Turner Collie & Braden Inc.

Final Report

FEASIBILITY STUDY FOR THE IMPLEMENTATION OF A WATER REUSE PROJECT IN FAIRFIELD VILLAGE

A STUDY PARTIALLY FUNDED THROUGH
A TEXAS WATER DEVELOPMENT BOARD GRANT

STATE OF TEXAS
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INTRODUCTION

GENERAL

Texas Water Development Board (TWDB) literature reports that Texans used an average of 15.9 billion gallons of water per day in 1980. Projections indicate that water demand may reach 22.7 billion gallons per day by the year 2000 and 27.1 billion gallons per day by the year 2030 unless some forms of water conservation are implemented. By comparison, the State's estimated future, dependable water supply is about 18.7 to 19.0 billion gallons per day of which 4.6 billion gallons is obtained through recharge to the State's aquifers. The TWDB, as well as other State agencies, such as the Texas Water Commission (TWC) and the Texas Department of Health (TDH) recognize that alternative solutions, including water conservation and reuse, must be implemented to ensure future adequate supply.

The Houston, Texas metropolitan area has historically relied on abundant quantities of groundwater to meet water needs. Unrestricted withdrawal has resulted in lower water tables and compaction of underlying clay layers within the aquifers and, subsequently, ground subsidence. In 1985, the Harris-Galveston Coastal Subsidence District (H-GCSD), a special district created by the Texas legislature, adopted and implemented a Regulatory Action Plan that called for the timed conversion from groundwater to surface water in Harris and Galveston counties. The Plan divided Harris and Galveston counties into eight regulatory areas with the intent that, depending on the proximity to the coast of Galveston Bay, the conversion to surface water would be accelerated to reduce land subsidence and the potential damage caused by flooding. In light of these concerns about limited water resources, the effects of subsidence caused by extensive groundwater withdrawal, and changing policy regarding water conservation, alternatives to reliance on groundwater resources in the Houston area merit further investigation. Sharing these concerns, Harris County Municipal Utility District (HCMUD) No. 322 and Harris County Water Control and Improvement District (HCWCID) No. 155, two existing districts within the planning area, in cooperation with the H-GCSD, applied for and obtained a planning grant from the TWDB in November 1989 to partially fund a regional water reuse study to develop and evaluate the potential of implementing a water reuse project in the Houston-Galveston region.

Water reuse, or use of reclaimed, treated wastewater effluent, is not new to the area. In fact, several area golf courses, especially those in the coastal H-GCSD regulatory areas which are required to reduce groundwater consumption to 10 percent of total supply, utilize treated effluent for irrigation to comply with H-GCSD regulations, as well as to reduce the expense of irrigation with potable water. Policies of the TWC and the TDH, until recently, limited the use of reclaimed waters to "restricted access" lands. Golf courses and certain types of agricultural land not utilized for direct food sources are examples of "restricted access" lands. In April, 1990, the TWC adopted new regulations governing the use of reclaimed water. The new rules permit use of wastewater effluent for irrigation of unrestricted access lands such as parks, school yards, and private landscapes.

Use of reclaimed water in unrestricted areas is practiced in other areas of the country where limitations of water supply or stringent wastewater effluent requirements justify the economics of constructing dual distribution systems, that is, provision of separate water distribution systems for potable and non-potable needs. A similar impetus exists in the local area with the impending conversion of potable water supply from primarily groundwater to primarily surface water supply. This study, therefore, has been proposed to investigate the feasibility of implementing a dual use system in the historically water-rich Houston-Galveston area.

PURPOSE AND OBJECTIVES

This study examines the potential benefits of using treated wastewater effluent for irrigation of selected common areas, including the potential for reclaimed water to be used for irrigation, fire protection, and cooling water in residential and commercial areas. Potential lands for irrigation include esplanades, park areas, greenbelts, and homeowner landscapes. The purpose of the study is to determine if such reuses are feasible, thereby reducing the requirement for new groundwater developments. Besides utilizing an otherwise wasted resource, long-term potential benefits include extension of the life of existing or planned supply facilities and reduction or elimination of wastewater effluent discharges to receiving streams. The results of the study apply to all such developments, especially those in areas regulated by the Harris-Galveston Coastal Subsidence District.

STUDY AREA DESCRIPTION

GENERAL

The study area is a proposed community known as Fairfield Village and is located between Cypress and Hockley, Texas, approximately 30 miles northeast of downtown Houston in northwestern Harris County. The area is presented on Exhibit II-1. U.S. Highway 290 bounds the study area on the south, Schields Road on the north, future Grand Parkway to the west, and undeveloped land to the east. The area lies within the Cypress Creek and Little Cypress Creek watersheds. These streams are tributaries to the west fork of the San Jacinto River.

The study area, which encompasses about 2,595 acres, is a master planned development initially opened in 1988, primarily as a residential suburban community of Houston. Proposed development will occur in several planned municipal utility districts.

Water and Wastewater Management Agencies

The planning area includes two existing political subdivisions of the State, a municipal water utility district and a master drainage district, authorized to provide regional water and wastewater facilities. Additional municipal water utility districts are planned. The first created water district, HCMUD No. 322, is currently being developed and is centered around the intersection of Mason Road and Cypresswood Drive. HCWCID No. 155 is the master drainage district for the watershed area which drains to Cypress Creek. In the future, it is expected that a similar drainage district may be formed for areas which drain to Little Cypress Creek.

Two new districts, HCMUD Nos. 354 and 358, are proposed for creation in 1990. Once created, HCMUD No. 358 is planned to be the master utility district for Fairfield; that is, it will plan, own, and operate regional water and wastewater utility facilities and contract for service to its primary municipal utility districts. Exhibit II-2 shows the boundaries of HCMUD Nos. 322, 354, and 358 and HCWCID No. 155.

The existing HCMUD No. 322 and HCWCID No. 155 were created under state law and are authorized as taxing entities by the Texas Constitution. HCMUD No. 322 operates pursuant to Chapter 54 of the Texas Water Code, whereas HCWCID No. 155 operates pursuant to Chapter 51. The districts' powers include the "...control, storage, preservation, and distribution of (their) water and floodwater and the water of (their) rivers and streams for irrigation, power, and all other useful purposes..." They may levy ad valorem taxes and issue bonds to pay for water and sewer facilities. They also have the authority to construct, maintain, and operate water and wastewater facilities. As a by-product of water and wastewater services, treated effluent for irrigation and distribution facilities for such waters are considered within the regulatory jurisdiction of the districts. Since HCMUD No. 358 is to be created under similar enabling legislation, it, too, would be empowered to operate a regional water reuse system.

