BEWEIDDODEINTEGRACIONIDIRECTA

Este método plantea un procedimiento basado en estudios de: Bakhmeteff, Mononobe, Lee y Von Seggern, encaminados a resolver directamente la Ecuación de flujo gradualmente variado.

Para determinar el perfil, el canal se divide en un número de tramos de tal forma de que en cada tramo las secciones 1 y 2 consideradas deben estar a una distancia tal que los exponentes hidráulicos M y N se mantengan constantes.

Los Exponentes Hidráulicos M y N se pueden expresar en función de la profundidad de flujo en canales trapezoidales de la siguiente manera:

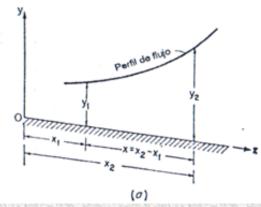
M: Exponente hidráulico para el flujo crítico

N: Exponente hidráulico para el flujo uniforme

La longitud de cada tramo a partir de los tirantes conocidos o supuestos en los extremos del tramo, se calcula con la siguiente expresión:

$$L = x_2 - x_1 = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_c}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

$$x = \frac{y_n}{S_0} \left\{ u - F(u, N) + \left(\frac{y_c}{y_n}\right)^M \frac{J}{N} * F(v, J) \right\}$$



 $L = x_2 - x_1$ = Distancia entre las secciones consecutivas 1 y 2 de características conocidas.

 $u = y/y_n$ = Relación entre el tirante cualquiera y el normal.

 y_n = Tirante normal.

y_c = Tirante crítico.

 S_0 = Pendiente del fondo del canal.

$$L = x_2 - x_1 = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_e}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

M y N = Exponentes hidráulicos, en función de la geometría de la sección y del tirante del agua.

$$N = \frac{10}{3} \left[\frac{1 + 2Z(y/b)}{1 + Z(y/b)} \right] - \frac{8}{3} \left[\frac{\sqrt{1 + Z^2}(y/b)}{1 + 2\sqrt{1 + Z^2}(y/b)} \right]$$
 (Abaco 1)

$$M = \frac{3(b+2Zy)^2 - 2Zy(b+Zy)}{(b+2Zy)(b+Zy)}$$
 (Abaco 2)

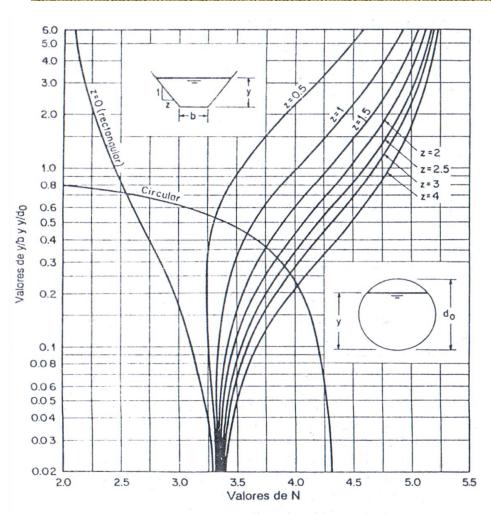


Figura 6-2. Curvas de valores de N.

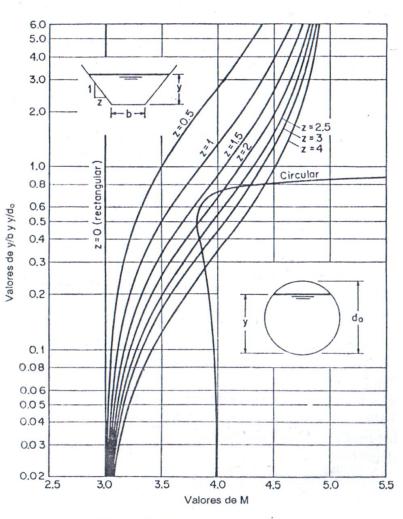


Figura 4-2. Curvas de valores de M.

$$L = x_2 - x_1 = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_c}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

v; J = Variables introducidas por Ven Te Chow, siendo:

$$v = u^{N/J} \qquad J = \frac{N}{N - M + 1}$$

F(u,N) = Función del Flujo Variado, calculado por Bakhmetev, cuyos valores se muestran en la tabla D1

$$F(u, N) = \int_{0}^{u} \frac{du}{1 - u^{N}}$$

F(v,J) = Función del Flujo Variado, se calcula con la misma tabla de Bakhmetev ingresando con los valores de v y J en lugar de u y N

$$F(v, J) = \int_{0}^{v} \frac{dv}{1 - v^{J}}$$

- 1.- Calcular y_n, y_c.
- 2.- Identificar la sección de control
- 3.- Identificar el perfil de flujo
- 4.- Calcular los exponentes hidráulicos N y M para un tirante promedio, a partir de los tirantes en los extremos.

$$N = \frac{10}{3} \left[\frac{1 + 2Z(y/b)}{1 + Z(y/b)} \right] - \frac{8}{3} \left[\frac{\sqrt{1 + Z^2} (y/b)}{1 + 2\sqrt{1 + Z^2} (y/b)} \right]$$

$$M = \frac{3(b + 2Zy)^{2} - 2Zy(b + Zy)}{(b + 2Zy)(b + Zy)}$$

5.- Calcular J; N/J y J/N

$$J = \frac{N}{N - M + 1}$$

6.- Calcular para la sección inicial y final del tramo los valores de «u» y «v»

$$u = y/y_n$$
 $v = u^{N/J}$

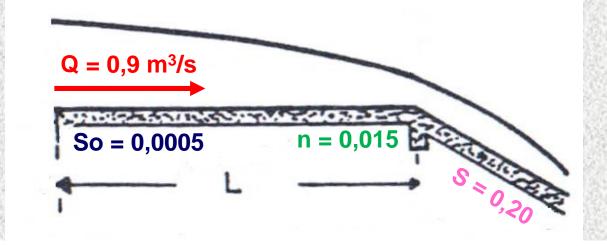
- 7.- Calcular las funciones del flujo variado F(u,N) y F(v,J) con la ayuda de la tabla D1.
- 8.- Calcular la longitud del tramo que separa las dos secciones extremas.

$$x = \frac{y_n}{S_0} \left\{ u - F(u, N) + \left(\frac{y_c}{y_n}\right)^M \frac{J}{N} * F(v, J) \right\}$$

$$L = x_2 - x_1 = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_c}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

9.- Graficar y vs x.

