Rumus PPTB utk berbagai bentuk saluran

Rumus umum PPTB (berlaku utk sembarang profil)

$$\boxed{\frac{dh}{ds} = i\left\{\frac{1-\frac{\delta Q^2}{iA^3}\cdot P}{1-\frac{\alpha Q^2}{gA^3}\cdot B}\right\}} \quad \ldots (A)$$

dimana :

dh = selisih dalam air antara 2 potongan saluran
ds = jarak antara 2 potongan saluran
i = kemiringan dasar saluran
δ = $\frac{1}{C^2}$, C adalah koefisien Chezy.

atau $\delta = \frac{n^2}{R^{1/3}}$

n = koef. Manning

Q = debit saluran
P = kell. basah
A = luas basah
α = koef. Coriolis
g = grafitasi
B = lebar muka air

h normal (= H), jika :

$$\frac{A^3}{P} = \frac{\delta Q^2}{i} \quad \ldots (I)$$

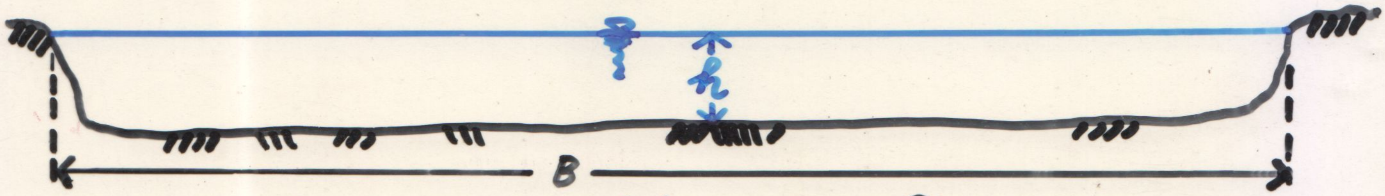
h_{kr} jika :

$$\frac{A^3}{B} = \frac{\alpha Q^2}{g} \quad \ldots (II)$$

$$u_{kr}^3 = \frac{gQ}{\alpha B_{kr}} \qquad u_{kr}^2 = \frac{gA_{kr}}{\alpha B_{kr}} \quad \ldots (III)$$

$$i_{kr} = \frac{\delta g}{\alpha} \cdot \frac{P_{kr}}{B_{kr}} \quad \ldots (IV)$$

Profil Saluran dg $B = \infty$, $B \ggg h$



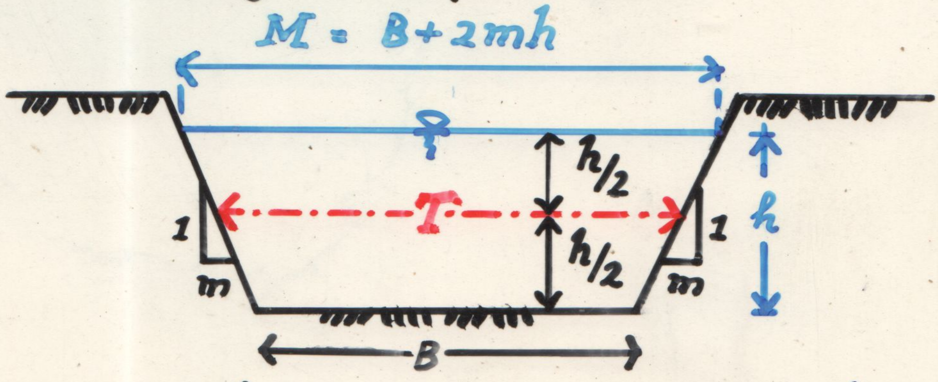
Debit tiap satuan lebar

$$\left.\begin{array}{l} q = \dfrac{Q}{B} \\ A = B.h \end{array}\right\} q = \bar{u}h$$

$$P = B$$

1. $H^3 = \dfrac{\delta q^2}{i}$	3. $u_{kr}^3 = \dfrac{g q}{\alpha}$
2. $h_{kr}^3 = \dfrac{\alpha q^2}{g}$	4. $i_{kr} = \dfrac{\delta g}{\alpha}$

Profil Trapesium.



