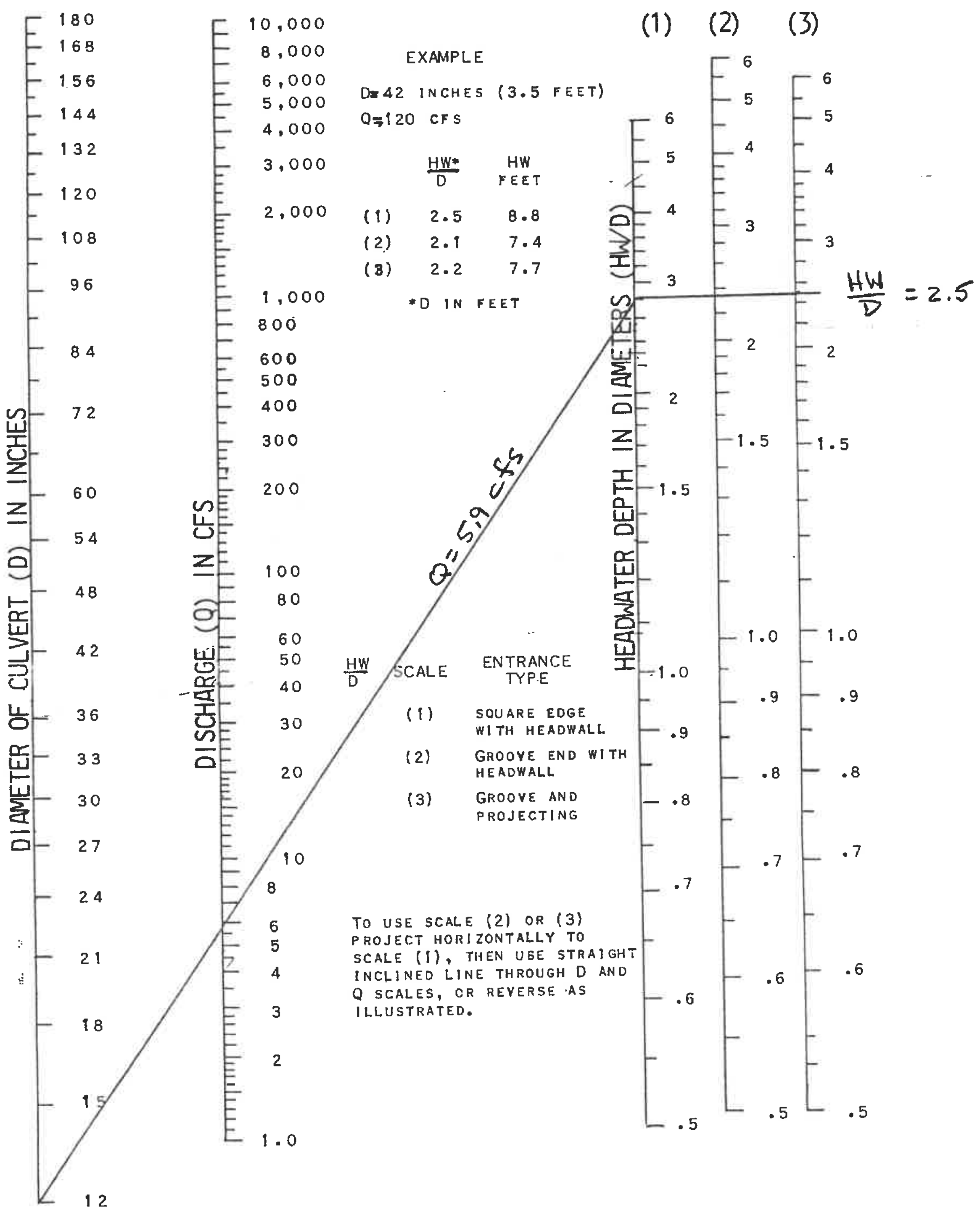
∴ Allowable $Q = 6.84 - 0.40 - 0.47 = 5.97$ cfs

From Fig. 7-430.01 F, for 12" dia. RCP

Max. depth = 2.5'

$\frac{HW}{D} = \frac{2.5}{1.0} = 2.5$

Q = 5.9 cfs



HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

FIG. 7-430.01 F

PROJECT: BROADLAWN ESTATES - WATERSHED B DATE: 94 02 25
ENGINEER:MORLEY AND ASSOCIATES,INC

DESIGN RETURN PERIOD:	5-25-100
RELEASE RATE PERIOD:	5-25-100
WATERSHED AREA (ACRES):	14.75
TIME OF CONCENTRATION(UNDEVELOPED):	29.13
RAINFALL INTENSITY (INCHES/HR):	3.39
UNDEVELOPED RUNOFF COEFFICIENT:	.33
UNDEVELOPED RUNOFF RATE (CFS):	16.50
DEVELOPED RUNOFF COEFFICIENT:	.455

25 YEAR STORM

STORM DURATION (HRS)	RAINFALL INTENSITY (INCH/HR)	INFLOW RATE (CFS)	OUTFLOW RATE (CFS)	STORAGE RATE (CFS)	REQUIRED STORAGE (ACRE-FT)
.08	6.85	45.97	16.50	29.47	.196
.17	5.45	36.58	16.50	20.08	.284
.25	4.65	31.21	16.50	14.71	.306
.33	4.15	27.85	16.50	11.35	.312
.42	3.80	25.50	16.50	9.00	.315
.50	3.40	22.82	16.50	6.32	.263
.58	3.20	21.48	16.50	4.98	.240
.67	2.85	19.13	16.50	2.63	.147
.75	2.75	18.46	16.50	1.96	.122
.83	2.60	17.45	16.50	.95	.066
.92	2.45	16.44	16.50	-.06	-.004
1.00	2.30	15.44	16.50	-1.06	-.089
1.25	2.05	13.76	16.50	-2.74	-.286
1.50	1.85	12.42	16.50	-4.09	-.511
1.75	1.60	10.74	16.50	-5.76	-.840
2.00	1.40	9.40	16.50	-7.11	-1.184
2.50	1.25	8.39	16.50	-8.11	-1.690
3.00	1.10	7.38	16.50	-9.12	-2.280
4.00	.84	5.64	16.50	-10.86	-3.621

