

COMPILATION OF A MANUAL FOR THE
DESIGN OF ROOF DRAINAGE SYSTEMS

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fulfilment of the requirements for the degree of Master
of Science in Engineering

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DECLARATION

I, the undersigned, declare that this dissertation:

1. is entirely my own work,
2. has not been submitted as a thesis for a Master's degree
at any other University.

.....


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SYNOPSIS

Roof drainage system design curves are determined by analysing existing data on short duration storms. These design curves are in the form of frequency - duration - mean annual precipitation curves for storms of five minute duration.

A 'standard gutter' consisting of a straight horizontal section of guttering, with uniform inflow along the length and outlet at one end is selected for theoretical analysis. A method of theoretically analysing such a gutter is presented. Proof of the adequacy of this analysis is given.

A large number of 'standard gutters' of differing shapes and lengths are theoretically analysed for various inflow rates.

The results of the above theoretical analyses are investigated and gutter design curves for trapezoidal, rectangular and half-round gutter sections are proposed.

Available literature on drainage system design is reviewed. Results from the relevant portion of this literature are compared with those from the proposed gutter design curves. The effect of variations of practical drainage systems from the 'standard gutter' is considered. Correction factors to account for such variations are presented.

The results of the previous sections are considered and a roof drainage system design manual is presented.

CHAPTER 1

INTRODUCTION

Roof drainage has for many years been a neglected subject of study in South Africa. Possibly this is due to the fact that the cost of drainage systems on any building is only a fraction of the total cost and in addition failure of the system by overflowing is seldom catastrophic. Generally, failure of the system is only of nuisance value. However in certain circumstances failure may result in damage to material within the building with resultant financial repercussions. In such instances it is desirable that gutter design be based on sound theoretical principles. Consideration should also be given to the hydroeconomics of the design. The cost of failure of the drainage system should be compared with the cost of the drainage system; buildings, such as art galleries, with a high failure cost, should have their drainage systems designed on large recurrence intervals of failure, whereas buildings, such as residential dwellings, with a low failure cost, should have their drainage systems designed on low recurrence intervals of failure.

At the present most gutter design in South Africa is based on rule of thumb techniques developed by experience. Most large firms or organisations have their own design criteria and many of these differ radically. Thus it appears that there is an urgent need for a manual outlining some rational basis, backed by sound

theoretical principles, upon which gutter design can be founded.

The problem of roof drainage was fairly comprehensively investigated by the Building Research Station in England in 1958 and again in 1969. These investigations entailed a large amount of experimentation on test gutters. Empirical formulae were then fitted to test results and design criteria were based on these formulae. Martin (1973) presented a method of drainage system design for Australian conditions. This method is essentially a modified version of the Building Research Station design method and is based on their empirical data. Martin does however present several improvements to the Building Research Station method, one of them being the introduction of the recurrence interval of failure to the design parameters.

Both of the above approaches are based on empirical data from a limited number of test gutters. In addition certain assumptions are made that, it is felt, do not always result in optimum drainage system design. Thus it was decided to seek some alternative method of gutter design based on theoretical principles.

Ward and Trim (1972) proposed a method by means of which a gutter can be theoretically analysed and their method has been adopted in this dissertation.

This investigation of drainage system design has been divided into several sections. The general aspects of these sections are briefly introduced in the following paragraphs.

(a) DETERMINATION OF THE CRITICAL RAINFALL INTENSITY
FOR GUTTER DESIGN

The rainfall duration of five minutes is selected as the critical storm duration for drainage system design.

Intensity, frequency, duration, mean annual precipitation co-axial plots for the three rainfall regions in South Africa are extrapolated to obtain the intensity, frequency and mean annual precipitation values for storm durations of five minutes. The co-axial plots employed are under criticism (see Bergman (1974)) but due to the absence of further data it is felt that this is the best method at present available. These values are plotted to give roof drainage system design curves.

(b) THE CONSTRUCTION AND VERIFICATION OF A MATHEMATICAL MODEL
BY MEANS OF WHICH A STANDARD GUTTER CAN BE ANALYSED

There are an extensive number of variables involved in the design of a practical roof drainage system. These variables include gutter length, cross-sectional area, size and position of downpipes and slope. If all such variables are taken into account a theoretical analysis of the drainage system will be extremely complex, if not impossible. Thus a 'standard gutter' is selected for analysis.

This 'standard gutter' consists of a straight, horizontal section of guttering, with an outlet at one end and uniform inflow along its total length. The flow condition in a standard gutter is an example of spatially varied flow and is analysed using an equation derived from momentum considerations.

This equation is termed the Hinds Equation, and it defines the water surface profile in the gutter in an iterative fashion. However, to apply the Hinds Equation the depth of flow at any one section must be known.

It is assumed that the gutter behaves like a free overfall spillway at the outlet. Results supporting this assumption are presented. This implies that the depth of flow at the outlet is below critical depth and passes through the critical depth some distance upstream from the outlet.

A supercritical flow depth in a horizontal channel is however not in keeping with the basic assumptions on which the Hinds Equation is based. Thus the problem arises as to whether to use the actual supercritical depth at the outlet or some other hypothetical depth as the starting depth in the Hinds analysis.

It is shown that theoretical results are in good agreement with experimental results if it is assumed that the depth of flow at the outlet is equal to the critical flow depth. The critical flow depth is thus used as the starting point in the Hinds analysis.

The analysis is applied to several gutters for which experimental results are available. Good correlation between experimental and theoretical results is obtained.

The effect of the value of Manning 'n' is investigated. The value $n = 0.016$ gives best agreement between theoretical and experimental results and is thus selected for use.

(c) THEORETICAL ANALYSIS OF A NUMBER OF STANDARD GUTTERS WITH DIFFERENT SHAPES, LENGTHS AND INFLOWS

A large number of standard gutters with differing shapes, lengths and inflows are analysed using the mathematical model developed in Chapter (b). The output from these analyses is the required cross-sectional area of flow for any given shape, length and inflow rate.

Computer programmes were developed to perform these analyses. These programmes are discussed and the results presented in the form of computer print-outs.

(d) THE ANALYSIS OF THE RESULTS OF (c)

The output from the previous section is a vast number of computer printouts containing the required cross-sectional area of gutter for a given shape, length and inflow rate. These printouts contain all the information that is necessary for the design of the particular gutter shapes and lengths analysed. This information is however contained in a form that is not readily usable.

Methods of abbreviating this output were sought so as to make it more practical for use in a gutter system design manual. In addition means of generalising the results to cater for any drainage system design problem were investigated.

Mathematical relationships between the variables, shape, length, inflow rate and required cross-sectional area were sought. Equations were found for trapezoidal, rectangular and half-round gutters such that all the design criteria reduced to points on a

single curve for each particular shape. These curves are general design curves that can readily be used in a gutter design manual.

(e) A REVIEW OF EXISTING METHODS OF GUTTER DESIGN AND A COMPARISON WITH THE RESULTS OF (d)

Existing methods of gutter design are briefly reviewed. These design methods are compared with the design curves of the previous section.

Most practical gutter systems vary from the standard gutter that has been theoretically analysed. The effect of variation of practical gutter systems from the standard gutter are considered. Such variations are accounted for by applying correction factors to the 'standard gutter' results. Correction factor values are obtained from previous investigators' results.

(f) PRESENTATION OF A TENTATIVE ROOF DRAINAGE SYSTEM DESIGN MANUAL

The results of the analyses of standard gutters are combined with relevant portions of the previous investigators' work to produce a manual for the design of practical roof drainage systems.

CHAPTER 2

DETERMINATION OF CRITICAL RAINFALL INTENSITIES FOR
GUTTER DESIGN

SELECTION OF CRITICAL DURATION

Given the recurrence interval of failure, there is a particular intensity of storm that will cause a gutter system to fail by overflowing. This intensity is termed the design intensity of the gutter system.

To determine this intensity it is necessary to consider the duration of storm that will be critical. This critical duration will equal the time elapsed from the start of the storm to when the whole roof is contributing inflow to the gutter outlet. The critical duration depends on many factors and cannot be obtained theoretically.

It is felt that a reasonable estimate of this duration for roof drainage systems is five minutes and this value has been adopted. Martin (1973) has also adopted this value.

AVAILABLE DATA ON SHORT DURATION STORMS

Van Wyk (1965) has investigated short duration, high intensity storms. The major problem encountered was the lack of data on such short duration storms. Van Wyk derived curves relating the mean annual precipitation to the rainfall intensity for different recurrence intervals and rainfall durations for the three meteorologically homogeneous regions in South Africa.

These regions are the winter, summer and year round rainfall regions as seen in Figure 1.

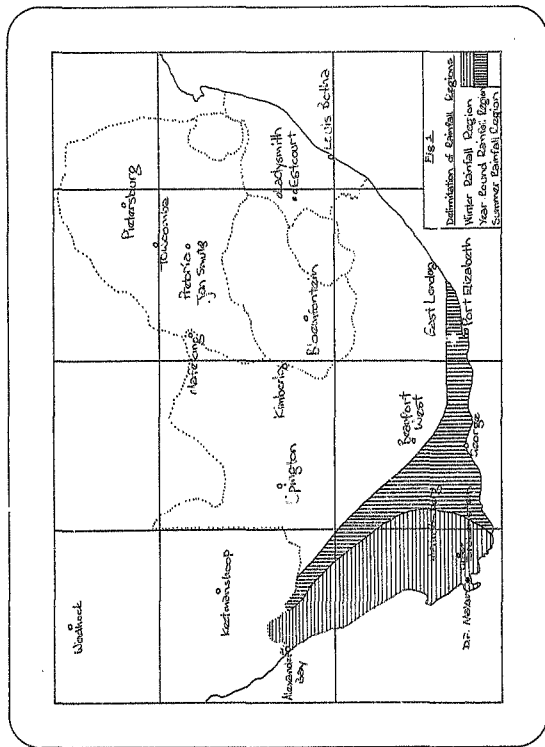
The Hydrological Research Unit (1972) employed the van Wyk curves in deriving a co-axial plot relating mean annual precipitation, frequency and duration to the depth of precipitation for the three rainfall regions. This co-axial plot is reproduced in Figure 2 and is employed in obtaining the rainfall intensities for storms of five minute duration.

COMPILATION OF GUTTER DESIGN CURVES

Data was abstracted from Figure 2 in the following manner: For a selected mean annual precipitation and recurrence interval, depths of precipitation were abstracted for the different storm durations for the three regions. The precipitation depths were converted to intensities and the process repeated for a number of mean annual precipitations and recurrence intervals.

All the abstracted values, converted to intensity values are listed in Appendix A and an example of the abstracted data for mean annual precipitation of 500 millimetres and recurrence interval of 50 years is given in Table 1.

These abstracted values were processed as follows: For a particular mean annual precipitation and recurrence interval, the intensity was plotted against time on semi-logarithmic paper. The resultant points approximated a straight line and the best fit line was drawn through those points. (It was felt that the general accuracy of the approach adopted did not warrant



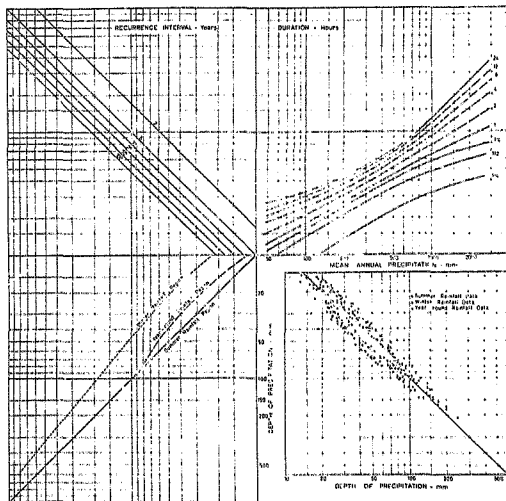


Fig. 2: Depth-duration-frequency
diagram for point rainfall
(after H.R.U. 1972)

TABLE 1: DEPTH, DURATION, FREQUENCY DATA ABSTRACTED FROM
FIGURE 2

Duration hrs	Depth of Precipitation - mm			Intensity - mm/hr		
	Summer	Winter	Year Round	Summer	Winter	Year Round
0,25	42	17,2	32	168	63,8	128
0,50	65	27	54,5	130	54	109
0,75	77,5	34	70	103,4	45,5	93,5
1,00	86	37,5	82	86	37,5	82
2,00	95	44	95	47,5	22	47,5
4,00	-	-	-			
8,00	-	-	-			
12,00	-	-	-			
24,00	-	-	-			

the drawing of regression curves through these points. In addition where a certain amount of scatter of the points existed, the line that gave a conservative result for the five minute duration intensity value was drawn.) This fitted line was then extrapolated to give the intensity for the five minute duration storm.

Examples of the curves thus obtained are in Appendix A and Figure 3 is an example for mean annual precipitation of 500 millimetres and recurrence interval of 50 years and for the summer, winter

and year-round rainfall regions.

The intensity values for the five minute duration storms are abstracted from these curves and results are listed in Table 2. The results were plotted, yielding curves of intensity versus mean annual precipitation for varying recurrence intervals for the three rainfall regions for the critical duration of five minutes. These curves are given in Figures 4, 5 and 6 and can be used to obtain the critical rainfall intensity for gutter design for buildings in South Africa.

Henceforth whenever the design intensity is referred to, it is the critical intensity for a gutter at a particular site and for a particular recurrence interval of failure as determined by these curves. It should be noted that these curves are applicable to any problem in which the five minute duration storm is considered critical.

Recent investigation has indicated that errors may exist in the co-axial plot (Figure 2) from which these design curves were derived. However in the absence of further data it is felt that the method employed is the best available. Readers are however advised to keep abreast with modern techniques of determining rainfall intensities for short duration storms.

Fig. 3: Plot of Intensity vs. duration for summer winter and year-round Rainfall Regions

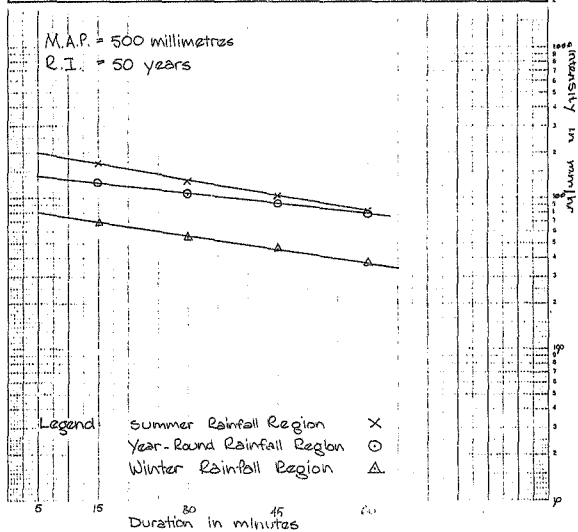


Fig. 3: Plot of intensity vs. duration for summer, winter and year-round Rainfall Regions

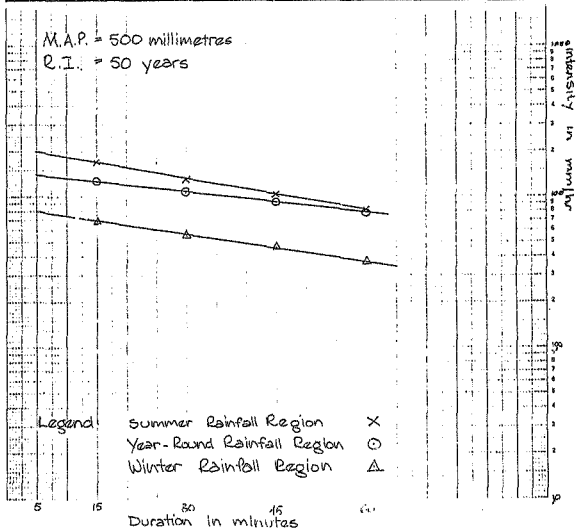


TABLE 2. VALUES USED IN PLOT OF INTENSITY VERSUS
M.A.P. FOR STORMS OF 5 MINUTE DURATION

M.A.P. in mm	R.T. in years	I N T E N S I T Y I N mm/hr		
		Summer	Winter	Year-round
50	2	-	-	-
	5	21	-	-
	10	23	-	28
	20	44	-	29
	50	44	-	30
100	100	52	24	39
	2	-	-	-
	5	42	-	36
	10	51	-	42
	20	66	25	48
200	50	70	31, 7	51
	100	84	38	66
	2	36	-	32
	5	65	27	54
	10	80	28, 5	64
500	20	100	40	75
	50	112	50	85
	100	140	60	100
	2	65	26	54
	5	108	32	80
750	10	136	37	105
	20	140	60	120
	50	192	80	138
	100	237	95	175
	2	82	31	61
1000	5	130	37	100
	10	173	60	120
	20	200	85	127
	50	270	100	170
	100	280	120	230
1500	2	100	30	70
	5	150	64	110
	10	184	77	127
	20	230	92	160
	50	270	120	210
2000	100	320	120	270
	2	106	35	76
	5	175	74	120
	10	220	85	150
	20	270	103	197
2200	50	310	130	260
	100	380	160	355
	2	112	49	95
	5	190	75	117
	10	240	95	170
2200	20	290	118	223
	50	350	142	300
	100	400	175	405
	2	130	51	90
	5	200	80	140
2200	10	230	98	180
	20	295	115	240
	50	360	150	318
	100	405	180	405

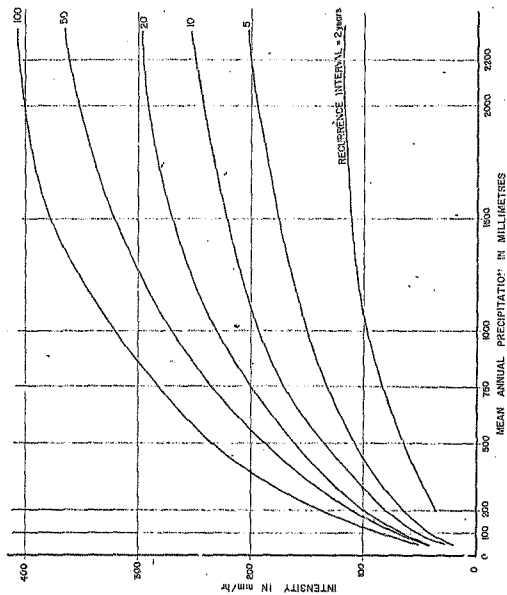


Fig. 4 GUTTER DESIGN CURVE FOR SUMMER RAINFALL REGIONS

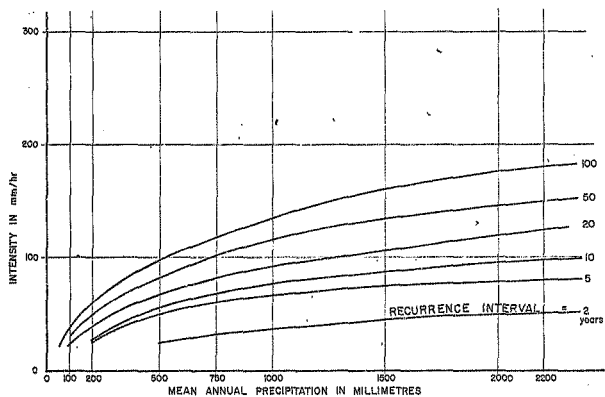


Fig. 5 GUTTER DESIGN CURVE FOR WINTER RAINFALL REGIONS

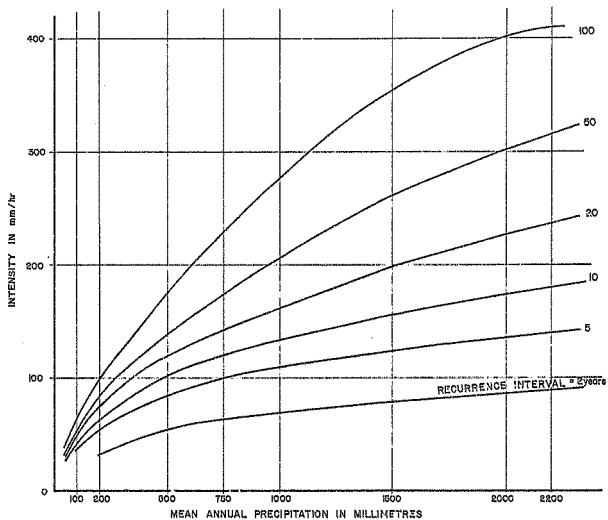


Fig. 6. GUTTER DESIGN CURVE FOR YEAR-ROUND RAINFALL REGION

CHAPTER 3

THE CONSTRUCTION AND VERIFICATION OF A MATHEMATICAL MODEL BY MEANS OF WHICH A STANDARD GUTTER CAN BE ANALYSED

DEFINITION OF A STANDARD GUTTER

Given the design intensity and the roof shape and slope, then the quantity of water flowing into a gutter can be determined. The distribution of the inflow, however, depends on the roof shape. Since the majority of practical roof systems are rectangular in shape, only gutters with uniform inflows will be considered.

The problem is further simplified by assuming;

- (a) the gutter to have one outlet at one end.
- (b) the gutter to be horizontal.

Thus the system to be theoretically analysed consists of a horizontal length of gutter with uniform inflow and an outlet at one end. This is referred to as the 'standard gutter'.

DEVELOPMENT OF A THEORETICAL ANALYSIS OF A STANDARD GUTTER

The analysis of a standard gutter comprises of the determination of the water surface profile in a gutter of given length and shape and for a given inflow.

The flow situation in the standard gutter is an example of spatially varied flow. This has a non-uniform discharge resulting from the addition or reduction of water along its length. The added water will cause disturbance in the energy or momentum content of the flow. As a result the hydraulic behaviour of a

spatially varied flow situation is more complicated than that of a constant discharge. Since gutter flow is a problem of increased discharge only this will be considered. A typical example of this type of flow situation is a side channel spillway.

SPATIALLY VARIED FLOW WITH INCREASING DISCHARGE

The problem was first investigated in 1926 by Julian Hinds in connection with the capacity of and energy losses in side-channel spillways. Since then much work has been done on it and equations describing the water surface profile have been developed. At this stage it must be pointed out that due to the very nature of the flow situation, with inflow normal to outflow, turbulence and secondary currents will be developed. This mixing of the added water and the water already flowing in the channel, results in high energy losses that cannot be computed. Another result of the high energy losses is that the momentum equation is found to be more convenient than the energy equation in solving the flow situation.

In the derivation of the spatially varied flow equation, the following assumptions are made:

- 1) The flow is unidirectional. Actually there are usually cross currents in the form of spiral flows - the effect of these currents and the accompanying turbulence cannot be easily evaluated, but is taken into account if the momentum principle is employed. IN ADDITION THE LATERAL UNEVENNESS OF THE WATER SURFACE DUE TO CROSS CURRENTS IS IGNORED.

- 2) The velocity distribution across the channel section

is constant and uniform. This implies that the velocity distribution coefficient is unity. Proper values of the coefficient may however be used.

4) The slope of the channel is small; thus its effect on the pressure head is small. If the slope is appreciable, corrections to this effect may be applied.

5) The Manning formula may be used to evaluate friction losses due to shear along the channel edges (viz. flow is steady and uniform)

6) The effect of air entrainment is negligible. A correction however may be applied to the computed results where necessary. (These assumptions should be noted and borne in mind when applying results of the analysis.)

Consider the diagrammatic representation of the flow situation as shown in Figure 7. By applying the momentum equation between sections (1) and (2) and using the Manning equation to derive the head loss between the sections, the dynamic equation for spatially varied flow with increasing discharge can be determined. The derivation is presented in reference 5 and the final equation has the form;

$$\frac{dy}{dx} = \frac{S_o - S_f - 2\alpha Qq / gA^2}{1 - \alpha Q^2 / gA^2 D}$$

where $\frac{dy}{dx}$ = rate of change of depth with distance along channel bed.

S_o = bed slope

$$S_f = \text{friction slope} = \frac{Q^2 n^2}{A^2 R^{4/3}}$$

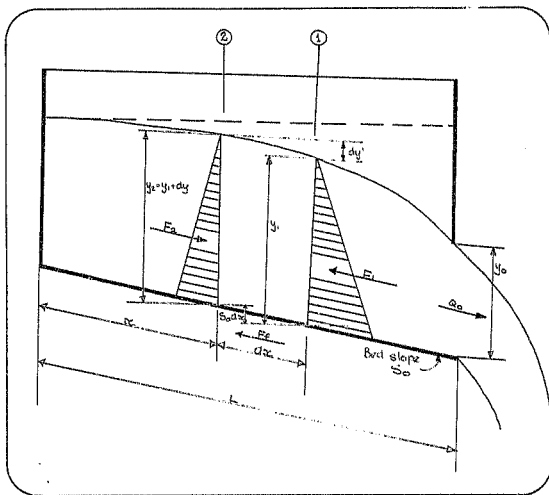


Fig 7 : Diagrammatic representation of specially varied flow.

α = energy coefficient to account for nonuniform velocity distribution

Q = total discharge at a section

$q^* = \frac{dQ}{dx}$ = inflow per unit length

A = cross-sectional area of flow

D = hydraulic depth which is the cross-sectional area of water normal to the direction of flow in the channel divided by the width of free surface. For rectangular channels this equals the depth of flow.

Note that if q^* equals zero, the equation becomes the dynamic equation for gradually varied flow with constant discharge.

For simple cases this equation can be directly integrated. However for most cases a method of numerical integration must be used. Since the numerical method is the more general method, this will be applicable in most gutter problems and for this reason the numerical integration equation is used.

THE NUMERICAL INTEGRATION EQUATION FOR SPATIALLY VARIED FLOW

This equation is derived in Appendix B by using momentum considerations. The equation is referred to as the Hinds equation and has the form:

$$\Delta y' = Sf \Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2} \right) \alpha \frac{Q_1}{g} \left(\Delta v + \frac{V_2}{Q_1} \Delta Q \right)$$

where, referring to figure 7;

$\Delta y'$ = change in elevation of water surface

Sf = slope of the energy line between the two sections

Δx = horizontal distance between the two sections

V = velocity at appropriate section

Q = discharge at appropriate section

α = energy coefficient to account for non-uniform velocity distribution

ΔV = change in velocity between sections

ΔQ = change in discharge between sections

The change in water surface elevation is given by;

$$\Delta y' = +\Delta y + S_o \Delta x$$

where Δy = change in flow depth

S_o = channel slope

The slope of the energy line is, according to the assumptions

of the analysis, given by;

$$S_f = \frac{\bar{V}^2 n^2}{R^{4/3}}$$

where $\bar{V}$ = average velocity between sections

$\bar{R}$ = average hydraulic radius between sections

n = Manning's n value

In the Hinds equation the first term on the righthand side, $S_f \Delta x$, represents the effects of friction, while the second term represents the effects of impact loss and turbulence.

In the case of the standard horizontal gutter, the slope effect falls away and;

$$\Delta y' = \Delta y$$

In addition it is assumed that the energy correction coefficient equals unity.

Thus the equation that is used to determine the water surface profile in a standard gutter is;

$$\Delta y = Sf \Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2} \right) \cdot \frac{Q_1}{g} \left(\Delta V + \frac{V_2}{Q_1} \Delta Q \right)$$

This equation can be solved by an iterative process and will be referred to as the Hinds equation.

THE FLOWDEPTH AT THE OUTLET

In applying the Hinds equation, the flow depth at one section must be known. The flow depth at all other sections can then be calculated.

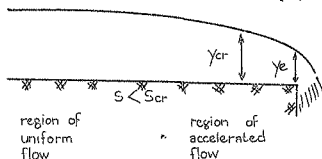
At the outlet, the depth of flow depends on several factors such as gutter size and shape, type of outlet, flowrate etc. Possible flow conditions at outlet might be approximated by; free weir, drowned weir, orifice, orifice with suction etc., or some combination of the above.

Many drainage systems serving large roof areas drain into box-receivers. Flow into these receivers will approximate free overfall conditions. In the case of vertical downpipes draining directly from the gutter, Martin (1973) considers that flow conditions will approximate weir conditions. Inspection of this type of system during periods of intense rainfall tends to verify the condition of the free weir (assuming that a bend is not situated directly beneath the outlet, causing a backup of flow). Thus in order to calculate the flow depth at the outlet, free overfall weir flow must be briefly considered.

SOME THEORETICAL CONSIDERATIONS PERTAINING TO FLOW OVER A FREE OVERFALL WEIR

Consider a channel in which the flow is subcritical, with

a free overfall weir at one end.



The critical depth, Y_{cr} , will occur some distance upstream of the overfall, while at the overfall itself a depth Y_e , the end depth, will occur. O'Brien found that for channels with a level bed the critical depth was approximately 12 Y_{cr} upstream from the brink, the distance increasing as the channel slope increased.

Rouse (1936) has shown that for slopes less than the critical the end depth, Y_e , is 0,715 Y_{cr} or $Y_{cr} = 1,40 Y_e$.

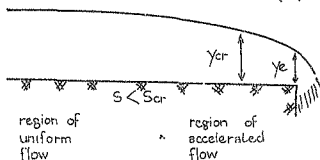
Bauer (1971) has shown that for slopes less than the critical and within the range $0,0 < S < 0,0038$ and for Manning n roughness values lying between 0,11 and 0,14, that $Y_{cr} = 1,2947 Y_e$.

Thus it appears that a reasonable estimate of the end depth is the Rouse value of $Y_e = 0,715 Y_{cr}$.

PROOF OF THE ASSUMPTION OF FREE OVERFLOW CONDITIONS AT OUTLET

To test the assumption that flow at the gutter outlet is approximated by flow over a free overfall weir, available test results are compared with computed theoretical results.

a free overfall weir at one end.



The critical depth, Y_{cr} , will occur some distance upstream of the overfall, while at the overfall itself a depth Y_e , the end depth, will occur. O'Brien found that for channels with a level bed the critical depth was approximately 1.2 Y_{cr} upstream from the brink, the distance increasing as the channel slope increased.

Rouse (1936) has shown that for slopes less than the critical the end depth, Y_e , is 0.715 Y_{cr} or $Y_{cr} = 1.40 Y_e$.

Bauer (1971) has shown that for slopes less than the critical and within the range $0.0 < S < 0.0038$ and for Manning n roughness values lying between 0.11 and 0.14, that $Y_{cr} = 1.2947 Y_e$.

Thus it appears that a reasonable estimate of the end depth is the Rouse value of $Y_e = 0.715 Y_{cr}$.

PROOF OF THE ASSUMPTION OF FREE OVERTFLOW CONDITIONS AT OUTLET

To test the assumption that flow at the gutter outlet is approximated by flow over a free overfall weir, available test results are compared with computed theoretical results.

Marsh (1968) has published experimental results giving the water surface profile in half-round gutters for various flowrates. The profiles for a 0,1524 metre (6 inch) true half-round gutter are shown in Figure 8. (It is realised that a small half-round gutter is not truly representative of the large valley gutters draining large roof areas. Experimental data on such gutters are however limited.)

The theoretical end depth is determined from the expression, $Y_e = 0,715 Y_{cr}$. Hence it is necessary to determine the critical depth in the gutter for various flowrates. This can be found by using the fact that $\frac{Q^2 B}{g A^3} = 1$ when flow is critical. Where

Q = total flowrate

B = water surface width

A = cross-sectional area of flow

A programme was written to calculate the end depth in half-round gutters. This programme is discussed in Appendix C. Results of the programme are compared with experimental end depths as abstracted from Figure 8 in Table 3.

It can be seen that theoretical values are in reasonable agreement with experimental values. This strengthens the belief that flow at the outlet tends to free overflow conditions.

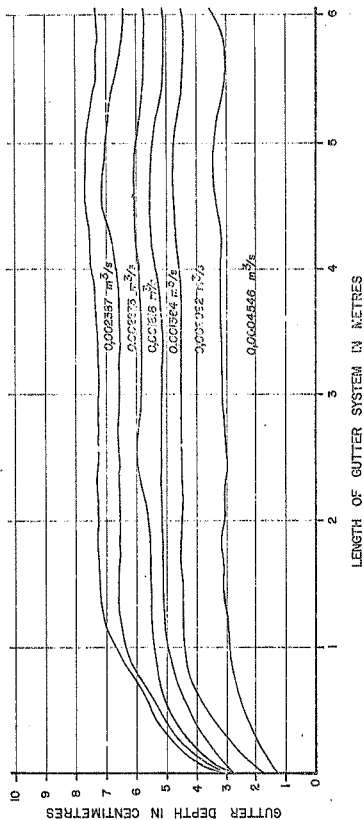


Fig. 8 RESULTS OF TESTS ON 0.1524 m (6") TRUE HALF-ROUND GUTTERS (AFTER NASH 1973)

TABLE 3: COMPARISON OF THEORETICAL AND EXPERIMENTAL END DEPTHS
IN HALF-ROUND GUTTERS

GUTTER LENGTH - 6,096 metres
GUTTER RADIUS - 0,0762 metres
GUTTER SHAPE - true half-round

DISCHARGE in $\frac{m^3}{s}$	EXPERIMENTAL DEPTH AT OUTLET in metres	CALCULATED DEPTH AT OUTLET, Y_e in metres	CRITICAL DEPTH Y_{cr} in metres	% ERROR IN DEPTH AT OUTLET
0,0004546	0,0132	0,0133	0,0187	+ 0,07
0,0009092	0,0175	0,0189	0,0264	+ 8,0
0,001364	0,0269	0,0235	0,0329	-12,6
0,001818	0,0279	0,0270	0,0378	- 3,2
0,002273	0,0294	0,0303	0,0424	+ 2,4
0,002387	0,0310	0,0314	0,04386	+ 1,3

SELECTION OF FLOWDEPTH AT OUTLET

It has been pointed out that depth of flow at outlet approaches the end depth of a free overfall weir, i.e. $Y_e = 0,715 Y_{cr}$. Using this end depth as the starting value in the Hinds equation however, results in a contradiction to one of the basic assumptions on which the analysis is based, namely that the pressure in the flow is hydrostatic. Considering a gutter with a subcritical slope, it is impossible for the flow depth to be less than the critical if the pressure is to remain hydrostatic. Thus an end depth of $Y_e = 0,715 Y_{cr}$ implies that the pressure at this section is non-hydrostatic (which it is) and flow is non-uniform.

For these reasons it is felt that application of the critical depth as the starting point in the Hinds analysis may result in more accurate values for the peak depth in the gutter than will result from application of the actual end depth as the starting depth. Starting with the critical depth will result in the theoretical water surface profile lying above the true profile near the outlet. It is however considered that the theoretical profile will rapidly converge on the true profile.

To determine whether to use end or critical depth as the starting value it is necessary to calculate the water surface profile using both Y_e and Y_{cr} as starting values and to compare these results with experimental results. The available experimental results are the Marsh results in Figure 8 and the Li (1955) results for rectangular channels as given in Table 4.

TABLE 4: TEST RESULTS FOR 9" (0.229m) RECTANGULAR
CHANNEL WITH LEVEL BOTTOM (AFTER LI)

CHANNEL LENGTH - 2,286metres

DISCHARGE IN $\frac{m^3}{s}$	DISTANCE FROM OUTLET, x, in metres	0,0524	0,8390	1,269	1,680	2,211
F L O W D E P T H at x in metres						
0,08665		0,3597	0,3962	0,4115	0,4237	0,4267
0,07136		0,3200	0,3475	0,3658	0,3810	0,3810
0,0640		0,3109	0,3261	0,3475	0,3597	0,3627
0,0606		0,2865	0,3139	0,3261	0,3383	0,3383
0,05239		0,2713	0,2896	0,3078	0,3170	0,3200
0,04531		0,2591	0,2774	0,2896	0,2987	0,2987
0,03540		0,2134	0,2286	0,2403	0,2408	0,2499

CHANNEL LENGTH - 1,716metres

DISCHARGE IN $\frac{m^3}{s}$	DISTANCE FROM OUTLET, x, in metres	0,516	0,841	1,283	1,678
F L O W D E P T H at x in metres					
0,06088		0,3078	0,3261	0,3383	0,3353
0,04644		0,2865	0,3018	0,2987	0,2987
0,03936		0,2438	0,2560	0,2652	0,2682
0,02492		0,1768	0,1890	0,1859	0,1890

It is seen that the experimental water surface profiles given by Marsh are rather uneven. This is due to turbulence and secondary currents and cannot be calculated theoretically. These secondary effects are eliminated by drawing the best fit smooth curves through the actual profiles. These smooth curves define the adjusted profiles with secondary effect eliminated. The adjusted profiles are given in Table 5.

The water surface profiles in rectangular and half-round gutters are calculated with the aid of the Hinds equation. This is done by computer and the programmes are discussed in Appendix C.

Basically the programmes start with a given depth at the outlet (either end or critical depth). A value for the change in water surface elevation from the outlet to the next section is assumed. The assumed flow depth at the next section is applied in the Hinds equation to calculate the change in flow depth. The assumed and calculated flow depths are compared and if they do not agree to the specified accuracy, a new change in flow depth is assumed. The process is repeated until the required accuracy is obtained. The change in flow depth between the next two sections is then found in the same manner and in this way the water surface profile in the gutter is defined.

The results of the programme for half-round gutters are in Appendix C. The theoretical profiles found by starting with the critical depth are in Table 6.

TABLE 5: ADJUSTED MARSH RESULTS FOR HALF-ROUND GUTTER

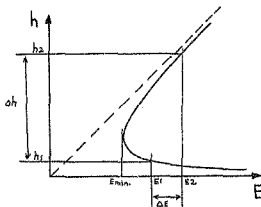
DISCHARGE IN m^3/s	0,002387	0,002273	0,001818	0,001364	0,0009092	0,0004546
DISTANCE FROM OUTLET in metres	F L O W D E P T H in metres					
0	0,032	0,030	0,028	0,027		
0,1524	0,043	0,043	0,038			
0,3048	0,050	0,047	0,044	0,037		
0,4572	0,054	0,051	0,047			
0,6096	0,056	0,055	0,050	0,044		
0,9144	0,064	0,051	0,053	0,048		
1,219	0,070	0,065	0,054	0,050		
1,829	0,072	0,065	0,055	0,050		
2,438	0,072	0,065	0,056	0,051		
3,048	0,072	0,065	0,057	0,052		
3,658	0,072	0,066	0,058	0,052		
4,267	0,072	0,066	0,058	0,052	0,045	0,032
4,877	0,072	0,066	0,058	0,052	0,045	0,032
5,182	0,073	0,066	0,058	0,052	0,095	0,032
5,486	0,073	0,066	0,058	0,052	0,045	0,032
6,096	0,073	0,066	0,058	0,052	0,045	0,032

TABLE 1: THEORETICAL WATER SURFACE PROFILES IN HALF-ROUND GUTTERS WITH $n = 0.014$

DISCHARGE IN $\frac{m^3}{s}$	D	E	P	T	H	i	n	p	e	t	r	s
DISTANCE FROM OUTLET in metres												
0	0,04386	0,0424	0,0378	0,0329	0,0264	0,0187						
0,305	0,05386	0,0524	0,0478	0,0409	0,0344	0,0247						
0,610	0,0578	0,0564	0,0508	0,0439	0,0364	0,0267						
0,914	0,0598	0,0584	0,0528	0,0459	0,0384	0,0277						
1,219	0,0618	0,0604	0,0548	0,0469	0,0394	0,0287						
1,829	0,0648	0,0634	0,0568	0,0489	0,0414	0,0307						
2,438	0,0668	0,0654	0,0588	0,0509	0,0434	0,0307						
3,048	0,0688	0,0674	0,0608	0,0519	0,0434							
3,658	0,0698	0,0684	0,0608	0,0519								
4,267	0,0698	0,0684	0,0608	0,0519								
4,877	0,0698	0,0684	0,0608	0,0519								
5,182	0,0698	0,0684	0,0608	0,0519								
5,486	0,0698	0,0684	0,0608	0,0519								
6,096	0,0698	0,0684	0,0608	0,0519								

Comparison of table 5 and table 6 reveals that using the end depth as the starting depth results in theoretical water surface profiles well above experimental profiles. An explanation of why this occurs follows:

Starting with a depth less than the critical, the specific energy at the outlet, E_1 , is greater than the minimum specific energy, E_{min} , and the flow is supercritical. In moving upstream to the next station the flow must become subcritical (since channel slope is subcritical). In addition there is an increase of specific energy, ΔE , due to the increased flow depth. This situation is seen on the specific energy diagram below.

