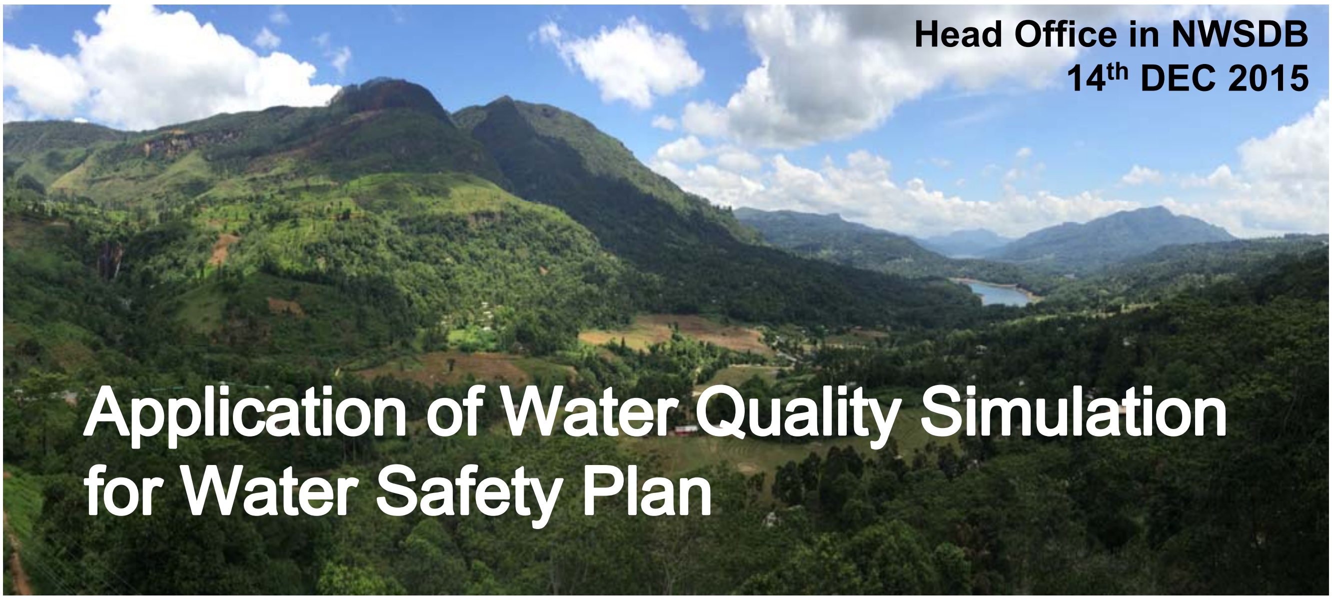

Application of Water Quality Simulation for Water Safety Plan

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Agenda

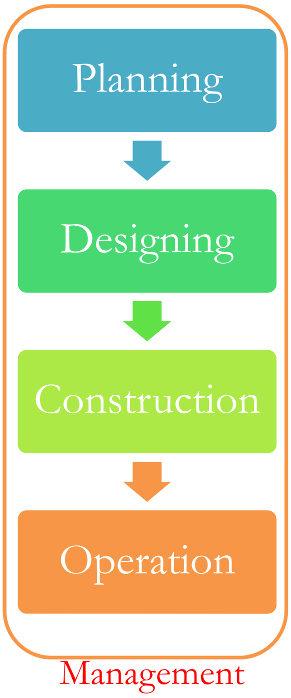
- Introduction
- Background and Objective
  - Significance of Modeling Approach
  - Review of a Water Safety Plan
- Methodology
  - Model Framework and prioritized model
- Results and Discussion
  - Simulation Results for Present Status
  - Evaluation of Countermeasures
- Conclusion and Recommendation

Who We Are?

Nihon Suido Consultants Co., Ltd.
Water and Environmental Consultants

- ✓ Offering total solution for **Water and Water Environment**
- ✓ **No.1 share** in Japan domestic Water Supply Consultancy market
- ✓ Business experiences in over 50 countries

Our Business Field



- ✓ Project Appraisal and evaluation
- ✓ Master Plan
- ✓ Feasibility Study
- ✓ Preliminary & Detailed Design
- ✓ Construction Supervision
- ✓ Training for Plant Operation & Maintenance
- ✓ Training for Technology Transfer
- ✓ Review of Existing Management Organization and Practices
- ✓ Environmental Impact Assessment
- ✓ Water Quality Analysis & Assessment
- ✓ Pollution Control Programs
- ✓ Leakage & NRW control Programs
- ✓ Data Mapping & GIS
- ✓ Asset Management

Research Framework

- Collaborative research between NSC and University of Peradeniya for Water and Environment

EWBSL | Nihon Suido Consultants Co., Ltd. Water and Environmental Consultants | InRC (International Research Center) University of Peradeniya

- Joint Workshop

- MoU formulation

Background

- Emerging Water Environment Issues in Sri Lanka
  - Eutrophication, Agrochemicals
  - Water-related Diseases
  - Incidents by Wastewater Pollutions
  - Leachate from Waste Disposal Site

Meda-Ela Confluent, Kandy

- Countermeasures to secure Safe Drinking Water
  - Water Safety Plan
    - Unknown likelihood and Significance of Risks
    - Need stakeholders involvement to control

Background and Objective

- Modeling and Simulation Approach

Merits	Problems
- Prospective Approach: Give scientific verification to policies, Evaluate Countermeasures **- Accountability:** Show visually to explain to the public	- **Input / Verification data are not always available** - Ad-hoc, Not replicable by practitioners

- Objectives
  - Review water resources problems from actual water safety plan
  - To establish the simulation model to evaluate the risks at water safety **under limited resource conditions**

Study Area: Mahaweli River Basin near Kandy

Greater Kandy WTP:
72,000 m3/day
(Phase II, by 2014)
Population Served:
400,000

WSP:
formulated on July 2014

Research Flow

- Review of WSP
- Identification of Risk Incidents
- Determination of Model
- Data Collection
- Modeling
- Output Results

- Communication with corresponding authorities

- Literature Review
- Site Inspection
- Preliminary Data Collection

- Data gathering

Review of Greater Kandy Water Safety Plan (1)

