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In [1]: import os
os.environ['USE_PYGEOS'] = '0'
import geopandas as gpd
import pandas as pd
import numpy as np
```

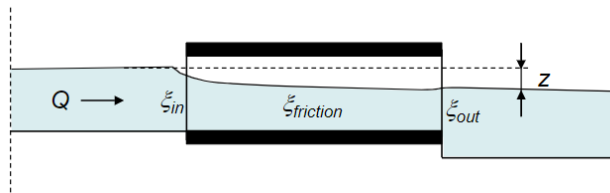
Goal: design of culvert from current area into water storage area

Using: $Q = \mu A \sqrt{2gz} \rightarrow z = (\Sigma \zeta) \frac{u^2}{2g}$

Strikler: $\frac{\delta h}{L} = \frac{u^2}{k^2 R^{\frac{4}{3}}}$

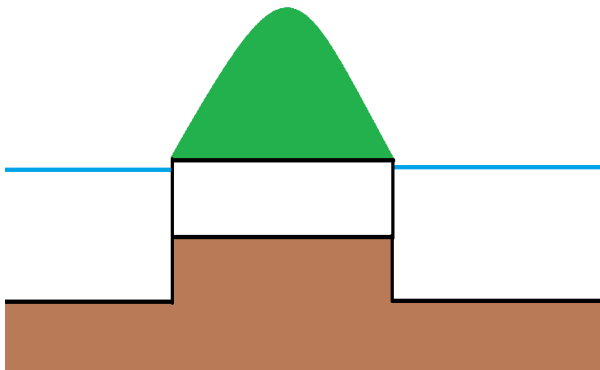
We can rewrite $\zeta_{friction} = \frac{2gL}{k^2 R^{\frac{4}{3}}}$

And:



using $z_{max} = 5mm$, $\zeta_{in} = 0.3$, $\zeta_{out} = 1$

design situation, with of culvert topview in red on the right





from Sobek we know the discharge should be around $0.56[m^3/s]$

$$A = 0.25D^2\pi, v = Q/A$$

```
In [2]: Q = 0.56 # m^3/s
        k = 50 # m^(1/3)/s - for rough concrete culvert
        zeta_in = 0.6
        zeta_out = 1
```

```
In [3]: culvert = gpd.read_file("new_culvert.gpkg", crs="EPSG:28992")
        L = culvert.iloc[0]['length']
        print(f'{L:.2f}m')
```

42.82m

```
In [4]: def zeta_friction(L, D, k, Q):
        A = 0.25 * D**2 * np.pi
        R = A / (np.pi * D)
        u = Q / A
        zeta_f = (2 * 9.81 * L) / (k**2 * R**(4/3))
        return zeta_f, u
```

```
In [5]: D = 0.2 # m
        zeta_f, u = zeta_friction(L, D, k, Q)
        z = (zeta_in + zeta_f + zeta_out) * u**2 / (2 * 9.81)
        print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

with a diameter of 0.2m yields a headloss of 321.34m

```
In [6]: D = 0.4 # m
        zeta_f, u = zeta_friction(L, D, k, Q)
        z = (zeta_in + zeta_f + zeta_out) * u**2 / (2 * 9.81)
        print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

with a diameter of 0.4m yields a headloss of 8.95m

increase to 4 culverts instead of one

```
In [7]: Q = 0.56/4 # m^3/s
        D = 0.8 # m
        zeta_f, u = zeta_friction(L, D, k, Q)
        z = (zeta_in + zeta_f + zeta_out) * u**2 / (2 * 9.81)
        print(f'with a diameter of {D}m yields a headloss of {z:.2f}m')
```

with a diameter of 0.8m yields a headloss of 0.02m

```
In [8]: Q = 0.56/4 # m^3/s
D = 1.0 # m
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z*1000:.4f}mm')
```

with a diameter of 1.0m yields a headloss of 6.0465mm

```
In [9]: Q = 0.56/4 # m^3/s
D = 1.13 # m - sobek has this size available
zeta_f, u = zeta_friction(L, D, k, Q)
z = (zeta_in + zeta_f + zeta_out) * u**2/(2*9.81)
print(f'with a diameter of {D}m yields a headloss of {z*1000:.4f}mm')
```

with a diameter of 1.13m yields a headloss of 3.3898mm

Thus we need 4 culverts of 1100mm in diameter to be able to supply the water storage areas with the peak flow.