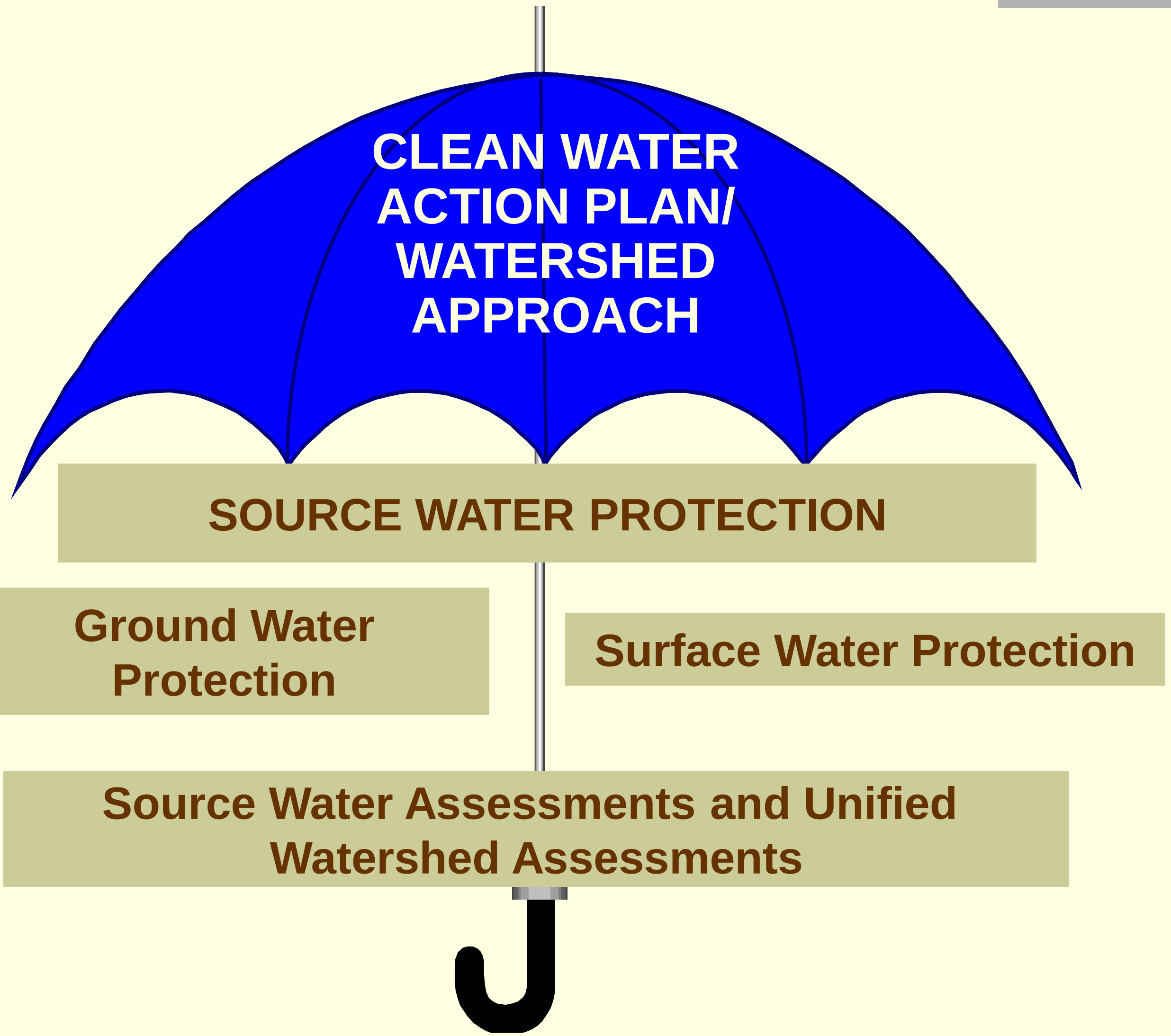
3. Source Water Protection

1996 reauthorization of the federal Safe Drinking Water Act (SDWA)

Source Water Protection under the Clean Water Act

- “Point” sources or “non-point” sources
- National Pollutant Discharge Elimination System (NPDES)
- Water quality standards
- Total Maximum Daily Loads (TMDLs)

Source Water Protection and Watershed-Based Water Quality Management



What Does Surface Water Contamination Look Like?