$T = B + mh$

$A = (B + mh)h = T.h$

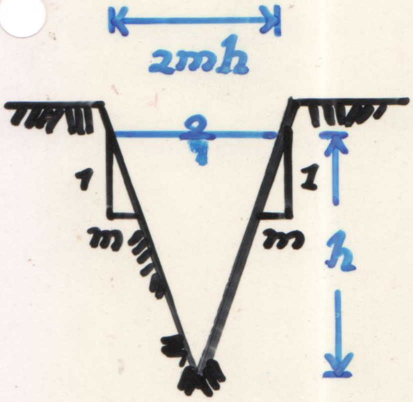
$P = B + 2h\sqrt{1+m^2}$

(Empat persegi panjang ≡ Trapesium dg $m = 0$)

1. $H^3 = \dfrac{\delta Q^2}{i} \cdot \dfrac{B + 2H\sqrt{1+m^2}}{(B+mH)^3}$	3. $u_{kr}^2 = \dfrac{g}{\alpha} \cdot \dfrac{(B+mh_{kr}).h_{kr}}{B+2mh_{kr}}$
2. $h_{kr}^3 = \dfrac{\alpha Q^2}{g} \cdot \dfrac{B+2mh_{kr}}{(B+mh_{kr})^3}$	4. $i_{kr} = \dfrac{\delta g}{\alpha} \cdot \dfrac{B+2h_{kr}\sqrt{1+m^2}}{B+2mh_{kr}}$

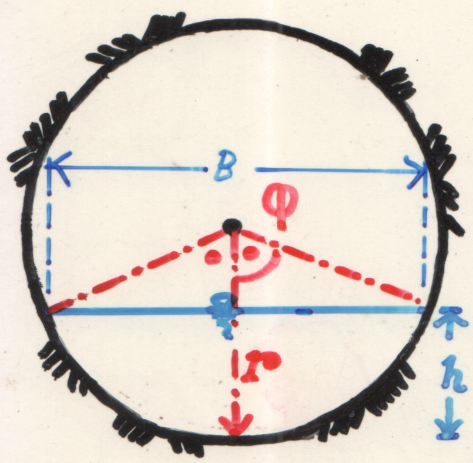
Profil Segitiga.

Profil Δ samakaki $\equiv$ profil trapesium dengan $B = 0$



1. $H^5 = \dfrac{\delta Q^2}{i} \cdot \dfrac{2\sqrt{1+m^2}}{m^3}$
2. $h_{kr}^5 = \dfrac{\alpha Q^2}{g} \cdot \dfrac{2}{m^2}$
3. $u_{kr}^2 = \dfrac{g h_{kr}}{2\alpha}$
4. $i_{kr} = \dfrac{\delta g}{\alpha} \cdot \dfrac{\sqrt{1+m^2}}{m}$

Profil Lingkaran



φ dlm ~~radial~~ radian !

$P = 2\varphi r$

$A = r^2 (\varphi - \frac{1}{2} \sin 2\varphi)$

$B = 2r \sin \varphi$

$h = r(1 - \cos\varphi)$

1. H jika : $\dfrac{(\varphi - \frac{1}{2}\sin 2\varphi)^3}{2\varphi} = \dfrac{\delta Q^2}{i r^5}$	3. $u_{kr}^2 = \dfrac{g}{\alpha} \cdot \dfrac{r_{kr}(\varphi_{kr} - \frac{1}{2}\sin 2\varphi_{kr})}{2\sin\varphi_{kr}}$
2. h_{kr} jika : $\dfrac{(\varphi_{kr} - \frac{1}{2}\sin 2\varphi_{kr})^3}{2\sin\varphi_{kr}} = \dfrac{\alpha Q^2}{g r_{kr}^5}$	4. $i_{kr} = \dfrac{\delta g}{\alpha} \cdot \dfrac{\varphi_{kr}}{\sin\varphi_{kr}}$

Karakteristik Bentuk Aliran.