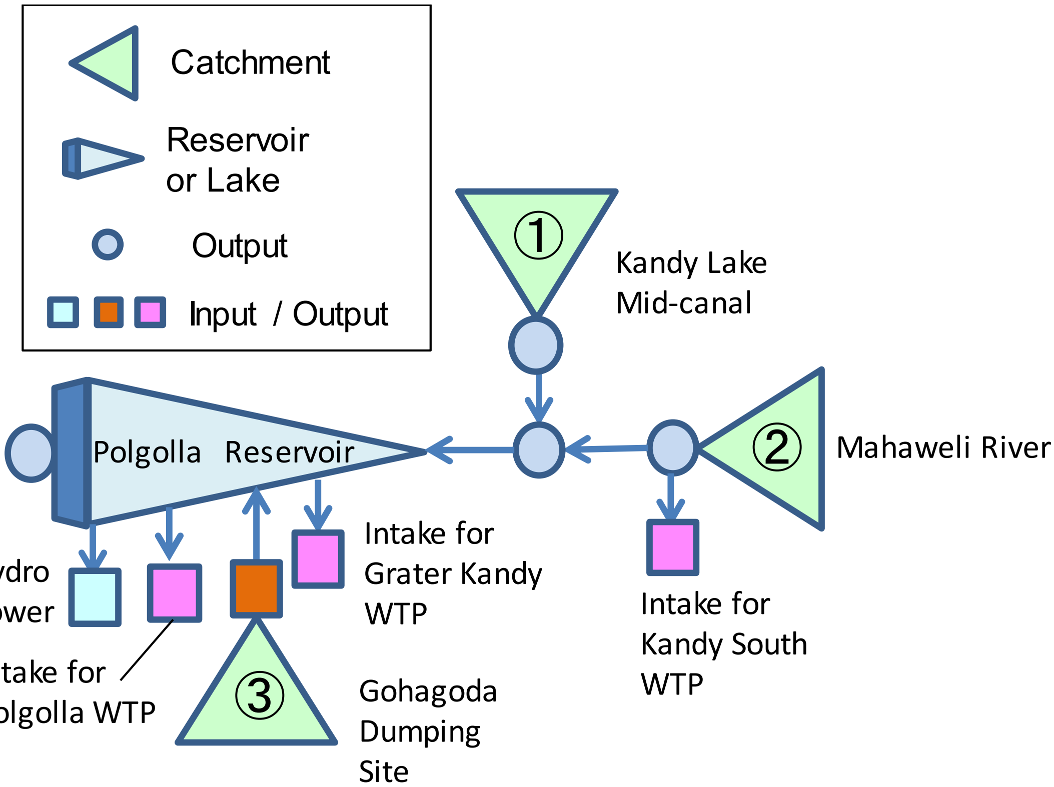
- "Very High" Risk Incidents focused at Source

Location / Process step	Hazardous event	Hazard type
Source	Pathogenic contamination from septic tanks and waste from Kandy city through Middle canal (Meda-Ela)	Physical/Chemical/microbiological
Source	**Leachate from Kandy city garbage dumping site entering intake**	**Physical/Chemical/microbiological**
Source	Pollution by agrochemicals during spraying season	Chemical
Distribution chamber	Power failure at WTP	Chemical & Microbial
Service reservoirs	Unauthorized personnel entering premises	Chemical & Microbial
Pipe network	Contamination of treated water	Microbial

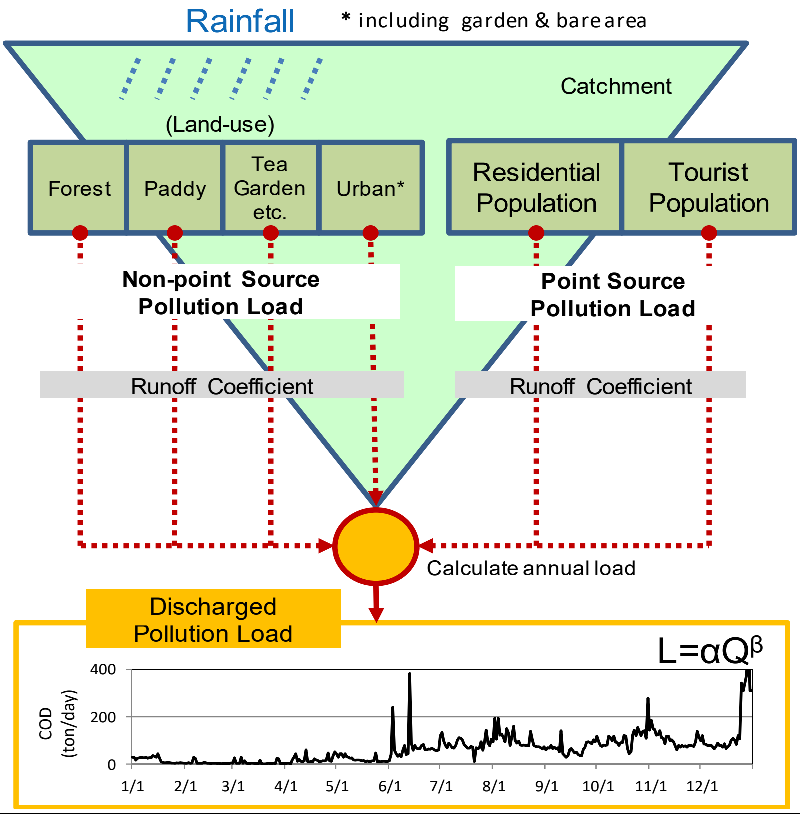
Review of Greater Kandy Water Safety Plan (2)

- Hazard identified at source (catchment)
  - WTP is near to Solid Waste Dumping Site at Gohagoda
  - There is some possibility for contamination from back flow of the Mahaweli River
  - **Major concern but difficult to evaluate its significance**