PEAK STORAGE (ACRE/FT): .32
PEAK STORAGE (CUBIC FT): 13724.33

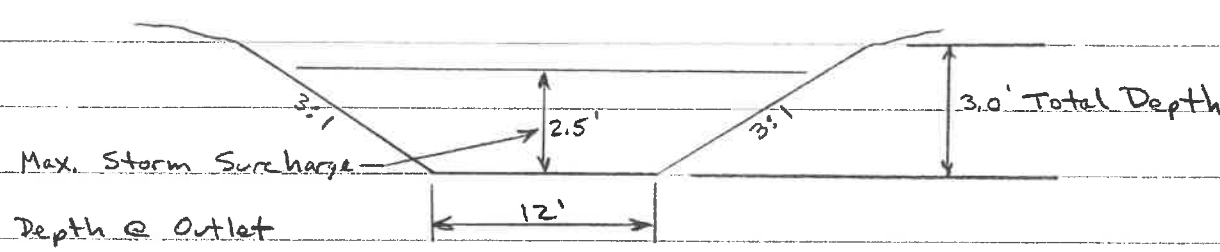
BROADLAWN ESTATES

DETENTION SWALE 'B'

Req'd Vol. = 13,724 cu. ft.

Storm surcharge to be provided in part of the relocated channel and two drainage swales, one on the north side and one on the south side.

Dimensions: Bottom Width = 12' (all sections)
Side Slopes = 3:1
Depth @ Outlet = 3.0' (min.) @ outlet
Storage Depth = 2.5' (max) @ outlet
Lengths (Bottom):
Relocated Channel = 100' @ 1.45 % Slope
South Swale = 120' @ 0.5 %
North Swale = 160' @ 0.5 %



Cross Sectional Area @ 2.5' Depth

$= (2.5')(12') + (2.5')^2(3) = 48.75$ S.F.

BROADLAWN ESTATES

Storage Volume Provided

Relocated Channel - area between outlet pipe and west road culvert.

Depth @ upstream limit (100' @ 1.45%) = 1.05'

Cross Sectional Area = $(1.05)(12) + (1.05)^2(3)$

= 15.90 S.F.

Vol. = ½ (48.75 + 15.90)(100) = 3232.5 cu. ft.

South Swale

Depth @ 120' @ 0.5% = 1.90'

Cross Sectional Area = $(1.90)(12) + (1.9)^2(3)$

= 33.63 S.F.

Vol. = ½ (48.75 + 33.63)(120) = 4942.8 cu. ft.

North Swale

Depth @ 160' @ 0.5% = 1.7'

Cross Sectional Area = $(1.7)(12) + (1.7)^2(3)$

= 29.07 S.F.

Vol. = ½ (48.75 + 29.07)(160) = 6225.6 cu. ft.

Total Storage Volume Provided

= 3232.5 + 4942.8 + 6225.6 = 14,400.9 cu. ft. > 13,724

BROADLAWN ESTATES

DETENTION SWALE / CHANNEL 'B'

Determine allowable discharge for outlet

From Watershed B

Allow. Q_{25} = 16.50 cfs

From Upstream 42.0 Ac. Watershed

Q_{25} = 41.4 cfs

Allow. Q = 57.9 cfs

Check peak flow to outlet pipe.

Total Area = 42.0 + 14.75 = 56.75 ac.

Wt'd C = 0.364

Use i_{25} = 2.59"/hr.

Q_{25} = (1.1)(0.364)(2.59)(56.75) = 58.85 cfs

Allow. Q = 58.85 − (22.75 − 16.50)

= 52.6 cfs

Use Allow. Discharge for Outlet Culvert

Q = 52.6 cfs

For Storm Storage ⇒ H.W. = 2.5'

Max. H.W. = 3.0'

From Fig. 7-430.01 G.

