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    - Modeling of Water Networks
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Bottom-Up Approach for Energy Balance of Water Distribution Pumping Station: Case Study from Bangkok, Thailand

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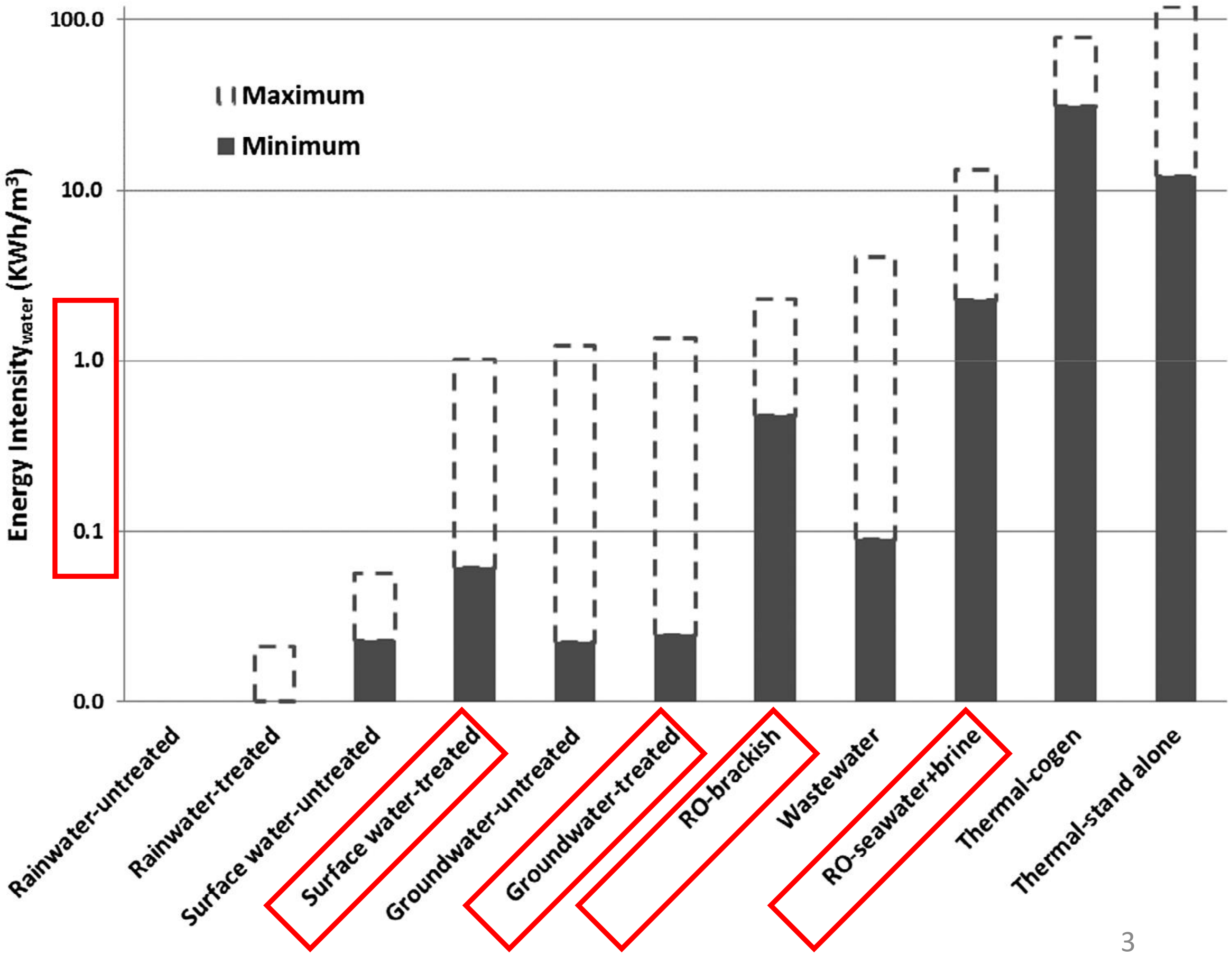
in collaboration with Metropolitan Waterworks Authority (MWA), Thailand

Energy used for water demand

- Energy required for different water sources and extraction technologies.
- Treated surface water and groundwater consume less energy than RO.
- Magnitude of energy intensity is roughly in the order of 0.1 – 1 kWh/m^3.
- Water transported over long distances is not considered due to difficulty!

