Generalized Smart Markets for Water Resources.

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1. Markets & water. **Transaction costs.**
2. Ground water, rural. Marlborough, Selwyn, *Tianqiao.*
3. Nutrient runoff, rural.

4. *Impervious cover, urban, flood control. Auckland.*
5. *Sediment runoff, urban, waterway protection. Auckland.*

Summary: **on-line auction**, cap & trade with complicated caps.
Connect a hydrological simulation,
to an economic model,
to the internet.

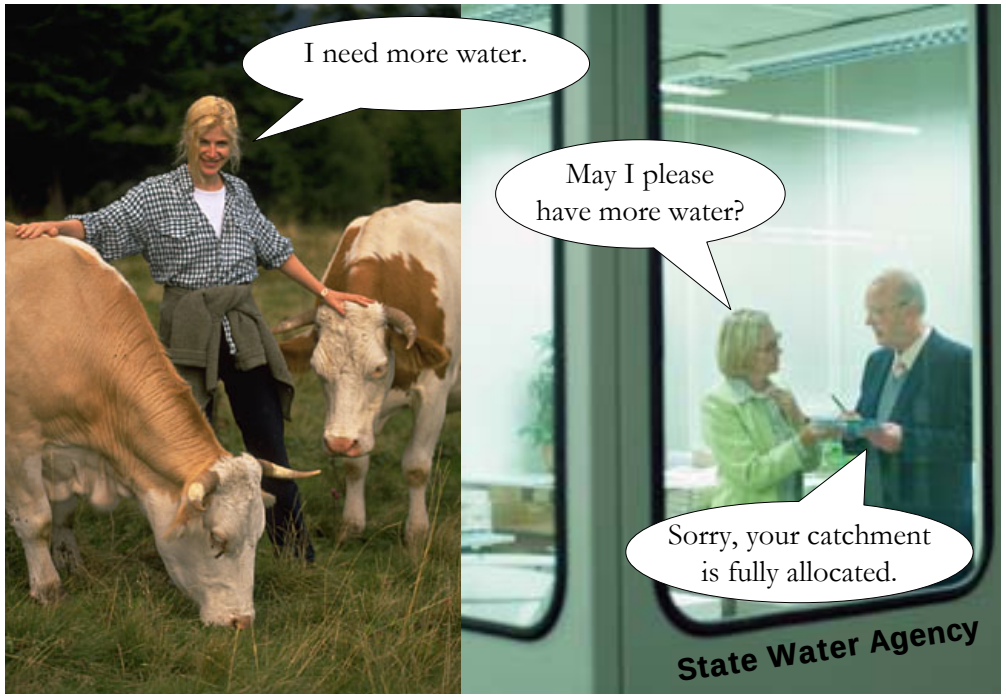
Water markets?

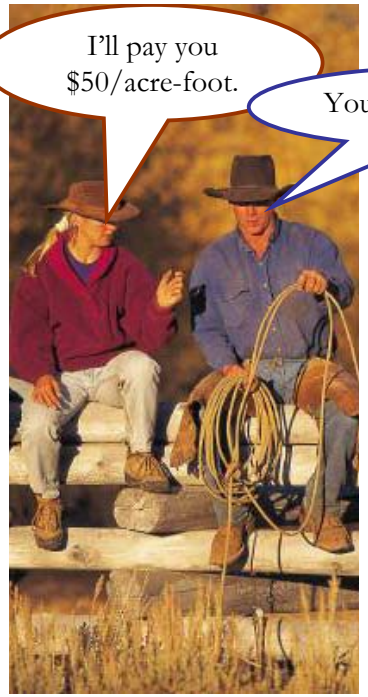
Hirshleifer, DeHaven & Milliman 1960; Lund & Israel 1995; Thobani 1997; McCann & Zilberman 1999; Easter & Rosegrant 1999; Rosegrant, Ringler, McKinney, Cai, Keller, Donoso 2000; Dinar 2000; Holland & Moore 2003; Iglesias, Garrido & Gómez 2001; Bate 2002; Griffin & Characklis 2002; Chakravorty & Umetsu 2003; Gleick 2003; Foellmi & Meister 2004; Sharp 2004 …

Negative Chilean experience, Bauer 1997, Thobani 1997.
"Free market" ≠ market.

Gov't procurement:
Bryan et al 2005 (Australia); FSA 2008 (USA);
Cummings, Holt & Laury 2004 (USA).

Jack Hirshliefer





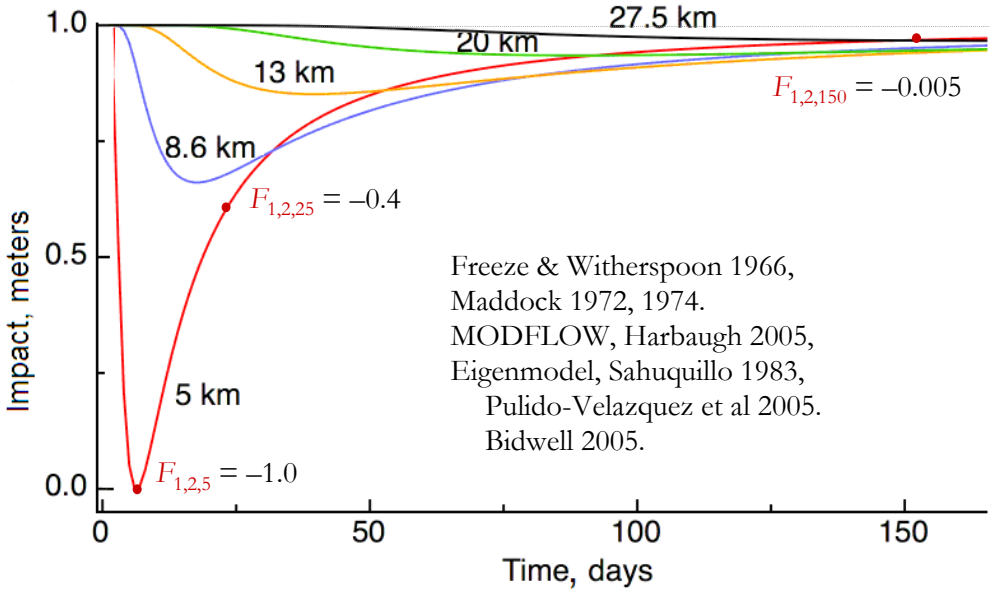
Weeks later…

I'll pay you $110/acre-foot.

