# Modeling of surface roughness effect on near bed Turbulent Kinetic Energy in a stormwater detention basin

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# Outline

- Background
- Objectives
- Methodology
- Results
- Conclusions

# Background

- **Turbulence kinetic energy** (TKE) is the mean kinetic energy per unit mass

$$\begin{cases} u = \overline{u} + u' \\ v = \overline{v} + v' \\ w = \overline{w} + w' \end{cases}$$

$$k = \frac{1}{2}\left(u'^2 + v'^2 + w'^2\right)$$

# Background

- Near Bed Turbulent Kinetic Energy (BTKE) can strongly impact the sediment deposition

$$k_c = av^2$$

$k_c$- critical value for deposition ($m^2/s^2$)

v - settling velocity (m/s)

a - coefficient (=1)

# Background

- Near bed turbulence is affected by the roughness elements
- Variable spatial roughness exists on the bed of various stormwater detention basins


Django Reinhardt Basin in Lyon,France

# Problem statement

- Consider the surface roughness effect
- Hard to evaluate the surface roughness effects on turbulence in settling process
- Few studies focus on that in full scale stormwater detention basins

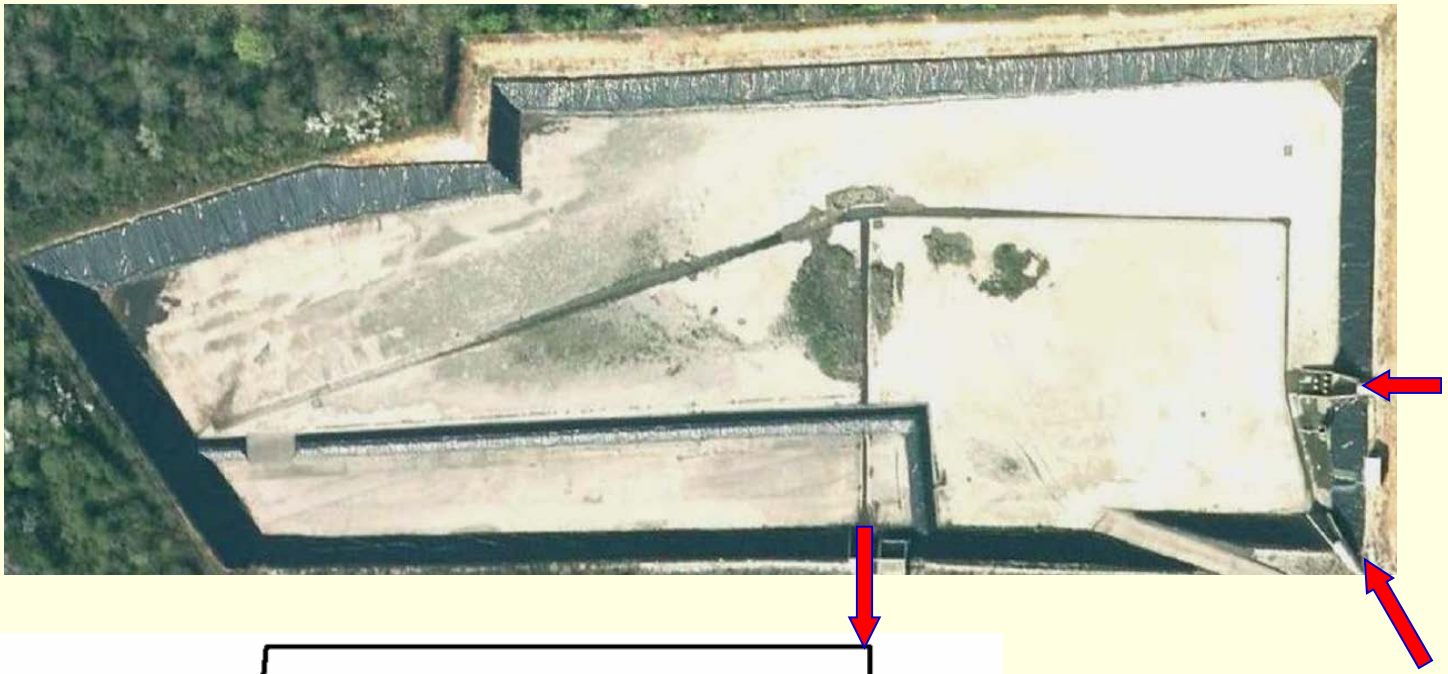
# Objectives

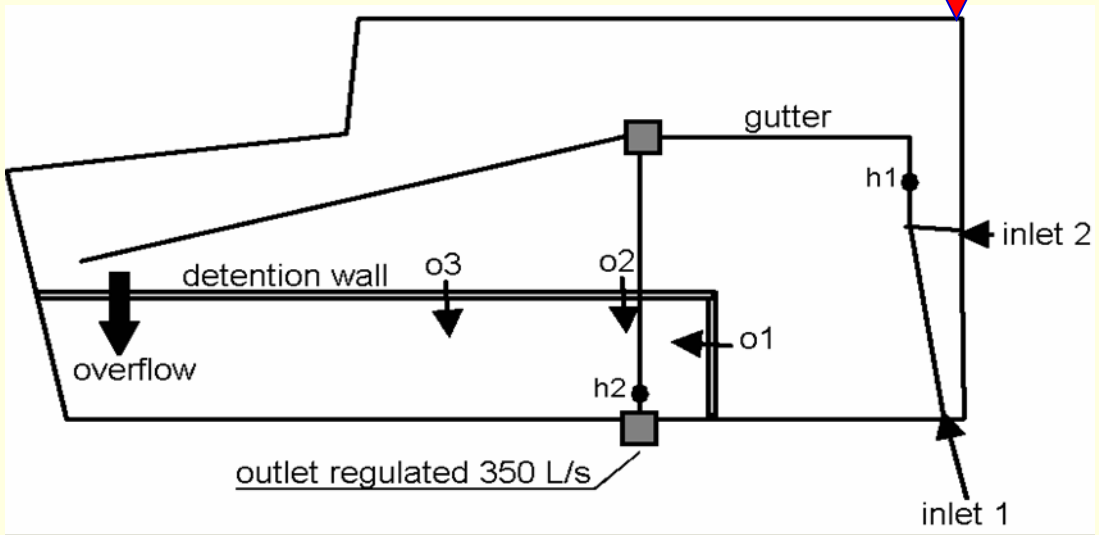
- Establish,test and verify hydrodynamic modeling
- Near bed turbulence quantity (BTKE)

  vs. sediment deposition zone
- Analyze the sensitivity of near bed turbulence (BTKE)

  to surface roughness

# Methodology – Experimental site



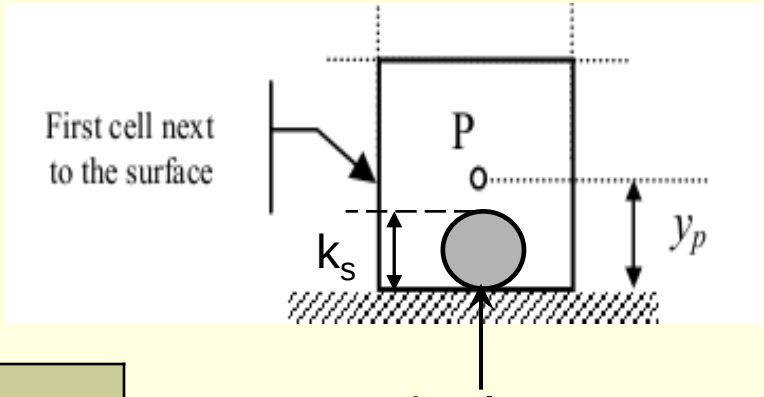



Catchment:185 ha
Area: 1.1 ha
Volume: 32000 $m^3$

# Methodology

- Strategy of modeling
  - Test with different roughness sizes on the bottom according to concrete Strickler coefficient ***K*** (unique K for initial condition)

$$K \times k_s^{\frac{1}{6}} = 6.5 \times \sqrt{g}$$ (Hager, 2010)




| cases | Ks1 | Ks2 | Ks3 | Ks4 |
|---|---|---|---|---|
| $K(m^{1/3}/s)$ | 75 | 65 | 55 | 50 |
| $k_s$ (m) | 0.00040 | 0.00094 | 0.0026 | 0.0045 |