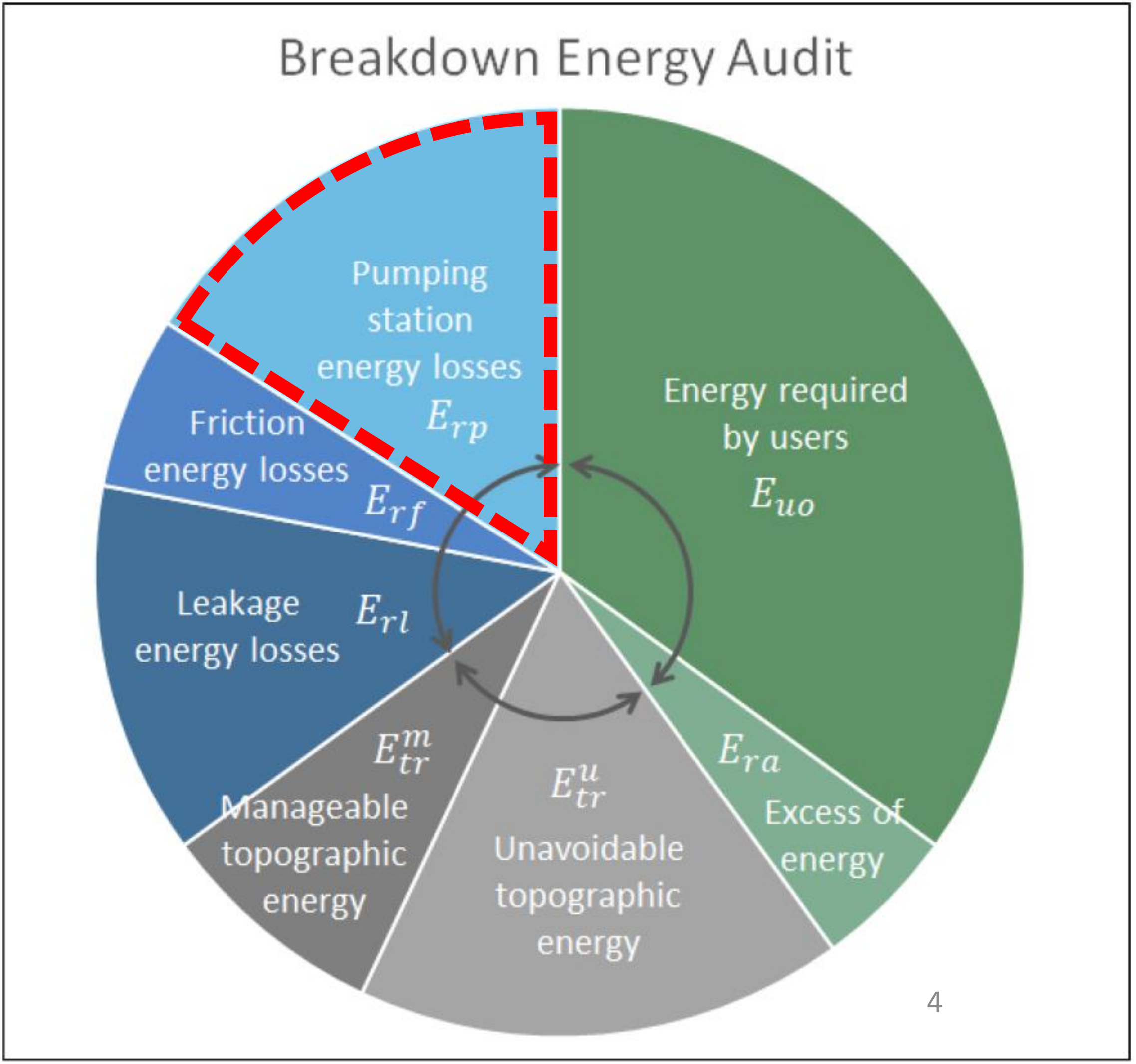


Napoli and Garcia-Tellez (2016) A framework for understanding energy for water.

Energy audit for water transport

- According to waterworks processes, energy uses can be divided into
  - Raw water extraction
  - Water treatment
  - **Water distribution (or water transport)**

- This study focuses on the detailed pumping station energy loss (E_{rp}) using EPANET model (Bottom-up Approach).



Gómez et al. (2018) Labeling water transport efficiencies.

Metropolitan Waterworks Authority (MWA)