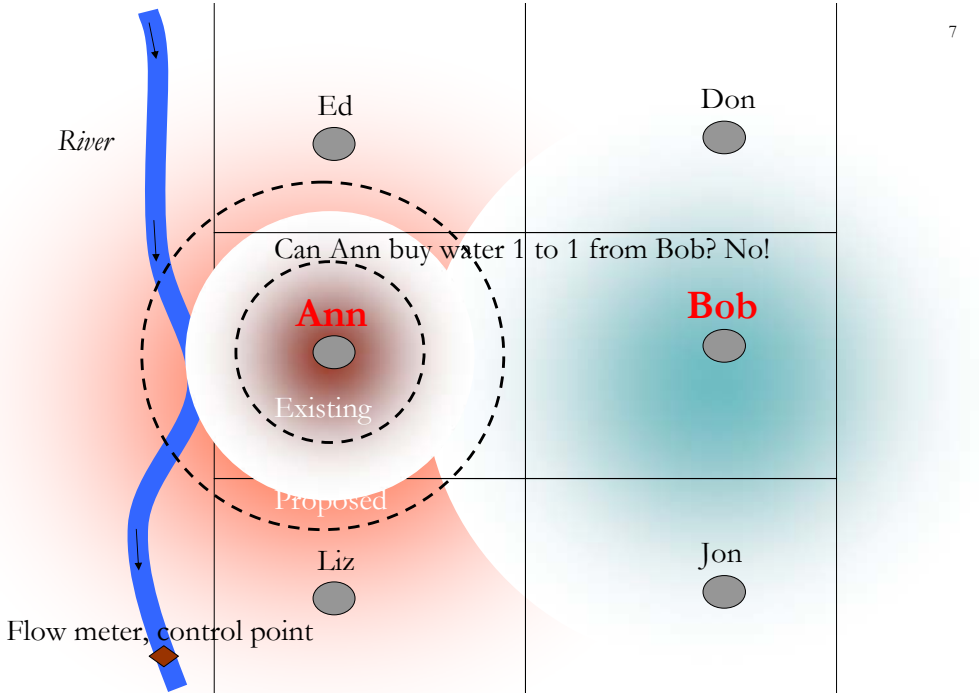
Okay. But we still need gov't approval.

And I want a contract to ensure you deliver.

Impact of well 1 on control pts 2, 3, 4,…, at time *t*



Freeze & Witherspoon 1966,
Maddock 1972, 1974.
MODFLOW, Harbaugh 2005,
Eigenmodel, Sahuquillo 1983,
Pulido-Velazquez et al 2005.
Bidwell 2005.



THE PRESS
www.thepress.co.nz

Court says yes to water appeal

THURSDAY , 25 AUGUST 2005

By JOHN KEAST TIMARU

Environment Canterbury (ECan) has been dealt a major blow in its efforts to control essential water resources.

The Environment Court, in a sometimes harshly critical ruling, has overturned ECan's decision to stop a $17 million dairy company from doubling its groundwater take in the Rakaia-Selwyn red (or fully allocated) zone.

ECan fears that 70 other water applications may be affected. There are 320 outstanding applications for water in Canterbury's seven red zones. ECan's position is to turn down new applications for water abstraction in them.

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Your path: The Industry > Classifieds > Water Trading Register

Water Trading Register

Bundaberg

High transaction costs result in a few big trades.

Buy

Buy: Temporary Transfer, 2007/2008 Financial year. Phone Ar 399.

Buy: Zone AA, Up to 150ML Permanent Trade. Phone DR Tow

Sell

Sell: Zone AD. 30ML Temp Trade (until June 2008). $200/ML

Sell: Zone AD, 100ML Temp Trade (2007/08 water year), $50(

More related research

Simulate a water market with LP. Academic only. Dual gives market prices.
Becker 1995, Newlin et al 2002, Draper et al 2003, Tisdell et al 2004, Yu et al 2003, Wang et al 2003, …

Smart markets.
Electricity: Schweppe et al, 1988, *Spot Pricing of Electricity*.
1995: NZ electricity market, Hogan, Read & Ring 1996; Alvey et al 1998.
Lots of great research.
Radio spectrum, natural gas, course registration, Chilean school lunches …

Environmental and Resource Economics **17:** 375–394, 2000.

The Design of "Smart" Water Market Institutions Using Laboratory Experiments*

JAMES J. MURPHY[1], ARIEL DINAR[2], RICHARD E. HOWITT[3], STEVEN J. RASSENTI[4] and VERNON L. SMITH[5]

Ground water: not controlled, but can be optimized.

Burt 1964; Provencher 1993; Carter 1995; Ejaz & Peralta 1995; Yang 1999; Brozovic 2004; Pulido-Velazquez et al 2005-6; Young 2005; Sethi, Panda & Nayak 2006; Papadopoulou, Pinder & Karatzas 2006.

Software: Greenwald 1998, Ahlfeld & Mulligan 2000.
Minimize cost of hydraulic remediation.