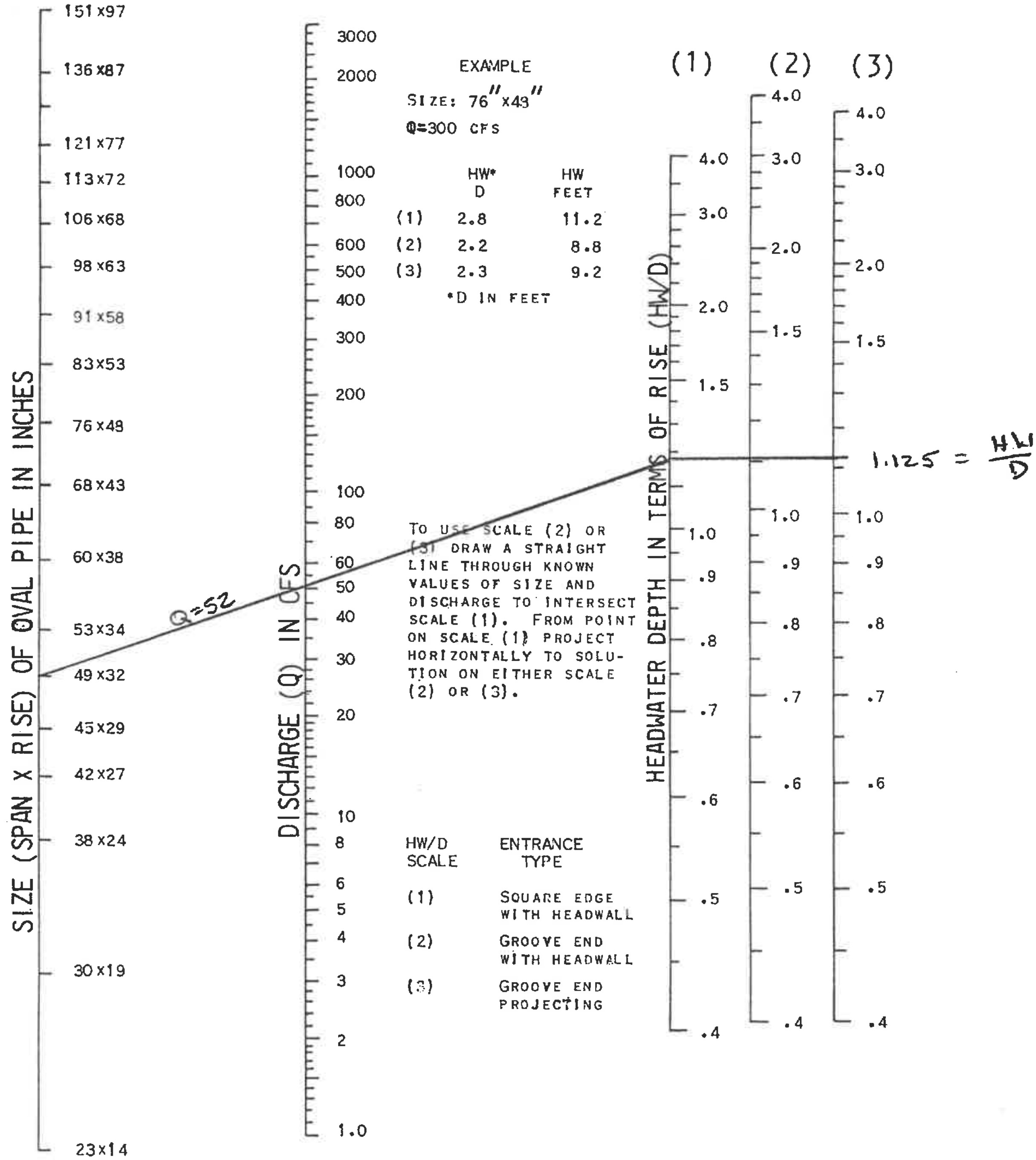
For 32" x 49" Oval RCP

BROADLAWN ESTATES

$\frac{HW}{D} = \frac{36}{32} = 1.125$

$Q \simeq 52$ cfs

∴ Use 32" x 49" RCP for outlet pipe @ 1.45 % slope



HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH <u>INLET CONTROL</u>.

FIG. 7-430.01 G

BROADLAWN ESTATES

Sub-basin # 1-1 A = 1.16 Ac.

			C	N
Structures	(3)(1450 ft²)	= 0.10 Ac	0.95	0.02
Drives	(3)(400 ft²)	= 0.03 Ac	0.95	0.02
Pavement		0.10 Ac	0.95	0.02
Patios	(3)(150 ft²)	= 0.01 Ac	0.95	0.02
Sidewalks	(5')(270')	= 0.03 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		0.89 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd C = [(0.27)(0.95) + (0.89)(0.15)] / 1.16 = 0.336

N = [(0.27)(0.02) + (0.89)(0.40)] / 1.16 = 0.312

H = 449 - 432 = 17'
L = 440'
S = 17/440 = 0.0386

$$t^c = .827 \left[\frac{(0.312)(440)}{(0.0386)^{1/2}} \right]^{0.467} = 17.61 \text{ min.}$$

i = 4.79 "/hr. , ∴ Q = (1.1)(0.336)(4.79)(1.16) = 2.05 cfs

Sub-basin # 1-2 A = 0.22 Ac.

			C	N
Structures				
Drives	(2)(400 ft²) =	0.02 Ac.	0.95	0.02
Pavement		0.09 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(260') =	0.03 Ac.	0.95	0.02
Terrain 1 Lawn, Flat		0.08 Ac.	0.10	0.40
Terrain 2				
Terrain 3				

Wt'd C = [(0.14)(0.95) + (0.08)(0.10)] / 0.22 = 0.641

N = [(0.14)(0.02) + (0.08)(0.40)] / 0.22 = 0.158

H = 435 - 430 = 5'
L = 230
S = 5/230 = 0.0217

$$t^c = .827 \left[\frac{(0.158)(230)}{(0.0217)^{1/2}} \right]^{0.467} = 10.83 \text{ min.}$$

i = 6.12 "/hr. , ∴ Q = (1.1)(0.641)(6.12)(0.22) = 0.95 cfs

BROADLAWN ESTATES

Sub-basin # 1-3 A = 0.82 Ac.

