INTEGRATED WATER SUPPLY AND WASTE DISPOSAL IN THE COASTAL ZONE AND THEIR IMPACT ON COASTAL ECOSYSTEM

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1. Introduction

It is estimated that 1370x1015m^3 of water is available on earth but 97.3% of this is salt water, 2.1% is snow or ice and only 0.6% (8.2x1015m^3 only) is available as fresh water. When it is considered that 98% of this 0.6% is ground water, of which half occurs at a depth of more than 800 m below ground level (where its salt content is high and in nearly all cases recovery is too expensive), it will be clear that the available freshwater on earth is indeed a precious commodity (Huisman and Olsthoorn, 1983). This realisation does not, however, limit man's ever-increasing quest for fresh water. Having used and abused the easily available water sources for years, he has now been forced to think in terms of using some unconventional sources like sea water and reclaimed water from wastewater, for meeting his ever-growing demand. The reclamation of water from wastewater would appear to hold promise and indeed become inevitable for meeting man's future water demands.

2. Artificial Recharge of Aquifers

The potential of recycle and reuse of wastewater has been demonstrated extensively in industry-based applications and, to a smaller extent, in community-based applications. One outstanding case of a community-based application could be the management of water supply and waste disposal facilities for a coastal town. Lack of surface water sources and limitations in using ground water sources make the water supply problem very acute in such areas. Take, for example, the towns and villages of the southern coastal districts in Tamil Nadu state. Being a rain-starved area, surface water sources are scarce in Ramanathapuram District for meeting its water demand. Wells are the only source of water and they do not get recharged adequately because of inadequate rainfall. There is thus the potential for salt water intrusion into freshwater in many places in the coastal zone of the district. Artificial recharge of aquifers in such areas may be of help in preventing the negative effects of lowering of ground water table, such as the salt water intrusion. In the management of water resources, artificial increase of surface water entering an aquifer is a feasible option to allow a larger rate of ground water abstraction. This option is relevant in the context of: (a) water quality considerations, (b) storage, (c) transportation and (d) maintenance of ground water levels and disposal of unwanted waters (Huisman and Olsthoorn, 1983).

3. Impact of over-extraction

With increasing usage of ground water as a primary or supplemental source in water supplies for agricultural, drinking and other purposes, the concept of 'optimal' extraction assumes great significance. Coastal aquifers are already being developed and increasingly brought to use in India. In such aquifers, the problems attendant with over-extraction, if any, could manifest in several ways: higher unit costs of ground water supply, reduction of seepage and surface fresh water resulting in drying up of streams and lakes, salinity intrusion, alteration of salinity regimes in bays and estuaries, loss of recreational and fisheries resources, and land subsidence, to name a few.

In certain coastal regions of the U.S.A., artificial recharge of the aquifers with (treated) used ground water has been endorsed by planners, policy makers and public bodies as an important device in the management of their total water resources; steps towards its implementation were initiated long ago. The example of Long Island in the state of New York is a case in point (Nassau-Suffolk Regional Planning Board Report, 1973; McGuinness and Pitchai, 1972). A brief summary of the Long Island example which follows illustrates the genesis of the Long Island problem, structuring of solutions and assessment of ground water management methods; the experience from such a planning example has the potential for widespread application.

4. The Natural Hydrologic System of Long Island, U.S.A.

A vast 60-trillion (US) gallon aquifer system, a highly simplified cross-section of which is depicted in Fig.1, underlays Long Island on the eastern seaboard of the United States (McGuinness and Pitchai, 1972). Nassau and Suffolk counties of New York State, which tap these aquifers for their water supply, account for 86 per cent of Long Island's total land area.

The total precipitation in the bicounty water budget area averages about 1600 mgd. A quantitative representation of the aquifer recharge and discharge processes is contained in Fig. 2 (McGuinness and Pitchai, 1972). It can be traced that

* Nearly half the total precipitation falling on the water budget area returns to the atmosphere as evapo-transpiration, primarily from the land surface;
* Nearly a quarter enters the sea as surface flow, essentially as baseflow of streams; and
* Over a quarter is discharged to the sea as underflow from the aquifers.