Source Water Protection Program in Hawaii

Surface Source

Groundwater Source

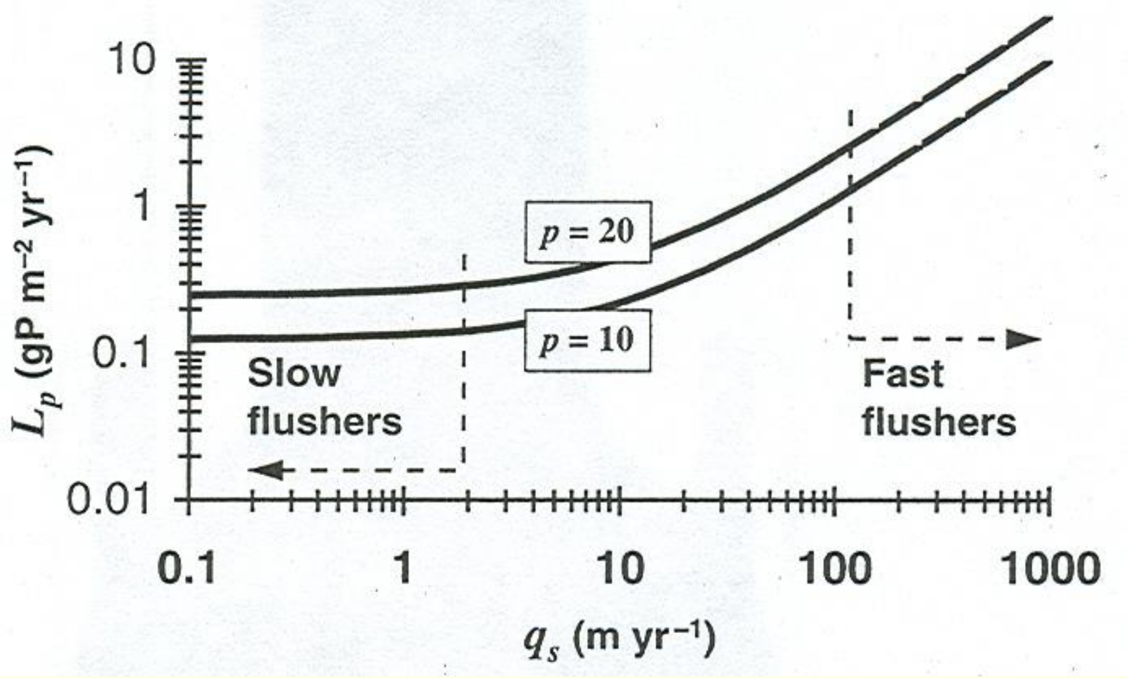
Benefits of Source Water Protection

- Cost savings by complying with standards
- Monitoring waivers
- Water as a commodity or raw material -- quality matters

4. Principles of Reservoir Restoration

Phosphorus and reservoir eutrophication

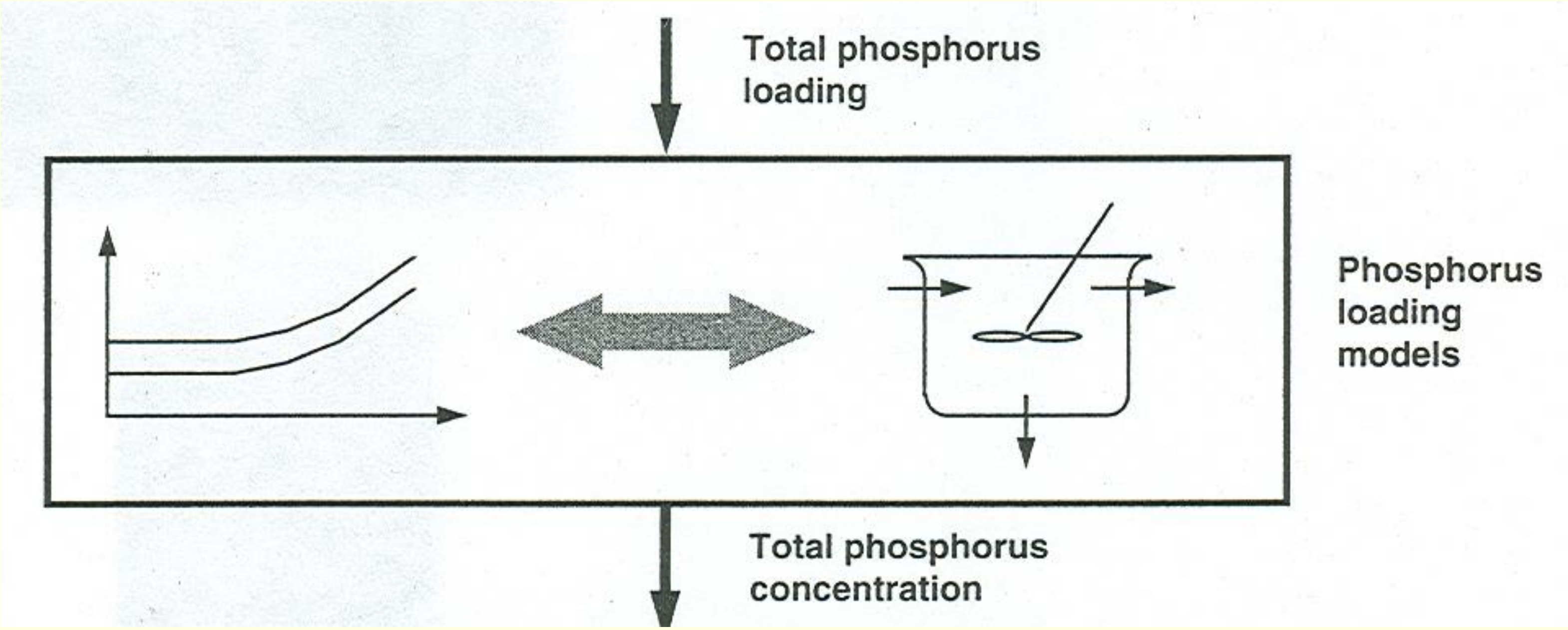
Variable	Oligotrophic	Mesotrophic	Eutrophic
Total phosphorus (μgP L^{-1})	< 10	10–20	> 20
Chlorophyll *a* (μgChl*a* L^{-1})	< 4	4–10	> 10
Secchi-disk depth (m)	> 4	2–4	< 2
Hypolimnion oxygen (% saturation)	> 80	10–80	< 10