EJERCICIO: Un canal trapezoidal tiene un ancho de solera b = 1m, talud z = 1 y con una pendiente de 0,0005 conduce un caudal de 900 l/s en flujo uniforme con un coeficiente de rugosidad n = 0,015. A partir de cierta sección como se muestra en la figura es necesario aumentar la pendiente del canal a 0,20. a) Calcular el perfil del flujo.



1.- Cálculo de los tirantes normal y crítico (yn; yc)

Tirante normal

$$Q = \frac{1}{n} *A *R^{2/3} *S^{1/2}$$

$$0.9 = \frac{1}{0.015} (y_n + y_n^2) \left(\frac{y_n + y_n^2}{1 + 2y_n \sqrt{2}} \right)^{2/3} (0.0005)^{1/2}$$

 $\underline{y_n} = 0.68m$

Tirante crítico

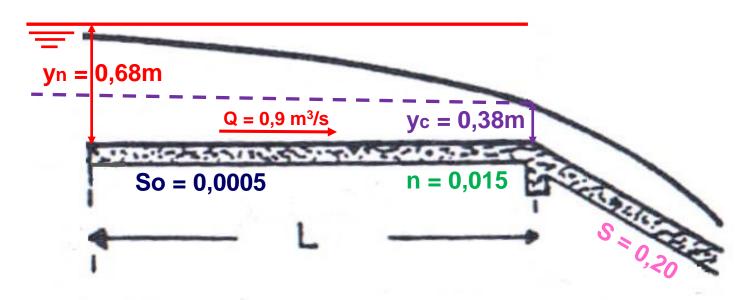
$$\frac{v^2}{a}=D;$$

$$\frac{Q^2}{A^2g} = \frac{A}{T};$$

$$\frac{v^2}{g} = D; \qquad \frac{Q^2}{A^2 g} = \frac{A}{T}; \qquad Q = \sqrt{\frac{A^3 g}{T}}$$

$$0.9 = \sqrt{\frac{[y_c + y_c^2]^{3*9.8}}{1 + 2y_c}}$$

$$y_c = 0.38m$$



2.- Sección de control.

La sección de control en este caso está ubicada en el punto de cambio de pendiente, presentándose el tirante crítico $y_c = 0.38$ m en dicho punto. (ZONA 2)

3.- Perfil de flujo.

$$y_n = 0.68 \text{m} > y_c = 0.38 \text{m}$$

$$\downarrow$$

$$CURVA TIPO M$$

$$\downarrow$$

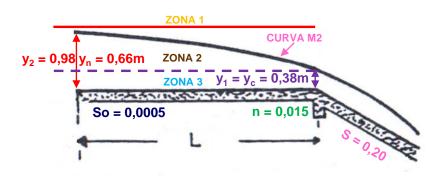
$$ZONA 2 (Perfil tipo M2)$$

y_{01} y_{01} y_{038m} y_{02} y_{02} y_{02}

4.- Cálculo del perfil.

El cálculo se efectúa desde $y_c = 0.38$ m hacia aguas arriba, hasta un valor del tirante correspondiente al 98% yn, es decir y = 0.66 m.

RANGO: [0,66m - 0,38m]



5.- Calculo de los exponentes hidráulicos N y M para un tirante promedio, a partir de los tirantes en los extremos.

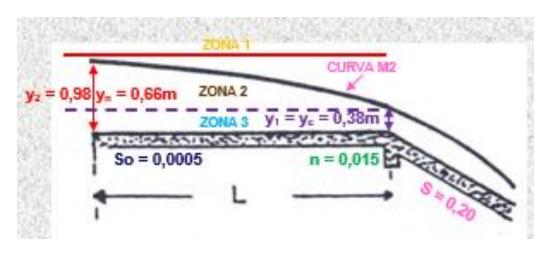
El valor del y promedio para el tramo será:

$$\bar{y} = \frac{y_1 + y_2}{2} = \frac{0.38 + 0.66}{2} = 0.52m$$

$$\frac{y}{b} = \frac{0.52}{1} = 0.52;$$
 Z = 1

$$N = \frac{10}{3} \left[\frac{1 + 2Z(y/b)}{1 + Z(y/b)} \right] - \frac{8}{3} \left[\frac{\sqrt{1 + Z^2}(y/b)}{1 + 2\sqrt{1 + Z^2}(y/b)} \right]$$

$$N = \frac{10}{3} \left[\frac{1 + 2(0.52)}{1 + 0.52} \right] - \frac{8}{3} \left[\frac{\sqrt{2}(0.52)}{1 + 2\sqrt{2}(0.52)} \right]$$



N = 3,68 (Igual valor obtenemos en el ábaco con y/b=0,52, Z=1)

$$M = \frac{3(b+2Zy)^2 - 2Zy(b+Zy)}{(b+2Zy)(b+Zy)}$$

$$M = \frac{3(1+2*1*0,52)^2 - 2*1*0,52(1+1*0,52)}{(1+2*0,52)(1+0,52)}$$

M = 3,52 (Igual valor obtenemos en el ábaco con y/b=0,52, Z=1)

