FLOW VELOCITY BEHAVIOR PROGRAMMING ON OPEN CHANNEL BENDS

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ABSTRACT

Flow velocity on open channel bends generally experiences additional velocity which is called secondary velocity. This paper aims to analys and calculate the velocity that occurs in an open channel bend in general. The calculation that the writer uses is the calculation with fortran programming, in a case study of a river that bends, where the variables that must be present are given . The results of calculations and measurements of Secondary Speeds that occur at channel bends in this Open Channel will be very useful for river channel improvement or flood prevention in river channels, especially on existing bends. The conclusion is that at the bend of an open channel or river, there will be an increase in flow velocity in the transverse direction. This additional velocity is caused by the additional secondary velocity, namely the transverse velocity.

Keywords:
Flow velocity; Channel bends; Open channel; River; Secondary velocity; Transverse direction

1. INTRODUCTION

In open channel planning, bends in the alignment are often unavoidable. The difficulty in designing is often caused by the complex flow around the bend. The flow line is not a linear curve, but intertwined and the centrifugal force that occurs in the surrounding flow. The result of this will cause an increase in the water level at the outer radius of the bend, and the inner radius will decrease which is called superelevation.
The purpose of this paper is to examine the effect of channel bends on flow velocity and changes in water level in the transverse direction of the channel (superelevation), and the transverse slope of the base on the bend for moving base (sediment) including:
a. Predicts the secondary velocity at the bend of the channel.
b. If it is known that the secondary velocity is large and its direction, it will be able to calculate the velocity of water acting at the specified points.
c. From these points, we can predict the occurrence of scouring and sedimentation.
d. Become the basis for calculating the design of buildings on the river bank. Either in the form of river groves, retaining walls or sediment storage.

2. METHODS

2.1. Review of several previous studies.

Flow in cornering channels has received attention or consideration from hydraulic engineers because of the presence of complex phenomena. The curved shape of a river channel creates a centrifugal force that occurs simultaneously with forces due to hydrostatic pressure, gravity, and shear forces in the boundary plane. All of these can cause a spiral flow and changes in the water level (super elevation) and scouring of the channel bed.

2.2. Flow on river bends

The plan of a river consists of a straight section and a bend (bend) part. In the corner there will be an increase in speed. The increase in secondary speed (V) on the corner is quite large compared to the straight area. So that the secondary flow (V) is very influential.