Methods(1) : **Overall Model Framework**

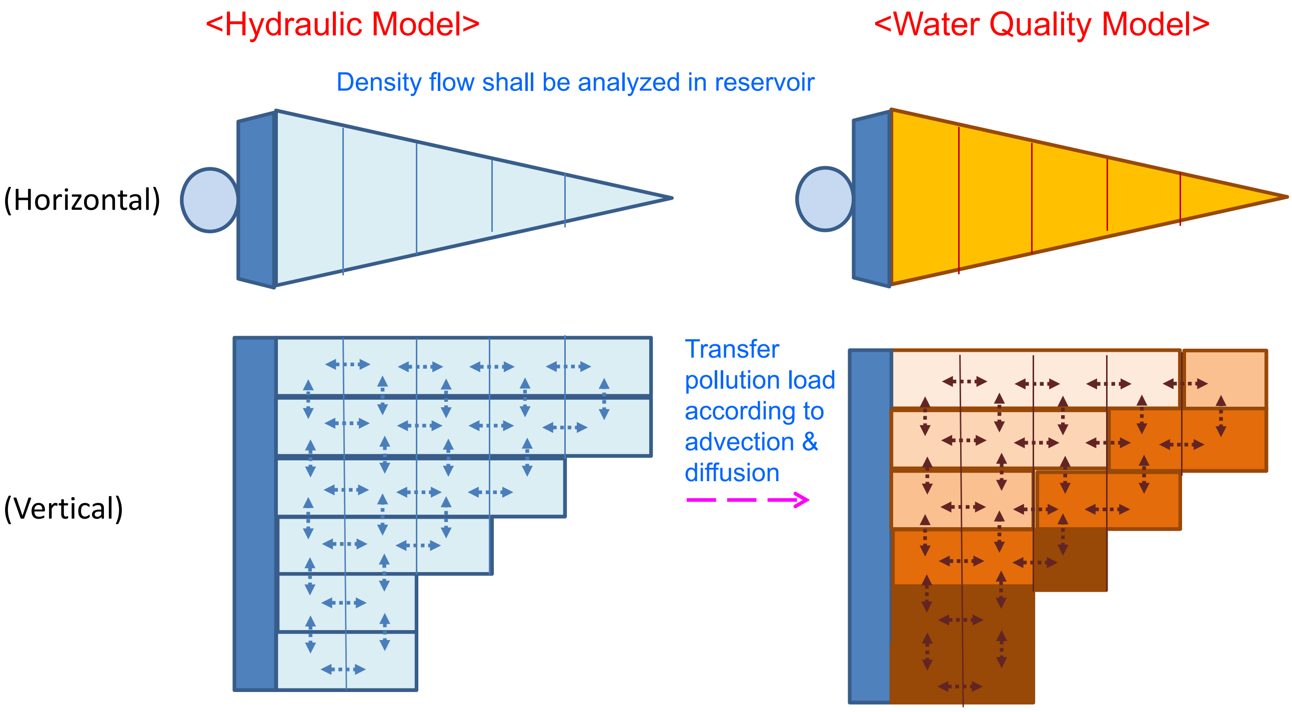


Methods(2) : **Catchment Model**



Methods(3) : **Reservoir Model**

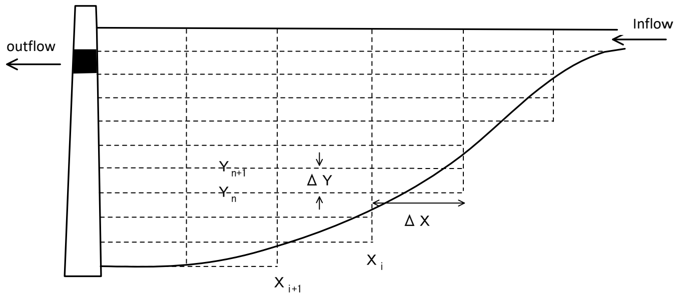
Vertical two dimensional Model



Methods(4) : **Detail of Reservoir Model**

Hydraulic Model

- Flow velocity in flow and vertical direction
- Water level (water volume)
- Density



Equation for Continuity

$$\frac{\partial \bar{u}}{\partial x}+\frac{\partial \bar{v}}{\partial y}=0$$

Equation for Conservation of Momentum

$$\frac{\partial \bar{u}}{\partial t}+\frac{\partial}{\partial x}\left(\overline{uu}\right)+\frac{\partial}{\partial y}\left(\overline{uv}\right)=-\frac{\partial}{\partial x}\left(\frac{P}{\rho}\right)+\frac{\partial}{\partial x}\left(A_x\frac{\partial \bar{u}}{\partial x}\right)+\frac{\partial}{\partial y}\left(A_y\frac{\partial \bar{u}}{\partial y}\right)$$

$$\frac{\partial P}{\partial y}=-\rho g$$ (Assumption of hydrostatic pressure distribution)

Methods(5) : **Detail of Reservoir Model**

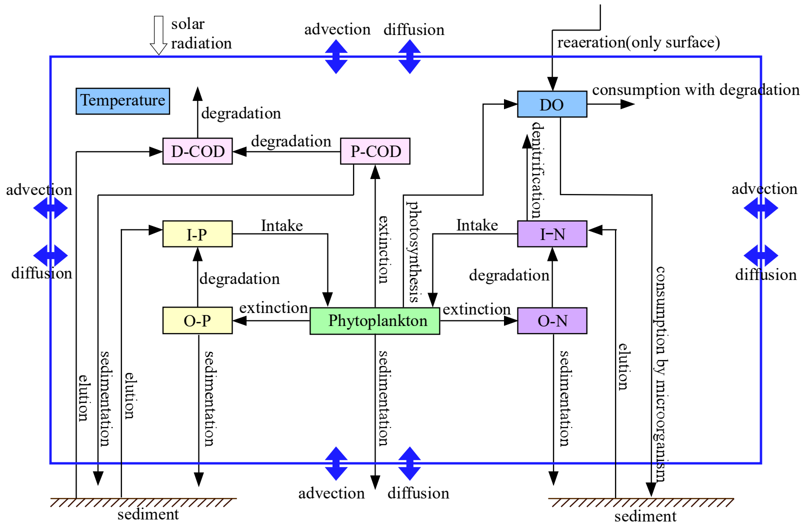
Water Quality Model

Equation for Temperature Balance

$$\frac{\partial T}{\partial t}+\bar{u}\frac{\partial T}{\partial x}+\bar{v}\frac{\partial T}{\partial y}=\frac{\partial}{\partial x}\left(K_x\frac{\partial T}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial T}{\partial y}\right)+\frac{H}{\rho C_w}$$

Equation for Ecological Model

$$\frac{\partial C}{\partial t}+\bar{u}\frac{\partial C}{\partial x}+\bar{v}\frac{\partial C}{\partial y}=\frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right)+\frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right)+S$$



Methods (5): **Scoping Target Water Quality Indicators**

- Background Water Quality [1)]
  - Cd (3.9-21.5 μg/L)
- Heavy Metals in Leachate [2)]
  - Cr, Fe, Ni, As, Cd, Se, **Pb**
- Other Substances in Leachate [3)]
  - Mn, PO_4^{3-}

1) Bandara et al., 2010
2) Sewanndi et al, 2012
3) Dharmarathne and Gunatilake, 2013

