Planning and Analysis for Water Reuse Projects

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Drought-induced water shortages and concern for long-term reliable water supplies are giving impetus to exploring innovative options for water supply. Water pollution control efforts have made available treated effluent, which can be an economical water supply compared with the increasing expense of developing new sources. Poorly conceived planning efforts, however, often lead to the rejection of worthwhile water reclamation and reuse projects or to the implementation of projects that will not achieve the intended goals. This article discusses the critical planning factors in wastewater reclamation and reuse and presents a systematic approach for the successful implementation of water reuse projects.

Barges run aground on the Mississippi River and emergency water conservation measures enacted in California cities during 1988 were evidence of the worst drought in North America in 50 years.[1] Recycling has often been associated with nonrenewable resources, but it must be recognized that water, although the most renewable of our essential resources, is available in too limited a quantity to be used only once before being returned to the natural cycle.

Long-term trends in water supply and demand have spurred interest in water reuse. Demand often exceeds available, reliable water supplies, even in normal rainfall years, and new supply development is increasingly costly. Considerable investment has been made in treating wastewater, resulting in high quality effluents available for reuse. In some cases, expensive advanced wastewater treatment facilities can be avoided through reuse. Nevertheless, local conditions must be analyzed carefully to determine whether water reclamation and reuse is appropriate for a particular wastewater and water resources system.

A common misconception in planning for wastewater reuse is that reclaimed water represents a low-cost new supply. This assumption is generally true only when wastewater reclamation facilities are conveniently located near large industrial or agricultural users and when additional wastewater treatment is not required. The distribution system for reclaimed water represents the principal cost of most proposed reuse projects. Recent experience in California indicates that approximately $3 million in average capital cost are required for each 1,000 acre-ft/year (1,233 ML/year) of reclaimed municipal wastewater made available for reuse. Assuming a facility life of 20 years and a 9 percent interest rate, the amortized cost of this reclaimed water is around $300/acre-ft ($243/ML), excluding operation and maintenance (O&M) costs.

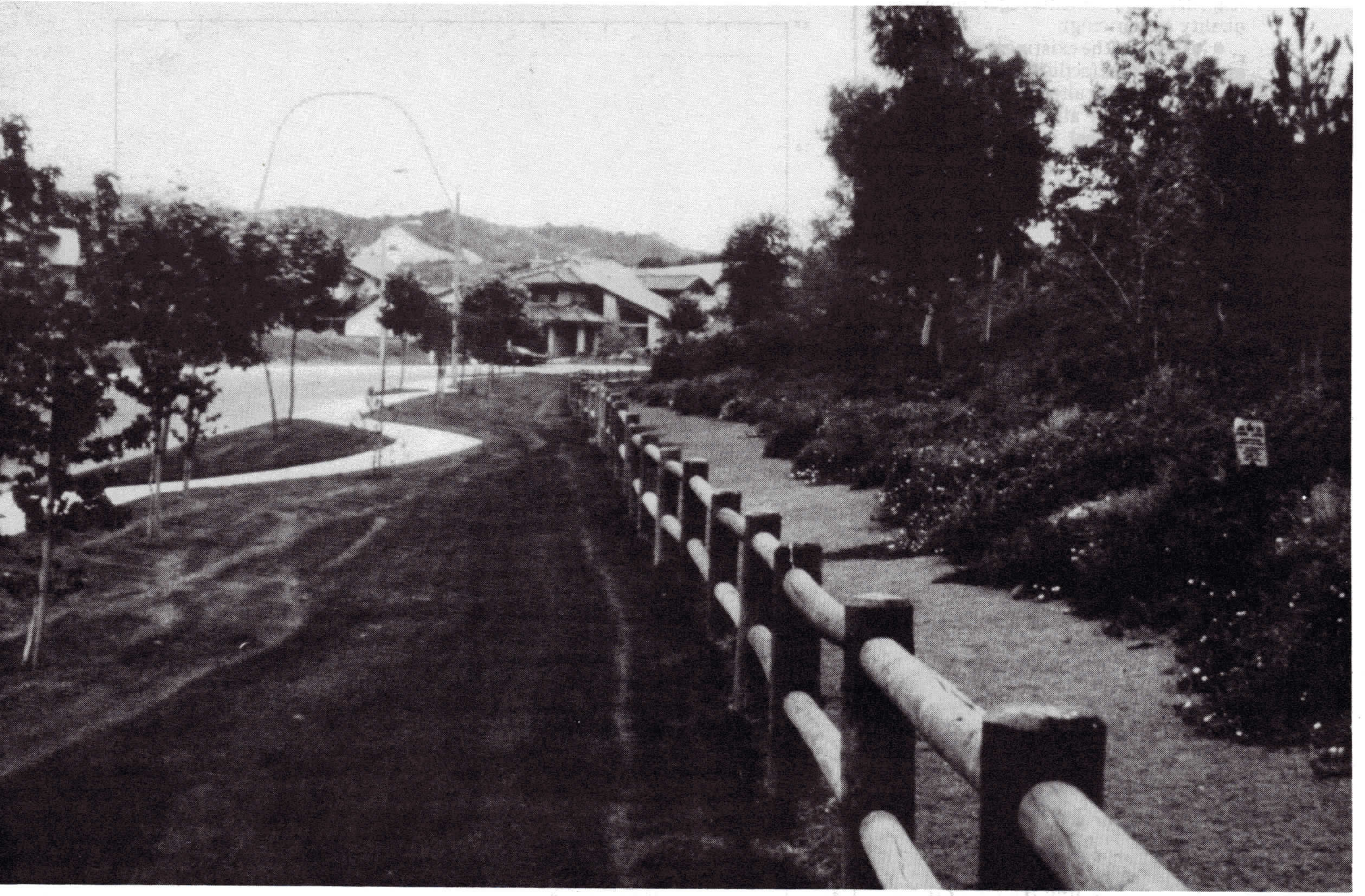
Walnut Valley, a suburb of Los Angeles, began using reclaimed water on parks and schoolyards in 1986.

For most of this century, wastewater was reused primarily as a low-cost treatment and disposal method by utilizing land application, especially in rural areas where land is easily accessible. The role of reclaimed water in water supply has become much more important in the last decade. Although a wastewater reclamation and reuse project may be justified on the basis of being the least-cost alternative to other water pollution control projects, it is more likely to be justified by taking into consideration the costs of developing alternative, new freshwater supplies. The optimum water reclamation project is best achieved by integrating both wastewater treatment and water supply needs. Thus, facilities planning for wastewater reclamation and reuse should consist of the following:

- wastewater treatment and disposal needs assessment,
- water supply and demand assessment,
- detailed reclaimed-water market analyses,
- engineering and economic analyses of alternatives, and
- an implementation plan with financial analyses.