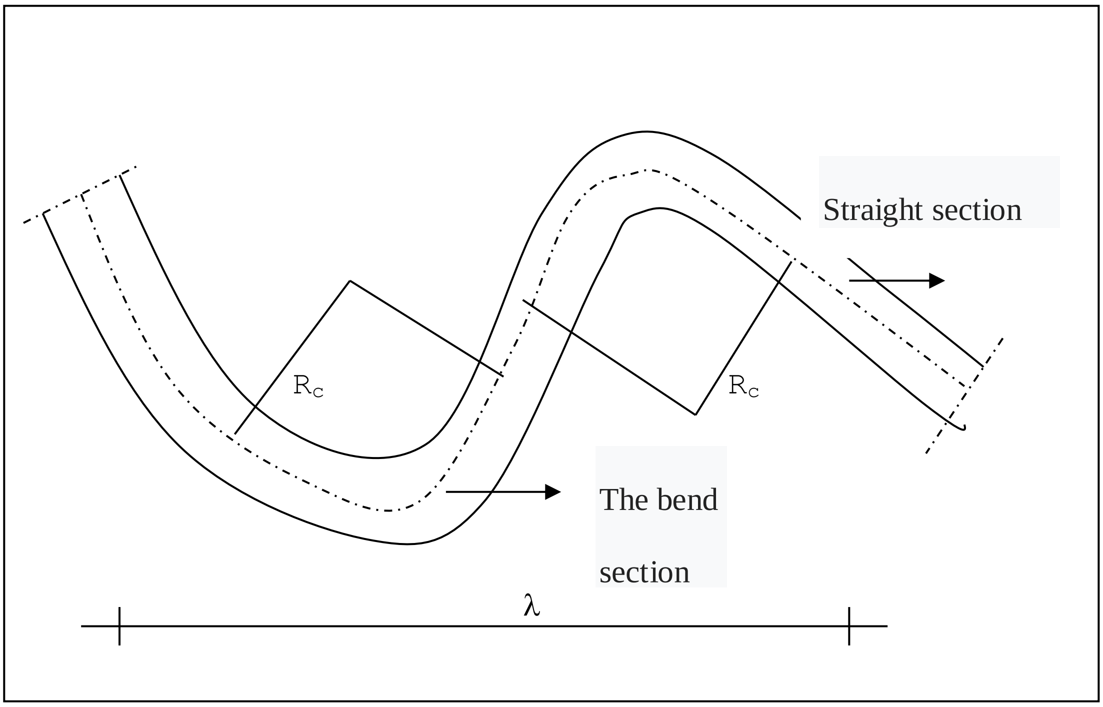

Figure 2.1.Denah Bend a Channel or River

Flow Energy in Bends are:

γ * Q * S = γ * Q * S '+ γ * Q * S "

S = S '+ S "

Where :

S '= slope of the water level in the longitudinal direction

S "= slope of the water level in the transverse direction

From the Darcy-weisbach formula:

S '= f * U2 / (8g * R)

Where :

F = roughness factor

R = hydraulic radius

U = main speed

G = gravity

If manning (n) is used then:

S '= n2 * U2 / (2.21$R^{4/3}$)

Secondary Flow Variation

According to the Navier-stooks equation

U (∂v / ∂s) + v (∂v / ∂r) + w (∂v / ∂z) = (u2 / r) -g * Sr + ∂ / ∂z (ε∂ / ∂z)

For steady and ideal flow

(∂v / ∂r) = 0, (∂v / ∂z) = 0

According to Rozovskii

$\partial / \partial z (\varepsilon \partial / \partial z) = -X * (f * U * V / (2D)$

Where :

X = von Karman constant (0.4)

D = depth of flow

So that the Navier-stooks equation above will be:

$U (\partial v / \partial s) = (u2 / r) -g * Sr-X * (f * U * V / (2D)$

Where :

Sr = slope of the water level in the lateral direction

Slope of the Lateral Direction (Sr) and Super Elevation (Δz) of Water Level

The lateral water level slope is a function of Rc, U, B, and D

$Sr = k * V2 / 2g$

$k = n2 + 2n + 1 / (n2 + 2n)$

$n = X * (8 / f) 0.5$

or

$Sr = 1.1 * Cn * Rc2 * Ui / (g * Ri)$

The super elevation of the water level is

$\Delta z = 1.1 * Cn (1- (Rc / Ri) 2) * Ui / 2g$

$Cn = n2 + 2n + 1 / (n2 + 2n)$

Where :

Rc = radius of bend

Ri = the radius at a point

Ui = velocity at a point

The calculation of the transverse velocity (V) and the longitudinal velocity (U) can be calculated as follows:

The maximum speed that occurs:

$V / U = (D / (X * Rc)) * (10/3 - 1 / X * 5/9 * (f / 2) 0.5)$

The velocity at any given point is:

Vj + 1 = [Vj + F1 (f) * U / Rc * eF2 (f) .□s * □s] * e-F2 (f) .□s

$F1 (f) = [(f / 2) 0.5 * (10/3 - 1 / X * 5/9 * (f / 2) 0.5]$

$F2 (f) = X / D * (f / 2) 0.5 * m / (m + 1)$

$m = X * (8 / f) 0.5$

3. RESULTS AND DISCUSSION

3.1. Case Study

A River Bend Case Study is presented, in order to further delve into the secondary velocities arising on a river bend or open channel

Known :

A river bend with the following data:

f = 0.017

U = 1 m / sec

1 D = 1 METER

X = 0.4

Vo = 0.1 m / sec

2 RC = 4 METERS

Asked:

Review the secondary velocity distribution on the bend and take 3 point of view.