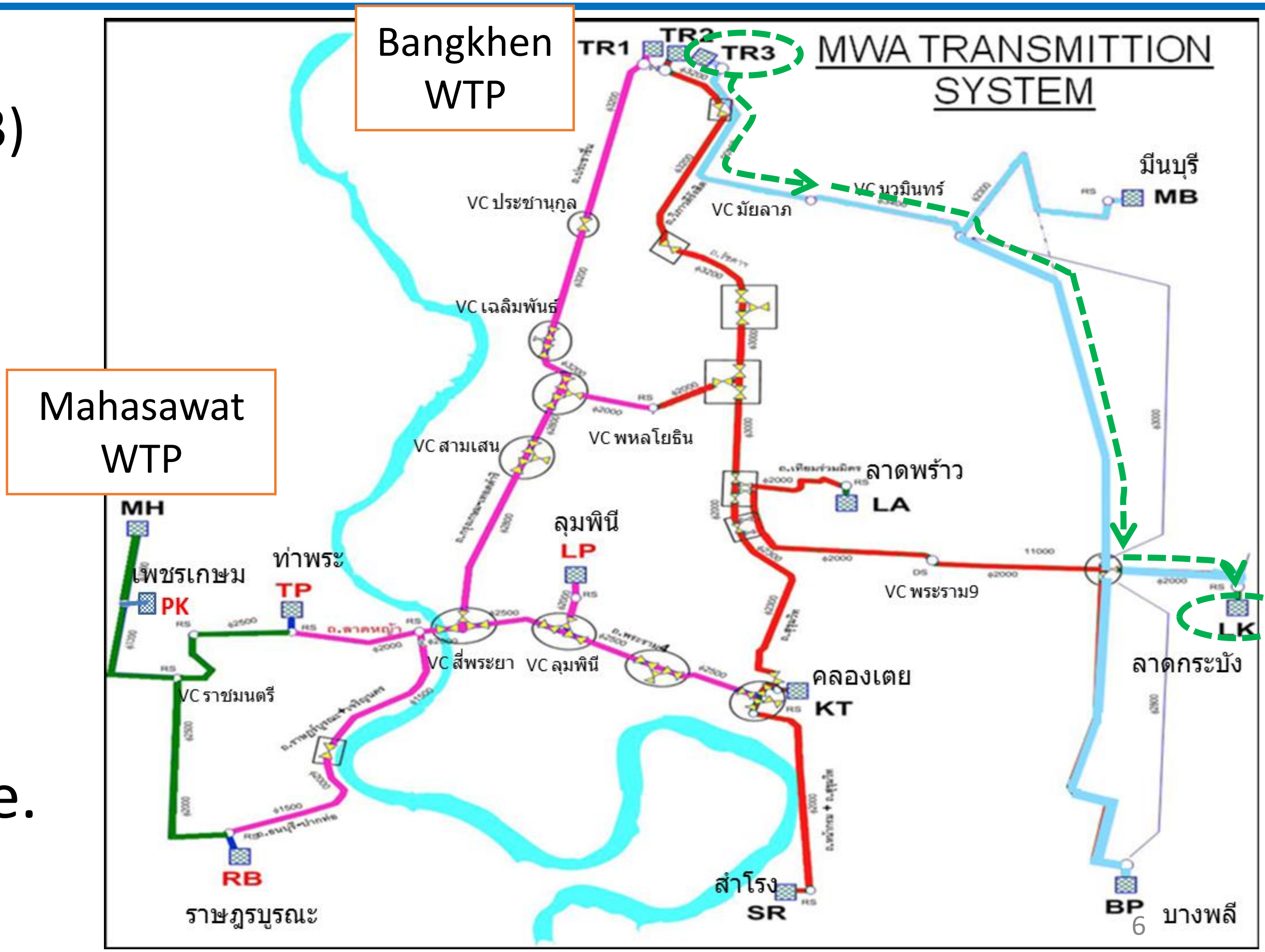
- A state enterprise under the Ministry of interior, Thailand
- Producing, distributing and selling treated water in 3 provinces:
  - Bangkok
  - Nonthaburi
  - Samutprakarn
- Service area of 2,500 km^2
- Pipe length of 38,000 km
- 2.4 million customer connections
- Water production of 2 billion m^3/ year
- Water consumption of 1.4 billion m^3/ year

Treated Water Transmission System

- Source water is from
  - Bangkhen WTP (TR1, TR2, TR3)
  - Mahasawat WTP (MH)
  - Inflow ≈ 4.3 million m^3/day

- Tunnel length = 191 km (D = 1-3.4 m)

- Our study is Ladkrabang distribution pumping station (LK PS) on the TR3 tunnel line.