Planning basis

Having clearly defined objectives is essential for rational project planning. The typical framework for analysis is first to establish whether a project is



The first customers in Walnut Valley to use reclaimed water were farmers, but with the shift to urbanization, the predominant use has changed to landscape irrigation.

intended as primarily single or multipurpose, i.e., to serve two or more basic functions. Generally wastewater reclamation projects serve the functions of either water pollution control or water supply. Because most public works agencies, or subdivisions of agencies, are established as single-purpose entities, planning for wastewater reclamation projects is usually initiated with a single purpose in mind. For example, one city wastewater department may be confronted with the need to meet upgraded effluent discharge permits and investigates wastewater reclamation and reuse as one of several pollution control options. On the other hand, a water department may be faced with a falling groundwater table and view wastewater reclamation and reuse as a means of supplementing water supply.

Two recent trends in the United States should change the prevailing view of wastewater reclamation and reuse projects as single-purpose options.

- Standards for the discharge of wastewater are becoming increasingly more stringent.
- Freshwater resources are becoming increasingly stressed to meet growing water demands.

Many projects originally intended to be single-purpose inevitably have spillover benefits. If the multiple benefits and beneficiaries were recognized at the outset, planners could take advantage of additional available options such as sharing project responsibility and costs and achieving the optimum balance of benefits (i.e., realizing maximum net benefits). The point of emphasizing the multipurpose concept is that the traditional perspective of a single-purpose agency and funding program is often outmoded, not to mention a disservice to meeting the increasingly complex needs of an environment-conscious society.

The project study area is another critical planning issue. The typical approach is to equate the study area with the project sponsor's jurisdictional boundaries, but this approach can have serious pitfalls. The project study area should include all of an area that can potentially benefit from water reclamation and reuse of effluent from a particular wastewater treatment plant. Because water supply is typically dependent on water resources outside the project study area, it is essential to look beyond the local area to obtain an understanding of the water resources situation. For example, the effects of overdrafted groundwater basins may be felt by communities many miles beyond the local area. Thus, implementing water reuse in the project area could result in a water supply savings in another.

Planning for water reuse typically evolves through three stages: (1) conceptual level planning, (2) preliminary feasibility investigation, and (3) facilities planning.

During conceptual planning, a potential project is sketched out, rough costs are estimated, and a potential reclaimed water market is identified. If the concept appears worthwhile, a preliminary feasibility investigation takes place, which consists of:

- performing a market assessment, i.e., identifying a market for reclaimed water and determining the conditions that must be met to serve that market (e.g., user requirements regarding water quality and pricing);

- assessing the existing water supply and wastewater facilities and developing some preliminary alternatives that could serve portions or all of the market and meet its technical and water quality requirements;
- developing or identifying the alternative nonreclamation facilities, such as wastewater treatment for stream discharge or constructing a reservoir for water supply, with which to compare a wastewater reclamation and reuse option; and
- performing a preliminary screening of water reclamation alternatives to consider technical requirements, economics, financial attractiveness, marketability of reclaimed water, and other constraints, such as health protection.

Based on the preceding preliminary feasibility investigation, if wastewater reclamation and reuse appear viable and desirable, then detailed planning can be pursued, refined facilities alternatives developed, and a final facilities plan proposed.

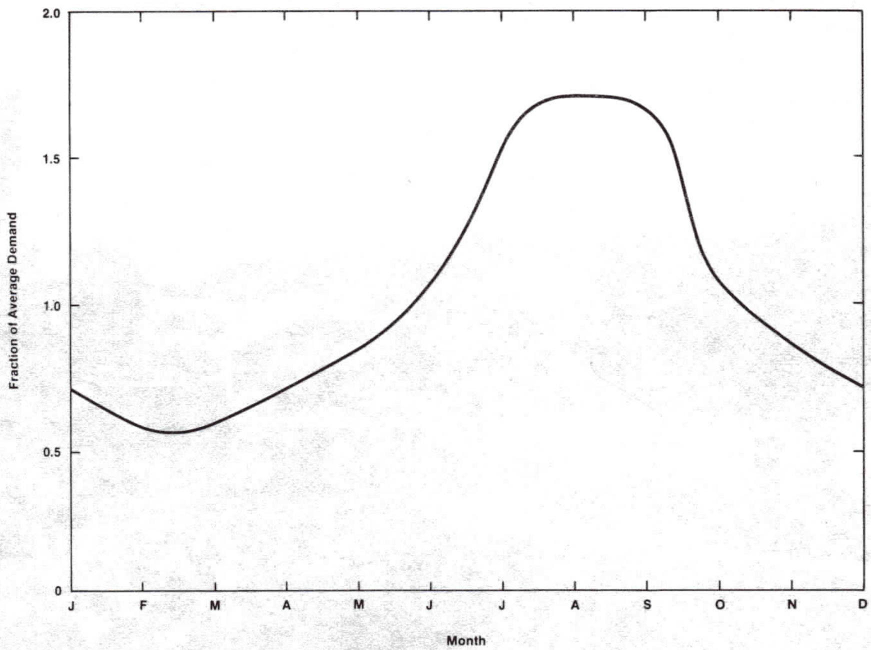


Figure 1. Seasonal demand for reclaimed water as seen in landscape irrigation

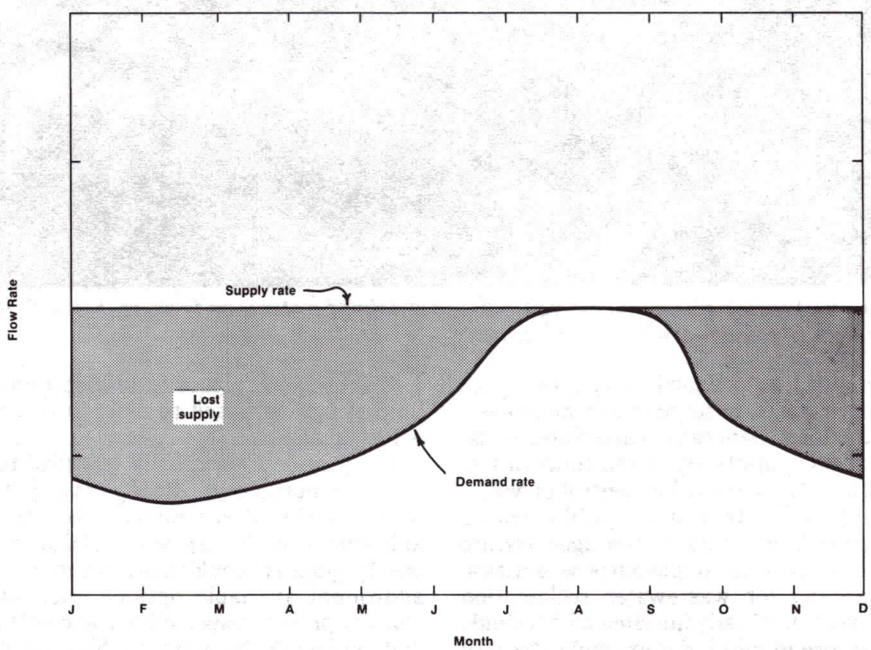


Figure 3. Supply and demand for reclaimed wastewater without seasonal storage

Market assessment

A key task in planning a water reclamation project is to find potential customers who want and know how to use reclaimed water. The approach to take in marketing the reclaimed water depends on two factors.

