Selected Economic Aspects of Water Quality Trading

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Outline

1. Identify a pollution trading system appropriate for water (trading ratio system).
2. Discuss a simple modeling demonstration of potential pollution trades and cost savings.
3. Identify the data requirements for further empirical analysis.

Components of Tradable Permit Systems to Meet Environmental Quality Objectives at Minimum Cost

1. There must be substantial and transparent gains from trade after accounting for differential sources, costs, location, and fate and transport.
2. The nature of the pollutant and the regulatory conditions must be amenable to the establishment of a clear property rights structure.
3. Only when these (and other) fundamental prerequisites are met can one consider establishing a market appropriate for the particular, unidirectional characteristics of water pollution.

Tradable Permit Systems for Non-uniformly Mixed Assimilative Pollutants (NMAP)

- Alternative tradable pollution permit systems with the potential to achieve minimum cost (cost-effective) abatement have been suggested over the years.
  - Ambient Permit System (Montgomery, 1972)
  - Pollution Offset System (Krupnick, *et al*., 1983)
  - Trading-Ratio System (Hung and Shaw, 2005)
- Simpler schemes, such as trading of emissions permits within one or several zones:
  - Can be viewed as modifications of the above systems.
  - Are generally not cost-effective for NMAP.
- A trading-ratio system has advantages for water pollution.

Trading-Ratio System: Critical Inputs

1. Total load standards can be derived directly from water quality standards in each zone.
2. Pollution flow is unidirectional, from upstream to downstream.
3. Must calculate pollutant transfer coefficients between zones (contribution of one unit of pollutant discharged from one upstream zone to a downstream zone).
4. Zonal load caps can be set one-by-one, working from upstream to downstream zones, taking into account:
   - Background/natural pollution levels,
   - Inflow from upstream sources adjusted for transfer coefficient.
5. Need total and marginal abatement cost functions.

Trading-Ratio System: Economic Characteristics

1. By setting permit trading ratios equal to transfer coefficients
   - Sales of permits *are always* from upstream (sell) to downstream (buy),
   - Values of permits between zones that trade differ by the trading ratios.
2. Each source minimizes abatement costs subject to the constraint that actual emissions be less than or equal to:
   - Permits initially allocated to the source,
   - (plus) Permits purchased from upstream weighted by trading ratios,
   - (minus) Permits sold downstream (un-weighted).
3. If there are no transaction costs or strategic behavior, a trading-ratio system achieves a pollution target at minimum cost.

Formal Model (one polluter per zone): The Objective Function

$$\underset{E_i, T_{ik}, T_{ki} \geq 0}{Min} \quad \sum_{i=1}^{n} C_i \, (E_i^0 - E_i)$$

E_i^0 = primary effluent level of zone *i*,

E_i = final effluent level of zone *i*,

$(E_i^0 - E_i)$ = amount abated in zone *i*,

$C_i \, (E_i^0 - E_i)$ = total cost of abatement for zone *i*.

Formal Model:
The Zonal Load Cap Constraint

$$E_i - \sum_{k=1}^{i-1} d_{ki}\, T_{ki} + \sum_{k=i+1}^{n} T_{ik} \le A_i^{Max}, \quad i = 1, \cdots, n.$$

A_i^{Max} = zonal load cap taking into account background/natural levels of pollutant and inflow from upstream sources adjusted for transfer coefficient,

T_{ki} = Tradable discharge Permits (TDPs) purchased by zone *i* from zone *k*,

T_{ik} = TDPs sold by zone *i* to zone *k*,

d_{ki} = transfer coefficient (trading ratio) -- contribution of one unit from discharger *k* to total effluent load for *i*, $0 \le d_{ki} \le 1$.