Solution:

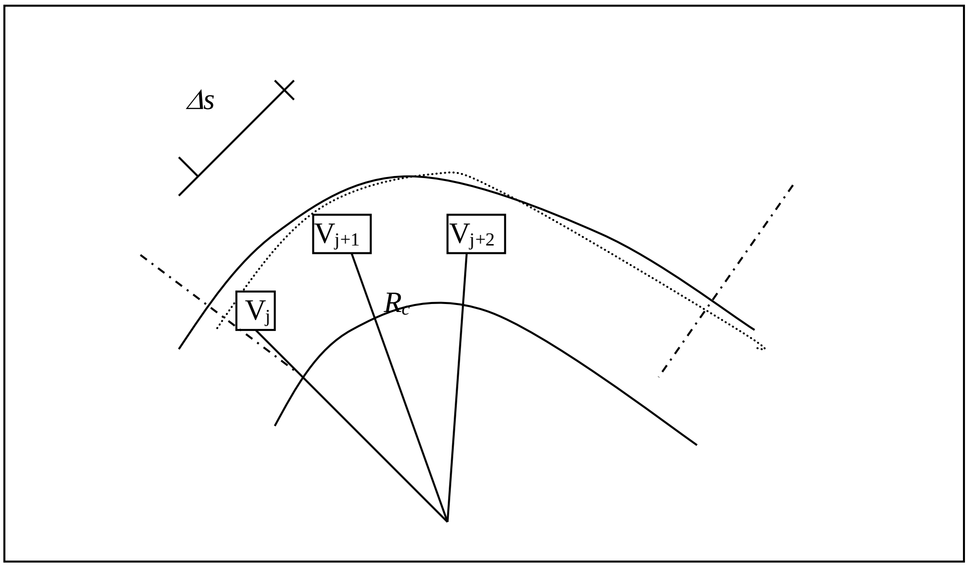

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Figure 3.1 Changes in flow velocity at a bend in a channel or river

Δs taken = 0.5 meter
For secondary speed, the numerical solution applies:
Maximum speed that occurs:

$$V_{j+1} = [V_j + F_1(f) \text{ x } U/rc \text{ x } e^{F_2(f).\Delta s} \text{ x } \Delta s] \text{ x } e^{-F_2(f).\Delta s}$$

$F_1(f)$ $= [(f/2)^{0.5} \text{ x } (10/3 – 1/X \text{ x } 5/9 \text{ x } (f/2)^{0.5}]$
$= [(0.017/2)^{0.5} \text{ x } (10/3 – 1/0.4 \text{ x } 5/9 \text{ x } (0.017/2)^{0.5}]$
$= 0.296$

m $= X \text{ x } (8/f)^{0.5}$
$= 0.4 \text{ x } (8/0.017)^{0.5}$
$= 8.677$

$F_2(f)$ $= X/D \text{ x } (f/2)^{0.5} \text{ x } m/(m + 1)$
$= 0.4/1 \text{ x } (0.017/2)^{0.5} \text{ x } 8.677/(8.677 + 1)$
$= 0.033$

We review point j

V_j $= [Vo + F_1(f) \text{ x } U/R_c \text{ x } e^{F_2(f).\Delta s} \text{ x } \Delta s] \text{ x } e^{-F_2(f).\Delta s}$
$= [0.1 + 0.296 \text{ x } 1/4 \text{ x } e^{0.033 \text{ x } 0.5} \text{ x } 0.5] \text{ x } e^{-0.033 \text{ x } 0.5}$
= 0.135 m/det

We review point j +1

V_{j+1} $= [V_j + F_1(f) \text{ x } U/rc \text{ x } e^{F_2(f).\Delta s} \text{ x } \Delta s] \text{ x } e^{-F_2(f).\Delta s}$
$= [0.135 + 0.296 \text{ x } 1/4 \text{ x } e^{0.033 \text{ x } 0.5} \text{ x } 0.5] \text{ x } e^{-0.033 \text{ x } 0.5}$
= 0.169 m/det