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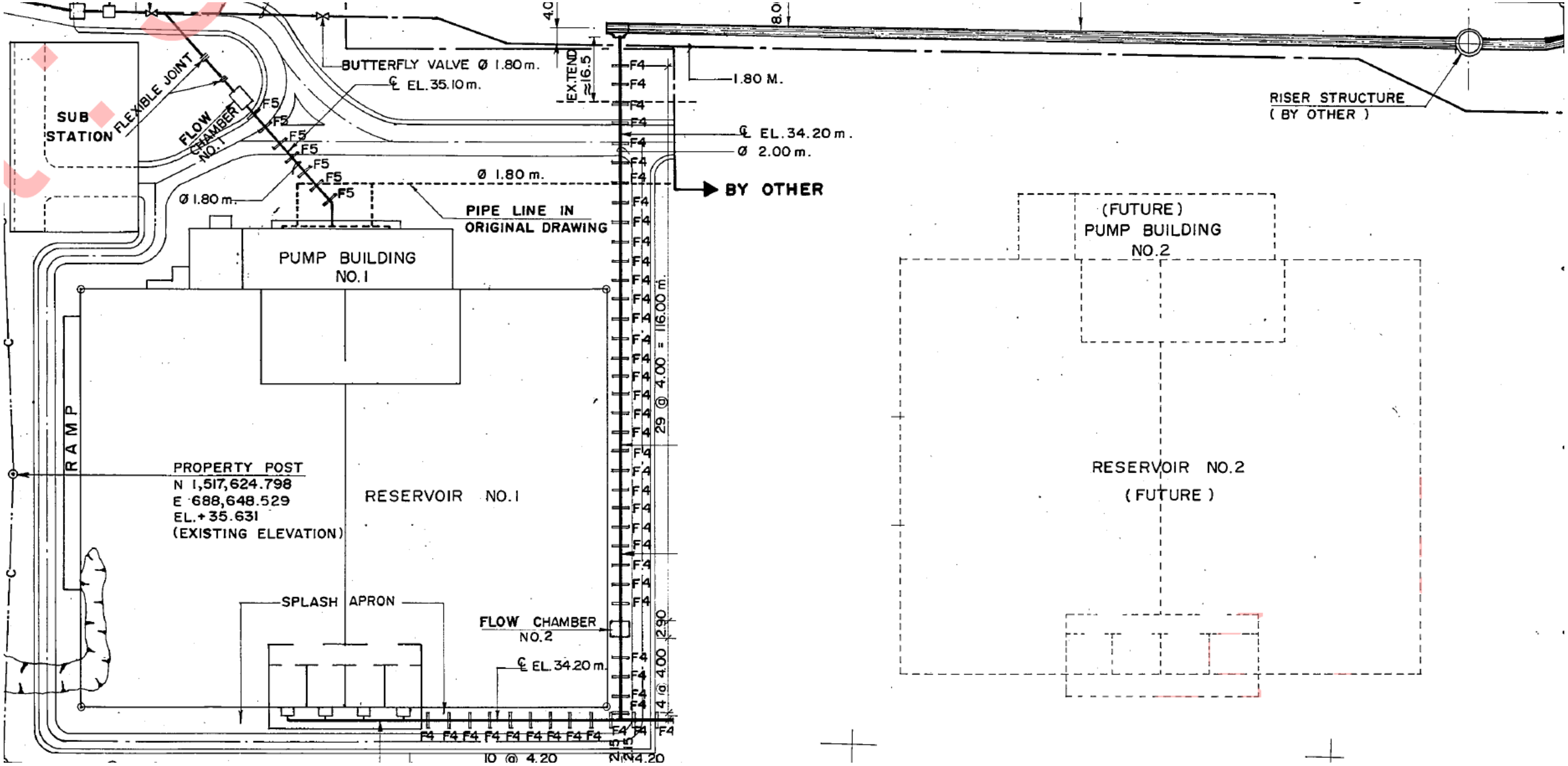