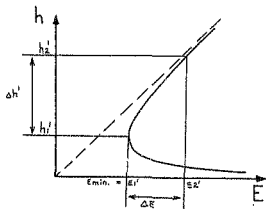


The flow depth at the upstream station is given by

$$h_2 = h_1 + \Delta h$$

Starting with the critical depth at outlet, the change in specific energy to the upstream station will be approximately the same as before i.e. ΔE . The resulting change in flow depth as

seen below, $\Delta h^1 = h_2^1 - h_1^1$, is obviously less than in the previous case.



Indications that this is what actually occurs are;

(a) The major discrepancy between the change in flow depth calculated by starting with the critical and end depths is seen to occur between the outlet section and the next upstream section. This is the large difference between Δh and Δh^1 above.

(b) At the few stations immediately upstream from the outlet the change in flow depth from station to station found using the end depth is less than the change found using the critical depth. This is due to the fact that at specific energy values close to E_{min} , the slope of the E/h curve is greater than at higher specific energy values. This indicates that the two starting points on the E/h diagram, E_1 and E_1^1 are as shown above.

(c) Several sections upstream from the outlet, the change in depth from section to section is the same irrespective of whether end or critical depth was used as starting value.

This implies that these sections are in the range where the slope of the E/h diagram tends to unity.

Inspection of Table 6 indicates that the theoretical water surface profiles found using critical depth as starting point are in good agreement with the experimental profiles after a few sections upstream from the outlet. The theoretical profiles rapidly converge on the experimental profiles. In this study the region of interest is the peaks of the water surface profiles and a comparison of the theoretical and experimental peaks for the half-round gutter is given in Table 7. Inspection of this table indicates that the proposed method of analysis is correct if using the critical depth as the starting depth at the outlet.

The peak depths in rectangular gutters found by starting with the critical depth were abstracted from the computed profiles. These peaks are compared with the Li experimental results in Table 8 and Table 9. The theoretical peaks were found using Manning n values of 0,014 and 0,016. Inspection of these results indicates good agreement between experimental and theoretical peaks and that the peak depth is very insensitive to the roughness value. Slightly better agreement is obtained when the Manning n value equals 0,016. It is acknowledged that this value is larger than the n value of a clean gutter, but it allows for an accumulation of rust and debris in the gutter.

TABLE 7: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK DEPTHS
IN HALF-ROUND GUTTERS

DISCHARGE in $\frac{3}{m^3/s}$	EXPERIMENTAL PEAK DEPTH in metres	CALCULATED PEAK DEPTH USING $r = 0,014$ in metres	PERCENTAGE ERROR	CALCULATED PEAK DEPTH USING $n = 0,016$ in metres	PERCENTAGE ERROR
0,0004546	0,0318	0,0307	-2,3	0,0307	-3,5
0,0007072	0,0446	0,0434	-2,7	0,0434	-2,7
0,001364	0,0519	0,0519	0	0,0529	+1,9
0,001818	0,0584	0,0608	+4,1	0,0608	+4,1
0,002273	0,0660	0,0684	+3,6	0,0694	+5,2
0,002387	0,0728	0,0698	-4,1	0,0714	-1,2

TABLE 8: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK
 DEPTHS FOR A 0,229m RECTANGULAR GUTTER

CHANNEL LENGTH in metres	DISCHARGE in m^3/s	APPROXIMATE EXPERIMENTAL PEAK DEPTH in metres	THEORETICAL PEAK DEPTH in metres	PERCENTAGE ERROR
2,286	0,08665	0,4267	0,4274	+0,17
	0,07136	0,3810	0,3757	-1,41
	0,06400	0,3627	0,3497	-3,72
	0,06060	0,3383	0,3366	-0,50
	0,05239	0,3200	0,3067	-4,34
	0,04531	0,2987	0,2766	-6,70
	0,03540	0,2499	0,2366	-5,60
1,716	0,06088	0,3353	0,3371	+0,54
	0,04644	0,2987	0,2822	-5,85
	0,03936	0,2682	0,2534	-5,80
	0,02492	0,1890	0,1865	-1,34
1,335	0,07079	0,3810	0,3726	-2,26
	0,06994	0,3871	0,3669	-4,94
	0,05380	0,3353	0,3099	-8,20
	0,05295	0,3200	0,3070	-4,25
	0,04304	0,2686	0,2663	-0,62
	0,04248	0,2743	0,2650	-3,40
	0,03002	0,2103	0,2105	+0,95

The above are with $n = 0,014$

TABLE 9: COMPARISON OF THEORETICAL AND EXPERIMENTAL PEAK
 DEPTHS FOR A 0,229m RECTANGULAR GUTTER

CHANNEL LENGTH in metres	DISCHARGE in m ³ /s	APPROXIMATE EXPERIMENTAL PEAK DEPTH in metres	THEORETICAL PEAK DEPTH in metres	PERCENTAGE ERROR
2,286	0,08665	0,4267	0,4284	+0,36
	0,07136	0,3810	0,3767	-1,13
	0,06400	0,3627	0,3517	-3,03
	0,06060	0,3383	0,3366	-0,505
	0,05239	0,3200	0,3077	-3,84
	0,04531	0,2987	0,2796	-6,40
	0,03540	0,2499	0,2366	-5,60
1,716	0,06088	0,3353	0,3311	+0,60
	0,04644	0,2987	0,2832	-5,18
	0,03936	0,2682	0,2534	-5,80
	0,02492	0,1890	0,1865	-1,34
1,335	0,07079	0,3810	0,3736	-1,94
	0,06994	0,3871	0,3698	-4,45
	0,05380	0,3353	0,3109	-7,27
	0,05295	0,3200	0,3080	-3,77
	0,04304	0,2682	0,2663	-0,71
	0,04248	0,2743	0,2649	-3,42
	0,03002	0,2103	0,2106	+0,14

The above are with $n = 0,016$

CONCLUSIONS

It has been shown that a mathematical model of a 'standard gutter' can be constructed. The gutter can be analysed by means of the Hinds equation using critical depth at outlet as the starting value.

A Manning n value of 0,016 is selected for use. This is larger than the n value applicable to smooth gutters and allows for an accumulation of rust and debris in the gutter.

It is noted that the experimental results used to test the programme apply to gutters that are not truly representative of large commercial gutters. The theoretical considerations employed are however completely general and since they approximate flow in the test gutters they should give reasonable estimates of the flow situation in any gutter.

CHAPTER 4

THEORETICAL ANALYSIS OF A NUMBER OF STANDARD GUTTERS WITH DIFFERENT SHAPES, LENGTHS AND INFLOWS

SUMMARY OF MODEL GUTTER AND PRACTICAL APPLICABILITY THEREOF

In the previous Chapter a mathematical model of a standard gutter has been developed and proof of the adequacy of the model presented. The assumptions used in constructing the model are summarised below;

- (a) Uniform inflow per unit length
- (b) Straight horizontal gutter
- (c) Outlet at one end
- (d) Peak point of the water surface profile can be found using the Hinds equation
- (e) The starting depth in the Hinds equation is the depth at outlet, equal to critical depth
- (f) Manning $n = 0,016$

Practical gutters often differ considerably from this model. They often contain central outlets, bends, slopes etc. These variations from the ideal complicate the analysis considerably, frequently rendering it intractable. In the approach adopted the 'standard gutter' model is employed to determine the peak depth in a particular gutter. Correction factors can then be applied to account for variations from the standard.

FREEBOARD ALLOWANCE

Turbulent mixing in the gutter results in an uneven water surface. In addition leaves and debris will reduce the effective cross-sectional area of flow with time. For these reasons a 'freeboard allowance' is added to the calculated peak depth to obtain the final design depth for a particular gutter.

The Building Research Station (1969) recommends that the gutter sides should rise vertically above the required depth by 75 millimetres to give the design depth. Martin (1973) maintains that a freeboard of not more than one-quarter of the required depth, with a maximum freeboard of 2,54 centimetres is adequate. Inspection of Tables 7, 8 and 9 indicates good agreement between theoretical and experimental results.

Thus it is felt that a reasonable estimate of freeboard is 15 percent of the required flow depth for rectangular and trapezoidal gutters and 10 percent of the required flow depth for smaller half-round gutters. This is fairly conservative and should compensate for differences between theoretical and experimental results as well as allow for unevenness of the water surface.

USE OF THE MODEL IN DETERMINING REQUIRED GUTTER SIZES

The model is used to analyse a large number of commercially available gutter shapes and sizes for all practical lengths and inflow rates. This provides data for the solution of many gutter design problems.

The gutter shapes analysed are trapezoidal, rectangular and half-round. The lengths considered are 3m, 5m, 10m, 15m, 20m, 25m and in certain instances, 30m. These lengths cover most practical roof lengths. The range of inflows considered varies for different gutter sizes. Larger inflows are used with larger gutters. The inflow rates applicable to practical gutters were determined as follows:

Maximum design intensity from Figures 4, 5 and 6 = 400mm/hr

Maximum practical roof breadth = 30m

$$\begin{aligned}\text{Maximum inflow per unit length} &= \frac{400 \times 30 \cdot 10^{-3}}{3600} \text{ m}^2/\text{s} \\ &= 0,003 \text{ m}^2/\text{s}\end{aligned}$$

Minimum design intensity, say = 50 mm/hr

Minimum breadth, say = 5m

$$\text{Minimum inflow per unit length} = 0,00005 \text{ m}^2/\text{s}$$

This gives the range of inflows per unit length to practical gutters. Additional inflow rates between these limits were also selected. These can be seen on the printout in Appendix C.

Whilst the programmes were running it was decided to extend the inflow rates and gutter sizes to obtain data for problems slightly beyond the terms of reference of this dissertation. In engineering practice many problems similar to gutter flow problems are encountered. Examples are effluent channels of sedimentation tanks and of similar units. These situations often have flow rates beyond the normal gutter flow rates. Thus by employing larger inflow rates and channel sizes, data are obtained for such design purposes.

Programmes were written to determine the design cross-sectional area of flow for trapezoidal and rectangular gutters. The programmes use the Hinds equation to calculate the peak depth in a particular gutter. A number of different gutter sizes were analysed and for each size, the design cross-sectional area was found for six different gutter lengths. Each length was in turn subjected to six different inflow rates. Thus thirty six results were obtained for each gutter size.

The programme CRECTI analysed rectangular gutters while TRAP analysed trapezoidal gutters.

Half-round gutters were analysed by determining the maximum discharge (flow capacity) that a given half-round gutter could cater for. The programme, HR, performed this analysis.

Details of the various programmes are given in Appendix C.

CHAPTER 5

ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL

The output from Chapter 4 consists of a vast number of computer printouts containing all the necessary information for gutter design. This information is however in a form not readily usable in a design manual. Thus methods of reducing this information to a more practical form were sought.

ANALYSIS OF THE RECTANGULAR GUTTER RESULTS

It was found that for a particular gutter base breadth and length, a plot of $\log(\text{inf})$ against $\log(Y)$ gave a straight line, where inf = inflow per unit length and Y = design depth. The plots for base breadth = 0,3m are given as a typical example in graph 1. The plots for the remaining base breadths are in Appendix D. Attempts were made to reduce these 36 curves to a more usable number by mathematical manipulation.

Consider the plots for base breadth = 0,3m. These are straight lines with equations given by;

$$\log \text{inf} = m \log Y + c \quad \dots\dots 5.1$$

$$\text{or } \text{inf} = Y^m K \quad \dots\dots 5.2$$

where inf = inflow per unit length in m^2/s

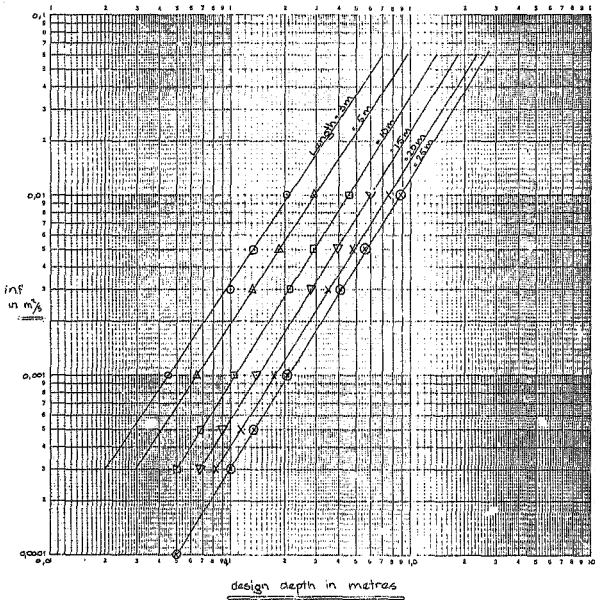
m = slope of line

Y = design depth in metres

c = constant = $\log K$

and the slope, m , is given by $m = \frac{\log(\text{inf1}) - \log(\text{inf2})}{\log(y1) - \log(y2)}$

Graph 1: Plot of $\log(\text{inf})$ vs $\log(\text{design depth})$ for a rectangular gutter of base breadth = 0,3m



The above equation was used to determine the slope values for the curves shown in graph 1. The results are in Table 10.

It is seen that the slope, m , increases as the length, x , increases. The difference in slope between the curves for $x = 3m$ and for $x = 25$ metres is however small. A mean value of $m = 1,5414$ was adopted and equation 5.2 used to determine the constant K . i.e. $K = \inf/Y^{1,5414}$. Results are tabulated in Table 10.

It is seen that K decreases as length increases. It was attempted to reduce these six K values to a single value of K by inclusion of some factor of x , $f(x)$, such that $K = \text{Constant} \cdot f(x)$. Various values of $f(x)$, such as x , $\log x$, x^n were tried with no success. Values for $K = \text{Constant}/x$ are tabulated in Table 10.

After consideration of the form of the Martin design equation (viz. $f = (0,00209 A_{pw}^{0,5})^{0,667}$) $\inf$ was plotted against $Y.b^{0,67}$ on log-log paper, where b = gutter base breadth in metres. This appeared to yield a straight line. In order to verify this, all practical results were abstracted from the data files in Appendix C and a program, YA, written to calculate $Y.b^{0,67}$. The programme and results thereof are in Appendix D.

It is seen from the output files of YA in Appendix D that for any particular gutter length and inflow, the value of $Y.b^{0,67}$ is almost constant, i.e. it is independent of the value of b . For given lengths and inflows the values of $Y.b^{0,67}$ were averaged and these results are presented in Table 11. These results were then plotted on log-log paper and resulted in the six

straight lines shown in graph 2, i.e. one straight line for each length.

Methods of dealing with the length factor were then sought. Firstly $\text{inf}.x$ was plotted against $Y.b^{0,67}$ on log-log paper. The results are tabulated in Table 11 and plotted in graph 3. It is seen from graph 3 that the points fall within a narrow band. A conservative curve drawn through these points, as in graph 3, can result in a 20 percent overestimate of $Y.b^{0,67}$ in the lower $\text{inf}.x$ regions, which was not considered satisfactory.

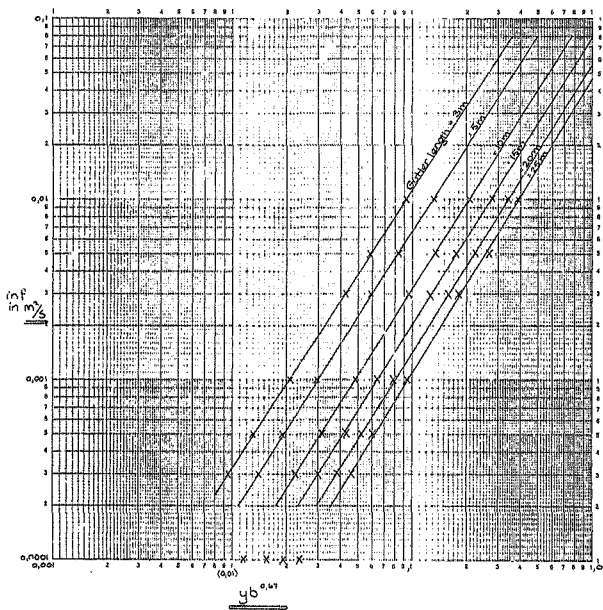
TABLE 10: DETERMINATION OF THE EQUATIONS OF THE CURVES IN GRAPH 1

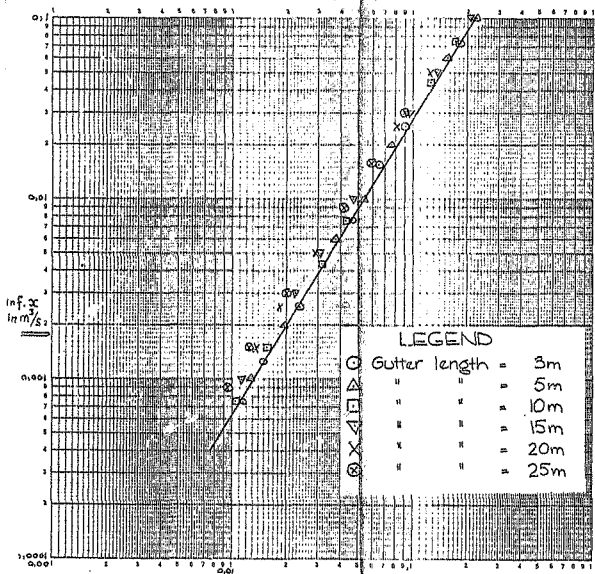
Length in metres	Slope m	K value for $m = 1,5414$	Constant = $K.x$
3	1,5048	0,11992	0,3576
5	1,5377	0,0676	0,3380
10	1,5425	0,0322	0,3220
15	1,5499	0,0208	0,3120
20	1,5583	0,01504	0,3008
25	1,5553	0,01182	0,29557

A plot of $\text{inf}.x^n$ versus $Y.b^{0,67}$ was then attempted. It was found, by trial and error, that $n = 1,05$ gave best results. Values of $\text{inf}.x^{1,05}$ and $Y.b^{0,67}$ are listed in Table 11 and plotted in graph 4. It is seen that the use of $\text{inf}.x^{1,05}$ reduces considerably the scatter of the points in graph 3. In graph 4

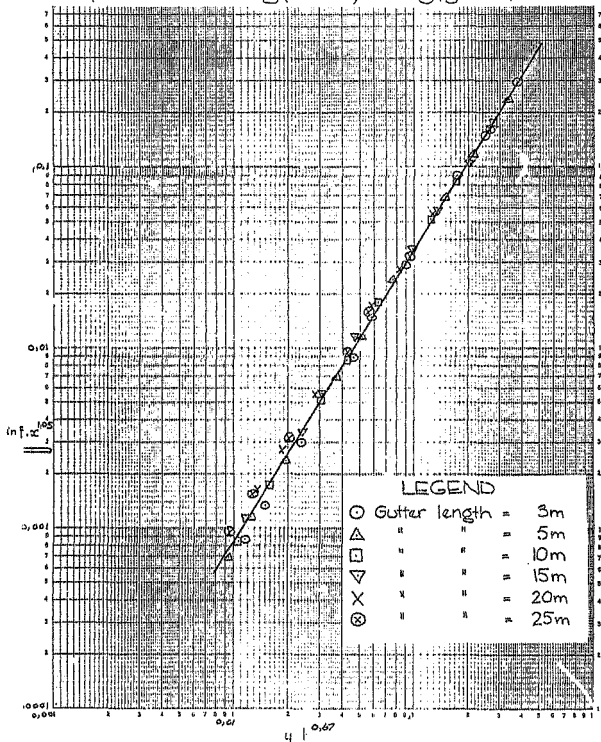
TABLE 11. CALCULATED VALUES OF $\gamma_0 \cdot 67$, $\ln \epsilon \cdot X$ AND $\ln \epsilon \cdot X^{-1.05}$

$\gamma_0 \cdot 67$ in m^2/s	0.0003	0.0005	0.001	0.003	0.005	0.01	0.03	0.05	0.1	0.2	0.5	1.0	2.0	5.0	10	15	20	25	LENGTH in metres
$\gamma_0 \cdot 67$ mean	.0113	.0150	.0214	.0447	.0594	.0598	.1895	.2590	.3876	.425	.5976	.7250	.8976	.1122	.1290	.1477	.1747	.2071	25
$\ln \epsilon \cdot X_{-0.05}$	.00073	.00115	.0023	.0075	.0115	.0123	.0393	.053	.075	.125	.168	.259	.387	.425	.597	.725	.897	.112	
$\ln \epsilon \cdot X_{-0.05}$	.00081	.00147	.00293	.0081	.01468	.02937	.0881	.1468	.2936										
$\gamma_0 \cdot 67$ mean	.0094	.0127	.0193	.0376	.0517	.0775	.2543	.333	.425	.597	.725	.897	.112	.129	.147	.174	.207	.25	20
$\ln \epsilon \cdot X_{-0.05}$	.00056	.001	.002	.0069	.01162	.02123	.06969	.11616	.2323										
$\ln \epsilon \cdot X_{-0.05}$	.000697	.00162	.00223	.006969	.01162	.02123	.06969	.11616	.2323										
$\gamma_0 \cdot 67$ mean	.0103	.0154	.0215	.0405	.0515	.0827	.282	.375	.477	.575	.725	.897	.112	.129	.147	.174	.207	.25	15
$\ln \epsilon \cdot X_{-0.05}$	.00075	.00115	.0023	.0075	.0115	.0123	.0393	.053	.075	.125	.168	.259	.387	.425	.597	.725	.897	.112	
$\ln \epsilon \cdot X_{-0.05}$	.000987	.001717	.002192	.005987	.011717	.02132	.06987	.11717	.232										
$\gamma_0 \cdot 67$ mean	.0112	.0226	.0399	.0775	.0956	.1229	.3071	.405	.501	.601	.701	.801	.901	.1001	.1101	.1201	.1301	.1401	10
$\ln \epsilon \cdot X_{-0.05}$	.001	.002	.003	.009	.015	.025	.075	.125	.200	.275	.350	.425	.500	.575	.650	.725	.800	.875	
$\ln \epsilon \cdot X_{-0.05}$	.00122	.002186	.00361	.01122	.02186	.0361	.1122	.2186	.361	.512	.661	.812	.961	.1112	.1261	.1412	.1561	.1712	
$\gamma_0 \cdot 67$ mean	.0116	.0197	.0309	.0594	.0827	.109	.282	.375	.477	.575	.725	.897	.112	.129	.147	.174	.207	.25	5
$\ln \epsilon \cdot X_{-0.05}$	.0013	.0023	.0039	.0095	.015	.025	.075	.125	.200	.275	.350	.425	.500	.575	.650	.725	.800	.875	
$\ln \epsilon \cdot X_{-0.05}$	.001626	.002709	.00419	.01266	.02709	.0419	.1266	.2709	.419	.561	.709	.8519	.9919	.1139	.1279	.1419	.1559	.1699	
$\gamma_0 \cdot 67$ mean	.0094	.0139	.0206	.0417	.0581	.0827	.282	.375	.477	.575	.725	.897	.112	.129	.147	.174	.207	.25	3
$\ln \epsilon \cdot X_{-0.05}$	.00085	.00139	.00206	.00417	.00581	.00827	.0282	.0375	.0477	.0575	.0725	.0897	.112	.129	.147	.174	.207	.25	
$\ln \epsilon \cdot X_{-0.05}$	.001585	.002169	.003169	.008169	.01585	.02169	.0695	.1369	.2169	.3169	.4169	.5169	.6169	.7169	.8169	.9169	.10169	.11169	

Graph 2: Plot of $\log(\text{inf})$ vs $\log(y \cdot b^{0.67})$ 

Graph 3: Plot of $\log(\text{inf. } x) \text{ vs. } \log(y \cdot b^{0.67})$ 

$y \cdot b^{0.67}$

Graph 4: Plot of $\log(\inf. x^{1.05})$ vs. $\log(y \cdot b^{0.67})$ 

the scatter in the higher regions is almost negligible whilst there is only a slight scatter in the lower inf.x regions.

A curve drawn through these points can therefore be used with considerable confidence as a design curve for rectangular gutters. To determine which straight line through the plotted points would be adopted as the design curve the following factors were taken into account;

- 1) The 'best-fit' curve would be non-conservative in the upper inf.x region.
- 2) The 'maximum-envelope' curve would be non-conservative if extrapolated above the plotted points.
- 3) A line drawn through the upper inf.x points could possibly be extrapolated to increase the range of the plot.

The curve chosen as the design curve is as shown in graph 4. It is seen that in the upper inf.x region the points all lie on the line, while in the lower regions an error of about +10 percent to -5 percent may occur.

The equation of this line has the form

$$\log (\text{inf.x}^{1.05}) = m \log (Y.b^{0.67}) + C$$

$$\text{or } \text{inf.x}^{1.05} = (Y.b^{0.67})^{m.K}$$

where $K = \log C$

The values of m and K are determined in Appendix D

and are $m = 1.614$

$K = 1.4294$

Thus the equation of the curve is;

$$\text{inf.x}^{1,05} = 1,4294 (Y.b^{0,67})^{1,614} \dots 5.3$$

or written in a form from which the design depth can readily be determined;

$$Y = \left(\frac{\text{inf.x}^{1,05}}{1,4294} \right)^{0,620} \frac{1}{b^{0,67}} \dots 5.4$$

To check the validity of this equation, a number of values of design depth were abstracted at random from the output files of CRECTI and checked against values obtained using the above equation. The results are in Table 12.

It is seen that use of the above equation results in excellent agreement with computed design depths. The cases where the percentage error is rather large, viz. +7,0 percent and +10,2 percent fall in the lower $\text{inf.x}^{1,05}$ region where the scatter of points was greatest. However in both instances a conservative result is obtained.

It was felt that the general accuracy of the whole approach to the gutter design problem might warrant the use of the curve shown in graph 3 as a design curve, i.e. the plot of inf.x against $Y.b^{0,67}$. To check this hypothesis the equation of the line in graph 3 was determined in Appendix D. The result was

$$\text{inf.x} = 1,1854 (Y.b^{0,67})^{1,625} \dots 5.5$$

This validity of this equation was checked by comparing the actual value of inf.x with the value of inf.x as given by the above equation for a particular value of $Y.b^{0,67}$. The results are given in Table 13.

TABLE 12: COMPARISON OF THE RESULTS OF PROPOSED DESIGN
EQUATION AND OF CRECT 1

b in metres	inf in σ^2/s	x in metres	Y from output files in metres	Y as calculated in metres	% error
0,6	0,05	3	0,37189	0,3604	-3,1
0,6	0,01	20	0,47101	0,4567	-3,0
0,6	0,003	25	0,2539	0,2505	-1,3
0,5	0,003	15	0,20104	0,2030	+1,0
0,5	0,001	25	0,14306	0,1433	+0,2
0,4	0,005	3	0,10518	0,1135	+7,0
0,4	0,001	15	0,11538	0,1194	+3,5
0,3	0,05	3	0,59142	0,5734	-3,0
0,3	0,01	10	0,46526	0,4630	-0,5
0,3	0,005	25	0,56189	0,5469	-2,6
0,3	0,01	5	0,2914	0,2949	+1,2
0,2	0,003	10	0,28101	0,2881	+2,5
0,2	0,0003	20	0,1082	0,1086	+0,4
0,2	0,0005	25	0,1754	0,1723	-1,7
0,1	0,0005	5	0,08733	0,0862	-10,2
0,1	0,005	3	0,2741	0,2874	+4,5

where Y is calculated using the expression;

$$Y = \left(\frac{\inf_{\sigma^2} 1,05}{1,4294} \right)^{0,62} \frac{1}{b^{0,67}}$$

TABLE 13: COMPARISON OF inf.x (GIVEN) WITH inf.x (CALCULATED)

inf.x given	$\gamma_b^{0,67}$	inf.x calculated
0,1	0,218	0,10038
0,07	0,175	0,07018
0,04	0,125	0,04056
0,02	0,081	0,02009
0,01	0,0532	0,01008
0,003	0,0252	0,02986
0,001	0,0128	0,00099
0,0007	0,0103	0,000695

It is seen that near perfect agreement is obtained. It is however felt that, since graph 4 has a smaller scatter of points than graph 3, the use of equations 5.3 and 5.4 is more desirable.

CONCLUSIONS

The design equation for rectangular gutters over the range $0,0007 < \inf.x^{1,05} < 0,3$ is given by;

$$Q = 1,4294 (Y.b^{0,67})^{1,614} / x^{0,05}$$

$$\text{or } Y = \left(\frac{Q.x^{0,05}}{1,4294} \right)^{0,62} \frac{1}{b^{0,67}}$$

where Q is the flow rate in m^3/s for which the gutter must cater.

The method used to obtain the above design equation is purely empirical and thus the equation should not be applied outside of the range of $\inf.x^{1,05}$ values stipulated. It is felt that there may be good theoretical reasons to account for the manner in which the large number of results in Appendix C reduce to a single design curve. Such an investigation is however beyond the scope of this dissertation.

ANALYSIS OF TRAPEZOIDAL GUTTER RESULTS

The analysis of the results of the trapezoidal gutter programme, TRAP, proceeded as follows;

The variables involved are (i) inflow per unit length, $\inf$ (ii) length, x (iii) base breadth, b (iv) side slope, $\deg$ (v) design cross-sectional area, A .

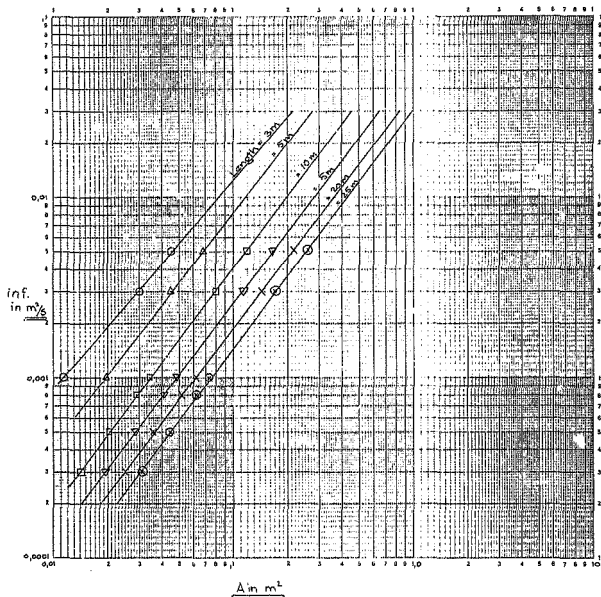
Consider the results for $b = 0,2m$ and side slopes of 45° and 60° . A plot of $\log(\inf)$ against $\log(A)$ results in a straight line for each length as seen in graphs 5 and 6.

Consider the plots for $b = 0,3m$ and $x = 10m$ as seen in graph 7. It is seen that the curves for different side slopes diverge as the inflow increases. It is desired to eliminate this side slope effect. It was attempted to do this by plotting $\inf$ against $A \cdot f(\deg.)$ where $\deg =$ side slope in radians as measured from the horizontal. Values of $f(\deg)$ tried were $\deg^{0,4}$, $\deg^{0,2}$, $\deg^{0,3}$ and $\deg^{0,25}$. It was found that $\deg^{0,25}$ gave best results and the results for $b = 0,3$ and $x = 10m$ are tabulated in Table 14. The results of $A \deg^{0,25}$ for the three different $\deg$ values are averaged and this mean value is used in the plot of $\inf$ against $A \deg^{0,25}$ seen in graph 8. This results in a straight line.

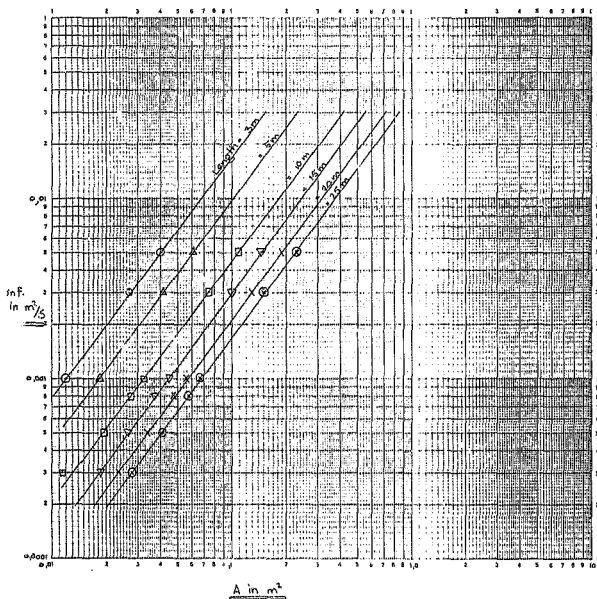
To further reduce these curves a plot of $\inf$ against $(A \deg^{0,25})^{0,67}$ was tried on log-log paper as for rectangular gutters. This was however to no avail. It was discovered that to obtain a straight line $A \deg^{0,25}$ must be divided by some function of b . Trial and error led to the conclusion that $b^{0,09}$ gave the best result.

Values of $A \deg^{0,25} / b^{0,09}$ were calculated from the data in the output files for gutters of base breadth = $0,2$, $0,3$, $0,4$ and $0,5m$. These calculated values are listed in Appendix D. For a given base breadth, inflow and length, the mean values of

Graph 5: Plot of $\log(\text{inf})$ vs $\log(A)$ for $b=0.2\text{m}$ & $\text{deg}45^\circ$



Graph 5: Plot of $\log(\text{inf})$ vs. $\log(A)$ for $b=0,2\text{m}$ & $\alpha=60^\circ$



Graph 7: Plot of $\log(\text{inf})$ vs. $\log(\text{area})$ for trapezoidal gutters of $b=0.3\text{m}$ and $\text{length}=10\text{m}$

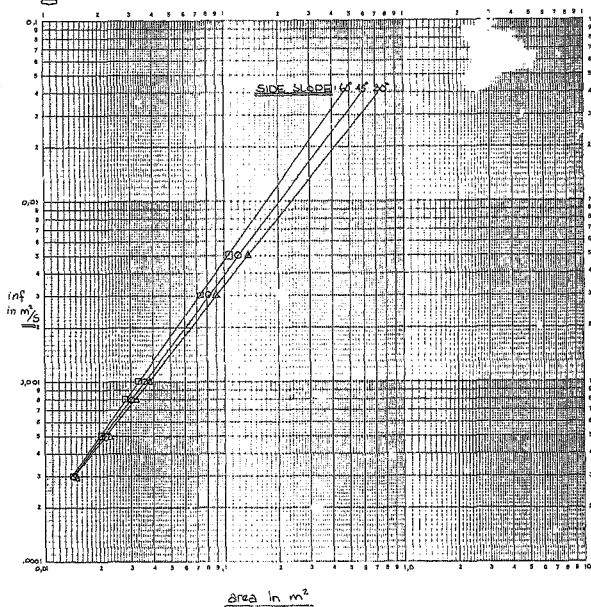


TABLE 14: VALUES OF $\inf$ AND $\text{Adeg}^{0,25}$ FOR $b = 0,3\text{m}$ and $x = 10\text{m}$

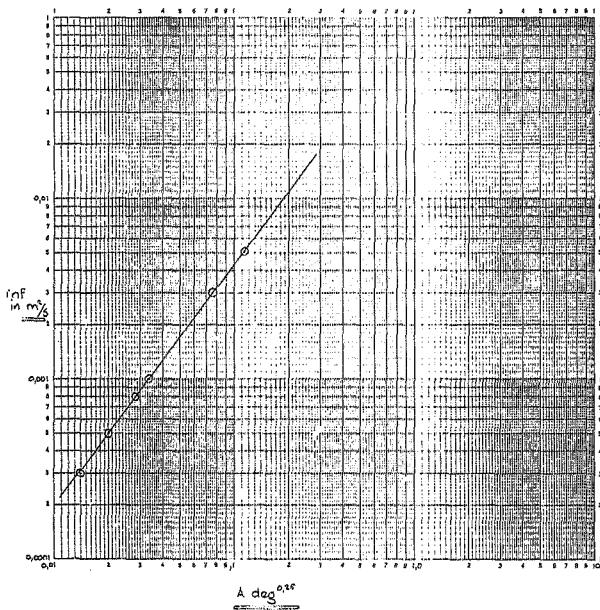
$b = 0,3\text{m}$

$x = 10\text{m}$

$\inf$ $\frac{2}{\text{m}^2/\text{s}}$	$\text{Adeg}^{0,25}$ for deg=0,5236	$\text{Adeg}^{0,25}$ for deg=0,7854	$\text{Adeg}^{0,25}$ for deg=1,0472	mean value of $\text{Adeg}^{0,25}$
0,0003	0,02703	0,02910	0,02935	0,02849
0,0005	0,02013	0,02091	0,02075	0,02060
0,0003	0,01393	0,01411	0,01516	0,01440
0,001	0,03239	0,03291	0,03477	0,03336
0,003	0,07532	0,07619	0,07663	0,07605
0,005	0,11298	0,11225	0,10938	0,11154

where deg is in radians

Graph 8: Plot of $\log(\text{inf})$ vs $\log(A \deg^{0.25})$ for length=10m



$Adeg^{0,25/b^{0,09}}$ for the three different side slopes were calculated. These means are shown in Appendix D, as well as the calculated values of $inf.x$. All the values of the mean $Adeg^{0,25/b^{0,09}}$ value were abstracted from Appendix D, as well as the $inf.x$ values. These are shown in Table 15. The mean of the $Adeg^{0,25/b^{0,09}}$ values was then calculated for different $inf.x$ values as seen in Table 15. $Inf.x$ was then plotted against these final mean values of $Adeg^{0,25/b^{0,09}}$ on log-log paper in graph 9.

A line through these points can be used as a design curve for trapezoidal gutters. Considering the factors outlined in the rectangular gutter result analysis, a straight line was drawn through these points. This line is then the design curve.

The equation of this curve is determined in Appendix D and is given by;

$$inf.x = 0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338} \dots 5.6$$

or rewritten in another form

$$A = \left(\frac{inf.x}{0,6969} \right)^{0,7474} \cdot \frac{b^{0,09}}{deg^{0,25}} \dots 5.7$$

The validity of this equation, 5.7, was checked by randomly abstracting values of design area from the trapezoidal gutter output files. The values of the design area were then calculated using equation 5.7 and compared with the abstracted values. Results are in Table 16.