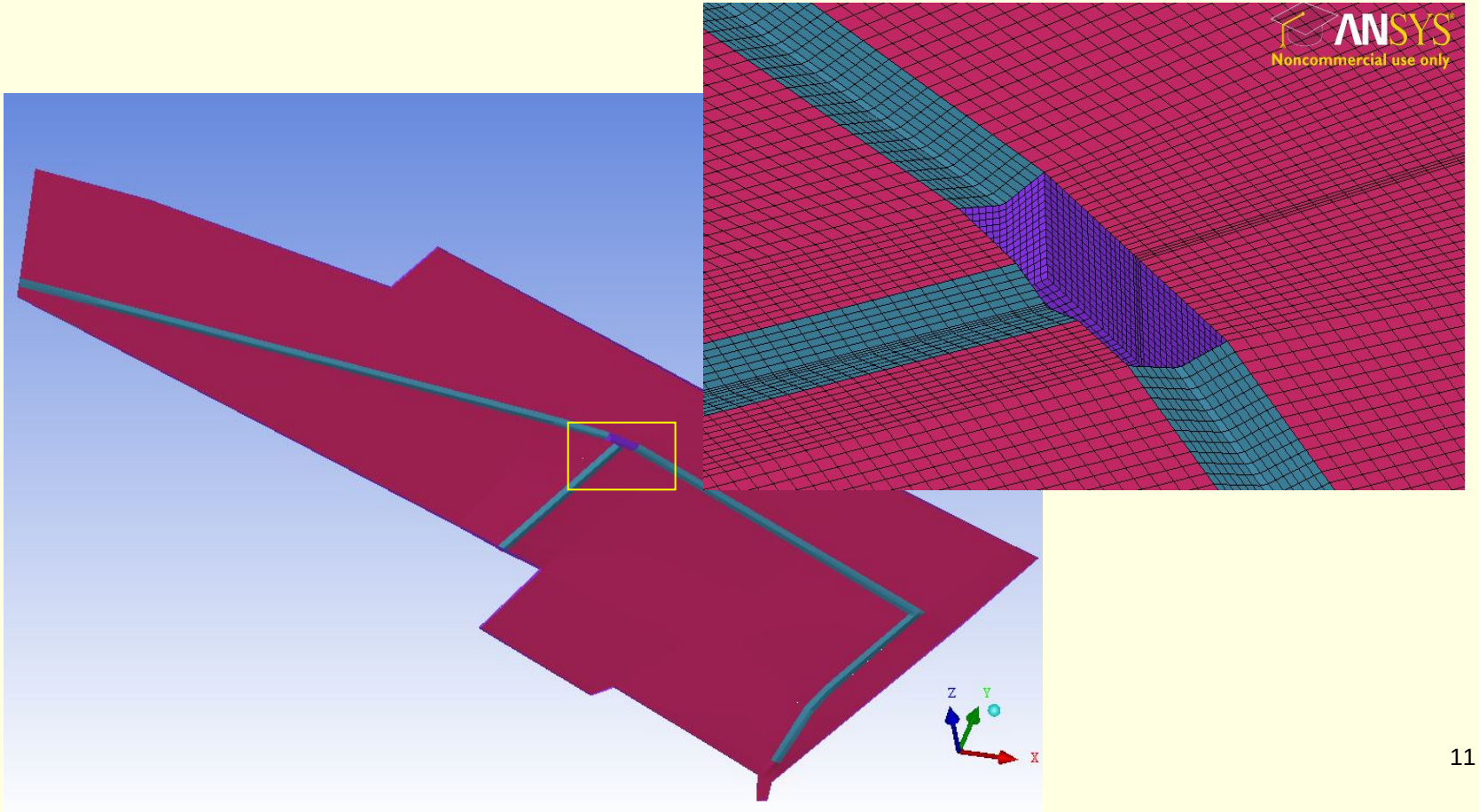
# Methodology

- Model setup

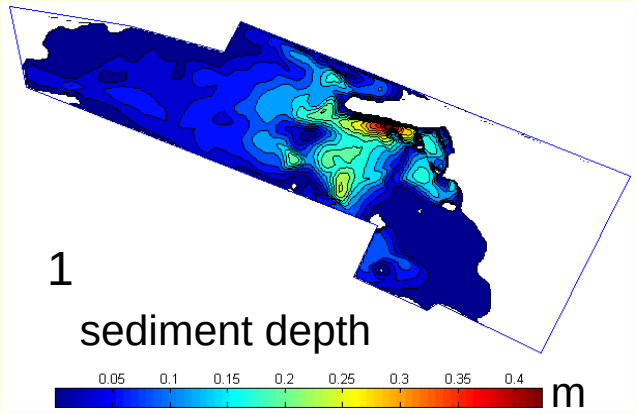
  - Flow regime: steady state
  - Inflow: 0.35$m^3/s$
  - Fixed lid for free surface representation
  - Fixed water depth: $h_1$=0.55m