- Project purpose: Is the intent solely to treat and dispose of the wastewater or also to obtain optimum water supply benefit?
- User option: Will the use of the reclaimed water be on a voluntary or mandatory basis?

If the primary purpose is to treat and dispose of wastewater on land, then planners usually seek land application sites where water can be applied at high rates, usually in excess of optimum crop uptake rates, at the least cost. Unless the system is designed with backup wastewater disposal methods, users will have to make a long-term commitment to accept the treated effluent and may not have full control over the quantities of water delivered. If users cannot be found to accept treated effluent on a voluntary contractual basis, the wastewater agency will have to purchase wastewater application sites and apply the water or lease the land to a private farmer.

Projects designed with the primary purpose of water supply can usually be operated more flexibly if an alternative disposal method, such as stream discharge, is available for disposing of effluent that cannot be reused. The reclaimed water can be marketed on a voluntary basis. If water supply is critical, however, the managing agency may choose to impose the use of reclaimed water in place of freshwater where it is safe to do so.

Whether a user is capable of using reclaimed water depends on the quality of effluent available and its suitability for the type of use involved. Willingness to use reclaimed water depends on whether use is voluntary and, if so, on how well reclaimed water competes with freshwater with respect to cost, quality, and convenience. It is essential to have a thorough knowledge of the water supply situation, especially if reclaimed water is to be marketed on a voluntary basis.

The market assessment consists of (1) determination of background information and (2) a survey of potential reclaimed-water users and their needs. The steps to gathering information and conducting a survey include:

- Inventory potential users and uses of reclaimed water.
- Determine health-related requirements regarding water quality and application requirements (e.g., treatment reliability, backflow prevention, use-area controls, irrigation methods) for each type of application of reclaimed water.

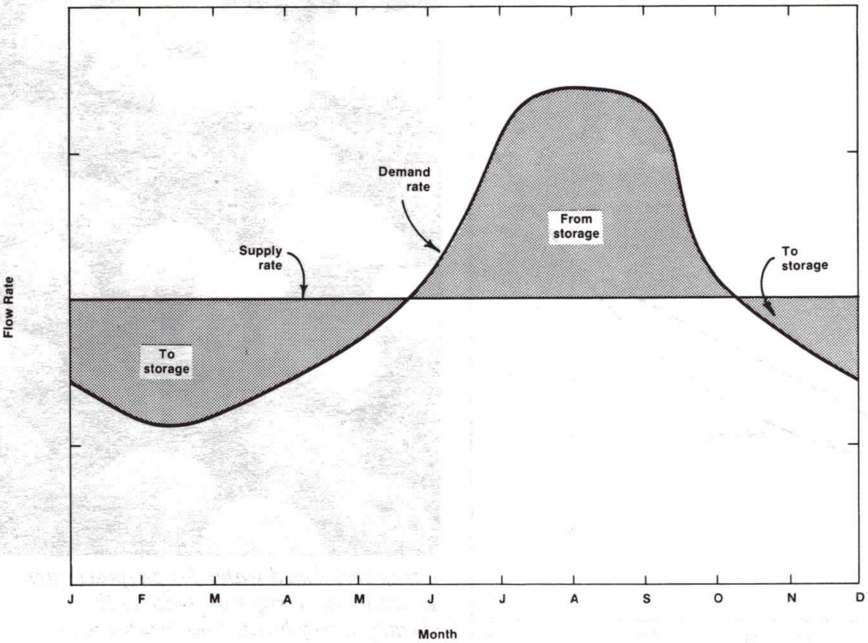


Figure 2. Supply and demand for reclaimed wastewater with seasonal storage

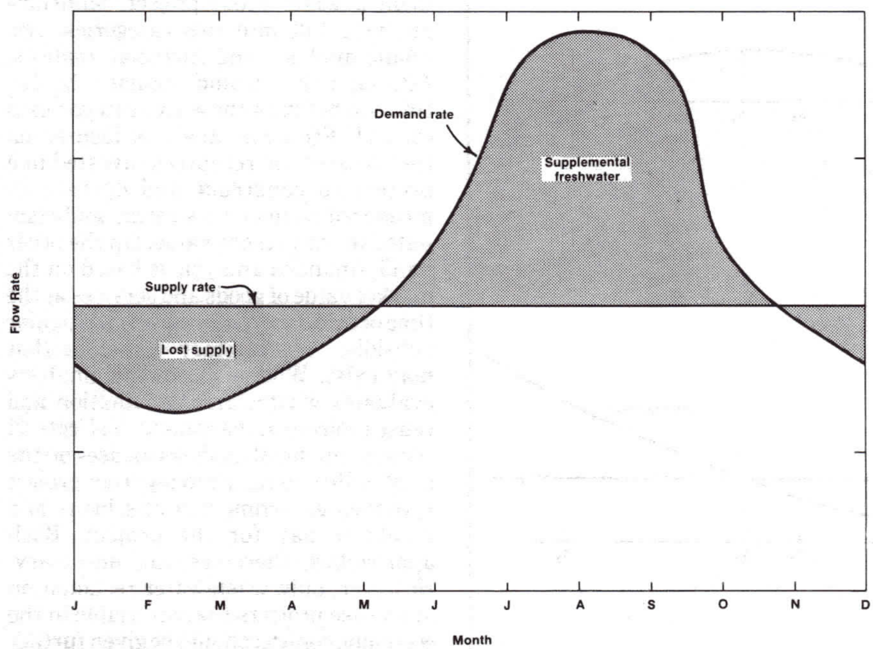


Figure 4. Supply and demand for reclaimed wastewater without seasonal storage, but with supplemental freshwater supply

- Determine regulatory requirements to prevent nuisance and water quality problems, such as restrictions to protect groundwater.
- Develop assumptions regarding probable water quality that would be available in the future with various levels of treatment and compare those with regulatory and user requirements.
- Develop an estimate of future freshwater supply costs to potential users of reclaimed water.
- Survey potential reclaimed-water users, obtaining the following information: specific potential uses of reclaimed water; present and future quantity needs; timing and reliability of needs; quality needs; on-site facilities modifications needed to convert reclaimed water and meet regulatory requirements for protection of public health and prevention of pollution problems from reclaimed water; capital investment requirements of the user for on-site facilities modifications, changes in operational costs, desired pay-back period or rate of return and desired water-cost savings;plans for changing use of site in the future; and preliminary willingness to use reclaimed water now or in the future.
- Inform potential users of applicable regulatory restrictions, probable water quality available with different levels of treatment, reliability of the reclaimed-water supply, future costs, and quality of freshwater versus reclaimed water.