			C	N
Structures	(3)(1450 ft²) =	0.10 Ac.	0.95	0.02
Drives	(1½)(400 ft²) =	0.01 Ac.	0.95	0.02
Pavement				
Patios	(3)(150 ft²) =	0.01 Ac.	0.95	0.02
Sidewalks				
Terrain 1 Lawn, Avg.		0.70 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.12)(0.95) + (0.70)(0.15)] / 0.82 = 0.267$

$N = [(0.12)(0.02) + (0.70)(0.40)] / 0.82 = 0.344$

H = 433 − 427 = 6'
L = 300'
S = 6/300' = 0.0200

$$t^c = .827 \left[\frac{(0.344)(300)}{(0.0200)^{1/2}} \right]^{0.467} = 17.97 \text{ min.}$$

$i = 4.73$ "/hr. , ∴ $Q = (1.1)(0.267)(4.73)(0.82) = 1.14$ cfs

Sub-basin # 1-4 A = 0.46 Ac.

			C	N
Structures	(1)(1450 ft²) =	0.03 Ac.	0.95	0.02
Drives	(½)(400 ft²) =	0.01 Ac. (Drives + Patios)	0.95	0.02
Pavement				
Patios	(1)(150 ft²) =		0.95	0.02
Sidewalks				
Terrain 1 Lawn, Avg.		0.42 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.04)(0.95) + (0.42)(0.15)] / 0.46 = 0.220$

$N = [(0.04)(0.02) + (0.42)(0.40)] / 0.46 = 0.367$

H = 449 − 430 = 19'
L = 340'
S = 19/340 = 0.0559

$$t^c = .827 \left[\frac{(0.367)(340)}{(0.0559)^{1/2}} \right]^{0.467} = 15.45 \text{ min.}$$

$i = 5.16$ "/hr. , ∴ $Q = (1.1)(0.220)(5.16)(0.46) = 0.57$ cfs

Sub-basin # 1-5 A = 1.86 Ac.

			C	N
Structures	(6)(1450 ft²) =	0.20 Ac.	0.95	0.02
Drives	(6)(400 ft²) =	0.06 Ac	0.95	0.02
Pavement		0.14 Ac.	0.95	0.02
Patios	(6)(150 ft²) =	0.02 Ac	0.95	0.02
Sidewalks	(5')(415') =	0.05 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		1.39 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.47)(0.95) + (1.39)(0.15)]/1.86 = 0.352$

$N = [(0.47)(0.02) + (1.39)(0.40)]/1.86 = 0.304$

H = 441 − 413 = 28'
L = 430'
S = 28/430 = 0.0651

$$t_c = .827 \left[\frac{(0.304)(430)}{(0.0651)^{1/2}}\right]^{0.467} = 15.24 \text{ min.}$$

$i = 5.20$ "/hr. , ∴ $Q = (1.1)(0.352)(5.20)(1.86) = 3.74$ cfs

Sub-basin # 1-6 A = 0.86 Ac.

			C	N
Structures	(5)(1450 ft²) =	0.17 Ac.	0.95	0.02
Drives	(5)(400 ft²) =	0.05 Ac.	0.95	0.02
Pavement		0.14 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(415') =	0.05 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		0.45 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.41)(0.95) + (0.45)(0.15)]/0.86 = 0.531$

$N = [(0.41)(0.02) + (0.45)(0.40)]/0.86 = 0.219$

H = 433 − 412 = 21'
L = 410'
S = 21/410 = 0.0512

$$t_c = .827 \left[\frac{(0.219)(410)}{(0.0512)^{1/2}}\right]^{0.467} = 13.52 \text{ min.}$$

$i = 5.53$ "/hr. , ∴ $Q = (1.1)(0.531)(5.53)(0.86) = 2.78$ cfs

2/9/94, 2/25/94

BROADLAWN ESTATES

Sub-basin # 1-7 A = 1.24 Ac.

			C	N
Structures				
Drives				
Pavement				
Patios	(10)(150 ft²) =	0.03 Ac.	0.95	0.02
Sidewalks				
Terrain 1 Lawn, Avg.		1.21 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.03)(0.95) + (1.21)(0.15)] / 1.24 = 0.169$

$N = [(0.03)(0.02) + (1.21)(0.40)] / 1.24 = 0.391$

H = 429 - 412 = 17'
L = 450'
S = 17/450 = 0.0378

$$t^c = .827 \left[\frac{(0.391)(450)}{(0.0378)^{1/2}} \right]^{0.467} = 19.87 \text{ min.}$$

$i = 4.45$ "/hr. , ∴ $Q = (1.1)(0.169)(4.45)(1.24) = 1.03$ cfs

Sub-basin # 1-8 A = 2.21 Ac.

			C	N
Structures	(6)(1450 ft²) =	0.20 Ac.	0.95	0.02
Drives	(6)(400 ft²) =	0.06 Ac.	0.95	0.02
Pavement		0.20 Ac.	0.95	0.02
Patios	(6)(150 ft²) =	0.02 Ac.	0.95	0.02
Sidewalks	(5')(550') =	0.06 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		1.67 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.54)(0.95) + (1.67)(0.15)] / 2.21 = 0.345$

$N = [(0.54)(0.02) + (1.67)(0.40)] / 2.21 = 0.307$

H = 418 - 407 = 11'
L = 510'
S = 11/510 = 0.0216

$$t^c = .827 \left[\frac{(0.307)(510)}{(0.0216)^{1/2}} \right]^{0.467} = 21.45 \text{ min.}$$

$i = 4.23$ "/hr. , ∴ $Q = (1.1)(0.345)(4.23)(2.21) = 3.55$ cfs

2/9/94, 2/25/94

BROADLAWN ESTATES

Sub-basin # 1-9 A = 1.19 Ac.