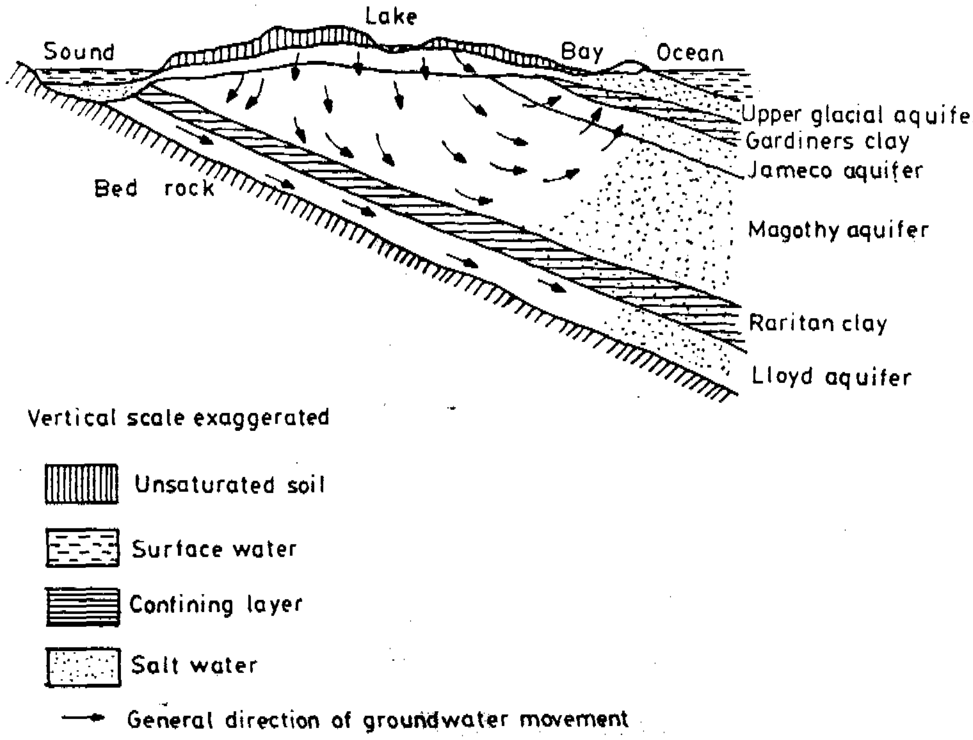
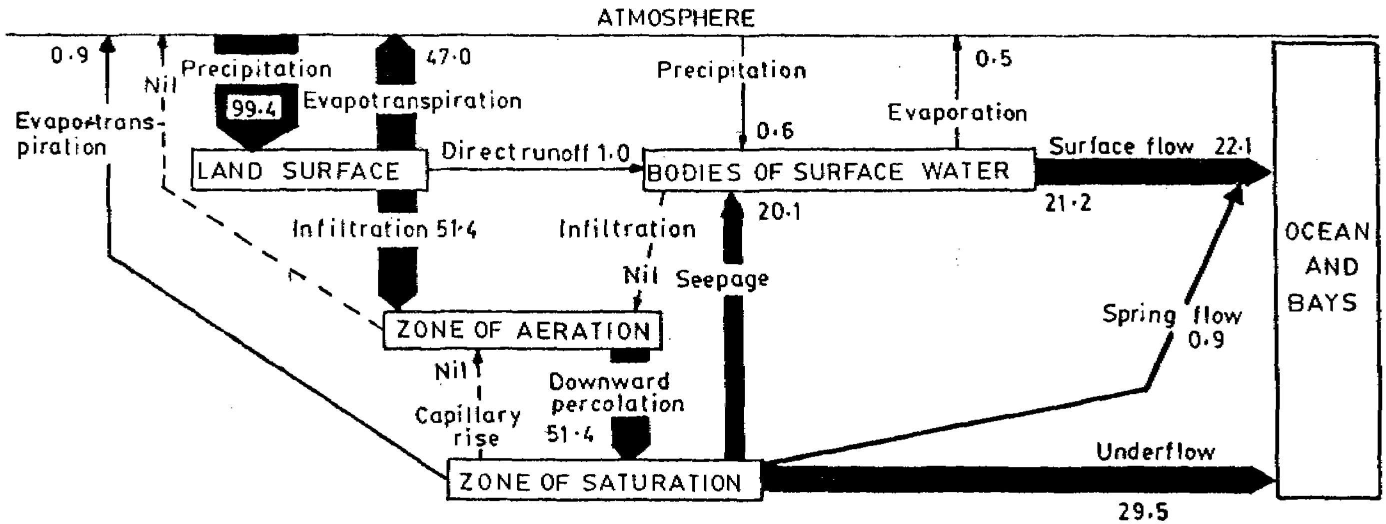


FIG. 1 LONG ISLAND AQUIFERS (after McGuinness and Pitchai, 1972)