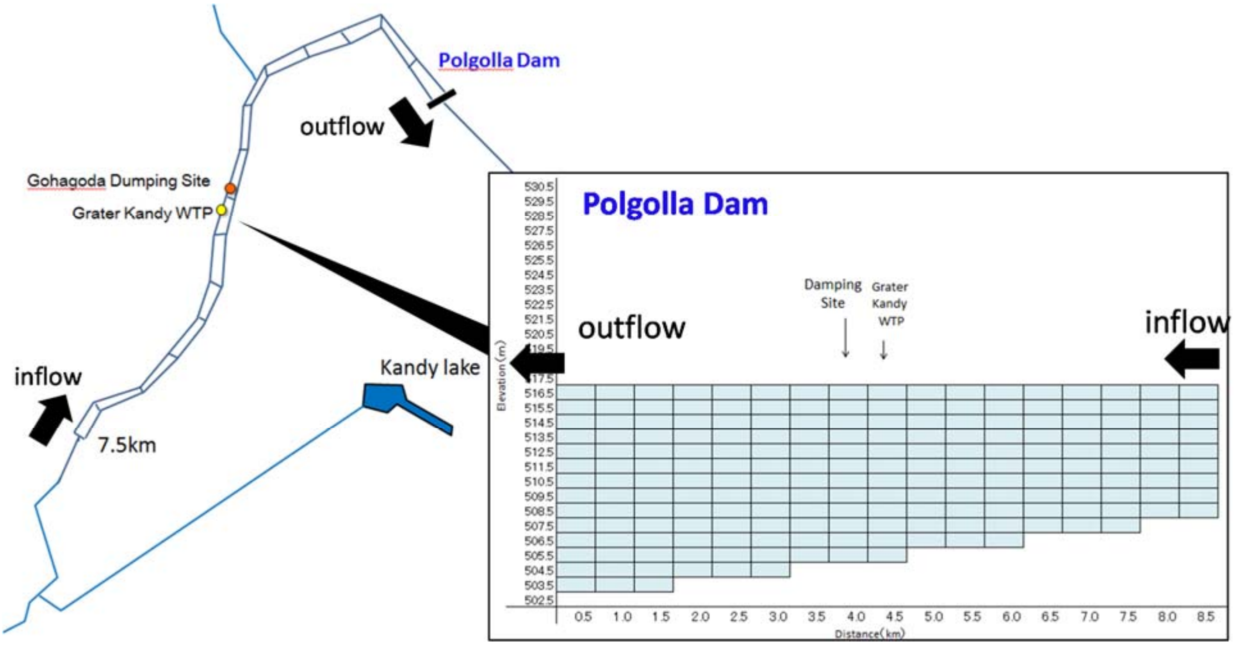
⇒ Pb in leachate is higher than other substances.

Pb was selected as model indicator for simulation in this study.

Required Input Data for Boundary Conditions

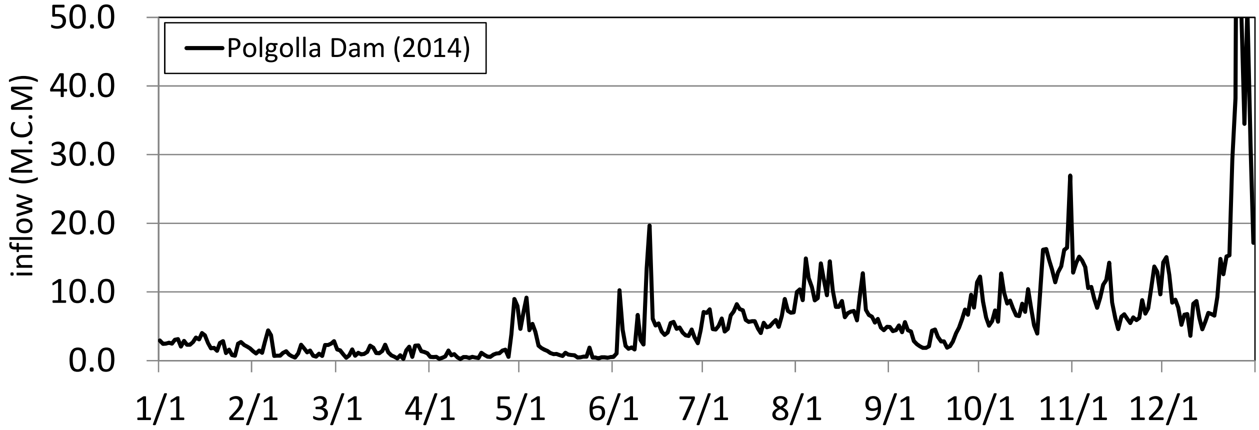
Items	This Study	Source
Catchment Framework	✔	
River Profile	✔	Provided by Uni.
Hydrology (Precipitation / Flow Volume)	✔	Provided by Uni.
Water Quality	✔	Literature
Meteorology	✔	Literature
Dimension of Dam	✔	
Operation Rule of Dam / Barrage		

Topographical Condition (River Profile)



Polgolla Reservoir with total length of 7.5 km was divided into meshes at intervals of 0.5 km in flow direction and 1.0 m in vertical direction

Hydrological Condition



Inflow condition for Polgolla Reservoir was set according to the actual record of inflow volume in year 2014.

Hydrological condition in 2014 corresponds to dry year in recent 7 years.

Meteorological Condition

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temp(℃)	23.4	24.2	25.5	26.1	25.7	25.0	24.7	24.7	24.7	24.6	24.4	23.7
solar radiation (W/m2)	371	386	406	416	408	393	387	396	409	412	398	378
relative humidity(%)	83.8	79.0	76.5	82.5	83.5	83.4	82.0	81.0	81.2	85.2	87.8	86.8
wind speed(m/s)	0.8	0.6	0.3	0.2	0.8	1.0	1.0	1.0	1.0	0.5	0.8	0.8
cloud amount(-)	0.48	0.42	0.47	0.58	0.71	0.72	0.74	0.73	0.77	0.72	0.66	0.58

Meteorological Condition is required to calculate water temperature for sunshine and heat balance in water surface in reservoir