Ground water market:
Constraints are chosen by gov't + community + hydrologists.
Head differences, aquifer drawdown, surface water flows…

Center pivot irrigation, Ogallala Aquifer.

Spot market for ground water

Data: $F_{\text{user } i, \text{ control pt } j, \text{ time } t}$ = impact of user i on control pt j at time t,
$R_{\text{user } i, \text{ time } t}$ = **initial permit** of user i at time t. User pays has $R_{it} = 0$.
$PBuy_{itb}$, $PSell_{itb}$, $QBuy_{itb}$, $QSell_{itb}$ = user i's price & qty for bid b, time t.
$U_{\text{control pt } j, \text{ time } t}$ = reqd flow at control pt j at time t.

Variables: buy_{itb}, $sell_{itb}$ = bid accepted.
q_{it} = pumping at well i, period t.

Raffensperger & Milke 2007

1. Max $\sum_{\text{users } j} \sum_{\text{time } u=1}^{T} \sum_{\text{bids } b} (PBuy_{itb} buy_{itb} - PSell_{itb} sell_{itb})$.

2. Sustainability: $\sum_{\text{users } i} \sum_{\text{time } u=1}^{t} F_{iju} q_{iu} \le U_{jt}$, all control pts j & periods t.

3. Bids, $0 \le buy_{itb} \le Qbuy_{itb}$, $0 \le sell_{itb} \le QSell_{itb}$, for all i, t, b.
4. Pumping = scaled initial permit + buy – sell.
$q_{\text{user } i, \text{ time } t} = \alpha R_{it} + \sum_{\text{bids } b} (buy_{itb} - sell_{itb})$. Dual var p_{it} = mkt price.

Surface water & hydroelectric: Pulido-Velazquez, Andreu & Sahuquillo 2006.

Revenue sufficiency & initial rights αR_{it}

α = % permit allowed.

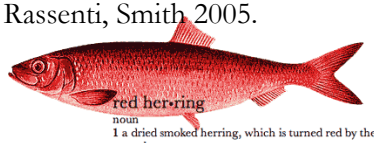
$\alpha = 0$ — $\alpha = 1.$

Users pay gov't. — Over allocated. Gov't pays users.

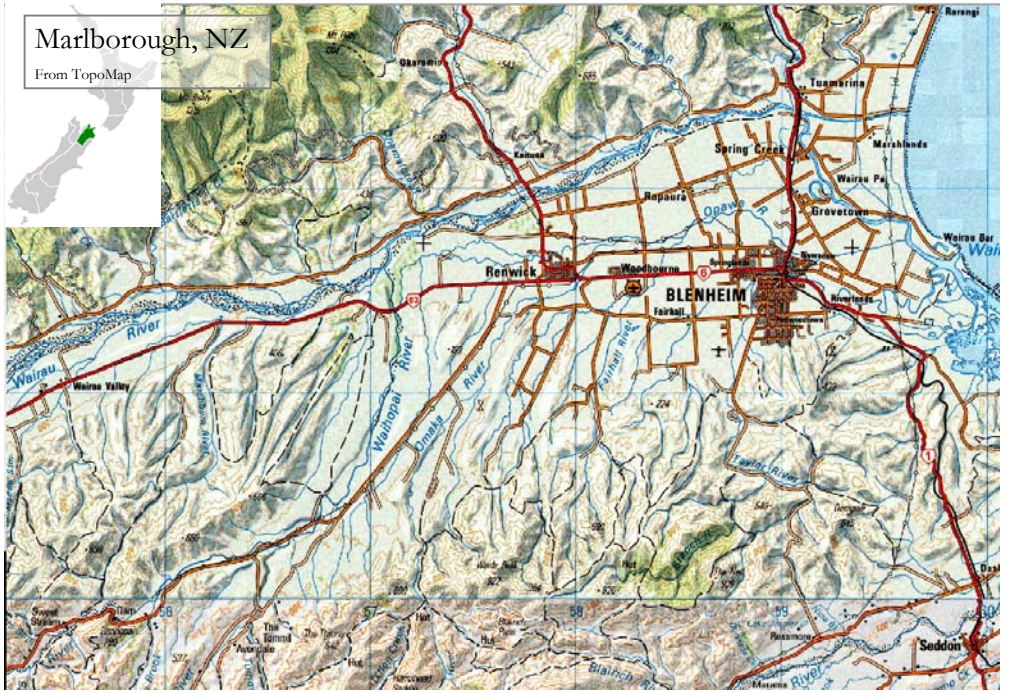
So find α where net revenue = \$0, "user trades."
Auction manager must have authority to adjust α.