We review point j +2

V_{j+2} $= [V_{j+1} + F_1(f) \text{ x } U/rc \text{ x } e^{F_2(f).\Delta s} \text{ x } \Delta s] \text{ x } e^{-F_2(f).\Delta s}$
$= [0.169 + 0.296 \text{ x } 1/4 \text{ x } e^{0.033 \text{ x } 0.5} \text{ x } 0.5] \text{ x } e^{-0.033 \text{ x } 0.5}$

= 0.204 m/det

The complete calculation is shown in the table:

DATA SUNGAI

Kecepatan utama (U)	1	m/det
Kecepatan sekunder aw	0.1	m/det
Jari-jari tikungan (R	4	meter
Konstanta von karman	0.4	
Kedalaman aliran (D)	1	meter
Angka kekasaran (f)	0.017	

Titik	As (m)	Jarak (m)	Vo (m/det)	U (m/det)	m	F1	F2	V (m/det)
1	0.500	0.000	0.100	1.000	8.677	0.296	0.033	0.135
2	0.500	0.500	0.135	1.000	8.677	0.296	0.033	0.170
3	0.500	1.000	0.170	1.000	8.677	0.296	0.033	0.204
4	0.500	1.500	0.204	1.000	8.677	0.296	0.033	0.238
5	0.500	2.000	0.238	1.000	8.677	0.296	0.033	0.271
6	0.500	2.500	0.271	1.000	8.677	0.296	0.033	0.303
7	0.500	3.000	0.303	1.000	8.677	0.296	0.033	0.335
8	0.500	3.500	0.335	1.000	8.677	0.296	0.033	0.367
9	0.500	4.000	0.367	1.000	8.677	0.296	0.033	0.398
10	0.500	4.500	0.398	1.000	8.677	0.296	0.033	0.428
11	0.500	5.000	0.428	1.000	8.677	0.296	0.033	0.458
12	0.500	5.500	0.458	1.000	8.677	0.296	0.033	0.487
13	0.500	6.000	0.487	1.000	8.677	0.296	0.033	0.516
14	0.500	6.500	0.516	1.000	8.677	0.296	0.033	0.545
15	0.500	7.000	0.545	1.000	8.677	0.296	0.033	0.573
16	0.500	7.500	0.573	1.000	8.677	0.296	0.033	0.600
17	0.500	8.000	0.600	1.000	8.677	0.296	0.033	0.628
18	0.500	8.500	0.628	1.000	8.677	0.296	0.033	0.654
19	0.500	9.000	0.654	1.000	8.677	0.296	0.033	0.680
20	0.500	9.500	0.680	1.000	8.677	0.296	0.033	0.706

Table 3.1. Calculation of Secondary Velocity on Channel Bend.

3.2 Conclusion

From the calculation results above are obtained
Main speed (U): 1 m / sec
Initial secondary speed (V0): 0.1 m / s
Bend Radius (Rc): 0.4
Depth of Flow (D): 1 meter
Roughness number (f): 0.017
From table 3. 1. It can be seen that the value of the secondary speed (V) is getting bigger, with the point being towards the middle of the bend.

So that it can be concluded as follows:
1. At the bend of an open channel or river, there will be an increase in flow velocity in the transverse direction.
2. This additional speed is caused by additional secondary velocity, namely the transverse speed.

3. At the bend of an open channel or river, there is a lateral slope of the water level and a super elevation of ΔZ water level, that is, the water rise on the outside of the bend, and the inside of the bend will fall.
4. The magnitude of the ΔZ super elevation is influenced by:
   a. The radius of the bend Channel or river bend R
   b. Longitudinal velocity of flow U
   c. The width of the channel or river bed b
   d. Depth of water Channel or river D

4. ACKNOWLEDGEMENT

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• Faculty of Engineering, Indonesian Christian University, Jakarta
• Prof, Indratmo Soekarno, Bandung Institute of Technology