Rumus PPTB utk saluran psg pj lebar ($B = \infty$)

1. $$\frac{dh}{ds} = i \frac{1 - \frac{\delta q^2}{ih^3}}{1 - \frac{\alpha q^2}{gh^3}}$$

2. $$H^3 = \frac{\delta q^2}{i}$$

3. $$h_{kr}^3 = \frac{\alpha q^2}{g}$$

dari ketiga pers. diatas didapat :

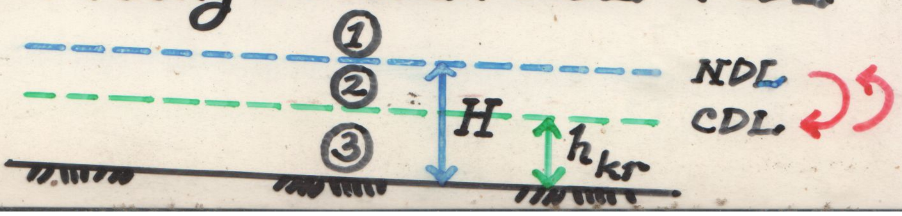
$$\boxed{\frac{dh}{ds} = i \frac{h^3 - H^3}{h^3 - h_{kr}^3}}$$

Bentuk Aliran (flow profile) terlihat dari kurva muka air dari aliran. Secara grs besar terdapat 2 macam - bentuk aliran yi :

1. Backwater, jika dalam air h bertambah searah aliran ($dh/ds > 0$)
2. Drawdown, jika dalam air h berkurang searah aliran ($dh/ds < 0$)

Untuk suatu Q tertentu dan keadaan saluran tertentu, NDL dan CDL akan membagi saluran menjadi 3 zone yi

1. Zone 1 : ruang diatas NDL & CDL
2. Zone 2 : ruang diantara NDL & CDL
3. Zone 3 : ruang dibawah NDL & CDL



Ditinjau pers. $$\frac{dh}{ds} = i\,\frac{h^3 - H^3}{h^3 - h_{kr}^3}$$

1). $\frac{dh}{ds} > 0 \rightarrow$ Backwater !

a. $h^3 - H^3 > 0 \longrightarrow h > H$
$h^3 - h_{kr}^3 > 0 \longrightarrow h > h_{kr}$ } Zone 1 !
$\longrightarrow$ subcritical flow !

b. $h^3 - H^3 < 0 \longrightarrow h < H$
$h^3 - h_{kr}^3 < 0 \longrightarrow h < h_{kr}$ } zone 3 !
$\longrightarrow$ super critical flow !

2). $\frac{dh}{ds} < 0 \rightarrow$ Drawdown !

a. $h^3 - H^3 > 0 \longrightarrow h > H$
$h^3 - h_{kr}^3 < 0 \longrightarrow h < h_{kr}$ } zone 2 !
$\longrightarrow$ supercritical flow !