Regional Water and Wastewater Facilities Planning

Both regional water and wastewater treatment facilities have been proposed and planned for the Fairfield development. The implementation of a water reuse project will certainly alter existing planning concepts, especially the potable water supply and distribution systems. A brief history of the previous planning is necessary to fully understand the nature of these changes. The initial master plan for regional water and wastewater facilities for Fairfield was completed in 1986. The proposed plan called for construction of five independent water plants consisting of separate groundwater wells, ground storage facilities, and booster pumping facilities. Each system was planned to provide average-day and peak-day demand requirements for its respective service area with interconnections opened between systems only on an emergency basis. The individual systems did not require elevated storage facilities as a result of the TDH regulations, the land plan, and the segregation of service areas in effect at the time. Because the service areas and plants were separated, this system has been termed a "decentralized" system. The initial phase construction of Fairfield's first water plant was completed following the 1986 master plan. The existing water plant serves current development and is located in HCMUD No. 322 as shown in Exhibit II-2.

As development in Fairfield continued, the land plan changed and, as a result, the water system master plan was revised in September 1988. The revised plan proposed a regional service area with three remote elevated storage tanks . TDH minimum requirements for elevated storage were recommended with increasing water demands intended to be supplied by both the now partially constructed HCMUD No. 322 water plant and the elevated storage tanks. As planned, each elevated tank will be supplied by an independent water well or pair of wells. In effect, the elevated tanks are proposed as separate water plants and the need for decentralized water plants with booster pump stations is negated. This proposed concept, termed the "centralized" system, is the concept presently being followed to supply potable water demands. To date, no elevated storage facilities have been constructed. Subsequent to the 1988 master water plan update, additional information concerning water use patterns for similar developments in the Houston area has been published. These data suggest that water demand design criteria previously utilized to size the major water supply system components for Fairfield are underestimated. This realization prompted another update to the water system master plan to verify cost-effectiveness of the proposed supply concept. The latest update, completed in June 1990, maintains the centralized system concept, but increases elevated storage volume requirements from the TDH minimum to a volume based on computer modeling to compensate for the expected higher water demands. This latest update and proposed system improvements, therefore, become the basis of comparison for cost-effectiveness of a nonpotable reuse system.

Regional wastewater facilities also are planned for the Fairfield community based on master planning studies. Unlike the potable water system, changing land use patterns have not significantly altered the original layout plans, nor will implementation of a reuse project change the size of proposed facilities.

Topography of the planning area is gently sloping from the northwest to southeast with the exception of that portion of the area that drains northward towards Little Cypress Creek. A single regional wastewater plant, therefore, is planned at a location near the southeast corner of the development as shown on Exhibit II-2. The location is important to the feasibility of water reuse since the regional plant effluent is the proposed source of nonpotable supply. Current wastewater treatment is provided by a temporary plant located on a smaller tract near the regional plant site. These facilities are proposed for abandonment when the regional plant is constructed sometime in 1993.

ENVIRONMENTAL SETTING

Climate

Normal precipitation data for Cypress, Texas, summarized in Table II-1, were obtained from the National Oceanic and Atmospheric Administration climatological data. The average annual rainfall, based on a monitoring period from 1951 to 1980, is 47.24 inches, with the monthly average distribution as shown in the table. The mean net and mean gross annual evaporation are 15.48 inches and 50.1 inches, respectively (Lake Houston data, 37 miles east of Fairfield) from the record period of 1940 to 1987.

In Conroe, Texas, approximately 28 miles northeast of Fairfield Village, the average annual high temperature is 79°F and the average annual low is 56°F. Prevailing winds in southeast Texas are southerly, except for northerly winds associated with winter frontal passage.

Geography and Topography

The study area is located primarily in the Cypress Creek watershed; a section of the north-central study area drains northward to Little Cypress Creek. The topography of the study area is essentially flat to gently sloping (less than ten feet per mile), with the exception of a prominent fault band, the Hockley fault, passing through the site. Its surface expression is a scarp, approximately 40 feet in height, which trends northeastward across the site. The overland slopes through this area are as great as 50 feet per mile.

Soils on the property are classified by the Soil Conservation Service (SCS) as primarily Hockley fine sandy loam or Hockley fine sandy loam with scattered Gessner loam and Gessner complex. Each of these classifications is of a friable, dark grayish brown loam which is fairly common throughout this portion of Harris County. The SCS defines these soils as "C" in the hydrologic soil group.

Surface and Groundwater Resources

The study area lies within the H-GCSD Regulatory Area 8 which does not currently have a specified timetable for conversion to surface water. At present, there are no surface for northwest Harris County's conversion to surface water are presented in the draft "Implementation Plan" completed by the West Harris County Surface Water Supply Corporation (WHCSWSC) in November 1988. The most cost-effective alternative developed in the plan describes completion of surface water supply lines along U.S. Highway 290 by year 2030. The proposed surface water supply source is a surface water treatment plant obtaining water from the Brazos River, approximately 25 miles south of Fairfield. At best, then, surface water availability and conversion is at least 40 years away.

Until such time as surface water becomes available, or alternative water strategies are implemented, all water needs of the study area are reliant upon groundwater resources. The current Fairfield Water Master Plan is based on development of groundwater wells and related facilities to be constructed in phase with planned growth.

LAND USE AND POPULATION PROJECTIONS

Land Use Projections

Detailed master planning and land planning studies provide the basis of land uses for the Fairfield development. Projected development includes single-family, multifamily, commercial, and institutional (parks, schools, churches, and utility sites) uses. Part of the commercial development includes a regional shopping mall planned in the southwest corner of the development. Certain reserves have been set aside as drill sites for possible oil and gas exploration and a significant portion of the area is provided for drainage channel rights-of-way. One impetus for investigating water reuse for the area are special areas planned for manicured landscaping and greenbelt areas for recreation and park access.

Exhibit II-3 presents the projected fully-developed land use plan utilized for prediction of water needs for the study area. Development is expected to occur according to the schedule shown on Exhibit II-4 with discreet areas provided for occupation every few years. Population is expected to lag development by one to two years.

Population Projections

Population projections for the study area and surrounding area were compiled from five available sources. These include the TWDB Water Data Collection, Studies, and Planning Division (September 1988 forecast for unincorporated areas of Harris County), the Houston Water Master Plan (HWMP) for Municipal Demand Area 32, Houston-Galveston Area Council (HGAC) projections for Census Tract 545.01, draft projections for Area 8 developed for the H-GCSD Regulatory Plan Update, and projections provided by the developer, Friendswood Development Company (FDC). Table II-2 and Figure I-1 present a comparison of each source. All of the forecasts project population increases in the region, however, in varying degrees. The HGAC and HWMP projections indicate lesser growth in the area, but these forecasts were developed prior to the announcement of Fairfield's inception and do not account for the development. The TWDB and H-GCSD projections encompass areas significantly larger than the study area and are not sufficiently accurate for site specific projections of population and water needs. For these reasons, the projections provided by the developer, which are based on a detailed land plan, were utilized for developing potable and reclaimed water needs.