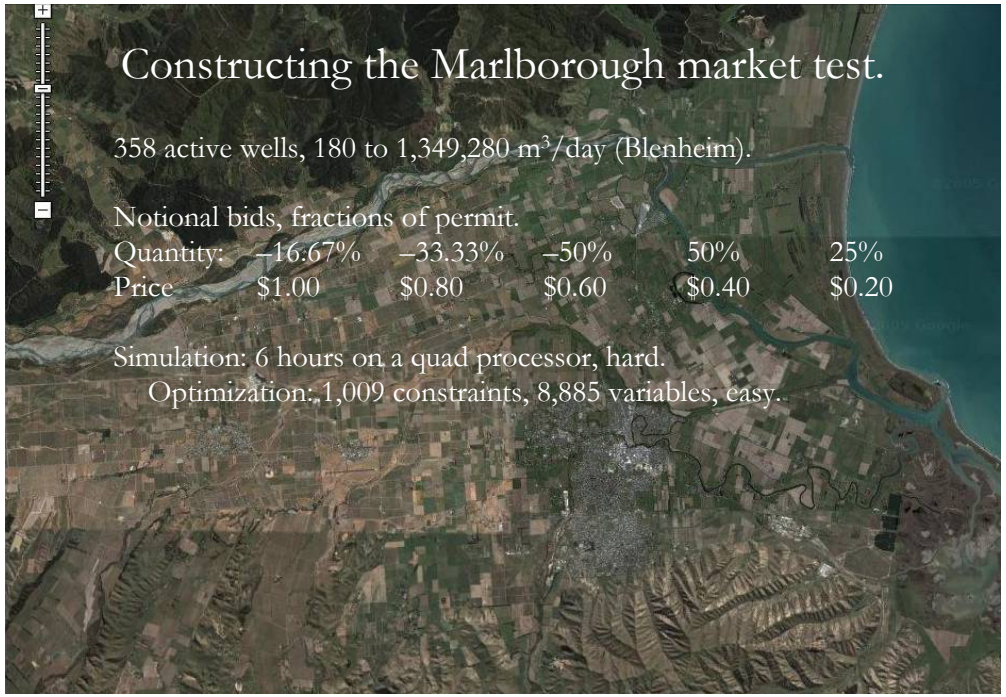
But proportional adjustment is not fair; impacts are not equal.

- Easy to buy extra water for the environment.
  Murphy, Dinar, Howitt, Mastrangelo, Rassenti, Smith 2005.
- Uncertainty of data – a red herring.



red her•ring
noun
1 a dried smoked herring, which is turned red by the smoke.
2 something, esp. a clue, that is or is intended to be misleading or distracting : *the book is fast-paced, exciting, and full of red herrings.* [ORIGIN: so named from the practice of using the scent of red herring in training hounds.]





Constructing the Marlborough market test.

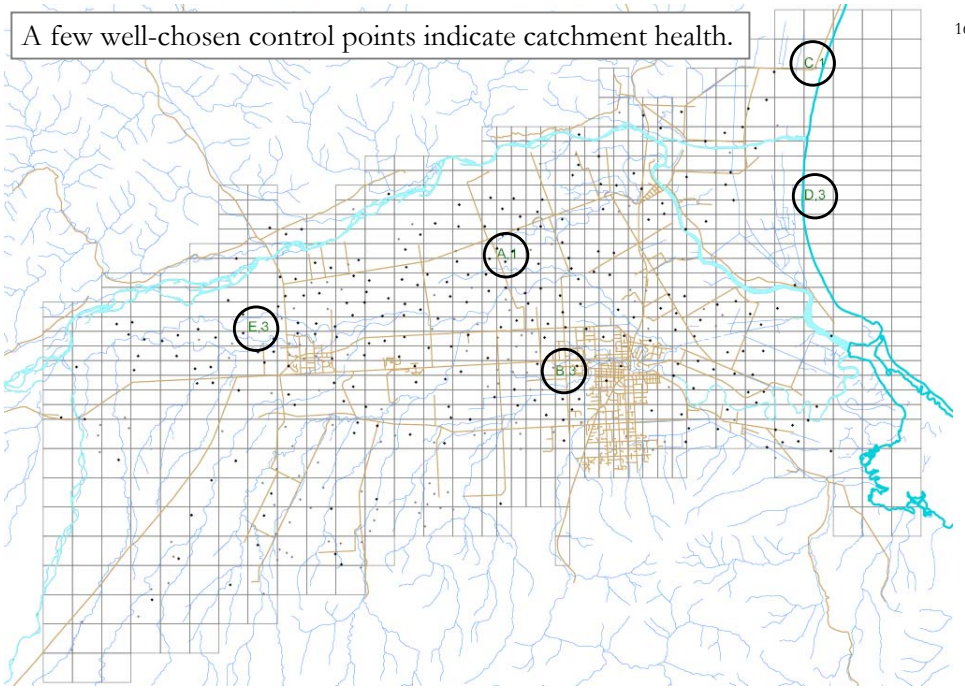
358 active wells, 180 to 1,349,280 m^3/day (Blenheim).

Notional bids, fractions of permit.

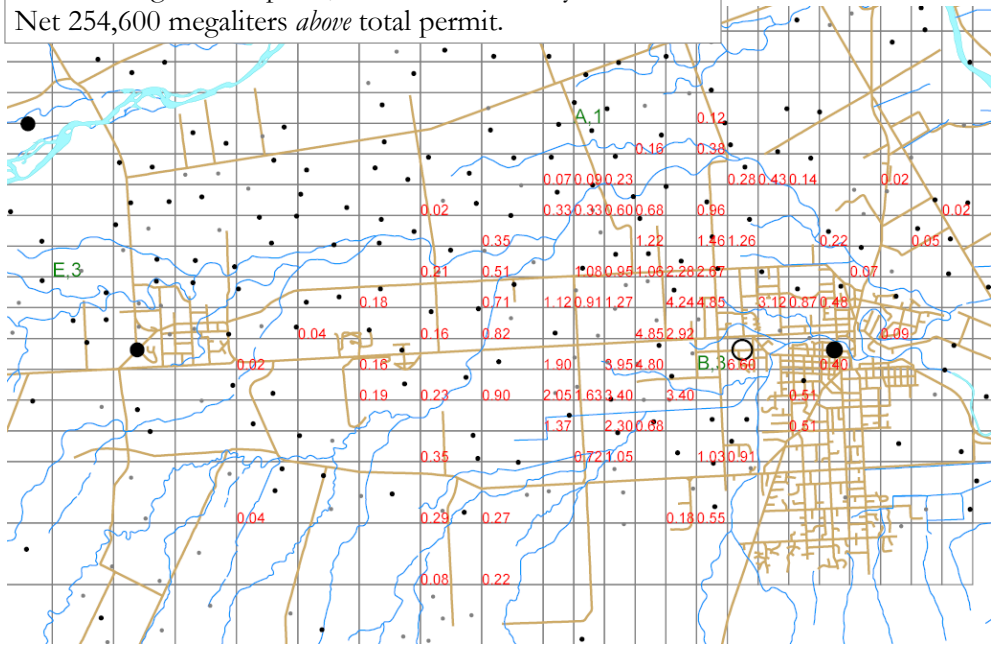
Quantity:	–16.67%	–33.33%	–50%	50%	25%
Price	\$1.00	\$0.80	\$0.60	\$0.40	\$0.20

Simulation: 6 hours on a quad processor, hard.
Optimization: 1,009 constraints, 8,885 variables, easy.