It is seen that reasonable agreement between the two values is obtained. The maximum error is about +10 percent,

TABLE 15: VALUES OF $\ln f_x$ AND MEAN $\text{Adj. } 0.25/b, 0.09$ FOR
TRAFFIC JUNCTIONS

$\ln f_x$ $\ln m^1/s$	VALUES OF MEAN FOR				TOTAL MEAN
	$b=0.2m$	$b=0.3m$	$b=0.4m$	$b=0.5m$	
0,023			0,0135		0,0135
0,001	0,01543	0,01005			0,01478
	0,01365	0,01402			
0,0045	0,02147	0,02237			0,02192
0,005	0,02245	0,02292	0,02339	0,02286	0,0228
	0,02132	0,02117	0,02102		
0,006	0,02740	0,02813			0,02777
	0,02360	0,03394			
0,008	0,03152	0,03175			0,03164
0,000	0,02933	0,04003			0,03599
	0,03197	0,03261			
0,01	0,03902	0,04038	0,04190	0,03929	0,03909
	0,03723	0,03718	0,03851		
0,0105	0,04485	0,04476			0,0448
0,012	0,0444	0,04411			0,04557
		0,04300			
0,0175	0,04822		0,04942		0,04882
0,015	0,05511	0,05626	0,05720	0,05500	0,05200
	0,04820	0,04890	0,05294	0,05417	
	0,04853	0,04930			
	0,05243	0,05220			
0,016	0,05635	0,05695			0,05615
0,0175	0,06713	0,06380			0,05907
	0,06426				
0,02	0,06580	0,06568	0,06559	0,06742	0,06612
0,0208		0,06758			0,06758
0,024	0,07976	0,07703			0,07882
0,025	0,07367	0,07174	0,07651	0,07274	0,07623
	0,08079	0,07897	0,07215	0,08084	
0,028	0,08075	0,08090			0,08028
0,03	0,08592	0,08463	0,09170	0,08547	0,08806
				0,09322	
0,045	0,1203	0,1171		0,1177	0,1184
0,05	0,1283	0,1241	0,1237	0,1284	0,1240
			0,1214	0,1219	
0,06	0,1532	0,1492		0,1467	0,1497
0,075	0,1770	0,1737	0,1694	0,1713	0,1754
	0,1827	0,1786		0,1742	
0,09			0,2141	0,2030	0,2030
0,10	0,2277	0,2194	0,2142	0,2142	0,2139
			0,2087	0,2096	
				0,2038	
0,125	0,2731	0,2607	0,2576	0,2566	0,2580
0,150			0,2904	0,2858	0,2919
			0,2863	0,2852	
0,20			0,3632	0,3609	0,3620
0,25			0,4376	0,4308	0,4356
			0,4501	0,4336	
0,36			0,5077	0,4992	0,5035
0,50			0,7350	0,7209	0,7258
			0,7304	0,7167	
0,75			1,013	0,9987	1,006
1,0				1,215	1,235

Graph 9: Plot of $\log(\text{inf})$ vs $\log(\text{Adeg}^{0.25}/b^{0.09})$

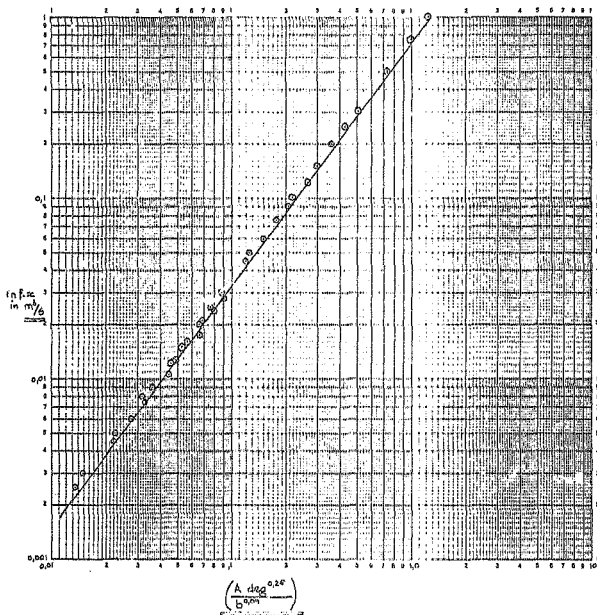


TABLE 16: COMPARISON OF RESULTS OF TRAP AND
DESIGN AREA EQUATION

BASE BREADTH b in metres	dog in degrees	inf in m ^{1/2}	x in metres	DESIGN AREA FROM TRAP EQUATION in m ²	DESIGN AREA AS CALCULATED BY EQUATION in m ²	% ERROR
0,2	30	0,0004	10	0,0024	0,00201	+1,5
	45	0,001	10	0,1121	0,11056	-1,4
	60	0,001	10	0,0323	0,03089	+4,6
0,25	30	0,005	10	0,1509	0,1332	+11,3
	60	0,0005	30	0,0409	0,04957	-20,7
0,30	30	0,0008	35	0,0400	0,05465	-26,3
	45	0,005	15	0,1662	0,16014	+3,1
	60	0,001	10	0,07547	0,08452	-10,9
0,35	60	0,001	30	0,01308	0,0137	+4,4
0,40	30	0,05	10	0,01115	0,0446	+4,1
	45	0,001	25	0,07962	0,0813	+2,2
	60	0,05	15	0,03306	0,06164	+6,4
0,45	30	0,001	30	0,09080	0,10425	+14,5
	30	0,1	5	0,01041	0,0536	+5,3
	45	0,05	10	0,72101	0,7713	+6,7
	60	0,01	15	0,20301	0,29188	+11,6
0,50	30	0,005	30	0,3113	0,3504	+12,6
	45	0,01	20	0,30127	0,3926	+29,7
	60	0,05	15	0,00405	0,0011	+10,0

Where the design area is calculated using the expression:

$$A = \left(\frac{\inf \cdot x}{0,0009} \right)^{0,7474} \frac{10,09}{\deg^{0,25}}$$

which, considering the large number of variables involved is adequate. In addition the errors tend to be on the conservative side. Thus equations 5.6 or 5.7 can safely be used as design equations for trapezoidal gutters.

To check whether the trapezoidal gutter design equation holds for rectangular gutters, values of design area were randomly abstracted from the rectangular gutter output files. The values of the design area were then calculated by means of equation 5.7 with the side-slope, $\text{deg} = 1,5708$ (90°). The results are listed in Table 17 and comparison of those results with those in Table 12 reveals that the results of trapezoidal gutter design equation with $\text{deg} = 1,5708$ radians are in good agreement with the results of the rectangular gutter design equation.

The problem then arose as to whether to employ both equations in the gutter design manual or whether to employ only the trapezoidal gutter design equation and apply it to both rectangular and trapezoidal gutters. To resolve this problem the equations were compared;

$$\text{Rectangular gutter equation: } Y = \left(\frac{\text{inf. } x}{1,4294} \right)^{0,620} \frac{1}{b^{0,67}} \dots 5.4$$

$$\text{Trapezoidal gutter equation for gutters A with side slope, deg} = 1,5708 \text{ radians } A = \left(\frac{\text{inf. } x}{0,6969} \right)^{0,7474} \frac{b^{0,09}}{(2,5708)^{0,25}} \dots 5.7$$

$$\text{or rewritten in another form } Y = \frac{(\text{inf. } x)^{0,7474}}{0,85469} \frac{1}{b^{0,91}} \dots 5.8$$

TABLE 17. COMPARISON OF RESULTS OF RECTANGULAR GUTTER PROGRAMME
AND RESULTS OF TRAPEZOIDAL DESIGN FUNCTION FOR TRAPEZOIDAL
GUTTERS

BASE BREADTH b in metres	deg in degrees	inf in m ² /s	x in metres	DESIGN AREA FROM RECTANG RESULTS in m ²	DESIGN AREA AS CALCULATED BY EQUATION in m ²	% ERROR
0,6	90	0,05	3	0,22313	0,2192	-3,2
0,6	90	0,01	20	0,2835	0,2740	-3,0
0,5	90	0,003	13	0,1269	0,1252	-1,3
0,3	90	0,001	25	0,07153	0,07165	+1,7
0,4	90	0,005	3	0,04147	0,04542	+6,9
0,4	90	0,001	15	0,04615	0,04774	+3,4
0,3	90	0,05	3	0,17743	0,17202	-3,0
0,3	90	0,005	25	0,16956	0,16407	-2,1
0,2	90	0,003	10	0,05632	0,05762	+2,3
0,2	90	0,0005	25	0,03508	0,03446	-1,8
0,1	90	0,005	3	0,02735	0,02879	+5,1

where the design area is calculated using the expression;

$$A = \left(\frac{\inf \cdot b}{0,6969} \right)^{0,7474} \left(\frac{0,69}{1,5708} \right)^{0,25}$$

Comparisons of equations 5.4 and 5.8 reveals that the form of the equations is similar. Equation 5.4, however, contains a power of the length x , ($x^{1,05}$) while equation 5.8 does not. It was pointed out in an earlier section that the use of a power of x in the lower inf.x regions reduces the scatter of the points. Thus it is felt that greater accuracy will be achieved in the lower inf.x regions if equation 5.4 is used for rectangular gutters, while equation 5.7 is used only for trapezoidal gutters.

CONCLUSIONS

The design equation for trapezoidal gutters over the range $0,003 < \text{inf.x} < 1,0$ is given by;

$$Q = 0,6969 \left(\frac{A \deg^{0,25}}{b^{0,09}} \right)^{1,338}$$

$$\text{or } A = \left(\frac{Q}{0,6969} \right)^{0,7474} \cdot \frac{b^{0,09}}{\deg^{0,25}}$$

Again it should be noted that these are empirical equations and are valid only over the specified range.

ANALYSIS OF HALF-ROUND GUTTER RESULTS

The outputs of programme HR, that calculates the flow capacity of a gutter of given size and length, are in Appendix C.

The Building Research Station (1969) has presented a formula for deriving the flow capacity of eaves gutters. This formula can be written in the form

$$Q_{\max} = 0,8433 A^{1,25}$$

where $Q_{\max}$ is the flow capacity of the gutter in m^3/s and A is

the cross-sectional area of gutter in m^2 .

This equation assumes that the flow capacity of a given gutter size is independent of gutter length. Inspection of equation 5.4 for rectangular gutters reveals that this may not be true. It was decided to determine the effect of length on the flow capacity and if necessary to modify the Building Research Station formula to account for length.

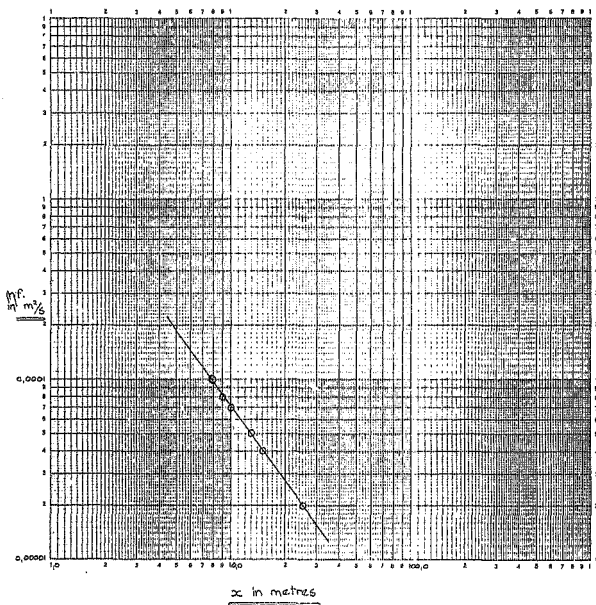
The results of programme HR for a true half-round gutter of diameter equal to 0,1016 metres are shown in Table 18. The values of $\inf(\max)$ are plotted against x on log-log paper in graph 10 where $\inf(\max)$ equals the inflow per unit length capacity, $Q_{\max}/x$, and x is the gutter length in metres. This results in a straight line of slope $m = 1,40$. Hence for this particular gutter $\inf(\max) = Kx^{1,40}$.

This equation suggests that the Building Research Station formula might be modified by including a factor x^n in the formula, i.e. $\inf(\max) \cdot x^n = 0,8433 \cdot A^{1,25}$

An obvious estimate of x^n is $x^{1,40}$ and values of $\inf(\max) = 0,8433 \cdot A^{1,25} / x^{1,40}$ are tabulated in Table 18. It is seen that this overestimates the given values of $\inf(\max)$.

Another estimate of n was obtained from the Building Research Station results. It is thought, though not yet confirmed, that the Building Research Station formula was based on tests performed on 6,096m (20 ft.) long gutters. Their results for various gutters sizes are tabulated in Table 19 and

Graph 10: Plot of $\log(\text{inf})$ vs $\log(x)$ for half-round gutters of $\phi = 0,1016 \text{ m}$



assuming that $x = 6,096\text{m}$, the value of n can be found from the relationship;

$$n = \log_{6,096} \left(\frac{0,8433 \cdot A^{1,25}}{\text{inf}(\text{max})} \right)$$

Calculated values of n are tabulated in Table 19 (an indication that the length of the test gutters used by the Building Research Station was $6,096\text{m}$ can be obtained by extrapolating backwards the curve in graph 10. The value of $\text{inf}(\text{max})$ for a gutter diameter of $0,1016\text{m}$ and length of $6,096\text{m}$ is then abstracted and equals $0,000145 \text{ m}^2/\text{s}$. This approximately equals the value given by the Building Research Station in Table 19.)

It is seen that n is almost a constant value and the mean value is $1,47$. Using this value of n the inflow rates for the gutter of diameter equal to $0,1016\text{m}$ are calculated using the relationship;

$$\text{inf}(\text{max}) = \frac{0,8433 A^{1,25}}{x^{1,47}}$$

The calculated values are compared with the computed values in Table 18. It is seen that good agreement is obtained between the results.

This equation is now checked against the Building Research Station data in Table 19. Results are listed in Table 19. Excellent agreement is obtained.

TABLE 18: RESULTS OF HR AND COMPARISON WITH
RESULTS OF MODIFIED B.R.S. FORMULA

Gutter diameter = 0,1016metres

Cross-sectional area = 0,0081m²

Length in metres	R E S U L T S O F H R		RESULTS OF MODIFIED B.R.S.	
	inf(max) in m ² /s	inf(max).x in m ³ /s	$\frac{0,8433A^{1,25}}{x^{1,4}}$	$\frac{0,8433A^{1,25}}{x^{1,47}}$
8	0,0001	0,0008	0,000111	0,000096
9	0,00008	0,00072	0,000095	0,000081
10	0,00007	0,0007	0,000082	0,00009
13	0,00005	0,00065	0,000057	0,000047
15	0,00004	0,0006	0,000046	0,000038
25	0,00002	0,0005	0,000023	0,000018

TABLE 19: B.R.S. RESULTS AND COMPARISON WITH
RESULTS OF MODIFIED B.R.S. FORMULA

Nominal gutter diam in metres	B.R.S. R E S U L T S		MODIFIED B.R.S. RESULTS	
	Flow capacity in m ³ /s	inf(max)in m ² /s	n	$\frac{0,8433A^{1,25}}{x^{1,47}}$ in m ² /s
0,075	0,00042	0,000069	1,46	0,000067
0,100	0,00083	0,000136	1,43	0,000138
0,1125	0,00113	0,000185	1,47	0,000186
0,1250	0,00150	0,000246	1,465	0,000242
0,1500	0,00233	0,000382	1,467	0,000382

As a final check on the validity of the equation, the Marsh (1968) result for a gutter of diameter equal to 0,1524m (6") and length equal to 6,096m (20') is compared with the result computed using the above formula. Results as shown below.

$$\text{GUTTER DIAMETER} = 0,1524\text{m}$$

$$\text{GUTTER LENGTH} = 6,096\text{m}$$

$$\text{inf(max) as found experimentally by Marsh} = 0,000397\text{m}^{2/5}$$

$$\text{inf(max)} = \frac{0,8433A^{1,25}}{6,096^{1,47}} = 0,00041\text{m}^{2/5}$$

$$\text{percent error} = +3,2 \text{ percent}$$

Good agreement is obtained between theoretical and experimental results. Thus it is felt that the Building Research Station equation for half-round gutters should be altered to the following form to cater for the length factor;

$$\text{inf(max)} \cdot x^{1,47} = 0,8433A^{1,25}$$

or in terms of the discharge capacity

$$Q_{\text{max}} = \frac{0,8433A^{1,25}}{x^{0,47}}$$

where Q_{max} is in m^3/s ,

A is in m^2 and x is in metres.

CHAPTER 6

REVIEW OF EXISTING METHODS OF GUTTER DESIGN AND COMPARISON WITH RESULTS OF PREVIOUS CHAPTER

At present numerous methods of gutter design are employed in South Africa. These methods are generally based on rule of thumb techniques derived from past experience. An example of such a method is that presented in the Standard Building Regulations, 1970; 'The size of a rainwater gutter shall be calculated on the basis of 7cm^2 of cross-sectional area for every 5m^2 of roof area served by such gutter. The size of rainwater downpipe shall be calculated on the basis of 7cm^2 of cross-sectional area for every 7m^2 of roof area served by such downpipes.'

Such methods are not based on sound theoretical principles and take no account of the many variables involved in gutter design.

The Building Research Station (1958 and 1969) has produced a manual that attempts to take into account the variables involved and to rationalise gutter design. A summary of the relevant sections of B.R.S. Digest 107 (1969) is given below.

SUMMARY OF BUILDING RESEARCH STATION METHOD OF GUTTER DESIGN

PART 1 - TO DETERMINE THE SIZES OF EAVES GUTTERS AND DOWNPIPES AND SMALL VALLEY GUTTERS

Eaves Gutters

Calculate the flow load according to the pitch of the roof.

- (i) For roof pitches up to 50° , the angle of pitch is ignored.

(ii) For pitches over 50° , the flow load is calculated using the plan area of the roof.

Flow Capacity (litres/minute) of level gutters, outlet at one end.

Nominal Gutter	Flow capacity of true half-round gutters	
size in millimetres	in litres/min	in m^3/s
75	25	0,00042
100	50	0,00083
112,5	68	0,00113
125	90	0,00150
150	140	0,00233

The above table gives the flow capacity of true-half round gutters, fitted level and with outlet at one end as calculated from $Q = 0,0016A^{1,25}$ where A is in mm^2 and Q is in l/min. This formula may also be used to calculate the flow capacity of nominal half-round, segmental, ogee and other similar gutter sections.

These flow capacities can be adjusted for:

falls not less than 1/600	+40%
bends within 2m of an outlet,	
on level gutters, sharp cornered bend	-20%
round cornered bend	-10%
on sloping gutters	-25%
bends within 2-4m of an outlet, half the above figures	
length, sloping gutters up to 6m long	-10%

Downpipe sizes for level and sloping gutters

HR nominal gutter size	Sharp-(SC) or round-cornered (RC) outlet	Outlet at end of gutter	Outlet not at end of gutter
75	SC	50	50
	RC	50	50
100	SC	62,5	62,5
	RC	50	50
112,5	SC	62,5	75
	RC	50	62,5
125	SC	75	87,5
	RC	62,5	75
150	SC	87,5	100
	RC	75	100

Downpipe sizes appropriate to stated gutter sizes are listed in the Table above.

Rectangular and box gutters

The above method for determining the size of eaves gutters is valid for rectangular and box gutters in which the ratio of width/depth is about 2:1.

PART 2 - TO DETERMINE THE SIZES OF LARGE VALLEY GUTTERS, OUTLETS OF RECEIVERS AND RAINWATER PIPES

Shape of Gutter

The width of sole should be not less than 300 millimetres to facilitate maintenance. The sides of the gutter should rise 75 millimetres vertically above the required height to provide a freeboard allowance.

Flow Capacity for free discharge

Gutters should be provided with outlets designed to accept the flow from gutters without increasing the flow depth in the gutter.

In a gutter discharging freely, the flow capacity is given by:

$$Q = 0,0058 \sqrt{\frac{A^3}{B}} \quad \dots \quad 6.1$$

where Q = flow capacity in litres/minute

A = area of flow at outlet in mm^2

B = width of water surface at outlet in millimetres

It is assumed that the depth of flow at outlet, H_o , is half the peak flow depth at the far end, D .

Box-type receiver

Whenever possible the gutter should discharge into a box-type receiver, the depth of which can be chosen so as to permit the use of a rainwater pipe of convenient size.

The receiver should be at least as wide as the maximum gutter width and it should be long enough to prevent the flow from the gutter over-shooting the box. A suitable shape for an external box-type receiver is shown in Figure 9 in which the recommended depth of the edge is $H_d + 2/3 H_d$ where H_d is the depth of water at the inlet to the rainwater pipe required to give the necessary discharge capacity. The length of the box L_b is given by $L_b = 2\sqrt{FH_o}$ where F is the fall between water surfaces and H_o is the depth of flow at the gutter outlet.

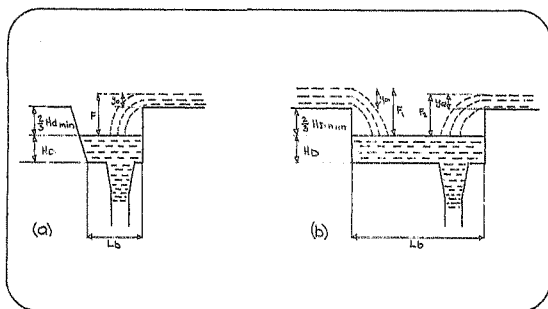


Fig. 9: Dimensions of box-type receivers

- (a): External length, $L_b = 2\sqrt{F_1 y_{01}}$
 (b): Internal length, $L_b = 2\sqrt{F_1 y_{01}} + 2\sqrt{F_2 y_{02}}$

Where the box is situated part way along a length of roof, a separate value L_b should be calculated for each gutter length draining into it and the two lengths added to give the total length of the box.

Rainwater pipes

Where the gutter discharges directly into a rainwater pipe, the rainwater pipe inlet, should be designed to allow free discharge from the gutter. The discharge capacity of the rainwater pipe inlet depends on the diameter of the inlet, the depth of water (head) over the inlet and on whether the water swirls about the inlet.

Swirl can be neglected if the inlet is at a distance less than its diameter from the nearest vertical side of the gutter or box. In this case the inlet acts as a weir for a head of flow H up to $d/3$ for which range

$$Q = 0,0116 \, dH \sqrt{H} \quad \dots \quad 6.2$$

where Q = discharge capacity of inlet in litres/minute

d = diameter of inlet in millimetres

H = head of water over inlet in millimetres

Where H is greater than $d/3$ the inlet acts as an orifice

$$\text{and } Q = 0,0039d^2 \sqrt{H} \quad \dots \quad 6.3$$

Swirl will occur if the inlet is at a distance greater than its diameter from the nearest vertical side. In this instance the weir discharge is unchanged but the orifice discharge is reduced by swirl to

$$Q = 0,0029 d^2 \sqrt{H} \quad \dots \quad 6.4$$

When sizing the inlet to a rainwater pipe leading directly from the gutter, the head H should be taken as the depth of flow at the gutter outlet, H_o , calculated when determining the gutter capacity.

The diameter of the rainpipe can be reduced to two-thirds of the effective inlet diameter provided that the transition is made over a length of not less than the diameter of the inlet.

A second method of gutter design was proposed by Martin (1973) for Australian conditions. This method is based on the Building Research Station results and is essentially the same as the BRS method. Several improvements were however presented and these are summarized below.

SUMMARY OF RELEVANT PORTIONS OF MARTIN METHOD OF GUTTER DESIGN

THE CATCHMENT AREA

Wind influences the effective catchment area by altering the direction of the rainfall. It is argued from simple geometry that a sloping roof must intercept more wind-driven rain descending at an angle from the normal. However limited data exists upon which an estimate of such a 'wind factor' can be based.

In saw-tooth type of construction, rain will be directed onto the vertical roof portions, increasing the effective catchment area. Thus in cases of high wind a percentage of the vertical surface might be exposed to rainfall and this area must be added

to the adjacent sloping roof area in determining the effective catchment area.

High rise buildings, however, affect the intensity of rainfall during windy periods. The buildings will obstruct the flow of air and the resulting pattern of air movement will cause raindrop trajectories to diverge over the obstruction and converge on the leeward side as seen in Figure 10. Thus roofs of high buildings may be expected to receive lower intensities of rainfall than are recorded on open ground. The same would apply to roofs on adjacent buildings, but lower buildings at some distance on the leeward side might experience higher intensities.

However until further research has been performed on the effect of wind, no fixed rules can be stated. It appears that, for the present, the designer should increase the plan area of the roof to account for wind effects. This factor must be based on subjective knowledge of the wind conditions at the site. In extreme conditions, the total roof area may be taken as the catchment area.

Hail is not taken into account in the rainfall intensity data. It is generally agreed that runoff from hail and snow is lower than from rain and the major problem is due to the likelihood of blockage of drainage channels and downpipes. Downpipes may be protected by wire mesh guards.

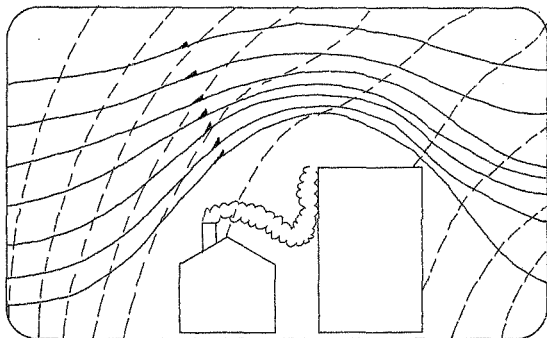


Fig 10: Air flow over buildings and probable trajectories for raindrops of one size (broken lines)
(After Martin 1973)

FLOW CAPACITY AND DESIGN OF DRAINAGE CHANNELS

Eaves gutters fitted with downpipe

Martin uses an imperial unit equivalent of the BRS formula for eaves gutters to determine the flow capacity of eaves gutters.

$$Q = a^{1,25} (1 + x)$$

where Q is in gallons/minute

a is in in²

x is a gutter design coefficient depending upon slopes, bends etc. These x values are similar to the BRS reduction factors.

Since potential damage from failure of external eaves gutters is not likely to be great, their design can be based on low recurrence intervals of rainfall intensity (say 10 years).

The optimum size of vertical downpipes to serve such gutters is given by the rule that the cross-sectional area of downpipe needs to be half the cross-sectional area of gutter. This method has worked satisfactorily in Australia for 7 years.

Valley and box gutters with free discharge to receiver and downpipe

These usually have a minimum width of 300 millimetres to facilitate maintenance. For the horizontal case with open end, the flow capacity of the gutter is given by

$$Q = 4,167 (f^3/w)^{0,5}$$

where f is the cross-sectional area of flow at outlet in in²

W is the width of flow of the water surface at the outlet in inches.

Q is the flow capacity in gallons/minute

This is the imperial unit equivalent of the BRS formula for valley gutters.

The influence of slope has been studied empirically by Martin and Tilley (1968) and the following relationship found for both box trapezoidal and vee gutters:

Up to 1° slope the square of the discharge capacity is directly proportional to the sine of the angle of slope.

For slopes from 1° to 20° the reciprocal of the maximum depth of flow is directly proportional to the square root of the sine of the angle of slope. Figure 11 illustrates the results in terms of a relative discharge capacity factor (n). Thus if a is the calculated cross-sectional area of gutter required for the horizontal case, then $a = na^1$, where a^1 is the cross-sectional area of gutter required for the sloping case.

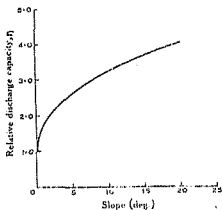


Fig. 11. Influence of slope on discharge capacity of a drainage channel. (After Martin and Tilley 1968.)

The box-type receiver and downpipe may be designed to serve the freely discharging box-gutters as recommended by the Building Research Station (1969)

Downpipes to flat roofs

Where downpipes are fed by flat areas such as sealed membrane roofs and not by gutters, separate consideration needs to be given to the estimation of the required size of the downpipe. Assuming an effective discharge velocity of 350 ft/min (1,78 m/s) in the downpipe during peak flow conditions, the discharge capacity is given by

$$Q = \frac{\pi D^2}{576} \times 0,350 \times 6,23 \dots 6.5$$

where Q is in gallons per minute

D is the pipe diameter in inches

Marsh (1968) has presented a design method for PVC eaves gutters. This method is based on experimental data for 6,096 metre (20 ft.) long gutters. The appropriate results are summarised below.

SUMMARY OF RELEVANT PORTIONS OF MARSH METHOD OF GUTTER DESIGN FOR PVC HALF-ROUND EAVES GUTTERS

A level gutter with an outlet at the centre has almost twice the capacity of a similar gutter with an end outlet.

A fall of 1/600 increases the level gutter flow capacity by 20 per cent.

A fall of 1/300 increases the level gutter flow capacity by 30 percent.

An angle within 6 ft. (2m) of the outlet of a level gutter, reduces the flow capacity of the straight gutter by 10 percent.

An angle further than 6 ft. (2m) from the outlet of the level gutter, reduces the flow capacity of the straight gutter by 5 percent.

An angle within 6 ft. (2m) of the outlet of a gutter fitted to a fall, reduces the flow capacity of the straight gutter by 20 percent.

SUMMARY OF HELLINGS' METHOD OF DETERMINING
THE OPTIMUM POSITION OF EAVES GUTTERS

Hellings (1967) proposed a theoretical method of determining the optimum position of eaves gutters by considering the trajectory of the water flowing from the roof into the gutter. The method was verified experimentally.

This method is used to determine the trajectory of the water flowing from a valley gutter into a box receiver. The result obtained provides a check on the proposed dimensions of box-receiver presented by the Building Research Station.

The trajectory of a particle in a frictionless medium is given by

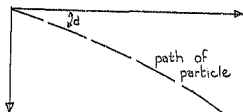
$$a = \tan(d) b + \frac{g \cdot b^2}{2V_o^2 \cdot \cos^2(d)} \quad \dots \quad 6.6$$

where a = vertical distance travelled by particle

b = horizontal distance travelled by particle

V_o = initial velocity

d = angle that the initial direction of the particle makes with the horizontal



Assuming that the jet of liquid discharging from a gutter behaves in a similar manner, then the trajectory of the jet of water is given by equation 6.6

It has been shown in Chapter 3 that the flow depth at outlet, Y_e , is less than the critical depth, Y_{cr} , and is approximately equal to $Y_e = 0,715 Y_{cr}$. Assuming the gutter to be rectangular, the outlet velocity, V_o , will then equal $1,4 V_{cr}$, where V_{cr} is the critical velocity.

The critical velocity can be obtained from the expression

$$\frac{Q^2 B}{g A^3} = 1$$

$$\text{i.e. } V_{cr}^2 = \frac{g A}{B}$$

$$\text{Thus } V_o^2 = \frac{g A}{B} (1,4)^2$$

Substituting for the end velocity, V_o , into equation 6.6 gives

$$a = \tan(d) \cdot b \cdot \frac{g \cdot b^2}{2 \cdot (1,4)^2 \cdot \frac{g A}{B} \cos^2(d)}$$

Assuming a level gutter, i.e. $d = 0^\circ$, gives

$$a = \frac{b^2}{2 \cdot (1,4)^2 \cdot Y}$$

$$\text{Hence } b \approx 2 \sqrt{a \cdot Y}$$

This equation is compared with the equation for the minimum length of box-receiver as proposed by the Building Research Station. viz. $L_b = 2 \sqrt{FH_o}$. It is seen that the equations are identical. Thus it is concluded that the BRS formula is based on the assumptions outlined above.

Hence the BRS formula will be adequate provided that V_o does not exceed $1.4 V_{cr}$. This may occur in certain instances, but the effect thereof will be compensated for by inbuilt safety factors in the equation. Namely

- (i) the effect of friction, which is ignored in the analysis.
- (ii) the length of receiver is calculated assuming that the jet of water discharging from the gutter may not impinge on the far vertical wall of the receiver. In fact, it may without affecting the operation of the receiver.

Thus it is felt that the Building Research Station formula for design of box-receivers is adequate.

MIDGLEY RESULTS FOR THE FLOW CAPACITY OF DOWNPIPES

Midgley (1964) investigated the hydraulic characteristics of gullies and downpipes and presented a theoretical discussion on the general behaviour of typical downpipes.

The flow condition at the downpipe inlet can be

- (i) free weir condition
- (ii) orifice condition
- (iii) orifice condition with suction
- (iv) weir condition with suction
- (v) pipe condition or
- (vi) partial pipe condition.

The existing condition depends primarily upon the head of water at the inlet.

The Building Research Station recommends that inlets should be designed to allow free discharge from the gutter. In this case, depending on the head, either condition (i) or (ii) will hold.

If the free weir condition holds then

$$Q = C_d \pi D \cdot H_o^{1,5} = K \cdot D \cdot H_o^{1,5}$$

and if the orifice condition holds

$$Q = \frac{C_d \pi D^2 \sqrt{2g}}{4} H_o^{\frac{1}{2}} = K^1 \cdot D^2 \cdot H^{\frac{1}{2}}$$

where Q = discharge capacity of inlet

C_d = coefficient of discharge

D = inlet diameter

H_o = driving head

Compare the form of these equations with those presented by the Building Research Station, namely;

$$Q = 0,0116 D H^{1,5} \quad \dots \quad 6.2$$

$$\text{and } Q = 0,0039 D^2 \sqrt{H} \quad \dots \quad 6.3$$

It is seen that the Building Research Station results are based on the theoretical flow conditions (i) and (ii) outlined above.

Since these equations have a sound theoretical backing it is felt that they can be safely applied.

LI RESULTS FOR LEVEL CHANNELS WITH PARALLEL SIDE WALLS

Li (1958) investigated spatially varied flow in level channels with parallel side walls. Using momentum considerations and assuming that the flow depth at outlet equals the critical

depth, Li showed that

$$\frac{Y_p}{Y_o} = \sqrt{2F_o^2 + 1}$$

where Y_p = peak flow depth at upstream end of channel

Y_o = flow depth at outlet

$$F_o = \text{Froude number at outlet} = \frac{Q_o^2 B_o}{g A_o^3}$$

Assuming the end depth = critical depth, Y_{cr} , then $F_o = 1$

and the above equation reduces to;

$$Y_p = \sqrt{3} Y_o = 1.732 Y_o$$

The Building Research Station design method however assumes that $Y_p = 2Y_o$. A further estimate of the value of the ratio Y_p/Y_o can be obtained by abstracting data from the rectangular gutter output files and calculating the ratio Y_p/Y_o .

This is done in Table 20.

It is seen that for rectangular gutters the ratio Y_p/Y_o is not constant but varies between the limits of about 1.75 to 2.0. An average value appears to be about 1.85. Thus the Building Research Station value of $Y_p/Y_o = 2$ is a conservative result.

Values of Y design are also abstracted from the output files, where Y design = the design flow depth, i.e. the upstream depth with the freeboard allowance added. Values of Y design/ Y_o are tabulated in Table 20.

It is seen that an average value is about 2.2.

Thus it can be concluded that conservative estimates of the peak upstream depth Y_p and the design depth Y_d are given by

TABLE 20: CALCULATION OF THE RATIOS Y_1/Y_0 AND Y_d/Y_0
FOR RECTANGULAR CHANNELS

BASE BREADTH b in metres	inf in m ² /s	LENGTH x in metres	$Y_0 = Y_{cr}$ in metres	Y_p in metres	Y_p/Y_0	Y_d in metres	Y_d/Y_0
0,6	0,005	5	0,05614	0,10214	1,82	0,11746	2,09
		15	0,11678	0,21478	1,84	0,2470	2,11
		25	0,16417	0,3097	1,86	0,35094	2,16
	0,01	5	0,26026	0,45690	1,75	0,52521	2,02
		25	0,26060	0,4746	1,83	0,5458	2,09
		10	0,18538	0,33138	1,79	0,3811	2,06
0,4	0,01	20	0,28428	0,53628	1,82	0,6167	2,09
		5	0,05234	0,09433	1,8	0,1068	2,07
		15	0,10806	0,20086	1,82	0,2310	2,11
	0,0003	25	0,15301	0,20803	1,87	0,3312	2,16
		5	0,01128	0,02128	1,87	0,0245	2,17
		15	0,02345	0,04845	2,06	0,0557	2,36
0,3	0,005	25	0,03297	0,07097	2,15	0,0816	2,47
		3	0,06140	0,11340	1,79	0,1304	2,05
		10	0,14147	0,25747	1,82	0,2961	2,09
	0,001	20	0,07600	0,14940	1,95	0,1723	2,24
		25	0,08912	0,17512	1,96	0,2014	2,26
		10	0,18538	0,34138	1,85		
0,2	0,005	15	0,24292	0,45092	1,85		
		5	0,08308	0,15708	1,82		
		10	0,13188	0,24488	1,86		

$$Y_p = 2.Y_o$$

$$Y_d = 2,3 . Y_o \text{ where } Y_o \text{ is assumed to be the critical depth}$$

These values can be used to obtain a quick estimate of the required flow depth for a particular gutter problem.

COMPARISON OF EXISTING METHODS OF DETERMINING REQUIRED FLOW AREAS AND DESIGN CURVES PROPOSED IN CHAPTER 5

The existing methods of determining the required cross-sectional area of valley gutters for given flow conditions are all based on the Building Research Station equation

$$Q = 0,0058 \sqrt{\frac{A^3}{B}} \quad \dots \quad 6.1$$

where Q is in litres/minute, A in mm^2 and B in millimetres.

Compare this with the discharge capacity obtained by assuming that the flow depth at outlet is critical, viz.

$$Q = 0,00595 \sqrt{\frac{A^3}{B}}$$

Thus it is seen that the flow capacity as given by equation 6.1 is practically the same as the flow capacity obtained by assuming the outlet depth to be critical. Thus equation 6.1 assumes the outlet depth to equal the critical depth. The Building Research Station method then assumes the peak depth to be twice the critical depth. This however is not always true, as was pointed out in the previous section. It is however a reasonable, conservative estimate.

The equations proposed in this dissertation for the design of rectangular and trapezoidal gutters are:

$$\text{For rectangular gutters } Y = \left(\frac{Q \cdot x^{0,05}}{1,4204} \right)^{0,6200} \cdot \frac{1}{b^{0,67}}$$

$$\text{For trapezoidal gutters } Y = \left(\frac{Q \cdot x^{0,05}}{1,4204} \right)^{0,7474} \cdot \frac{b^{0,09}}{\deg^{0,25}}$$

It is felt that use of these equations will take better account of the variables involved in gutter design. The form of these equations is similar to that of equation 6.1 as can be seen by rewriting equation 6.1 in the form below:

$$Y = \frac{(Q)^{0,67}}{K} \cdot b^{0,33}$$

CHAPTER 7CORRECTION FACTORS TO BE APPLIED TO STANDARD GUTTER RESULTS
AND THE SIZING OF BOX-RECEIVERS AND DOWNPIPES

A number of standard gutters were analysed in Chapter 4 and the results of these analyses presented in the form of design criteria in Chapter 5. These design criteria are however only applicable to the particular standard gutters analysed i.e. to straight horizontal gutters with outlet at one end and of rectangular, trapezoidal or half-round section. Means of extending these results to include all aspects of the design of practical gutter systems were sought.

It was felt that due to the lack of data on the subject, the only feasible approach to the variations from the standard gutter would be to abstract relevant information from previous investigators' work. If different investigators employed different means of accounting for such variations, then the most conservative result will be employed.

The relevant abstracted results are as listed below:

CORRECTION FACTORS TO BE APPLIED TO THE STANDARD
GUTTER RESULTSEaves Gutters

The discharge capacity of a standard gutter can be adjusted for:

Falls not less than 1/600

+ 20%

Bends within 2m of an outlet on level gutters,

sharp-cornered bends	- 20%
round-cornered bends	- 10%

on sloping gutters	- 25%
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Bends within 2m - 4m of an outlet

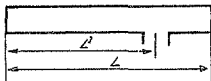
half of the above results

Non-central downpipe in a level gutter, the discharge capacity is given by $\frac{Q \cdot L}{L^1}$ where

Q = discharge capacity

L = gutter length

L^1 = length of longer arm of gutter



Valley Gutters

No results are available on the effects of bends. Bends are seldom incorporated in large valley gutters, but if such gutters should have bends, the designer must apply correction factors of his own choice. The factors above for eaves gutters may be used as a guide.