5. Man's Perturbations on the System

An accounting of man's use of water in the bicounty area in 1972 showed that about 314 mgd of water was pumped from the aquifers. 55 per cent of total pumpage was eventually recharged to the aquifers, principally as wastewater from cesspools and as stormwater infiltration from specially provided recharge basins. The remaining 45 per cent represented consumptive losses: 19 per cent to atmosphere by evapotranspiration and 26 per cent to the bays and ocean through sewer outfalls. It was estimated that instead of the large-scale use of cesspools for wastes disposal in eastern Long Island, if the entire area were sewered and ocean outfalls were used, the consumptive losses would rise to over 85 per cent (McGuinness and Pitchai, 1972). In other words, the recharge of the aquifers would shrink from the then prevailing 55 per cent to an estimated 15 per cent. The anticipated consequences, both short-term and long-term, of such a drastic reduction in recharge led resource planners and managers in the bicounty region to seriously examine, among others, the following important alternatives and effects:

* The feasibility of intercounty transfer of water and of importing water form the adjacent New York City systems;



Numerical entries represent average flow in percent of total precipitation:

"nil" indicates negligible amounts

Total inflow	:	100.0% in precipitation
Total inflow	:	48.4% in evapotranspiration to atmosphere
		22.1% in surface flow to ocean
		29.5% in underflow to ocean
		100.0%

FIG.2 FLOW DIAGRAM OF THE HYDROLOGIC SYSTEM, WATER BUDGET AREA, UNDER NATURAL CONDITIONS

* The feasibility of treating wastewaters collected by the sewers and recharging the effluent through

  stormwater basins,

  injection wells,

  spray irrigation, and

  direct discharge into surface waters; and

* The effects of greatly lowered ground water levels on

  saltwater intrusion,

  bay salinity regimes and marine ecosystems, and

  the economic and recreation potential of the fresh and marine waters, and potential land subsidence.

6. Study of Integrated Water Supply and Wastewater System Alternatives

A state-of-the-art review was made of the integrated water supply-wastewater disposal system consisting of eight sequential phases: the acquisition, transmission, treatment, distribution and use of fresh water, as well as the collection, treatment and disposal of wastewater. The most important choices in developing an integrated system emerged as those made for

* The acquisition phase [local groundwater (G) or water imported from New York City (N)],
* The wastewater treatment phase [cesspools (R), secondary treatment (S), or advanced wastewater treatment (A)], and
* The disposal phase [ground water recharge (G) or ocean outfalls (O)].

A total of 16 integrated system alternatives were considered; four dominated the rest. The cost, environmental and institutional characteristics of the four surviving systems are summarised in Table 1. The first letter of each system indicates sources of water (G or N), the second letter indicates degree of wastewater treatment (R, S or A) and the third letter indicates the sink for effluent disposal (G or O).

The first system (NRG) envisioned importing water from New York City and continuing to employ cesspools. Its cost would be about three billion dollars less than the average of the other three. Ground water quality will deteriorate but it is not used for water supply; quantity is not affected. Effects on the aquatic ecosystem would depend on the contaminants leaching into the streams, bays and lakes. Since the ground water would progressively become contaminated, it would not become available to supplement New York City's water during droughts. Lack of general public support for this alternative also weighed with the planners and managers.

TABLE - 1 SURVIVING SYSTEM CHARACTERISTICS

Sl. No.	System	Full System Costs 10^9 $	General Environmental Impacts**			Institutional - political
			Ground water quality	Quality of water supply	Aquatic ecosystem	
1.	NRG	9.7	Acc.	Acc.	Obj.	Dependence on external source
2.	NSO	12.1	Acc.	Acc.	Ben. to Obj.	-do-
3.	GAG	12.9	Acc.	Acc.	Acc.	No problems
4.	GSG	12.9	Acc.	Acc.	Acc.	Intercounty transfer, external land

**Acc. = Acceptable Obj. = Objectionable Ben. = Beneficial

The second system (NSO) also envisioned importing New York City water, but then it included sewers, secondary treatment and ocean outfalls. It costs less than the two other systems by nearly a billion dollars, and ground water quantity and quality were preserved. Because of difference of opinion among scientists and engineers on the marine effects of discharging secondary effluents into the ocean (some held that productivity would increase, others would prohibit any "pollution" of the oceans), the design of the systems was to be flexible to adapt to other modes of disposal such as recharge, if necessary. Interstate and intercounty transfer of water involved in this system could lead to institutional problems; various cost-sharing formulae needed to be devised.