The developer expects the study area will be fully developed by year 2012. Populations are expected to stabilize following full development. The developer's population forecasts are based on a housing density of 3.5 persons per single-family connection, consistent with similar developments in the Houston area. Multifamily development is based on a projection of 20 equivalent single-family connections (ESFC) per acre, while commercial and small retail development assumes an allowance of ten ESFC per acre. In master planning for water and wastewater facilities, additional allowances have been provided for miscellaneous categories, such as schools, churches, and parks. Based on the current land use plan, the total projected population for the study area is approximately 25,158 persons. For calculating water demand, this is also equivalent to 12,802 ESFC, or 44,807 equivalent persons. Table II-3 provides a breakdown of the various land uses and equivalent single-family connections used as the basis for system evaluation.

TABLE II-1 - HISTORICAL PRECIPITATION DATA

MONTH	AVERAGE PRECIPITATION (Inches)
January	3.64
February	3.78
March	2.50
April	3.82
May	4.98
June	4.39
July	3.13
August	3.11
September	5.39
October	4.19
November	3.78
December	4.53
Total	47.24

Source: NOAA - Climatography of the United States No. 81 for Texas from 1951 to 1980

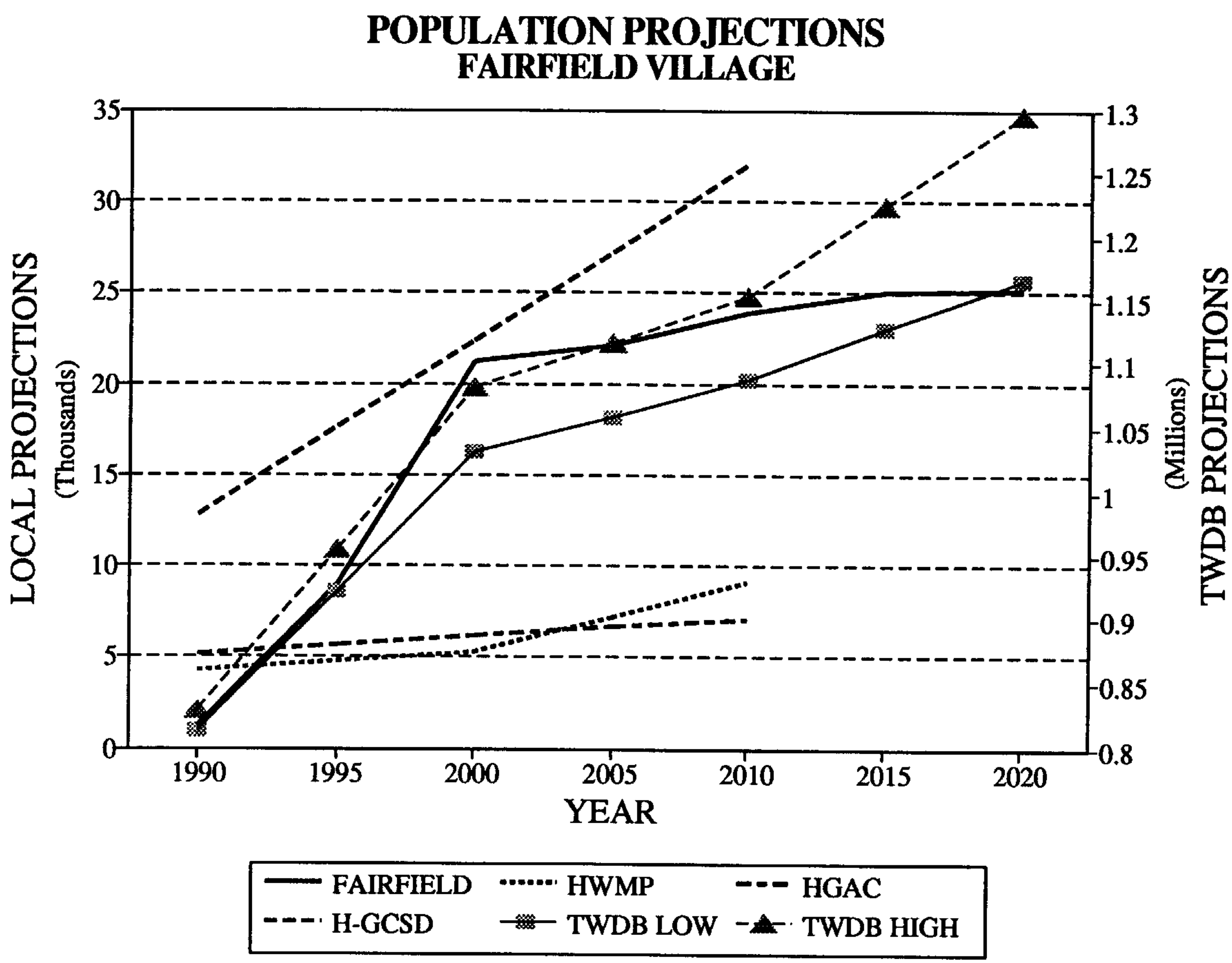
TABLE II-2 - POPULATION PROJECTION COMPARISON

YEAR	DEVELOPER DATA: SINGLE & MULTI - FAMILY TOTAL	CENSUS TRACT 545.01 DATA: HOUSTON WATER MASTER PLAN	HGAC	HGSCD	TWDB DATA: LOW SERIES	HIGH SERIES
1980	0	3,181	3,181	3,181		
1985	0					
1990	1,173	4,322	5,151	12,790	813,195	828,348
1995	8,902	4,825	5,643	17,595	922,729	955,409
2000	21,276	5,328	6,134	22,400	1,032,263	1,082,470
2005	22,029	7,246	6,626	27,204	1,059,773	1,118,348
2010	23,856	9,164	7,117	32,009	1,087,282	1,154,226
2015	24,986				1,127,312	1,224,778
2020	25,158				1,167,341	1,295,330