5. REFERENCES

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LAMPIRAN

Listing Program Menghitung Kecepatan Sekunder Pada Tikungan Saluran Terbuka atau Sungai

```
C     ******************************************************************
C     *       PROGRAM MENGHITUNG KECEPATAN SEKUNDER DI TIKUNGAN        *
C     *                       (SECONDARY FLOW)                         *
C     *                                                                *
C     *      Created by :                                              *
C     *      Nama             : Setiyadi                               *
C     *      NIDN             : 0302116402                             *
C     *      Institusi        : FT UKI Jakarta                        *
C     *      Alamat           : Jl. Mayjend Sutoyo Cawang Jkt          *
c     *                                                                *
C     ******************************************************************
C
C     KETERANGAN :
C
C               U     = KECEPATAN UTAMA ALIRAN (m/dt)
C               v     = KECEPATAN SEKUNDER AWAL (m/dt)
C               H     = KEDALAMAN ALIRAN (m)
C               Rc    = JARI-JARI DI TIKUNGAN (m)
C               Ds    = JARAK TIAP SECTION (m)
C               Miu_C = KONSTANTA VON KARMAN
C               f     = KOEFISIEN KEKASARAN DARCY-WEISBACH
C               Z     = KEMIRINGAN ARAH LOGITUDINAL
C
C     ******************************************************************
C
C     PROGRAM MENCARI KECEPATAN SEKUNDER
C
      REAL U, v, H, Rc, Ds, Miu_C, f
      REAL m, K, F1, F2, e, e1, e2, Vj
      OPEN (100,FILE='KEC-SEC.TXT',STATUS='UNKNOWN')
C
C     MASUKAN DATA
C
      WRITE (*,1)
    1 FORMAT(1X,49('_'))
      WRITE (*,*)'*************************************************'
      WRITE (*,*)'PROGRAM MENGHITUNG KECEPATAN SEKUNDER DI TIKUNGAN'
      WRITE (*,*)'                (SECONDARY FLOW)                 '
      WRITE (*,1)
      WRITE (*,*)
      WRITE (*,*)'                   Oleh:                         '
      WRITE (*,*)
      WRITE (*,*)'       Nama            :  Setiyadi              '
      WRITE (*,*)
      WRITE (*,*)'             FAKULTAS TEKNIK JURUSAN SIPIL       '
      WRITE (*,*)'             UNIVERSITAS KRISTEN INDONESIA       '
      WRITE (*,*)'             JAKARTA                             '
      WRITE (*,1)
      WRITE (*,*)'*************************************************'
      WRITE (*,*)'Suatu saluran dengan data sebagai berikut :      '
      WRITE (*,1)
      WRITE (*,*)
      WRITE (*,'(1X,a,\)')'Kecepatan Utama              U  (m/dt)  = '
      READ  (*,*)U
      WRITE (*,'(1X,a,\)')'Kecepatan Sekunder Awal      v  (m/dt)  = '
```

```
      READ  (*,*)v
      WRITE (*,'(1X,a,\)')'Kedalaman Aliran             H    (m) = '
      READ  (*,*)H
      WRITE (*,'(1X,a,\)')'Jari-jari Tikungan          Rc    (m) = '
      READ  (*,*)Rc
      WRITE (*,'(1X,a,\)')'Jarak Tiap Section          Ds    (m) = '
      READ  (*,*)Ds
      WRITE (*,'(1X,a,\)')'Konstanta Von Karman     Miu_C        = '
      READ  (*,*)Miu_C
      WRITE (*,'(1X,a,\)')'Koefisien Darcy-Weisbach     f        = '
      READ  (*,*)f
      WRITE (*,1)
      WRITE (*,*)
C
C     MENULIS DATA MASUKKAN PADA FILE 'TIKUNGAN.TXT'
C
      WRITE (100,*)'************************************************'
      WRITE (100,*)'            PROGRAM MENGHITUNG KECEPATAN SEKUNDER D
     +I TIKUNGAN   '
      WRITE (100,*)'                            (SECONDARY FLOW)      '
      WRITE (100,*)
      WRITE (100,5)
      WRITE (100,*)'************************************************'
      WRITE (100,*)'A. Input data saluran yang dihitung :'
      WRITE (100,5)
    5 FORMAT(1X,72('_'))
      WRITE (100,10)U, V, H, Rc, Ds, Miu_C, f
   10 FORMAT(1H /8X,
     +41H* Kecepatan Utama                  U = ,F8.4,9H m/dt    /8X,
     +41H* Kecepatan Sekunder Awal          v = ,F8.4,9H m/dt    /8X,
     +41H* Kedalaman Aliran                 H = ,F8.4,9H m       /8X,