Important water supply information includes a fairly complete background on all of the wholesale and retail water agencies in the planning area, their boundaries, quality of water served, prices charged, and willingness to allow reclaimed-water use in their jurisdictional areas. Because the introduction of reclaimed water could reduce freshwater revenues, at least temporarily, there might be resistance on the part of some agencies to implementing water reuse plans. There should be a willingness to consider the freshwater revenue effects in the analysis, along with appropriate revenue and cost sharing to obtain the full cooperation of all affected agencies.

It is possible to list most of the potential reclaimed-water-use categories in the study area, e.g., landscape irrigation, industrial cooling, irrigation of food crops, without much investigation. On the basis of the use categories, health and water pollution control regulatory authorities should be consulted to obtain their requirements. These would include treatment requirements, on-site facilities modifications (e.g., backflow prevention devices), and use-area controls (e.g., no irrigation in areas of direct human contact). Technical experts, such as farm advisors, can be consulted to determine acceptable water quality for various use categories.

It is then possible to begin identifying and contacting individual potential users of reclaimed water. Access to records of water retailers can be especially helpful. Several years of actual water-use records are helpful to ensure that planners are not misled by data from unusually wet or dry years. It is important to obtain actual prices paid for water or, if a user has its own supply, the user's fixed and variable costs. Potential users should be contacted and the reuse sites visited to determine potential site problems or on-site water system modifications needed to accommodate the use of reclaimed water. These factors have cost implications that must be assessed in the planning stage. The concern, needs, and financial expectations of users must be identified. Group presentations with potential users may be useful for disseminating information and providing technical experts to answer questions.

Monetary analyses

Although technical, environmental, and social factors are considered in project planning, monetary factors usually override other issues when decisions are

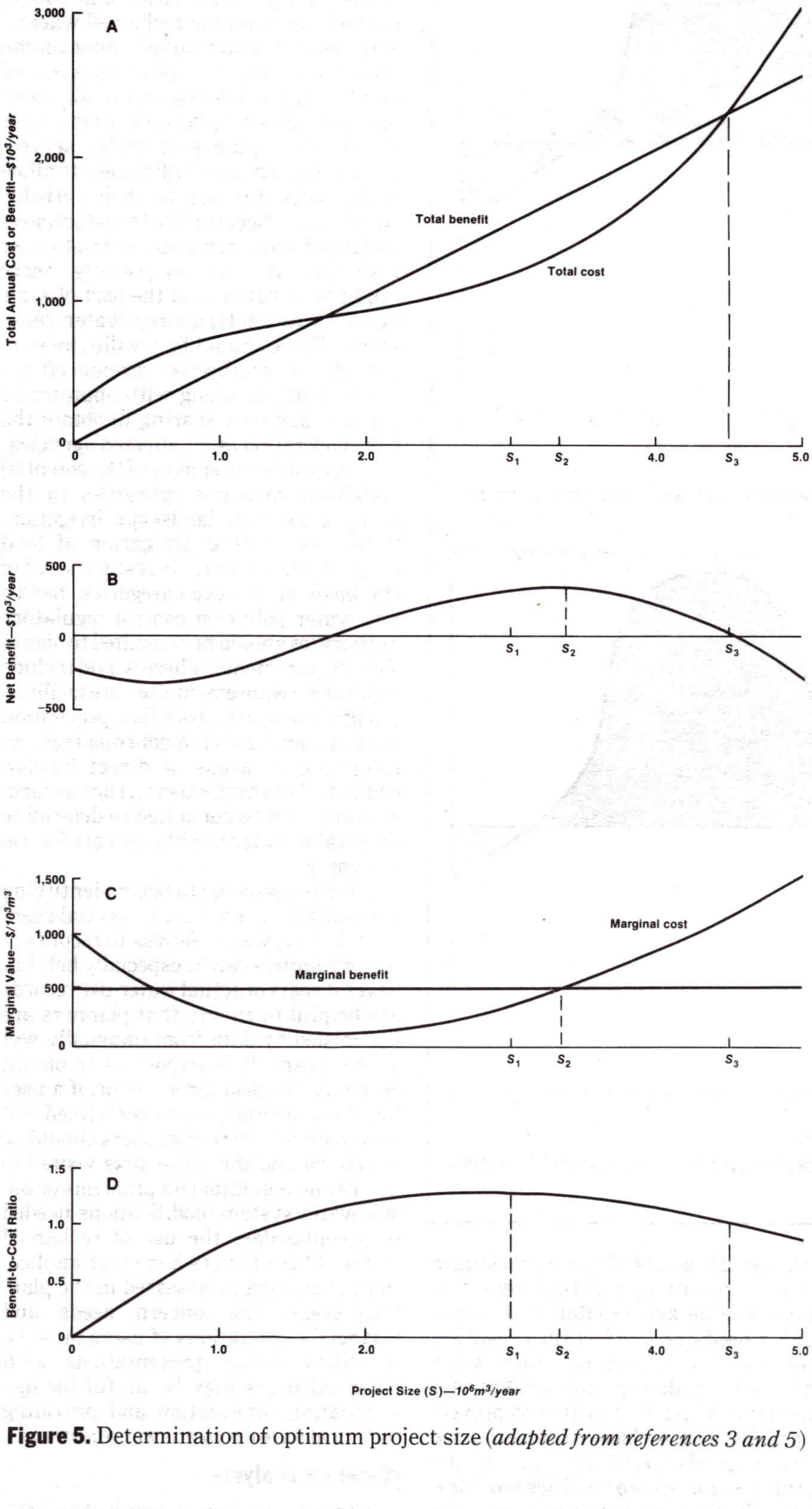


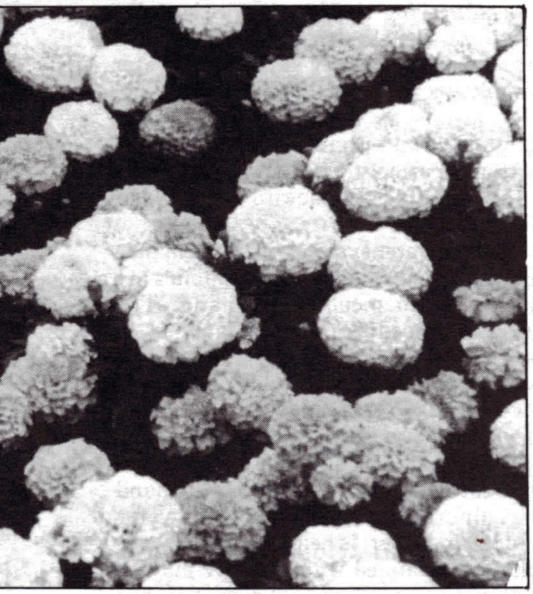
Figure 5. Determination of optimum project size (*adapted from references 3 and 5*)

Using reclaimed water for purposes such as landscape irrigation reduces the already heavy burden on potable water supplies.

made about whether and how to implement a water reuse project. Monetary analyses fall into two categories: economic analysis and financial analysis. Although they sound similar, the distinction between these two categories is critical. Economic analysis focuses on the value of the resources invested in a project to construct and operate it, measured in monetary terms and computed in the present value. On the other hand, financial analysis is based on the market value of goods and services at the time of sale, incorporating any particular subsidies or monetary transfers that may exist. Whereas economic analysis evaluates wastewater reclamation and reuse projects in the context of effects on society, financial analysis focuses on the local ability to raise money from project revenues, government grants, loans, and bonds to pay for the project. Both approaches, therefore, are necessary. However, only wastewater reclamation and reuse projects that are viable in the economic context should be given further consideration for a financial analysis.[2,3]

Economic analysis. The role of an economic analysis is to provide a basis for justifying a water reuse project in monetary terms. A project is considered justified if its total benefits exceed its total costs. If several alternatives can meet the same objective, then the alternative providing the maximum net benefit is the economically justifiable project. Although the benefit-to-cost ratio is a common measure of economic justification, it is not the best measure with which to determine the optimum project size.