Set initial TDP allocation for zone *i*, T_i^0, equal to zonal cap:

$$A_i^{Max} = T_i^0, \quad i = 1, \cdots, n$$

Interpreting the Constraint in Terms of TDPs Owned

Subject to $$E_i \;\le\; T_i^0 + \sum_{k=1}^{i-1} d_{ki}\, T_{ki} \;-\; \sum_{k=i+1}^{n} T_{ik} \;, \quad i = 1, \cdots, n.$$

Final Effluent Level ≤ { Initial TDP Allocation **+** TDPs Purchased by *i* weighted by Trading Ratios **-** TDPs Sold by *i* } **=** Effective TDPs Owned

Marginal Abatement Costs and Tradable Discharge Permit Prices

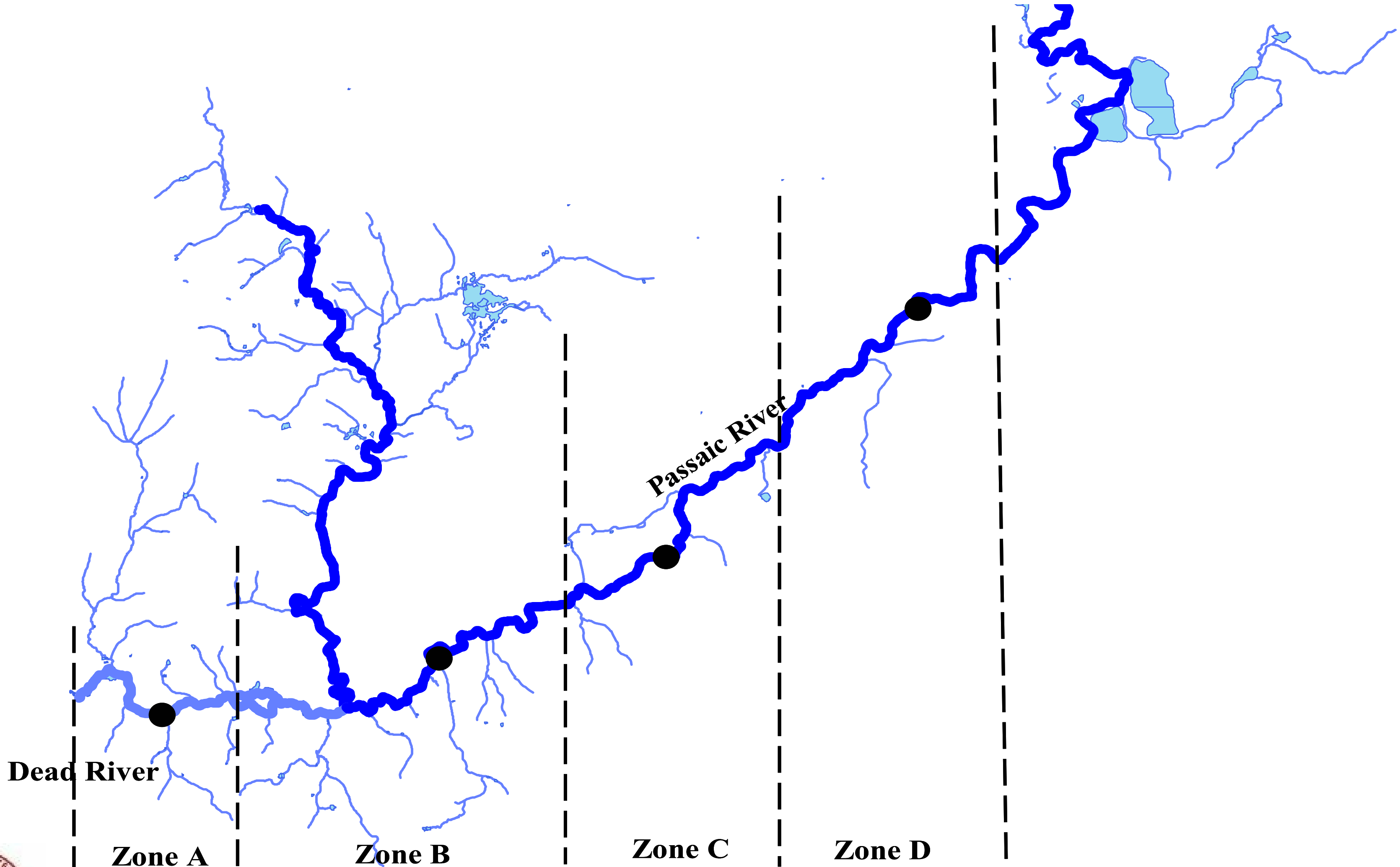
For the Minimum Cost Solution