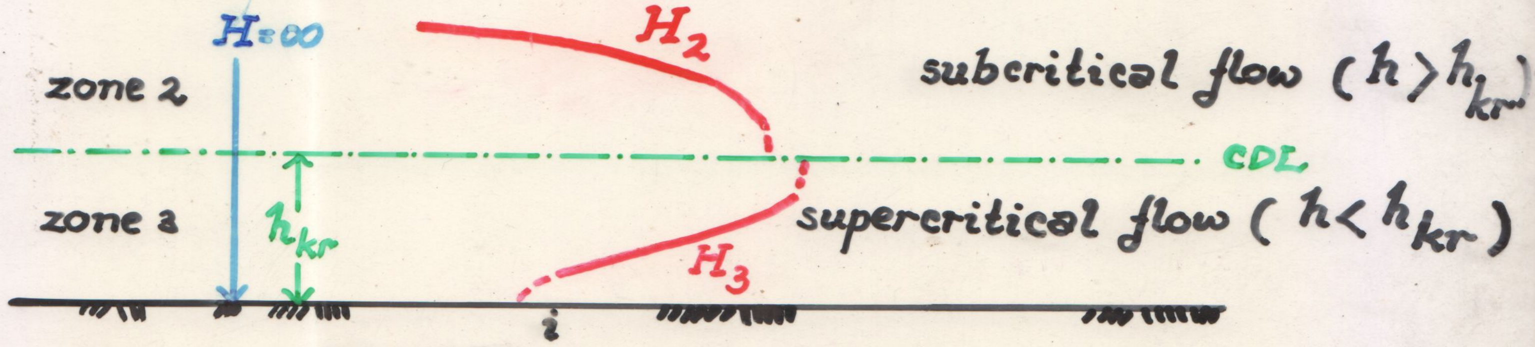
- h_{kr}
· h
- H

b. $h^3 - H^3 < 0 \longrightarrow h < H$
$h^3 - h_{kr}^3 > 0 \longrightarrow h > h_{kr}$ } zone 2
$\longrightarrow$ suberitical flow !

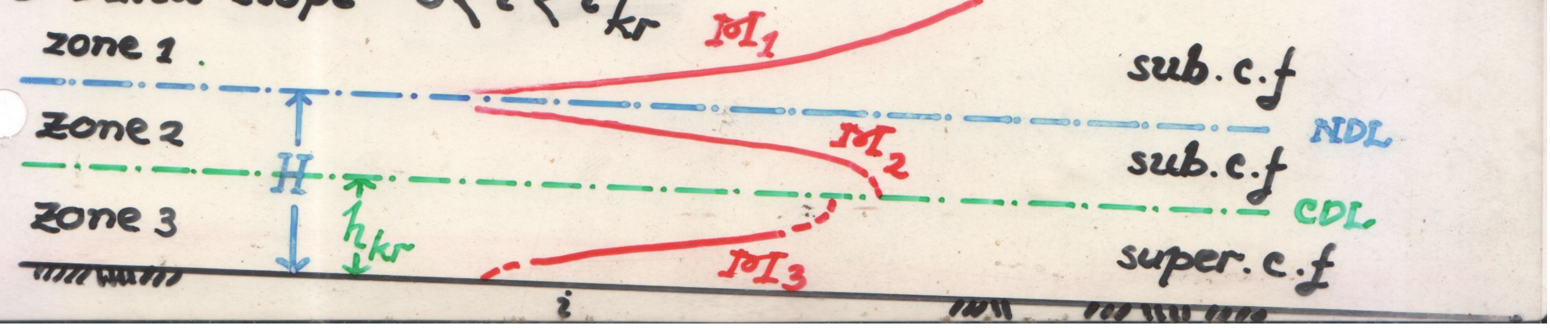
- H
·
- h_{kr}

Tinjauan flow profile untuk bermacam² i saluran :

