Rainwater Catchment in a Systems Perspective

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The Past, the Present and the Future

Rainwater catchment systems (RWCS) are a primordial technology. Early humankind recognized the merit of impounding rainfall in rock caverns for future needs. The first farmers recognized the merit of situating plots to where runoff could be diverted. Like the log canoe, the woven mat or the clay pot, RWCS were an early step in pursuit of human sustenance.

What is ancient in one respect, however, can remain new in another. RWCS are today employed worldwide for potable and agricultural water supply. Applications abound in both developing and economically advanced nations. RWCS include both low-technology adaptations to traditional dwellings and computerized water harvesting incorporated into modern architecture. RWCS merit consideration as a component of large scale water resource development. In an encompassing sense, RWCS are a robust technology.

While RWCS are prehistoric in use, and current in application, RWCS are yet a challenge of the future. In earlier times, the future was foreseen to herald new resources and noble conditions. Today's future is not so optimistic. Resources dwindle. Needs magnify. To the degree that technology can preserve resources and yet satisfy human needs, technology provides part of the successful route through that future. RWCS represent such future technology.

The Disparity

The RWCS concept ("catch it when it falls, store it, use it when it's needed") is hardly complex. The cost is generally cheap. The product is desirable. One might thus suppose that RWCS implementation would be inherently endorsed. Unfortunately, it appears, simplicity weighs against RWCS in a world that has grown to venerate bigness, sophistication, and hierarchy. Were RWCS to incorporate microchips, high-tech materials, laser beams and a strong role for government, its technical legitimacy would be enhanced. RWCS are not particularly disliked in today's world; RWCS are simply too often either ignored or uncritically dismissed.

Such disparity is unfortunate for many reasons, but one reason is sufficient -- people need the water.

This paper addresses ten challenges, areas in which RWCS need to be better understood and promoted. As these challenges are addressed, RWCS can be appropriately incorporated into the planning and design process and RWCS will be brought to the forefront as a tool of innovative water management.

1. The Conjunctive Challenge

RWCS are a conjunctive water source, complementary with surface or groundwater utilization. A user need not forego pumping from a well, diverting from a stream or taping a public water line because he or she also has a rainbarrel. More than one water source may provide reliable supply and let the user draw upon the least costly alternative.

In ecology, organisms find their niche in the ecosystem. In economics, a firm seeks its niche in the supply sector. Reverse osmosis desalination, wastewater recycling, a billion cubic-meter reservoir and RWCS likewise each has a niche in water provision.

Unlike the desalination, recycling or reservoir, however, RWCS can find multitudes of conjunctive niches in many environments. Unlike the larger projects, RWCS generally have only small economies of scale. Individuals can implement RWCS as cheaply as the government. The RWCS niche is often in the corners, beyond the effective scope of larger projects and authorities.

Water supply problems (like many other problems of development) are best addressed by conjunctive strategies. There is not the "best" fish for the sea. RWCS may rarely in itself satisfy a broad water need, but it may efficiently satisfy the bulk of select particular needs.

2. The Scale Challenge

RWCS are not simply a small-scale water supply alternative. Large-scale solutions in water resources engineering tend to be erroneously thought of as physically large structures -- reservoirs, waterways, levees, treatment plants, etc. If, on the other hand, scale is appraised by impact, large-scale solutions can also be achieved by dispersed, less obtrusive measures. RWCS become a potential large-scale technology for regional water development. In the order of 100,000,000 persons utilize RWCS for water supply. These consumers deserve well thought-out systems, not trial-and-error implementation.

The potentials for both good and bad consequences of rainwater utilization are large. The consequences of under design can be catastrophic. The consequences of over design can impose undue costs on economically marginal communities. To the one who drinks the rainwater, what the rainbarrel provides is no small-scale issue.

On one side of modern technologists are those who equate smallness with unimportance, a hindrance to pursuing a mega-solution. On the other side are those who reject bigness as inhuman, an invitation to disaster. It is time to move past large-scale vs. small-scale divisiveness. RWCS is both.

3. The Pricing Challenge

Classical microeconomic price elasticity of demand is a measure of sensitivity. If price change is positive, consumption response tends to be negative. If water price rises 10 percent and demand falls 20 percent, water demand is said to be elastic. If demand falls only 5 percent (more likely the case), water demand is said to be inelastic. If demand does not change at all, it is said to be perfectly inelastic.

Price elasticity explains how consumers and producers interact until an equilibrium of supply and demand is achieved. Were water just another interchangeable commodity, its price should optimally regulate its allocation. Water development is, however, more than a pricing problem. Water is rarely a good satisfying idealized free market commodity criteria. Some would maintain that pricing is even a counterproductive consideration. None-the-less, water must be priced if the development infrastructure is to be activated.

Water pricing imposes a formidable challenge that must be addressed if RWCS is economically justified. Some price estimates measure effort expended in securing alternative water supply. Women-hours hauling water from a distant source is a classic (and perpetually unsettling) survey. Pipeline cost to remote dwellings is straightforward engineering economics.

Any endeavor to further RWCS development will be enhanced by even rudimentary analysis of the water’s economic value. In the vast majority of cases, the answer falls on the favorable side of RWCS.

4. The Modeling Challenge

Engineers in most nations are computationally and systematically competent. Consumers in no nation, rich or poor, comprehend the analytic basis for much of their infrastructure. The engineers in every society, therefore, shoulder the task of understanding technical complexities. RWCS are complex, analytically paralleling the techniques employed in "bigger" studies. There is no justification for looking at RWCS otherwise. A RWCS sized by a back-of-envelope calculation is like a bridge beam selected by kicking the available stock of steel.