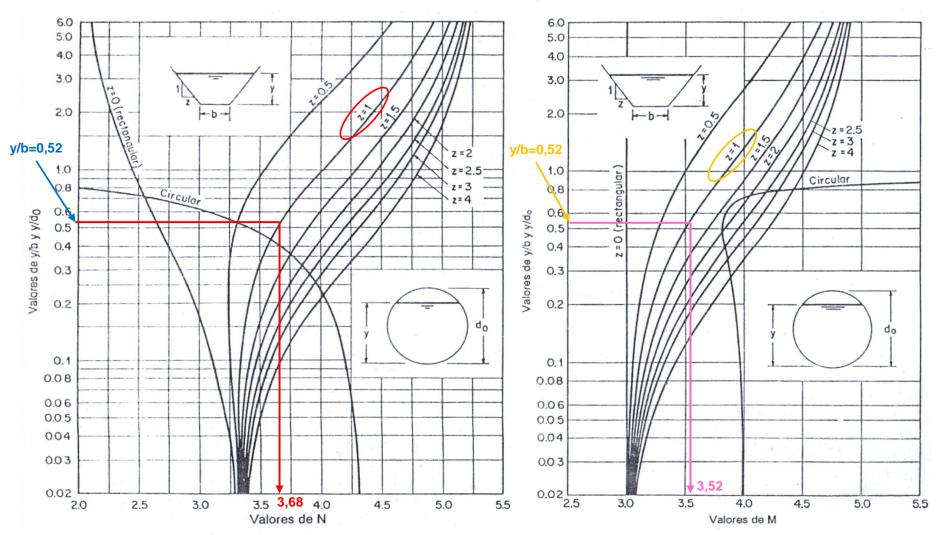


Figura 6-2. Curvas de valores de N.

Figura 4-2. Curvas de valores de M.

6.- Cálculo de J; J/N; N/J.

$$J = \frac{N}{N - M + 1}$$
 $J = \frac{3,68}{3,68 - 3,52 + 1}$

$$J = 3,17$$

$$J/N = 3,17/3,68$$

$$J/N = 0.861$$

$$N/J = 3,68/3,17$$

$$N/J = 1,16$$

7.- Cálculo de los valores de u y v para cada sección.

• Sección (1)

$$u_1 = \frac{y_1}{y_n} = \frac{0.38}{0.68}$$

$$u_1 = 0.56$$

$$v_1 = u_1^{N/J} = 0.56^{1.16}$$

$$v_1 = 0,51$$

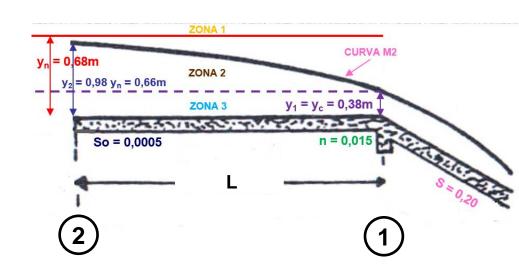
• Sección (2)

$$u_2 = \frac{y_2}{y_n} = \frac{0.66}{0.68}$$

$$u_2 = 0,97$$

$$v_2 = u_2^{N/J} = 0.97^{1.16}$$

$$v_2 = 0.97$$



8.- Cálculo de las Funciones del Flujo Variado F(u,N) y F(v,J).

Interpolando valores en la tabla D1 se obtiene:

• Sección (1)

$$F(u_1,N) = F(0,56; 3,68)$$
 $F(v_1,J) = F(0,51; 3,17)$ $F(v_1,J) = F(0,51; 3,17)$

$$F(u_1,N) = 0,575$$

$$F(v_1,J) = 0.526$$

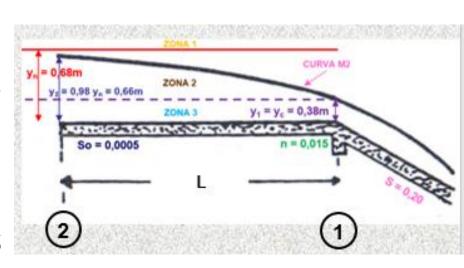
• Sección (2)

$$F(u_2,N) = F(0,97; 3,68)$$

$$F(v_2,J) = F(0,97,3,17)$$

$$F(u_2,N) = 1,486$$

$$F(v_2,J) = 1,504$$



SECCION	у	u	V	F(u,N)	F(v,J)
1	0.38	0.56	0.51	0.575	0.526
2	0.66	0.97	0.97	1.486	1.504
DIFERE	ENCIAS	0.41		0.911	0.978

Tabla D-1. La función de flujo variado para pendientes positivas, F(u,N)