$C_i^{'}(E_i^0 - E_i^{pt}) = \lambda_i = P_i$ → C_i' (.) = i's post trade marg. abatement cost
= shadow value of i's initial TDP, λ_i
= i's permit price, P_i,

$P_k \geq d_{ki} P_i \ (k < i)$ → If >, then there is no trade between k and i,

$P_k = d_{ki} P_i \ (k < i)$ → If trade takes place between k and i then P_k = k's permit price = trading ratio multiplied by P_i for i downstream.

A Stylized Four-Zone Empirical Example



A Stylized Empirical Example

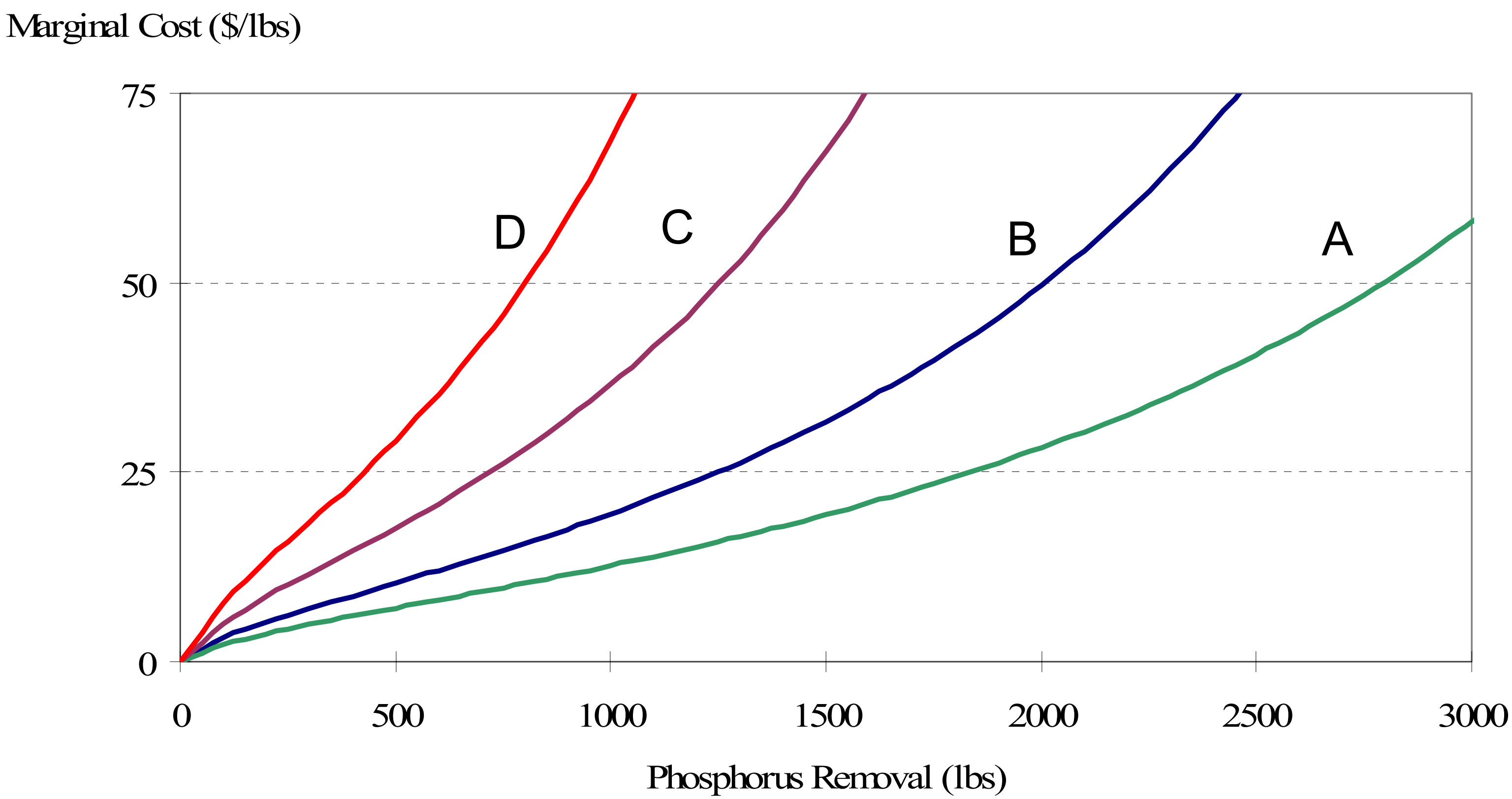
Zone	Flow (1000L/Y)	Primary Load (E_i^0) (lbs/Y)	Permitted Load (E_i) (lbs/Y)
A	2,387,371	20,924	1,522
B	432,096	4,713	487
C	461,787	3,010	286
D	1,214,261	6,089	852