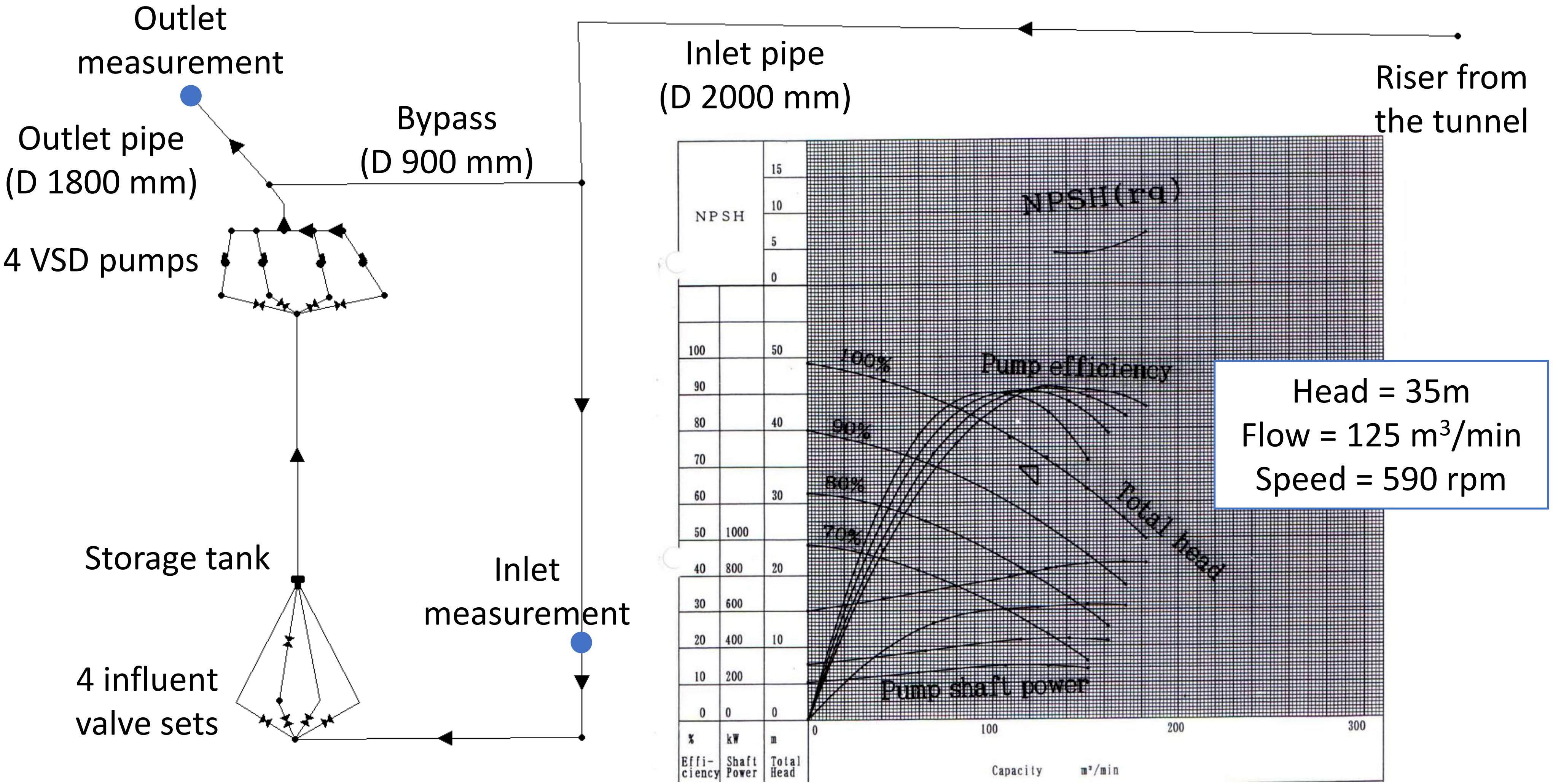
Ladkrabang pumping station (LK PS) As-built drawing