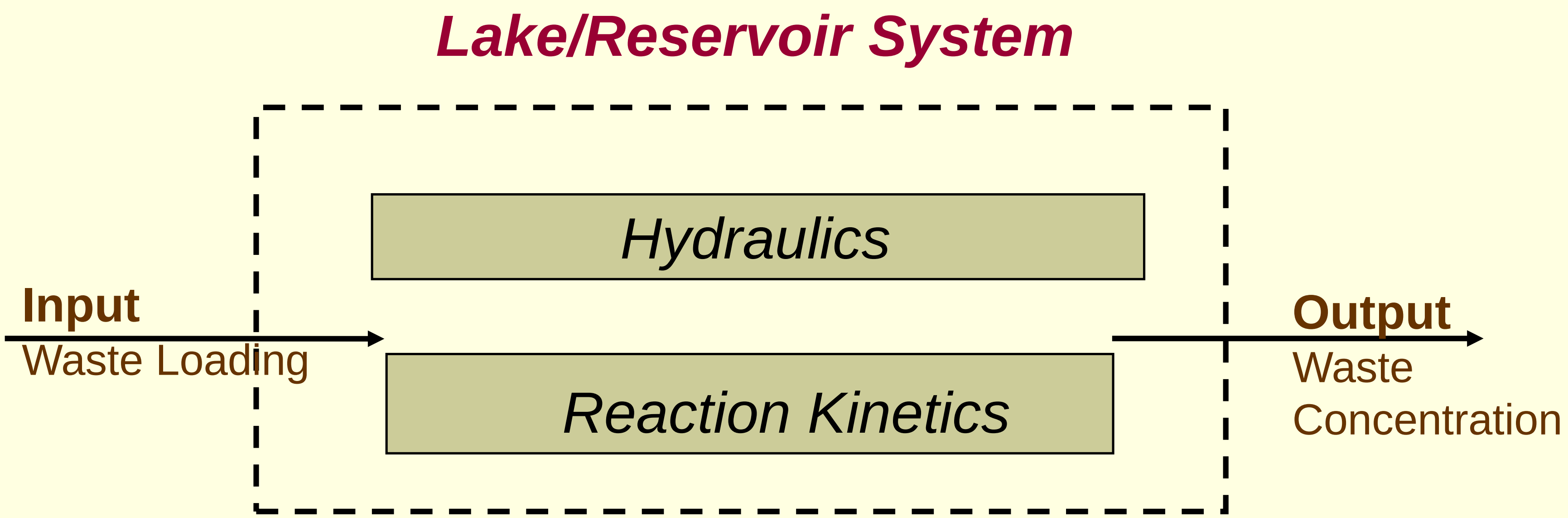
Loading

Overflow rate

Reservoir System Response to Phosphorus Loading



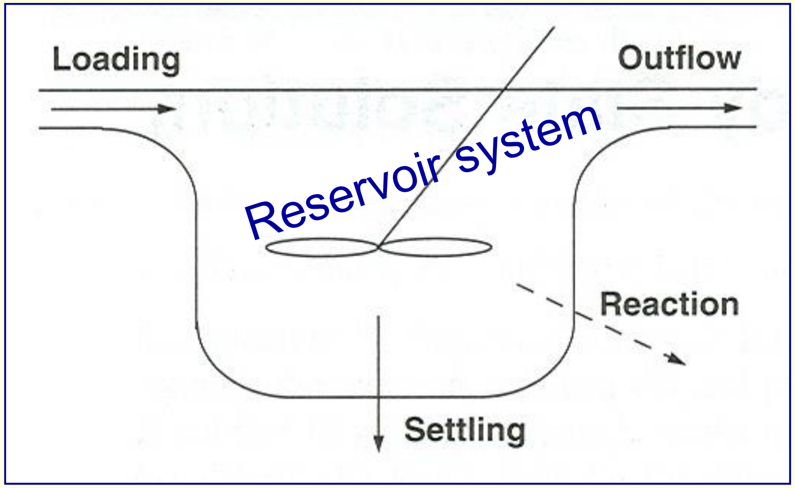
Reservoir System Response to Phosphorus Loading