A. Horisontal slope $i = 0$



B. Mild slope $0 < i < i_{kr}$



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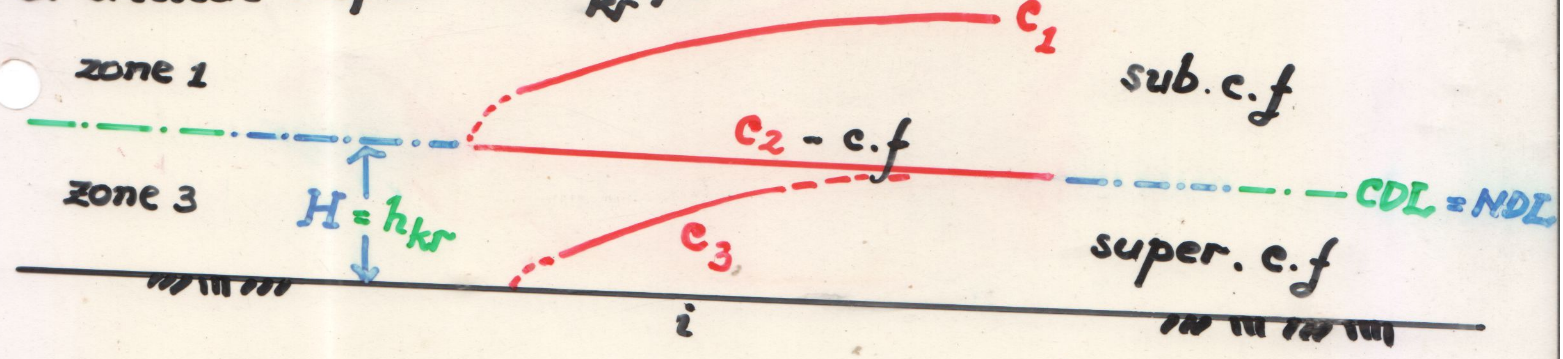
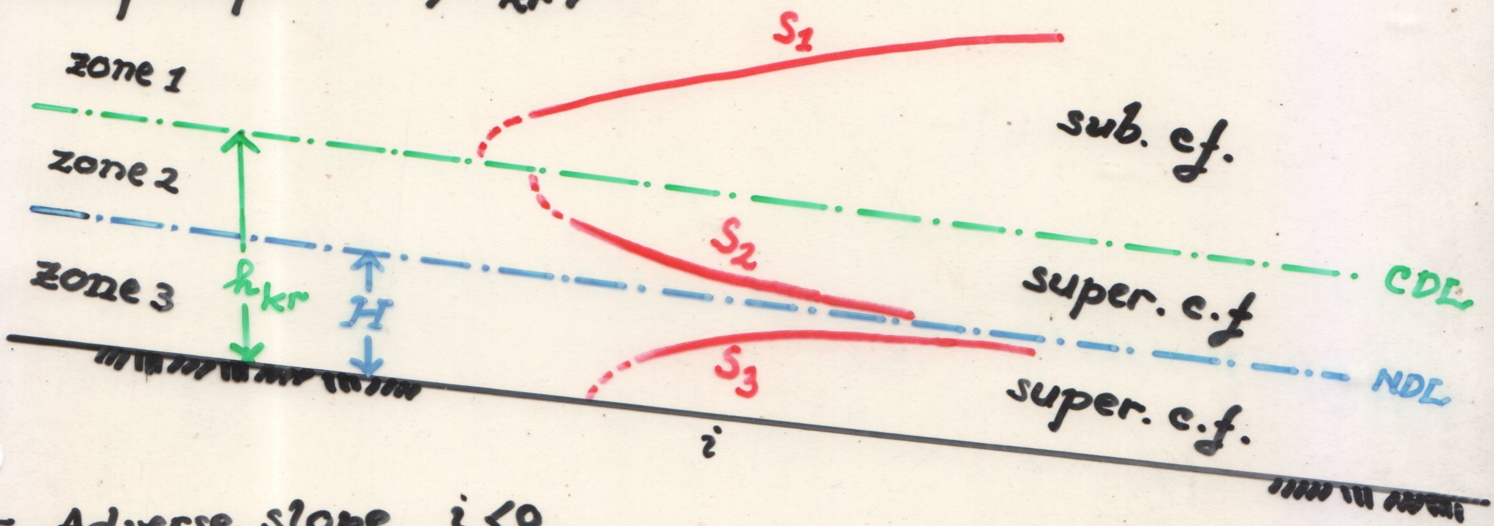
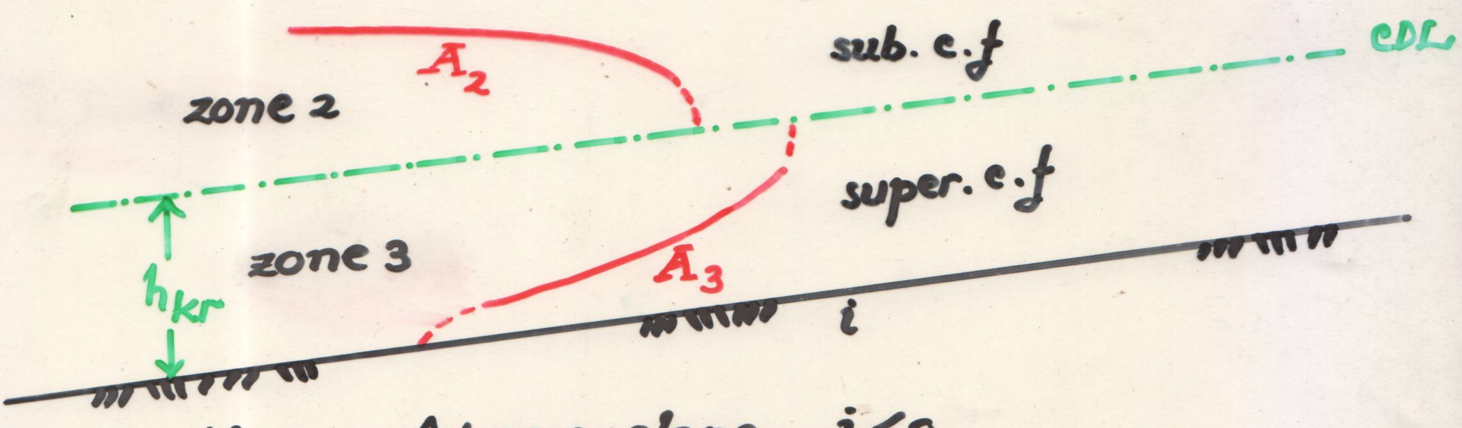
C. Critical Slope $i = i_{kr} > 0$