EPANET model (extended period simulation)



Outlet measurement

Outlet pipe (D 1800 mm)

Bypass (D 900 mm)

Inlet pipe (D 2000 mm)

Riser from the tunnel

4 VSD pumps

Storage tank

Inlet measurement

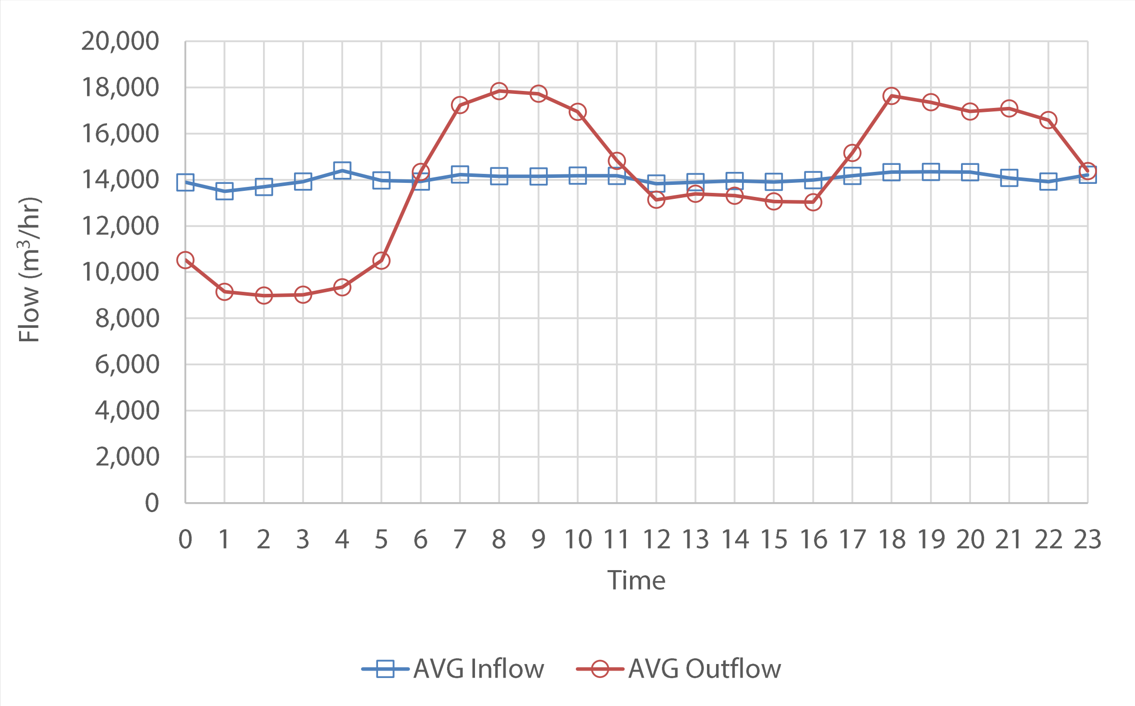
4 influent valve sets

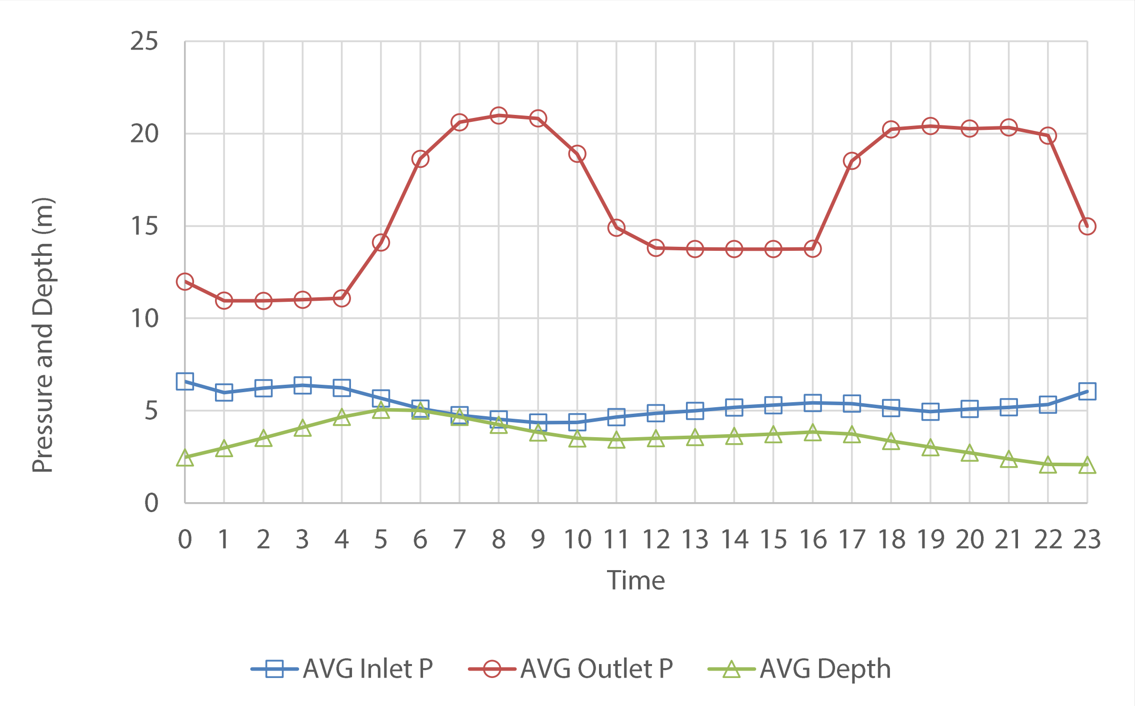
Head = 35m

Flow = 125 m^3/min

Speed = 590 rpm

Average hourly flow and pressure

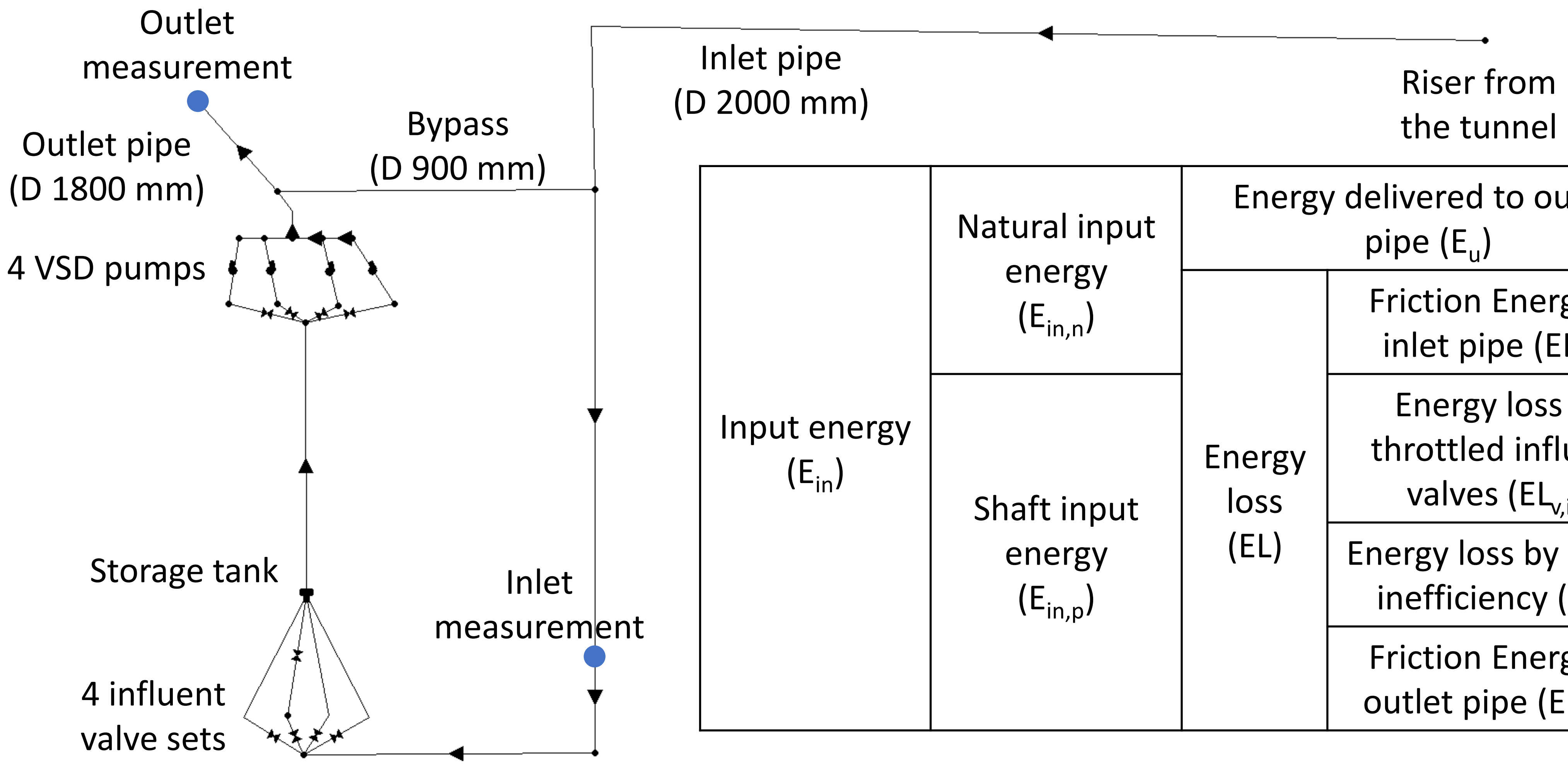




AVG Inflow = AVG Outflow = 14,000 m^3/hr

AVG Inlet P = 5.3 m MSL
AVG Outlet P = 16.2 m MSL
AVG Water Depth in Tank = 3.5 m MSL
Reference = Bottom of Tank = 0 m MSL

Concept of Bottom-Up Approach for Energy Balance



Input energy (E_{in})	Natural input energy ($E_{in,n}$)	Energy delivered to outlet pipe (E_u)	
		Energy loss (EL)	Friction Energy of inlet pipe ($EL_{f,in}$)