Mathematical modeling is an appropriate technology for insight into complex systems. Reservoirs are modeled. Pipe networks are modeled. Irrigation systems are modeled. A RWCS study that does not use some degree of modeling is suspect.

RWCS computer modeling is straightforward. Realistic simulation is feasible. Computers are an appropriate technology. RWCS simulation is not complex, but it can be lengthy. An 8086 machine is enough to look at the data. Whether it takes 4 seconds or 40 minutes to get useful output is inconsequential.

Modeling reveals the influences of rainfall pattern, catchment area, storage capacity and demand on system performance. The value of such knowledge outweighs the costs of the modeling effort.

5. The Optimization Challenge

RWCS design is an optimization problem in terms of both inputs and outputs. At its simplest, an optimization challenge exists relating the area of the catchment to the volume of the cistern. While a household roof provides a first cut estimate of catchment area, that size is by no means an appropriate size a family. More or less catchment may be needed for reliable and sufficient supply. If less is needed, the design problem may be moot. If more is required, catchment extension may be justified.

Storage volume requirement obviously increases with both the length of dry durations and the assurance expected of the RWCS. The "more is better" approach, however, is fundamentally no more wise than it would be if applied to atomic power. The RWCS challenge relates to the efficient allocation of resources, balancing marginal costs and benefits.

RWCS development should be viewed in terms of optimal investment, determining the system sizes that most efficiently balance the results.

6. The Uncertainty Challenge

Water projects of any scale that work well "on the average" may work poorly in an uncertain world. Rainfall has randomness. Demands have random aspects as well. RWCS analysis can consider such uncertainties.

While few engineers enjoy randomness in their calculations, it is part of good design. Given even a rough knowledge of historical rainfall, the probability of drought over a certain period can be approximated. Unlike flood control, where system design might address some yet-to-be-seen statistical event, RWCS are more likely sized in relation to a weather pattern that occurs perhaps every few years, on the average. Statistically, the challenge is not overwhelming.

Any system carries with it some aspect of risk. Incorporating randomness into RWCS analysis is in effect an up-front admission that the system will not satisfy its demand at all times. This is a failing only if expectations are otherwise. By considering the consequences of uncertain behaviors, RWCS can be realistically understood and appropriately relied upon.

7. The Data Challenge

Rainfall data is nearly always obtainable in some form. Every RWCS project has at least a minimally-literate person in the field with access to a tin can and ruler. Although the resulting rainfall data may be less than rigorous, it is an adequate start. Even if no data has been formally acquired, residents know the weather. If data is missing, a nearby raingage might be employed with some adjustment for topography. Again, even a crude guess is instructive.

One-hundred years of unbroken data can still miss some extreme possibilities. Many substantial water development projects are sized on 20-40 year records. A RWCS can probably be accurately assessed from five years of data, but even a single year's record is likely to provoke useful insight.

Unlike more massive water supply alternatives, RWCS remain relatively expandable over time. If the planning data overestimated the rainfall, RWCS catchment area can be added over time. More than most data in the world, rainfall data is easily taken, estimatable by common experience, and understandable. Data is a small expense for good RWCS development.

8. The Demand Challenge

A RWCS may be sized to provide X liters of water per capita per day, but if water appears to be available, the user may take 2X. If things are looking dry, the same user may take X/2.

Demand is a function, not a number. Demand relates to price, consequence of failure, risk, and human nature. Because the status of a RWCS tends to be immediately apparent to a consumer, and because the consequence of an empty cistern tends to be personal to that consumer, RWCS usage provides a clear view of that function. While water rationing or wasting may have a theoretical basis, the behaviors are best revealed by watching at the tap.

RWCS design can incorporate water demand into analytic consideration not just as a target, but as a function that itself changes with the situation. So doing, the RWCS is better understood in its human dimension.

9. The Impact Challenge

Good RWCS design respects, and should take advantage of cultural, ecological and economic systems. RWCS can be sensitive to such constraints. Conflict between such constraints and RWCS stems from the narrowest imposition of engineering.

There are no compelling reasons why water supply systems must do anything except provide water. Additional impacts are negotiable tradeoffs. Cultural impacts might be good or bad. Disrupting a stable pattern of socializing at the village pump would be unfortunate, but freeing children from water bearing might allow them time for school. Environmental consequences might be good or bad. An open cistern might foster mosquito larvae, but the cistern water may no longer be contaminated with feces. Economics might be good or bad. Subsidized tin roofing for a region may be at the short-term expense of better roads, but the tin roofs might encourage local manufacturing. The challenge of RWCS is not finding the "everything is better" solution, but pursuing possibilities with net-beneficial multi-objective tradeoffs.

Not all RWCS need look alike, use the same materials, satisfy the same cultural constraints, or have the same outcome. An appropriateness of RWCS is, in fact, how different they can be. The differences usually reflect the cultural, the ecological and the economic environments.

10. The Learning Challenge

Good design sharpens both the skill and, perhaps what is more important, the creativity of the analyst. RWCS analysis draws upon, and contributes to, understanding the realities of water supply The engineer becomes more observant, less prone to unquestioningly rely on the computer screen. Good design is fun. To make things that work is not the goal of engineering. To make things that work well is.

RWCS work is satisfying because it makes a difference. It is vital and engaging. The challenge makes it worth it.

Summary

Systems challenges cannot be resolved in isolation. Investigators must draw upon ongoing developments in engineering, the natural sciences and the social sciences. Not only engineers, but also community organizers, health workers, builders, farmers, financiers and educators have roles in defining both the needs and possible solutions.

Were there not RWCS challenges, the critics would be correct: RWCS are just another dated technology in need of retirement. The truth is to the contrary, however: RWCS remain potential water-supply solutions in a diverse systematic perspective.