Optimizing Usage and Transportation of Recycled Water

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Water scarcity is common to vast regions of the world. Growing population in urban areas is a source of waste water which after purification can be recycled into the pipeline network and utilized to irrigate crops. The recycling system has numerous advantages. Its generated flow is relatively robust as its change over time is nearly proportional to the population sourcing it and remains largely unaffected by non-extreme seasonal variations. Its production cost is nearly vanishes as the mandatory acute need to purify and sufficiently displaced from its original generated locality without adversely affecting other areas, must bear the lion share of the cost involved. Ineffective transportation of the recycled water from the purifying Plants into the available storage Pools and from there to the crops irrigating Users may result in unduly transportation cost due to non-optimal routings, penalties paid for spillage to seas or to oceans, and or retributions paid to Users for unfulfilled water quotas.

A generic software package has been constructed to transport the recycled water in optimized effective way, dynamically up to a predetermined planning horizon.

Target System
A whole State or a Region within it defines the Target System. A detailed map determines the exact location of the following Objects:

- Purifying Plants - their location on the map, daily and monthly production over time.
- Storage Pools - their maximum and minimum capacities; Evaporation and Seepage rates.
- Water Wells - source of underground water to supplement surplus in User's demand, as well as to keep the Pools at, or over, their specific minimum level.
- Network of Pipelines interconnecting the above objects. Each pipe is defined by its input and output location, their corresponding relative heights and the pipe's flow capacity.
- Users of water, Recycled or underground pumped, defined by their location and annual and monthly quota rights.
- Set of prices: Electric Energy (3 levels - Peak, Shoulder and Trough defined hours intervals daily); Penalty for Spill-to-Sea; Penalty for insufficient supply to satisfy Users’ quotas. Scarcity price for underground water.

Objective

Minimize Total Cost over time of combined transfers of water from:

- Plants to Pools + Pools to Pools + Plants to Users + Pools to Users +
- Wells to Pools + Wells to Users + Penalties for Plants' Spills + Penalties for Pools' Spills + Penalties for Users' Deficits + Underground Scarcity cost.

Subject to Set of dynamic functional constraints accounting for physical and hydraulic rules imposed.

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Solution Construction
1. Convert the regular map into the program's Object's Scheme.
2. Insert all parameters' value associated with each object.
3. Construct the Scheme. Converting a regular map into Object oriented digitized scheme. This process is followed by the program's generation of 2 sets. Set of functions simulating the water dynamics at each Object. A matrix of parameters defining all conditional constraints.
4. Run the Minimum cost algorithm to generate all individual (conditional) transfer costs from any point i to any point j.
5. Run the Multi-stage N-dimensional Dynamic Programming to obtain the multi-periods solution up to the user's defined Planning Horizon.

Implementation
The region lies between Israel's Tel-Aviv North to Haifa South has been modeled into the above mentioned program. Each run is performed for two time frameworks:
A. Monthly - for moving 36 months ahead.
B. Daily - for next month.

Results and Conclusions
Optimal water transactions from each object to any object are generated, subject to the Scheme's pipeline network connections. Reports translate these transactions to real world water transfers. Significant savings in total cost of transportation is achieved. A complete set of pipelines optimal capacity is generated as suggestions for improvements. Total penalties reduced. A convenient way to tradeoff underground water utilization with some of the recycled water remaining unused in remote pools to save some cost of transportation. This tradeoff is a policy tools conveniently managed by the Scarcity Value parameter.
These results and conclusions will be presented.