An important aspect of the economic analysis is that it takes into consideration all costs and benefits associated



with the alternatives under consideration, placing all alternatives on equal footing for comparison. Also, this analysis is completely independent of financing considerations. To identify all costs and benefits, it is essential to look beyond the boundaries of the agency doing the planning. For example, an agency may be seeking a new source of supply from outside its boundaries. To perform an economic comparison, it would be necessary to identify the construction and O&M costs of this supply.

Another important aspect of an economic analysis is that it considers only the future flow of resources invested in or derived from a project. Past investments are considered sunk costs that are irrelevant to future investment decisions. Thus, debt service on past investments is not included in an economic analysis. A common error in this respect is to confuse the water price with the water cost.

Water price is the purchase price paid to a water wholesaler or retailer to purchase water and usually reflects a melding of current and past expenditures for a combination of projects, as well as water system administration costs, which are generally fixed costs. The only costs of relevance to an economic analysis are those for future construction and O&M. If a water reuse project was compared with a new water supply development, the relevant costs would be the future stream of costs to construct new freshwater facilities and to operate and maintain all of the facilities needed to treat and deliver the new increment of water supply developed. This stream of costs may bear no resemblance to the present or future price, at the wholesale or retail level, charged for water. In contrast, water prices embody debt service on existing facilities, and future projections are an average price to recover costs for both existing facilities and future additions. Typically, the water price will be much lower than the marginal cost of developing a new water supply, because the cost of each new source of supply is increasingly expensive because of inflation and the difficulty in developing new supplies.

Financial analysis. The basic result of the economic analysis is to answer the question: Should a reuse project be constructed? Equally important, however, is the question: Can a reuse project be constructed? The financial analysis addresses the second question, i.e., to determine whether a water reuse project is financially feasible. The project sponsor will need a source of capital and sources of revenue to pay for debt service and operational costs for both the proposed reuse project and any existing facilities. Fixed costs for existing facilities, although irrelevant in the economic analysis, must be considered in a financial analysis if they are a continuing financial obligation. The water reclamation and reuse project sponsor is not the only important party to consider in a financial analysis. Of particular importance is the participation of the user of the reclaimed water. The user will expect the net cost for reclaimed water to be no more than would have been paid for freshwater. For example, a reclaimed-water customer may have to invest in

TABLE 1

Wastewater reclamation and reuse facilities plan outline

Study area characteristics: geography, geology, climate, groundwater basins, surface waters, land use, and population growth.

Water supply characteristics and facilities: agency jurisdictions, sources and qualities of supplies, description of major facilities, water-use trends, future facilities needs, groundwater management and problems, present and future freshwater costs, subsidies, and customer prices.

Wastewater characteristics and facilities: agency jurisdictions, description of major facilities, quantity and quality of treated effluent, seasonal and hourly flow and quality variations, future facilities needs, need for source control of constituents affecting reuse, and description of existing reuse (users, quantities, contractual and pricing agreements).

Treatment requirements for discharge and reuse and other restrictions: health- and water-quality-related requirements, user-specific water quality requirements, and use-area controls.

Potential water reuse customers: description of market analysis procedures, inventory of potential reclaimed water users and results of user survey.

Project alternative analysis: capital and O&M costs, engineering feasibility, economic analyses, financial analyses, energy analysis, water quality effects, public and market acceptance, water rights effects, environmental and social effects, and comparison of alternatives and selection, such as:
- treatment alternatives,
- alternative markets—based on different levels of treatment and service areas,
- pipeline route alternatives,
- alternative reclaimed water storage locations and options,
- freshwater alternatives,
- water pollution control alternatives, and
- no project alternative.

Recommended plan: description of proposed facilities, preliminary design criteria, projected cost, list of potential users and commitments, quantity and variation of reclaimed water demand in relation to supply, reliability of supply and need for supplemental or backup water supply, implementation plan, and operational plan.

Construction financing plan and revenue program: sources and timing of funds for design and construction; pricing policy of reclaimed water; cost allocation between water supply benefits and pollution control purposes; projection of future reclaimed water use, freshwater prices, reclamation project costs, unit costs, unit prices, total revenue, subsidies, sunk costs and indebtedness; and analysis of sensitivity to changed conditions.

TABLE 2

*Comparison of project alternatives for Walnut Valley Water District**

Item	Alternative A	Alternative B	Alternative C	Alternative D‡
New water yield—acre-ft/year†	0	6,160	2,278	
Equivalent electrical energy consumption—kW·h/acre-ft	3,610	1,230	280	3,610
Total net economic cost§—$/acre-ft	286	296	266	448

*Data from Reference 7
†1 acre-ft = 1.233 ML
‡A composite of several major new freshwater developments; the new water yield, not quantifiable for this comparison, would be on the order of several hundred thousand acre-ft/year.
§Engineering News Record Construction Cost Index (Los Angeles) = 3,300 (July 1978)