			C	N
Structures	(6)(1450 ft²) =	0.20 Ac	0.95	0.02
Drives	(6)(400 ft²) =	0.06 Ac	0.95	0.02
Pavement		0.18 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(550) =	0.06 Ac.	0.95	0.02
Terrain 1 Lawn, Flat		0.69 Ac.	0.10	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.50)(0.95) + (0.69)(0.10)] / 1.19 = 0.457$

$N = [(0.50)(0.02) + (0.69)(0.40)] / 1.19 = 0.240$

$H = 413 - 406 = 7'$
$L = 440'$
$S = 7/440 = 0.0159$

$$t^c = .827 \left[\frac{(0.240)(440)}{(0.0159)^{1/2}} \right]^{0.467} = 19.17 \text{ min.}$$

$i = 4.55$ "/hr. , ∴ $Q = (1.1)(0.457)(4.55)(1.19) = 2.72$ cfs

Sub-basin # 1-10 A = 1.64 Ac.

			C	N
Structures				
Drives				
Pavement		0.03 Ac	0.95	0.02
Patios	(12)(150 ft²) =	0.04 Ac.	0.95	0.02
Sidewalks				
Terrain 1 Lawn,		1.57 Ac.	0.10	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.07)(0.95) + (1.57)(0.10)] / 1.64 = 0.136$

$N = [(0.07)(0.02) + (1.57)(0.40)] / 1.64 = 0.384$

$H = 412 - 404 = 8'$
$L = 450'$
$S = 8/450 = 0.0178$

$$t^c = .827 \left[\frac{(0.384)(450)}{(0.0178)^{1/2}} \right]^{0.467} = 23.49 \text{ min.}$$

$i = 3.98$ "/hr. , ∴ $Q = (1.1)(0.136)(3.98)(1.64) = 0.98$ cfs

2/9/94, 2/25/94

BROADLAWN ESTATES

Sub-basin # 2-1 A = 1.10 Ac.

			C	N
Structures	(3)(1450 ft²) =	0.10 Ac.	0.95	0.02
Drives	(3)(400 ft²) =	0.03 Ac.	0.95	0.02
Pavement		0.19 Ac.	0.95	0.02
Patios	(3)(150 ft²) =	0.01 Ac.	0.95	0.02
Sidewalks	(5')(225') =	0.03 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		0.74 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.36)(0.95) + (0.74)(0.15)] / 1.10 = 0.412$

$N = [(0.36)(0.02) + (0.74)(0.40)] / 1.10 = 0.276$

H = 430 − 419 = 11'
L = 300'
S = 11/300 = 0.0367

$$t_c = .827 \left[\frac{(0.276)(300.)}{(0.0367)^{1/2}} \right]^{0.467} = 14.07 \text{ min.}$$

i = 5.42 "/hr , ∴ Q = (1.1)(0.412)(5.42)(1.10) = 2.70 cfs

Sub-basin # 2-2 A = 0.23 Ac.

			C	N
Structures				
Drives				
Pavement		0.12 Ac.	0.95	0.02
Patios				
Sidewalks				
Terrain 1 Lawn, Avg.		0.11 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.12)(0.95) + (0.11)(0.15)] / 0.23 = 0.567$

$N = [(0.12)(0.02) + (0.11)(0.40)] / 0.23 = 0.202$

H = 432 − 422 = 10'
L = 310'
S = 10/310 = 0.0323

$$t_c = .827 \left[\frac{(0.202)(310)}{(0.0323)^{1/2}} \right]^{0.467} = 12.73 \text{ min.}$$

i = 5.69 "/hr , ∴ Q = (1.1)(0.567)(5.69)(0.23) = 0.82 cfs

Sub-basin # 2-3 A = 0.84 Ac.

			C	N
Structures	(5)(1450 ft²) =	0.17 Ac.	0.95	0.02
Drives	(5)(400 ft²) =	0.05 Ac.	0.95	0.02
Pavement		0.13 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(390') =	0.04 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		0.45 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd c = [(0.39)(0.95) + (0.45)(0.15)] / 0.84 = 0.521

N = [(0.39)(0.02) + (0.45)(0.40)] / 0.84 = 0.224

H = 423 - 408 = 15'
L = 450'
S = 15/450 = 0.0333

$$t^c = .827\left[\frac{(0.224)(450)}{(0.0333)^{1/2}}\right]^{0.467} = 15.78 \text{ min.}$$

i = 5.10 "/hr. , ∴ Q = (1.1)(0.521)(5.10)(0.84) = 2.46 cfs

Sub-basin # 2-4 A = 0.81 Ac.

			C	N
Structures	(5)(1450 ft²) =	0.17 Ac.	0.95	0.02
Drives	(5)(400 ft²) =	0.05 Ac.	0.95	0.02
Pavement		0.13 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(390') =	0.04 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.		0.42 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd c = [(0.39)(0.95) + (0.42)(0.15)] / 0.81 = 0.535

N = [(0.39)(0.02) + (0.42)(0.40)] / 0.81 = 0.217

H = 420 - 407 = 13'
L = 450'
S = 13/450 = 0.0289

$$t^c = .827\left[\frac{(0.217)(450)}{(0.0289)^{1/2}}\right]^{0.467} = 16.07 \text{ min.}$$

i = 5.05 "/hr. , ∴ Q = (1.1)(0.535)(5.05)(0.81) = 2.41 cfs

2/9/94, 2/25/94

BROADLAWN ESTATES

Sub-basin # 2-5 A = 1.19 Ac.