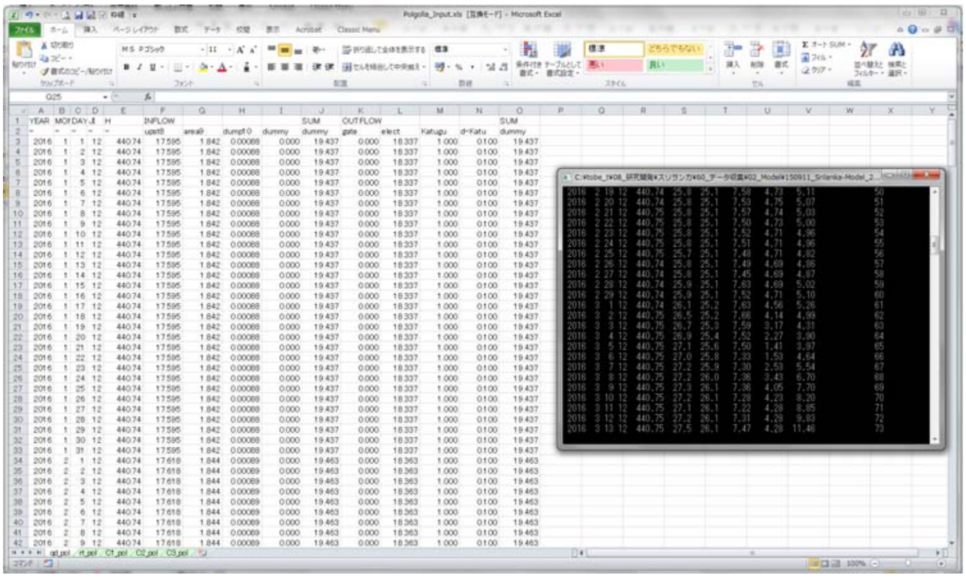
Water Quality Condition

	①Inflow from Kandy Lake	②Inflow from Mahaweli River	③Leachate from Gohagoda Damping Site
Catchment Area (km^2)	255	1063	0.06
Discharge Volume (m^3/s)	13.1	54.6	0.006
COD (mg/L)	22.4	8.0	700
T-N (mg/L)	5.9	1.9	700
T-P (mg/L)	1.1	0.4	8.0
Pb (mg/L)	0.005	0.005	12.9
Zn (mg/L)	0.145	0.145	700

Water quality condition was set according to discharged water quality calculated through the catchment model.

Concentration of Pb was set according to the observed data.

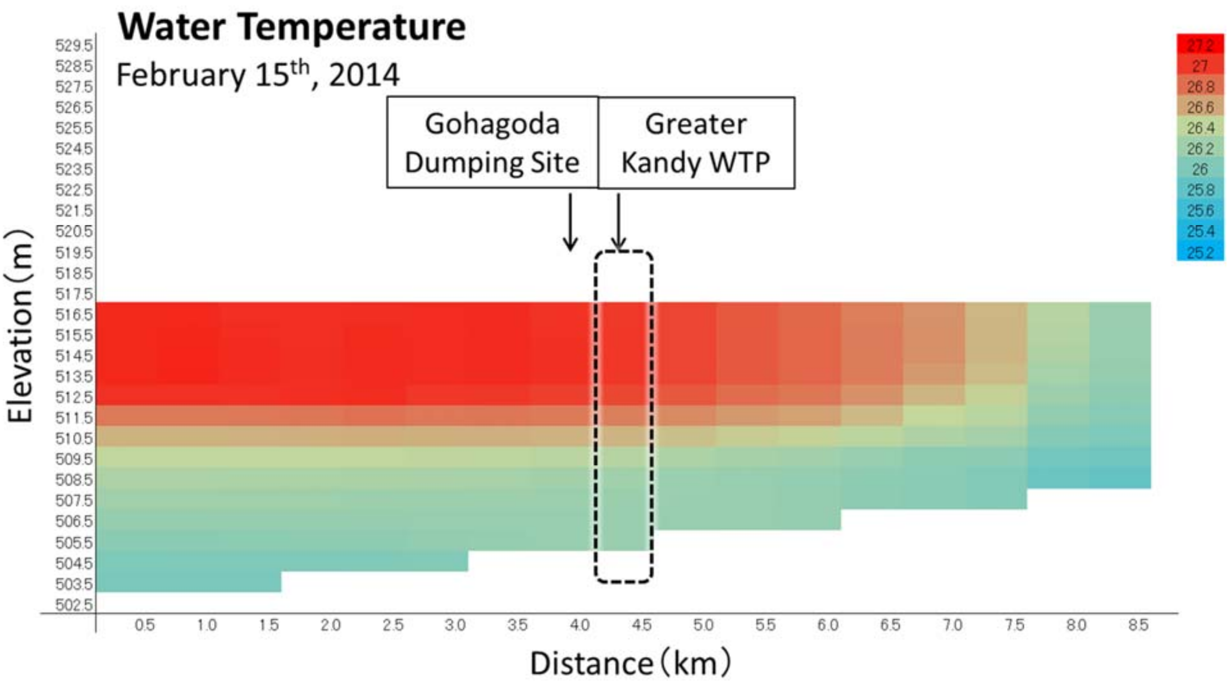
Interface of Simulation Model



The Simulation Model can configure input and output data on Microsoft Excel interface.

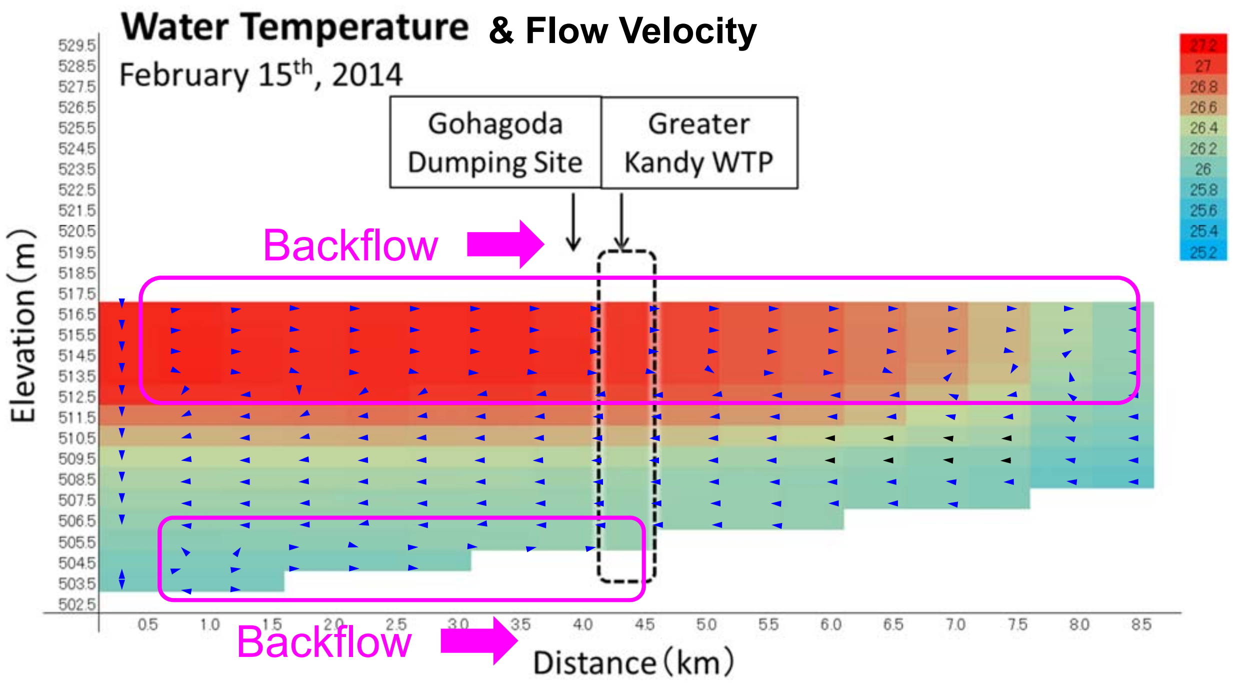
Users can easy to handle the simulation model (e.g. change of input data and evaluation of simulation results).