1	abia D-	I. La Iui	icion de	Hujo va	N=3,68									
$\frac{N}{u}$	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0				
0.00 0.02 0.04 0.06 0.08	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080				
$ \begin{array}{c} 0.10 \\ 0.12 \\ 0.14 \\ 0.16 \\ 0.18 \\ \end{array} $	0.100 0.120 0.141 0.161 0.181	0.100 0.120 0.140 0.161 0.181	0.100 0.120 0.140 0.160 0.181	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180				
$\begin{array}{c} 0.20 \\ 0.22 \\ 0.24 \\ 0.26 \\ 0.28 \end{array}$	0.202 0.223 0.243 0.264 0.286	0.201 0.222 0.242 0.263 0.284	0.201 0.221 0.242 0.262 0.283	$\begin{array}{c} 0.201 \\ 0.221 \\ 0.241 \\ 0.262 \\ 0.282 \end{array}$	$\begin{array}{c} 0.200 \\ 0.221 \\ 0.241 \\ 0.261 \\ 0.282 \end{array}$	0.200 0.220 0.241 0.261 0.281	0.200 0.220 0.240 0.261 0.281	0.200 0.220 0.240 0.260 0.281	0.200 0.220 0.240 0.260 0.280	$ \begin{array}{c} 0.200 \\ 0.220 \\ 0.240 \\ 0.260 \\ 0.280 \end{array} $				
$ \begin{array}{r} 0.30 \\ 0.32 \\ 0.34 \\ 0.36 \\ 0.38 \end{array} $	0.307 0.329 0.350 0.373 0.395	0.305 0.326 0.348 0.370 0.392	0.304 0.325 0.346 0.367 0.389	$\begin{array}{c} 0.303 \\ 0.324 \\ 0.344 \\ 0.366 \\ 0.387 \end{array}$	0.302 0.323 0.343 0.364 0.385	0.302 0.322 0.343 0.363 0.384	0.301 0.322 0.342 0.363 0.383	0.301 0.321 0.342 0.362 0.383	0.301 0.321 0.341 0.362 0.382	$ \begin{array}{c} 0.300 \\ 0.321 \\ 0.341 \\ 0.361 \\ 0.382 \end{array} $				
0.40 0.42 0.44 0.46 0.48	0.418 0.441 0.465 0.489 0.514		$\begin{array}{c} 0.411 \\ 0.433 \\ 0.456 \\ 0.478 \\ 0.502 \end{array}$	$ \begin{array}{c} 0.408 \\ 0.430 \\ 0.452 \\ 0.475 \\ 0.497 \end{array} $	$\begin{array}{c} 0.407 \\ 0.428 \\ 0.450 \\ 0.472 \\ 0.494 \end{array}$		$\begin{array}{c} 0.404 \\ 0.425 \\ 0.446 \\ 0.468 \\ 0.489 \end{array}$	0.403 0.424 0.445 0.466 0.488	0.403 0.423 0.444 0.465 0.486	0.402 0.423 0.443 0.464 0.485				
$ \begin{array}{r} 0.50 \\ 0.52 \\ 0.54 \\ \hline 0.56 \\ 0.58 \\ \end{array} $	0.539 0.565 0.592 0.619 0.647	$\begin{array}{c} 0.531 \\ 0.556 \\ 0.582 \\ 0.608 \\ 0.635 \end{array}$	$\begin{array}{c} 0.525 \\ 0.550 \\ 0.574 \\ 0.600 \\ 0.626 \end{array}$	$\begin{array}{c} 0.521 \\ 0.544 \\ 0.568 \\ 0.593 \\ 0.618 \end{array}$		$\begin{array}{c} 0.514 \\ 0.536 \\ 0.559 \\ 0.583 \\ 0.607 \end{array}$	0.511 0.534 0.556 0.579 0. 6 03		$\begin{array}{c} 0.508 \\ 0.529 \\ 0.551 \\ 0.574 \\ \hline 0.596 \end{array}$	0.506 0.528 0.550 0.572 0.594				
0.60 0.61 0.62 0.63 0.64	$\begin{array}{c} 0.676 \\ 0.691 \\ 0.707 \\ 0.722 \\ 0.738 \end{array}$	$\begin{array}{c} 0.663 \\ 0.677 \\ 0.692 \\ 0.707 \\ 0.722 \end{array}$	0.653 0.666 0.680 0.694 0.709	$\begin{array}{c} 0.644 \\ 0.657 \\ 0.671 \\ 0.684 \\ 0.698 \end{array}$	0.637 0.650 0.663 0.676 0.690	0.631 0.644 0:657 0.669 0.683	0.627 0.639 0.651 0.664 0.677	0.623 0.635 0.647 0.659 0.672	$\begin{array}{c} 0.620 \\ 0.631 \\ 0.643 \\ 0.655 \\ 0.667 \end{array}$	0.617 0.628 0.640 0.652 0.664				
0.65 0.66 0.67 0.68 0.69	0.754 0.771 0.787 0.805 0.822		0.724 0.739 0.754 0.769 0.785	$0.742 \\ 0.757$		$\begin{array}{c} 0.696 \\ 0.709 \\ 0.723 \\ 0.737 \\ 0.751 \end{array}$	0.689 0.703 0.716 0.729 0.743	0.684 0.697 0.710 0.723 0.737	$egin{array}{c} 0.680 \\ 0.692 \\ 0.705 \\ 0.718 \\ 0.731 \end{array}$	0.676 0.688 0.701 0.713 0.726				

Tabla D-1. La función de flujo variado para pendientes positivas, F(u,N)