  - Turbulent model: RNG k-epsilon
  - Roughness set: standard wall function

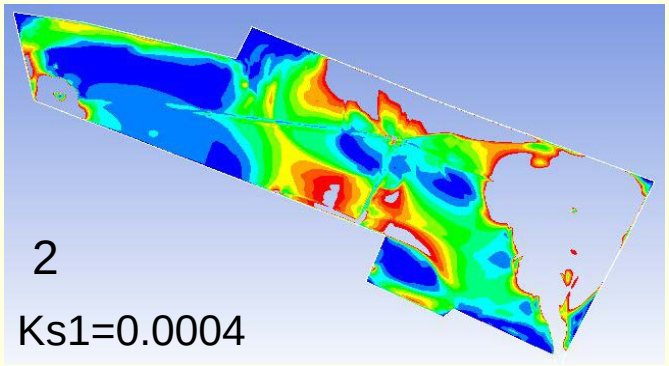
# Geometry & mesh

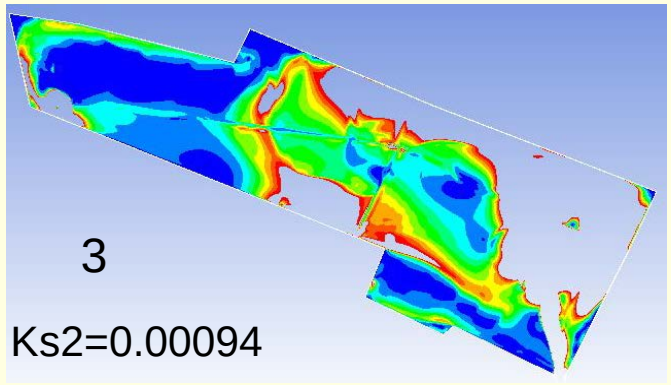
- Independent mesh test (coarse-650 000, median-850 000, fine-1000 000 cells mesh)