Results(1): **Simulation Results for Reservoir**



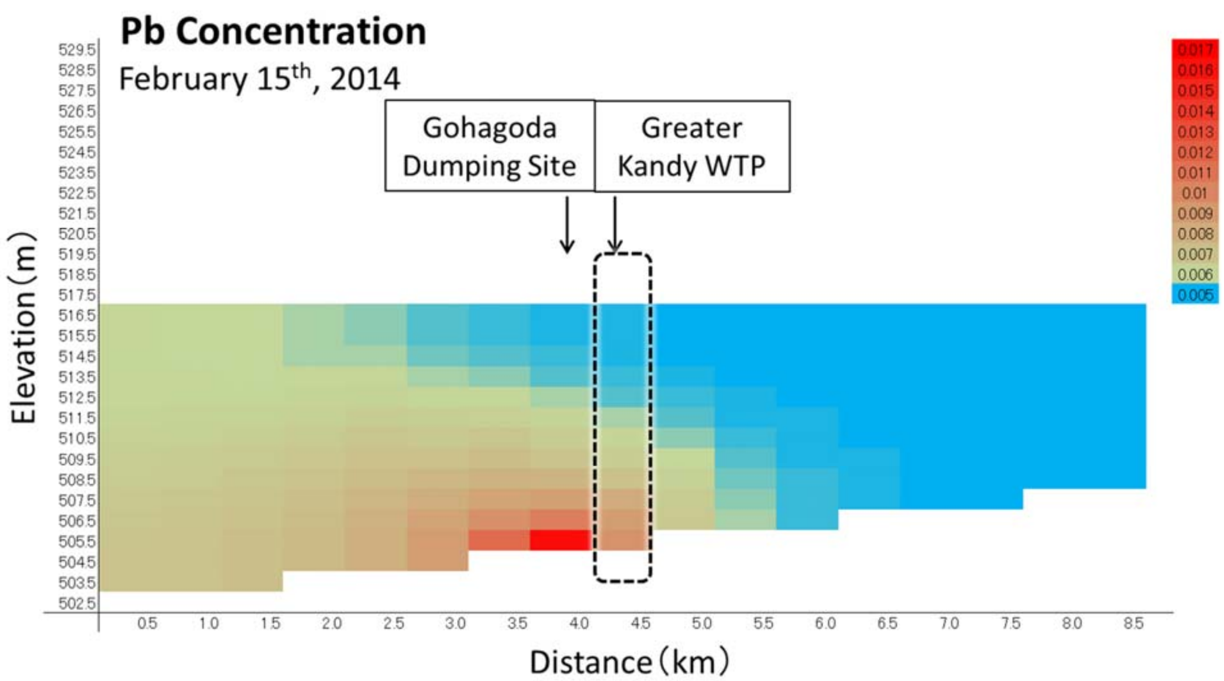
- **Water temperature;** between surface and bottom layer is different due to sunshine and low flow volume especially in dry season.

Results(2): **Simulation Results for Reservoir**



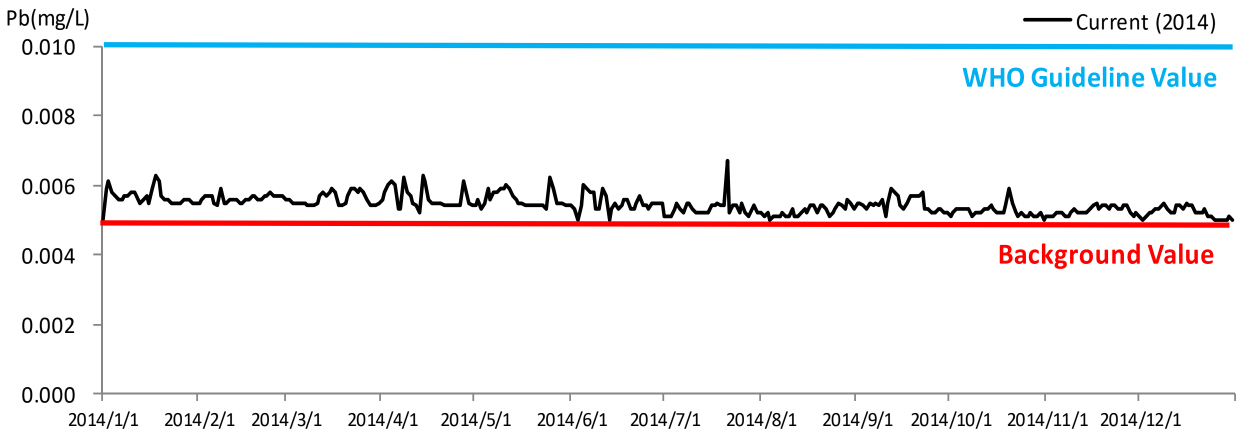
- **Flow Velocity:** Difference in temperature makes density flow (Fair current in middle layer and backflow in surface and bottom layer).

Results(3): **Simulation Results for Intake Water Quality**



- **Backflow:** Substances in Leachate could flow back to upstream by approx. 2 km due to density flow.