The effect of slope can be taken into account by means of the Martin method, as outlined in the previous Chapter. It is felt that this method could be improved by determining the effect

of slope theoretically. This could be done by including slope effects in the analysis outlined in Chapter 3 and comparing these results with the horizontal gutter results. This may well result in a better understanding of the effect of slopes on a gutter.

SIZING OF BOX-RECEIVERS AND DOWNPIPES

DOWNPIPES FROM EAVES GUTTERS

Martin recommends that the cross-sectional area of downpipe be half the cross-sectional area of gutter that it is draining. The Building Research Station recommends that downpipe sizes be based on the table reproduced in Table 21.

Both these methods assume that the flow capacity of a particular gutter is fixed and hence the size of the downpipe serving such a gutter is fixed. If the modified form of the Building Research Station eaves gutter design equation is used, viz. $Q = 0.8433A^{1.25}/x^{0.47}$, then the flow capacity is not fixed, but depends on the length of the gutter. Thus when applying the modified BRS equation, it is desirable to modify the Building Research Station method of downpipe sizing to take into account the gutter length, x .

The downpipe size can be found from the following theoretical analysis:

Assume that the flow conditions at the gutter outlet approximate orifice flow conditions, then the discharge capacity, Q , of the outlet according to equations 6.3 and 6.4 is given by;

$$Q = 0,0039 d^2 \sqrt{H}$$

$$\text{or } Q^1 = 0,0029 d^2 \sqrt{H} \text{ if swirl occurs}$$

where Q is in litres/minute

d is the outlet diameter in millimetres

H is the driving head in millimetres

Assume that the driving head equals the critical depth

and assume that the critical depth equals half the peak depth.

Then for half-round gutters

$$H = Y_{cr}$$

$$Y_{cr} = \frac{1}{2} Y_p = \frac{D}{4}$$

where D is the gutter diameter

And the discharge capacity of the outlet is

$$Q = 0,00195 d^2 \sqrt{D}$$

$$\text{or } Q^1 = 0,00145 d^2 \sqrt{D} \text{ if swirl occurs}$$

The required outlet diameter is thus

$$d = \sqrt{\frac{513 Q}{\sqrt{D}}} \quad \dots \quad 7.1$$

$$d^1 = \sqrt{\frac{690 Q^1}{\sqrt{D}}} \text{ if swirl occurs} \quad \dots \quad 7.2$$

To check the validity of these equations, the Building Research Station equation for the flow capacity of eaves gutters, viz. $Q = 0,0016A^{1,25}$, is substituted into them and the downpipe sizes computed. The next largest standard downpipe size is then selected for use. The results are in Table 21.

TABLE 21: DETERMINATION OF DOWNPIPE SIZES REQUIRED TO SERVE EAVES GUTTERS

Nominal Gutter Size D in millimetres	Flow capacity, Q as found from $Q=0,0016A^{1,25}$ in l/min	$d=(0,513/\sqrt{D})^{\frac{1}{3}}$ in millimetres	$d=(690.Q/\sqrt{D})^{\frac{1}{3}}$ in millimetres	DOWNPIPE SIZES RECOMMENDED BY THE B.R.S.		
				Sharp (S.C.) corner or round corner (R.C.) outlet	Outlet at end of gutter in milli- metres	Outlet not at end of gutter in milli- metres
75	25	38,5 50	44,6 50	SC RC	50 50	50 50
100	50	51,5 62,5	59,6 62,5	SC RC	62,5 50	62,5 50
112,5	68	57,4 62,5	66,6 75	SC RC	62,5 50	75 62,5
125	90	64,4 75	74,5 75	SC RC	75 62,5	87,5 75
150	140	76,7 87,5	88,7 100	SC RC	87,5 75	100 100

Note: upper n. - is d(calculated), lower one
is the n. largest standard gutter size

Comparison of these results with the downpipe sizes recommended by the Building Research Station leads to the conclusion that the above method was the method employed by the Building Research Station in determining the downpipe sizes required by gutters with sharp cornered outlets. No swirl was assumed to exist if the outlet was at the end of the gutter, while swirl was assumed to exist if the outlet was not at the end of the gutter.

Thus it appears that equations 7.1 and 7.2 can be used to determine the downpipe sizes required by half-round gutters, provided that the discharge capacity, Q , used in the equations is the actual discharge capacity of the gutter and not the adjusted discharge capacity (i.e. the discharge capacity after correction factors have been applied).

It is assumed that these equations will also hold for nominal half-round, ogee and other similar gutter sections.

Altering the units involved in equations 7.1 and 7.2 they can be written

$$d = \sqrt{\frac{0.973Q}{\sqrt{D}}} \quad \dots \quad 7.3$$

$$\text{or } d^1 = \sqrt{\frac{1.309Q}{\sqrt{D}}} \quad \text{with swirl} \quad \dots \quad 7.4$$

where d is in metres

D is in metres

Q is in m^3/s

Substituting the modified Building Research Station value for the discharge capacity, Q , into these equations will give a

general design formula for downpipes.

$$d = \sqrt{\frac{0,973 \cdot 0,8433A^{1,25}}{\sqrt{D} \cdot x^{0,47}}}$$

$$\text{or } d = \sqrt{\frac{1,309 \cdot 0,8433A^{1,25}}{\sqrt{D} \cdot x^{0,47}}} \quad \text{with swirl}$$

These reduce to

$$d = \sqrt{\frac{0,82A^{1,25}}{x^{0,47} \sqrt{D}}} \quad \dots\dots 7.5$$

$$\text{or } d = \sqrt{\frac{1,10A^{1,25}}{x^{0,47} \sqrt{D}}} \quad \text{with swirl} \quad \dots\dots 7.6$$

These then are the design equations for eaves downpipes, where equation 7.5 is used for round-cornered outlets and 7.6 is used for sharp-cornered outlets.

BOX-TYPE RECEIVERS FROM VALLEY GUTTERS

The Building Research Station recommendations for sizing box-receivers are discussed in Chapter 6. These will be adopted for use. The recommended receiver size, as seen in figure 9 below, depends on the depth of flow at the gutter outlet, Y_o .

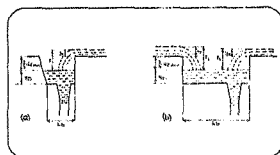


Fig. 2 Dimensions of box-type receivers
(a) External length. $L_E = 2 \text{ ft } 0 \text{ in.}$
(b) Internal length. $L_I = 2 \text{ ft } 0 \text{ in.} + 2 \text{ ft } 0 \text{ in.}$

The depth of flow at the outlet is less than the critical depth and is approximated by

$$Y_o = 0.715 Y_{cr}.$$

It is felt however that it is more desirable to employ the critical depth as the Y_o value in the equation for box length, L_b . This provides a certain safety factor and allows for errors in the analysis used to determine the box length equation (see previous chapter).

If design is based on the design equations recommended in Chapter 5 then the critical depth can be assumed to be equal to $Y_{design/2,3}$ (see Chapter 6 for explanation).

DOWNPIPES FROM BOX-RECEIVERS AND VALLEY GUTTERS

The Building Research Station method will be used. The problem exists as to what is the driving head of water over the downpipe inlet. This head will be assumed to be the critical depth and hence is given by $Y_{design/2,3}$.

GUTTER SECTIONS OTHER THAN RECTANGULAR OR TRAPEZOIDAL SECTIONS

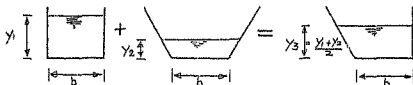
Various methods of theoretically relating the results of rectangular and trapezoidal gutters to other gutter sections were attempted without success. Attempts were made to determine a ratio between the critical depth in a rectangular section and the critical depth in a trapezoidal section with one side vertical and one side sloping, but it was found that this ratio was a variable.

It was decided that the best method of extending the results was as follows:

- (i) Where a high degree of accuracy is not required

The required area of the gutter is determined by combining the results of rectangular and trapezoidal gutters with equal side slope in a suitable fashion.

For example



- (ii) Where a higher degree of accuracy is required

The design depth may be assumed to be 2,3 times the critical flow depth in the gutter. Thus it will be necessary to determine the critical flow depth. This can be done by a trial and error solution of the equation

$$\frac{Q^2 B}{g A^3} = 1$$

CHAPTER 8PRESENTATION OF A GUTTER DESIGN MANUAL FOR
SOUTH AFRICAN CONDITIONSINTRODUCTION

At present several methods of gutter design based on rule of thumb techniques are employed in South Africa. These methods often give widely differing solutions and it is felt that they do not always result in optimum drainage system design. An attempt has been made to rationalize gutter design by applying sound theoretical principles to the critical elements of a drainage system. The validity of all theoretical analyses employed was checked against available experimental data from test gutters. Where the assumptions used in the theoretical analyses resulted in conditions that differed from practical gutter systems, the effect of these assumptions is taken into account by means of correction factors.

The correction factors and several of the design equations have been abstracted from the design methods proposed by Martin (1973) and the Building Research Station (1969). The layout of this manual follows the layout of the Martin manual.

POSITION OF DOWNPIPES (after Martin (1973))

'Although general location of downpipes is fixed by considerations other than designing for optimum drainage, the number to be installed is usually a design variable. Obviously, the more downpipes the smaller the catchment area and the smaller

the sizing of drainage channels. However the high cost of additional downpipes to multi-storey buildings in particular, usually ensures that as few as possible will be used. Some simple commonsense rules apply. ² Roof catchments should be kept smaller than 900m² and at least two downpipes should be installed on all roofs with total catchments greater than about 45m². Drainage from roofs should not be directed onto other roofs but into separate downpipes.

External downpipes are preferred on the basis of ease of maintenance, lower potential damage should blockage occur, and the facility for installing overflow weirs at the downpipe. Flat gratings to minimize the blockage to internal downpipes serving flat roofs should not be used unless the inlet to the downpipes is greater than 150 millimetres diameter, and then the restricted area of flow must be used in the calculations. One of the most troublesome causes of blockage of downpipes serving flat roofs to multi-storey buildings is caused by rain leaching free lime from cement-rich concrete paving. The lime is carbonated and deposited at the inlet to the downpipe as calcium carbonate. Such deposits can only be removed with difficulty by mechanical means. Neat cement powder must not be used as a drier for such concrete paving.

The detailed position of downpipes serving drainage channels will influence the discharge capacity of the channel. Where possible the position should be in the centre of the length of the channel and so located that the water in the channel does not need to traverse a bend to reach the inlet.'

THE CATCHMENT AREA

Wind influences the effective catchment area by altering the direction of the rainfall. It is argued from simple geometry that a sloping roof must intercept more wind-driven rain, descending at an angle from the normal. However very little

data exists upon which an estimate of such a 'wind factor' can be based.

In saw-tooth type of construction rain will be directed onto the vertical roof portions, increasing the effective catchment area. Thus in cases of high wind a percentage of the vertical surface might be exposed to rainfall and this area must be added to the adjacent sloping roof area in determining the effective catchment area.

High rise buildings affect the intensity of rainfall during windy periods. The buildings will obstruct the flow of air and the resulting pattern of air movement will cause raindrop trajectories to diverge over the obstruction and converge on the leeward side.

Thus roofs of high buildings may be expected to receive lower intensities of rainfall than are recorded on open ground. The same would apply to roofs on adjacent buildings, but lower buildings at some distance on the leeward side might experience higher intensities.

However until further research has been performed on the effect of wind, no fixed rules can be stated. For the present, the designer should increase the plan area of roof to account for wind effects. The amount by which it is increased should be based on subjective knowledge of the wind conditions at the particular site. In extreme circumstances the total roof area may be taken as the catchment area.

THE DESIGN RAINFALL INTENSITY

Hail is not taken into account in the design rainfall intensity. It is generally agreed that runoff from hail is lower than from rain and the major problem is due to the likelihood of blockage of drainage channels and downpipes. Downpipes may be protected by wire mesh guards.

The critical duration of storm likely to cause overtopping of the drainage system is considered to be five minutes. Rainfall intensities for the three meteorologically homogeneous rainfall regions in South Africa, as seen in Figure 1, have been computed for various recurrence intervals of failure. These intensities for various recurrence intervals have been plotted against the mean annual precipitation at the particular site in Figures 2, 3 and 4.

The recurrence interval of failure employed should depend on the potential damage that may be caused by overtopping of the drainage system and leakage of water into the building. Design of external eaves gutters with low damage potential if overtopping occurs may be based on recurrence intervals of 5 to 10 years, while design of large valley gutters may be based on longer recurrence intervals of failure.

Hence the design rainfall intensity for gutter design is obtained by

- (i) deciding on the appropriate recurrence interval of failure
- (ii) determining the rainfall region of the gutter site from

Figure 1.

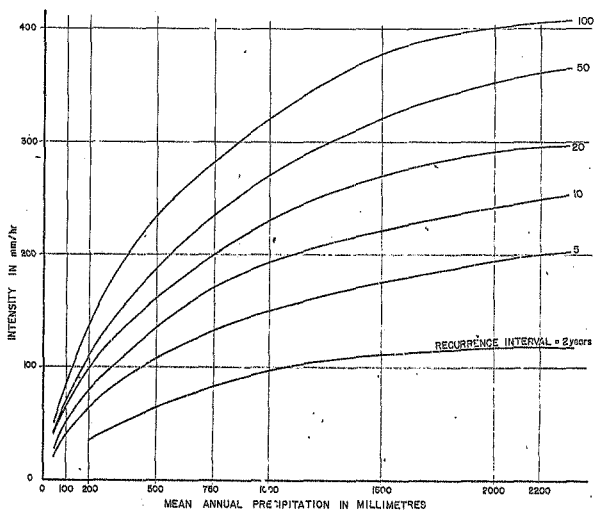


Fig. 2 GUTTER DESIGN CURVE FOR SUMMER RAINFALL REGIONS

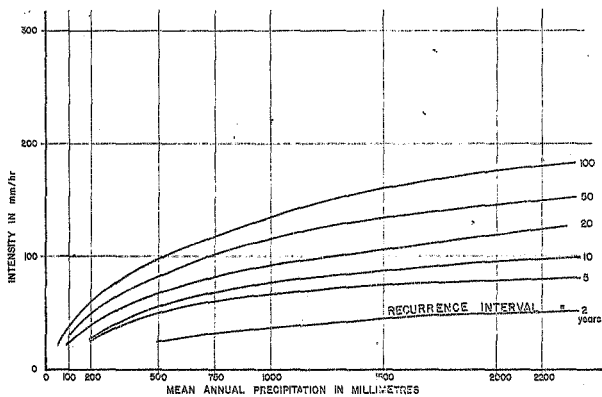


Fig. 3 GUTTER DESIGN CURVE FOR WINTER RAINFALL REGIONS

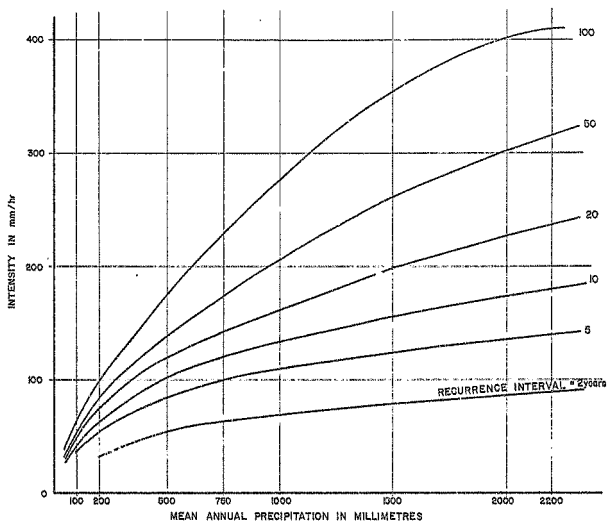


Fig. 4. GUTTER DESIGN CURVE FOR YEAR-ROUND RAINFALL REGION

- (iii) determining the mean annual precipitation at the site
- (iv) determining the design rainfall intensity using Figure 2, 3 or 4.

The design rainfall intensity is given in millimetres per hour. This manual is based on units of metres and seconds. To convert the intensity in millimetres per hour to metres per second multiply the intensity by $0,2778 \times 10^{-6}$.

DESIGN OF DRAINAGE SYSTEM

Eaves gutter design is based on the flow capacity of standard gutter sizes while valley gutter design is based on the determination of the required cross-sectional area of gutter to cater for the particular inflow rate.

TO DETERMINE THE SIZE OF EAVES GUTTERS FITTED WITH DOWNPIPES

The flow capacity of level eave gutters, of half-round, segmental and ogee section, with outlet at one end is given by:

$$Q = \frac{0,8433A^{1,25}}{x^{0,47}} \dots\dots 1$$

where Q is the flow capacity in m^3/s

A is the cross-sectional area of the gutter in m^2

x is the length of the gutter in metres

The flow capacity as determined by equation 1 may be adjusted for:

Falls not less than $\frac{1}{600}$ + 20%

Bends within 2m of an outlet

on level gutters, sharp-cornered bends - 20%

round-cornered bends	- 10%
on sloping gutters,	- 25%
Bends within 2 - 4m of an outlet	
half of the above results	

Downpipe not at end of gutter. The discharge capacity is given by $Q \cdot \frac{x_1}{x}$ where Q is the flow capacity with downpipe at end, x is the total gutter length and x_1 is the length of the longer arm of the gutter.

Eaves gutters are designed by a trial and error process. A gutter size is estimated, the flow capacity is determined, correction factors are applied if necessary and the result is compared with the discharge that the gutter must cater for. This is repeated until the optimum solution is obtained.

TO DETERMINE THE SIZE OF DOWNPIPES DRAINING EAVES GUTTERS

The flow is influenced by the shape of the outlet, whether sharp-cornered or round-cornered. Thus separate equations exist for the two different conditions.

The size of outlets may be determined by the following equations:

$$d = \sqrt{\frac{0,82A^{1,25}}{x^{0,47}\sqrt{D}}} \quad \text{for round-cornered outlets} \quad \dots\dots\dots 2$$

$$d = \sqrt{\frac{1,1A^{1,25}}{x^{0,47}\sqrt{D}}} \quad \text{for sharp-cornered outlets} \quad \dots\dots\dots 3$$

where d is the outlet diameter in metres

A is the gutter cross-sectional area in m^2

x is the gutter length in metres

D is the nominal diameter of the gutter in metres

TO DETERMINE THE SIZE OF VALLEY AND BOX GUTTERS DISCHARGING FREELY INTO RECEIVER AND DOWNPIPE

These gutters are vee, trapezoidal or rectangular in shape and should have a minimum base width of 0,3m to facilitate maintenance. Bends are generally not incorporated and discharge is preferably via an open end into a box-receiver.

Rectangular sections:

The required cross-sectional area of gutter with freeboard is given by:

$$A = \left(\frac{Q \cdot x^{0,05}}{1,4294} \right)^{0,62} \cdot b^{0,33} \quad \dots \quad 4$$

Trapezoidal Sections with equal side slopes:

The required cross-sectional area of gutter with freeboard is given by

$$A = \left(\frac{Q}{0,6969} \right)^{0,7474} \frac{b^{0,09}}{\deg^{0,25}} \quad \dots \quad 5$$

where A is the design cross-sectional area in m^2

Q is the flow rate that the gutter must carry in m^3/s

x is the gutter length in metres

b is the base width in metres

$\deg$ is the side slope in radians, as measured by the external angle that the gutter sides make with the horizontal.

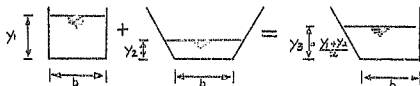
Sections other than rectangular or trapezoidal with equal side slope

The required cross-sectional area of gutter with freeboard can be determined in either of two ways.

- (i) Where a high degree of accuracy is not required;

The required cross-sectional area can be found by combining the results of rectangular and trapezoidal with equal side slope gutters in a suitable fashion.

For example to size a trapezoidal gutter with one side sloping and the other side vertical, the following combination could be used.



- (ii) Where a greater degree of accuracy is necessary;

The required depth of flow, with freeboard may be assumed to be 2,3 times the critical flow depth in the particular gutter.

$$\text{i.e. } Y_d = 2,3 Y_c \quad \dots \quad 6$$

The critical flow depth may be found by a trial and error solution of the following equation.

$$\frac{Q^2 B}{g A^3} = 1 \quad \dots \quad 7$$

where Q is in flow rate that the gutter must carry in m^3/s

B is the width of water surface at outlet in metres

A is the area of flow at outlet in m^2

For the common case of trapezoidal section with one side

vertical and one side sloping, equation 7.3 is given by:

$$\frac{Q^2}{g} = \frac{\left[b \cdot Y_{cr} + \frac{Y_{cr}^2}{2 \tan \theta} \right]^2}{\left[b + \frac{Y_{cr}}{\tan \theta} \right]^3} \quad \dots \quad 8$$

where Y_{cr} is the critical depth at outlet in metres

θ is the side slope in degrees

CORRECTION FACTORS APPLIED TO THE REQUIRED AREA

Bands generally are not incorporated in valley gutters and little data on their effect exists. If bands are present, then the designer must increase the required area using his judgement. The factors given for coves gutters may be used as a guide.

The influence of slope has been studied empirically by Martin and Tilley (1968) and the following relationship found for both box trapezoidal and vee gutters.

Up to 1° slope the square of the discharge capacity is directly proportional to the sine of the angle of slope.

For slopes from 1° to 20° the reciprocal of the maximum depth of flow is directly proportional to the square root of the sine of the angle of slope. Figure 5 illustrates the results in terms of a relative discharge capacity, n . Thus if A is the calculated cross-sectional area required for the horizontal case then

$$A = nA^1$$

where A^1 is the cross-sectional area required for the sloping case.

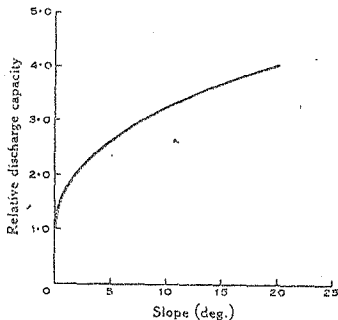


Fig. 5: Influence of slope on discharge capacity of a drainage channel. (After Martin and Tilley, 1968)

TO DETERMINE THE SIZE OF BOX-RECEIVERS FROM VALLEY GUTTERS

Box-receivers may be designed to serve the freely discharging box gutter as recommended by the Building Research Station (1969).

The receiver should be at least as wide as the maximum gutter width and should be designed to prevent the flow from the gutter overshooting the box. A suitable shape for an external box-type receiver is in Figure 6.

The value of the flow depth at outlet used in the formula to determine the length of the receiver is given by:

$$Y_o = \frac{Y_d}{2,3}$$

Where Y_d is the peak flow depth with freeboard as found from equations 4, 5 or 6.

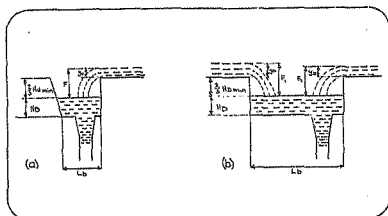


Fig. 6: Dimensions of box-type receivers
 (a): External length, $L_b = 2\sqrt{R Y_d}$
 (b): Internal length, $L_b = 2\sqrt{R Y_d} + 2\sqrt{R Y_d}$

TO DETERMINE THE SIZE OF DOWNPIPES FROM RECEIVERS OR VALLEY GUTTERS

Where the gutter discharges directly into the downpipe, the downpipe inlet should be designed to allow for free discharge from the gutter. The discharge capacity of a downpipe depends on the inlet diameter, the head of water over the inlet and on whether the water swirls about the inlet.

The downpipe inlet should be placed at a distance less than its diameter from the nearest vertical side of the gutter or box. The required inlet size is then given by

$$d = \frac{0,164Q}{H^{1,5}} \quad \dots \quad 9$$

provided that H is less than $\frac{d}{3}$

When H is greater than $d/3$ the outlet acts as an orifice and the inlet diameter is given by

$$d = \sqrt{\frac{0,487Q}{H^{0,5}}} \quad \dots \quad 10$$

If the inlet is at a distance greater than its diameter from the nearest vertical wall, swirl will occur and the orifice discharge will change. Thus if H is greater than $d/3$ and swirl is present, the inlet diameter is given by

$$d = \sqrt{\frac{0,655Q}{H^{0,5}}} \quad \dots \quad 11$$

where d is the downpipe diameter required in metres

Q is the flow rate that the downpipe must cater for in m^3/s

H is the head of water over the inlet in metres

When sizing an inlet to a downpipe leading directly from the gutter, the head H is assumed to be equal to the critical depth of flow. This can be assumed to be $Y_d/2,3$ where Y_d is the peak flow depth with freeboard as found from equations 4,5 and 6.

The diameter of the downpipe can be reduced to two-thirds of the effective inlet diameter provided that the transition is made over a length of not less than the diameter of the inlet.

TO DETERMINE THE SIZE OF DOWNPIPES FROM FLAT ROOFS

Where downpipes are fed by flat areas such as sealed membrane roofs and not by gutters, separate considerations need

to be given to the estimation of the required size of downpipe.
Assuming an effective discharge velocity of 1,8m/s in the
downpipe during peak flow conditions, the discharge capacity is
given by:

$$Q = \pi \frac{d^2}{4} \cdot 1,8$$

$$\text{i.e. } d = \sqrt{0,707Q}$$

where d is the required outlet diameter in metres

Q is the discharge rate that the outlet must cater for in
 m^3/s .

MAINTENANCE

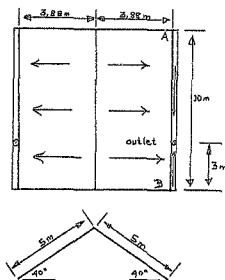
The commonest cause of drainage system failure is the
accumulation of dirt and debris in the drainage channels. On
buildings where the damage potential due to failure of drainage
system is high, regular maintenance of the drainage channels must
be performed.

TYPICAL EXAMPLES

Several simple examples are given indicating the manner
in which this manual can be used to design practical roof drainage
systems. It should be noted that these examples are of an
elementary nature and that no attempt has been made to obtain the
optimum design. In large roof drainage systems, the optimum
design should always be obtained by considering several alternative
designs and comparing the costs of these alternatives.

GUTTER SYSTEM FOR A RESIDENTIAL BUILDING IN JOHANNESBURG

Consider a residential building with a roof system as sketched below.



It is required to design the drainage system for this building.

Downpipe positions; Assume that aesthetics dictated the downpipe positions and that they are as shown.

Catchment area; Damage potential if overtopping of the gutters occurs is low, thus neglect wind effects and use the plan area of the roof as the catchment area.

$$\begin{aligned}\text{Area of roof draining into gutter AB} &= 5,0 \cdot \cos 40^\circ \cdot 10 \text{ m}^2 \\ &= 38,3 \text{ m}^2\end{aligned}$$

Design rainfall intensity; Since damage potential is low, use a low recurrence interval of failure of say, 5 years.

Mean annual precipitation in Johannesburg = 760 millimetres

Rainfall region - summer rainfall region.

Hence design intensity from fig.4 = 134 mm/hr.

$$= 134.0.2778.10^{-6} \text{ m/s}$$

$$= 37.2.10^{-6} \text{ m/s}$$

Required discharge capacity of gutter; This is given by

$$37.2.10^{-6}.38.8 \text{ m}^3/\text{s}$$

$$= 1.442.10^{-3} \text{ m}^3/\text{s}$$

Sizing of gutter AB; Assume eaves gutters of half-round section will be used. Assume the gutter will be fitted to a fall of 1/600.

The flow capacity of a level gutter with an outlet at one end is given by

$$Q = \frac{0.8433A^{1.25}}{x^{0.47}}$$

where $x = 10\text{m}$

$$\text{Thus } Q = 0.286A^{1.25}$$

Correction factors to account for variations from the standard gutter can be applied to the discharge capacity. They are (i) gutter has slope of 1/600, thus increase discharge capacity by 20 percent

(ii) outlet is not at end of gutter, thus increase discharge capacity by a factor of

$$\frac{x}{1} = \frac{10}{7} = 1.43$$

Hence corrected discharge capacity is

$$Q = 0,286 \cdot A^{1,25} \cdot 1,20 \cdot 1,43$$

$$Q = 0,491 \cdot A^{1,25}$$

Try gutter of diameter = 0,10m and $A = 0,00784 \text{ m}^2$

Then its discharge capacity = $0,491 \cdot 0,00784^{1,25}$

$$= 1,03 \cdot 10^{-3} \text{ m}^3/\text{s}$$

Compare this with the required discharge capacity of $1,442 \cdot 10^{-3} \text{ m}^3/\text{s}$

and it is seen that a larger gutter is required.

Try gutter of diameter = 0,125m and $A = 0,0123 \text{ m}^2$

Then discharge capacity = $0,491 \cdot 0,0123^{1,25}$

$$= 2,06 \cdot 10^{-3} \text{ m}^3/\text{s}$$

Hence this gutter size will be adequate.

Sizing of downpipes draining from gutter; Assume that the outlet is sharp cornered, then the required outlet diameter

is given by $d = \sqrt{\frac{1,1 \cdot A^{1,25}}{x^{0,47} \cdot \sqrt{D}}} \dots\dots 3$

$$\text{i.e. } d = \sqrt{\frac{1,1 \cdot 0,0123^{1,25}}{10^{0,47} \cdot \sqrt{0,125}}}$$

$$= \sqrt{\frac{0,00462}{1,042}}$$

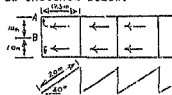
$$= 0,0665 \text{ metres}$$

$$= 66,5 \text{ millimetres}$$

The next largest standard size is then selected for use.

GUTTER SYSTEM FOR AN INDUSTRIAL BUILDING IN PORT ELIZABETH

Consider an industrial building, housing a motor car assembly plant, as sketched below.



It is required to design the drainage system for this building.

Downpipe positions; Assume that the downpipes are situated as shown.

Catchment area; Damage potential if overtopping of the gutter system occurs is fairly high. In addition strong winds are frequent in the Port Elizabeth area. Thus use the total sloping roof area as the catchment area. Area of roof draining into gutter AB = 20.10 m^2
 $= 200 \text{ m}^2$

Design rainfall intensity; Since damage potential is high use a high recurrence interval of failure, say, 50 years.

Mean annual precipitation in Port Elizabeth = 580 millimetres

Rainfall region = year-round rainfall region.

Hence design intensity from fig. 6 = 150 mm/hr

$$= 150.0 \cdot 2778 \cdot 10^{-6} \text{ m/s}$$

$$= 41.6 \cdot 10^{-6} \text{ m/s}$$

Required discharge capacity of gutter; This is given by

$$41.6 \cdot 10^{-6} \cdot 200 \text{ m}^3/\text{s}$$

$$8.32 \cdot 10^{-3} \text{ m}^3/\text{s}$$

Sizing of gutter AB; Assume that a trapezoidal gutter section with equal side slopes will be used and assume that the gutter discharges into a box-receiver and downpipe and assume that the gutter is fitted level.

The required cross-sectional area of gutter with freeboard is given by

$$A = \left(\frac{Q}{0,6969} \right)^{0,7474} \frac{b^{0,09}}{\deg^{0,25}} \dots\dots 5$$

Assume a side slope of 60° and base breadth

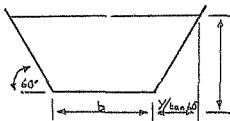
$b = 0,30$ metres, then

$$A = \left(\frac{8,32 \cdot 10^{-3}}{0,6969} \right)^{0,7474} \cdot \frac{(0,30)^{0,09}}{(1,0472)^{0,25}}$$

$$= 0,0320 \text{ m}^2$$

Thus required depth of gutter is given by

$$A = Y \cdot b + \frac{Y^2}{\tan 60^\circ}$$



The solution of this is given by $Y \approx 0,10$ metres

Sizing of box-receiver from gutter; The minimum width of the receiver is given by

$$b + 2 \cdot Y / \tan 60^\circ = 0,3 + 2 \cdot 0,10 / 1,73 \text{ metres}$$

$$= 0,45 \text{ metres}$$

The flow depth at gutter outlet, $Y_o = Y_d / 2,3$

$$= 0,1/2,3 \text{ metres}$$

$$= 0,0435 \text{ metres}$$

Assume that the driving head of water in the box,

HD = 0,05 metres, then the fall from the gutter to

the surface of the water in the box is given by

$$\begin{aligned}
 F &= Y_0 + \frac{2}{3} HD \\
 &= 0,0435 + 0,0333 \text{ metres} \\
 &= 0,0768 \text{ metres}
 \end{aligned}$$

$$\begin{aligned}
 \text{Hence minimum box length, } L_b &= 2\sqrt{FY_0} \\
 L_b &= 2\sqrt{0,0768 \cdot 0,0435} \\
 L_b &= 0,106 \text{ metres} \\
 \text{Say } L_b &= 0,110 \text{ metres}
 \end{aligned}$$

Sizing of downpipe from box-receiver; Assume that the downpipe is situated at a distance less than its diameter from the nearest vertical wall of the box.

Thus if $h < d/3$ then the downpipe size is given by

$$d = \frac{0,164Q}{H^{1,5}} \quad \dots\dots 9$$

In this instance $H = H_1 = 0,05$ metres and

$$d = \frac{0,164 \cdot 8,3210^{-3}}{(0,05)^{1,5}} \text{ metres}$$

$$d = 0,134 \text{ metres}$$

but $H > d/3$ thus the above formula does not hold. In this instance the downpipe size is given by

$$d = \sqrt{\frac{0,487Q}{H^{0,5}}} \quad \dots\dots 10$$

$$\text{i.e. } d = \sqrt{\frac{0,487 \cdot 8,32 \cdot 10^{-3}}{(0,05)^{0,5}}}$$

$$d = 0,134 \text{ metres}$$

The next largest standard downpipe size is then selected for use. The diameter of the downpipe may be reduced to

$2\frac{2}{3}$. 0,134 metres in diameter provided that this transition occurs over a distance of not less than the downpipe diameter.

GUTTER SYSTEM FOR, SAY, AN ART GALLERY

Seepage of water into a building such as an art gallery would have disastrous effects, thus the possibility of failure of the gutter system cannot be tolerated. In such an instance the total roof area would be used as the catchment area and a recurrence interval of failure of 100 years would be used. In addition safety factors should be applied to the gutter cross-sectional area.

APPENDIX A

TABLES OF RAINFALL INTENSITY VALUES AS ABSTRACTED FROM
FIGURE 2 AND TYPICAL CURVES USED TO OBTAIN THE FIVE MINUTE
DURATION STORM INTENSITY VALUE.

TABLE 22: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 50mm

RECURRENT INTERVAL in years	Time in hours		0,25	I N T E N S I T Y			0,50	0,75	1		2	RAINFALL REGION
									mm / hr			
2								14,7	10,5 12,6	6,2 7,8		w y-r s
5								15,4 18,6	12,5 15,0	7,5 9,6		w y-r s
10							1,00					w y-r s
20								17,3 22,4	14,8 18,2	8,5 11,7		w y-r s
50								20,0 26,6	10,0 17,6 22,3	6,0 10,5 11,5		w y-r s
100								14,0 24,0 32,0	11,3 20,0 27,0	7,0 12,0 16,5		w y-r s

TABLE 23: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 100mm

RECURRENT INTERVAL in years	Time in hours	I N T E N S I T Y					mm / hr		RAINFALL REGION
		0,25	0,50	0,75	1	2			
2							10,5	5,7 6,3	winter year-round summer
5			23,0 28,0	17,7 21,6			14,0 18,0	8,0 10,7	w y-r s
10			28,0 35,0	20,6 28,0			10,0 17,0 23,2	5,8 10,0 13,2	w y-r s
20					14,3 24,7 33,3		11,7 20,0 27,0	6,7 12,0 16,3	w y-r s
50					16,7 29,4 40,0		14,0 24,5 33,0	8,2 14,5 19,5	w y-r s
100					19,3 34,7 47,5		16,5 29,0 39,0	9,2 13,0 23,5	w y-r s

TABLE 24: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 200mm

RECURRENT INTERVAL in years	Time in hours	I N T E N S I T Y					0.75 in	1 2		RAINFALL REGION
						mm / hr				
2				21.0 25.0		15.6 19.0	12.5 16.0	7.0 9.0	winter year-round summer	
5			44.8 54.0	32.6 44.0		14.7 24.7 33.4	11.7 20.0 26.5	6.6 7.8 15.5	w y-r s	
10			52.8 68.0	23.0 40.0 53.0		17.3 31.4 41.4	14.2 25.0 34.5	8.0 14.2 19.5	w y-r s	
20			62.0 84.0	27.0 48.0 66.0		21.4 36.7 49.5	17.0 30.0 40.0	9.5 13.0 23.5	w y-r s	
50			42.0 72.0 96.0	32.0 56.0 77.0		24.7 45.3 60.0	20.0 38.0 49.0	11.7 22.5 28.0	w y-r s	
100			50.0 88.0 112.0	38.0 70.0 93.0		29.4 55.5 72.0	24.0 47.5 59.0	14.0 28.0 33.5	w y-r s	

TABLE 25: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 500mm

RECURRENT INTERVAL in years	Time in hours	I N T E N S I T Y					1 2		RAINFALL REGION
		0,25	0,50	0,75	in mm / hr		1	2	
2		44,0 54,0	32,0 42,0	14,3 24,6 32,0	11,5 19,5 24,5	6,4 11,2 15,0			winter year-round summer
5		40,8 68,0 92,8	30,0 48,0 73,0	23,3 42,7 58,0	19,0 35,0 46,5	12,5 20,5 29,0			w y-r s
10		49,2 88,0 116,0	37,0 68,0 90,0	29,4 54,0 76,5	24,0 45,0 57,5	13,5 27,5 32,5			w y-r s
20		58,8 104,0 136,0	45,0 85,0 109,0	36,0 70,0 94,7	29,0 60,0 69,0	17,5 37,0 39,5			w y-r s
50		68,8 128,0 168,0	54,0 109,0 130,0	45,5 93,5 109,4	37,5 82,0 86,0	22,0 47,5 47,5			w y-r s
100		84,0 152,0 200,0	67,0 140,0 155,0	53,5 120,0 120,0	45,0 100,0 100,0	29,0 55,5 55,5			w y-r s

TABLE 26: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 750mm

RECU RRENCE INTERVAL in years	Time in hours	I N T E N S I T Y					0,75	1		RAINFALL REGION
		mm / hr								
2			52,0 66,0	22,0 37,0 50,0		17,0 30,0 40,0	14,0 24,5 33,0	8,3 14,5 19,5	winter year-round summer	
5			48,0 84,0 112,0	36,0 64,0 86,0		28,7 52,7 68,7	23,5 46,0 57,5	14,0 29,0 34,0	w y-r s	
10			58,8 104,0 140,8	4,0 84,0 116,0		36,0 70,6 85,5	30,0 62,0 70,2	18,5 40,5 42,0	w y-r s	
20			72,0 128,0 172,0	55,0 110,0 130,0		44,7 94,6 104,0	33,0 86,0 86,0	23,0 50,0 50,0	w y-r s	
50			84,0 156,0 204,0	76,0 142,0 154,0		56,0 122,8 122,8	47,5 101,0 101,0	28,7 60,5 60,5	w y-r s	
100			102,0 196,0 240,0	84,0 184,0 184,0		68,0 146,8 146,8	58,0 121,0 121,0	35,5 71,0 71,0	w y-r s	

TABLE 27: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 1000mm

RECURRENCE INTERVAL in years	Time in hours					I N T E N S I T Y			1	2	RAINFALL REGION
	0,25	0,50	0,75	in		mm / hr					
2		58,0 74,8	24,0 42,0 56,0	19,4 33,3 52,0	16,0 28,0 36,0	9,5 18,0 23,0	winter year-round summer				
5		54,0 96,0 128,0	40,0 74,0 94,0	33,3 62,6 80,0	27,5 57,5 67,5	16,0 38,0 40,0	w y-r s				
10		66,0 118,4 160,0	51,0 98,0 120,0	42,6 86,6 98,7	37,0 80,0 83,0	23,0 50,0 50,0	w y-r s				
20		80,0 148,0 192,0	63,0 130,0 148,0	53,4 117,5 117,5	46,0 100,0 100,0	28,7 60,0 60,0	w y-r s				
50		102,0 186,0 232,0	78,0 175,0 175,0	66,6 144,0 144,0	58,0 121,0 121,0	35,5 73,0 73,0	w y-r s				
100		116,0 240,0 272,0	96,0 210,0 210,0	80,0 171,0 171,0	70,0 147,0 147,0	43,5 85,0 85,0	w y-r s				

TABLE 28: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 1500mm

RECURRENT INTERVAL in years	Time in hours	I N T E N S I T Y				I mm / hr	RAINFALL REGION
		0,25	0,50	0,75	in		
2		66,0 88,0	27,6 48,0 66,0	22,0 38,7 53,4		19,0 36,5 47,5	winter year-round summer
5		62,0 110,0 150,0	46,0 90,0 112,0	37,4 77,5 90,5		36,0 76,0 82,0	w y-r s
10		76,0 140,0 188,0	58,0 120,0 140,0	50,0 113,5 113,5		47,5 103,0 103,0	w y-r s
20		92,0 176,0 224,0	74,0 160,0 168,0	63,9 137,5 137,5		58,0 122,0 122,0	w y-r s
50		112,0 230,0 268,0	92,0 200,0 200,0	90,6 165,2 165,2		73,0 147,0 147,0	w y-r s
100		141,2 304,0 320,0	114,0 240,0 240,0	97,5 196,0 196,0		84,0 176,0 176,0	w y-r s

TABLE 30: RAINFALL INTENSITIES ABSTRACTED FROM FIGURE 2 FOR REGIONS WITH M.A.P. = 2200

RECURRENT INTERVAL in years	Time in hours	I N T E N S I T Y				1 mm / hr	RAINFALL REGION
		0,25	0,50	0,75	in		
2		42,8 72,0 100,0	30,0 53,0 73,0	24,7 45,2 60,0		24,0 45,0 57,0	winter year-round summer
5		68,0 126,0 168,0	52,0 104,0 126,0	45,2 93,4 102,7		45,0 98,0 98,0	w y-r s
10		88,0 162,0 212,0	68,0 144,0 156,0	57,4 126,7 126,7		58,0 120,0 120,0	w y-r s
20		104,0 208,0 252,0	86,0 188,0 188,0	73,4 152,0 152,0		74,0 147,0 147,0	w y-r s
50		132,0 270,0 300,0	106,0 222,0 222,0	91,5 187,0 187,0		110,0 119,0 178,0	w y-r s
100		160,0 352,0 352,0	130,0 270,0 270,0	112,0 220,0 220,0		110,0 210,0 210,0	w y-r s

Fig. 12: Plot of intensity vs. duration for summer winter and year-round Rainfall Regions.