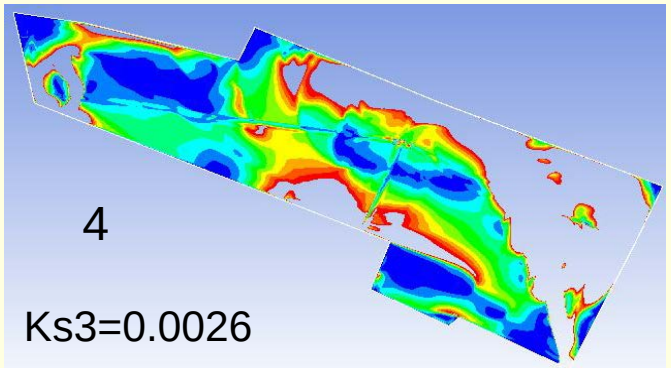


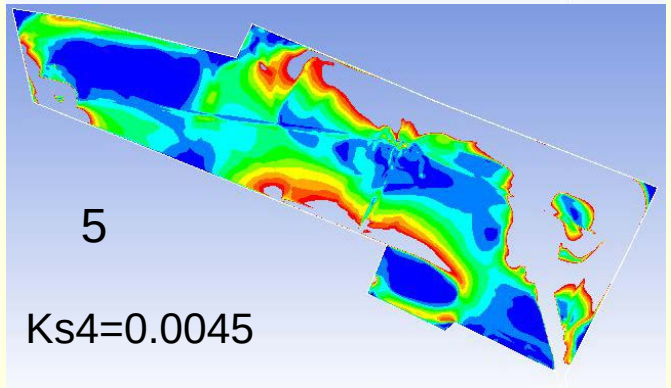
# Results: BTKE vs. deposition zones

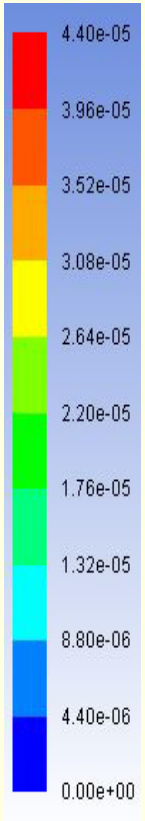


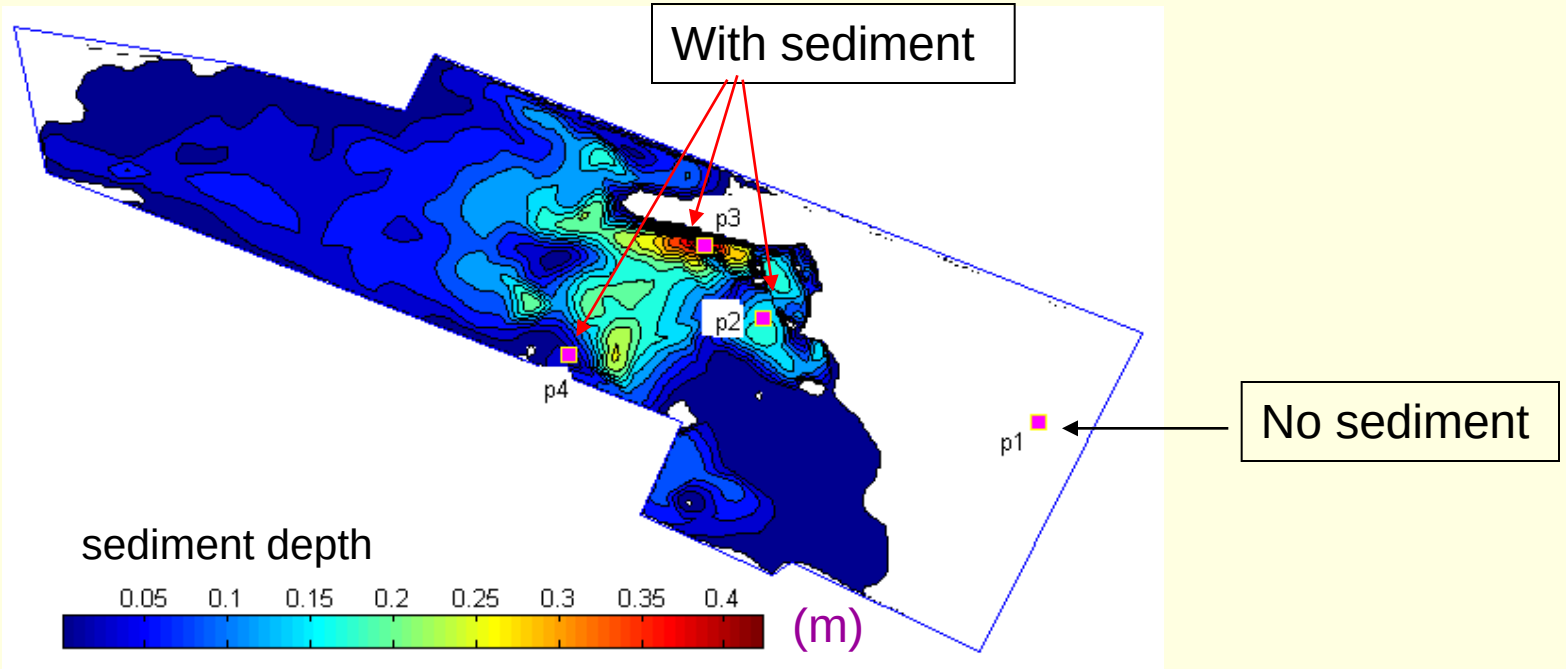




Bed turbulent
kinetic energy (BTKE)