Modeling Analysis

CSTR Model of Phosphorus Concentration in a reservoir

$$V\frac{dC}{dt} = W(t) - QC - kVC - vA_s C$$



Lake Characteristic Value, λ

$$V\frac{dC}{dt} = W(t) - QC - kVC - vA_s C$$

$$V\frac{dc}{dt} + (Q + kV + vA_s)C = W(t)$$

$$or,\ \frac{dc}{dt} + \lambda c = \frac{W(t)}{V}$$

$$\lambda = \text{Characteristic Value} = \frac{Q}{V} + k + \frac{v}{H}$$

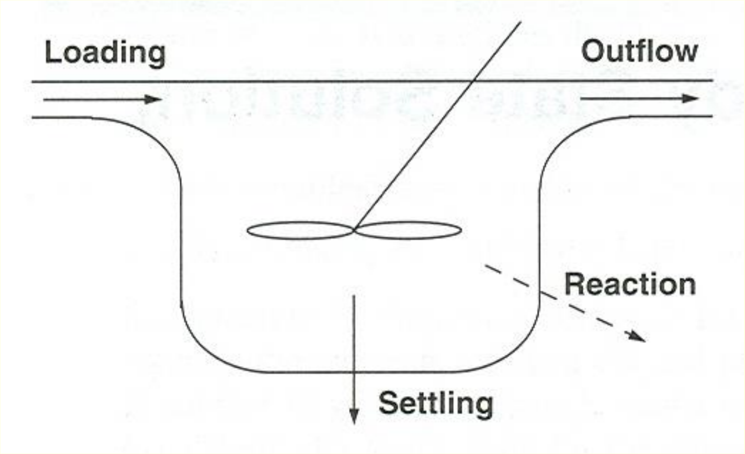
Simple Lake Modeling Analysis

$$V\frac{dC}{dt} = W(t) - QC - kVC - \nu A_S C$$

$$V\frac{dc}{dt} + (Q + kV + \nu A_S)C = W(t)$$

$$or,\ \frac{dc}{dt} + \lambda c = \frac{W(t)}{V}$$

$$\lambda = eigenvalue = \frac{Q}{V} + k + \frac{\nu}{H}$$



Simple Lake Modeling Analysis

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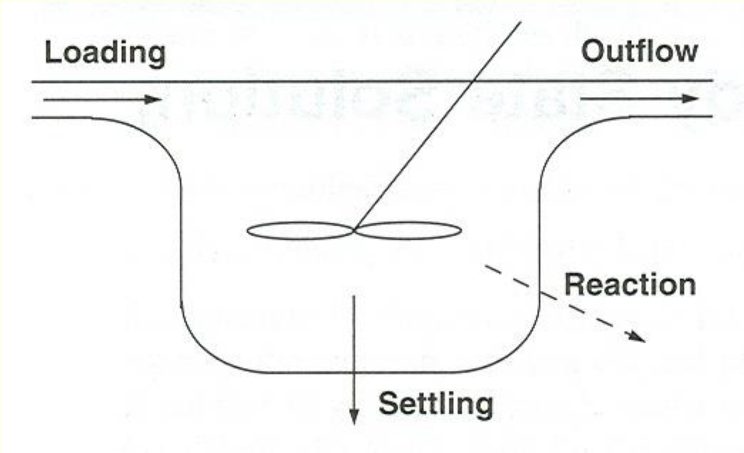
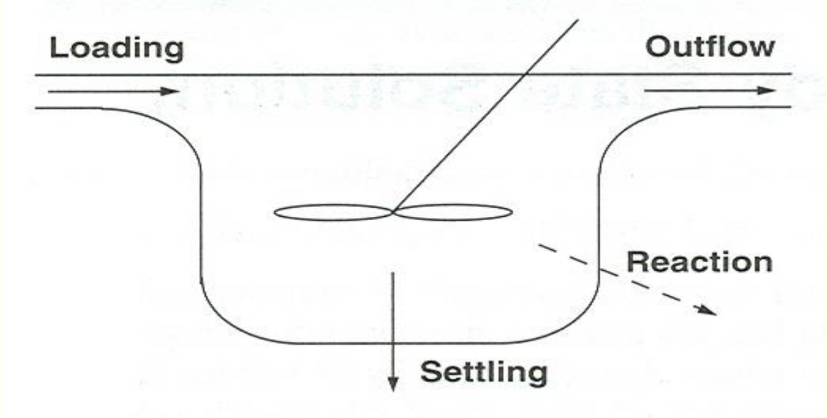


Linear Systems Modeling

Physically-based Model

$$\frac{dc}{dt} + \lambda c = \frac{W(t)}{V}$$



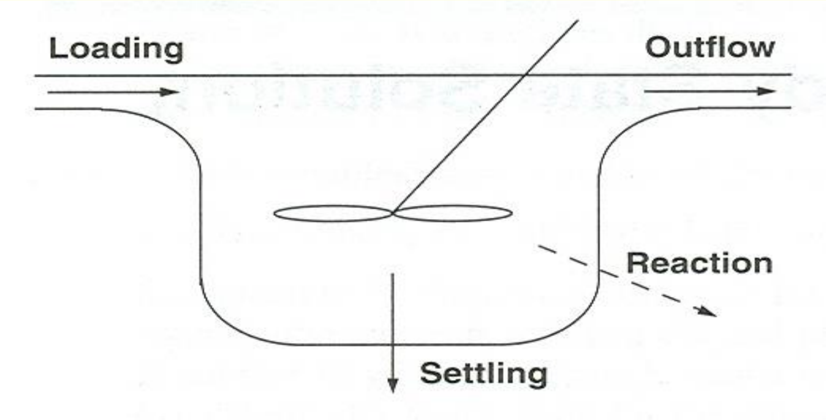
Linear Systems Model

$$C(t) = \int_0^t W(\tau) h(t-\tau) d\tau$$

Impulse response function :

$$\mathrm{h}(\mathrm{t} - \tau) = \frac{1}{\mathrm{V}} e^{-\lambda(t-\tau)}$$

Potential of Reservoir Restoration



- **Reduction of Waste Loading** $W(t)$
- **Enhancement of Assimilative Capacity** $\mathrm{h(t)} = \frac{1}{\mathrm{V}} e^{-\lambda t}$