			C	N
Structures	(6)(1450 ft²) =	0.20 Ac.	0.95	0.02
Drives	(6)(400 ft²) =	0.06 Ac.	0.95	0.02
Pavement		0.18 Ac.	0.95	0.02
Patios				
Sidewalks	(5')(550') =	0.06 Ac.	0.95	0.02
Terrain 1 (Lawn, Flat)		0.69 Ac.	0.10	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.50)(0.95) + (0.69)(0.10)]/1.19 = 0.457$

$N = [(0.50)(0.02) + (0.69)(0.40)]/1.19 = 0.240$

H = 411 − 403 = 8'
L = 450'
S = 8/450 = 0.0178

$$t_c = .827 \left[\frac{(0.240)(450)}{(0.0178)^{1/2}} \right]^{0.467} = 18.86 \text{ min.}$$

$i = 4.60$ "/hr. , ∴ $Q = (1.1)(0.457)(4.60)(1.19) = 2.75$ cfs

Sub-basin # 2-6 A = 2.57 Ac.

			C	N
Structures	(6)(1450 ft²) =	0.20 Ac.	0.95	0.02
Drives	(6)(400 ft²) =	0.06 Ac.	0.95	0.02
Pavement		0.20 Ac.	0.95	0.02
Patios	(11)(150 ft²) =	0.04	0.95	0.02
Sidewalks	(5')(550') =	0.06 Ac.	0.95	0.02
Terrain 1 (Lawn, Avg.)		2.01 Ac.	0.15	0.40
Terrain 2				
Terrain 3				

Wt'd $C = [(0.56)(0.95) + (2.01)(0.15)]/2.57 = 0.324$

$N = [(0.56)(0.02) + (2.01)(0.40)]/2.57 = 0.317$

H = 417 − 400 = 17'
L = 750'
S = 17/750 = 0.0227

$$t_c = .827 \left[\frac{(0.317)(750)}{(0.0227)^{1/2}} \right]^{0.467} = 25.76 \text{ min.}$$

$i = 3.72$ "/hr. , ∴ $Q = (1.1)(0.324)(3.72)(2.57) = 3.41$ cfs

Sub-basin # 2-7 A = 0.11 Ac.

		C	N
Structures			
Drives			
Pavement	0.05 Ac.	0.95	0.02
Patios			
Sidewalks			
Terrain 1 Lawn, Avg.	0.06 Ac.	0.15	0.40
Terrain 2			
Terrain 3			

Wt'd $C = [(0.05)(0.95) + (0.06)(0.15)] / 0.11 = 0.514$

$N = [(0.05)(0.02) + (0.06)(0.40)] / 0.11 = 0.227$

H = 421-416 = 5'
L = 150'
S = 5/150 = 0.0333

$$t^c = .827 \left[\frac{(0.227)(150)}{(0.0333)^{1/2}} \right]^{0.467} = 9.51 \text{ min.}$$

$i = 6.45$ "/hr. , ∴ $Q = (1.1)(0.514)(6.45)(0.11) = 0.40$ cfs

Sub-basin # 2-8 A = 0.12 Ac.

		C	N
Structures			
Drives			
Pavement	0.06 Ac.	0.95	0.02
Patios			
Sidewalks			
Terrain 1 Lawn, Avg.	0.06 Ac.	0.15	0.40
Terrain 2			
Terrain 3			

Wt'd $C = [(0.06)(0.95) + (0.06)(0.15)] / 0.12 = 0.550$

$N = [(0.06)(0.02) + (0.06)(0.40)] / 0.12 = 0.210$

H = 421-416 = 5'
L = 160'
S = 5/160 = 0.0313

$$t^c = .827 \left[\frac{(0.210)(160)}{(0.0313)^{1/2}} \right]^{0.467} = 9.59 \text{ min.}$$

$i = 6.43$ "/hr. , ∴ $Q = (1.1)(0.550)(6.43)(0.12) = 0.47$ cfs

2/9/94, 2/25/94

BROADLAWN ESTATES

Sub-basin # 2-9 A = 1.18 Ac.

		C	N
Structures	(4)(1450 ft²) = 0.13 Ac.	0.95	0.02
Drives	(2)(400 ft²) = 0.02 Ac.	0.95	0.02
Pavement			
Patios	(4)(150 ft²) = 0.01 Ac.	0.95	0.02
Sidewalks			
Terrain 1 Lawn, Avg.	1.02 Ac	0.15	0.40
Terrain 2			
Terrain 3			

Wt'd $C = [(0.16)(0.95) + (1.02)(0.15)]/1.18 = 0.258$

$N = [(0.16)(0.02) + (1.02)(0.40)]/1.18 = 0.348$

H = 430 - 416 = 14'
L = 600'
S = 14/600 = 0.0233

$$t^c = .827\left[\frac{(0.348)(600)}{(0.0233)^{1/2}}\right]^{0.467} = 24.10 \text{ min.}$$

i = 3.90 "/hr. , ∴ Q = (1.1)(0.258)(3.90)(1.18) = 1.31 cfs

Sub-basin # 2-10 A = 0.20

		C	N
Structures			
Drives	(2)(400 ft²) = 0.02 Ac.	0.95	0.02
Pavement	0.09 Ac.	0.95	0.02
Patios			
Sidewalks	(5')(225') = 0.03 Ac.	0.95	0.02
Terrain 1 Lawn, Avg.	0.06	0.15	0.40
Terrain 2			
Terrain 3			