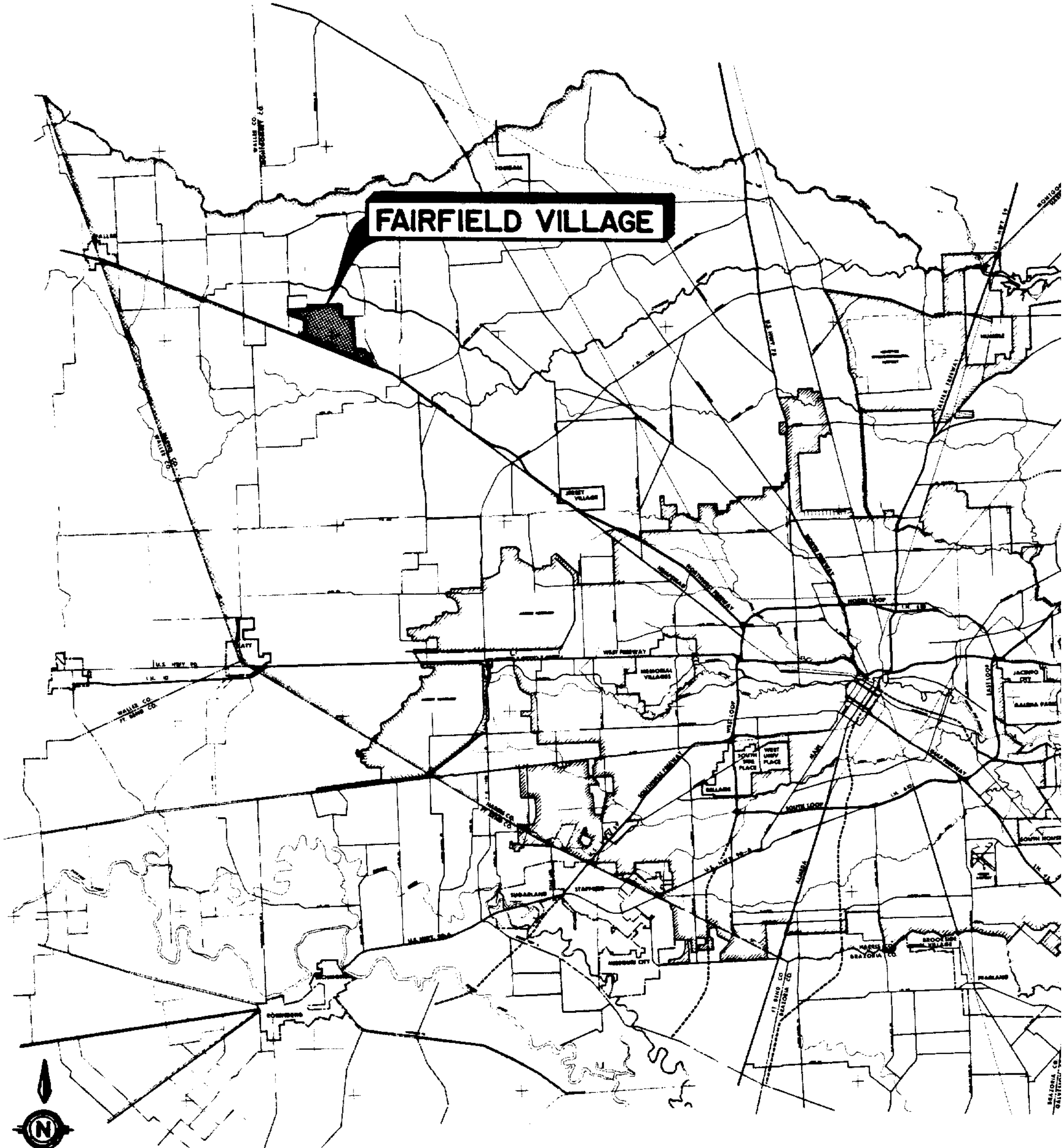
TABLE II-3 - LAND USE AND POPULATION SUMMARY

LAND USE	ACREAGE	ESFC *	EQUIVALENT POPULATION
Single-Family	1,526.6	5,758	20,153
Multi-Family	71.5	1,430	5,005
Commercial	494.3	4,943	17,299
Small Retail	17.5	185	648
Plant Sites	16.5	2	7
Drainage Channel	119.3	0	0
Private Utility Easement	25.0	0	0
Transportation & R.O.W.	197.4	0	0
School/Church/Library	63.1	317	1,110
Recreation/Parks	63.8	167	585
TOTALS	2,595.0	12,802	44,807

* Equivalent Single-Family Connections



POPULATION PROJECTIONS
FAIRFIELD VILLAGE
LOCAL PROJECTIONS
(Thousands)
TWDB PROJECTIONS
(Millions)
YEAR
0
5
10
15
20
25
30
35
0.8
0.85
0.9
0.95
1
1.05
1.1
1.15
1.2
1.25
1.3
1990
1995
2000
2005
2010
2015
2020
FAIRFIELD
HWMP
HGAC
H-GCSD
TWDB LOW
TWDB HIGH