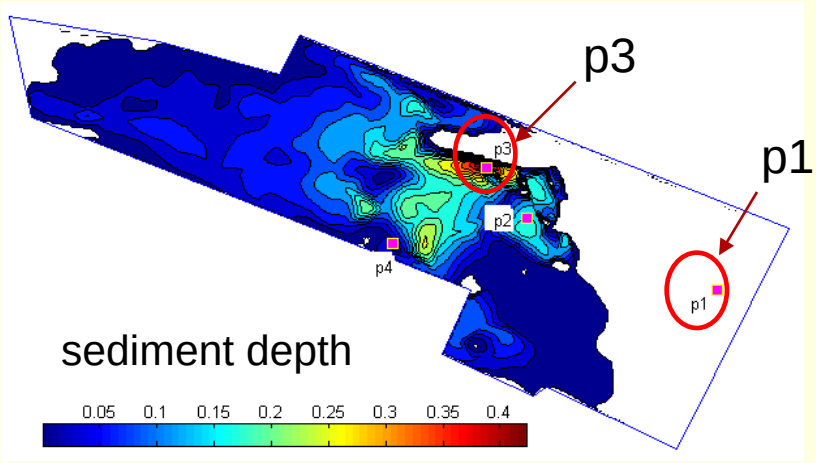
$0< k< k_c=V_{80}^2$

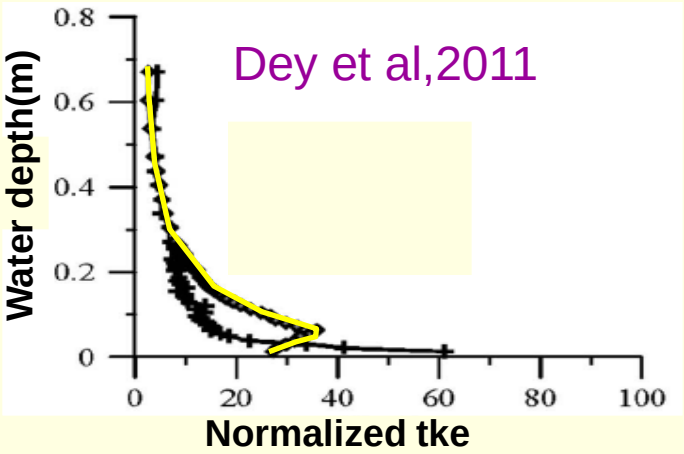
# Vertical TKE distribution

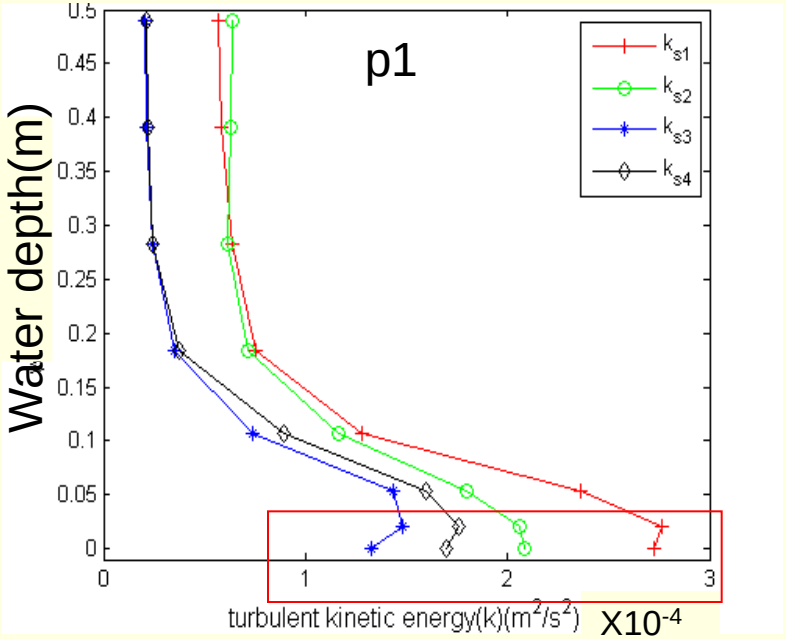


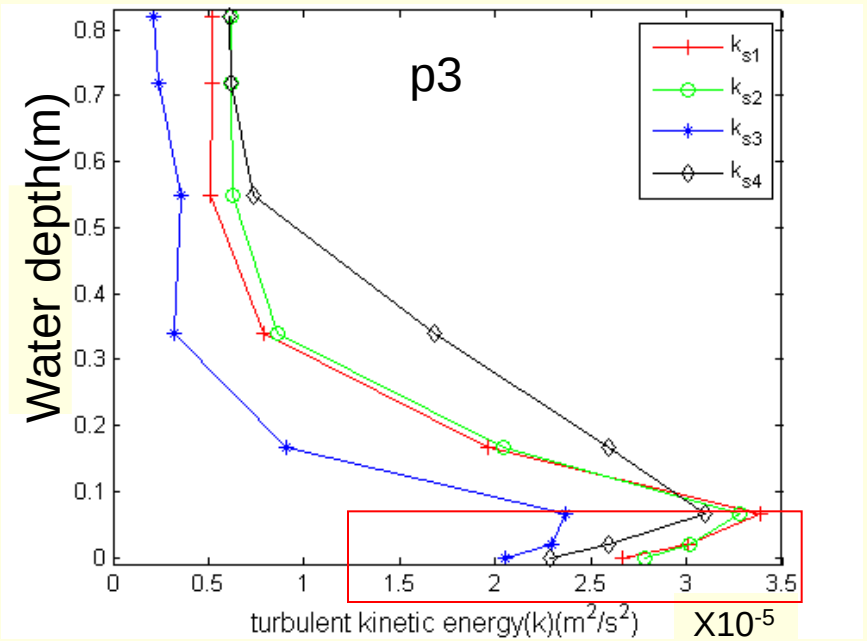

Layout of the checked points

# Results: vertical TKE distribution

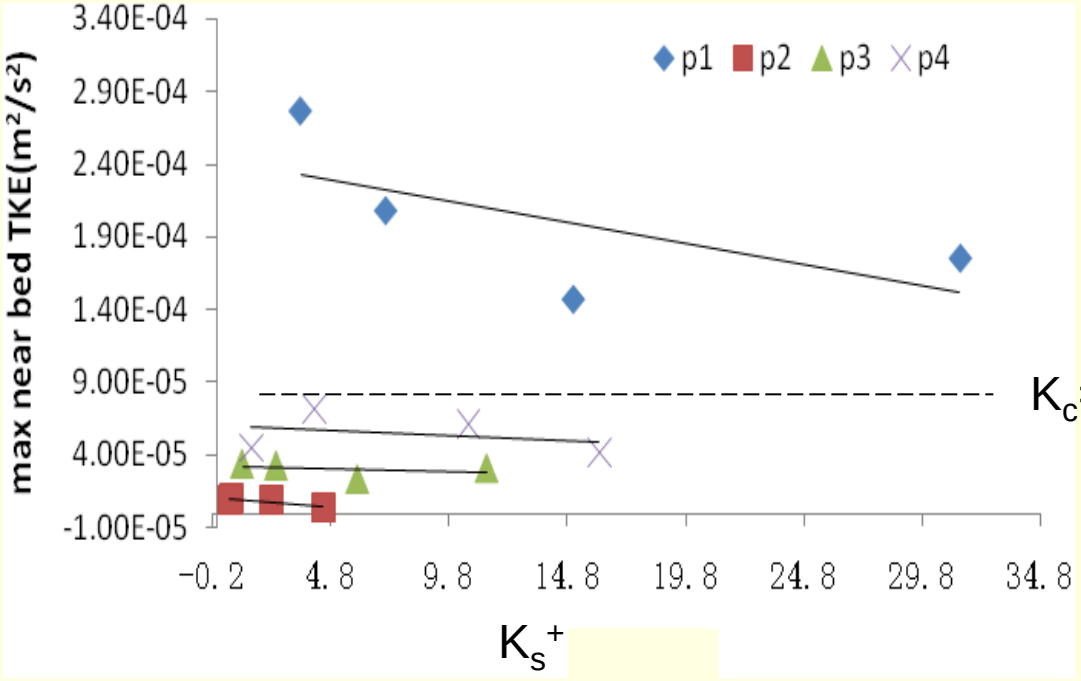


# Results: Effect of roughness height




$$K_s^+ = \rho K_s u_* / \mu$$

# Conclusions

- BTKE is sensitive to surface roughness
- BTKE could be used to estimate the outer contour of the sediment zone with a critical value($k_c=v_{80}*v_{80}$)
- Different roughness height might be set for different zones: higher for sediment zones and lower for concrete surface
- No clear quantitive relation was found between BTKE and dimensionless roughness height