A few well-chosen control points indicate catchment health.

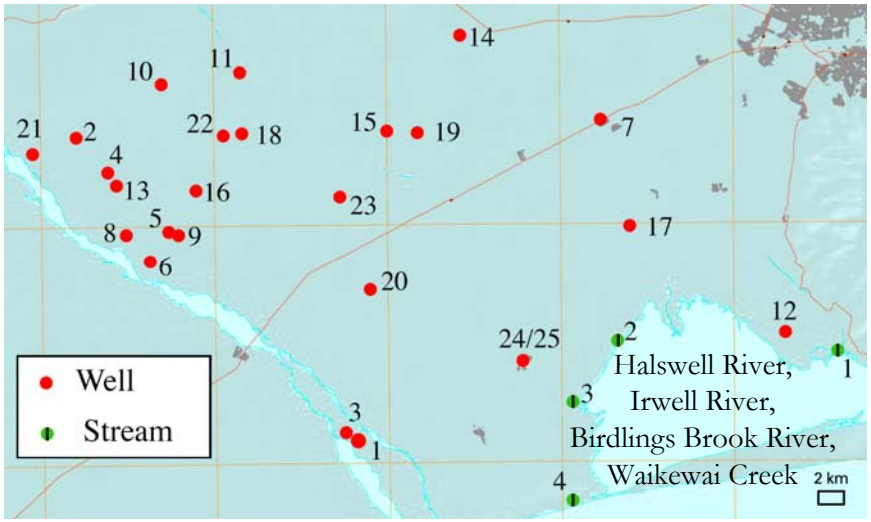


One binding control point, B3 at Blenheim city.
Net 254,600 megaliters *above* total permit.



Price	$1.00	$1.25	$1.50	$1.60	$2.00	$5.00
Quantity	200%	183%	150%	50%	33%	17%

Market ran 52 weeks, *constraints* for 78 weeks.