J	• • • • • • • • • • • • • • • • • • • •											
$\bigvee_{V} N$	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0		
0.00 0.02 0.04 0.06 0.08	0.000 0.020 0.040 0.060 0.080	$\begin{array}{c} 0.000 \\ 0.020 \\ 0.040 \\ 0.060 \\ 0.080 \end{array}$										
0.10 0.12 0.14 0.16 0.18	0.100 0.120 0.141 0.161 0.181	0.100 0.120 0.140 0.161 0.181	0.100 0.120 0.140 0.160 0.181	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	$\begin{array}{c} 0.100 \\ 0.120 \\ 0.140 \\ 0.160 \\ 0.180 \end{array}$		
0.20 0.22 0.24 0.26 0.28	0.202 0.223 0.243 0.264 0.286	0.201 0.222 0.242 0.263 0.284	0.201 0.221 0.242 0.262 0.283	0.201 0.221 0.241 0.262 0.282	0.200 0.221 0.241 0.261 0.282	$\begin{array}{c} 0.200 \\ 0.220 \\ 0.241 \\ 0.261 \\ 0.281 \end{array}$	$\begin{array}{c} 0.200 \\ 0.220 \\ 0.240 \\ 0.261 \\ 0.281 \end{array}$	$\begin{array}{c} 0.200 \\ 0.220 \\ 0.240 \\ 0.260 \\ 0.281 \end{array}$	0.200 0.220 0.240 0.260 0.280	$\begin{array}{c} 0.200 \\ 0.220 \\ 0.240 \\ 0.260 \\ 0.280 \end{array}$		
0.30 0.32 0.34 0.36 0.38	$\begin{array}{c} 0.307 \\ 0.329 \\ 0.350 \\ 0.373 \\ 0.395 \end{array}$	$\begin{array}{c} 0.305 \\ 0.326 \\ 0.348 \\ 0.370 \\ 0.392 \end{array}$	0.304 0.325 0.346 0.367 0.389	0.303 0.324 0.344 0.366 0.387	0.302 0.323 0.343 0.364 0.385	$\begin{array}{c} 0.302 \\ 0.322 \\ 0.343 \\ 0.363 \\ 0.384 \end{array}$	0.301 0.322 0.342 0.363 0.383	0.301 0.321 0.342 0.362 0.383	0.301 0.321 0.341 0.362 0.382	0.300 0.321 0.341 0.361 0.382		
0.40 0.42 0.44 0.46 0.48	0.418 0.441 0.465 0.489 0.514	0.414 0.437 0.460 0.483 0.507	$\begin{array}{c} 0.411 \\ 0.433 \\ 0.456 \\ 0.478 \\ 0.502 \end{array}$	0.408 0.430 0.452 0.475 0.497	$\begin{array}{c} 0.407 \\ 0.428 \\ 0.450 \\ 0.472 \\ 0.494 \end{array}$	$\begin{array}{c} 0.405 \\ 0.426 \\ 0.448 \\ 0.470 \\ 0.492 \end{array}$	$\begin{array}{c} 0.404 \\ 0.425 \\ 0.446 \\ 0.468 \\ 0.489 \end{array}$	$\begin{array}{c} 0.403 \\ 0.424 \\ 0.445 \\ 0.466 \\ 0.488 \end{array}$	0.403 0.423 0.444 0.465 0.486	0.402 0.423 0.443 0.464 0.485		
v=0.51 0.50 0.52 0.54 0.56 0.58	0.539 0.565 0.592 0.619 0.647	0.531 0.556 0.582 0.608 0.635	$\begin{array}{c} 0.525 \\ 0.550 \\ 0.574 \\ 0.600 \\ 0.626 \end{array}$	0.521 0.544 0.568 0.593 0.618	0.517 0.540 0.563 0.587 0.612	$\begin{array}{c} 0.514 \\ 0.536 \\ 0.559 \\ 0.583 \\ 0.607 \end{array}$	$\begin{array}{c} 0.511 \\ 0.534 \\ 0.556 \\ 0.579 \\ 0.603 \end{array}$	0.509 0.531 0.554 0.576 0.599	0.508 0.529 0.551 0.574 0.596	0.506 0.528 0.550 0.572 0.594		
0.60 0.61 0.62 0.63 0.64	$\begin{array}{c} 0.676 \\ 0.691 \\ 0.707 \\ 0.722 \\ 0.738 \end{array}$	$\begin{array}{c} 0.663 \\ 0.677 \\ 0.692 \\ 0.707 \\ 0.722 \end{array}$	$\begin{array}{c} 0.653 \\ 0.666 \\ 0.680 \\ 0.694 \\ 0.709 \end{array}$	$\begin{array}{c} 0.644 \\ 0.657 \\ 0.671 \\ 0.684 \\ 0.698 \end{array}$	0.637 0.650 0.663 0.676 0.690	0.631 0.644 0.657 0.669 0.683	0.627 0.639 0.651 0.664 0.677	$\begin{array}{c} 0.623 \\ 0.635 \\ 0.647 \\ 0.659 \\ 0.672 \end{array}$	$\begin{array}{c} 0.620 \\ 0.631 \\ 0.643 \\ 0.655 \\ 0.667 \end{array}$	$\begin{array}{c} 0.617 \\ 0.628 \\ 0.640 \\ 0.652 \\ 0.664 \end{array}$		
0.65 0.66 0.67 0.68 0.69	0.754 0.771 0.787 0.805 0.822	$\begin{array}{c} 0.737 \\ 0.753 \\ 0.769 \\ 0.785 \\ 0.802 \end{array}$	0 724 0.139 0.751 0.769 0.785		$\begin{array}{c} 0.703 \\ 0.717 \\ 0.731 \\ 0.746 \\ 0.761 \end{array}$	$\begin{array}{c} 0.696 \\ 0.709 \\ 0.723 \\ 0.737 \\ 0.751 \end{array}$		$\begin{array}{c} 0.684 \\ 0.697 \\ 0.710 \\ 0.723 \\ 0.737 \end{array}$	$\begin{array}{c} 0.680 \\ 0.692 \\ 0.705 \\ 0.718 \\ 0.731 \end{array}$	$\begin{array}{c} 0.676 \\ 0.688 \\ 0.701 \\ 0.713 \\ 0.726 \end{array}$		
	lata			0	E4 I	0.47						

Interpolamos para N = 3,68

Interpolamos para v = 0.51 y J = 3,17

9.- Cálculo de la longitud del tramo que separa las dos secciones extremas.

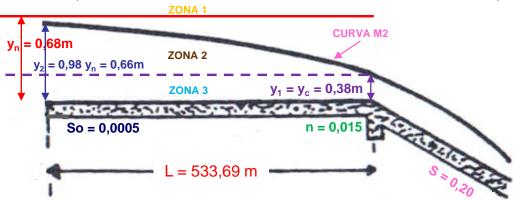
$$L = x_2 - x_1 = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_c}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

SECCION	у	u	٧	F(u,N)	F(v,J)
1	0.38	0.56	0.51	0.575	0.526
2	0.66	0.97	0.97	1.486	1.504
DIFERE	ENCIAS	0.41		0.911	0.978

$$L = \frac{y_n}{S_0} \left\{ (u_2 - u_1) - \left[F(u_2, N) - F(u_1, N) \right] + \left(\frac{y_c}{y_n} \right)^M \frac{J}{N} \left[F(v_2, J) - F(v_1, J) \right] \right\}$$

$$L = \frac{0.68}{0.0005} \left\{ 0.41 - 0.911 + \left(\frac{0.38}{0.68} \right)^{3.52} *0.861*0.978 \right\}$$

L = 533,69m



Cálculo del perfil M2 en el tramo aguas arriba

Utilizamos la información obtenida en la parte anterior:

$$y_n = 0.68m$$

$$y_c = 0.38m$$

$$y = 0.66m$$

$$N = 3,68$$

$$M = 3,52$$

$$J = 3,17$$

$$J/N = 0.861$$

$$N/J = 1,16$$

Calculamos el perfil desde $y_c = 0.38m$ hasta y = 0.66; para lo cual establecemos un rango de datos de y, luego procedemos a calcular u, v, F(u,N), F(v,N), x, L.