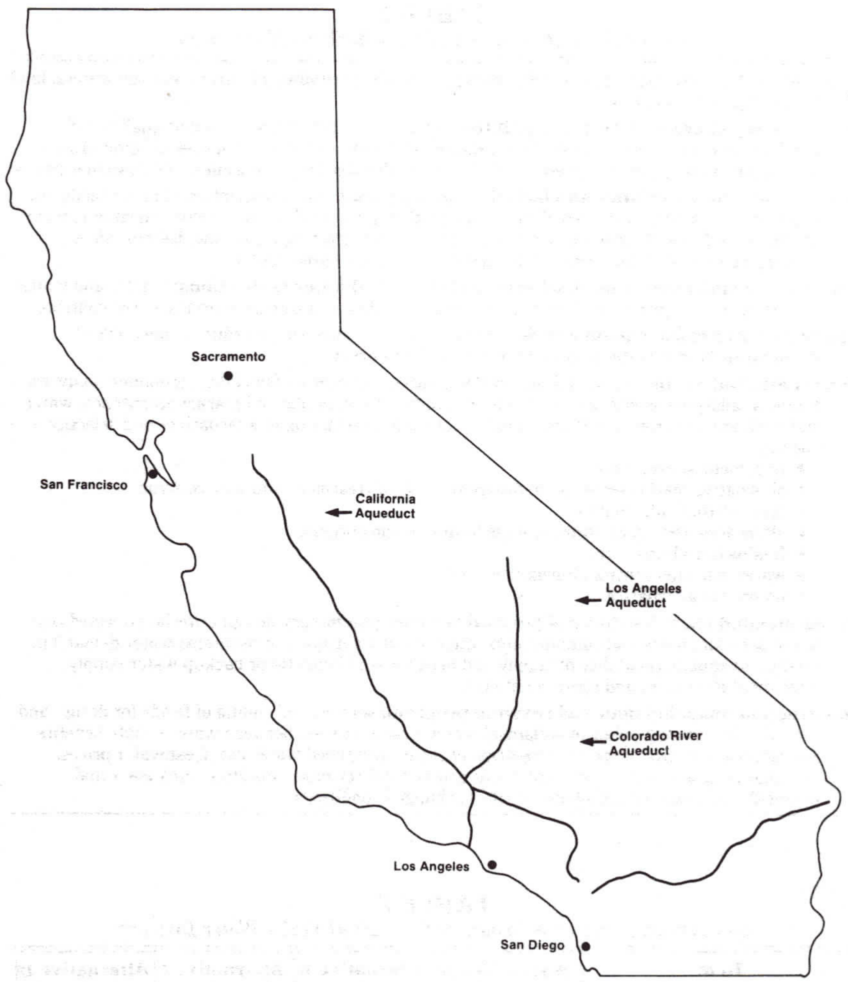


Figure 6. Imported water supplies serving Southern California (*courtesy of Brown & Caldwell*)

piping modifications or a dual water system to accommodate the reclaimed water. Or, a farmer may be able to save on fertilizer costs by taking advantage of nitrogen and phosphorus contained in reclaimed water. A prospective user will expect the difference in price between freshwater and reclaimed water to reflect any added costs or savings.

Because the sale of reclaimed water may reduce revenue from freshwater sale, there may be a need to evaluate the effect on the freshwater retailer and freshwater prices. It may be necessary to allocate some of the reclaimed water revenue to compensate for the freshwater revenue loss. On the other hand, if reclaimed water offsets the purchase or development of more expensive freshwater, then it may be appropriate for freshwater revenue to be used to subsidize the water reuse project.

It is not uncommon for potential users to have different sources of water or different rate schedules. It is important not to assume that there is an average price that all users are paying. Failure to take into account the financial situation of each user could result in the loss of key reclaimed-water customers. The initial market assessment should include this financial data. And finally, there should be flexibility in tailoring a financial scheme to optimally fit each situation.

Other planning factors

A number of factors besides the monetary aspects must be evaluated during the planning for a water reclamation and reuse project, such as environmental effects. Particularly significant factors in project development are related to engineering and public health.

Engineering involves more than distribution system design. A water reuse project is a relatively small-scale water supply project that includes such considerations as matching supply and demand, appropriate levels of wastewater treatment, water storage, and supplemental or backup freshwater supply.

In freshwater systems, water demands are first projected and then supplies are developed to meet the demand. The reverse procedure is often applied in water reuse system planning. The wastewater supply rate is accepted as a given, and the reclaimed-water demand is added to the system until the economic optimum is met. For example, as shown in Figure 1, landscape irrigation demand in California is seasonal. Wastewater supply, however, is nearly uniform year-round. Reclaimed water supply may be sufficient to meet annual demands, but only if seasonal storage is available (Figure 2). But seasonal storage is costly and, in urban settings, extremely difficult to site.

Another option is to include fewer users in the system so that peak demands can be met entirely by the reclaimed-water supply without seasonal storage (Figure 3). This could, however, result in the waste of as much as 40 percent of the reclaimed water. The optimum situation would probably be to add users in excess of supply and meet peak demands with supplemental freshwater (Figure 4). There may still be some supply that cannot be used or economically stored during low-water-demand periods, but this lost supply can be reduced substantially because of the availability of a supplemental supply in the peak season. Some projects have incorporated an added benefit by utilizing a poor-quality water supply unsuitable for potable use, such as an abandoned groundwater basin, to supplement reclaimed water.

Supplemental freshwater can be blended with reclaimed water in the distribution system or on the user's site. Because of public health concerns about potential cross connection or backflow of reclaimed water into potable water supply systems, it may be necessary to provide an air gap between the supplemental water supply and the reclaimed-water system.

Even if supplemental water is not needed to meet demands, there may still be a need to provide an emergency backup water supply during certain periods, such as in the event of an equipment failure. Because a backup water supply would be utilized in place of, rather than simultaneously with, reclaimed water, there are more options for introducing it into the system. With appropriate backflow prevention, the reclaimed water distribution system can be connected to the potable system during the emergency

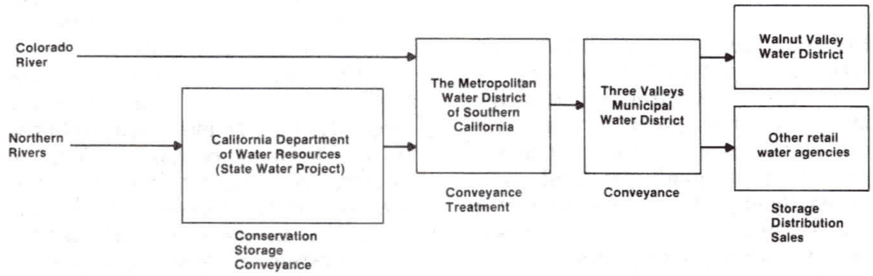


Figure 7. Potable water system structure serving Walnut Valley Water District (*adapted from reference 6*)

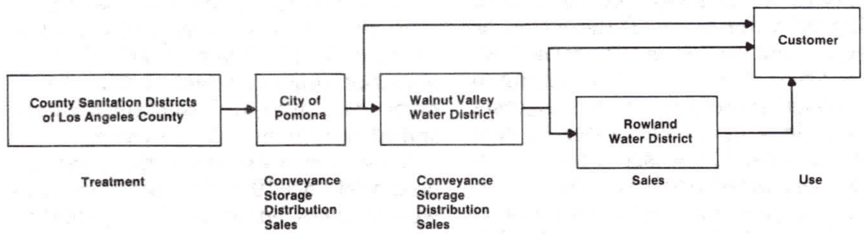


Figure 8. Reclaimed water system structure serving Walnut Valley Water District (*adapted from reference 6*)

period. It should be noted that with the availability of a backup water supply, there is less need for equipment redundancy in the reclaimed water system to ensure 100 percent reliability.