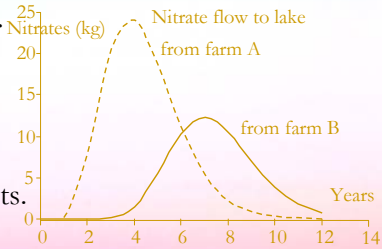


Wells, by distance to Lake Ellesmere →

Weeks ↓

	12	24	25	17	20	3	1	7	19	23	15	13	18	22	16	9	5	6	11	8	14	10	4	2	21
1	1													28	1.25	1.24	1.24	1.21	1.18	1.08	0.96	0.93	0.94	0.72	0.67
2	1													29	1.26	1.25	1.24	1.22	1.18	1.08	0.95	0.92	0.93	0.71	0.66
3	1													29	1.26	1.25	1.24	1.22	1.18	1.08	0.95	0.91	0.92	0.70	0.65
4	1													30	1.27	1.25	1.25	1.22	1.18	1.07	0.94	0.91	0.92	0.69	0.63
5	1	0.68	0.81	0.81	1.56	1.78	1.79	1.80	1.80	1.76	1.78	1.73	1.55	1.35	1.30	1.27	1.26	1.25	1.22	1.18	1.07	0.94	0.90	0.91	0.68	0.62
6	1				1.60	1.83	1.84	1.85	1.84	1.79	1.82	1.76	1.56	1.35	1.31	1.27	1.26	1.25	1.22	1.18	1.07	0.93	0.89	0.90	0.67	0.61
7	1				1.65	1.88	1.88	1.90	1.88	1.82	1.85	1.79	1.58	1.36	1.31	1.28	1.26	1.25	1.22	1.18	1.06	0.92	0.88	0.89	0.66	0.60
8	1				1.71	1.93	1.94	1.95	1.92	1.85	1.88	1.82	1.59	1.36	1.31	1.28	1.26	1.25	1.22	1.18	1.06	0.91	0.87	0.88	0.64	0.58
9	1				1.76	1.98	1.99	2.00	1.96	1.89	1.92	1.85	1.61	1.36	1.31	1.28	1.26	1.25	1.22	1.17	1.06	0.90	0.86	0.87	0.63	0.57
10	1		0.97	0.97	1.82	2.04	2.04	2.05	2.00	1.92	1.95	1.88	1.62	1.37	1.31	1.28	1.26	1.25	1.22	1.17	1.04	0.89	0.85	0.86	0.62	0.55
11	2		1.01	1.01	1.88	2.10	2.10	2.11	2.04	1.95	1.99	1.90	1.63	1.37	1.31	1.27	1.25	1.25	1.21	1.16	1.03	0.88	0.84	0.85	0.60	0.54
12	2		1.06	1.06	1.95	2.16	2.16	2.17	2.09	1.98	2.02	1.93	1.64	1.36	1.31	1.27	1.25	1.24	1.21	1.16	1.02	0.86	0.83	0.84	0.58	0.52
13	2	2.14	1.10	1.10	2.02	2.22	2.22	2.23	2.13	2.01	2.06	1.96	1.65	1.36	1.30	1.26	1.24	1.24	1.20	1.15	1.01	0.85	0.81	0.82	0.57	0.51
14	2	2.21	1.16	1.16	2.09	2.29	2.29	2.29	2.17	2.04	2.09	1.99	1.66	1.36	1.30	1.26	1.23	1.23	1.19	1.14	1.00	0.83	0.79	0.81	0.55	0.49
15	2	2.29	1.21	1.21	2.17	2.36	2.36	2.35	2.22	2.07	2.13	2.01	1.67	1.35	1.29	1.25	1.23	1.22	1.18	1.13	0.98	0.82	0.78	0.79	0.53	0.47
16	2	2.37	1.27	1.27	2.25	2.43	2.43	2.42	2.26	2.10	2.16	2.04	1.67	1.35	1.28	1.24	1.22	1.21	1.17	1.11	0.97	0.80	0.76	0.77	0.51	0.45
17	2	2.45	1.34	1.34	2.34	2.50	2.50	2.49	2.30	2.13	2.19	2.06	1.68	1.34	1.27	1.23	1.20	1.19	1.16	1.10	0.95	0.78	0.74	0.75	0.49	0.43
18	2	2.54	1.41	1.42	2.43	2.50	2.58	2.56	2.35	2.16	2.23	2.08	1.68	1.33	1.26	1.21	1.19	1.18	1.14	1.08	0.93	0.76	0.72	0.73	0.47	0.41
19	2	2.50	1.50	1.50	2.53	2.50	2.50	2.63	2.39	2.18	2.25	2.10	1.68	1.31	1.25	1.20	1.17	1.16	1.12	1.07	0.91	0.74	0.70	0.71	0.45	0.39
20	2	2.50	1.59	1.60	2.50	2.50	2.50	2.70	2.43	2.20	2.28	2.12	1.68	1.30	1.23	1.18	1.15	1.15	1.11	1.05	0.89	0.72	0.67	0.69	0.43	0.37
21	2	2.82	1.70	1.70	2.50	2.50	2.50	2.77	2.46	2.22	2.30	2.13	1.67	1.28	1.21	1.16	1.14	1.13	1.08	1.03	0.86	0.69	0.65	0.66	0.41	0.35
22	2	2.92	1.83	1.83	2.50	2.50	2.50	2.84	2.50	2.24	2.33	2.14	1.67	1.27	1.19	1.14	1.11	1.11	1.06	1.00	0.84	0.67	0.63	0.64	0.39	0.33
23	3	3.02	1.98	1.98	2.50	2.50	2.50	2.91	2.53	2.25	2.34	2.15	1.66	1.25	1.17	1.12	1.09	1.08	1.04	0.98	0.81	0.64	0.60	0.61	0.36	0.31
24	3	3.12	2.15	2.16	2.50	2.50	2.50	2.96	2.56	2.27	2.36	2.16	1.65	1.23	1.15	1.09	1.07	1.06	1.01	0.95	0.79	0.61	0.57	0.58	0.34	0.29
25	3	2.50	2.38	2.38	2.50	2.50	3.07	3.01	2.58	2.28	2.37	2.17	1.64	1.20	1.12	1.07	1.04	1.03	0.99	0.92	0.76	0.58	0.54	0.55	0.31	0.26
26	3	2.77	2.50	2.50	2.50	2.50	3.11	3.04	2.50	2.29	2.38	2.17	1.63	1.18	1.09	1.04	1.01	1.00	0.95	0.89	0.72	0.55	0.51	0.52	0.29	0.24
27	3	3.32	2.50	2.50	2.50	2.50	2.50	3.06	2.50	2.30	2.40	2.18	1.62	1.15	1.06	1.00	0.98	0.97	0.92	0.86	0.69	0.52	0.48	0.49	0.26	0.22
28	3	3.33	2.50	2.50	2.50	2.50	3.15	3.08	2.50	2.32	2.42	2.20	1.60	1.11	1.03	0.97	0.94	0.93	0.88	0.82	0.65	0.48	0.44	0.45	0.24	0.20
29	3	3.33	2.50	2.50	2.50	2.50	3.17	2.50	2.50	2.34	2.45	2.21	1.58	1.07	0.99	0.93	0.90	0.89	0.84	0.78	0.61	0.45	0.41	0.42	0.21	0.17
30	3	3.39	2.50	2.50	2.50	2.50	3.25	3.19	2.50	2.36	2.48	2.21	1.55	1.03	0.94	0.88	0.85	0.85	0.80	0.73	0.57	0.41	0.37	0.38	0.19	0.15
31	3	3.63	2.60	2.60	3.46	2.60	3.36	2.60	2.50	2.37	2.60	2.21	1.51	0.98	0.90	0.83	0.81	0.80	0.76	0.69	0.62	0.37	0.34	0.34	0.16	0.13
32	3	3.69	2.30	2.30	3.63	2.50	3.48	3.40	2.50	2.38	2.51	2.21	1.47	0.93	0.84	0.78	0.75	0.74	0.70	0.64	0.48	0.33	0.30	0.31	0.14	0.11
33	3	3.87	2.46	2.47	3.83	2.50	3.60	3.51	2.50	2.37	2.50	2.19	1.42	0.87	0.78	0.72	0.70	0.69	0.64	0.58	0.43	0.29	0.26	0.27	0.12	0.09
34	4	4.05	2.50	2.50	2.50	2.50	3.72	3.62	2.50	2.36	2.51	2.16	1.36	0.81	0.72	0.66	0.64	0.63	0.58	0.53	0.38	0.25	0.22	0.23	0.10	0.07
35	4	4.25	2.50	2.50	2.50	2.50	3.85	3.73	2.50	2.33	2.50	2.13	1.29	0.74	0.65	0.60	0.57	0.56	0.52	0.47	0.33	0.21	0.19	0.19	0.08	0.06
36	4	4.46	2.50	2.50	2.50	2.50	3.97	3.84	2.50	2.47	2.07	1.23	0.66	0.58	0.53	0.51	0.50	0.46	0.47	0.42	0.28	0.18	0.15	0.16	0.06	0.04
37	4	4.69	2.50	2.50	2.50	2.50	4.09	3.94	2.50	2.23	2.42	2.00	1.12	0.58	0.51	0.46	0.44	0.43	0.39	0.35	0.23	0.14	0.12	0.13	0.04	0.03
38	4	4.93	2.50	2.50	2.50	2.50	2.50	4.03	2.50	2.15	2.35	1.91	1.02	0.50	0.43	0.39	0.37	0.36	0.33	0.29	0.19	0.11	0.09	0.10	0.03	0.02
39	5	5.17	2.50	2.50	2.50	2.50	4.32	4.10	2.50	2.05	2.25	1.80	0.91	0.42	0.36	0.32	0.30	0.29	0.26	0.23	0.14	0.08	0.07	0.07	0.02	0.01
40	5	5.43	2.50	2.50	2.50	2.50	2.50	4.15	2.50	1.92	2.13	1.66	0.79	0.34	0.28	0.25	0.23	0.23	0.20	0.17	0.11	0.06	0.05	0.05	0.01	0.01
41	5	5.68	2.50	2.50	2.50	2.50	4.46	4.18	2.77	1.76	1.97	1.50	0.66	0.26	0.21	0.19	0.17	0.17	0.15	0.12	0.07	0.04	0.03	0.03	0.01	0
42	5	5.93	2.50	2.50	2.50	2.50	4.47	4.15	2.50	1.57	1.78	1.31	0.53	0.19	0.15	0.13	0.12	0.12	0.10	0.08	0.05	0.02	0.02	0.02	0	0
43	6	2.50	2.50	2.50	2.50	2.50	4.42	4.06	2.40	1.34	1.54	1.10	0.40	0.12	0.10	0.08	0.08	0.07	0.06	0.05	0.03	0.01	0.01	0.01	0	0
44	6	6.32	2.50	2.50	2.50	2.50	4.29	3.88	2.14	1.09	1.27	0.86	0.28	0.07	0.06	0.05	0.04	0.04	0.03	0	0	0	0	0	0	0
45	6	6.39	2.50	2.50	2.50	2.50	4.03	3.58	1.80	0.82	0.97	0.63	0.17	0.04	0.03	0.02	0.02	0.02	0.02	0	0	0	0	0	0	0
46	6	2.50	2.50	2.50	2.50	2.50	3.60	3.13	1.41	0.55	0.67	0.40	0.09	0.01	0.01	0.01	0.01	0.01	0.01	0	0	0	0	0	0	0
47	6	2.50	2.50	2.50	2.50	2.50	2.97	2.50	0.98	0.30	0.38	0.21	0	0	0	0	0	0	0	0	0	0	0	0	0	0
48	6	5.14	2.50	2.50	2.50	2.50	2.37	2.14	1.72	0.57	0.13	0.16	0.08	0	0	0	0	0	0	0	0	0	0	0	0	0
49	6	3.79	2.50	2.50	2.50	2.50	1.31	1.17	0.88	0.23	0.03	0.04	0.02	0	0	0	0	0	0	0	0	0	0	0	0	0
50	6	2	2.50	2.50	2.50	2.50	0.40	0.36	0.24	0.05	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
51	6	0.4	2.50	2.50	2.50	2.50	0.03	0.02	0.01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
52	6	0	2.50	2.50	0.20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Smart market for nutrient runoff