D. Steep slope $i > i_{kr} > 0$



E. Adverse slope $i < 0$



Tinjauan khusus Adverse slope $i < 0$

$$H^3 = \frac{\alpha q^2 / g}{i} \rightarrow H_{negatif} \rightarrow \text{imajiner} \rightarrow \therefore h^3 - H^3 > 0$$

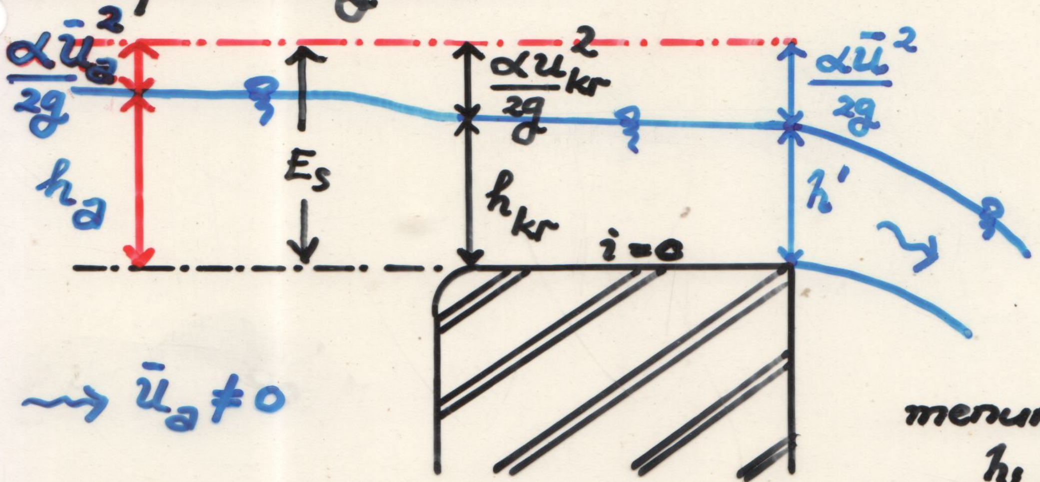
maka $$\frac{dh}{ds} = i \, \frac{h^3 - H^3}{h^3 - h_{kr}^3}$$

$$\frac{dh}{ds} > 0 \rightarrow \text{backwater, jika } h < h_{kr} \text{ (zone 3)}$$

$$\frac{dh}{ds} < 0 \rightarrow \text{drawdown, jika } h > h_{kr} \text{ (zone 2)}$$

Pengaliran melalui peluap.