If a significant market could be added by upgrading reclaimed-water quality, project alternatives should be developed for various treatment levels. The levels of wastewater treatment and water quality for landscape and agricultural irrigation uses are normally governed by health-related regulations, though crop sensitivity to effluent constituents such as salts and boron should be investigated.[4] Industrial users will have more stringent physical and chemical water quality requirements that will affect levels for wastewater treatment. Generally, it is impractical to serve more than one quality of water. Thus, the level of treatment provided may be higher than many of the users actually require. If there is a reclaimed-water market for two levels of water quality, it should be considered whether the distribution system can be separated so that the higher and more expensive treatment can be sized to serve only those users needing such higher-quality water.

Figure 5 is a conceptual representation of determining optimum project size in terms of reclaimed-water yield based on the cost of a project and the benefit derived from such a project. Engineering and economics are directly interacting in this analysis, and the objective is to maximize net benefit derived from the project.[3,5] Total benefits and costs, shown in part A of Figure 5, were derived from the economic analysis discussed in the preceding section.

By subtracting total cost from total benefit, the net benefit curve shown in part B of Figure 5 is developed, in which the maximum net benefit point, S_2, is the optimum project size. Another way of depicting the optimum project size is to analyze the marginal costs and benefits. The marginal costs and benefits are the incremental costs and benefits associated with each incremental expansion of the project size, such as adding each additional user (part C, Figure 5). Marginal cost factors include added pipeline to reach each new potential user considered, the added cost of upgraded treatment to add users needing improved water quality, and the variable operational costs. The marginal water supply benefit may be measured as equal to the unit cost of the least-cost alternative freshwater supply, assumed to be a constant value, as shown in part C of Figure 5. At the point at which the marginal cost to add a new user or group of users exceeds the marginal benefit (i.e., S_2), the maximum net benefit has been achieved, and it is not economically justified to expand the project further. The benefit-to-cost (B:C) ratio (part D, Figure 5) can be misleading. The project with maximum B:C ratio, S_1, may not correspond with the optimum project size. The region beyond the optimum size shown in Figure 5, i.e., between S_2 and S_3, still has a B:C ratio greater than 1 and thus appears to be cost-effective. Yet in this region, marginal cost exceeds marginal benefit (see part C, Figure 5). Making decisions based on the B:C ratio alone may lead to uneconomic, oversized projects.

Because of external subsidies or other methods of cost allocation, the project yielding the greatest net revenue may be oversized compared with the optimum size determined in the economic analysis. As long as financial feasibility permits, the economic analysis should govern the size of a project, not the ability to generate maximum revenues.

Planning report

The results of the completed planning effort should be documented in a facilities planning report on wastewater reclamation and reuse. A suggested outline is shown in Table 1, which also serves as a checklist for planning considerations. All of the items listed affect the evaluation of a water reclamation and reuse project at one time or another. Thus, although all of the factors shown do not deserve an in-depth analysis, each should at least be considered. The overall level of detail should be commensurate with the size and complexity of the proposed project. Although the emphasis on the wastewater or water supply aspects will vary depending on whether a project is single or multipurpose, the nature of wastewater reclamation and reuse is such that both aspects must at least be considered.

Even if it is determined that a wastewater reclamation and reuse project is not feasible at the conclusion of the study, it is still advisable to publish the information and data collected and the analyses performed to arrive at this conclusion. Wastewater reclamation and reuse is good public policy in appropriate situations and public interest in recycling water will continue as long as water supply needs are perceived to be critical, such as in drought years. Documentation of even unsuccessful reuse planning is helpful in responding to public inquiry and in developing future planning efforts.

User contracts

Facilities design is the next logical step after a positive recommendation to implement a wastewater reclamation and reuse project. Equally important, however, is securing users to take the reclaimed water. There are two approaches to achieve this: mandatory and voluntary. When the conditions and political climate warrant, and when no harm to the user is considered to be present, some water districts have mandated the acceptance of reclaimed water based on a "waste and unreasonable use of water" doctrine. Usually, however (at least in California), reclaimed water customers are elicited on a voluntary basis.

Before an agency or a sponsor embarks on the significant cost of a water reuse project, it may wish to ensure participation of potential users through contractual agreements. Experience has shown that although potential users quite easily express positive interest in using reclaimed water, they may resist acceptance after the facilities are built. Several reasons for such resistance are (1) the user may be concerned about detrimental effects of reclaimed water on industrial processes, landscaping, or crops; (2) the user may have its own water supply at less cost than either municipal water supply or the offered reclaimed-water price; (3) there may be disagreement over acceptable reclaimed-water price; (4) the user is unwilling to pay or incapable of paying for extra costs for pipelines or on-site water system modifications; (5) the user lies outside of the project proponent's boundaries, requiring negotiations with other jurisdictions; and (6) local or state health departments may disapprove because of health risks. The contract-negotiating process can also be an educational process to win the support and confidence of potential customers and bring out hidden issues much earlier in the project development process.

Some of the factors to address in a user contract are:

- contract duration—term, conditions for termination;
- reclaimed water characteristics—source, quality, pressure;
- quantity and flow variations;
- reliability of supply—potential lapses in supply, backup provisions;
- commencement of use—when user can or will begin use;
- financial arrangement—pricing of reclaimed water, payment for facilities;
- ownership of facilities, rights-of-way—responsibility for operation and maintenance;
- miscellaneous—liability, restrictions on use, right of purveyor to inspect the site.

Contracts need to address the concerns of the purveyor and the user and to clearly establish financial and operational responsibility and legal liability.

Walnut Valley, Calif.: A case study

To illustrate the planning processes, the following case study at the Walnut Valley Water District in California is discussed.[6-8] Parks and school yards began receiving reclaimed water in 1986 from a new 22-mi (35-km) distribution system in Walnut Valley, a suburb of the Los Angeles metropolitan area. The project also features a 4-mgd (15.1-ML/d) main pump station, a 1.4-mgd (5.3-ML/d) booster pump station, and a 2-mil-gal (7.6-ML) reservoir. It is designed to deliver 2,000 acre-ft/year (2,467 ML/year) of reclaimed municipal wastewater and supplemental well water.

The County Sanitation Districts of Los Angeles County are responsible for wastewater management in most of the county. The most economical level of treatment (advanced primary) is permitted by discharge directly to the Pacific Ocean. This involves, however, an extensive system of sewer interceptors that traverse miles of urbanized areas. A series of satellite treatment plants has been constructed to lessen the load on the sewers and increase the opportunities for reuse of the effluent. The Pomona Water Reclamation Plant is in the vicinity of Walnut Valley. Because treated effluent from the plant must be discharged into a river where there is potential human contact, tertiary treatment (consisting of coagulant addition and filtration) must be provided.

Reclaimed water from this plant has been used since 1928. The first customers were farmers, but with urbanization the predominant use has shifted to landscape irrigation. In addition, reclaimed water is used for paper manufacturing. To remove constituents that can discolor paper, activated carbon is used in the tertiary treatment plant.