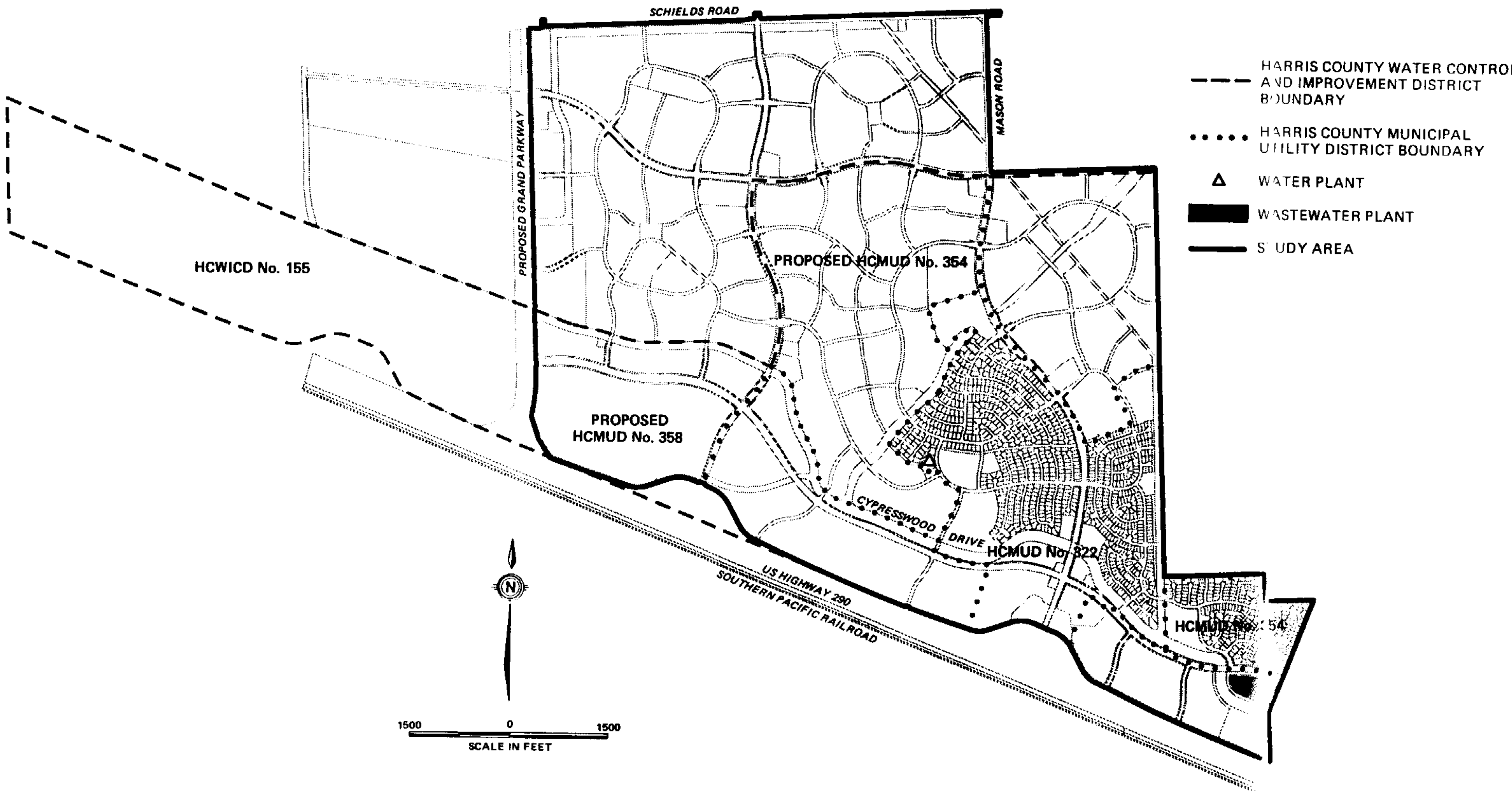


0 6.7
SCALE IN MILE

VICINITY MAP

October 1990

Exhibit II-1

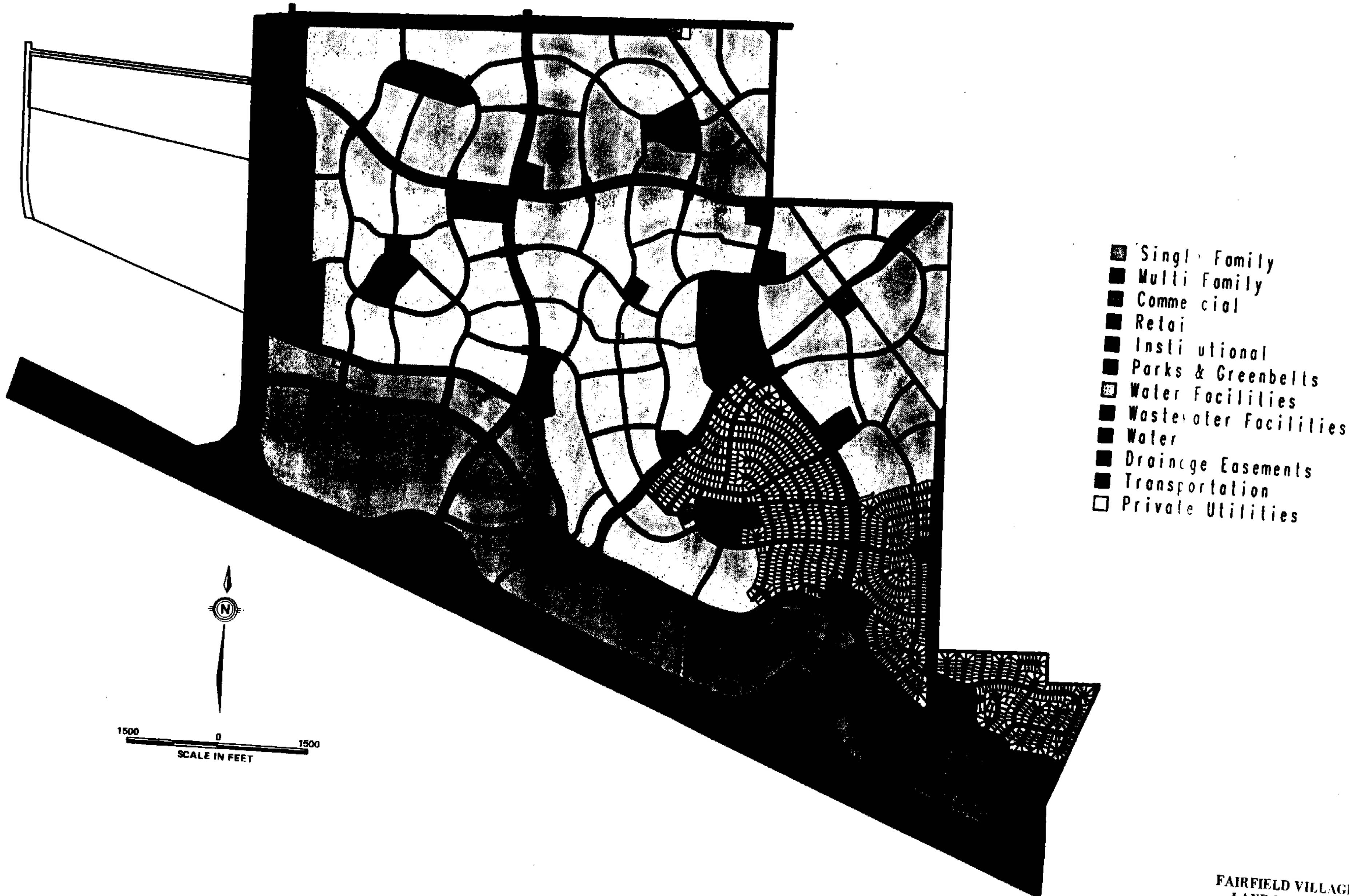


DISTRICT AND STUDY AREA BOUNDARIES

Turner Collie & Braden Inc.