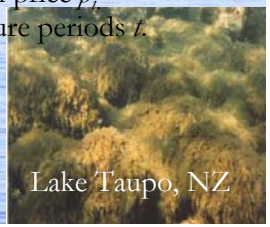
Lots of research, no smart markets.
Fox River market failed due to transaction costs.

H_{ijt} = ↑ conc. at control pt j, time t, per user i discharge.
Lots of research.

Prabodanie, Raffensperger & Milke 2008

1. Max $\sum_i (buy_i PB_i - sell_i PS_i)$,
2. Bids: $buy_i \le MaxBuy_i$, $sell_i \le MaxSell_i$, for all i.
3. Rights: $discharge_i = InitialPermit_i + buy_i - sell_i$, for all i; dual price p_j
4. Sustainability: $\sum_i \sum_{u=1}^{t} H_{ijt} discharge_i \le S_{jt}$, for all j, all future periods t.
5. $Q_i, B_i, S_i \ge 0$.

Point + non-point sources.
Wetland: $H_{ijt} < 0$. Hey, Urban & Kostel 2005.



Impervious cover

Southwest Activity Center, Volisia County, Fla

Urban development → increased runoff → flooding + erosion.
Research says use BMPs, which ignore $. **Hardin 1968.**
Walls & McConnell 2004, Parikh et al 2005:
Impact fees – litigious. Tradable dev. rights – **high trans. costs**.

Buy & sell land-type area.