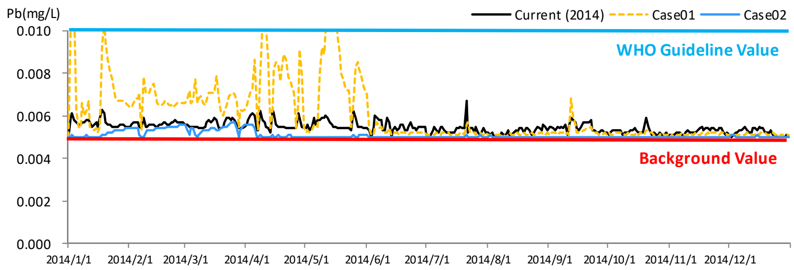
Results(4): **Simulation Results for Intake Water Quality**

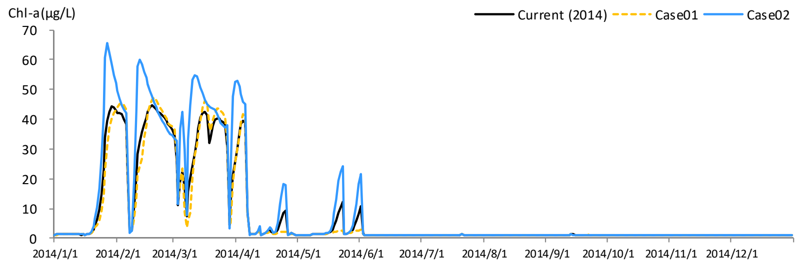


- **Seasonal variation:** variation exists but not significant

Results(5): **Control Measure Identification**

Case	Control Measure
Case 01	**Installation of fence** in bottom layer
Case 02	Raw water **Intake from surface layer**





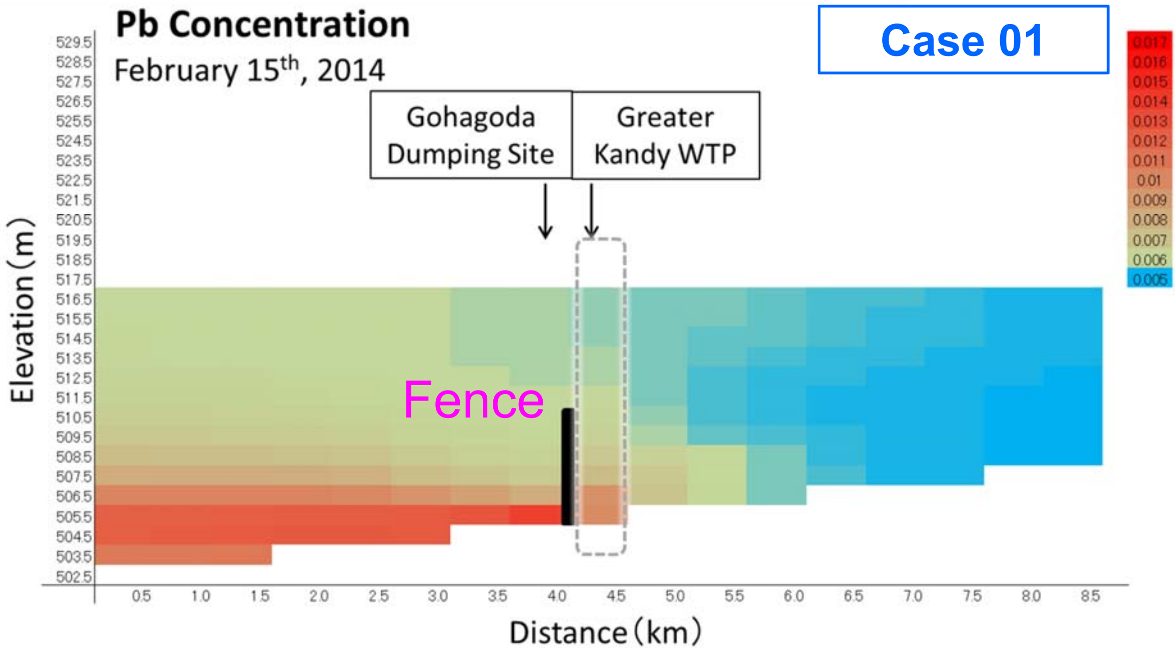
Case 01:

Pb increased due to retention at bottom layer.

Case 02:

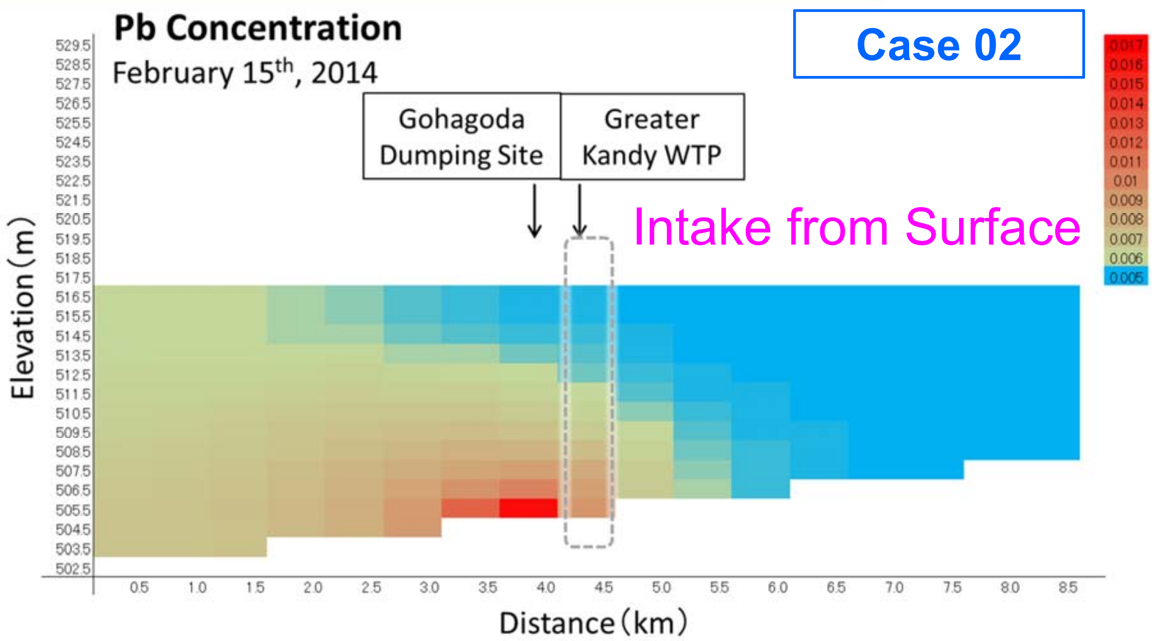
Pb decreased, while Chl-a increase especially in dry season due to growth of phytoplankton.