I. Peluap ambang lebar.



menurut V.T Chow:
$h_{kr} = 1,4\, h'$

Anggapan:
1. ambang datar $\rightarrow i = 0$
2. geseran pd ambang $= 0 \rightarrow h_f = 0$

Pers. umum PPTB:

$$i\,ds - dh = \frac{P}{A} \cdot \frac{\bar{u}^2}{C^2} \cdot ds + \alpha \frac{d\bar{u}^2}{2g}$$

$$i\,ds - dh = h_f + \alpha \frac{d\bar{u}^2}{2g}.$$

Jadi $dh + \alpha \frac{d\bar{u}^2}{2g} = 0 \quad \ldots (1)$

$$E_s = h + \alpha \frac{\bar{u}^2}{2g} \rightarrow \frac{dE_s}{dh} = \frac{dh + \alpha\, d\left(\frac{\bar{u}^2}{2g}\right)}{dh} \quad \ldots (2)$$

(1) & (2) didapat $\frac{dE_s}{dh} = 0$

Kesimpulan: pada peluap ambang lebar dan datar E_s minimum $\rightarrow$ jadi dalam air diatas ambang adalah h_{kr}.

Jadi ambang lebar akan meluapkan suatu debit tertentu dengan menggunakan energi sekecil mungkin (E_s minimum) d.p.l ambang lebar akan meluapkan Q sebesar mungkin pd suatu harga E_s tertentu.

Prinsip ini dikenal dg nama :
" Prinsip des maximalen durchflusses von Belanger "
(th 1849)

Hitungan Q yg mell. peluap :
Dari bab E_s didepan didapat bahwa pada h_{kr} :

$$\frac{\alpha \bar{u}_{kr}^2}{2g} = \frac{D}{2} \rightarrow \text{dimana } D = \text{hydraulic mean depth}$$

Ambang $\rightarrow$ $\boxed{4 \text{ psg pj} \rightarrow D = h_{kr}}$

$$E_{s_{kr}} = h_{kr} + \frac{\alpha \bar{u}_{kr}^2}{2g}$$

$$= h_{kr} + \frac{1}{2} h_{kr} \longrightarrow \boxed{h_{kr} = \frac{2}{3} E_s} \quad \text{(I)}$$

Sedangkan menurut rumus PPTB saluran 4 psg pj :

$$u_{kr}^2 = \frac{gA}{\alpha B} \longrightarrow u_{kr}^2 = \frac{g}{\alpha} h_{kr}$$

Debit tiap satuan lebar peluap :

$$q = u_{kr} \cdot h_{kr} \cdot \mu \rightarrow \mu = \text{koefisien peluap.}$$

$$= \mu \sqrt{\frac{g}{\alpha} h_{kr}} \cdot h_{kr}$$

Jadi :

$$\boxed{q = \mu \sqrt{\frac{g}{\alpha}} \cdot h_{kr}^{3/2}} \quad \text{(II)}$$

II. Peluap trapesium ambang lebar.

Analog diatas : $E_{s_{kr}} = h_{kr} + \frac{D}{2}$.

$$D = \frac{\text{Luas Basah}}{\text{Lebar m.a}} = \frac{T_{kr} \cdot h_{kr}}{M_{kr}}$$

$$\boxed{E_s = \left(1 + \frac{T_{kr}}{2M_{kr}}\right) h_{kr}} \quad (I)$$

Dari PPTB didpt :