Wt'd $C = [(0.14)(0.95) + (0.06)(0.15)]/0.20 = 0.710$

$N = [(0.14)(0.02) + (0.06)(0.40)]/0.20 = 0.134$

H = 423 - 419 = 4'
L = 160'
S = 4/160 = 0.0250

$$t^c = .827\left[\frac{(0.134)(160)}{(0.0250)^{1/2}}\right]^{0.467} = 8.19 \text{ min.}$$

i = 6.80 "/hr. , ∴ Q = (1.1)(0.710)(6.80)(0.20) = 1.06 cfs

STORM SEWER DESIGN SHEET – RATIONAL METHOD

PROJECT Broadlawn Estates DATE 2/25/94 SHEET 1 OF 1

ENGINEER DJH DESIGN STORM 25 YR MANNINGS n 0.013

1-3 ¢

Line Number	Upstream Manhole	Downstream Manhole	Length (Ft)	1.1 x C_j	A_j (Acres)	C_jA_j	ΣA_jC_j	t_j (min)	t_{cum} (min)	I [inches/hr]	Q (CFS)	Pipe Diameter (inches)	Pipe Slope (%)	Pipe Capacity (CFS)	Velocity (Ft/Sec)	Travel Time (min)	Rim Elevation Upstream	Rim Elevation Downstream	Invert Elevation Upstream	Invert Elevation Downstream	Pipe Cover Upstream	Pipe Cover Downstream
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1-1	600	601	50	0.370	1.16	0.429	0.429	17.61	17.61	4.79	2.05	12	0.5	2.7	3.3	0.25						
1-2	601	619	120	0.705	0.22	0.155	0.584	10.83	17.86	4.75	2.77	12	0.75	3.2	3.9	0.68						
2-2	602	603	130	0.624	0.23	0.144	0.144	12.73	12.73	5.69	0.82	12	0.5	2.7	3.3	0.66						
2-1	603	604	29	0.385	1.92	0.739	0.883	17.97	17.97	4.73	4.18	12	1.5	4.5	5.5	0.09						
2-10	604	618	120	0.781	0.20	0.156	1.039	8.19	18.06	4.72	4.90	12	2.0	5.1	6.5	0.31						
1-4		619	–	0.242	0.46	0.111	0.111	15.45	15.45	5.16	0.57	–				SWALE #1						
29	619		–	0.284	1.18	0.335	1.030	24.10	24.10	3.90	4.02	–				SWALE #2						
																DETENTION SWALE 'A'						
1-5	605	606	29	0.387	1.86	0.720	0.720	15.24	15.24	5.20	3.74	12	1.5	4.5	5.5	0.09						
1-6	606	607	145	0.584	0.86	0.502	1.222	13.52	15.33	5.18	6.33	15	1.25	7.5	5.9	0.41						
1-7	–	607	–	0.186	1.24	0.231	0.231	19.87	19.87	4.45	1.03	–				SWALE #3						
1-10	607	–	–	0.150	1.64	0.246	1.699	23.49	23.49	3.98	6.76	–				SWALE #4						
2-3	615	616	29	0.573	0.84	0.481	0.481	15.78	15.78	5.10	2.46	12	0.5	2.7	3.3	0.15						
2-4	616	617	120	0.589	0.81	0.477	0.958	16.07	16.07	5.05	4.84	12	2.0	5.1	6.5	0.31						

2/10/94, 2/25/94
DJH

BROADLAWN ESTATES

UPSTREAM WATERSHED - TO RELOCATED CHANNEL

Area = 42.0 Acres

L = 1850'

$\Delta H = 482 - 408 = 74'$

$S = 74/1850 = 0.040$

	Ac.	C	N
Residential	3.0	0.40	0.20
Pasture	21.6	0.30	0.40
Woodland	15.0	0.30	0.60
Pavement	0.7	0.95	0.02
Water	1.7	1.00	0

Wtd $C = [(0.40)(3.0) + (0.30)(21.6+15.0) + (0.95)(0.7) + (1.0)(1.7)]/42.0$

$= 0.346$

Wtd $N = [(0.20)(3.0) + (0.40)(21.6) + (0.60)(15.0) + (0.02)(0.7) + (0)(1.7)]/42.0$

$= 0.435$

$$t_c = 0.827 \left[\frac{(0.435)(1850)}{(0.040)^{1/2}} \right]^{0.467} = 39.89 \text{ min.}$$

$i_{25} = 2.59$ "/hr. $\qquad i_{100} = 3.30$ "/hr.

$Q_{25} = (1.1)(0.346)(2.59)(42.0) = 41.4$ cfs

$Q_{100} = (1.1)(0.346)(3.30)(42.0) = 52.8$ cfs

BROADLAWN ESTATES

Relocated Channel Capacity

(From East Property Line to West Rd. Culvert)

Bottom Width = 4'

Side Slopes = 3:1

Channel Slope = 1.45 %

Manning's 'n' = 0.035

Depth (ft.)	Area (ft²)	W.P. (ft.)	Hyd. Rad.	Vel. (fps)	Q (cfs)
0.25	1.1875	5.581	0.2128	1.822	2.16
0.50	2.75	7.162	0.3840	2.701	7.43
1.00	7.00	10.325	0.6780	3.946	27.62
1.50	12.75	13.487	0.9454	4.925	62.79

BROADLAWN ESTATES

Peak Flow to Culvert Under East Road

Upstream Watershed = 42.0 ac.

Sub-basins : 1-8 & 1-9 = 3.40 ac.

Total Area = 45.40 ac.

Wt'd c = 0.349

i_{25} = 2.59 "/hr.

Dev. Q_{25} = (1.1)(0.349)(2.59)(45.4)

= 45.14 cfs

Peak Flow to Culvert Under West Road

Upstream Watershed = 42.0 ac.

Sub-basins : 1-5, 1-6, 1-7, 1-8, 1-9, 1-10, 2-5

= 10.19 ac.

Total Area = 52.19 ac.

Wt'd c = 0.343

i_{25} = 2.59 "/hr.