October 1990

Exhibit II-2

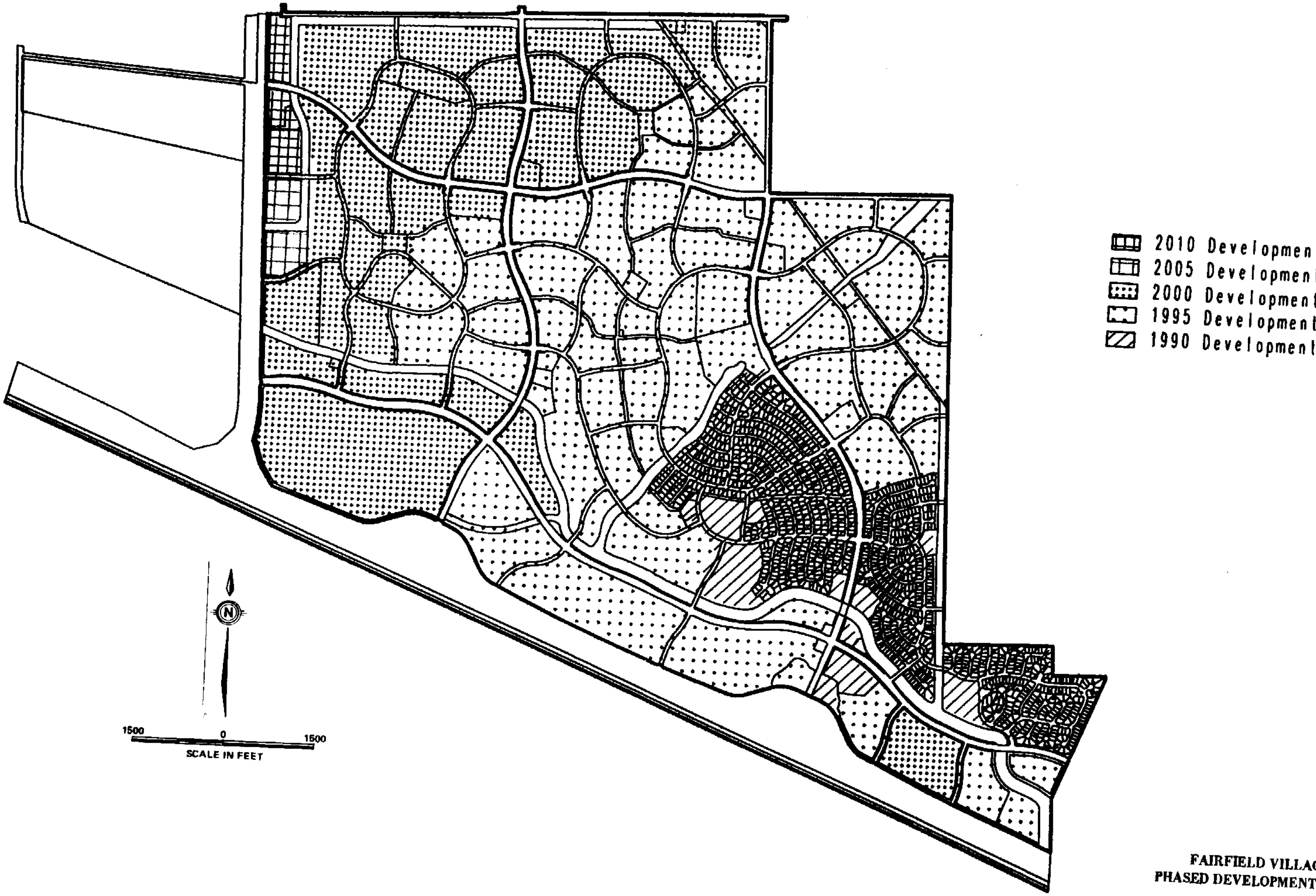


FAIRFIELD VILLAGE
LAND USE PLAN

Turner Collie & Braden Inc.

October 1990

Exhibit II-3



FAIRFIELD VILLAGE
PHASED DEVELOPMENT PLAN

Turner Collie & Braden Inc.

October 1990

Exhibit II-4

LITERATURE REVIEW AND POTENTIAL FOR WATER REUSE

LITERATURE REVIEW

One of the tasks of this study is a review of available literature on existing water reuse projects to evaluate existing water quality, engineering design criteria, and treatment processes used by other communities. Texas has specific criteria which address potable water systems and newly adopted criteria for nonpotable systems which, until tested or contested, need to be followed to implement a dual use system. Nevertheless, the literature in many instances provides valuable insight to design problems and operating experiences encountered in other projects. Specific case examples were uncovered that reinforce conclusions drawn from this study, as well as some of the rationale which most likely influenced the adopted Texas regulations. Most importantly, the literature seems to indicate a growing public acceptance of reclaimed water utilization.

Presented below is a summary of the literature review and an overview of the more significant projects found throughout the United States to assist the reader in developing a background for water reuse. Subsequent sections further address the potential for reuse in the study area, including cooling water reuse applications and construction of greywater systems in commercial installations. A bibliography of pertinent references is attached at the end of this report.

Type of Reuse

Reuse is generally classified into two major categories: potable and nonpotable. Nonpotable reuse utilizes wastewater plant effluent directly and generally for irrigation and industrial use applications. Nonpotable reuse is the most common form of reuse and has been practiced and accepted for over 100 years. Potable reuse can be either direct or indirect. Direct potable reuse is the immediate treatment of wastewater plant effluent by a water treatment facility for public consumption. There are no completely direct potable reuse projects in the United States although practically every municipality dependent on a surface water supply participates in some form of indirect potable reuse. Indirect potable reuse is the treatment of diluted wastewater plant effluent after natural mixing with surface water supplies for some period of time. Aquifer recharge, detention pond mixing, or mixing with water in large reservoirs are examples of this concept. Some cities plan for indirect reuse by direct discharge to a local water body for future recovery while others practice such uses by circumstance. A local example of indirect use is the City of Houston's main surface water supply source, Lake Houston, whose tributaries convey stormwater runoff, as well as treated effluent, from upstream dischargers.

It is important to note that this study addresses only the potential of irrigation uses with nonpotable treated wastewater effluent. Potable uses, either directly or indirectly, have not been considered.

Water Quality and Public Health Risks

Water quality is of utmost importance in any water reuse project. By its very name, the source of reclaimed water, wastewater, connotes negative images which must be overcome to successfully implement a reuse project. Wastewater is a general term applied to all the liquid (and sometimes solid) wastes collected in a sanitary sewer and conveyed to the local treatment plant. Such wastewaters are a combination of effluents from domestic household, commercial and industrial sources, infiltration from groundwaters above the sewers, and inflow related to rainfall events. The chemical and biological quality of wastewater, then, as well as the quantity, is related to each of its sources. Wastewater quantities as related to this study are explored in a later section.

Typical composition of untreated municipal wastewater is shown in Table III-1. The water quality parameters of primary concern in raw wastewater and treated effluent are presented in Table III-2. Table III-3 presents effluent quality from several advanced wastewater treatment facilities in California, a state that has very demanding standards and which makes considerable use of effluents for reuse. By comparison, quality data from the existing Fairfield wastewater treatment plant is shown in Table III-4. Based on these data, the existing plant already produces effluent of acceptable quality for irrigation. The existing plant is a temporary facility which will be replaced by a larger, more sophisticated plant in the near future. The new plant, which is proposed to include effluent filters, should consistently produce effluent of quality comparable to the California treatment facilities.

Is it safe? The literature indicates that the major advantage of nonpotable reuse lies in the fact that trace chemical contaminants remaining in well-treated effluents cannot have significant effects on public health. The primary concern, however, is the potential of exposure to infectious bacteria and viruses through consumption of raw food crops irrigated with inadequately treated effluent, through exposure to aerosols emanating from spray irrigation or cooling towers, and through accidental ingestion at areas irrigated with nonpotable supplies.

It is important to note that disease is rarely induced by a single bacterium. In fact, infective doses normally range in the thousands of viable cells. The literature reports that disinfection to 200 fecal coliforms per 100 milliliters (FC/100 ml) results in bacterial pathogen levels of, at most, fractions of an infective dose. Thus, fecal coliforms at this limit, or lower, is felt to provide ample public protection from infectious diseases.

Standardized methods of monitoring for enteric viruses have not been established, nor have criteria been universally accepted for defining acceptable levels of such microorganisms. Instead, bacterial tests utilized to monitor effluents for public "safety," for example, total coliforms, fecal coliforms, or fecal streptococci, rely on implicit correlation as indicator organisms. There is a substantial amount of evidence in the literature which supports both proponents and opponents on the validity of this argument. Nevertheless, the new Texas standards, presented in the next section, utilize bacterial limits of 75 FC colony forming units as a measure of viable pathogen activity.