Results(6): **Control Measure Identification**



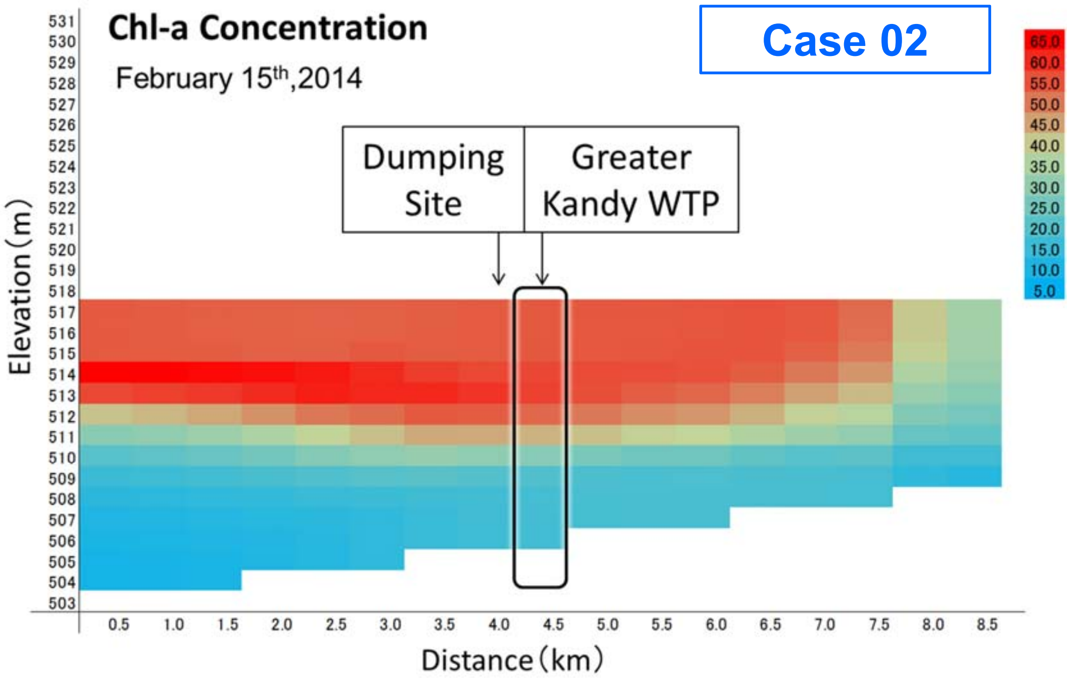
As for Case 01, due to installation of fence, contaminated substances stay longer in bottom layer at intake and intake water quality of Pb increase.

Results(7): **Control Measure Identification**



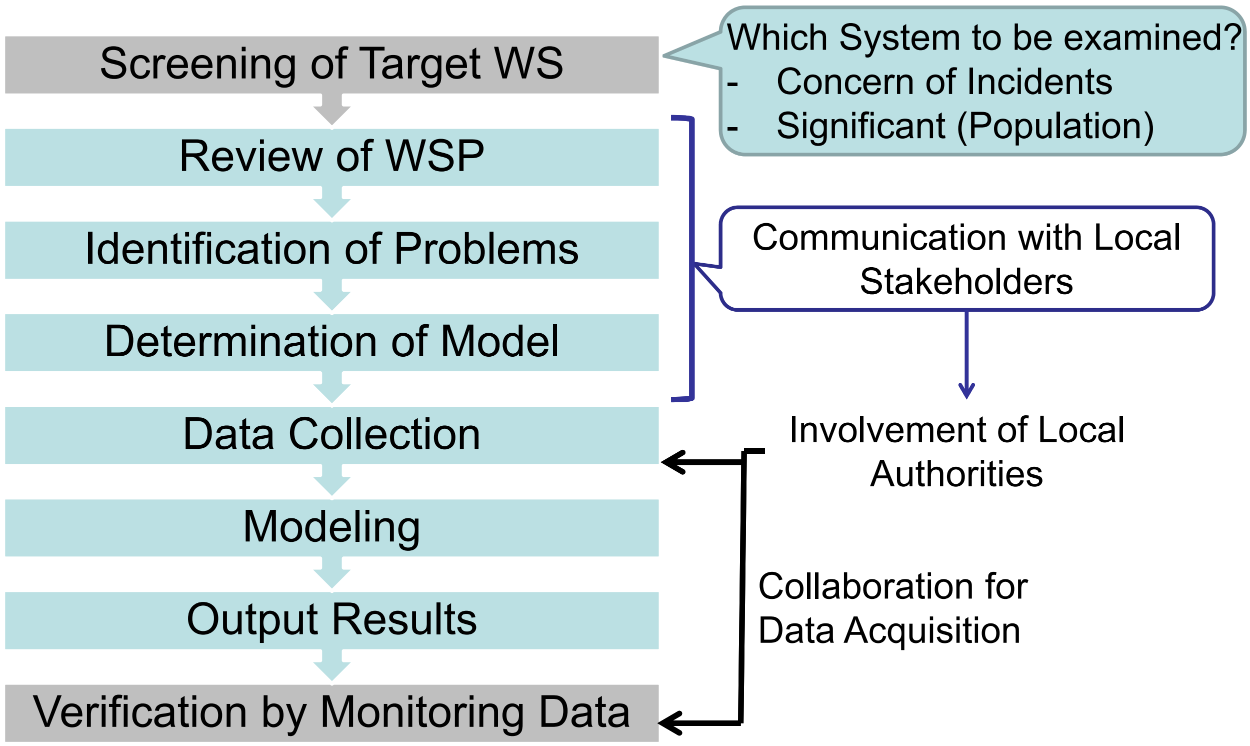
As for Case 02, intake water quality of Pb decrease by intake from surface.

Results(8): **Control Measure Identification**



As for Case 02, intake of Chl-a increase especially in dry season due to growth of phytoplankton in surface.

Discussion: **Model Flow of Simulation Application to WSP**



Conclusion (1)

- Water Safety Plan of Greater Kandy WTP indicated water source issues are identified as “Very High” risk because of **unavailability of observed data**.
- Water Quality Simulation model for Pollgolla Reservoir implied that;
  - Leachate contamination may flow back by 2km due to density flow*.
  - As countermeasure, fences at Intake (Case 01) may have adverse impact on water quality and Intake at surface (Case 02) is effective
    while Chl-a (phytoplankton) concern remains.

* Modeled substance (Pb) is below WHO guideline value

Conclusion (2)

- In this research, we could not reach quantitative re-risk assessment utilizing the results because the concentration of modelled substances (Pb) did not go beyond the WHO guideline level.
- More research is needed for identifying the possible harmful substances such as agro-chemicals, carcinogenic substances and other unknown substances.
- Application of water quality simulation model for water safety is effective to manage raw water quality and figure out likelihood and significance of risks for incidents.

Recommendations

- **Utilize simulation approach for public communication and policy making**
  - **Visualization** for communicating with stakeholders
  - Acceleration for Proactive Measures
- **Establish replicable simulation models/workflows considering limited resources**
  - **Data Availability** is the Key Factor
  - Improvement of usability is necessary
- **Monitoring**
  - Data Collection and Communication among institutions
  - Find Feasible, Expandable and Continuous methods