Dev. Q_{25} = (1.1)(0.343)(2.59)(52.19) = 51.00 cfs

Max. H.W. = 3.0' for both (temporary pooling in relocated channel)

BROADLAWN ESTATES

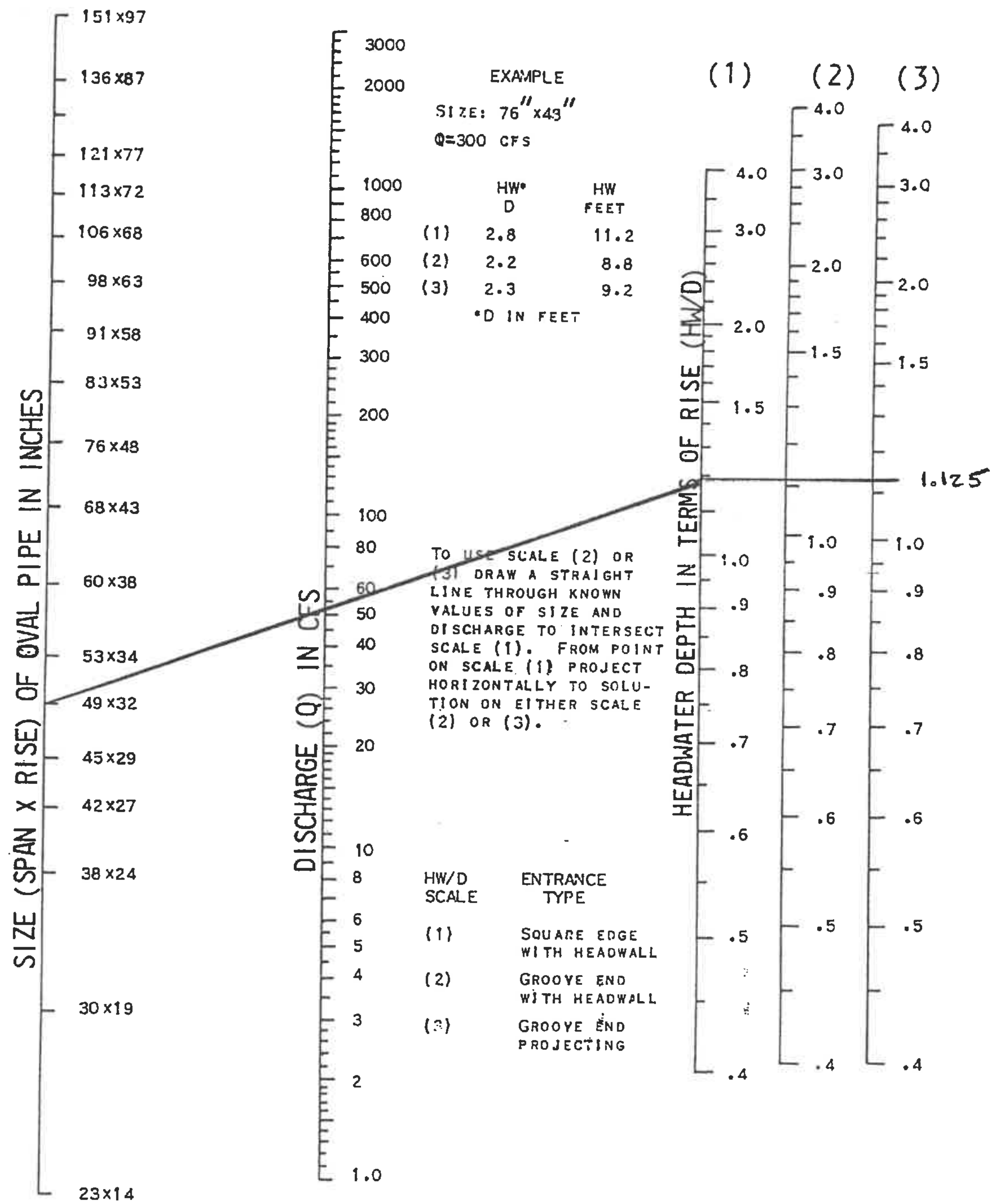
From Fig. 7-430.01 G

For 32" x 49" RCP

$$\frac{HW}{D} = \frac{36}{32} = 1.125$$

$Q = 52$ cfs

∴ Use 32" x 49" RCP for both roads.



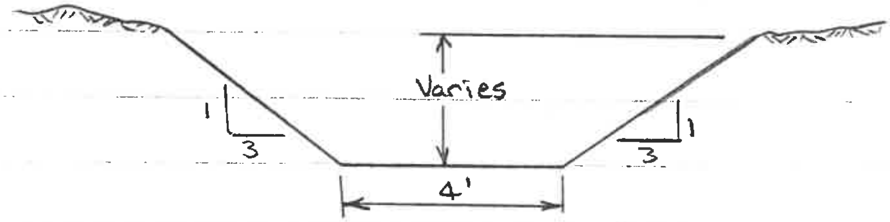
HEADWATER DEPTH FOR OVAL CONCRETE PIPE CULVERTS LONG AXIS HORIZONTAL WITH INLET CONTROL.

FIG. 7-430.01 G

BROADLAWN ESTATES

DRAINAGE SWALES

Typical X-Section



Max. Q_{25} = 20 cfs

Slope varies: 0.01 - 0.06

All drainage swales to be lined with erosion control blanket.

EMERGENCY OUTLET CHANNEL

Both detention swales shall have an emergency open-channel spillway provided at 2.5 feet above the I.E. of the primary pipe outlet structure.