There has been significant debate over appropriate limits for these biological indicator organisms. California, for example, requires a limit of 2.0 total coliforms/100 ml for parkland irrigation; Arizona, 25 FC/100 ml; and Florida, no detectable FC. Epidemiological studies have been completed elsewhere, the most publicized case involving the City of Colorado Springs, Colorado, to determine acceptable disinfection limits. This two-year study, completed in 1984, consisted of tests on 2,642 subjects which frequented parks irrigated with potable water and nonpotable water, either of effluent origin or of stormwater origin. Effluent nonpotable supplies were generally disinfected to a limit of less than 200 FC per 100 ml, whereas stormwater supplies were usually at a limit of less than 500 FC per 100 ml. The data indicated there was no difference in self-reported gastrointestinal illnesses for any group regardless of age, gender, income, park switching (visiting either park), degree of exposure, level of physical exertion, type of activity (golfing, soccer, softball, picnicking, etc.), weather conditions, or frequency of prior exposure.

Some other general observations drawn from the Colorado Springs investigation are perhaps of more interest to this study. One finding was that there were statistically significant increases in gastrointestinal symptoms, i.e., stomach disorders plus either diarrhea, vomiting, cramps, fever, weight loss, excessive gas, or blood in the stool, associated with fecal coliform and fecal streptococci organism levels above 500 per 100 ml and total coliform densities above 3,000 per 100 ml. These data tend to support Texas' limit of 75 FCU per 100 ml. Another significant finding was that "wet grass conditions" caused by irrigation with either potable or nonpotable sources were responsible for statistically significant increases in gastrointestinal symptoms across all park groups and categories investigated. For this reason, the study concluded it is probably wise to water, regardless of the source, when the irrigated areas are not occupied. In application to the study area, options might include at night or early morning providing time for the sun to evaporate excess moisture. Researchers pointed out, however, that since these symptoms occurred with both potable and nonpotable wet grass conditions, the finding may not be of significant concern. The Texas regulations, nonetheless, do require watering with nonpotable sources during periods of public inactivity.

Another common safety question involves the possibility of cross-connections of the nonpotable system with the potable distribution system. The question is valid because outbreaks of disease did occur in early nonpotable systems constructed for firefighting needs. Careful planning and extensive line marking programs in recently constructed systems, however, appear to have mitigated this problem.

The potential exists for unacceptable concentration of trace elements in water supply sources using reclaimed discharges. Physiological effects of direct water reuse are being studied by a number of entities. Preliminary results of a two-year chronic toxicity and carcinogenicity study, being conducted for the Denver Water Department, reports that no significant effects of any kind can be determined from the reuse of wastewater. While this study was directed primarily at investigating the potential health effects for a direct potable reuse system in Denver, the results are applicable to indirect reuse systems as well. A second part of the health effects study began in mid-1989. This portion will examine the reproductive toxicity aspects of consuming reclaimed water compared to Denver's current drinking water. Considering the preliminary results of the Denver study and epidemiological studies conducted in Colorado Springs, reclaimed discharges present an excellent potential resource for future water supply.

Education and Reuse

Numerous articles have pointed out the need for public education for the successful implementation of reclaimed water for water supply. Generally, the water supply is viewed from two perspectives--linear and circular. Linear, the more common perspective, uses and disposes of water. For this process, a new supply source must be sought unless the previous source is replenished. The public has general knowledge of linear reuse -- water supply is treated, stored, distributed, used, and disposed. After the process is complete, a tremendous potential resource has been lost.

A circular perspective is a process that reclaims this resource. Before effluent is discharged, it is diverted to a reuse system. Once water is reclaimed, it can again be treated, stored, distributed, and reused. This circular perspective is theoretically a never ending cycle and is a mimic of nature's hydrological cycle. This untapped resource can successfully be reclaimed if a reuse system is in operation.

The system proposed for implementation at Fairfield shares both linear and circular characteristics, but might be considered a "single-loop" system. Here, wastewater would be required for a single one-time reuse as irrigation water (or for fire-fighting) without re-introduction into a circular loop.

At the recent Reuse Symposium IV, held in Denver, Colorado, an impromptu survey was conducted about reuse concepts. Results of the survey indicated that reuse of waste-water has a high rate of approval for most uses except for human consumption. A similar study was conducted in the Clear Lake area in 1987 by a University of Houston-Clear Lake team to assess public attitudes toward reuse of treated effluent at a local golf course and other public areas. In this study, questionnaires were mailed to residents selected at random. The maximum margin of error from respondents was estimated at six to sixteen percent from two selected sampling groups. The principal survey findings were: 1) the quality of irrigation water was not of particular concern to area residents; 2) a majority of residents favored the use of reclaimed water for irrigation as a means of reducing the cost of parks; and 3) about 85 percent of the respondents favored use of reclaimed water for irrigation of golf courses and esplanades provided that state and local public health standards were met. The researchers pointed out the need to include comparative costs and public health aspects in any public information program and to follow-up with a "post-hoc" evaluation if a reuse program were to be implemented. The researchers further believed planning for the follow-up survey should proceed prior to program implementation to avoid controversy over evaluation standards and procedures.

Based on the results of these studies, a public education program is considered beneficial, if not essential, for effective implementation. Informing the public about reuse and the circular perspective, or the "single-loop" perspective, is a major step that must be a long-term commitment that should begin immediately.

Overview of Significant Water Reuse Projects

Water reuse is not a new concept. Essentially all water has been used over and over as a result of the hydrologic cycle, nature's reuse system. Water consumed, flushed, or used for watering lawns all re-enters the water cycle. This method of reuse is indirect and essentially unplanned. However, throughout regions of the United States water reuse is now purposefully being planned and implemented.

In Texas, there are many documented reuse projects. A study funded by Texas Water Resources Institute indicates that approximately 220 of the State's 1,800 municipal and industrial permitees are now conducting reuse programs. The majority of these involve agricultural irrigation which utilize effluent to irrigate such crops as grasses, small grains, sorghum, and cotton. Irrigation of golf courses, cemeteries, and similar restricted access sites is reported as fairly common in west and central Texas and several golf courses in the Houston area utilize, or are planning to utilize, treated effluent for irrigation.

Other, larger scale, projects have demonstrated economic and technical feasibility of wastewater reuse. The Las Colinas project in Irving, Texas, for example, utilizes about 7 million gallons per day (mgd) of reclaimed wastewater, blended with stormwater and water from the Elm Fork of the Trinity River to irrigate four golf courses, highway medians, and open spaces and to supply water to 158 acres of man-made lakes. Irrigating landscape areas at the Dallas-Fort Worth International Airport from this source also has been proposed.

The City of El Paso has in effect one of the State's most ambitious reuse projects. Here, wastewater is highly treated to meet drinking water standards, then injected into the Hueco Bolson aquifer to recharge groundwater supplies. Eventually (estimates are approximately two years), the water will be recovered in the City's groundwater wells, completing the reuse cycle.

