Environmental Hydrodynamics in Lakes and Reservoirs

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Introduction

For the group of Water Quality, Tuni Reservoir = one of Main Research Objects

Tuni Reservoir

Basin of Tuni Reservoir

Today’s Presentation:
Basic Methods from our previous studies in Lakes and Reservoirs.
Measurements in Miharu Reservoir

General Information

- **Catchment:** 226.4 km²
- **Capacity:** $4.2 \times 10^6$ m³
- **Purpose:** Flood control, Water supply, Industrial water, Irrigation, Power generation

Eutrophication Problems

- Water Bloom, every summer (cyanobacteria)
Field Measurements in a Reservoir

Plan view of Miharu

What we measure:

a) Stratification
   Thermal stratification, Vertical distribution of WQ

b) Temporal change of WQ
   Water temperature, DO, Chlorophyll-a, etc.

c) Deposition flux
   Including Sediment, Detritus, etc.
Field Measurements in a Reservoir

How we measure:

a) Stratification
   (Vertical distribution)
   Hanging and sinking sensors from a boat.

b) Temporal change of WQ
   Deploying self-recording devices on ropes with floats

c) Deposition flux
   Using sediment traps deployed
Examples of Results - In Miharu Reservoir-

a) Stratification (Vertical distribution)

- Water temp.
- Turbidity
- Chlorophyll-a
- DO

- Aug. 5, 2008
- Aug. 14, 2008
- Sep. 5, 2008
b) Temporal change of WQ
(Measurement by the Dam Office, MLIT)

History of vertical distributions

Water Temp.

DO

Turbidity

Hydraulic Numerical Modeling

Solvers are selected depending on requirements:

**Spatial Resolution**
- 1-dimensional (vertical)
- 2-dimensional (vertical)
- 3-dimensional

Simple, but sometimes gives more realistic solution than higher dimension analysis.

**Variables**
- Water temperature
- Turbidity
- Salinity
- Chlorophyll-a (phytoplankton)
- Nutrients (Phosphorus, Nitrogen)
- Dissolved Oxygen

Related to density structure.

Related to eutrophication.
Example of Computation

Vertical 1-D Modeling in a coastal lagoon

Conceptual diagram of Vertical 1-D Model

Lake Jusan:
- Facing the Japan Sea
- Very shallow lagoon: Mean depth = 1m
- Famous for product of shelfish
Results: Validation of Time Series

Vertical 1-D computation

- **Discharge** [m³/s]
- **Salinity 1** [psu]
- **Salinity 2** [psu]
- **DO** [mg/l]

Blue line: Measurement
Red line: Computation
Results: History of Vertical Structure

Vertical 1-D computation

Elevation [m]

Salinity

Elevation [m]

DO

Jun. 9  Jul. 7  Aug. 5  Sep. 1  Oct. 6

Freshwater (white)

Saline water (blue)

High DO (white)

Low DO (Red)
Numerical Modeling

Solvers are selected depending on requirements:

**Spatial Resolution**
- 1-dimensional (vertical)
- 2-dimensional (vertical)
- 3-dimensional

Most often used in practical works

**Variables**
- Water temperature
- Turbidity
- Salinity
- Chlorophyll-a (phytoplankton)
- Nutrients (Phosphorus, Nitrogen)
- Dissolved Oxygen

related to density structure.

related to eutrophication.
Method of 2-D analysis

The most typical modeling for reservoirs.

**Vertical 2-D Reservoir Hydrodynamic Model**

Governing Equations
- Momentum Eq.
- Continuity Eqs
- Transport Eqs of scalars
- $K$-$\varepsilon$ turbulence model Eqs

\[
\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} = -\frac{1}{\rho} \frac{\partial p}{\partial x} + \frac{1}{B} \left[ \frac{\partial}{\partial x} \left( v_L B \frac{\partial u}{\partial x} \right) \frac{\partial}{\partial z} \left( v_{eff} B \frac{\partial u}{\partial z} \right) \right]
\]

\[
\frac{\partial}{\partial x} (uB) + \frac{\partial}{\partial z} (wB) = 0 , \text{ etc.}
\]

Including the bathymetry effect of breadth $B$. 
Longitudinal & Vertical Distribution of Suspended Sediment

From an Investigation of High Turbidity Problem Caused by Flood Water Intrusion
Water Quality in Miharu Reservoir

**Chlorophyll – a**

- (µg/l)

**Inorganic Phosphorus**

- (mg/l)

**Inorganic Nitrogen**

- (mg/l)

*Lines: Computation, Dots: Measurement*

- May July Sep.
- 2008
Summary

- Basic research methods for environmental hydraulics in lakes and reservoirs were presented.
- Field measurements in Miharu Reservoir was shown as a typical example.
- Water quality numerical modeling in a coastal lagoon (case of 1-D) and a reservoir (2-D) were demonstrated.