	Shaft input energy ($E_{in,p}$)		Energy loss by throttled influent valves ($EL_{v,in}$)
			Energy loss by pump inefficiency (EL_p)
			Friction Energy of outlet pipe ($EL_{f,out}$)

Energy balance calculation

- Natural input energy

$$E_{in,n}(t_p) = \gamma \cdot \sum_{i=1}^{n_N} \left[\sum_{t_k=t_1}^{t_p} Q_{N_i}(t_k) \cdot H_{N_i}(t_k) \right] \cdot \Delta t$$

- Shaft input energy

$$E_P(t_p) = \gamma \cdot \sum_{i=1}^{n_P} \left[\sum_{t_k=t_1}^{t_p} Q_{P_i}(t_k) \cdot H_{P_i}(t_k) / \eta_i(t_k) \right] \cdot \Delta t$$

- Energy delivered to outlet

$$E_U(t_p) = \gamma \cdot \sum_{i=1}^{n_{DM}} \left[\sum_{t_k=t_1}^{t_p} q_{u_i}(t_k) \cdot H_{u_i}(t_k) \right] \cdot \Delta t$$

- Friction Energies of inlet and outlet pipes

$$EL_F(t_p) = \gamma \cdot \sum_{i=1}^{n_p} \left[\sum_{t_k=t_1}^{t_p} q_{p_i}(t_k) \cdot \Delta h_{p_i}(t_k) \right] \cdot \Delta t$$