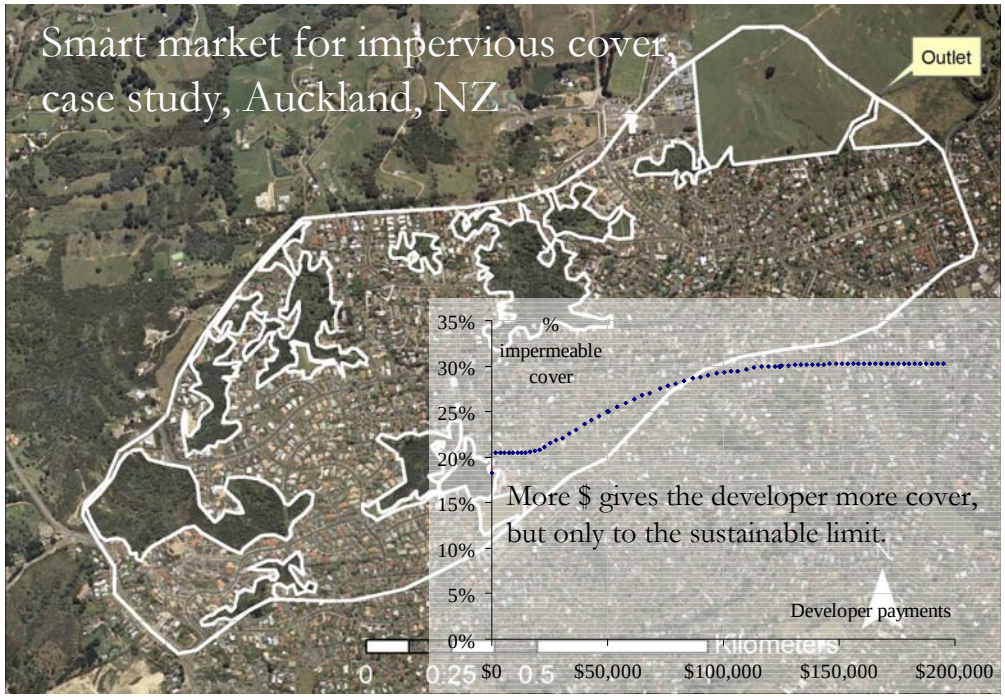
Raffensperger & Cochrane 2008

Q_j = current level of runoff from owner j.
$F_l(CN_{lk})$ = effect on channel flow, control point k, h units area, land type l.

1. Max $\sum_{h=1}^{H}\sum_{j=1}^{J}\sum_{l=1}^{L}\left(PBuy_{hjl} buy_{hjl} - PSell_{hjl} sell_{hjl}\right)$
2. Bids: $0 \le buy_{hjl} \le A$, $0 \le sell_{hjl} \le A$.
3. Flow control: $\sum_{j=1}^{J}\left(Q_j + \sum_{h=1}^{H}\sum_{l=1}^{L}\left(buy_{hjl} - sell_{hjl}\right)F_l\left(CN_{lk}\right)\right) \le Qmax_k$ for each cp k.

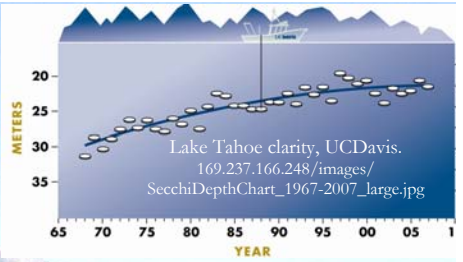
Rent on channel capacity $\sum_k p_k (Qmax_k - \sum_j Q_j)$.

Smart market for impervious cover, case study, Auckland, NZ



Smart market for sediment

From hydrology discharge model,
get impact coefficients $F_{i,k}$
= sediment that reaches control pt k
from land owner i.



- Spreadsheet for users, to compare options & costs, help prepare bids.
- Spreadsheet for the market manager.

Max $\sum_{i \in \text{firms}} \sum_{b \in \text{steps}} \text{Price}_{i,b}\ \text{discharge}_{i,b}$,
$\text{Discharge}_{i,b} \le \text{Demand}_{i,b}$, for each firm i and step b.
$\text{TotalDischarge}_i = \alpha * \text{permit}_i + \text{buy}_i - \text{sell}_i$.
$\text{TotalDischarge}_i = \sum_{b \in \text{steps}} \text{discharge}_{i,b}$.
$\sum_{i \in \text{firms}} F_{i,k} * \text{totalDischarge}_i \le \text{sedimentLimit}_k$.

Pinto, Raffensperger & Cochrane 2008

Gross pool market. Periodic auction, perhaps 4/year.
Future work: combine IC & sediment.

Lake Tahoe

Some current dialog on smart markets

A Combinatorial Auction Mechanism for Airport Time Slot Allocation
Author(s): S. J. Rassenti, V. L. Smith, R. L. Bulfin
Source: *The Bell Journal of Economics*, Vol. 13, No. 2 (Autumn, 1982),

August 5, 2008 The New York Times nytimes.com

Authority to Fight Landing Slot Auction Proposal

"When you get on the ground, you'll have to turn around and go back," said William R. DeCota, the director of aviation for the Port Authority.

Main difficulty: initial rights.
Who owns the landing slots?

September 19, 2008 The New York Times nytimes.com

Private Ownership of Fisheries May Shore Up Stocks

Just *thinking* of "$"
makes people less cooperative!
Vohs, Meade & Goode 2006.

Generalized smart markets for water resources

Max $\sum_i (buy_i PB_i - sell_i PS_i)$,
$buy_i \le MaxBuy_i$, $sell_i \le MaxSell_i$, for all i.
$q_i = Permit_i + buy_i - sell_i$, for all i; dual price p_i.
Aq ≤ Limit. **Sustainability!**

Endangered whooping crane

Reduce costs for business
and force business in aggregate to act sustainably.
General model: use GIS for % green cover, % forest cover, anything that can be simulated.

Recipe:
1. Set initial rights. Hard.
   Manager must adjust initial rights to conditions.
2. Get impact coefficients. Often, already available!
3. Choose env. limits. Loose first, then tighten, like SO2.
4. Write web page, announce auction, run the LP, report the results.
5. Enforce the law. *[End.]*