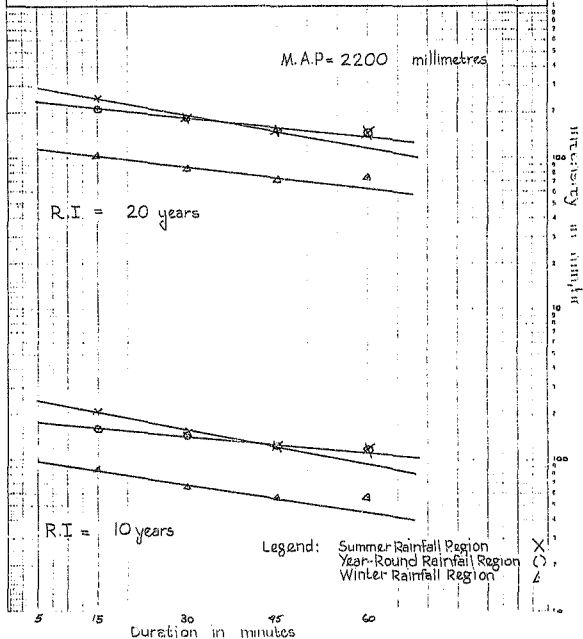


Fig 13: Plot of intensity vs. duration for Summer
Winter and year-round Rainfall Regions:

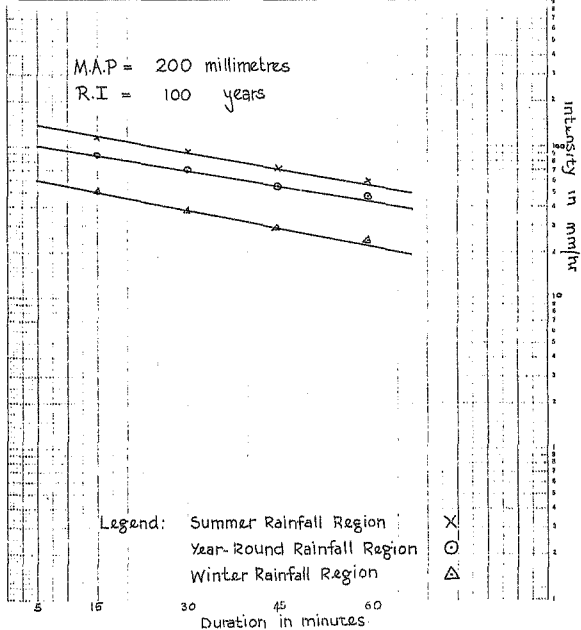
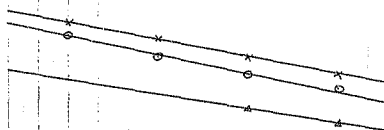


Fig 14: Plot of intensity vs. duration for summer winter and year-round Rainfall Regions

M.A.P = 500 millimetres
R.I = 2 years



Legend: Summer Rainfall Region X
Year-Round Rainfall Region O
Winter Rainfall Region Δ

Duration in minutes

APPENDIX BDERIVATION OF THE NUMERICAL INTEGRATION EQUATION FOR SPATIALLY VARIED FLOW

In deriving the numerical integration equation the assumptions are as outlined in Chapter 3, page 19 and the flow situation is as shown in Figure 7.

Consider Figure 7. Energy losses are high and thus momentum considerations are applied. Consider the momentum per unit time or momentum flux passing section 1. This equals QV where Q and V are the discharge and average velocity at section 1. Or written in another form $\frac{\gamma}{g} V Q$

Similarly the momentum flux at section 2 is $\frac{\gamma}{g} (Q + dQ)(V + dV)$ where dQ and dV are the changes in discharge and velocity between sections 1 and 2. The change of momentum flux between sections 1 and 2 is thus:-

$$\frac{\gamma}{g} (Q + dQ)(V + dV) - \frac{\gamma}{g} QV = \frac{\gamma}{g} (QdV + (V + dV)dQ)$$

This rate of change of momentum is, according to Newton II, equated to the forces causing it. These forces are the frictional force F_f , the pressure forces F_1 and F_2 and the component of the sections own weight in the direction of flow, W^1 .

The values of these forces are as follows:

Let W be the weight of the body of water between the sections. Then the component of W in the flow direction is $W \sin \theta$, where

θ = channel slope and $W \sin \theta = (A + \frac{1}{2}dA)dx$, So

i.e. $W^1 \approx \gamma A dx$. So

where $So = \tan \theta \approx \sin \theta$ and 2nd order terms are neglected.

The drop in friction head between the two sections is equal to the slope of the energy line, S_f , multiplied by the section length, dx , or $hf = S_f \cdot dx$ where S_f may, by assumption, be evaluated by the Manning equation as

$$S_f = \frac{V_n^2}{R^{4/3}} = \frac{\bar{Q}_n^2}{A^2 R^{4/3}} \quad \text{where the bar refers to mean values.}$$

The frictional force along the channel floor, F_f , is then equal to the equivalent pressure due to the friction head loss multiplied by the average area.

$$\begin{aligned} \text{i.e. } F_f &= hf \gamma (A + \frac{1}{2}dA) \\ &= S_f \cdot dx \cdot \gamma \cdot (A + \frac{1}{2}dA) \end{aligned}$$

neglecting 2nd order terms $F_f = S_f \cdot dx \cdot \gamma \cdot A$ where S_f is as shown above.

The pressure force on section 1, F_1 , is the pressure at the centroid of section 1 multiplied by the area. Similarly the pressure force on section 2, F_2 , is the pressure at the centroid of section 2 multiplied by the area of section 2. (see Fig.15 below).

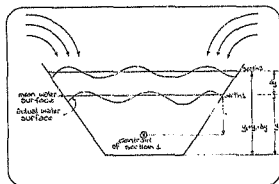


Fig.15: Section of channel with unequally varied flow

Thus $F_1 = \bar{z} A \gamma$

$$F_2 = \gamma (\bar{z} + dy) A + \frac{\gamma}{2} dA dy$$

or neglecting 2nd order terms

$$F_2 = \gamma (\bar{z} + dy) A$$

The resultant hydrostatic pressure force acting on the free body

between sections 1 and 2 is thus: $F_1 - F_2 = -\gamma A dy$

Applying Newton II to the free body gives:

$$\begin{aligned} \frac{\gamma}{g} (QdV + dQ(V + dV)) &= F_1 - F_2 - W^1 + FF \\ &= -\gamma A dy - \gamma A dx So + Sfdx \gamma A \end{aligned}$$

Considering the differentials as small finite increments, the

equation may be rewritten:-

$$\begin{aligned} \frac{\gamma}{g} (Q \Delta V + \Delta Q(V + \Delta V)) &= -\gamma \int A dy - \gamma So \int A dx + \gamma Sf \int A dx \\ &= -\gamma \bar{A} \Delta y - \gamma So \bar{A} \Delta x + \gamma Sf \bar{A} \Delta x \end{aligned}$$

where $\bar{A}$ is the average area.

Since the discharge varies with the finite increment of the

channel length, the average area may be taken as:-

$$\bar{A} = \frac{Q_1 + Q_2}{V_1 + V_2}$$

Also $V_2 = V_1 + \Delta V$

Thus $\frac{\gamma}{g} (Q_1 \Delta V + \Delta Q V_2) = -\gamma \bar{A} \Delta y - \gamma So \bar{A} \Delta x + \gamma Sf \bar{A} \Delta x$

i.e. $\Delta y = -So \Delta x + Sf \Delta x - \frac{1}{\bar{A}g} (Q_1 \Delta V + \Delta Q V_2)$

i.e. $\Delta y = -So \Delta x + Sf \Delta x - \frac{(Q_1 \Delta V + \Delta Q V_2)}{\left(\frac{Q_1 + Q_2}{V_1 + V_2} \right) \cdot g}$

$$\text{Thus } \Delta y = -S_o \Delta x + S_f \Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2} \right) \frac{Q_1}{g} \left(\Delta V + \Delta Q \frac{V_2}{Q_1} \right)$$

Referring to Fig.7, it is seen that the change in water surface elevation between sections 1 and 2 is given by:-

$$\begin{aligned} dy^1 &= y_2 + S_o dx - y_1 \\ &= S_o dx + dy \end{aligned}$$

When dy^1 is the increase in depth from 1 to 2

Converting to finite increments:

$$\Delta y^1 = S_o \Delta x + \Delta y$$

Substituting for Δy in the equation for Δy above and introducing the energy correction factor for non-uniform velocity distribution α , gives:-

$$\Delta y^1 = S_f \Delta x - \left(\frac{V_1 + V_2}{Q_1 + Q_2} \right) \alpha \frac{Q_1}{g} \left(\Delta V + \Delta Q \frac{V_2}{Q_1} \right)$$

This equation is the numerical equation used to determine the water surface profile in a spatially varied flow situation. On the right hand side of the equation, the first term represents the effects of friction, while the second term represents the effects of impact loss, turbulence etc.

APPENDIX CDETAILS OF ALL COMPUTER PROGRAMMES USED

PROGRAMME TO CALCULATE THE END DEPTH IN
HALF-ROUND GUTTERS

NAME: GUT 2

OBJECT: To calculate the end depth in half-round gutters

INPUTS: Gutter radius R

Output code K

Gutter length X

Gutter discharge rate Q

OUTLINE OF COMPUTATIONAL METHOD:

The end depth is equal to 0.715 times the critical
depth. The critical depth is found using the identity:-

$$\frac{Q^2 B}{g A^3} = 1 \quad \text{when flow is critical}$$

$$\text{i.e.} \quad \frac{V_{cr}^2}{g} = \frac{A}{B} = Y_m \quad \dots \quad \text{C.1}$$

where V_{cr} = critical velocity

A = area of flow

B = width of water surface

Y_m = mean flow depth

To determine the critical depth, an estimate of the
critical depth is made and equation C.1 checked. If the two
sides of the equation are not to within the specified accuracy,
the critical depth is re-estimated and the process repeated
until the required accuracy is obtained.

OUTPUTS: Output Code $K \neq 1$ - the values of the variables after each iteration are printed out

Output Code $K = 1$ - the final results are printed out. The critical depth, end depth, and values of $Vcr^{2/g}$ and Ym are printed out.

Calibration of Programme

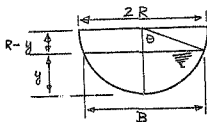
The following variables were found, by trial and error, to give the best results;

- (i) Initial estimate of flow depth $\left(\frac{Q^2}{(0,66R)^2 g} \right)^{0,333}$
- (ii) Accuracy limits of equation - 0,001 metres
- (iii) Increments to initial estimate of depth - 0,001 metres

Limits Placed on Programme

If the number of iterations exceeds 40 the programme stops.

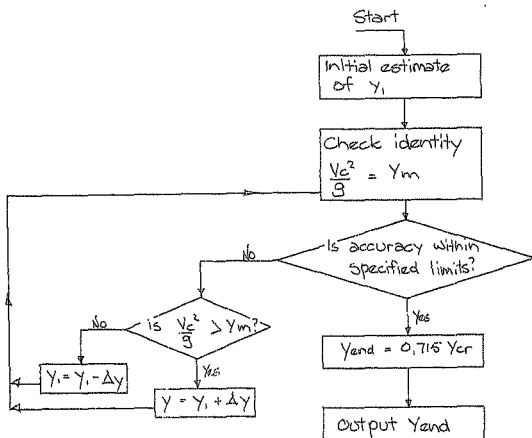
Geometry and Symbols



$$\theta = \cos^{-1} \left(\frac{R - Y}{R} \right)$$

$$B = 2R \sin \theta$$

$$A = \frac{1}{2} R^2 (2\theta^\circ - \sin 2\theta^\circ)$$

FLOW CHART FOR GUT. 2

PROGRAMME TO CALCULATE THE WATER SURFACE
PROFILE IN HALF-ROUND GUTTERS

NAME: GUT 3

OBJECT: To calculate the water surface profile in half-round
gutters, given the depth and discharge rate at outlet.

Inputs:	Gutter radius	R
	Number of stations	NT
	Output code	K
	Gutter length	X
	Increment to estimated depth if required accuracy is not obtained	DEL
	Limits within which the estimated and calculated flow depths must agree	ACC
	Discharge rate at outlet	Q(1)
	Flow depth at outlet	Y(1,1)

Outline of Computational Method

The depth at the outlet (station 1) is given. An estimate of the change in flow depth from station one to two is made. Using the estimated flow depth at station two and the Hinds equation, the change in flow depth from station one to two is calculated. The estimated and calculated flow depths are compared. If they do not agree to the specified accuracy, the change in flow depth from one to two is re-estimated and the process repeated until the required accuracy is obtained. This will define the flow depth at station two.

This iterative process is then repeated from station two to three etc., until the water surface profile in the gutter is defined.

OUTPUTS:

Code ~~K=1~~ - the values of every iteration at every station are printed out

Code $K = 1$ - the final values at each station are given.

These include:

Station number	N
distance upstream from downpipe	DISDP(N)
discharge rate at station	Q(N)
calculated increment in depth from previous station	DELY(N,J)
assumed increment in depth from previous station	DELYAS(N,J)
flow depth	Y(N,J)

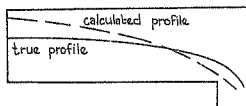
Limits placed on programme

The maximum number of iterations at any station is forty

Problems associated with programme and calibration of variables:

The programme was found to be very sensitive to the relative values of the accuracy limit (ACC) and the depth increment (DEL); If the depth increment value was much larger than the accuracy limit, the programme 'jumped' past the true depth value without the estimated and calculated depths agreeing to the specified

accuracy. The programme then oscillated about this value, never converging. On the other hand if the depth increment value was much smaller than the accuracy limit the following occurred: After about four stations the estimated depth was always greater than the true depth, thus the programme always converged on the true water surface profile from the upper side. If the depth increment value was much smaller than the accuracy value, the calculated water surface profile always lay slightly above the true profile. The error incurred at each station accumulated, resulting in an overestimate of peak depth of about 20 percent. This situation is sketched below



Thus a careful balance had to be maintained between the depth increment and accuracy values. It was found that both the above effects were eliminated if the depth increment was twice the accuracy value ($DEL = 2 \times ACC$). This allowed convergence and also caused the calculated water surface profile to oscillate on either side of the true profile preventing accumulation of error.

The values that gave best results were

$DEL = 0,001$ metres

$ACC = 0,0005$ metres

Number of Stations

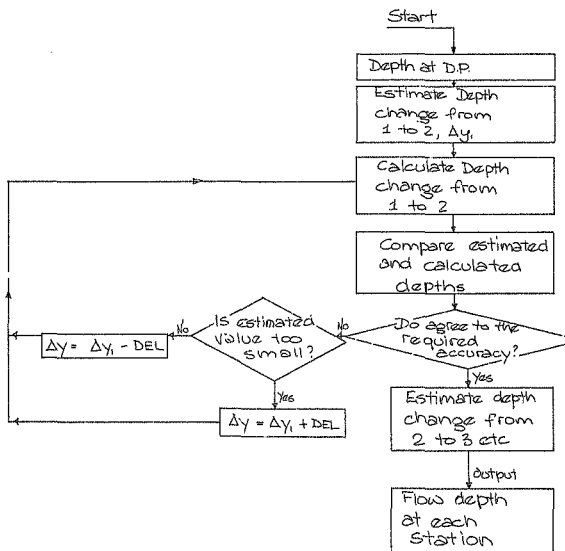
NT = 20 or more, but 20 is adequate

Geometry and Symbols

as for GUT 2

FLOW CHART FOR GUT. 3

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Results of GUT 3 for half-round gutters starting
with end depth Ye, at the outlet

```

gutter radius=.076200
gutter length=.090000
outflow at d.p.=.0013540
no.of stations= 21      del=.0010acc=.0005depth at d.p.=.023500
station no.  disdp  disch  dely  delyas  y
2      .305  .001296  .030823  .031000  .054500
3      .610  .001228  .000900  .001000  .055500
4      .914  .001159  .000743  .001000  .056500
5      1.219  .001091  .000683  .001000  .057500
6      1.524  .001023  .000593  .001000  .058500
7      1.829  .000955  .000513  .001000  .059500
8      2.134  .000887  .000408  *.000000  .059500
9      2.438  .000818  .000370  *.000000  .059500
10     2.743  .000750  .000334  *.000000  .059500
11     3.048  .000682  .000298  *.000000  .059500
12

```

```

gutter radius=.076200
gutter length=.090000
outflow at d.p.=.0018180
no.of stations= 21      del=.0010acc=.0005depth at d.p.=.027000
station no.  disdp  disch  dely  delyas  y
2      .305  .001727  .036251  .036000  .063000
3      .610  .001636  .001020  .001000  .064000
4      .914  .001545  .000839  .001000  .065000
5      1.219  .001454  .000791  .001000  .066000
6      1.524  .001363  .000694  .001000  .067000
7      1.829  .001273  .000607  .001000  .068000
8      2.134  .001182  .000529  .001000  .068999
9      2.438  .001091  .000429  *.000000  .068999
10     2.743  .001000  .000387  *.000000  .068999
11     3.048  .000909  .000347  *.000000  .068999
12     3.353  .000818  .000307  *.000000  .068999
13     3.658  .000727  .000270  *.000000  .068999
14

```

```

gutter radius=.076200
gutter length=.090000
outflow at d.p.=.0022750
no.of stations= 21      del=.0010acc=.0005depth at d.p.=.030300
station no.  disdp  disch  dely  delyas  y
2      .305  .002153  .040299  .040000  .070300
3      .610  .002046  .001147  .001000  .071300
4      .914  .001932  .001019  .001000  .072300
5      1.219  .001818  .000904  .001000  .073300
6      1.524  .001705  .000793  .001000  .074300
7      1.829  .001591  .000703  .001000  .075300
8      2.134  .001477  .000617  .001000  .076299
9      2.438  .001364  .000538  .001000  .077299
10     2.743  .001250  .000442  *.000000  .077299
11     3.048  .001136  .000396  *.000000  .077299
12     3.353  .001023  .000352  *.000000  .077299
13     3.658  .000909  .000309  *.000000  .077299
14

```

Results of GUT 3 for half-round gutters starting
with critical depth at outlet and $n = 0.014$

gutter radius = .076220
gutter length = 6.000000
outflow at $d, n = .000540$
no. of stations = 21
date = 00100000 = .0005 length at $d, n = .018700$

station no.	h ₁	h ₂	h ₃	h ₄	h ₅
2	.105	.000432	.000446	.000500	.024700
3	.079	.000407	.000421	.000400	.026700
4	.054	.000386	.000400	.001000	.027700
5	1.117	.000504	.000612	.001000	.028700
6	1.524	.000541	.000647	.001000	.029700
7	1.823	.000513	.000510	.001000	.030700
8	2.174	.000235	.000374	*.001000	.030700
9	2.478	.000273	.000354	*.000000	.030700
10	2.747	.000280	.000297	*.000000	.030700
11	3.040	.000227	.000262	*.000000	.030700
12	3.253	.000225	.000228	*.000000	.030700
13	3.450	.000136	.000136	*.000000	.030700
14	3.623	.000134	.000136	*.000000	.030700
15	3.787	.000136	.000137	*.000000	.030700
16	3.972	.000136	.000132	*.000000	.030700
17	4.177	.000131	.000137	*.000000	.030700
18	4.382	.000000	.000000	*.000000	.030700
19	4.586	.000000	.000000	*.000000	.030700
20	4.791	.000000	.000000	*.000000	.030700
21	4.996	.000000	.000000	*.000000	.030700

no. of times that h₁ follows st. h₁ = 5
5.55 3.00 + 2.55

gutter radius = .076220
gutter length = 6.000000
outflow at $d, n = .000540$
no. of stations = 21
date = 00100000 = .0005 length at $d, n = .026400$

station no.	h ₁	h ₂	h ₃	h ₄	h ₅
2	.105	.000084	.000567	.000000	.034400
3	.079	.000110	.000730	.000000	.036400
4	.054	.000773	.001529	.000200	.036400
5	1.117	.000727	.001749	.000100	.034400
6	1.524	.000502	.000200	.001000	.044400
7	1.823	.000630	.000777	.001000	.041400
8	2.174	.000701	.000514	.001000	.042400
9	2.478	.000536	.000510	.001000	.043400
10	2.747	.000500	.000507	*.000000	.043400
11	3.040	.000456	.000543	*.000000	.043400
12	3.253	.000309	.000500	*.000000	.043400
13	3.450	.000284	.000222	*.000000	.043400
14	3.623	.000312	.000224	*.000000	.043400
15	3.787	.000273	.000330	*.000000	.043400
16	3.972	.000227	.000354	*.000000	.043400
17	4.177	.000132	.000132	*.000000	.043400
18	4.382	.000136	.000132	*.000000	.043400
19	4.586	.000000	.000000	*.000000	.043400
20	4.791	.000000	.000000	*.000000	.043400
21	4.996	.000000	.000000	*.000000	.043400

no. of times that h₁ follows st. h₁ = 0
5.57 3.00 + 2.57

Results of GUT 3 for half-round gutters starting
with critical depth at outlet and $n = 0.016$

```

gutter fullness .97500
gutter length= .05000
outflow at l.p.= .004500
no. of stations 11
      station no.      High      Low      Depth      Delay      y
1      .000      .000000      .000000      .000000      .024700
2      .005      .000000      .000000      .000000      .024700
3      .010      .000000      .000000      .000000      .024700
4      .015      .000000      .000000      .000000      .024700
5      .020      .000000      .000000      .000000      .024700
6      .025      .000000      .000000      .000000      .024700
7      .030      .000000      .000000      .000000      .024700
8      .035      .000000      .000000      .000000      .024700
9      .040      .000000      .000000      .000000      .024700
10     .045      .000000      .000000      .000000      .024700
11     .050      .000000      .000000      .000000      .024700

```

```

gutter fullness .97500
gutter length= .05000
outflow at l.p.= .004500
no. of stations 11
      station no.      High      Low      Depth      Delay      y
1      .000      .000000      .000000      .000000      .024700
2      .005      .000000      .000000      .000000      .024700
3      .010      .000000      .000000      .000000      .024700
4      .015      .000000      .000000      .000000      .024700
5      .020      .000000      .000000      .000000      .024700
6      .025      .000000      .000000      .000000      .024700
7      .030      .000000      .000000      .000000      .024700
8      .035      .000000      .000000      .000000      .024700
9      .040      .000000      .000000      .000000      .024700
10     .045      .000000      .000000      .000000      .024700
11     .050      .000000      .000000      .000000      .024700

```

cutter rollage .03200
 cutter lap-thick .00500
 outflow at 1.0 = .001300
 no. of stations 11
 hole .001000 = .0005 depth at d.p. = .03200

station no.	hole	depth	only	only	y
1	1.000	.001000	.000500	.000000	.041000
2	1.000	.001000	.000500	.000000	.044000
3	1.000	.001000	.000500	.000000	.046000
4	1.000	.001000	.000500	.000000	.047000
5	1.000	.001000	.000500	.000000	.047000
6	1.000	.001000	.000500	.000000	.047000
7	1.000	.001000	.000500	.000000	.047000
8	1.000	.001000	.000500	.000000	.050000
9	1.000	.001000	.000500	.000000	.051000
10	1.000	.001000	.000500	.000000	.052000
11	1.000	.001000	.000500	.000000	.052000
12	1.000	.001000	.000500	.000000	.052000
13	1.000	.001000	.000500	.000000	.052000

cutter rollage .03200
 cutter lap-thick .00500
 outflow at 1.0 = .001300
 no. of stations 11
 hole .001000 = .0005 depth at d.p. = .03200

station no.	hole	depth	only	only	y
1	1.000	.001000	.000500	.000000	.047000
2	1.000	.001000	.000500	.000000	.050000
3	1.000	.001000	.000500	.000000	.050000
4	1.000	.001000	.000500	.000000	.050000
5	1.000	.001000	.000500	.000000	.050000
6	1.000	.001000	.000500	.000000	.050000
7	1.000	.001000	.000500	.000000	.050000
8	1.000	.001000	.000500	.000000	.050000
9	1.000	.001000	.000500	.000000	.050000
10	1.000	.001000	.000500	.000000	.050000
11	1.000	.001000	.000500	.000000	.050000

PROGRAMME TO FIND THE WATER SURFACE PROFILE
IN RECTANGULAR GUTTERS

NAME: GUT 6

OBJECT: To determine the water surface profile in rectangular
gutters given the discharge rate at outlet

Inputs: Base breadth B

The remaining inputs - as for GUT 3

Outline of Programme

The programme is the same as GUT 3 except that the starting
depth at station one (equal to the critical depth) is calculated
by the programme

General

All other facets of this programme are the same as GUT 3

Results of GUT 6 for channel with $B = 0.229m$ and $x = 1.716m$ and $n = 0.014$

		Y	
/out 17	1.933	0.0000	0.0000
	1.934	0.0000	0.0000
	1.935	0.0000	0.0000
	1.936	0.0000	0.0000
number of times that delay is greater than delay = 1		0.0000	0.0000
/out 17	1.933	0.0000	0.0000
	1.934	0.0000	0.0000
	1.935	0.0000	0.0000
	1.936	0.0000	0.0000
number of times that delay is greater than delay = 1		0.0000	0.0000
/out 17	1.933	0.0000	0.0000
	1.934	0.0000	0.0000
	1.935	0.0000	0.0000
	1.936	0.0000	0.0000
number of times that delay is greater than delay = 1		0.0000	0.0000
/out 33	1.933	0.0000	0.0000
	1.934	0.0000	0.0000
	1.935	0.0000	0.0000
	1.936	0.0000	0.0000
number of times that delay is greater than delay = 1		0.0000	0.0000

PROGRAMME TO DETERMINE THE DESIGN DEPTH
IN RECTANGULAR GUTTERS

NAME: CRECTI

OBJECT To estimate the design depth in rectangular gutters
for various gutter lengths and inflow rates

Checks

The validity of the programme was checked by comparing the peak depths with those calculated by GUT 6. Both these peak depths were compared with the Li experimental peak depths. See

Table 31

Inputs:	Gutter base breadth	B
	Number of stations	NT
	Output code	K
	Inflow per unit length to gutter	INF
	Gutter length	X

Outline of Programme

For particular inflow and length values, the critical depth at outlet is calculated. This is used as the starting depth in the Hinds analysis. The water surface profile in the gutter is calculated in the manner discussed in Appendix B. (i.e. the same approach as adopted in GUT 3). Once the water surface profile has been calculated, the upstream depth is abstracted. This is the peak depth and the design depth is obtained by adding the freeboard to it. A rough check on the design depth so calculated is obtained by multiplying the critical depth

by $\sqrt{3}$ (for an explanation see Chapter 6).

Outputs:

Code K = 1 - values of all variables after every iteration
at every station are given

Code K = 2 - final values of variables and flow depths
are given at each station

Code K > 2 - the values at the last upstream station are
given. These include;

Gutter length	X
critical flow depth	Y(1,1)
$\sqrt{3}$ times critical flow depth	YUPS
peak flow depth	Y(NT,J)
peak flow area	A(NT,J)
design flow depth	YFIN
design flow area	AFIN

Limits placed on programme

The maximum number of iterations at any station is 40.

Problems associated with programme

Some problems as for GUT 3 and in addition a further problem occurred when analysing large gutters with large inflow rates. In such gutters the depth change between stations at the first few stations is large. If the values of accuracy bounds (ACC) and assumed depth increment (DEL) as used for smaller gutters are used with these large gutters, the programme will not converge in 40 iterations. Hence;

for gutters of base breadth greater than

0,3m use

ACC = 0,001metres

DEL = 0,002metres

for smaller gutters use

ACC = 0,0005 metres

DEL = ,001 metres

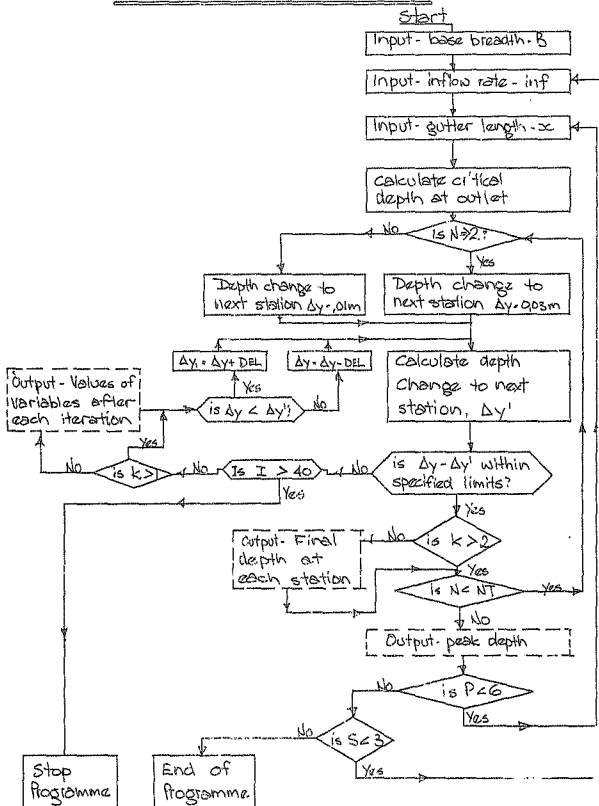
In all instances it was found that twenty one stations gave
adequate results, i.e. NT = 21.

TABLE 31: COMPARISON OF LI'S RESULTS WITH OUTPUTS
OF GUT 6 AND CRECTI

CHANNEL LENGTH in metres	DISCHARGE RATE m^3/s	PEAK DEPTH AFTER LI in metres	PEAK DEPTH FROM GUT 6 in metres	PEAK DEPTH FROM CRECTI in metres
2,286	0,06060	0,3383	0,3366	0,3365
2,286	0,08665	0,4267	0,4274	0,4279
1,716	0,02492	0,1890	0,1865	0,1864
1,335	0,05380	0,3353	0,3099	0,3114

FLOW CHART FOR CRECT 1

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PTC ACCT 3 DEPT 3F CIVIL ENG FILE ACCL9 TYP 14/2/74 (74-045) TIME 21.32

 * RECTANGULAR CUTTER OF BASE .10TH= .1000 M *

INFLD= PER UNIT LENGTH OF CUTTER= .005000 CU.M/S.

CUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	RAD DEPTH	RAD AREA
3.000	.13184	.22452	.23430	.2238577	* .27471	.0274708
3.000	.13184	.22452	.23430	.2238577	* .39429	.0394290
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						

INFLD= PER UNIT LENGTH OF CUTTER= .001000 CU.M/S.

CUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	RAD DEPTH	RAD AREA
3.000	.07816	.08310	.08310	.2093121	* .09257	.0092556
3.000	.07816	.08310	.08310	.2093121	* .13616	.0136139
3.000	.07816	.08310	.08310	.2093121	* .26806	.0268058
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2						

INFLD= PER UNIT LENGTH OF CUTTER= .000500 CU.M/S.

CUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	RAD DEPTH	RAD AREA
3.000	.02841	.04924	.05241	.2524212	* .06227	.0062274
3.000	.02841	.04924	.05241	.2524212	* .08733	.0087329
3.000	.02841	.04924	.05241	.2524212	* .10674	.0106739
3.000	.02841	.04924	.05241	.2524212	* .12615	.0126153
3.000	.02841	.04924	.05241	.2524212	* .14556	.0145567
3.000	.02841	.04924	.05241	.2524212	* .16497	.0164971
3.000	.02841	.04924	.05241	.2524212	* .18438	.0184385
3.000	.02841	.04924	.05241	.2524212	* .20379	.0203791
3.000	.02841	.04924	.05241	.2524212	* .22320	.0223203
3.000	.02841	.04924	.05241	.2524212	* .24261	.0242616
3.000	.02841	.04924	.05241	.2524212	* .26202	.0262021
3.000	.02841	.04924	.05241	.2524212	* .28143	.0281431
3.000	.02841	.04924	.05241	.2524212	* .30084	.0300836
3.000	.02841	.04924	.05241	.2524212	* .32025	.0320241
3.000	.02841	.04924	.05241	.2524212	* .33966	.0339647
3.000	.02841	.04924	.05241	.2524212	* .35907	.0359053
3.000	.02841	.04924	.05241	.2524212	* .37848	.0378459
3.000	.02841	.04924	.05241	.2524212	* .39789	.0397865
3.000	.02841	.04924	.05241	.2524212	* .41730	.0417311
3.000	.02841	.04924	.05241	.2524212	* .43671	.0436717
3.000	.02841	.04924	.05241	.2524212	* .45612	.0456123
3.000	.02841	.04924	.05241	.2524212	* .47553	.0475529
3.000	.02841	.04924	.05241	.2524212	* .49494	.0494935
3.000	.02841	.04924	.05241	.2524212	* .51435	.0514341
3.000	.02841	.04924	.05241	.2524212	* .53376	.0533747
3.000	.02841	.04924	.05241	.2524212	* .55317	.0553153
3.000	.02841	.04924	.05241	.2524212	* .57258	.0572559
3.000	.02841	.04924	.05241	.2524212	* .59199	.0591965
3.000	.02841	.04924	.05241	.2524212	* .61140	.0611371
3.000	.02841	.04924	.05241	.2524212	* .63081	.0630827
3.000	.02841	.04924	.05241	.2524212	* .65022	.0650233
3.000	.02841	.04924	.05241	.2524212	* .66963	.0669639
3.000	.02841	.04924	.05241	.2524212	* .68904	.0689045
3.000	.02841	.04924	.05241	.2524212	* .70845	.0708451
3.000	.02841	.04924	.05241	.2524212	* .72786	.0727857
3.000	.02841	.04924	.05241	.2524212	* .74727	.0747263
3.000	.02841	.04924	.05241	.2524212	* .76668	.0766669
3.000	.02841	.04924	.05241	.2524212	* .78609	.0786075
3.000	.02841	.04924	.05241	.2524212	* .80550	.0805481
3.000	.02841	.04924	.05241	.2524212	* .82491	.0824887
3.000	.02841	.04924	.05241	.2524212	* .84432	.0844293
3.000	.02841	.04924	.05241	.2524212	* .86373	.0863700
3.000	.02841	.04924	.05241	.2524212	* .88314	.0883106
3.000	.02841	.04924	.05241	.2524212	* .90255	.0902512
3.000	.02841	.04924	.05241	.2524212	* .92196	.0921918
3.000	.02841	.04924	.05241	.2524212	* .94137	.0941324
3.000	.02841	.04924	.05241	.2524212	* .96078	.0960730
3.000	.02841	.04924	.05241	.2524212	* .98019	.0980136
3.000	.02841	.04924	.05241	.2524212	* .99960	.0999542
3.000	.02841	.04924	.05241	.2524212	* .10000	.1000000

PFC ACCT 3 DEPT 3F CIVIL E/G FILE REC/OS WES 13/7/74 14-041 TIME 12-23

 * RECTANGULAR GUTTER OF BASE WIDTH= 2070 M *
 * *****

INFLOW PER UNIT LENGTH OF GUTTER= .05390 CU-M/3-

GUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	ROD DEPTH	ROD AREA
3-700	.05910	.10542	.10510	.0210398	.12286	.0241127
5-900	.08369	.14397	.15108	.0321254	.17374	.0347477
10-200	.11721	.26848	.23968	.0551815	.27161	.0576157
20-900	.20834	.56578	.49234	.0864586	.56261	.0915359
25-900	.24282	.82537	.67392	.0967340	.64501	.1039015

INFLOW PER UNIT LENGTH OF GUTTER= .08000 CU-M/3-

GUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	ROD DEPTH	ROD AREA
3-700	.01273	.02207	.02375	.057465	.02729	.0045894
5-900	.03780	.03502	.03940	.0077797	.03898	.0077966
10-200	.06723	.06452	.07423	.0152459	.08765	.0175328
20-900	.09510	.07816	.09410	.0188231	.10822	.0216431
25-900	.09234	.09970	.11135	.0228670	.12893	.0254801

INFLOW PER UNIT LENGTH OF GUTTER= .08000 CU-M/3-

GUTTER LENGTH	CRIT DEPTH	YOPS	PEAK DEPTH	AREA	ROD DEPTH	ROD AREA
3-700	.00563	.00563	.00665	.0015712	.00903	.0016068
5-900	.01061	.01061	.01412	.0028242	.01624	.0032478
10-200	.01800	.01800	.02372	.0051812	.02187	.0053776
20-900	.01486	.01486	.02472	.0044933	.02892	.0058696

NUM ITERATIONS AT STATION NO.= 2

NO CONVERGENCE


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*****
* rectangular gutter of base of 0.4m  .3530 m x 2
*
*****

inlet per unit length of gutter  .01136 cm/s.
*****
water length  width  area  wet length  wet area
1.000  .2100  .2100  .2100  .2100
2.000  .2100  .4200  .4200  .4200
3.000  .2100  .6300  .6300  .6300
4.000  .2100  .8400  .8400  .8400
5.000  .2100  1.0500  1.0500  1.0500
6.000  .2100  1.2600  1.2600  1.2600
7.000  .2100  1.4700  1.4700  1.4700
8.000  .2100  1.6800  1.6800  1.6800
9.000  .2100  1.8900  1.8900  1.8900
10.000  .2100  2.1000  2.1000  2.1000
11.000  .2100  2.3100  2.3100  2.3100
12.000  .2100  2.5200  2.5200  2.5200
13.000  .2100  2.7300  2.7300  2.7300
14.000  .2100  2.9400  2.9400  2.9400
15.000  .2100  3.1500  3.1500  3.1500
16.000  .2100  3.3600  3.3600  3.3600
17.000  .2100  3.5700  3.5700  3.5700
18.000  .2100  3.7800  3.7800  3.7800
19.000  .2100  3.9900  3.9900  3.9900
20.000  .2100  4.2000  4.2000  4.2000
21.000  .2100  4.4100  4.4100  4.4100
22.000  .2100  4.6200  4.6200  4.6200
23.000  .2100  4.8300  4.8300  4.8300
24.000  .2100  5.0400  5.0400  5.0400
25.000  .2100  5.2500  5.2500  5.2500
26.000  .2100  5.4600  5.4600  5.4600
27.000  .2100  5.6700  5.6700  5.6700
28.000  .2100  5.8800  5.8800  5.8800
29.000  .2100  6.0900  6.0900  6.0900
30.000  .2100  6.3000  6.3000  6.3000
31.000  .2100  6.5100  6.5100  6.5100
32.000  .2100  6.7200  6.7200  6.7200
33.000  .2100  6.9300  6.9300  6.9300
34.000  .2100  7.1400  7.1400  7.1400
35.000  .2100  7.3500  7.3500  7.3500
36.000  .2100  7.5600  7.5600  7.5600
37.000  .2100  7.7700  7.7700  7.7700
38.000  .2100  7.9800  7.9800  7.9800
39.000  .2100  8.1900  8.1900  8.1900
40.000  .2100  8.4000  8.4000  8.4000
41.000  .2100  8.6100  8.6100  8.6100
42.000  .2100  8.8200  8.8200  8.8200
43.000  .2100  9.0300  9.0300  9.0300
44.000  .2100  9.2400  9.2400  9.2400
45.000  .2100  9.4500  9.4500  9.4500
46.000  .2100  9.6600  9.6600  9.6600
47.000  .2100  9.8700  9.8700  9.8700
48.000  .2100  10.0800  10.0800  10.0800
49.000  .2100  10.2900  10.2900  10.2900
50.000  .2100  10.5000  10.5000  10.5000
51.000  .2100  10.7100  10.7100  10.7100
52.000  .2100  10.9200  10.9200  10.9200
53.000  .2100  11.1300  11.1300  11.1300
54.000  .2100  11.3400  11.3400  11.3400
55.000  .2100  11.5500  11.5500  11.5500
56.000  .2100  11.7600  11.7600  11.7600
57.000  .2100  11.9700  11.9700  11.9700
58.000  .2100  12.1800  12.1800  12.1800
59.000  .2100  12.3900  12.3900  12.3900
60.000  .2100  12.6000  12.6000  12.6000
61.000  .2100  12.8100  12.8100  12.8100
62.000  .2100  13.0200  13.0200  13.0200
63.000  .2100  13.2300  13.2300  13.2300
64.000  .2100  13.4400  13.4400  13.4400
65.000  .2100  13.6500  13.6500  13.6500
66.000  .2100  13.8600  13.8600  13.8600
67.000  .2100  14.0700  14.0700  14.0700
68.000  .2100  14.2800  14.2800  14.2800
69.000  .2100  14.4900  14.4900  14.4900
70.000  .2100  14.7000  14.7000  14.7000
71.000  .2100  14.9100  14.9100  14.9100
72.000  .2100  15.1200  15.1200  15.1200
73.000  .2100  15.3300  15.3300  15.3300
74.000  .2100  15.5400  15.5400  15.5400
75.000  .2100  15.7500  15.7500  15.7500
76.000  .2100  15.9600  15.9600  15.9600
77.000  .2100  16.1700  16.1700  16.1700
78.000  .2100  16.3800  16.3800  16.3800
79.000  .2100  16.5900  16.5900  16.5900
80.000  .2100  16.8000  16.8000  16.8000
81.000  .2100  17.0100  17.0100  17.0100
82.000  .2100  17.2200  17.2200  17.2200
83.000  .2100  17.4300  17.4300  17.4300
84.000  .2100  17.6400  17.6400  17.6400
85.000  .2100  17.8500  17.8500  17.8500
86.000  .2100  18.0600  18.0600  18.0600
87.000  .2100  18.2700  18.2700  18.2700
88.000  .2100  18.4800  18.4800  18.4800
89.000  .2100  18.6900  18.6900  18.6900
90.000  .2100  18.9000  18.9000  18.9000
91.000  .2100  19.1100  19.1100  19.1100
92.000  .2100  19.3200  19.3200  19.3200
93.000  .2100  19.5300  19.5300  19.5300
94.000  .2100  19.7400  19.7400  19.7400
95.000  .2100  19.9500  19.9500  19.9500
96.000  .2100  20.1600  20.1600  20.1600
97.000  .2100  20.3700  20.3700  20.3700
98.000  .2100  20.5800  20.5800  20.5800
99.000  .2100  20.7900  20.7900  20.7900
100.000  .2100  21.0000  21.0000  21.0000
101.000  .2100  21.2100  21.2100  21.2100
102.000  .2100  21.4200  21.4200  21.4200
103.000  .2100  21.6300  21.6300  21.6300
104.000  .2100  21.8400  21.8400  21.8400
105.000  .2100  22.0500  22.0500  22.0500
106.000  .2100  22.2600  22.2600  22.2600
107.000  .2100  22.4700  22.4700  22.4700
108.000  .2100  22.6800  22.6800  22.6800
109.000  .2100  22.8900  22.8900  22.8900
110.000  .2100  23.1000  23.1000  23.1000
111.000  .2100  23.3100  23.3100  23.3100
112.000  .2100  23.5200  23.5200  23.5200
113.000  .2100  23.7300  23.7300  23.7300
114.000  .2100  23.9400  23.9400  23.9400
115.000  .2100  24.1500  24.1500  24.1500
116.000  .2100  24.3600  24.3600  24.3600
117.000  .2100  24.5700  24.5700  24.5700
118.000  .2100  24.7800  24.7800  24.7800
119.000  .2100  24.9900  24.9900  24.9900
120.000  .2100  25.2000  25.2000  25.2000
121.000  .2100  25.4100  25.4100  25.4100
122.000  .2100  25.6200  25.6200  25.6200
123.000  .2100  25.8300  25.8300  25.8300
124.000  .2100  26.0400  26.0400  26.0400
125.000  .2100  26.2500  26.2500  26.2500
126.000  .2100  26.4600  26.4600  26.4600
127.000  .2100  26.6700  26.6700  26.6700
128.000  .2100  26.8800  26.8800  26.8800
129.000  .2100  27.0900  27.0900  27.0900
130.000  .2100  27.3000  27.3000  27.3000
131.000  .2100  27.5100  27.5100  27.5100
132.000  .2100  27.7200  27.7200  27.7200
133.000  .2100  27.9300  27.9300  27.9300
134.000  .2100  28.1400  28.1400  28.1400
135.000  .2100  28.3500  28.3500  28.3500
136.000  .2100  28.5600  28.5600  28.5600
137.000  .2100  28.7700  28.7700  28.7700
138.000  .2100  28.9800  28.9800  28.9800
139.000  .2100  29.1900  29.1900  29.1900
140.000  .2100  29.4000  29.4000  29.4000
141.000  .2100  29.6100  29.6100  29.6100
142.000  .2100  29.8200  29.8200  29.8200
143.000  .2100  30.0300  30.0300  30.0300
144.000  .2100  30.2400  30.2400  30.2400
145.000  .2100  30.4500  30.4500  30.4500
146.000  .2100  30.6600  30.6600  30.6600
147.000  .2100  30.8700  30.8700  30.8700
148.000  .2100  31.0800  31.0800  31.0800
149.000  .2100  31.2900  31.2900  31.2900
150.000  .2100  31.5000  31.5000  31.5000
151.000  .2100  31.7100  31.7100  31.7100
152.000  .2100  31.9200  31.9200  31.9200
153.000  .2100  32.1300  32.1300  32.1300
154.000  .2100  32.3400  32.3400  32.3400
155.000  .2100  32.5500  32.5500  32.5500
156.000  .2100  32.7600  32.7600  32.7600
157.000  .2100  32.9700  32.9700  32.9700
158.000  .2100  33.1800  33.1800  33.1800
159.000  .2100  33.3900  33.3900  33.3900
160.000  .2100  33.6000  33.6000  33.6000
161.000  .2100  33.8100  33.8100  33.8100
162.000  .2100  34.0200  34.0200  34.0200
163.000  .2100  34.2300  34.2300  34.2300
164.000  .2100  34.4400  34.4400  34.4400
165.000  .2100  34.6500  34.6500  34.6500
166.000  .2100  34.8600  34.8600  34.8600
167.000  .2100  35.0700  35.0700  35.0700
168.000  .2100  35.2800  35.2800  35.2800
169.000  .2100  35.4900  35.4900  35.4900
170.000  .2100  35.7000  35.7000  35.7000
171.000  .2100  35.9100  35.9100  35.9100
172.000  .2100  36.1200  36.1200  36.1200
173.000  .2100  36.3300  36.3300  36.3300
174.000  .2100  36.5400  36.5400  36.5400
175.000  .2100  36.7500  36.7500  36.7500
176.000  .2100  36.9600  36.9600  36.9600
177.000  .2100  37.1700  37.1700  37.1700
178.000  .2100  37.3800  37.3800  37.3800
179.000  .2100  37.5900  37.5900  37.5900
180.000  .2100  37.8000  37.8000  37.8000
181.000  .2100  38.0100  38.0100  38.0100
182.000  .2100  38.2200  38.2200  38.2200
183.000  .2100  38.4300  38.4300  38.4300
184.000  .2100  38.6400  38.6400  38.6400
185.000  .2100  38.8500  38.8500  38.8500
186.000  .2100  39.0600  39.0600  39.0600
187.000  .2100  39.2700  39.2700  39.2700
188.000  .2100  39.4800  39.4800  39.4800
189.000  .2100  39.6900  39.6900  39.6900
190.000  .2100  39.9000  39.9000  39.9000
191.000  .2100  40.1100  40.1100  40.1100
192.000  .2100  40.3200  40.3200  40.3200
193.000  .2100  40.5300  40.5300  40.5300
194.000  .2100  40.7400  40.7400  40.7400
195.000  .2100  40.9500  40.9500  40.9500
196.000  .2100  41.1600  41.1600  41.1600
197.000  .2100  41.3700  41.3700  41.3700
198.000  .2100  41.5800  41.5800  41.5800
199.000  .2100  41.7900  41.7900  41.7900
200.000  .2100  42.0000  42.0000  42.0000
201.000  .2100  42.2100  42.2100  42.2100
202.000  .2100  42.4200  42.4200  42.4200
203.000  .2100  42.6300  42.6300  42.6300
204.000  .2100  42.8400  42.8400  42.8400
205.000  .2100  43.0500  43.0500  43.0500
206.000  .2100  43.2600  43.2600  43.2600
207.000  .2100  43.4700  43.4700  43.4700
208.000  .2100  43.6800  43.6800  43.6800
209.000  .2100  43.8900  43.8900  43.8900
210.000  .2100  44.1000  44.1000  44.1000
211.000  .2100  44.3100  44.3100  44.3100
212.000  .2100  44.5200  44.5200  44.5200
213.000  .2100  44.7300  44.7300  44.7300
214.000  .2100  44.9400  44.9400  44.9400
215.000  .2100  45.1500  45.1500  45.1500
216.000  .2100  45.3600  45.3600  45.3600
217.000  .2100  45.5700  45.5700  45.5700
218.000  .2100  45.7800  45.7800  45.7800
219.000  .2100  45.9900  45.9900  45.9900
220.000  .2100  46.2000  46.2000  46.2000
221.000  .2100  46.4100  46.4100  46.4100
222.000  .2100  46.6200  46.6200  46.6200
223.000  .2100  46.8300  46.8300  46.8300
224.000  .2100  47.0400  47.0400  47.0400
225.000  .2100  47.2500  47.2500  47.2500
226.000  .2100  47.4600  47.4600  47.4600
227.000  .2100  47.6700  47.6700  47.6700
228.000  .2100  47.8800  47.8800  47.8800
229.000  .2100  48.0900  48.0900  48.0900
230.000  .2100  48.3000  48.3000  48.3000
231.000  .2100  48.5100  48.5100  48.5100
232.000  .2100  48.7200  48.7200  48.7200
233.000  .2100  48.9300  48.9300  48.9300
234.000  .2100  49.1400  49.1400  49.1400
235.000  .2100  49.3500  49.3500  49.3500
236.000  .2100  49.5600  49.5600  49.5600
237.000  .2100  49.7700  49.7700  49.7700
238.000  .2100  49.9800  49.9800  49.9800
239.000  .2100  50.1900  50.1900  50.1900
240.000  .2100  50.4000  50.4000  50.4000
241.000  .2100  50.6100  50.6100  50.6100
242.000  .2100  50.8200  50.8200  50.8200
243.000  .2100  51.0300  51.0300  51.0300
244.000  .2100  51.2400  51.2400  51.2400
245.000  .2100  51.4500  51.4500  51.4500
246.000  .2100  51.6600  51.6600  51.6600
247.000  .2100  51.8700  51.8700  51.8700
248.000  .2100  52.0800  52.0800  52.0800
249.000  .2100  52.2900  52.2900  52.2900
250.000  .2100  52.5000  52.5000  52.5000
251.000  .2100  52.7100  52.7100  52.7100
252.000  .2100  52.9200  52.9200  52.9200
253.000  .2100  53.1300  53.1300  53.1300
254.000  .2100  53.3400  53.3400  53.3400
255.000  .2100  53.5500  53.5500  53.5500
256.000  .2100  53.7600  53.7600  53.7600
257.000  .2100  53.9700  53.9700  53.9700
258.000  .2100  54.1800  54.1800  54.1800
259.000  .2100  54.3900  54.3900  54.3900
260.000  .2100  54.6000  54.6000  54.6000
261.000  .2100  54.8100  54.8100  54.8100
262.000  .2100  55.0200  55.0200  55.0200
263.000  .2100  55.2300  55.2300  55.2300
264.000  .2100  55.4400  55.4400  55.4400
265.000  .2100  55.6500  55.6500  55.6500
266.000  .2100  55.8600  55.8600  55.8600
267.000  .2100  56.0700  56.0700  56.0700
268.000  .2100  56.2800  56.2800  56.2800
269.000  .2100  56.4900  56.4900  56.4900
270.000  .2100  56.7000  56.7000  56.7000
271.000  .2100  56.9100  56.9100  56.9100
272.000  .2100  57.1200  57.1200  57.1200
273.000  .2100  57.3300  57.3300  57.3300
274.000  .2100  57.5400  57.5400  57.5400
275.000  .2100  57.7500  57.7500  57.7500
276.000  .2100  57.9600  57.9600  57.9600
277.000  .2100  58.1700  58.1700  58.1700
278.000  .2100  58.3800  58.3800  58.3800
279.000  .2100  58.5900  58.5900  58.5900
280.000  .2100  58.8000  58.8000  58.8000
281.000  .2100  59.0100  59.0100  59.0100
282.000  .2100  59.2200  59.2200  59.2200
283.000  .2100  59.4300  59.4300  59.4300
284.000  .2100  59.6400  59.6400  59.6400
285.000  .2100  59.8500  59.8500  59.8500
286.000  .2100  60.0600  60.0600  60.0600
287.000  .2100  60.2700  60.2700  60.2700
288.000  .2100  60.4800  60.4800  60.4800
289.000  .2100  60.6900  60.6900  60.6900
290.000  .2100  60.9000  60.9000  60.9000
291.000  .2100  61.1100  61.1100  61.1100
292.000  .2100  61.3200  61.3200  61.3200
293.000  .2100  61.5300  61.5300  61.5300
294.000  .2100  61.7400  61.7400  61.7400
295.000  .2100  61.9500  61.9500  61.9500
296.000  .2100  62.1600  62.1600  62.1600
297.000  .2100  62.3700  62.3700  62.3700
298.000  .2100  62.5800  62.5800  62.5800
299.000  .2100  62.7900  62.7900  62.7900
300.000  .2100  63.0000  63.0000  63.0000
301.000  .2100  63.2100  63.2100  63.2100
302.000  .2100  63.4200  63.4200  63.4200
303.000  .2100  63.6300  63.6300  63.6300
304.000  .2100  63.8400  63.8400  63.8400
305.000  .2100  64.0500  64.0500  64.0500
306.000  .2100  64.2600  64.2
```


PTC	ACCT 3	DEPT 3K CIVIL ENG	FILE	SECTION	MOD 13/2/74 (74-046)	TIME 12-23

L-0001						
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L-0051						

 * RECTANGULAR GUTTER OF BASE WIDTH = 3000 MM *
 * *****

INFLUX PER UNIT LENGTH OF GUTTER = 0.0030 CU.M/S.

GUTTER LENGTH	CRIT. DEPTH	YUPS	PEAK DEPTH	AREA	* R.O. DEPTH	R.O. AREA
3.375	0.6510	0.1816	0.0910	0.263102	0.09327	0.270707
5.397	0.6140	0.10987	0.11540	0.342198	0.13271	0.384127
15.233	0.5854	0.23454	0.18584	0.595273	0.23276	0.686876
26.233	0.5766	0.27686	0.10176	0.595273	0.34772	0.761176
25.233	0.1938	0.32127	0.35433	0.1263147	0.46754	0.1222619

INFLUX PER UNIT LENGTH OF GUTTER = 0.0030 CU.M/S.

GUTTER LENGTH	CRIT. DEPTH	YUPS	PEAK DEPTH	AREA	* R.O. DEPTH	R.O. AREA
3.375	0.6510	0.1816	0.0910	0.263102	0.09327	0.270707
5.397	0.6140	0.10987	0.11540	0.342198	0.13271	0.384127
15.233	0.5854	0.23454	0.18584	0.595273	0.23276	0.686876
26.233	0.5766	0.27686	0.10176	0.595273	0.34772	0.761176
25.233	0.1938	0.32127	0.35433	0.1263147	0.46754	0.1222619

INFLUX PER UNIT LENGTH OF GUTTER = 0.0030 CU.M/S.

GUTTER LENGTH	CRIT. DEPTH	YUPS	PEAK DEPTH	AREA	* R.O. DEPTH	R.O. AREA
3.375	0.6510	0.1816	0.0910	0.263102	0.09327	0.270707
5.397	0.6140	0.10987	0.11540	0.342198	0.13271	0.384127
15.233	0.5854	0.23454	0.18584	0.595273	0.23276	0.686876
26.233	0.5766	0.27686	0.10176	0.595273	0.34772	0.761176
25.233	0.1938	0.32127	0.35433	0.1263147	0.46754	0.1222619

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2

PIC	ACCT 3	DEPT OF CIVIL ENG	FILE	REGION	REQ 13/2/74 (74-044)	TIME 12:23
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PTC	ACCT 3	DEPT OF CIVIL ENG	FILE REC'D	THU 10/27/74 (14-245)	TIME 11:15
L-0001					
L-0002					
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L-0005					
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 * RECTANGULAR GUTTER ON CASE *
 *

INFLON PER UNIT LENGTH OF GUTTER = .005907 C.U./M/S.

GUTTER LENGTH	CHIT DEPTH	YUPS	PEAK DEPTH	AREA	RQ. DEPTH	RQ. AREA
3.000	.0787	.0787	.0787	.0787	.0787	.0787
5.000	.0787	.0787	.0787	.0787	.0787	.0787
10.000	.1167	.2294	.1167	.085113	.1167	.072403
15.000	.1537	.26520	.1537	.111611	.1537	.127334
20.000	.1907	.29100	.1907	.138088	.1907	.153265
25.000	.2277	.31680	.2277	.164565	.2277	.179196

INFLON PER UNIT LENGTH OF GUTTER = .001907 C.U./M/S.

GUTTER LENGTH	CHIT DEPTH	YUPS	PEAK DEPTH	AREA	RQ. DEPTH	RQ. AREA
3.000	.0170	.0170	.0170	.0170	.0170	.0170
5.000	.0170	.0170	.0170	.0170	.0170	.0170
10.000	.0394	.06922	.0394	.0393755	.0394	.039418
15.000	.0523	.09073	.0523	.0491339	.0523	.049140
20.000	.0652	.10997	.0652	.063597	.0652	.063610
25.000	.0781	.12780	.0781	.0776274	.0781	.077631

INFLON PER UNIT LENGTH OF GUTTER = .000950 C.U./M/S.

GUTTER LENGTH	CHIT DEPTH	YUPS	PEAK DEPTH	AREA	RQ. DEPTH	RQ. AREA
3.000	.0128	.01994	.02028	.041163	.02132	.0093264
5.000	.0128	.01994	.02028	.041163	.02132	.0093264
10.000	.0387	.05714	.06577	.0263976	.07586	.037309
15.000	.0387	.05714	.06577	.0263976	.07586	.037309
20.000	.0394	.06922	.08194	.0327754	.09423	.047617
25.000	.0433	.08032	.09534	.0381300	.10965	.043488

4900

010000

3,000	15118	11801	24708	0588310	16811	0670556
5,000	11576	20334	20478	0811135	23840	0842085
10,000	18238	32127	33138	1325521	39180	1824360
15,000	24832	46998	48228	2152018	58172	2565335
20,000	29832	56998	58228	2152018	61872	2665335
25,000	34188		62718	2569912	72160	2886598

080000

3,000	24282	42058	42082	1501682	48866	1854312
5,000	34368	53178	57948	2297913	51860	2237588
10,000	54306	93940	94206	3948210	130157	4413483

PTC ACCT 3 DEPT OF CIVIL ENG FILE PCE13 IMP 14/2/74 (74-045) TIME 11.02

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INFLOW PER UNIT LENGTH OF GUTTER= .000100 C.U./S.

GUTTER LENGTH CRIT DEPTH YUPS PEAK DEPTH AREA RPD DEPTH RPD AREA
3.000 .00332 .00076 .00632 .001604 * .00727 .0036359
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2
15.000 .00644 .00767 .0094355 * .01112 .005608
20.000 .00977 .01084 .02272 .011583 * .02812 .0150632
25.000 .01177 .02040 .02777 .013384 * .03194 .0159682
L-0023 .01366 .02367 .03266 .0161294 * .03756 .0187749
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INFLOW PER UNIT LENGTH OF GUTTER= .000950 C.U./S.

GUTTER LENGTH CRIT DEPTH YUPS PEAK DEPTH AREA RPD DEPTH RPD AREA
3.000 .00209 .00363 .00409 .0022445 * .0271 .0013515
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2
15.000 .00294 .00510 .00574 .0027712 * .02483 .0015165
20.000 .00509 .00897 .00943 .005005 * .01739 .0006645
25.000 .00860 .01491 .02260 .0113022 * .02400 .0124975
L-0037
L-0038
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L-0040
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L-0042
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INFLOW PER UNIT LENGTH OF GUTTER= .000010 C.U./S.

GUTTER LENGTH CRIT DEPTH YUPS PEAK DEPTH AREA RPD DEPTH RPD AREA
3.000 .00101 .00174 .00301 .0015031 * .00166 .0017285
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO.= 2
10.000 .00160 .00277 .00460 .0022386 * .00529 .0024614
15.000 .00209 .00363 .00597 .0039463 * .00701 .0035035
20.000 .00332 .00644 .00943 .005005 * .00887 .0041335
25.000 .00509 .00897 .00943 .005005 * .00887 .0041335
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L-0050
L-0051

.5000

.010000

5.000	.8715	.12407	.15359	.8627870	.16443	.0722165
10.000	.15976	.27685	.28576	.7841791	.23612	.1629169
15.000	.20994	.36279	.37734	.6884712	.33394	.2169718
20.000	.23188	.43949	.45760	.5788982	.47314	.2642707
25.000	.23928	.50918	.53178	.4641335	.54674	.3083561

.050000

5.000	.28924	.36278	.36534	.624712	.42014	.2103716
10.000	.18716	.30855	.32714	.438167	.39712	.4785035

STATION NO.	PEAK DEPTH	AREA	* RCD DEPTH	RCD AREA
1-0001	.0012	.00000	.00000	.00000
1-0002	.0012	.00000	.00000	.00000
1-0003	.0012	.00000	.00000	.00000
1-0004	.0012	.00000	.00000	.00000
1-0005	.0012	.00000	.00000	.00000
1-0006	.0012	.00000	.00000	.00000
1-0007	.0012	.00000	.00000	.00000
1-0008	.0012	.00000	.00000	.00000
1-0009	.0012	.00000	.00000	.00000
1-0010	.0012	.00000	.00000	.00000
1-0011	.0012	.00000	.00000	.00000
1-0012	.0012	.00000	.00000	.00000
1-0013	.0012	.00000	.00000	.00000
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1-0015	.0012	.00000	.00000	.00000
1-0016	.0012	.00000	.00000	.00000
1-0017	.0012	.00000	.00000	.00000
1-0018	.0012	.00000	.00000	.00000
1-0019	.0012	.00000	.00000	.00000
1-0020	.0012	.00000	.00000	.00000
1-0021	.0012	.00000	.00000	.00000
1-0022	.0012	.00000	.00000	.00000
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1-0025	.0012	.00000	.00000	.00000
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1-0036	.0012	.00000	.00000	.00000
1-0037	.0012	.00000	.00000	.00000
1-0038	.0012	.00000	.00000	.00000
1-0039	.0012	.00000	.00000	.00000
1-0040	.0012	.00000	.00000	.00000
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1-0042	.0012	.00000	.00000	.00000
1-0043	.0012	.00000	.00000	.00000
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1-0045	.0012	.00000	.00000	.00000
1-0046	.0012	.00000	.00000	.00000
1-0047	.0012	.00000	.00000	.00000
1-0048	.0012	.00000	.00000	.00000
1-0049	.0012	.00000	.00000	.00000
1-0050	.0012	.00000	.00000	.00000
1-0051	.0012	.00000	.00000	.00000
1-0052	.0012	.00000	.00000	.00000
1-0053	.0012	.00000	.00000	.00000
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1-0055	.0012	.00000	.00000	.00000
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1-0061	.0012	.00000	.00000	.00000
1-0062	.0012	.00000	.00000	.00000
1-0063	.0012	.00000	.00000	.00000
1-0064	.0012	.00000	.00000	.00000
1-0065	.0012	.00000	.00000	.00000

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*****
PTC      ACCT 3   DEPT OF CIVIL ENG      FILE      RECIP      THU 14/2/76 (74-545)      TIME 13.15
*****

*****
* RECTANGULAR GUTTER OF BASE WIDTH = 46.73 M *
*****

*****
TYPICAL PER UNIT LENGTH OF GUTTER. -202327 CU.M/RS.
*****
GUTTER LENGTH GUT DEPTH YUMT      PEAR DEPTH AREA      RCD DEPTH RCD AREA
-----
L-0901      3.000      -02941      -26024      -05161      -030472      * -03112      * -030472
L-0902      5.000      -03704      -32942      -07274      -0417412      * -03139      * -031376
L-0903      10.000      -07408      -65884      -14548      -0834824      * -03151      * -031536
L-0904      15.000      -10612      -98826      -21822      -1252136      * -03158      * -031598
L-0905      20.000      -13816      -131768      -29096      -1669448      * -03163      * -031653
L-0906      25.000      -17020      -164810      -36370      -2086710      * -03165      * -031665
L-0907      30.000      -20224      -197852      -43644      -2503972      * -03167      * -031687
L-0908      35.000      -23428      -230894      -50918      -2921234      * -03169      * -031707
L-0909      40.000      -26632      -263936      -58192      -3338496      * -03171      * -031727
L-0910      45.000      -29836      -296978      -65466      -3755758      * -03173      * -031747
L-0911      50.000      -33040      -330020      -72740      -4173020      * -03175      * -031767
L-0912      55.000      -36244      -363062      -79914      -4590282      * -03177      * -031787
L-0913      60.000      -39448      -396104      -87188      -5007544      * -03179      * -031807
L-0914      65.000      -42652      -429146      -94462      -5424806      * -03181      * -031827
L-0915      70.000      -45856      -472188      -101736      -5842068      * -03183      * -031847
L-0916      75.000      -49060      -515230      -109010      -6259330      * -03185      * -031867
L-0917      80.000      -52264      -558272      -116284      -6676592      * -03187      * -031887
L-0918      85.000      -55468      -601314      -123558      -7093854      * -03189      * -031907
L-0919      90.000      -58672      -644356      -130832      -7511116      * -03191      * -031927
L-0920      95.000      -61876      -687398      -138106      -7928378      * -03193      * -031947
L-0921      100.000      -65080      -730440      -145380      -8345640      * -03195      * -031967
L-0922      105.000      -68284      -773482      -152654      -8762902      * -03197      * -031987
L-0923      110.000      -71488      -816524      -159928      -9180164      * -03199      * -032007
L-0924      115.000      -74692      -859566      -167202      -9597426      * -03201      * -032027
L-0925      120.000      -77896      -902608      -174476      -10014688      * -03203      * -032047
L-0926      125.000      -81100      -945650      -181750      -10431950      * -03205      * -032067
L-0927      130.000      -84304      -988692      -189024      -10849212      * -03207      * -032087
L-0928      135.000      -87508      -1031734      -196298      -11266474      * -03209      * -032107
L-0929      140.000      -90712      -1074776      -203572      -11683736      * -03211      * -032127
L-0930      145.000      -93916      -1117818      -210846      -12101000      * -03213      * -032147
L-0931      150.000      -97120      -1160860      -218120      -12518262      * -03215      * -032167
L-0932      155.000      -100324      -1203902      -225394      -12935524      * -03217      * -032187
L-0933      160.000      -103528      -1246944      -232668      -13352786      * -03219      * -032207
L-0934      165.000      -106732      -1289986      -239942      -13770048      * -03221      * -032227
L-0935      170.000      -109936      -1333028      -247216      -14187310      * -03223      * -032247
L-0936      175.000      -113140      -1376070      -254490      -14604572      * -03225      * -032267
L-0937      180.000      -116344      -1419112      -261764      -15021834      * -03227      * -032287
L-0938      185.000      -119548      -1462154      -269038      -15439096      * -03229      * -032307
L-0939      190.000      -122752      -1505196      -276312      -15856358      * -03231      * -032327
L-0940      195.000      -125956      -1548238      -283586      -16273620      * -03233      * -032347
L-0941      200.000      -129160      -1591280      -290860      -16690882      * -03235      * -032367
L-0942      205.000      -132364      -1634322      -298134      -17108144      * -03237      * -032387
L-0943      210.000      -135568      -1677364      -305408      -17525406      * -03239      * -032407
L-0944      215.000      -138772      -1720406      -312682      -17942668      * -03241      * -032427
L-0945      220.000      -141976      -1763448      -319956      -18359930      * -03243      * -032447
L-0946      225.000      -145180      -1806490      -327230      -18777192      * -03245      * -032467
L-0947      230.000      -148384      -1849532      -334504      -19194454      * -03247      * -032487
L-0948      235.000      -151588      -1892574      -341778      -19611716      * -03249      * -032507
*****
TYPICAL PER UNIT LENGTH OF GUTTER. -050010 CU.M/RS.
*****
NON CONVERGENCE AFTER 40 ITERATIONS AT STATION NO. = 2
*****
GUTTER LENGTH GUT DEPTH YUMT      PEAR DEPTH AREA      RCD DEPTH RCD AREA
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L-0949      3.000      -00195      -00195      -00000      -00000      * -00000      * -00000
L-0950      5.000      -00370      -00370      -00000      -00000      * -00000      * -00000
L-0951      10.000      -00740      -00740      -00000      -00000      * -00000      * -00000
L-0952      15.000      -01110      -01110      -00000      -00000      * -00000      * -00000
L-0953      20.000      -01480      -01480      -00000      -00000      * -00000      * -00000
L-0954      25.000      -01850      -01850      -00000      -00000      * -00000      * -00000
L-0955      30.000      -02220      -02220      -00000      -00000      * -00000      * -00000
L-0956      35.000      -02590      -02590      -00000      -00000      * -00000      * -00000
L-0957      40.000      -02960      -02960      -00000      -00000      * -00000      * -00000
L-0958      45.000      -03330      -03330      -00000      -00000      * -00000      * -00000
L-0959      50.000      -03700      -03700      -00000      -00000      * -00000      * -00000
L-0960      55.000      -04070      -04070      -00000      -00000      * -00000      * -00000
L-0961      60.000      -04440      -04440      -00000      -00000      * -00000      * -00000
L-0962      65.000      -04810      -04810      -00000      -00000      * -00000      * -00000
L-0963      70.000      -05180      -05180      -00000      -00000      * -00000      * -00000
L-0964      75.000      -05550      -05550      -00000      -00000      * -00000      * -00000
L-0965      80.000      -05920      -05920      -00000      -00000      * -00000      * -00000
L-0966      85.000      -06290      -06290      -00000      -00000      * -00000      * -00000
L-0967      90.000      -06660      -06660      -00000      -00000      * -00000      * -00000
L-0968      95.000      -07030      -07030      -00000      -00000      * -00000      * -00000
L-0969      100.000      -07400      -07400      -00000      -00000      * -00000      * -00000
L-0970      105.000      -07770      -07770      -00000      -00000      * -00000      * -00000
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L-0974      125.000      -09250      -09250      -00000      -00000      * -00000      * -00000
L-0975      130.000      -09620      -09620      -00000      -00000      * -00000      * -00000
L-0976      135.000      -09990      -09990      -00000      -00000      * -00000      * -00000
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L-0980      155.000      -11470      -11470      -00000      -00000      * -00000      * -00000
L-0981      160.000      -11840      -11840      -00000      -00000      * -00000      * -00000
L-0982      165.000      -12210      -12210      -00000      -00000      * -00000      * -00000
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L-0986      185.000      -13690      -13690      -00000      -00000      * -00000      * -00000
L-0987      190.000      -14060      -14060      -00000      -00000      * -00000      * -00000
L-0988      195.000      -14430      -14430      -00000      -00000      * -00000      * -00000
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L-0990      205.000      -15170      -15170      -00000      -00000      * -00000      * -00000
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L-0993      220.000      -16280      -16280      -00000      -00000      * -00000      * -00000
L-0994      225.000      -16650      -16650      -00000      -00000      * -00000      * -00000
L-0995      230.000      -17020      -17020      -00000      -00000      * -00000      * -00000
L-0996      235.000      -17390      -17390      -00000      -00000      * -00000      * -00000
L-0997      240.000      -17760      -17760      -00000      -00000      * -00000      * -00000
L-0998      245.000      -18130      -18130      -00000      -00000      * -00000      * -00000
L-0999      250.000      -18500      -18500      -00000      -00000      * -00000      * -00000
*****

```


PROGRAMME TO DETERMINE THE DESIGN DEPTH IN
TRAPEZOIDAL GUTTERS WITH EQUAL SIDE SLOPES

NAME: TRAP

OBJECT: To determine the design depth in trapezoidal gutters
with equal side slopes for various gutter lengths and
inflow rates.

Checks: A side slope value of 90° was used and the results of
the programme were checked against the outputs of the rectangular
gutter programme, CRECTI. The comparison is seen in Table 32

Inputs:

Gutter base breadth	B
Gutter side slope in degrees	SS
Number of stations	NT
Output code	K
Inflow per unit length to gutter	INF
Gutter length	X

Outline of Programme:

For particular inflow and length values the critical
depth at the outlet is first calculated. This is done by an
iterative process as follows; An estimate of critical depth is made,
and the expressions Vc^2/g and Ym (see discussion on GUT 2)
are calculated and compared. If these expressions
do not agree to the required accuracy the critical depth is re-
estimated and the expression recalculated. In this manner the
critical depth is determined. This is then used as the starting

depth in the Hinds analysis and the water surface profile is determined in the manner outlined as for GUT 3. The peak depth is abstracted from the profile and the freeboard added to obtain the design depth and hence design area of gutter.

Outputs:

Code, $K = 1$ - values of all variables after every iteration at every station are given

Code, $K = 2$ - final values of variables and flow depths are given at each station. These flow depths define the water surface profile.

Code, $K > 2$ - the values at the last upstream station are given. These include;

length	X
critical depth at outlet	YCRIT
peak depth	Y(NT,J)
peak area	A(NT,J)
design depth	YFIN
design area	AFIN

Limits placed on programme:

The maximum number of iteration at the outlet when determining the flow depth is sixty

The maximum number of iterations at any particular station is forty.

Problems associated with programme:

Some problems as for GUT 3 and CRECTI and in addition it

was found that convergence on the critical depth at the outlet was slow. Thus it was necessary to allow at least sixty iterations at the outlet when determining the critical depth.

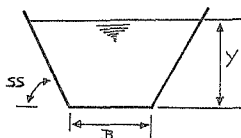
The values of accuracy limit and depth increment that gave best results were:

$$\text{DEL} = 0,002\text{m}$$

$$\text{ACC} = 0,001\text{m}$$

It was found that 21 stations were adequate, i.e. $\text{NT} = 21$

Geometry



SS is in degrees, while SSR is the value of SS in radians.