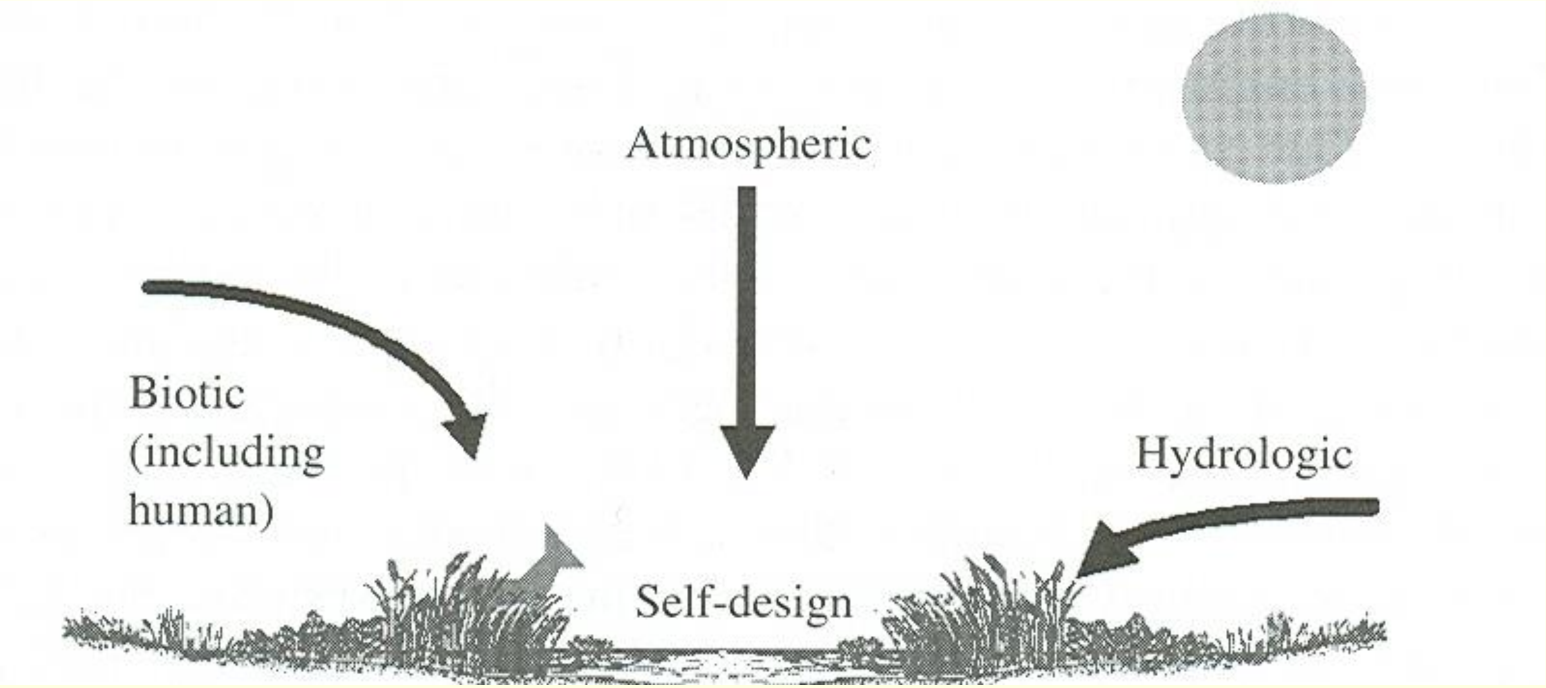
$$\lambda = \frac{Q}{V} + k + \frac{\upsilon}{H}$$

5. Ecological Engineering of Reservoir Restoration

Ecological engineering utilizes the Self-Designing Capacity of Ecosystems

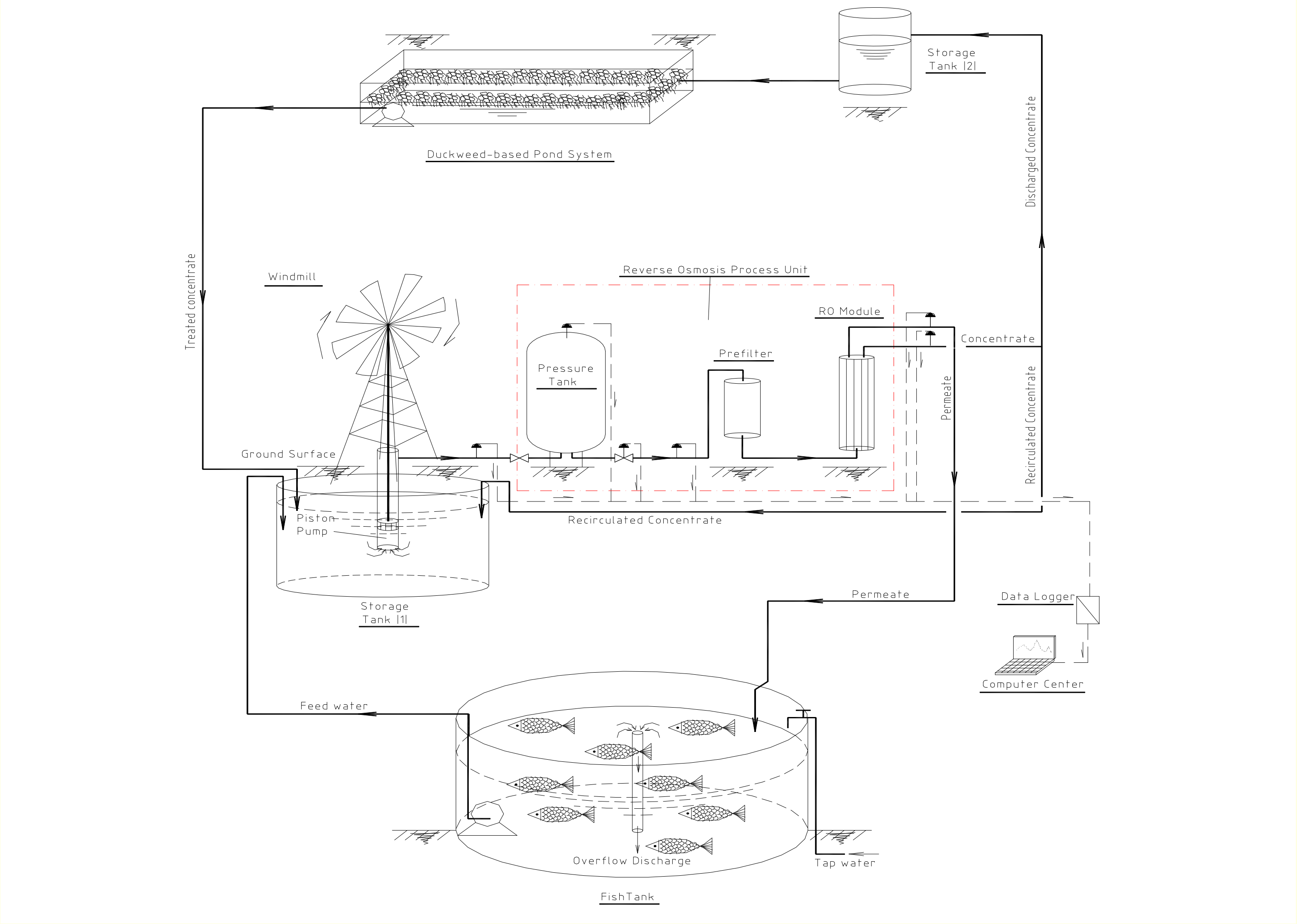
Ecological Engineering Approaches:

(1) Imitating natural ecosystems
(2) Conserving nonrenewable resources

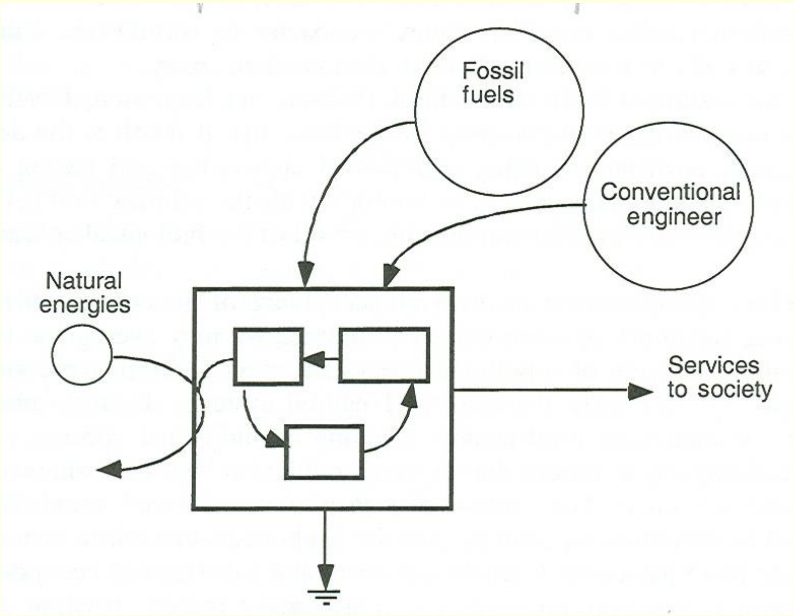


Wind-Driven Reverse Osmosis System in Hawaii

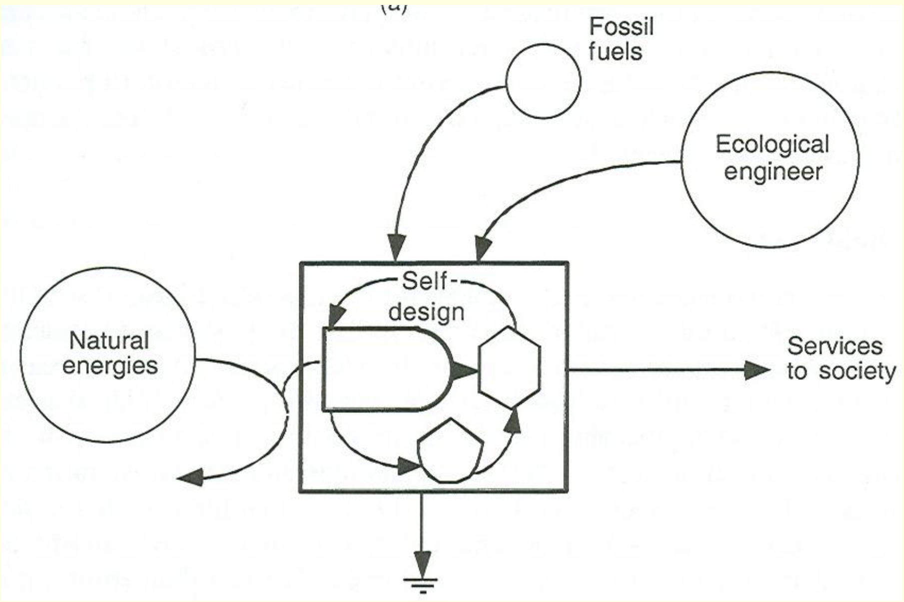
Ecological Engineering of Aquaculture Wastewater Treatment and Reuse