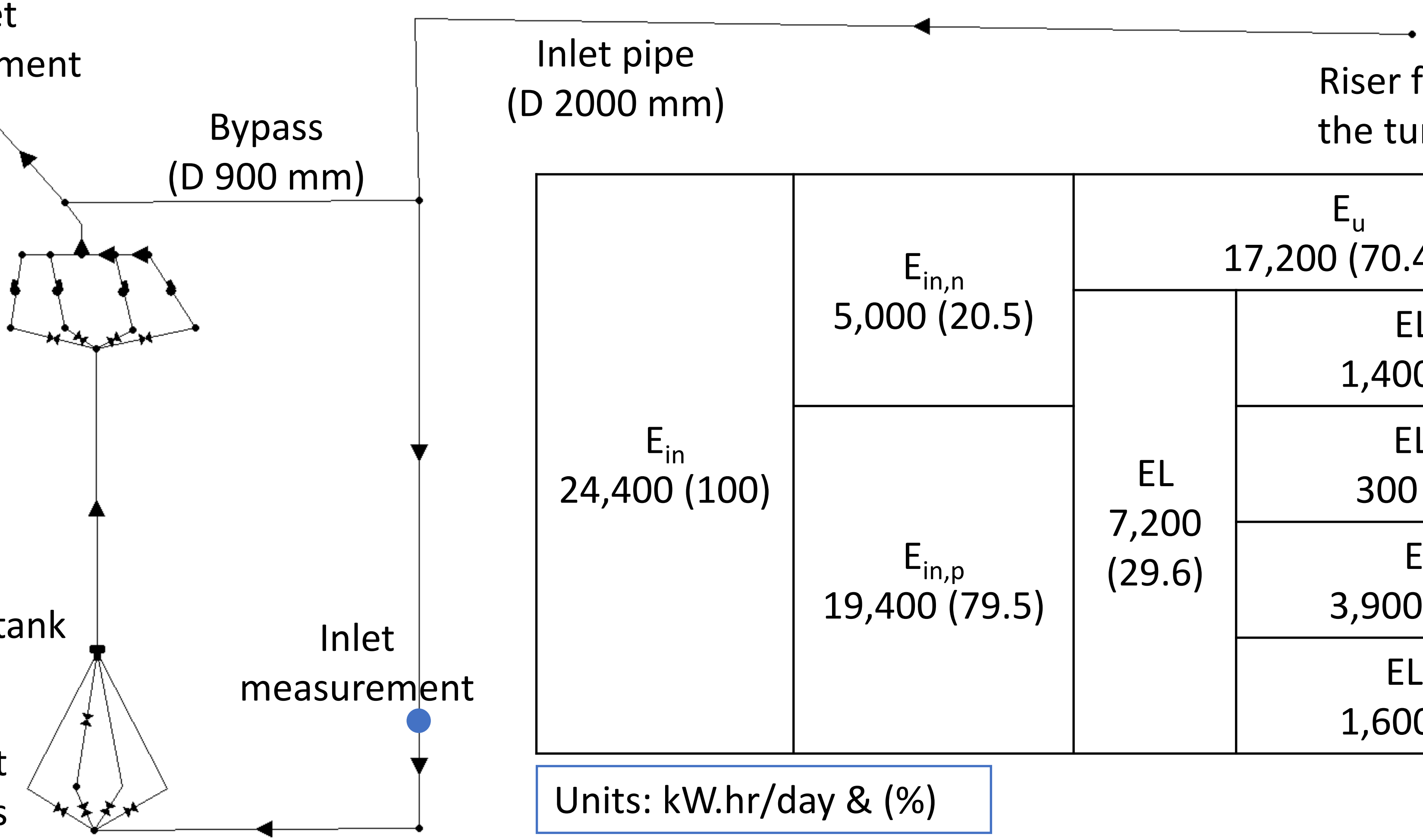
- Energy loss by throttled influent valves

$$EL_V(t_p) = \gamma \cdot \sum_{i=1}^{n_V} \left[\sum_{t_k=t_1}^{t_p} q_{V_i}(t_k) \cdot \Delta h_{V_i}(t_k) \right] \cdot \Delta t$$

- Energy loss by pump inefficiency

$$EL_P(t_p) = E_P(t_p) - \gamma \cdot \sum_{i=1}^{n_P} \left[\sum_{t_k=t_1}^{t_p} Q_{P_i}(t_k) \cdot H_{P_i}(t_k) \right] \cdot \Delta t$$

Energy Balance for April 2018



E_{in} 24,400 (100)	$E_{in,n}$ 5,000 (20.5)	E_u 17,200 (70.4%)	
		EL 7,200 (29.6)	$EL_{f,in}$ 1,400 (5.8)
	$E_{in,p}$ 19,400 (79.5)		$EL_{v,in}$ 300 (1.2)
			EL_p 3,900 (15.9)
			$EL_{f,out}$ 1,600 (6.7)

Units: kW.hr/day & (%)

Discussion

Compute performance indices:

- Percentage of energy loss is EL/E_{in}
    - 7,200/24,400 x 100% = 29.6%
- Energy intensity for water distribution is E_{in}/Q
    - 24,400 kW.hr/day ÷ 344,00 m^3/day = 0.071 kW.hr/m^3
- Normalized energy intensity by pressure head is $E_{in}/Q/P$
    - 0.071 kW.hr/ m^3 ÷ 16.2 m = 0.0044 kW.hr/m^3/m
- Pump efficiency is $1 – EL_p/ E_{in,p}$
    - (1 – 15.9/79.5) x 100% = 80%
- If LK PS is changed into a booster PS without a storage tank, it may save the energy roughly 1,700 kW.hr/day (7.0%) from a shorter inlet pipe, no throttled valves and tank, but the change will sacrifice water supply reliability.

Conclusion

- The bottom-up approach for energy balance by EPANET model can support water companies to evaluate energy loss of each physical process.
- Performance indices can be used to improve the energy use and to compare with other waterworks utilities.

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