TABLE 32 COMPARISON BETWEEN OUTPUTS OF
TRAP AND CRECTI

BASE BREADTH in metres	INFLOW RATE in m^3/S	LENGTH in metres	PEAK DEPTH FROM TRAP in metres	PEAK DEPTH FROM CRECTI in metres
0,3	0,01	10	0,4046	0,4062
0,3	0,005	20	0,4206	0,4192
0,2	0,0003	25	0,1113	0,11133
0,2	0,003	5	0,1511	0,15108

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OUTPUTS OF TRAP

PIC ACT 3 WPT OF CIVIL C.A. FILL 113 WPT 27/2/74 (74-1581) TIME 12:21

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IP#	ACCT # IN DEPT OF CIVIL JUS.	FILL	HIS	NDC	2752/74 (PA-058)	TIME	12-00

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

[illegible]

試料名	試料番号	試料重量 (g)	試料体積 (cm ³)	試料密度 (g/cm ³)	試料形状	試料状態	試料処理	試料分析	試料評価
試料 A	試料 A-1	1.234	0.567	2.156	立方体	固体	乾燥	元素分析	合格
試料 B	試料 B-1	0.987	0.432	2.289	立方体	固体	乾燥	元素分析	合格
試料 C	試料 C-1	1.567	0.789	1.987	立方体	固体	乾燥	元素分析	合格
試料 D	試料 D-1	0.789	0.345	2.289	立方体	固体	乾燥	元素分析	合格
試料 E	試料 E-1	1.345	0.678	1.987	立方体	固体	乾燥	元素分析	合格
試料 F	試料 F-1	0.678	0.234	2.901	立方体	固体	乾燥	元素分析	合格
試料 G	試料 G-1	1.678	0.890	1.885	立方体	固体	乾燥	元素分析	合格
試料 H	試料 H-1	0.567	0.234	2.423	立方体	固体	乾燥	元素分析	合格
試料 I	試料 I-1	1.456	0.789	1.845	立方体	固体	乾燥	元素分析	合格
試料 J	試料 J-1	0.890	0.456	1.952	立方体	固体	乾燥	元素分析	合格
試料 K	試料 K-1	1.789	0.901	1.987	立方体	固体	乾燥	元素分析	合格
試料 L	試料 L-1	0.345	0.123	2.805	立方体	固体	乾燥	元素分析	合格
試料 M	試料 M-1	1.901	0.987	1.926	立方体	固体	乾燥	元素分析	合格
試料 N	試料 N-1	0.234	0.090	2.600	立方体	固体	乾燥	元素分析	合格
試料 O	試料 O-1	1.012	0.567	1.785	立方体	固体	乾燥	元素分析	合格
試料 P	試料 P-1	0.456	0.234	1.949	立方体	固体	乾燥	元素分析	合格
試料 Q	試料 Q-1	1.234	0.678	1.819	立方体	固体	乾燥	元素分析	合格
試料 R	試料 R-1	0.789	0.345	2.289	立方体	固体	乾燥	元素分析	合格
試料 S	試料 S-1	1.567	0.789	1.987	立方体	固体	乾燥	元素分析	合格
試料 T	試料 T-1	0.678	0.234	2.901	立方体	固体	乾燥	元素分析	合格
試料 U	試料 U-1	1.345	0.678	1.987	立方体	固体	乾燥	元素分析	合格
試料 V	試料 V-1	0.890	0.456	1.952	立方体	固体	乾燥	元素分析	合格
試料 W	試料 W-1	1.678	0.890	1.885	立方体	固体	乾燥	元素分析	合格
試料 X	試料 X-1	0.567	0.234	2.423	立方体	固体	乾燥	元素分析	合格
試料 Y	試料 Y-1	1.456	0.789	1.845	立方体	固体	乾燥	元素分析	合格
試料 Z	試料 Z-1	0.890	0.456	1.952	立方体	固体	乾燥	元素分析	合格

TABLE 1. *Effect of temperature on growth of rainbow trout*

Time (h)	Wt. %	LDH	AS	n	SE	SE
0-5	0.77	0.65	0.12	3	0.09	0.07
5-10	0.72	0.57	0.15	3	0.07	0.07
10-15	0.64	0.54	0.10	3	0.06	0.06
15-20	0.63	0.49	0.15	3	0.06	0.06
20-25	0.78	0.47	0.30	3	0.06	0.06
25-30	0.72	0.42	0.30	3	0.06	0.06
30-35	0.73	0.42	0.31	3	0.06	0.06
35-40	0.73	0.42	0.31	3	0.06	0.06
40-45	0.73	0.42	0.31	3	0.06	0.06
45-50	0.73	0.42	0.31	3	0.06	0.06
50-55	0.73	0.42	0.31	3	0.06	0.06
55-60	0.73	0.42	0.31	3	0.06	0.06
60-65	0.73	0.42	0.31	3	0.06	0.06
65-70	0.73	0.42	0.31	3	0.06	0.06
70-75	0.73	0.42	0.31	3	0.06	0.06
75-80	0.73	0.42	0.31	3	0.06	0.06
80-85	0.73	0.42	0.31	3	0.06	0.06
85-90	0.73	0.42	0.31	3	0.06	0.06
90-95	0.73	0.42	0.31	3	0.06	0.06
95-100	0.73	0.42	0.31	3	0.06	0.06

INLOW PER UNIT LENGTH OF BUTTER = .000300 CU. IN./5.

LC-20-20	90-31-10	10-PTN	40-CA	% Wt. H ₂ O	MS-14
13.0-10	0.5769	0.6149	0.17540	0.57462	0.5138273
13.5-20	0.5678	0.6243	0.161916	0.5722	0.5138273
14.0-30	0.5587	0.6337	0.148434	0.5697	0.5138273
14.5-40	0.5496	0.6431	0.134952	0.5673	0.5138273
15.0-50	0.5405	0.6525	0.121470	0.5649	0.5138273
15.5-60	0.5314	0.6619	0.107988	0.5625	0.5138273
16.0-70	0.5223	0.6713	0.094506	0.5601	0.5138273
16.5-80	0.5132	0.6807	0.081024	0.5577	0.5138273
17.0-90	0.5041	0.6901	0.067542	0.5553	0.5138273
17.5-100	0.4950	0.6995	0.054060	0.5529	0.5138273

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PAT	ACCT 3	CAPT OF CIVIL ENG	TITLE TO	WED 27/2774	(74-058)	TIME 12.00
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 93. 2013. 5. 9. 33:00 ~ 33:15
 94. 2013. 5. 9. 33:15 ~ 33:30
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 98. 2013. 5. 9. 34:15 ~ 34:30
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 105. 2013. 5. 9. 36:00 ~ 36:15
 106. 2013. 5. 9. 36:15 ~ 36:30
 107. 2013. 5. 9. 36:30 ~ 36:45
 108. 2013. 5. 9. 36:45 ~ 37:00
 109. 2013. 5. 9. 37:00 ~ 37:15
 110. 2013. 5. 9. 37:15 ~ 37:30
 111. 2013. 5. 9. 37:30 ~ 37:45
 112. 2013. 5. 9. 37:45 ~ 38:00
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 114. 2013. 5. 9. 38:15 ~ 38:30
 115. 2013. 5. 9. 38:30 ~ 38:45
 116. 2013. 5. 9. 38:45 ~ 39:00
 117. 2013. 5. 9. 39:00 ~ 39:15
 118. 2013. 5. 9. 39:15 ~ 39:30
 119. 2013. 5. 9. 39:30 ~ 39:45
 120. 2013. 5. 9. 39:45 ~ 40:00
 121. 2013. 5. 9. 40:00 ~ 40:15
 122. 2013. 5. 9. 40:15 ~ 40:30
 123. 2013. 5. 9. 40:30 ~ 40:45
 124. 2013. 5. 9.

TABLE 1. PERCENTAGE OF ALTERATION IN α -D-GC CUMULATIVE

[illegible]

1.400 PER UNIT LENGTH OF WIRE .500500 CU. IN./S.

Матрица	КСР II	МДП II	МР I	π	W (H)	М-П
1. $\text{C}_{10}\text{H}_8\text{O}_4$	0.72	0.53	0.1870	0.1610	0.224903	0.471
2. $\text{C}_{10}\text{H}_8\text{O}_4$	0.39	0.62	0.654721	0.7779	0.251182	
3. $\text{C}_{10}\text{H}_8\text{O}_4$	0.61	0.41	0.322610	0.9960	0.383178	
25. $\text{C}_{10}\text{H}_8\text{O}_4$	0.61	0.60	0.3062	0.1882	0.111567	
26. $\text{C}_{10}\text{H}_8\text{O}_4$	0.56	0.42	0.642959	0.1264	0.227572	
35. $\text{C}_{10}\text{H}_8\text{O}_4$	0.61	0.21	0.956496	0.1811	0.009519	

INCH PER UNIT LENGTH OF GUTTER= .009300 CU.M./S.

LC50 (μg)	Y ₁₀ (%)	DLPH	MDA	YFN	AI-N
15.0000	21.14	171.74	-0.120125	0.24142	0.00886
15.0000	27.69	151.43	-0.151002	0.25922	-0.01727
20.0000	31.26	106.56	-0.25641	0.16183	-0.02674
25.0000	37.92	67.50	-0.721264	0.39338	-0.026478
30.0000	56.23	10.12	-0.110275	0.95937	-0.073137
35.0000	74.73	0.113	-0.157421	1.15553	-0.025626

PIC ACT 3 DEPT OF CIVIL ENR FILE TRI TUE 26/274-174-9471 TIME 15:03

 * TRAP/HINGL GUTTER OF BASE WIDTH= .5000 M *
 * SIDE SLOPE= 45 DEG. *

14CM PER UNIT LENGTH OF GUTTER - .295500 CU-M./S.

ACT 3	DEPT OF CIVIL ENR	FILE TRI	TUE 26/274-174-9471	TIME 15:03
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14CM PER UNIT LENGTH OF GUTTER - .004000 CU-M./S.

ACT 3	DEPT OF CIVIL ENR	FILE TRI	TUE 26/274-174-9471	TIME 15:03
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14CM PER UNIT LENGTH OF GUTTER - .004000 CU-M./S.

ACT 3	DEPT OF CIVIL ENR	FILE TRI	TUE 26/274-174-9471	TIME 15:03
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PIC	DEPTH	DEPTH OF CHUTE	FULL TO	WED 2/2/77	174-0081	TIME 12.00
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L-0004	15.000					
L-0007	15.000					
L-0010	15.000					
L-0013	15.000					
L-0016	15.000					
L-0019	15.000					
L-0022	15.000					
L-0025	15.000					
L-0028	15.000					
L-0031	15.000					
L-0034	15.000					
L-0037	15.000					
L-0040	15.000					
L-0043	15.000					
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L-0052	15.000					
L-0055	15.000					
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L-0064	15.000					
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L-0070	15.000					
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L-0574	15.000					
L-0577	15.000					
L-0580	15.000					
L-0583	15.000					
L-0586	15.000					
L-0589	15.000					
L-0592	15.000					
L-0595	15.000					
L-0598	15.000					
L-0601	15.000					
L-0604	15.000					
L-0607	15.000					
L-0610	15.000					
L-0613	15.000					
L-0616	15.000					
L-0619	15.000					
L-0622	15.000					
L-0625	15.000					
L-0628	15.000					
L-0631	15.000					
L-0634	15.000					
L-0637	15.000					
L-0640	15.000					
L-0643	15.000					
L-0646	15.000					
L-0649	15.000					
L-0652	15.000					
L-0655	15.000					
L-0658	15.000					
L-0661	15.000					
L-0664	15.000					
L-0667	15.000					
L-0670	15.000					
L-0673	15.000					
L-0676	15.000					
L-0679	15.000					
L-0682	15.000					
L-0685	15.000					
L-0688	15.000					
L-0691	15.000					
L-0694	15.000					
L-0697	15.000					
L-0700	15.000					
L-0703	15.000					
L-0706	15.000					
L-0709	15.000					
L-0712	15.000					
L-0715	15.000					
L-0718	15.000					
L-0721	15.000					
L-0724	15.000					
L-0727	15.000					
L-0730	15.000					
L-0733	15.000					
L-0736	15.000					
L-0739	15.000					
L-0742	15.000					
L-0745	15.000					
L-0748	15.000					
L-0751	15.000					
L-0754	15.000					
L-0757	15.000					
L-0760	15.000					
L-0763	15.000					
L-0766	15.000					
L-0769	15.000					
L-0772	15.000					
L-0775	15.000					
L-0778	15.000					
L-0781	15.000					

Ph.	α_{ref}	μ_{ref}	σ_{ref}	FILE	MDN	TIME
1	00.00	00.00	0.00	FILE 1115	MDN 4/17/74 17h-0531	TIME 12-51

[illegible]
$$S^2/n^2 \rightarrow 0 \text{ as } n \rightarrow \infty \text{ and } E\{S^2/n^2\} = 0.$$

Year	W. 1970	W. 1971	W. 1972	W. 1973	W. 1974	W. 1975	W. 1976	W. 1977	W. 1978	W. 1979	W. 1980	W. 1981	W. 1982	W. 1983	W. 1984	W. 1985	W. 1986	W. 1987	W. 1988	W. 1989	W. 1990	W. 1991	W. 1992	W. 1993	W. 1994	W. 1995	W. 1996	W. 1997	W. 1998	W. 1999	W. 2000	W. 2001	W. 2002	W. 2003	W. 2004	W. 2005	W. 2006	W. 2007	W. 2008	W. 2009	W. 2010	W. 2011	W. 2012	W. 2013	W. 2014	W. 2015	W. 2016	W. 2017	W. 2018	W. 2019	W. 2020	W. 2021	W. 2022	W. 2023	W. 2024	W. 2025	W. 2026	W. 2027	W. 2028	W. 2029	W. 2030	W. 2031	W. 2032	W. 2033	W. 2034	W. 2035	W. 2036	W. 2037	W. 2038	W. 2039	W. 2040	W. 2041	W. 2042	W. 2043	W. 2044	W. 2045	W. 2046	W. 2047	W. 2048	W. 2049	W. 2050	W. 2051	W. 2052	W. 2053	W. 2054	W. 2055	W. 2056	W. 2057	W. 2058	W. 2059	W. 2060	W. 2061	W. 2062	W. 2063	W. 2064	W. 2065	W. 2066	W. 2067	W. 2068	W. 2069	W. 2070	W. 2071	W. 2072	W. 2073	W. 2074	W. 2075	W. 2076	W. 2077	W. 2078	W. 2079	W. 2080	W. 2081	W. 2082	W. 2083	W. 2084	W. 2085	W. 2086	W. 2087	W. 2088	W. 2089	W. 2090	W. 2091	W. 2092	W. 2093	W. 2094	W. 2095	W. 2096	W. 2097	W. 2098	W. 2099	W. 2100
1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	2051	2052	2053	2054	2055	2056	2057	2058	2059	2060	2061	2062	2063	2064	2065	2066	2067	2068	2069	2070	2071	2072	2073	2074	2075	2076	2077	2078	2079	2080	2081	2082	2083	2084	2085	2086	2087	2088	2089	2090	2091	2092	2093	2094	2095	2096	2097	2098	2099	2100	

VALUES PER UNIT LENGTH OF CURVE = .05795 CU.M./M.

[illegible]

FLOW PER UNIT LENGTH OF GUTTER = 1.6500 C.F./S.

PLC BLK 3 DEPT OF CIVIL ENG FILE TILS NIN 4/1/74 (74-053) TIME 12.51

 * PLANT/UNIT OUTPUT OF BASE WORTH * .3500 *
 * SIDE SLOPE * 45 DEG. *

INCH PER UNIT LENGTH OF CUTTER = .000500 CU.M./S.

LENGTH	DEPTH	AREA	WFIN	AFIN
1.000	.2533	.0131627	.72257	.0124626
1.000	.2574	.0134358	.71905	.0127410
1.000	.2615	.0137100	.71553	.0130194
1.000	.2656	.0139852	.71201	.0132978
1.000	.2697	.0142614	.70849	.0135762
1.000	.2738	.0145386	.70497	.0138546
1.000	.2779	.0148168	.70145	.0141330
1.000	.2820	.0150950	.69793	.0144114
1.000	.2861	.0153742	.69441	.0146898
1.000	.2902	.0156544	.69089	.0149682
1.000	.2943	.0159356	.68737	.0152466
1.000	.2984	.0162178	.68385	.0155250
1.000	.3025	.0164990	.68033	.0158034
1.000	.3066	.0167812	.67681	.0160818
1.000	.3107	.0170644	.67329	.0163602
1.000	.3148	.0173486	.66977	.0166386
1.000	.3189	.0176338	.66625	.0169170
1.000	.3230	.0179190	.66273	.0171954
1.000	.3271	.0182052	.65921	.0174738
1.000	.3312	.0184924	.65569	.0177522
1.000	.3353	.0187806	.65217	.0180306
1.000	.3394	.0190698	.64865	.0183090
1.000	.3435	.0193600	.64513	.0185874
1.000	.3476	.0196512	.64161	.0188658
1.000	.3517	.0199434	.63809	.0191442
1.000	.3558	.0202366	.63457	.0194226
1.000	.3599	.0205308	.63105	.0197010
1.000	.3640	.0208260	.62753	.0199794
1.000	.3681	.0211222	.62401	.0202578
1.000	.3722	.0214194	.62049	.0205362
1.000	.3763	.0217176	.61697	.0208146
1.000	.3804	.0220168	.61345	.0210930
1.000	.3845	.0223170	.60993	.0213714
1.000	.3886	.0226182	.60641	.0216498
1.000	.3927	.0229204	.60289	.0219282
1.000	.3968	.0232236	.59937	.0222066
1.000	.4009	.0235278	.59585	.0224850
1.000	.4050	.0238330	.59233	.0227634
1.000	.4091	.0241392	.58881	.0230418
1.000	.4132	.0244464	.58529	.0233202
1.000	.4173	.0247546	.58177	.0235986
1.000	.4214	.0250638	.57825	.0238770
1.000	.4255	.0253740	.57473	.0241554
1.000	.4296	.0256852	.57121	.0244338
1.000	.4337	.0259974	.56769	.0247122
1.000	.4378	.0263106	.56417	.0249906
1.000	.4419	.0266248	.56065	.0252690
1.000	.4460	.0269400	.55713	.0255474
1.000	.4501	.0272562	.55361	.0258258
1.000	.4542	.0275734	.55009	.0261042
1.000	.4583	.0278916	.54657	.0263826
1.000	.4624	.0282108	.54305	.0266610
1.000	.4665	.0285310	.53953	.0269394
1.000	.4706	.0288522	.53601	.0272178
1.000	.4747	.0291744	.53249	.0274962
1.000	.4788	.0294976	.52897	.0277746
1.000	.4829	.0298218	.52545	.0280530
1.000	.4870	.0301470	.52193	.0283314
1.000	.4911	.0304732	.51841	.0286098
1.000	.4952	.0308004	.51489	.0288882
1.000	.4993	.0311286	.51137	.0291666
1.000	.5034	.0314578	.50785	.0294450
1.000	.5075	.0317880	.50433	.0297234
1.000	.5116	.0321192	.50081	.0300018
1.000	.5157	.0324514	.49729	.0302802
1.000	.5198	.0327846	.49377	.0305586
1.000	.5239	.0331188	.49025	.0308370
1.000	.5280	.0334540	.48673	.0311154
1.000	.5321	.0337902	.48321	.0313938
1.000	.5362	.0341274	.47969	.0316722
1.000	.5403	.0344656	.47617	.0319506
1.000	.5444	.0348048	.47265	.0322290
1.000	.5485	.0351450	.46913	.0325074
1.000	.5526	.0354862	.46561	.0327858
1.000	.5567	.0358284	.46209	.0330642
1.000	.5608	.0361716	.45857	.0333426
1.000	.5649	.0365158	.45505	.0336210
1.000	.5690	.0368610	.45153	.0338994
1.000	.5731	.0372072	.44801	.0341778
1.000	.5772	.0375544	.44449	.0344562
1.000	.5813	.0379026	.44097	.0347346
1.000	.5854	.0382518	.43745	.0350130
1.000	.5895	.0386020	.43393	.0352914
1.000	.5936	.0389532	.43041	.0355698
1.000	.5977	.0393054	.42689	.0358482
1.000	.6018	.0396586	.42337	.0361266
1.000	.6059	.0400128	.41985	.0364050
1.000	.6100	.0403680	.41633	.0366834
1.000	.6141	.0407242	.41281	.0369618
1.000	.6182	.0410814	.40929	.0372402
1.000	.6223	.0414396	.40577	.0375186
1.000	.6264	.0417988	.40225	.0377970
1.000	.6305	.0421590	.39873	.0380754
1.000	.6346	.0425202	.39521	.0383538
1.000	.6387	.0428824	.39169	.0386322
1.000	.6428	.0432456	.38817	.0389106
1.000	.6469	.0436098	.38465	.0391890
1.000	.6510	.0439750	.38113	.0394674
1.000	.6551	.0443412	.37761	.0397458
1.000	.6592	.0447084	.37409	.0400242
1.000	.6633	.0450766	.37057	.0403026
1.000	.6674	.0454458	.36705	.0405810
1.000	.6715	.0458160	.36353	.0408594
1.000	.6756	.0461872	.36001	.0411378
1.000	.6797	.0465594	.35649	.0414162
1.000	.6838	.0469326	.35297	.0416946
1.000	.6879	.0473068	.34945	.0419730
1.000	.6920	.0476820	.34593	.0422514
1.000	.6961	.0480582	.34241	.0425298
1.000	.7002	.0484354	.33889	.0428082
1.000	.7043	.0488136	.33537	.0430866
1.000	.7084	.0491928	.33185	.0433650
1.000	.7125	.0495730	.32833	.0436434
1.000	.7166	.0499542	.32481	.0439218
1.000	.7207	.0503364	.32129	.0442002
1.000	.7248	.0507196	.31777	.0444786
1.000	.7289	.0511038	.31425	.0447570
1.000	.7330	.0514890	.31073	.0450354
1.000	.7371	.0518752	.30721	.0453138
1.000	.7412	.0522624	.30369	.0455922
1.000	.7453	.0526506	.30017	.0458706
1.000	.7494	.0530398	.29665	.0461490
1.000	.7535	.0534300	.29313	.0464274
1.000	.7576	.0538212	.28961	.0467058
1.000	.7617	.0542134	.28609	.0469842
1.000	.7658	.0546066	.28257	.0472626
1.000	.7699	.0550008	.27905	.0475410
1.000	.7740	.0553960	.27553	.0478194
1.000	.7781	.0557922	.27201	.0480978
1.000	.7822	.0561894	.26849	.0483762
1.000	.7863	.0565876	.26497	.0486546
1.000	.7904	.0569868	.26145	.0489330
1.000	.7945	.0573870	.25793	.0492114
1.000	.7986	.0577882	.25441	.0494898
1.000	.8027	.0581904	.25089	.0497682
1.000	.8068	.0585936	.24737	.0500466
1.000	.8109	.0589978	.24385	.0503250
1.000	.8150	.0594030	.24033	.0506034
1.000	.8191	.0598092	.23681	.0508818
1.000	.8232	.0602164	.23329	.0511602
1.000	.8273	.0606246	.22977	.0514386
1.000	.8314	.0610338	.22625	.0517170
1.000	.8355	.0614440	.22273	.0519954
1.000	.8396	.0618552	.21921	.0522738
1.000	.8437	.0622674	.21569	.0525522
1.000	.8478	.0626806	.21217	.0528306
1.000	.8519	.0630948	.20865	.0531090
1.000	.8560	.0635100	.20513	.0533874
1.000	.8601	.0639262	.20161	.0536658
1.000	.8642	.0643434	.19809	.0539442
1.000	.8683	.0647616	.19457	.0542226
1.000	.8724	.0651808	.19105	.0545010
1.000	.8765	.0655990	.18753	.0547794
1.000	.8806	.0660192	.18401	.0550578
1.000	.8847	.0664404	.18049	.0553362
1.000	.8888	.0668626	.17697	.0556146
1.000	.8929	.0672858	.17345	.0558930
1.000	.8970	.0677090	.16993	.0561714
1.000	.9011	.0681332	.16641	.0564498
1.000	.9052	.0685584	.16289	.0567282
1.000	.9093	.0689846	.15937	.0570066
1.000	.9134	.0694118	.15585	.0572850
1.000	.9175	.0698400	.15233	.0575634
1.000	.9216	.0702692	.14881	.0578418
1.000	.9257	.0706994	.14529	.0581202
1.000	.9298	.0711306	.14177	.0583986
1.000	.9339	.0715628	.13825	.0586770
1.000	.9380	.0719960	.13473	.0589554
1.000	.9421	.0724312	.13121	.0592338
1.000	.9462	.0728674	.12769	.0595122
1.000	.9503	.0733046	.12417	.0597906
1.000	.9544	.0737428	.12065	.0600690
1.000	.9585	.0741820	.11713	.0603474
1.000	.9626	.0746232	.11361	.0606258
1.000	.9667	.0750654	.11009	.0609042
1.000	.9708	.0755086	.10657	.0611826
1.000	.9749	.0759528	.10305	.0614610
1.000	.9790	.0763980	.9993	.0617394
1.000	.9831	.0768442	.9957	.0620178
1.000	.9872	.0772914	.9921	.0622962
1.000	.9913	.0777396	.9885	.0625746
1.000	.9954	.0781888	.9849	.0628530
1.000	.9995	.0786390	.9813	.0631314
1.000	1.0036	.0790902	.9777	.0634098
1.000	1.0077	.0795424	.9741	.0636882
1.000	1.0118	.0799956	.9705	.0639666
1.000	1.0159	.0804508	.9669	.0642450
1.000	1.0200	.0809070	.9633	.0645234
1.000	1.0241	.0813642	.9597	.0648018
1.000	1.0282	.0818224	.9561	.0650802
1.000	1.0323	.0822816	.9525	.0653586
1.000	1.0364	.0827418	.9489	.0656370
1.000	1.0405	.0832030	.9453	.0659154
1.000	1.0446	.0836652	.9417	.0661938
1.000	1.0487	.0841284	.9381	.0664722
1.000	1.0528	.0845926	.9345	.0667506
1.000	1.0569	.0850578	.9309	.0670290
1.000	1.0610	.0855240	.9273	.0673074
1.000	1.0651	.0859912	.9237	.0675858
1.000	1.0692	.0864594	.9201	.0678642
1.000	1.0733	.0869286	.9165	.0681426
1.000	1.0774	.0873988	.9129	.0684210
1.000	1.0815	.0878700	.9093	.0686994
1.000	1.0856	.0883422	.9057	.0689778
1.000	1.0897	.0888154	.9021	.0692562
1.000	1.0938	.0892896	.8985	.0695346
1.000	1.0979	.0897648	.8949	.0698130
1.000	1.1020			

PTC ACFT 3 NOT IN CIVIL LWR FILE T122 MON 4/3/74 (74-023) TIME 12:52

 * TRAPEZOIDAL GUTTER OF BASE WIDTH = .AC200 *
 * SIDE SLOPE = 3R DEG. *

INCH PER UNIT LENGTH OF GUTTER* .000500 CU.M./S.

DEPTH	WIDTH	AREA	W	VEL	AFTH
1.00	1.00	.5000	1.00	1.00	.000500
1.25	1.25	.7812	1.25	1.25	.000781
1.50	1.50	1.1250	1.50	1.50	.001125
1.75	1.75	1.5625	1.75	1.75	.001562
2.00	2.00	2.0000	2.00	2.00	.002000
2.25	2.25	2.5312	2.25	2.25	.002531
2.50	2.50	3.1250	2.50	2.50	.003125
2.75	2.75	3.7812	2.75	2.75	.003781
3.00	3.00	4.5000	3.00	3.00	.004500
3.25	3.25	5.2712	3.25	3.25	.005271
3.50	3.50	6.1250	3.50	3.50	.006125
3.75	3.75	7.0625	3.75	3.75	.007062
4.00	4.00	8.0000	4.00	4.00	.008000
4.25	4.25	9.0312	4.25	4.25	.009031
4.50	4.50	10.1250	4.50	4.50	.010125
4.75	4.75	11.2812	4.75	4.75	.011281
5.00	5.00	12.5000	5.00	5.00	.012500
5.25	5.25	13.7812	5.25	5.25	.013781
5.50	5.50	15.1250	5.50	5.50	.015125
5.75	5.75	16.5312	5.75	5.75	.016531
6.00	6.00	18.0000	6.00	6.00	.018000
6.25	6.25	19.5312	6.25	6.25	.019531
6.50	6.50	21.1250	6.50	6.50	.021125
6.75	6.75	22.7812	6.75	6.75	.022781
7.00	7.00	24.5000	7.00	7.00	.024500
7.25	7.25	26.2812	7.25	7.25	.026281
7.50	7.50	28.1250	7.50	7.50	.028125
7.75	7.75	29.9312	7.75	7.75	.029931
8.00	8.00	31.8000	8.00	8.00	.031800
8.25	8.25	33.7312	8.25	8.25	.033731
8.50	8.50	35.7250	8.50	8.50	.035725
8.75	8.75	37.7812	8.75	8.75	.037781
9.00	9.00	39.9000	9.00	9.00	.039900
9.25	9.25	42.0812	9.25	9.25	.042081
9.50	9.50	44.3250	9.50	9.50	.044325
9.75	9.75	46.6312	9.75	9.75	.046631
10.00	10.00	49.0000	10.00	10.00	.049000
10.25	10.25	51.4312	10.25	10.25	.051431
10.50	10.50	53.9250	10.50	10.50	.053925
10.75	10.75	56.4812	10.75	10.75	.056481
11.00	11.00	59.1000	11.00	11.00	.059100
11.25	11.25	61.7812	11.25	11.25	.061781
11.50	11.50	64.5250	11.50	11.50	.064525
11.75	11.75	67.3312	11.75	11.75	.067331
12.00	12.00	70.2000	12.00	12.00	.070200
12.25	12.25	73.1312	12.25	12.25	.073131
12.50	12.50	76.1250	12.50	12.50	.076125
12.75	12.75	79.1812	12.75	12.75	.079181
13.00	13.00	82.3000	13.00	13.00	.082300
13.25	13.25	85.4812	13.25	13.25	.085481
13.50	13.50	88.7250	13.50	13.50	.088725
13.75	13.75	92.0312	13.75	13.75	.092031
14.00	14.00	95.4000	14.00	14.00	.095400
14.25	14.25	98.8312	14.25	14.25	.098831
14.50	14.50	103.3250	14.50	14.50	.103325
14.75	14.75	107.8812	14.75	14.75	.107881
15.00	15.00	112.5000	15.00	15.00	.112500
15.25	15.25	117.1812	15.25	15.25	.117181
15.50	15.50	121.9250	15.50	15.50	.121925
15.75	15.75	126.7312	15.75	15.75	.126731
16.00	16.00	131.6000	16.00	16.00	.131600
16.25	16.25	136.5312	16.25	16.25	.136531
16.50	16.50	141.5250	16.50	16.50	.141525
16.75	16.75	146.5812	16.75	16.75	.146581
17.00	17.00	151.7000	17.00	17.00	.151700
17.25	17.25	156.8812	17.25	17.25	.156881
17.50	17.50	162.1250	17.50	17.50	.162125
17.75	17.75	167.4312	17.75	17.75	.167431
18.00	18.00	172.8000	18.00	18.00	.172800
18.25	18.25	178.2312	18.25	18.25	.178231
18.50	18.50	183.7250	18.50	18.50	.183725
18.75	18.75	189.2812	18.75	18.75	.189281
19.00	19.00	194.9000	19.00	19.00	.194900
19.25	19.25	200.5812	19.25	19.25	.200581
19.50	19.50	206.3250	19.50	19.50	.206325
19.75	19.75	212.1312	19.75	19.75	.212131
20.00	20.00	218.0000	20.00	20.00	.218000
20.25	20.25	223.9312	20.25	20.25	.223931
20.50	20.50	229.9250	20.50	20.50	.229925
20.75	20.75	235.9812	20.75	20.75	.235981
21.00	21.00	242.1000	21.00	21.00	.242100
21.25	21.25	248.2812	21.25	21.25	.248281
21.50	21.50	254.5250	21.50	21.50	.254525
21.75	21.75	260.8312	21.75	21.75	.260831
22.00	22.00	267.2000	22.00	22.00	.267200
22.25	22.25	273.6312	22.25	22.25	.273631
22.50	22.50	280.1250	22.50	22.50	.280125
22.75	22.75	286.6812	22.75	22.75	.286681
23.00	23.00	293.3000	23.00	23.00	.293300
23.25	23.25	300.0812	23.25	23.25	.300081
23.50	23.50	306.9250	23.50	23.50	.306925
23.75	23.75	313.8312	23.75	23.75	.313831
24.00	24.00	320.8000	24.00	24.00	.320800
24.25	24.25	327.8312	24.25	24.25	.327831
24.50	24.50	334.9250	24.50	24.50	.334925
24.75	24.75	342.0812	24.75	24.75	.342081
25.00	25.00	349.3000	25.00	25.00	.349300
25.25	25.25	356.5812	25.25	25.25	.356581
25.50	25.50	363.9250	25.50	25.50	.363925
25.75	25.75	371.3312	25.75	25.75	.371331
26.00	26.00	378.8000	26.00	26.00	.378800
26.25	26.25	386.3312	26.25	26.25	.386331
26.50	26.50	393.9250	26.50	26.50	.393925
26.75	26.75	401.5812	26.75	26.75	.401581
27.00	27.00	409.3000	27.00	27.00	.409300
27.25	27.25	417.0812	27.25	27.25	.417081
27.50	27.50	424.9250	27.50	27.50	.424925
27.75	27.75	432.8312	27.75	27.75	.432831
28.00	28.00	440.8000	28.00	28.00	.440800
28.25	28.25	448.8312	28.25	28.25	.448831
28.50	28.50	456.9250	28.50	28.50	.456925
28.75	28.75	465.0812	28.75	28.75	.465081
29.00	29.00	473.3000	29.00	29.00	.473300
29.25	29.25	481.5812	29.25	29.25	.481581
29.50	29.50	489.9250	29.50	29.50	.489925
29.75	29.75	498.3312	29.75	29.75	.498331
30.00	30.00	506.8000	30.00	30.00	.506800
30.25	30.25	515.3312	30.25	30.25	.515331
30.50	30.50	523.9250	30.50	30.50	.523925
30.75	30.75	532.5812	30.75	30.75	.532581
31.00	31.00	541.3000	31.00	31.00	.541300
31.25	31.25	550.0812	31.25	31.25	.550081
31.50	31.50	558.9250	31.50	31.50	.558925
31.75	31.75	567.8312	31.75	31.75	.567831
32.00	32.00	576.8000	32.00	32.00	.576800
32.25	32.25	585.8312	32.25	32.25	.585831
32.50	32.50	594.9250	32.50	32.50	.594925
32.75	32.75	604.0812	32.75	32.75	.604081
33.00	33.00	613.3000	33.00	33.00	.613300
33.25	33.25	622.5812	33.25	33.25	.622581
33.50	33.50	631.9250	33.50	33.50	.631925
33.75	33.75	641.3312	33.75	33.75	.641331
34.00	34.00	650.8000	34.00	34.00	.650800
34.25	34.25	660.3312	34.25	34.25	.660331
34.50	34.50	669.9250	34.50	34.50	.669925
34.75	34.75	679.5812	34.75	34.75	.679581
35.00	35.00	689.3000	35.00	35.00	.689300
35.25	35.25	699.0812	35.25	35.25	.699081
35.50	35.50	708.9250	35.50	35.50	.708925
35.75	35.75	718.8312	35.75	35.75	.718831
36.00	36.00	728.8000	36.00	36.00	.728800
36.25	36.25	738.8312	36.25	36.25	.738831
36.50	36.50	748.9250	36.50	36.50	.748925
36.75	36.75	759.0812	36.75	36.75	.759081
37.00	37.00	769.3000	37.00	37.00	.769300
37.25	37.25	779.5812	37.25	37.25	.779581
37.50	37.50	789.9250	37.50	37.50	.789925
37.75	37.75	800.3312	37.75	37.75	.800331
38.00	38.00	810.8000	38.00	38.00	.810800
38.25	38.25	821.3312	38.25	38.25	.821331
38.50	38.50	831.9250	38.50	38.50	.831925
38.75	38.75	842.5812	38.75	38.75	.842581
39.00	39.00	853.3000	39.00	39.00	.853300
39.25	39.25	864.0812	39.25	39.25	.864081
39.50	39.50	874.9250	39.50	39.50	.874925
39.75	39.75	885.8312	39.75	39.75	.885831
40.00	40.00	896.8000	40.00	40.00	.896800
40.25	40.25	907.8312	40.25	40.25	.907831
40.50	40.50	918.9250	40.50	40.50	.918925
40.75	40.75	929.0812	40.75	40.75	.929081
41.00	41.00	939.3000	41.00	41.00	.939300
41.25	41.25	949.5812	41.25	41.25	.949581
41.50	41.50	959.9250	41.50	41.50	.959925
41.75	41.75	970.3312	41.75	41.75	.970331
42.00	42.00	980.8000	42.00	42.00	.980800
42.25	42.25	991.3312	42.25	42.25	.991331
42.50	42.50	1001.9250	42.50	42.50	1.001925
42.75	42.75	1012.5812	42.75	42.75	1.012581
43.00	43.00	1023.3000	43.00	43.00	1.023300
43.25	43.25	1034.0812	43.25	43.25	1.034081
43.50	43.50	1044.9250	43.50	43.50	1.044925
43.75	43.75	1055.8312	43.75	43.75	1.055831
44.00	44.00	1066.8000	44.00	44.00	1.066800
44.25	44.25	1077.8312	44.25	44.25	1.077831
44.50	44.50	1088.9250	44.50	44.50	1.088925
44.75	44.75	1099.0812	44.75	44.75	1.099081
45.00	45.00	1109.3000	45.00	45.00	1.109300
45.2					

PTC ACCT 3 DEPT OF CIVIL ENG FILE 1234 PCB 4/27/74 174-22) TIME 15:38

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* TRAP POINTS LISTED ON PLAN SHEETS *
* *
* *

PLUCK PER UNIT LENGTH OF GLITTER - 100000 CL.W./S.

PLUCK PER UNIT LENGTH OF GLITTER - 100000 CL.W./S.

PLUCK PER UNIT LENGTH OF GLITTER - 100000 CL.W./S.

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PLUCK PER UNIT LENGTH OF GLITTER - 100000 CL.W./S.

PLUCK PER UNIT LENGTH OF GLITTER - 100000 CL.W./S.

PTC ACCT 3 DEPT OF CIVIL ENG FILE T129 WCN 4/27/76 T76-733 11PL 12-28

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PTC ACCT 3 CLPT OF CIVIL ENG

FILE 1134

MIN 4/7/74 174-0011

TIME 16.05

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*****
PFC      AUCT 3      DEPT OF CIVIL ENG      FILE  Y169      WED  8/27/74 174-0091      TIME 16.57
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*****
* TRAPEZOIDAL GUTTER OF BASE WIDTH= .5000 F *
* SIDE SLOPE= 60 DEG. *
*****

INLOW PER UNIT LENGTH OF GUTTER= .005000 CU-M./S.
*****

      LENGTH      VERT      DEPTH      AREA      YFIN      AFIN
*****
L-0001      5.000      .06264      .13666      .059015      * .12266      .070002
L-0002      10.000      .12538      .27538      .118030      * .24768      .136004
L-0003      15.000      .18766      .41766      .174045      * .37038      .204006
L-0004      20.000      .24766      .62766      .234060      * .51808      .288008
L-0005      25.000      .30538      .81538      .288075      * .66078      .376010
L-0006      30.000      .36038      .99538      .337090      * .80848      .456012
L-0007      35.000      .41266      .116266      .382105      * .95118      .528014
L-0008      40.000      .46266      .134266      .423120      * 1.08888      .592016
L-0009      45.000      .51038      .150266      .460135      * 1.22158      .648018
L-0010      50.000      .55538      .164266      .493150      * 1.34928      .696020
L-0011      55.000      .59766      .176266      .522165      * 1.47198      .736022
L-0012      60.000      .63766      .186266      .548180      * 1.59008      .768024
L-0013      65.000      .67538      .194266      .571195      * 1.70368      .792026
L-0014      70.000      .71038      .200266      .591210      * 1.81278      .808028
L-0015      75.000      .74266      .204266      .608225      * 1.91738      .816030
L-0016      80.000      .77266      .206266      .622240      * 2.01798      .818032
L-0017      85.000      .80038      .207266      .633255      * 2.11458      .814034
L-0018      90.000      .82538      .207266      .641270      * 2.20718      .804036
L-0019      95.000      .84766      .206266      .646285      * 2.29578      .788038
L-0020      100.000      .86766      .204266      .648300      * 2.38038      .766040
L-0021      105.000      .88538      .201266      .647315      * 2.46098      .738042
L-0022      110.000      .90038      .197266      .643330      * 2.53758      .704044
L-0023      115.000      .91266      .192266      .636345      * 2.61018      .664046
L-0024      120.000      .92266      .186266      .626360      * 2.67878      .618048
L-0025      125.000      .93038      .179266      .613375      * 2.74338      .566050
L-0026      130.000      .93538      .171266      .597390      * 2.80398      .508052
L-0027      135.000      .93766      .162266      .578405      * 2.86058      .444054
L-0028      140.000      .93766      .152266      .556420      * 2.91318      .374056
L-0029      145.000      .93538      .141266      .531435      * 2.96178      .300058
L-0030      150.000      .93038      .129266      .503450      * 3.00638      .222060
L-0031      155.000      .92266      .116266      .472465      * 3.04698      .140062
L-0032      160.000      .91266      .103266      .438480      * 3.08358      .054064
L-0033      165.000      .90038      .090266      .401495      * 3.11618      .000066
L-0034      170.000      .88538      .077266      .361510      * 3.14478      .000068
L-0035      175.000      .86766      .064266      .318525      * 3.16938      .000070
L-0036      180.000      .84766      .051266      .273540      * 3.18998      .000072
L-0037      185.000      .82538      .038266      .226555      * 3.20658      .000074
L-0038      190.000      .80038      .025266      .178570      * 3.21918      .000076
L-0039      195.000      .77266      .012266      .129585      * 3.22778      .000078
L-0040      200.000      .74266      .000266      .079600      * 3.23238      .000080
L-0041      205.000      .71038      .000000      .029615      * 3.23398      .000082
L-0042      210.000      .67538      .000000      .000000      * 3.23258      .000084
L-0043      215.000      .63766      .000000      .000000      * 3.22818      .000086
L-0044      220.000      .59766      .000000      .000000      * 3.22078      .000088
L-0045      225.000      .55538      .000000      .000000      * 3.21038      .000090
L-0046      230.000      .51038      .000000      .000000      * 3.19698      .000092
L-0047      235.000      .46266      .000000      .000000      * 3.18058      .000094
L-0048      240.000      .41266      .000000      .000000      * 3.16118      .000096
L-0049      245.000      .36038      .000000      .000000      * 3.13878      .000098
L-0050      250.000      .30538      .000000      .000000      * 3.11338      .000100
L-0051      255.000      .24766      .000000      .000000      * 3.08498      .000102
L-0052      260.000      .18766      .000000      .000000      * 3.05358      .000104
*****
INLOW PER UNIT LENGTH OF GUTTER= .005000 CU-M./S.
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PROGRAMME TO DETERMINE THE FLOW CAPACITY OF
TRUE HALF-ROUND GUTTERS

NAME: HR

OBJECT: To determine the flow capacity of true half-round
gutters of various lengths

Checks: The validity of the programme was checked by comparing
the peak depths as calculated by the programme with the Marsh
experimental peaks. This comparison is made in Table 33.