Ecological Engineering and Conventional Engineering

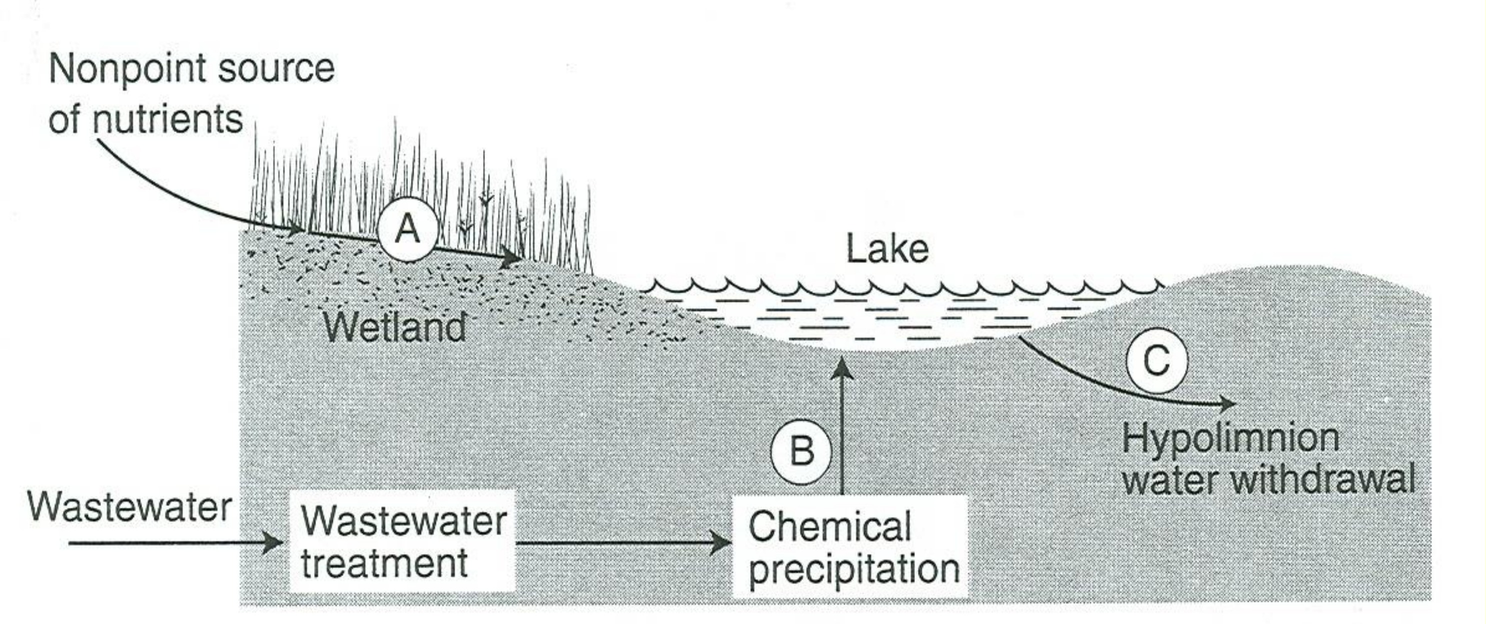


(a) Conventional Engineering



(b) Ecological Engineering

Reservoir Restoration by Ecological Engineering and by Conventional Engineering



(A) Ecological Engineering

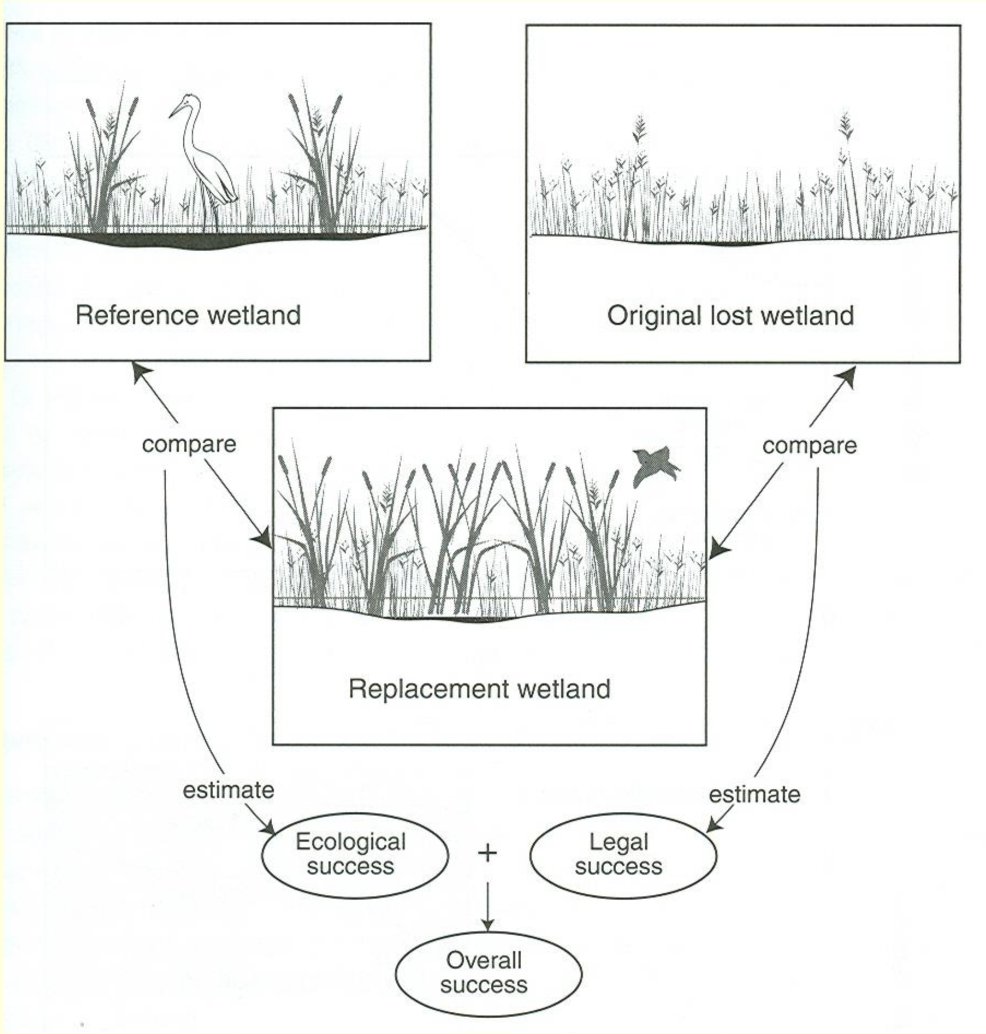
(B) and (C) Conventional Engineering

Conventional Engineering of Reservoir Restoration

Mechanical Algae removal in Wiahiwa Reservoir, Oahu, Hawaii

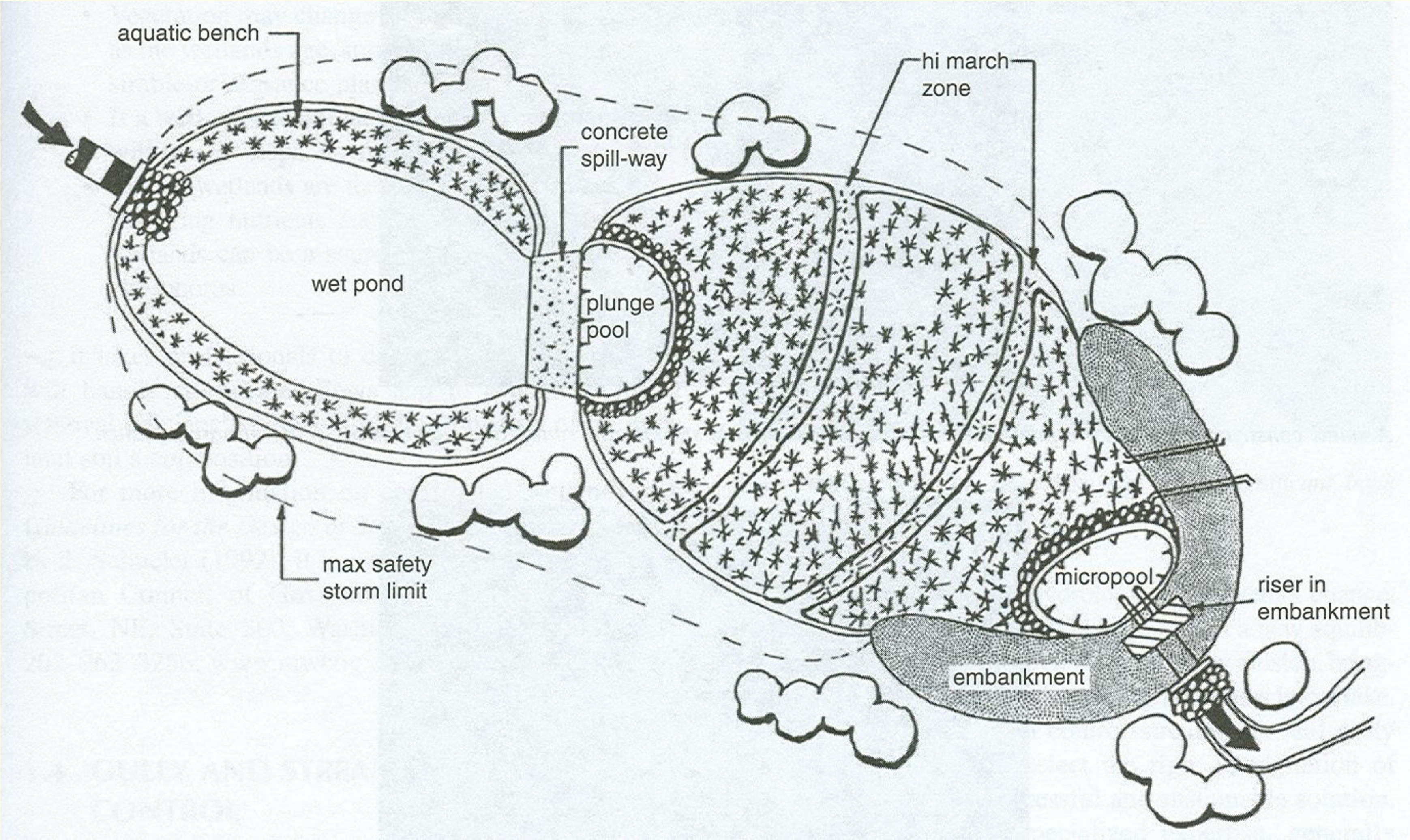
Reservoir Restoration by Ecological Engineering

Artificial Wetlands



Reservoir Restoration by Ecological Engineering

Constructed Wetlands



Reservoir Restoration by Ecological Engineering

Runoff control by grassed swale and filter strip

6. Concluding Remarks

1. The environmental quality of a reservoir can be improved by reducing waste loading and by enhancing waste assimilative capacity.

2. A comprehensive reservoir plan should include elements of watershed conservation, conventional engineering, and ecological engineering.