     +41H* Jari-jari Tikungan              Rc = ,F8.4,9H m       /8X,
     +41H* Jarak Tiap Section              Ds = ,F8.4,9H m       /8X,
     +41H* Konstanta Von Karman         Miu_C = ,F8.4,9H         /8X,
     +41H* Koef. Kekasaran Darcy-Weisbach   f = ,F8.4,9H         /)
      WRITE (100,5)
      WRITE (100,*)
C
C     FORMULA-FORMULA UNTUK PERHITUNGAN
C
   15 m      = Miu_C * SQRT(8./f)
      K      = f/2.
      F1     = SQRT(K) * ((10./3.) - ((1./Miu_C) * (5./9.)*SQRT(K)))
      F2     = (Miu_C * H) * SQRT(K) * (m / (m + 1))
      e      = 2.718281828
      e1     = e**(F2 * Ds)
      e2     = e**(-F2 * Ds)
      Vj     = (v + (F1*(U/Rc)*Ds)**e1)**e2
      Vj1    = (Vj + (F1*(U/Rc)*Ds)**e1)**e2
      Vj2    = (Vj1 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj3    = (Vj2 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj4    = (Vj3 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj5    = (Vj4 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj6    = (Vj5 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj7    = (Vj6 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj8    = (Vj7 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj9    = (Vj8 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj10   = (Vj9 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj11   = (Vj10 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj12   = (Vj11 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj13   = (Vj12 + (F1*(U/Rc)*Ds)**e1)**e2
```

```
      Vj14   = (Vj13 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj15   = (Vj14 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj16   = (Vj15 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj17   = (Vj16 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj18   = (Vj17 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj19   = (Vj18 + (F1*(U/Rc)*Ds)**e1)**e2
      Vj20   = (Vj19 + (F1*(U/Rc)*Ds)**e1)**e2
C
C     MENULIS DATA HASIL KONVERSI PADA FILE 'TIKUNGAN.TXT'
C
      WRITE (100,*)'B. Data hasil perhitungan sebagai berikut :        '
      WRITE (100,5)
      WRITE (100,20) m,F1,F2,Vj,Vj1,Vj2,Vj3,Vj4,Vj5,Vj6,Vj7,Vj8,Vj9,
     +Vj10,Vj11,Vj12,Vj13,Vj14,Vj15,Vj16,Vj17,Vj18,Vj19
   20 FORMAT(1H /8X,
     +41H                                    m = ,F8.2,9H          /8X,
     +41H                                   F1 = ,F8.6,9H          /8X,
     +41H                                   F2 = ,F8.4,9H          /8X,
     +41H* Kecepatan Sekunder di Titik 1     Vj = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 2   Vj+1 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 3   Vj+2 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 4   Vj+3 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 5   Vj+4 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 6   Vj+5 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 7   Vj+6 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 8   Vj+7 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 9   Vj+8 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 10  Vj+9 = ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 11  Vj+10= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 12  Vj+11= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 13  Vj+12= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 14  Vj+13= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 15  Vj+14= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 16  Vj+15= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 17  Vj+16= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 18  Vj+17= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 19  Vj+18= ,F8.4,9H m/dt     /8X,
     +41H* Kecepatan Sekunder di Titik 20  Vj+19= ,F8.4,9H m/dt     /)
      WRITE (100,5)
C
      WRITE (100,*)
      WRITE(100,*)'File :tikungan.txt'
      WRITE(100,*)'Tugas II Rekayasa sungai oleh Nastain-25098114'
      WRITE (100,5)
      WRITE (*,*)
      WRITE (*,*)'File Hasil Program : tikungan.txt'
      WRITE (*,*)
      STOP'Program Selesai!'
      END
```