Inputs:

Gutter diameter	D
Number of stations	NT
Output code	K
Gutter length	X
Initial estimate of maximum inflow rate per unit length	INF

Outline of programme:

An estimate of the maximum inflow per unit length that
the gutter can cater for is made. The critical depth at outlet
is found in an iterative fashion and this is employed as the
starting depth in the Hinds analysis. The water surface profile
is determined as explained for GUT 3 and the peak flow depth is
abstracted. The freeboard allowance is added to the peak flow
depth. This depth is compared with the gutter radius and if the
two values do not agree to a specified accuracy another estimate
of the maximum inflow rate is made and the process repeated until

the required accuracy is obtained.

Outputs:

Code, $K = 1$ - values of all variables after every iteration at every station for every estimated inflow rate value.

Code, $K = 2$ - final values of variables and flow depths are given at each station for every estimated flow depth value.

Code, $K > 2$ and $p = 1$ - the values of variables at the last upstream section are given for every estimated flow depth value

Code, $K > 2$ and $p \neq 1$ - the values of variables at the last upstream section are given only for the maximum permissible flow depth.

These variables include:

Maximum inflow rate per unit length	INF
Critical depth at outlet	YCRIT
Peak depth	$Y(NT, J)$
Peak area of flow	$A(NT, J)$
Design depth	YFIN
Design area of flow	AFIN

Limits placed on programme:

Maximum number of iterations when determining critical depth at outlet equals forty

Problems associated with programme:

As for previous programmes

Geometry:

As for GUT 2

TABLE 33: COMPARISON OF MARSH RESULTS WITH OUTPUT FROM HR

Discharge rate in m^3/s	Inflow per unit length in m^2/s	Marsh Peak Depth in metres	'HR' Peak Depth in metres
0,0004546	0,0000745	0,0318	0,03076
0,0009092	0,000149	0,0446	0,04366
0,001364	0,000224	0,0519	0,05270
0,001818	0,000298	0,0584	0,06104
0,002273	0,000373	0,0660	0,06870
0,002387	0,000392	0,0728	0,07078


```

L-0054 C
L-0055 57 SUPPLY W-2
L-0056 57 WTEC-CT-2) GO TO 17
L-0057 16 FORMATT(72, 'STATION NO', T13, '1', T19, 'DISP', T26, '01SCH', T37, 'AREA', T46, 'PRCY', T56, 'IMPV', T65, 'DELY', T75, 'T85, '
L-0058 08PM WRITE(KM, 12) MODSOP(13, Q11), A(11), Y(1, 1)
L-0059 17 FORMATT(75, T2, T16, T7, 4, T24, F8.6, T34, F8.6, T84, T7, 5)
L-0060 4 J=1, Y(1, 1)
L-0061 10 AGRT=11, 1)
L-0062 4 AGRT=11, 1)
L-0063 C FIDING NERMS AT ALL STATIONS USING FORMULA
L-0064 1 DELTA=11/27-1)
L-0065 1 DELTA=11/27-1)
L-0066 1 DELTA=11/27-1)
L-0067 1 DELTA=11/27-1)
L-0068 1 DELTA=11/27-1)
L-0069 1 DELTA=11/27-1)
L-0070 1 DELTA=11/27-1)
L-0071 25 Q(1, 21)=11-DELTA
L-0072 1 Q(1, 21)=11-DELTA
L-0073 25 Q(1, 21)=11-DELTA
L-0074 1 Q(1, 21)=11-DELTA
L-0075 1 Q(1, 21)=11-DELTA
L-0076 1 Q(1, 21)=11-DELTA
L-0077 1 Q(1, 21)=11-DELTA
L-0078 1 Q(1, 21)=11-DELTA
L-0079 1 Q(1, 21)=11-DELTA
L-0080 1 Q(1, 21)=11-DELTA
L-0081 1 Q(1, 21)=11-DELTA
L-0082 1 Q(1, 21)=11-DELTA
L-0083 1 Q(1, 21)=11-DELTA
L-0084 1 Q(1, 21)=11-DELTA
L-0085 1 Q(1, 21)=11-DELTA
L-0086 1 Q(1, 21)=11-DELTA
L-0087 1 Q(1, 21)=11-DELTA
L-0088 1 Q(1, 21)=11-DELTA
L-0089 1 Q(1, 21)=11-DELTA
L-0090 1 Q(1, 21)=11-DELTA
L-0091 1 Q(1, 21)=11-DELTA
L-0092 1 Q(1, 21)=11-DELTA
L-0093 1 Q(1, 21)=11-DELTA
L-0094 1 Q(1, 21)=11-DELTA
L-0095 1 Q(1, 21)=11-DELTA
L-0096 1 Q(1, 21)=11-DELTA
L-0097 1 Q(1, 21)=11-DELTA
L-0098 1 Q(1, 21)=11-DELTA
L-0099 1 Q(1, 21)=11-DELTA
L-0100 1 Q(1, 21)=11-DELTA
L-0101 1 Q(1, 21)=11-DELTA
L-0102 1 Q(1, 21)=11-DELTA
L-0103 1 Q(1, 21)=11-DELTA
L-0104 1 Q(1, 21)=11-DELTA
L-0105 1 Q(1, 21)=11-DELTA
L-0106 1 Q(1, 21)=11-DELTA
L-0107 1 Q(1, 21)=11-DELTA
L-0108 1 Q(1, 21)=11-DELTA
L-0109 1 Q(1, 21)=11-DELTA
L-0110 1 Q(1, 21)=11-DELTA
L-0111 1 Q(1, 21)=11-DELTA

```

```

L-0112 02      INS=INF-O-J0001
L-0113         PUP=1
L-0114         GO TO 67
L-0115 04      INF=INF--O0001
L-0116         PUP=1
L-0117         GO TO 67
L-0118 58      IF(P-GT-1) GO TO 63
L-0119         WRITE(XR,31) INP,ICRIT,NUT,J,J,PIAT,J1,YFIN,AFIN
L-0120         GO TO 63
L-0121 03      IF(YFIN-R1-17--005) GO TO 38
L-0122 51      PRINT(XR,38) N
L-0123         GO TO 63
L-0124 00      CONTINUE
L-0125 01      CONTINUE

```

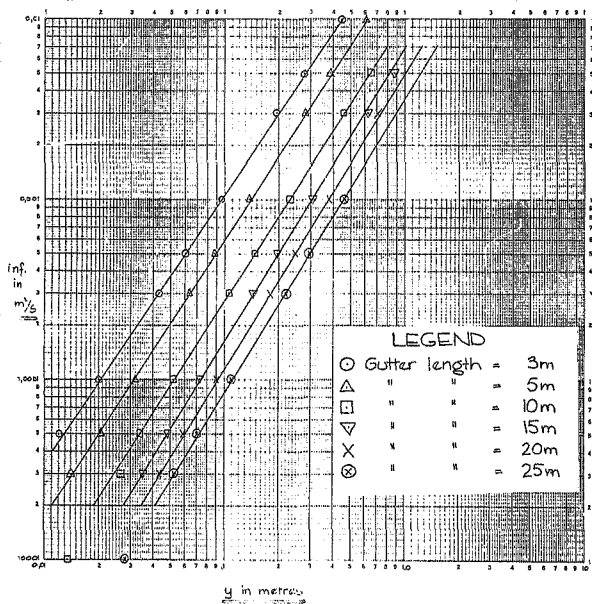
THE OUTER OVERFLOW AT STATION NO=*,IX,12)

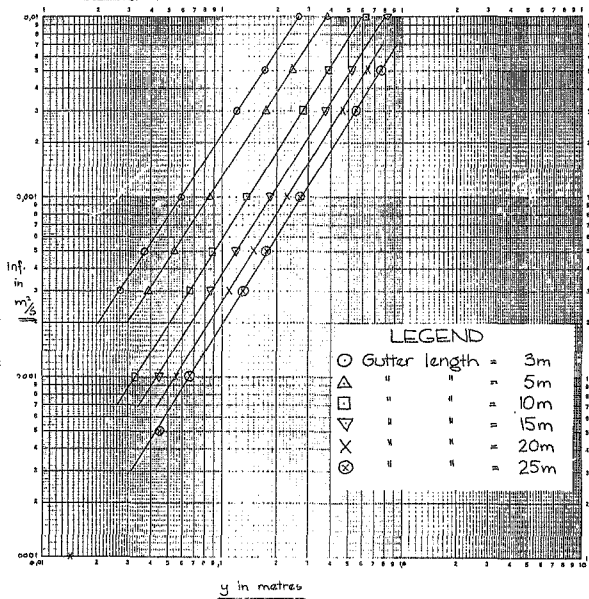
APPENDIX D

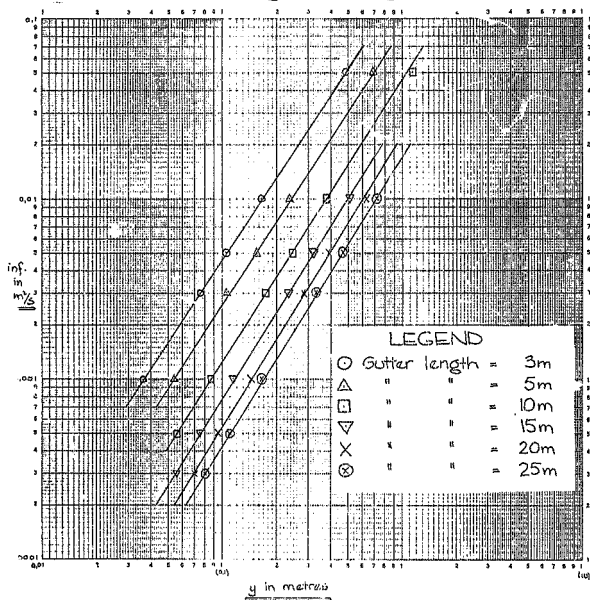
THE ANALYSIS OF THE RESULTS OF THE MATHEMATICAL MODEL

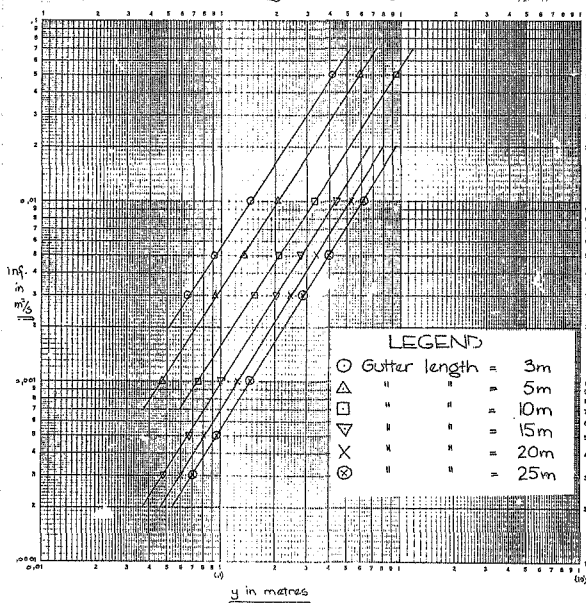
Analysis of the Rectangular gutter results

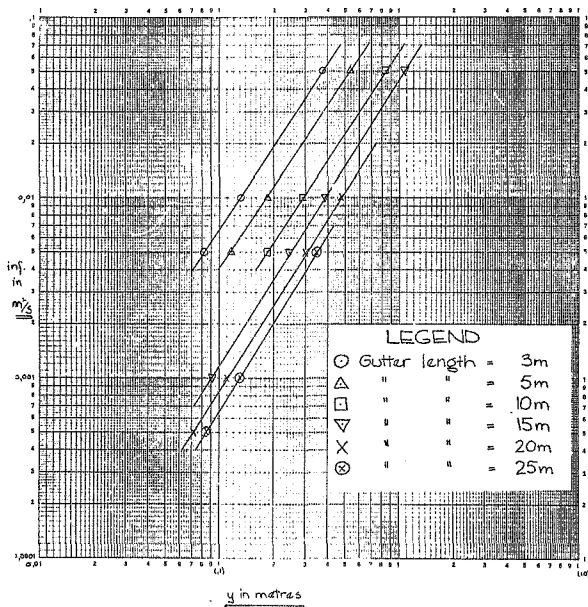
Graph 11: Plot of $\log(\text{inf})$ vs $\log(y)$ for $b = 0,1\text{m}$ for rectangular gutters



Graph 12: Plot of $\log(\text{inf})$ vs $\log(y)$ for $b = 0,2\text{m}$ 

Graph 13: Plot of $\log(\text{inf})$ vs $\log(y)$ for $b = 0.4\text{m}$ 

Graph 14: Plot of $\log(\ln f)$ vs $\log(y)$ for $b = 0.5m$ 

Graph 15: Plot of $\log(\text{inf})$ vs $\log(y)$ for $b=0,6m$ 

DETERMINATION OF THE EQUATION OF THE DESIGN CURVE FOR RECTANGULAR GUTTERS

The equation of the curve as seen in graph 4 has the form

$$\log (\text{inf.}x^{1,05}) = m \log (y_b^{0,67}) + C$$

$$\text{or } \text{inf.}x^{1,05} = (y_b^{0,67})^m \cdot K$$

where $K = \log C$

$$\text{and the slope } m = \frac{\log (\text{inf.}x^{1,05})_1 - \log (\text{inf.}x^{1,05})_2}{\log (y_b^{0,67})_1 - \log (y_b^{0,67})_2}$$

To determine the values of m and K accurately a large number of values of $\text{inf.}x^{1,05}$ and $y_b^{0,67}$ lying on the curve were abstracted from graph 4. These values are listed in Table 34. Pairs of $\text{inf.}x^{1,05}$ and $y_b^{0,67}$ values were then used to determine the slope m by means of the above formula. The results are in Table 34. The mean value of m is 1,6144 and this value of m is used to determine K from the formula

$$K = \frac{\text{inf.}x^{1,05}}{(y_b^{0,67})^{1,6144}}$$

The values of K thus determined are listed in Table 35. The mean value is then determined and is $K = 1,4294$.

Thus the equation of the curve is given by

$$\text{inf.}x^{1,05} = 1,4294 (y_b^{0,67})^{1,614}$$

This equation is checked by calculating the values of $\text{inf.}x^{1,05}$ using given values of $y_b^{0,67}$ and the above equation.

The results are listed in Table 35 and it is seen that the equation gives excellent agreement with the abstracted values of $\text{inf.}x^{1,05}$.

TABLE 34: DETERMINATION OF THE SLOPE OF GRAPH 4

$\text{inf. } x^{1,05}$	$y^{0,67}$	slope, m
0,0007	0,0089	1,61294
0,08	0,1680	
0,0009	0,0105	1,62099
0,10	0,1920	
0,007	0,0368	1,60959
0,30	0,3800	
0,01	0,0465	1,62377
0,10	0,1920	
0,001	0,0111	1,6074
0,01	0,0465	
0,002	0,0171	1,6176
0,10	0,1920	
0,004	0,0262	1,6157
0,20	0,2950	
0,02	0,0705	1,6019
0,15	0,2480	
0,01	0,0465	1,6188
0,08	0,1680	
0,03	0,0910	1,6130
0,20	0,2950	

Mean slope $m = 1,614369$

TABLE 35: VALUES ABSTRACTED FROM GRAPH 4 AND CHECK ON
VALIDITY OF DESIGN EQUATION

Inf. $x^{1,05}$ as abstracted from graph 4	$y^{0,67}$	K	$1,4294(y^{0,67})^{1,614}$
0,0007	0,0089	1,43088	0,000700
0,0009	0,0105	1,40875	
0,001	0,0111	1,43097	0,001001
0,002	0,0171	1,42456	
0,004	0,0262	1,43072	0,004002
0,007	0,0368	1,44675	
0,01	0,0465	1,41605	0,0101
0,02	0,0705	1,44713	
0,03	0,0910	1,43762	0,02986
0,05	0,1260	1,41687	
0,08	0,1680	1,42478	0,00803
0,1	0,1920	1,43502	0,09963
0,15	0,2480	1,42458	
0,20	0,2950	1,43533	0,1993
0,30	0,3800	1,43060	0,29996

Mean K = 1,42940

DETERMINATION OF THE EQUATION OF THE CURVE FOR
RECTANGULAR GUTTERS AS SEEN IN GRAPH 3

The equation of the curve also has the form

$$\log(\text{inf.}x) = m \log(yb^{0,67}) + C$$

$$\text{or } \text{inf.} x = (yb^{0,67})^m \cdot K.$$

Values of $\text{inf.}x$ and $yb^{0,67}$ were abstracted from graph 3

and are listed in Table 36. These values were then used to determine the slope values. Results are in Table 36.

The mean of all of these m values is 1,6287. It is seen that the m values marked with an asterisk differ considerably from the mean value. This is due to the difficulty in accurately abstracting the $yb^{0,67}$ values from graph 3. If these m values are neglected, the mean m value is equal to 1,62513.

The value of K is found using both of these values.

Results are listed in Table 36. The mean values are

$$(i) \quad \text{for } m = 1,629, \bar{K} = 1,20833$$

$$(ii) \quad \text{for } m = 1,625, \bar{K} = 1,18541$$

To check which of these gives the best results the value of $\text{inf.}x$ is calculated using the formula

$$\text{inf.}x = (yb^{0,67})^m \cdot K \text{ and the 2 sets of } m \text{ and } K \text{ values.}$$

Results are listed in Table 37.

It is seen that $\text{inf.}x = 1,1854 (yb^{0,67})^{1,625}$ gives slightly better agreement with the actual values. Thus this is the equation of the curve in graph 3.

TABLE: 36: VALUES USED IN DETERMINING THE
EQUATION OF GRAPH 3

inf.x in m ³ /s	y ^{0,67}	slope ,m	K for m = 1,629	K for m = 1,625
0,1	0,218	1,62321	1,19579	1,18852
0,08	0,190	1,62372	1,19674	1,18882
0,07	0,175	1,61023	1,19726	1,18895
0,05	0,142	1,74966*	1,20197	1,17909
0,04	0,125	1,56414*	1,18357	1,17378
0,03	0,104	1,62224	1,19777	1,18697
0,02	0,081	1,64882	1,19980	1,18780
0,01	0,0532	1,58837*	1,18984	1,17596
0,007	0,0425	1,16343	1,20075	1,18568
0,005	0,0345	1,62624	1,20465	1,18854
0,003	0,0252	1,64672	1,20570	1,18809
0,002	0,0197	1,60758	1,20045	1,18174
0,001	0,0128	1,63252	1,21159	1,19066
0,0007	0,0120	1,64513	1,21131	1,19008
0,0007	0,0103		1,20833	1,18642
MEANS			1,20037	1,18541

TABLE 37: CHECK ON CALCULATED EQUATION OF GRAPH 3

$y_b^{0,67}$	$1,1854(y_b^{0,67})^{1,625}$	$1,20037(y_b^{0,67})^{1,629}$	(inf.x) actual
0,218	0,0997	1,00383	0,1
0,175	0,06779	0,070182	0,07
0,125	0,04039	0,04056	0,04
0,081	0,019959	0,0200095	0,02
0,0532	0,01008	0,01008	0,01
0,0252	0,002993	0,002986	0,003
0,0128	0,0009956	0,00099074	0,001
0,0103	0,0006994	0,0006953	0,0007

PROGRAMME TO ANALYSE DATA FOR RECTANGULAR GUTTERS

NAME: YA

OBJECT: To analyse the data for rectangular gutters

Inputs:

Gutter length	x
Number of depth inputs	m
Inflow rate	inf
base breadth	b
design depth	yfin

Method of Computation:

The programme calculates

$$db = yfin \cdot b^{0,67}$$
 for a specified number of design depth

values

Outputs:

The outputs are inflow rate, base breadth, design depth
(required depth) and $db = y \cdot b^{0,67}$.

Outputs from YA

gutter length = 3.00 m

Inflow	base breadth	red depth	dh
.000300	.300	.0070	.0008
.000500	.300	.0093	.0120
.001000	.300	.0095	.0206
.001000	.300	.1076	.0420
.001000	.300	.1000	.0611
.005000	.300	.2730	.0595
.005000	.300	.1001	.0575
.005000	.300	.1001	.0522
.010000	.300	.2000	.0015
.010000	.300	.2001	.0017
.010000	.300	.1001	.0015
.050000	.300	.4001	.0015
.050000	.300	.4001	.0010
.050000	.300	.3010	.0011

END OF FILE (2ND LINE AFTER START 5)

/CAN?

/canEXEC 1.50 sec

GO

gutter length = 5.00 m

Inflow	base breadth	red depth	dh
.000300	.300	.0077	.0130
.000500	.300	.0073	.0107
.001000	.300	.1062	.0201
.001000	.300	.0050	.0200
.003000	.300	.2702	.0505
.003000	.300	.1002	.0501
.003000	.300	.1002	.0500
.005000	.300	.1001	.0017
.005000	.300	.1001	.0010
.010000	.300	.1001	.1000
.010000	.300	.2003	.1000
.010000	.300	.0050	.1075
.010000	.300	.2001	.1001
.050000	.300	.0001	.0000
.050000	.300	.0001	.1000

EXEC 2.02 sec

GO

cutler length = 10.00 m

Inflow	base breadth	red depth	dh
*****	*****	*****	*****
.0001000	.100	.0525	.0110
.0002000	.100	.1050	.0226
.0005000	.100	.1675	.0317
.0005000	.200	.0000	.0305
.0010000	.100	.2290	.0408
.0010000	.200	.1773	.0467
.0010000	.300	.1051	.0400
.0030000	.200	.2016	.0450
.0050000	.300	.2175	.0457
.0050000	.200	.2000	.1175
.0050000	.500	.2001	.1300
.0050000	.400	.2167	.1324
.0100000	.300	.4070	.2007
.0100000	.400	.3010	.2000
.0100000	.500	.2000	.2005
.050	.600	.0701	.5050

EXEC 1.74 sec
 00

cutler length = 15.00 m

Inflow	base breadth	red depth	dh
*****	*****	*****	*****
.0000000	.100	.0000	.0107
.0001000	.100	.0115	.0150
.0003000	.100	.1007	.0305
.0005000	.100	.1007	.0421
.0005000	.200	.0000	.0400
.0010000	.200	.1000	.0630
.0010000	.300	.1000	.0620
.0010000	.200	.1007	.1275
.0030000	.300	.2000	.1202
.0030000	.400	.2110	.1250
.0050000	.300	.2007	.1257
.0050000	.400	.1000	.1737
.0100000	.500	.4100	.2720
.0100000	.600	.3000	.2710

END OF FILE (2ND LINE AFTER OUTPUT 5)
 /CAP?
 /canEXEC 1.70 sec
 00

cutter length = 20.00 m

Inflow	base breadth	rad depth	dh
.000050	.100	.0001	.0127
.000100	.100	.0002	.0086
.000150	.100	.0003	.0107
.000200	.100	.0004	.0085
.000250	.100	.0005	.0076
.000300	.100	.0006	.0059
.000350	.100	.0007	.0050
.000400	.100	.0008	.0041
.000450	.100	.0009	.0032
.000500	.100	.0010	.0023
.000550	.100	.0011	.0014
.000600	.100	.0012	.0005
.000650	.100	.0013	.0006
.000700	.100	.0014	.0007
.000750	.100	.0015	.0008
.000800	.100	.0016	.0009
.000850	.100	.0017	.0010
.000900	.100	.0018	.0011
.000950	.100	.0019	.0012
.010000	.100	.0020	.0013

END OF FILE (END LINE AFTER STATE 5)
/CAH?
/canEXEC 1.00 sec
GO

cutter length = 25.00 m

Inflow	base breadth	rad depth	dh
.000050	.100	.0001	.0115
.000100	.100	.0002	.0050
.000150	.100	.0003	.0071
.000200	.100	.0004	.0058
.000250	.100	.0005	.0060
.000300	.100	.0006	.0055
.000350	.100	.0007	.0050
.000400	.100	.0008	.0041
.000450	.100	.0009	.0032
.000500	.100	.0010	.0023
.000550	.100	.0011	.0014
.000600	.100	.0012	.0005
.000650	.100	.0013	.0006
.000700	.100	.0014	.0007
.000750	.100	.0015	.0008
.000800	.100	.0016	.0009
.000850	.100	.0017	.0010
.000900	.100	.0018	.0011
.000950	.100	.0019	.0012
.010000	.100	.0020	.0013

END OF FILE (END LINE AFTER STATE 5)
/CAH?
/canEXEC 1.00 sec
GO

ANALYSIS OF THE TRAPEZOIDAL GUTTER

RESULTS

Values of $\inf.x$ and $= \frac{Adeg^{0,25}}{b^{0,09}}$ were calculated for various base-breadths using the output data from TRAP in Appendix

C. These values are shown in tables 38 to 41.

DETERMINATION OF THE EQUATION OF THE DESIGN CURVE FOR TRAPEZOIDAL GUTTERS (GRAPH 9);

The analysis proceeded in exactly the same manner as outlined for rectangular gutters. The mean slope is determined in table 42, and is given by $\bar{m} = 1,337971$. The mean K value is determined in table 43 and is given by $K = 0,69687$. The equation of graph 9 is thus $\inf.x = 0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338}$

This equation is then checked by calculating $\inf.x$ using the above formula and comparing the value so obtained with the actual value of $\inf.x$ abstracted from graph 9. Excellent agreement is obtained as seen in table 43.

TABLE 3: VALUES OF $\inf.x$ AND $\bar{g} = \frac{\Delta_{\text{deg}}^{0.25}}{0.09}$ FOR $b = 0.2$ metres

$\inf.x$ in m^2/s	x in metres	$\inf.x$ in m^2/s	$\bar{g}$ for Deg = 30	$\bar{g}$ for Deg = 45	$\bar{g}$ for Deg = 60	$\bar{g}$ mean
0.0008	10	0.008	0.030871	0.03176	0.03194	0.03152
	15	0.012	0.044599	0.04493	0.04379	0.0444
	20	0.016	0.05633	0.05668	0.05604	0.05635
	25	0.0208	0.056835	0.06804	0.05657	0.05715
	30	0.024	0.081009	0.07974	0.07852	0.07976
	35	0.028	0.092101	0.09179	0.08833	0.09075
0.0005	10	0.005	0.022190	0.02236	0.02281	0.02245
	15	0.0075	0.0359267	0.03682	0.02113	0.03096
	20	0.01	0.040143	0.03965	0.03966	0.03982
	25	0.0125	0.048464	0.04772	0.04847	0.04822
	30	0.015	0.057066	0.05605	0.0552	0.05511
	35	0.0175	0.0643607	0.06465	0.06376	0.06426
0.0003	10	0.003	0.01495	0.01513	0.01622	0.01543
	15	0.0045	0.021078	0.02139	0.02194	0.02147
	20	0.006	0.026486	0.02794	0.02777	0.02740
	25	0.0075	0.033520	0.03381	0.03371	0.03360
	30	0.009	0.039149	0.03989	0.03894	0.03933
	35	0.0105	0.045247	0.04504	0.04425	0.04485
0.005	3	0.015	0.048367	0.04880	0.04742	0.04820
	5	0.025	0.072896	0.07446	0.07185	0.07307
	10	0.05	0.130074	0.1284	0.1254	0.1283
	15	0.075	0.182527	0.1786	0.1716	0.1779
	20	0.1	0.233031	0.2290	0.2212	0.2277
	25	0.125	0.280704	0.2745	0.2648	0.2731
0.003	3	0.009	0.0318479	0.0326	0.03181	0.03197
	5	0.015	0.0493676	0.04880	0.04841	0.04853
	10	0.03	0.087375	0.08641	0.08398	0.08592
	15	0.045	0.120946	0.1220	0.1180	0.1203
	20	0.06	0.158270	0.1536	0.1508	0.1532
	25	0.075	0.187792	0.1838	0.1766	0.1827
0.001	3	0.003	0.0132619	0.01351	0.01408	0.01365
	5	0.005	0.0211396	0.02149	0.02127	0.02132
	10	0.01	0.036169	0.03752	0.03701	0.03723
	15	0.015	0.052636	0.05237	0.05243	0.05248
	20	0.02	0.065229	0.06670	0.06546	0.06500
	25	0.025	0.078117	0.08017	0.07807	0.08079

TABLE 3P: VALUES OF $\inf.x$ AND $\phi = \frac{\Delta \text{deg}}{b^{0.09}}$ FOR $b = 0.30 \text{ metres}$

$\inf.x$ in m^2/s	x in metres	$\inf.x$ in m^2/s	ϕ for Deg = 30	ϕ for Deg = 45	ϕ for Deg = 60	ϕ mean
0.0008	10	0.008	0.030117	0.03240	0.03272	0.03175
	15	0.0120	0.04362	0.04448	0.04482	0.04411
	20	0.016	0.05498	0.05576	0.05712	0.05593
	25	0.0208	0.06676	0.06872	0.06727	0.06758
	30	0.024	0.0772	0.07769	0.07883	0.07760
	35	0.028	0.09164	0.08981	0.08795	0.08960
0.0005	10	0.005	0.02244	0.02318	0.02313	0.02292
	15	0.0075	0.03045	0.03168	0.03300	0.03171
	20	0.01	0.04007	0.04019	0.04089	0.04018
	25	0.0125	0.04733	0.04780	0.04887	0.04800
	30	0.015	0.05628	0.05556	0.05694	0.05626
	35	0.0175	0.06395	0.06348	0.06396	0.06360
0.0003	10	0.003	0.01553	0.01573	0.01690	0.01605
	15	0.0045	0.02151	0.02237	0.02127	0.02237
	20	0.006	0.02771	0.03002	0.02865	0.02813
	25	0.0075	0.03292	0.03393	0.03507	0.03394
	30	0.009	0.03859	0.03977	0.04052	0.04003
	35	0.0105	0.04372	0.04463	0.04601	0.04476
0.0005	3	0.015	0.04733	0.04780	0.04887	0.04800
	5	0.025	0.07026	0.07174	0.0724	0.07147
	10	0.05	0.1259	0.1252	0.1219	0.1241
	15	0.075	0.1762	0.1744	0.1706	0.1737
	20	0.1	0.2228	0.2213	0.2142	0.2194
	25	0.125	0.2673	0.2596	0.2551	0.2607
0.003	3	0.009	0.03184	0.03296	0.03313	0.03261
	5	0.015	0.04733	0.04907	0.05001	0.04880
	10	0.03	0.08394	0.08488	0.08508	0.08463
	15	0.045	0.1174	0.1180	0.1160	0.1171
	20	0.06	0.1524	0.1489	0.1463	0.1492
	25	0.075	0.1813	0.1786	0.1758	0.1786
0.001	3	0.003	0.01359	0.01388	0.01508	0.01402
	5	0.005	0.02018	0.02117	0.02217	0.02117
	10	0.01	0.03810	0.03868	0.03875	0.03718
	15	0.015	0.05173	0.05293	0.05230	0.05220
	20	0.02	0.06311	0.06586	0.06604	0.06568
	25	0.025	0.07895	0.07915	0.07881	0.07897

TABLE 40: VALUES OF $\inf.x$ AND $\bar{g} = \frac{\text{Area}}{b^{0.09}}$ FOR $b = 0.4$ metres

$\inf$ in m^2/s	x in metres	$\inf.x$ in m^2/s	$\bar{g}$ for Deg = 30	$\bar{g}$ for Deg = 45	$\bar{g}$ for Deg = 60	$\bar{g}$ mean
0.0005	5	0.0025	0.0120	0.01374	0.01431	0.01335
	10	0.005	0.02207	0.02378	0.02432	0.02339
	15	0.0075	0.03127	0.03261	0.03289	0.03226
	20	0.01	0.03942	0.04156	0.04263	0.04120
	25	0.0125	0.04779	0.04928	0.05119	0.04942
	30	0.015	0.05641	0.05705	0.05843	0.05730
0.001	5	0.005	0.02086	0.02144	0.02317	0.02182
	10	0.01	0.03659	0.03890	0.04012	0.03851
	15	0.015	0.05163	0.05275	0.05443	0.05194
	20	0.02	0.06402	0.06533	0.06742	0.06559
	25	0.025	0.0767	0.0814	0.08048	0.07953
	30	0.03	0.09168	0.09123	0.09216	0.09170
0.005	5	0.025	0.07132	0.07183	0.07331	0.07215
	10	0.05	0.1220	0.1233	0.1251	0.1237
	15	0.075	0.1703	0.1699	0.1683	0.1694
	20	0.01	0.2143	0.2175	0.2105	0.2141
	25	0.0125	0.2595	0.2595	0.2559	0.2576
	30	0.015	0.3026	0.3009	0.2916	0.2984
0.01	5	0.05	0.1214	0.1202	0.1225	0.1214
	10	0.1	0.2099	0.2092	0.2074	0.2087
	15	0.15	0.2915	0.2891	0.2842	0.2863
	20	0.2	0.3691	0.3639	0.3568	0.3632
	25	0.25	0.4487	0.4375	0.4285	0.4376
	30	0.3	0.5173	0.5131	0.4926	0.5077
0.05	5	0.25	0.4251	0.4247	0.4111	0.4203
	10	0.5	0.7496	0.7382	0.7171	0.7350
	15	0.75		1.034	0.9929	1.013
0.1	5	0.5	0.7496	0.7341	0.7094	0.7304

TABLE 41: VALUE OF $\inf.x$ AND $g = \text{Add}_{b^{0.25}}^{0.09}$ FOR $b = 0.5$ metres

$\inf.x$ in m/s	x in metres	$\inf.x$ in m/s	g for Deg = 30	g for Deg = 45	g for Deg = 60	g mean
0.005	5	0.025	0.06971	0.07312	0.07539	0.07279
	10	0.05	0.1230	0.1245	0.1258	0.1244
	15	0.075	0.1704	0.1720	0.1715	0.1713
	20	0.1	0.2144	0.2142	0.2141	0.2142
	25	0.125	0.2569	0.2575	0.2555	0.2566
	30	0.15	0.3005	0.2939	0.2930	0.2958
0.003	5	0.015	0.04827	0.04990	0.05183	0.0500
	10	0.03	0.08355	0.08574	0.08713	0.08547
	15	0.045	0.1108	0.1172	0.1182	0.1177
	20	0.06	0.1446	0.1475	0.1481	0.1467
	25	0.075	0.1730	0.1742	0.1754	0.1742
	30	0.09	0.2022	0.2038	0.2031	0.203
0.001	5	0.005	0.02098	0.02335	0.02426	0.02286
	10	0.01	0.03680	0.03898	0.04118	0.03929
	15	0.015	0.05188	0.05461	0.05632	0.05417
	20	0.02	0.06514	0.06784	0.06988	0.06742
	25	0.025	0.07912	0.07999	0.08342	0.08084
	30	0.03	0.08952	0.09474	0.09539	0.09322
0.01	5	0.05	0.1207	0.1226	0.1223	0.1219
	10	0.1	0.2088	0.2094	0.2100	0.2094
	15	0.15	0.2837	0.2857	0.2861	0.2852
	20	0.2	0.3655	0.3620	0.3545	0.3608
	25	0.25	0.4386	0.4314	0.4225	0.4308
	30	0.3	0.5091	0.5024	0.486	0.4992
0.05	5	0.25	0.4180	0.4153	0.4060	0.4136
	10	0.50	0.7261	0.7245	0.7021	0.7209
	15	0.75	1.015	1.007	0.974	0.9987
	2	0.10	0.2011	0.2046		0.2038
0.1	5	0.5	0.7310	0.7204	0.6988	0.7167
	10	1.0		1.257	1.212	1.235

TABLE 42: DETERMINATION OF THE SLOPE OF GRAPH 9

$\frac{\ln x}{m^{3/5}}$	$\frac{A_{deg} 0,25}{b 0,09}$	m
0,003	0,0171	1,34106
0,09	0,216	
0,004	0,0211	
0,04	0,118	1,337615
0,005	0,025	
0,5	0,79	
0,007	0,0322	1,341819
0,09	0,216	
0,01	0,0422	
0,8	1,12	1,336528
0,02	0,07	
0,2	0,395	1,346137
0,04	0,118	
0,15	0,31	
0,005	0,025	1,342385
0,15	0,315	
0,07	0,178	
0,3	0,533	1,326923
0,01	0,0422	
0,15	0,31	

Mean $m = 1,337971$

TABLE 43: VALUES ABSTRACTED FROM PLOT OF $\inf.x$
 VERSUS $A.\deg^{0,25}/b^{0,09}$

$\inf.x$ $\frac{3}{m \cdot S}$	$\frac{Adeg^{0,25}}{b^{0,09}}$	K using $m=1,338$	$0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338}$
0,003	0,0171	0,69402	0,003009
0,004	0,0211	0,698506	0,003986
0,005	0,025	0,695867	0,005001
0,007	0,0322	0,694363	0,007016
0,01	0,0420	0,695172	0,01001
0,02	0,07	0,701922	0,01983
0,04	0,118	0,6980425	0,03988
0,05	0,139	0,700836	0,04965
0,07	0,178	0,704752	0,06913
0,09	0,216	0,699429	0,08956
0,15	0,315	0,703642	0,14837
0,20	0,395	0,693079	0,20084
0,3	0,533	0,696242	0,2999
0,5	0,79	0,6854014	0,50773
0,8	1,12	0,6874423	0,80996

Mean K = 0,69687

Thus $\inf.x = 0,6969 \left(\frac{Adeg^{0,25}}{b^{0,09}} \right)^{1,338}$

APPENDIX E

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