El valor de x calculamos con la expresión:

$$x = \frac{y_n}{S_0} \left\{ u - F(u, N) + \left(\frac{y_c}{y_n}\right)^M \frac{J}{N} * F(v, J) \right\} + cte.$$
 Cte = 0

$$L = x_1 - x_i$$

3.- METODO DE INTEGRACION DIRECTA (EJERCICIO)

$$u = {}^{y}/y_n \qquad v = u^{N/J}$$

TABLA D1

 $L = x_{inicial} - x_{indiv}$

y	u i	V	F(u,N)	F(v,J)	X	
0.3800	0.560	0.51	0.575	0.526	59.02	
0.4000	0.590	0.54	0.610	0.559	57.20	1.82
0.4500	0.660	0.62	0.695	0.652	50.85	8.18
0.4800	0.710	0.67	0.762	0.724	38.60	20.42
0.5100	0.750	0.72	0.820	0.798	25.29	33.73
0.5400	0.790	0.76	0.885	0.863	1.10	57.92
0.5700	0.840	0.82	0.980	0.977	-42.88	101.90
0.6000	0.880	0.86	1.074	1.072	-101.98	161.00
0.6300	0.930	0.92	1.241	1.271	-231.05	290.07
0.6600	0.970	0.97	1.486	1.504	-474.67	533.69

$$x = \frac{y_n}{S_0} \left\{ u - F(u, N) + \left(\frac{y_c}{y_n}\right)^M \frac{J}{N} * F(v, J) \right\} + cte.$$
 Cte = 0

3.- METODO DE INTEGRACION DIRECTA (EJERCICIO)

$$u = {}^{y}/y_n \qquad v = u^{N/J}$$

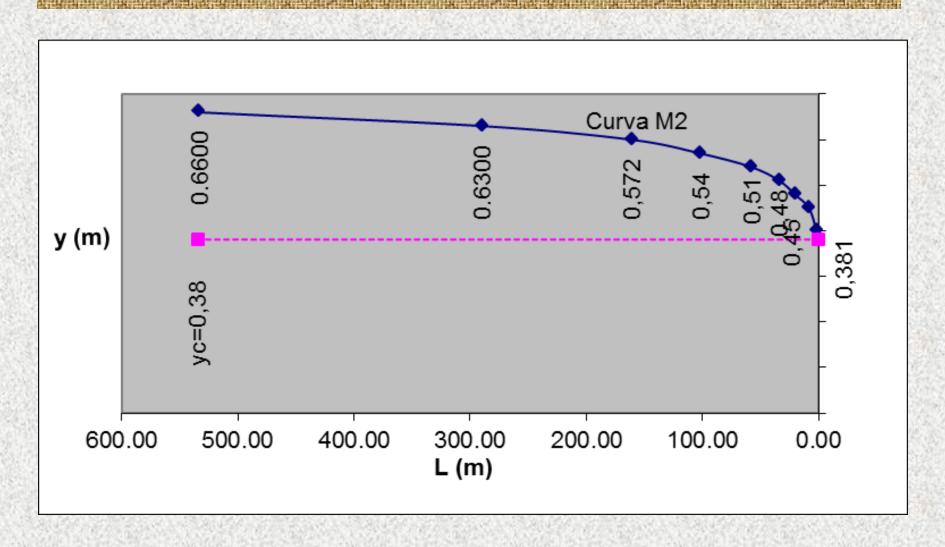
TABLA D1

 $L = x_{inicial} - x_{indiv}$

У	u	V	F(u,N)	F(v,J)	X	L
0.6600	0.970	0.97	1.486	1.504	-474.67	
0.6300	0.930	0.92	1.241	1.271	-231.05	243.62
0.6000	0.880	0.86	1.074	1.072	-101.98	372.69
0.5700	0.840	0.82	0.980	0.977	-42.88	431.79
0.5400	0.790	0.76	0.885	0.863	1.10	475.78
0.5100	0.750	0.72	0.820	0.798	25.29	499.96
0.4800	0.710	0.67	0.762	0.724	38.60	513.27
0.4500	0.660	0.62	0.695	0.652	50.85	525.52
0.4000	0.590	0.54	0.610	0.559	57.20	531.87
0.3800	0.560	0.51	0.575	0.526	59.02	533.69

$$x = \frac{y_n}{S_0} \left\{ u - F(u, N) + \left(\frac{y_c}{y_n}\right)^M \frac{J}{N} * F(v, J) \right\} + cte.$$
 Cte = 0

3.- METODO DE INTEGRACION DIRECTA (EJERCICIO)

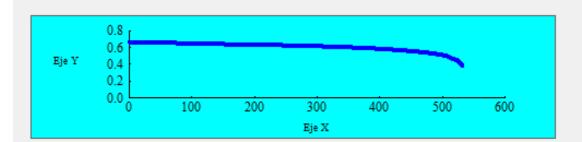




Cálculo de la curva de remanso, método de Bakhmeteff



Resultados	parciales: -								
Valor de	Valor de N: 3,6800 Valor de M: 3,5165 Valor de J: 3,1629								
у	u=y/yn	v=u^(N/J)	F(u,N)	F(v,J)	deltax	×			
0,6600	0,9706	0,9659	1,4913	1,5572	-473,0285	0,00			
0,6460	0,9500	0,9421	1,3394	1,3816	-320,9329	152,10			
0,6320	0,9294	0,9184	1,2378	1,2646	-228,4703	244,56			
0,6180	0,9088	0,8947	1,1603	1,1756	-164,4599	308,57			
0,6040	0,8882	0,8712	1,0969	1,1030	-117,1285	355,90			
0,5900	0,8676	0,8477	1,0427	1,0413	-80,7408	392,29			
0,5760	0,8471	0,8244	0,9950	0,9872	-52,0663	420,96			
0.5620	0 8265	N 8N11	0 9521	0 9388	-29 1040	443 92	Ţ		













Resultados finales:

×	у	•
0,00	0,6600	
152,10	0,6460	
244,56	0,6320	
308,57	0,6180	
355,90	0,6040	
392,29	0,5900	
420,96	0,5760	
443,92	0,5620	
462,50	0,5480	
477,62	0,5340	
489,94	0,5200	