The third system (GAG) envisioned drawing upon the ground water, providing sewers and Advanced Wastewater Treatment (AWT) sufficient to meet ground water recharge standards, and pumping the high-quality effluent to selected inland sites for recharge. This system had the merits of overall environmental acceptabilty and minimal institutional problems because it was self-contained. Also AWT has been evolving from its beginning as an appendage to conventional biological secondary treatment, towards self-sufficient, flexible, physical-chemical systems that could be devised to produce high-quality effluents from raw wastewater of highly varying quality. The technical feasibility of producing a wastewater effluent with

* B.O.D. of less than 10 mg/1;
* C.O.D. of less than 60 mg/1;

* Suspended solids of less than 10 mg/1;
* Phosphorus of less than 1 mg/1;
* Nitrogen of less than 10 mg/1;
* Dissolved solids comparable to supplied water

had already been demonstrated in experimental and full-scale plants. Limited operational experience with large-scale AWT plants, and significant technical problems associated with certain recharge methods such as deep well injection, of course, had to be resolved. Also, the cost of this system would be somewhat uncertain. In spite of its higher cost, the merits of the system led to its public support, and endorsement by planners and managers (Nassau-Suffolk Regional Planning Board Report, 1973).

The last system (GSG) envisions drawing upon the ground water, providing sewers and secondary treatment and recharging the ground water at selected inland sites with spray irrigation of the secondary effluent. There were several large extra costs in the system, including those for land at spraying sites, distribution and spray system, and possible effluent storage. Evapo-transpiration losses could be very significant. Decision on the adoption of such a system anywhere should be based upon a careful technical and economic feasibility study which would also include the possible increase in agricultural productivity.

7. Some Factors in Policy and Decision Making

The discussion illustrates some of the complex issues involved in a typical case of overall integrated ground water management in a coastal zone. The selection of an 'optimal' strategy from those identified would be prominently influenced by the resolution of key technical, economic and social issues. The rational basis for such a resolution would be priority research and data collection aimed at filling identified gaps in knowledge; and, equally significantly, value judgment exercised by the community. The latter involves assignment of relative weights to costs, environmental, technological, and political institutional aspects. In the given example, if preservation and enhancement of aquifer water quality overrode all other considerations, NRG got eliminated (although it was the cheapest) and sewering was required everywhere coupled with ocean outfalls. If overriding institutional problems were associated with regionalizing the integrated system across county lines, NSO and GSG got eliminated from further consideration. If such value judgments outweigh considerations of increased cost, the remaining management strategy of GAG would be selected and a safe, economical, technically feasible way to recharge would be developed and implemented. The preference of Long Islanders for this alternative was reflected in the guidelines developed by the Regional Marine Resources Council in 1973. In the absence of experienced and tried value judgments, a good policy would be to keep several options open, encourage problem-oriented research on a priority basis to sharpen understanding of key decision elements, and use the result in formulating the evolving strategy. In the Long Island example, the comprehensive study of integrated water supply and wastewater disposal resulted in the formulation of 55 key data collection and research projects designed to fill specific gaps in man's understanding of the system (Pitchai and McGuinness, 1972). They were grouped in four priority categories based prinicipally upon the value of the anticipated results to problem solution. The estimated cost of the 55 high-priority projects was in the vicinity of 20 million dollars in 1972, which, when compared with the estimated price tag of 10 to 13 billion dollars for satisfying the water supply and wastewater disposal of the bicounty region around year 2000, was considered a rather small fraction, viz., 0.2 per cent. The return on this investment was very high indeed!

8. Conclusion

Artificial ground water recharge with treated wastewaters, while remaining as an important management option in coastal water supply situations, is not without its own problems. For example, the cost of treating wastewater to recharge standards may be comparatively high, and certain technologies like deep-well injection call for advanced skills. In developing countries such as India, resources are always scarce even for water supply purposes: and wastewater disposal gets a much lower priority. Under such conditions, the pressure is always felt to dump the wastewater in the ocean wherever it is feasible, unmindful of environmental consequences such as

* rendering the coastline unaesthetic and unfit for recreational purposes, and
* damage to aquatic flora and fauna in the coastal waters directly resulting from the pollution,

in spite of the economic damage (loss) that such dumping involves, in addition to environmental degradations. If the recharge of coastal aquifers with treated wastewaters is evaluated in the context of the overall environmental and economic benefits that would accrue, an increasingly greater application for this alternative can be foreseen.

9. References

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