Cost of abatement (proportion of primary load abated)

$$TC = \alpha [(E_i^0 - E_i) / E_i^0]^{\beta}, \quad \alpha > 0, \ \beta > 1$$

$$MC = \alpha\beta [(E_i^0 - E_i) / E_i^0]^{\beta - 1}$$

Marginal Cost / lb. Removed



downstream ← upstream

The order of these marginal abatement costs is conducive to trading.

Four Scenarios

→ No trade — all trading ratios zero.

→

	Ratio 1--Lowest Ratio				Ratio 2--Middle Ratio			
	A	B	C	D	A	B	C	D
A	1	0.75	0.5	0.25	1	1	0.75	0.5
B		1	0.75	0.5		1	1	0.7
C			1	0.75			1	0.75
D				1				1

→ All trading ratios unity.

Four Scenarios—The Trades

Trade (lbs)	No Trade	Ratio 1	Ratio 2	1:1
A and B	0	0	475.8	0
A and C	0	0	0	0
A and D	0	0	0	475.8
B and C	0	251.4	727.2	0
B and D	0	0	0	251.4
C and D	0	0	348.2	135.5
Total Cost ($)	750,208	748,758	742,456	733,141

- Total cost falls as trading ratios rise.
- Maximum trading ratios 1:1.
    - -Minimum potential cost,
    - -Maximum benefits from trade.
- Maximum savings modest--cost functions identical.

Four Scenarios—Prices and M. Costs

	No Trade	Ratio 1		Ratio 2		Ratio Unity	
	M. Cost	Price	M. Cost	Price	M. Cost	Price	M. Cost
A	33.11	33.11	33.11	40.45	33.55	50.24	33.23
B	26.12	31.67	26.96	40.45	26.96	50.24	26.96
C	43.93	42.22	42.22	40.45	40.45	50.24	45.11
D	55.47	55.47	55.47	53.93	53.93	50.24	50.24

Note: The price at a zone is always equal to or above marginal cost.

Concluding Observations

- Factors conducive to pollution trading
  - Differential abatement costs,
  - Low-cost sites upstream,
  - High trading ratios.
- Some implications
  - Trades between distant zones are unlikely,
  - Exploit opportunities for trades within sub-watersheds or zones.
- Data needs are explicit in the modeling framework presented
  - Empirical models will be adapted to specific characteristics of the watershed system,
  - assessment of cost saving due to pollution trading will begin at the sub-watershed level.

References

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