Copiar al portapapeles los resultados



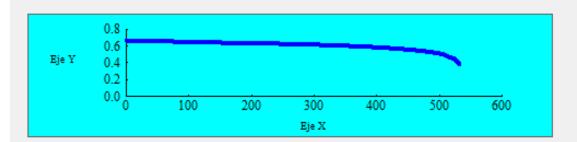


: <u>F</u>inales

Cálculo de la curva de remanso, método de Bakhmeteff

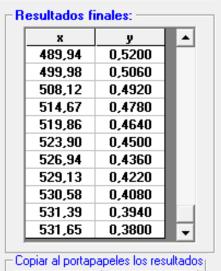


Resultados parciales: Valor de N: 3,6800 Valor de M: 3,5165 Valor de J: 3,1629									
у	u=y/yn	v=u^(N/J)	F(u,N)	F(v,J)	deltax	×	•		
0,4640	0,6824	0,6410	0,7240	0,6851	46,8313	519,86			
0,4500	0,6618	0,6186	0,6972	0,6559	50,8680	523,90			
0,4360	0,6412	0,5962	0,6712	0,6277	53,9135	526,94			
0,4220	0,6206	0,5740	0,6460	0,6005	56,1043	529,13			
0,4080	0,6000	0,5519	0,6214	0,5741	57,5556	530,58			
0,3940	0,5794	0,5300	0,5974	0,5485	58,3656	531,39			
0,3800	0,5588	0,5081	0,5739	0,5235	58,6188	531,65			









Finales

Parciales

Tabla D-1. La función de flujo variado para pendientes positivas, F(u,N)

$\frac{N}{u}$	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
0.00 0.02 0.04 0.06 0.08	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	0.000 0.020 0.040 0.060 0.080	$\begin{array}{c} 0.000 \\ 0.020 \\ 0.040 \\ 0.060 \\ 0.080 \end{array}$
0.10 0.12 0.14 0.16 0.18	0.100 0.120 0.141 0.161 0.181	0.100 0.120 0.140 0.161 0.181	0.100 0.120 0.140 0.160 0.181	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	0.100 0.120 0.140 0.160 0.180	$\begin{array}{c} 0.100 \\ 0.120 \\ 0.140 \\ 0.160 \\ 0.180 \end{array}$	0.100 0.120 0.140 0.160 0.180
$egin{array}{l} 0.20 \\ 0.22 \\ 0.24 \\ 0.26 \\ 0.28 \\ \end{array}$	0.202 0.223 0.243 0.264 0.286	$\begin{array}{c} 0.201 \\ 0.222 \\ 0.242 \\ 0.263 \\ 0.284 \end{array}$	$\begin{array}{c} 0.201 \\ 0.221 \\ 0.242 \\ 0.262 \\ 0.283 \end{array}$	$\begin{array}{c} 0.201 \\ 0.221 \\ 0.241 \\ 0.262 \\ 0.282 \end{array}$	$\begin{array}{c} 0.200 \\ 0.221 \\ 0.241 \\ 0.261 \\ 0.282 \end{array}$	0.200 0.220 0.241 0.261 0.281	$\begin{array}{c} 0.200 \\ 0.220 \\ 0.240 \\ 0.261 \\ 0.281 \end{array}$	$\begin{array}{c} 0.230 \\ 0.220 \\ 0.240 \\ 0.260 \\ 0.281 \end{array}$	0.200 0.220 0.240 0.260 0.280	0.200 0.220 0.240 0.260 0.280
0.30 0.32 0.34 0.36 0.38	0.307 0.329 0.350 0.373 0.395	$\begin{array}{c} 0.305 \\ 0.326 \\ 0.348 \\ 0.370 \\ 0.392 \end{array}$	$\begin{array}{c} 0.304 \\ 0.325 \\ 0.346 \\ 0.367 \\ 0.389 \end{array}$	0.303 0.324 0.344 0.366 0.387	0.302 0.323 0.343 0.364 0.385	0.302 0.322 0.343 0.363 0.384	$\begin{array}{c} 0.301 \\ 0.322 \\ 0.342 \\ 0.363 \\ 0.383 \end{array}$	0.301 0.321 0.342 0.362 0.383	0.301 0.321 0.341 0.362 0.382	0.300 0.321 0.341 0.361 0.382
0.40 0.42 0.44 0.46 0.48	0.418 0.441 0.465 0.489 0.514	$\begin{array}{c} 0.414 \\ 0.437 \\ 0.460 \\ 0.483 \\ 0.507 \end{array}$	$\begin{array}{c} 0.411 \\ 0.433 \\ 0.456 \\ 0.478 \\ 0.502 \end{array}$	0.408 0.430 0.452 0.475 0.497	$\begin{array}{c} 0.407 \\ 0.428 \\ 0.450 \\ 0.472 \\ 0.494 \end{array}$		$\begin{array}{c} 0.404 \\ 0.425 \\ 0.446 \\ 0.468 \\ 0.489 \end{array}$	$\begin{array}{c} 0.403 \\ 0.424 \\ 0.445 \\ 0.466 \\ 0.488 \end{array}$	0.403 0.423 0.444 0.465 0.486	0.402 0.423 0.443 0.464 0.485
0.50 0.52 0.54 0.56 0.58	0.539 0.565 0.592 0.619 0.647	$\begin{array}{c} 0.531 \\ 0.556 \\ 0.582 \\ 0.608 \\ 0.635 \end{array}$	$\begin{array}{c} 0.525 \\ 0.550 \\ 0.574 \\ 0.600 \\ 0.626 \end{array}$	$\begin{array}{c} 0.521 \\ 0.544 \\ 0.568 \\ 0.593 \\ 0.618 \end{array}$		$\begin{array}{c} 0.514 \\ 0.536 \\ 0.559 \\ 0.583 \\ 0.607 \end{array}$	0.511 0.534 0.556 0.579 0. 6 03	0.509 0.531 0.554 0.576 0.599	0.508 0.529 0.551 0.574 0.596	0.506 0.528 0.550 0.572 0.594
0.60 0.61 0.62 0.63 0.64	$\begin{array}{c} 0.676 \\ 0.691 \\ 0.707 \\ 0.722 \\ 0.738 \end{array}$		$\begin{array}{c} 0.653 \\ 0.666 \\ 0.680 \\ 0.694 \\ 0.709 \end{array}$	$\begin{array}{c} 0.644 \\ 0.657 \\ 0.671 \\ 0.684 \\ 0.698 \end{array}$	0.637 0.650 0.663 0.676 0.690	0.631 0.644 0:657 0.669 0.683	$\begin{array}{c} 0.627 \\ 0.639 \\ 0.651 \\ 0.664 \\ 0.677 \end{array}$	$\begin{array}{c} 0.623 \\ 0.635 \\ 0.647 \\ 0.659 \\ 0.672 \end{array}$	0.620 0.631 0.643 0.655 0.667	0.617 0.628 0.640 0.652 0.664
$0.65 \\ 0.66 \\ 0.67 \\ 0.68 \\ 0.69$	0.754 0.771 0.787 0.805 0.822	$\begin{array}{c} 0.737 \\ 0.753 \\ 0.769 \\ 0.785 \\ 0.802 \end{array}$		$ \begin{array}{c} 0.712 \\ 0.727 \\ 0.742 \\ 0.757 \\ 0.772 \end{array} $		$\begin{array}{c} 0.696 \\ 0.709 \\ 0.723 \\ 0.737 \\ 0.751 \end{array}$	$\begin{array}{c} 0.689 \\ 0.703 \\ 0.716 \\ 0.729 \\ 0.743 \end{array}$	$\begin{array}{c} 0.684 \\ 0.697 \\ 0.710 \\ 0.723 \\ 0.737 \end{array}$	0.680 0.692 0.705 0.718 0.731	0.676 0.688 0.701 0.713 0.726