$$u_{kr}^2 = \frac{g}{\alpha} \cdot \frac{A_{kr}}{M_{kr}}$$

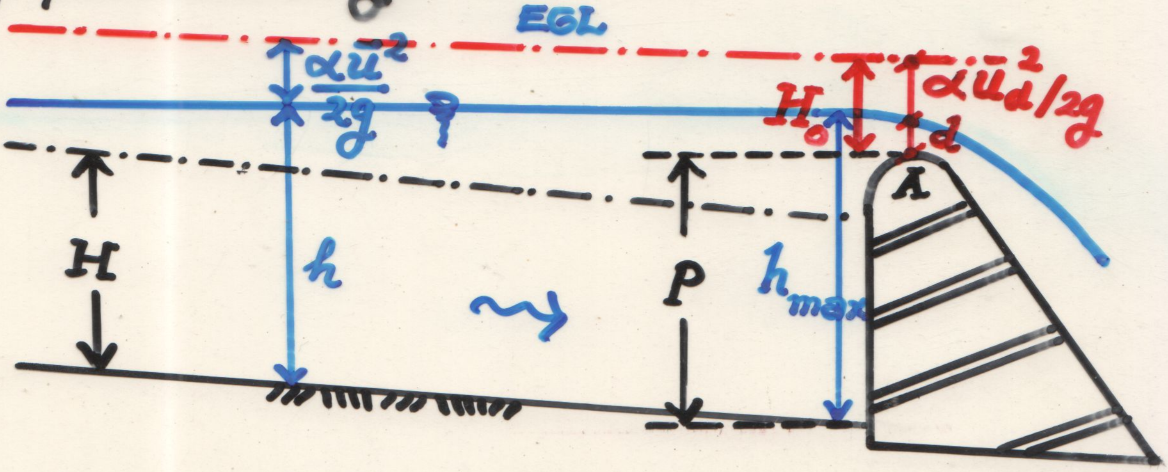
Jadi

$$Q = \mu . A_{kr}\, u_{kr}$$

$$= \mu . T_{kr}\, h_{kr} \cdot \sqrt{\frac{g}{\alpha}\,\frac{T_{kr} . h_{kr}}{M_{kr}}}$$

$$\boxed{Q = \mu\, h_{kr}^{3/2} \sqrt{\frac{g}{\alpha}\,\frac{T_{kr}^3}{M_{kr}}}} \quad (II)$$

II. Peluap pada bendung.



Pada titik A dianggap kejadiannya sama dg peluap ambang lebar, datar :

$$h_{kr} = \frac{2}{3} E_{s\,kr}$$

disini jarak antara h_{max} dan ttk A adalah pendek shg $h_f = 0 \rightarrow E_{s\,kr} = E_s$ pd h_{max}

Lihat gambar :

$$h_{kr} = \frac{2}{3} E_s \text{ pd } h_{max}$$

$$\boxed{d = \frac{2}{3} H_o} \quad (I)$$

Debit tiap satuan lebar peluap :

$$q = \mu \sqrt{\frac{g}{\alpha}} \cdot h_{kr}^{3/2}$$

$$\boxed{q = \mu \sqrt{\frac{g}{\alpha}} \cdot d^{3/2}} \quad (II)$$

Jika P = tinggi bendung, maka

$$P + H_o = h_{max} + \alpha \frac{\bar{u}^2}{2g}$$

$$\boxed{P + H_o = h_{max} + \alpha \frac{q^2}{2g h_{max}^2}} \quad (III)$$

$$H_o = \frac{3}{2} d$$

$$= \frac{3}{2} \left(\frac{q}{\mu} \sqrt{\frac{\alpha}{g}} \right)^{2/3}$$

Jadi pers III menjadi

$$P + \frac{3}{2} \left(\frac{q}{\mu}\right)^{2/3} \left(\frac{\alpha}{g}\right)^{1/3} = h_{max} + \alpha \frac{q^2}{2g h_{max}^2} \quad \cdots (IV)$$

Tampak bahwa pers terakhir merupakan fungsi h_{max}^3 jadi h_{max} dpt dicari dg trial & error dg menggunakan : pers (I, II, III) atau pers (IV)

Pers IV : $$P + \frac{3}{2} \left(\frac{q^2}{\mu^2} \cdot \frac{\alpha}{g} \right)^{1/3} = \frac{2g h_{max}^3 + \alpha q^2}{2g h_{max}^2}$$