Walnut Valley Water District, located near the Pomona Water Reclamation Plant, provides municipal water service to a rapidly developing area of 33 sq mi (85 km^2). The water it delivers is imported from the Colorado River and Northern California through a chain of wholesale entities (Figures 6 and 7). Demand for the imported water is nearing the supply capacity, and the potential for shortages is at hand. The Colorado River supply is being reduced as Arizona increases diversions of its share. A political consensus on how to augment California's State Water Project is difficult to achieve. Thus, Walnut Valley Water District investigated using reclaimed water with the hope of finding a lower-cost supply that would be more reliable during times of drought.

The study that resulted in Walnut Valley's water reclamation project began with a comprehensive market assessment. The study area included not only Walnut Valley Water District but also an adjacent district, Rowland Water District. Potential major users of reclaimed water, adjacent to the study area, were also identified. Cooperation of eight retail water agencies was sought, not only to facilitate gathering data, but also to build trust that is essential to constructing a project covering several jurisdictions. After more than 15,000 customer records were reviewed, 52 potential customers were identified.

A premise of Walnut Valley Water District's study was that potential users would be economically motivated to use reclaimed water on a voluntary basis. Even if the district was willing to require the use of reclaimed water in place of potable water within its own jurisdiction, it would be difficult to persuade other participating water retailers to adopt the same policy. Also, some major users operate their own wells and are not dependent on a supplier. Thus, user willingness was a key factor in the market assessment. Potential customers were kept well informed of the study, and each site was visited to identify the on-site customer costs that might be necessary to convert to reclaimed water and meet health requirements.

During the initial determination of potential users, customers were screened by the amount of their water demand. A minimum water demand was established, based on the smallest amount of demand at which it was likely that a customer could recover on-site costs and still achieve an acceptable savings in water costs. The following assumptions were made:

- the maximum achievable savings for the customer from purchase of reclaimed water in lieu of potable water would be $75/acre-ft ($61/ML),
- the expectation of the customer is to recover on-site capital costs within three years at a 15 percent return (based on typical industrial investment criteria of the region), and
- the minimum cost to the customer for on-site costs to convert to use of reclaimed water would be $2,500.

Under these conditions, the minimum demand was set at 1.15 acre-ft (1.42 ML) per month.

From the 52 potential users, a variety of distribution system alternatives could be developed. Because a high level of wastewater treatment was already required for river discharge and for existing reuse in paper manufacturing, it was unnecessary to evaluate different treatment levels. The maximum amount of reclaimed water available for this project was 2,000 acre-ft/year. The maximum project size could be larger if the Pomona treatment plant was expanded, if another treatment plant in the area was joined to the system, or if supplemental freshwater was used to accommodate peak demands. As shown in Table 2, four project alternatives were presented—two water reclamation alternatives and two other alternatives as a basis of comparison.

Alternative A, the "no project" alternative, assumed that neither a reclamation project nor augmentation of imported supplies would take place and the area would continue to rely on the current inadequate freshwater supply. The economic cost of this alternative was the

O&M cost of the most expensive existing water supply serving the study area—the State Water Project. Alternative B would provide maximum reuse in the study area by serving 52 users with reclaimed water from two treatment plants to be able to supply the full demand. Alternative C would provide limited reuse by serving 23 users with reclaimed water from only the Pomona reclamation plant and with nonpotable groundwater as a supplemental supply during peak demand periods. Alternative D consisted of augmentation of the imported freshwater supply, as has been proposed for the State Water Project. New facilities required under alternative D were a reservoir in Northern California and a major new canal. The economic cost of alternative D consists of the construction costs of the new facilities and the O&M costs of existing facilities to transport, treat, and distribute the water to users in Southern California. Several subalternatives to alternatives B and C were also evaluated. It is important to note that there were two objectives for the alternative analyses: to determine whether reclamation and reuse were justifiable as a water supply option (by comparing alternatives B and C to alternatives A and D) and to determine the most cost-effective water reclamation project (by comparing alternative B to alternative C). A few of the more important results of the analysis of alternatives are shown in Table 2. A comparison of the operational energy consumption of the alternatives reveals dramatic differences, with reclaimed water providing significant savings in energy use compared with importing water from Northern California. Also indicated in the table are significantly lower costs for reclaimed water compared with new imported-water sources.

Walnut Valley Water District selected alternative C, limited reuse, for implementation. Alternative B, although economically justified compared with constructing new freshwater facilities, was not selected because many of the potential users were not ready to use or capable of using reclaimed water and because it was inappropriate to implement the importation of reclaimed water from another plant before more studies could be conducted on the best use of effluent from that plant.

Although alternative C was economically justified as a new water supply, it was not financially feasible because existing imported water supplies were relatively inexpensive. The wholesale price that water retailers were paying for imported water was a melding of costs to construct and operate existing water developments. Even after adding local distribution costs, the total cost of the existing freshwater system was considerably lower than the cost of either new freshwater development (alternative D) or new water reclamation projects (alternatives B or C). Potable water prices in the study area at the time were in the approximate range of \$100–350/acre-ft (\$81–284/ML). Further, in order to provide the necessary incentive to achieve voluntary participation in the project, it was necessary to sell the reclaimed water at a price that was 15 percent less than potable water rates and to establish a separate wholesale rate to charge to the Rowland Water District. The financial problem was resolved when a grant from the state of California was provided for 75 percent of the construction costs.

During design of the project, adjustments had to be made to alternative C, based on users willing to provide firm commitments to use reclaimed water. The project is designed to deliver 2,000 acre-ft/year (2,470 ML/year), consisting of approximately 1,850 acre-ft (2,280 ML) of reclaimed water and 150 acre-ft (190 ML) of well water. There are 29 use areas with an annual demand of 1,173 acre-ft (1,447 ML). The project capacity is expected to be reached in five years. All applications are for landscape irrigation, including schools, parks, street and highway landscaping, a cemetery, a golf course, and plantings to stabilize slopes in residential developments. A well is under construction to supplement the reclaimed water during peak monthly demands.

The institutional arrangement for the project is illustrated in Figure 8. Walnut Valley Water District receives the reclaimed water from a pipeline operated by the city of Pomona. The district owns and operates the entire project, but Rowland Water District bills customers within its boundaries. All relationships between agencies and with each customer are firmly established by contracts.

Summary and conclusions

Increasing stresses on freshwater developments and the increasing controls on wastewater discharges have generated interest in water reclamation and reuse. Because water reuse serves the functions of both water pollution control and water supply, planning needs to include consideration of factors related to both.

Although technical, environmental, and social factors are considered in project planning, monetary factors tend to be the pivotal factors in deciding whether and how to implement a water reuse project. Monetary analyses fall into two categories: economic analysis and financial analysis. Other planning factors of particular significance in reclaimed-water project development are engineering and public health. Arriving at the optimum system design involves determination of the marginal or incremental costs of adding additional users and comparing those costs with the marginal benefit. Contracts need to address the concerns of the purveyor and the user and to clearly establish financial and operational responsibility and legal liability.

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