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Tabla D-1. La función de flujo variado para pendientes positivas, F(u,N) (continuación)

									Colonia de la Co	
$\frac{N}{u}$	2.2	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0
0.70	0.841	0.819	0.802	0.787	0.776	0.766	0.757	0.750	0.744	0.739
0.71	0.859	0.837	0.819	0.804	0.791	0.781	0.772	0.764	0.758	0.752
0.72	0.878	0.855	0.836	0.820	0.807	0.796	0.786	0.779	0.772	0.766
0.73	0.898	0.874	0.853	0.837	0.823	0.811	0.802	0.793	0.786	0.780
0.74	0.918	0.893	0.871	0.854	0.840	0.827	0.817	0.808	0.800	0.794
0.75	0.939	0.912	0.890	0.872	0.857	0.844	0.833	0.823	0.815	0.808
0.76	0.961	0.933	0.909	0.890	0.874	0.861	0.849	0.839	0.830	0.823
0.77	0.984	0.954	0.929	0.909	0.892	0.878	0.866	0.855	0.846	0.838
0.78	1.007	0.976	0.950	0.929	0.911	0.896	0.883	0.872	0.862	0.854
0.79	1.031	0.998	0.971	0.949	0.930	0.914	0.901	0.889	0.879	0.870
0.80	1.056	1.022	0.994	0.970	0.950	0.934	$\begin{array}{c} 0.919 \\ 0.938 \\ 0.958 \\ 0.979 \\ 1.001 \end{array}$	0.907	0.896	0.887
0.81	1.083	1.047	1.017	0.992	0.971	0.954		0.925	0.914	0.904
0.82	1.110	1.072	1.041	1.015	0.993	0.974		0.945	0.932	0.922
0.83	1.139	1.099	1.067	1.039	1.016	0.996		0.965	0.952	0.940
0.84	1.170	1.128	1.093	1.064	1.040	1.019		0.985	0.972	0.960
0.85	1.202	1.158	1.122	1.091	1.065	1.043	1.024	1.007	$\begin{array}{c} 0.993 \\ 1.015 \\ 1.039 \\ 1.064 \\ 1.091 \end{array}$	0.980
0.86	1.236	1.190	1.151	1.119	1.092	1.068	1.048	1.031		1.002
0.87	1.273	1.224	1.183	1.149	1.120	1.095	1.074	1.055		1.025
0.88	1.312	1.260	1.217	1.181	1.151	1.124	1.101	1.081		1.049
0.89	1.355	1.300	1.254	1.216	1.183	1.155	1.131	1.110		1.075
0.90	1.401	1.343	1.294	1.253	1.218	1.189	1.163	1.140	$\begin{array}{c} 1.120 \\ 1.152 \\ 1.187 \\ 1.226 \\ 1.270 \end{array}$	1.103
0.91	1.452	1.390	1.338	1.294	1.257	1.225	1.197	1.173		1.133
0.92	1.508	1.442	1.386	1.340	1.300	1.266	1.236	1.210		1.166
0.93	1.572	1.500	1.441	1.391	1.348	1.311	1.279	1.251		1.204
0.94	1.645	1.568	1.503	1.449	1.403	1.363	1.328	1.297		1.246
0.950	1.730	1.647	1.577	1.518	1.467	1.423	1.385	1.352	1.322	1.296
0.960	1.834	1.743	1.666	1.601	1.545	1.497	1.454	1.417	1.385	1.355
0.970	1.968	1.865	1.780	1.707	1.644	1.590	1.543	1.501	1.464	1.431
0.975	2.052	1.943	1.851	1.773	1.707	1.649	1.598	1.553	1.514	1.479
0.980	2.155	2.040	1.936	1.855	1.783	1.720	1.666	1.617	1.575	1.536
0.985 0.990 0.995 0.999	2.294 2.477 2.792 3.523	2.165 2.333 2.621 3.292	2.056 2.212 2.478 3.097	1.959 2.106 2.355 2.931	1.880 2.017 2.250 2.788	1.812 1.940 2.159 2.663	1.752 1.873 2.079 2.554	1.699 1.814 2.008 2.457 ∞	$\begin{array}{c} 1.652 \\ 1.761 \\ 1.945 \\ 2.370 \\ \infty \end{array}$	1.610 1.714 1.889 2.293 ∞

SECCION DE CONTROL

Algunos ejemplos de secciones de control son las presas, vertederos compuertas, así como también la intersección bien definida de la línea del perfil de flujo y la correspondiente al tirante crítico, esto ocurre en el punto de cambio de pendiente de dos tramos el de aguas arriba de pendiente suave y el de aguas debajo de pendiente fuerte.