The City of Odessa currently uses about three to four mgd of its effluent for various nonpotable water supplies. The City has developed a plan to expand or increase its current uses in the areas of agricultural irrigation, irrigation of golf courses and cemeteries, industrial reuse, and blending with raw water supplies to produce potable water.

The Lower Colorado River Authority (LCRA) has recently completed a study on the use of reclaimed water in the Highland Lakes area near Austin. The TWC has instituted a ban on new discharges into the lakes which essentially requires developers to set aside a portion of developable areas for effluent irrigation or construct low density developments with septic tank systems. Results of the study indicate that a dual distribution system for a new subdivision area coupled with continued irrigation of golf courses and other restricted access areas is an economically feasible alternative.

Each of the reuse examples presented above does not include extensive use of dual distribution systems as is being considered in Fairfield. Areas outside of Texas, most notably in Arizona, California, and Florida, have, however, successfully implemented more extensive dual distribution systems.

The dual system implemented in Phoenix, Arizona is unique in that canals transport the nonpotable supply by gravity for irrigation purposes. The potable system is a network of conventional, pressurized distribution lines. As a result, there are few problems differentiating between the two systems. In some residential areas, the canals parallel local streets allowing residents easy access to an irrigation source.

In California, the Irvine Ranch Water District (IRWD) has been supplying reclaimed wastewater for landscape and agricultural use since the mid-1960s. IRWD does not supply water directly to residential private properties, but to community associations responsible for irrigation of residential-area parks, greenbelts, and open space. Success in these areas of reuse, however, has extended reuse practices to private residential properties. In a telephone interview with a local official, it was learned that residential connections must have an installed sprinkler system as hose bibs or spigots are not provided. Irrigation is controlled by the responsible entity and occurs in zones at night when residential use is unlikely. These controls are provided to minimize contact with the water and cross-connections by the user. Additionally, only front yards are watered, again to minimize contact, and presumably, to provide a "safe" area for home recreation in the back yards. The ultimate service area for agricultural and landscape uses includes a service area of approximately 70,000 acres with an estimated reclaimed water demand of 30,000 acre-feet annually. In the future, reclaimed water will be available for industrial reuse and possibly non-restricted recreational impoundments. These uses are expected to exhaust the entire supply of reclaimed water through the planning period ending in 1999.

On a somewhat smaller scale, a dual distribution system has been in operation in the Las Virgenes Metropolitan Water District in Los Angeles County since the early 1970s. The system supplies reclaimed water for landscape irrigation of highway greenbelts, landfills, cemeteries, schools, and private residences. The system is designed to supply about 2,700 acre-feet annually. The project is considered highly successful and "... a source of pride for the entire community."

At another California installation, in the San Gabriel Valley east of Los Angeles, the Walnut Valley Water District (WVWD) recently completed a dual distribution system using reclaimed water from the Pomona Wastewater Reclamation Plant (PWRP) as an alternative source of water. PWRP acts as a wholesaler to WVWD, selling water to WVWD for distribution in its facilities. The system, completed in December 1986, includes a 4-mgd main pumping station, 1.4-mgd booster pump station, 2-mgd reservoir, over 25 miles of pipelines, and a small hydroturbine for energy recovery. Reclaimed water customers include schools, parks, and other tax-supported entities.

Perhaps the most extensive of all existing dual systems in the United States is that in St. Petersburg, Florida. In the early 1970s, the City was required by regulation to upgrade four existing treatment plants or cease discharges into Tampa Bay. At the same time, groundwater supplies were becoming increasingly strained with available new sources about 50 miles away. The City elected to cease discharges and ease potable supply demands by constructing the dual distribution system. Completed in 1977, the system supplied about 25 percent of the service area's 51 mgd demand in 1988. The system conveys filtered secondary effluent for supplemental fire protection and urban irrigation including schools, golf courses, parks, and commercial and residential areas. The water is reportedly clear and odorless with virus at undetectable limits. Existing storage is provided by a deep-well injection system and ground storage. Additional storage is planned using three new, covered, concrete storage reservoirs. When the project is fully complete by year 2000, the system will have capacity (42 mgd) to serve 17,000 customers and irrigate almost 9,000 acres.

Residents pay a flat monthly fee ($10.30) for unlimited use and commercial users pay a fee based on acreage. Residents are not required to use the reclaimed water, nonetheless, as an incentive, they must pay an availability fee. The entire system, including upgrade of the existing treatment plants was funded with federal subsidies.

POTENTIAL APPLICATIONS FOR REUSE IN THE STUDY AREA

As seen from the literature, the use of treated wastewater effluent has been implemented successfully on a limited basis throughout the United States without significant repercussions. In every situation, economics, or the cost to develop and transport new water supplies, is the deciding factor in the development of a reuse project. In order to be a cost-effective project in the study area, it is anticipated that the maximum potential application must be utilized. All feasible uses relative to the type of development were investigated for potential application. Presented in the following sections is a brief summary of potential uses reviewed and their applicability to the Fairfield reuse project.

Potential for Irrigation Reuse

Until recent adoption of the new Texas regulations regarding water reuse, widespread application for irrigation reuse, especially in unrestricted access areas such as parks and residential neighborhoods, was nonexistent. The new regulations will allow such uses and the cost-effectiveness of a widespread application needs to be fully explored.

Extensive landscaping of common areas is proposed and, in fact, is underway in the Fairfield community. According to the landscape architects, three basic types or levels of landscaping are planned. These include the following:

- **Polished Lawn Areas.** These areas are highly-manicured, heavily fertilized, and fully irrigated with extensive sprinkling systems. This level of landscaping occurs at the main entryway, in commercial areas, along major thoroughfares between the sidewalks and curbs, and in other limited "high impact" areas.

- **Tall Grass Areas.** These zones are predominantly native or drought resistant grasses which are infrequently mowed are irrigated only during establishment and periods of extreme drought. Example areas include the floodway portion of certain drainage channels, setback areas along US 290, drill sites, and the north portion of the fault zone.

- **No-Mow Areas.** These areas are heavily planted with trees, native shrubs, and ground covers. Open ground is covered with mulch and only the larger plants are drip irrigated during an establishment period. This type of landscaping occurs along most of the greenbelts, along major thoroughfares between the walkways and setback fence line, and in other limited open space areas, such as between walkways and back yard fences.

Irrigation of high-volume water use areas with treated effluent, such as golf courses, has been demonstrated to be an economical alternative to irrigation with potable supplies. If a residential area exhibits similar high-volume consumption, then it is very likely irrigation reuse will likewise be cost-effective. Coupled with above-normal irrigation demands required for the proposed, highly manicured areas in Fairfield, the potential for irrigation reuse in Fairfield appears very favorable.

Potential for Greywater Reuse

One of the tasks identified by the TWDB to be investigated is the potential of requiring separate greywater and blackwater systems for commercial developments in the study area. Greywater systems refer to dual water supply systems that allow the reuse of so-called "grey" wastewater generated from the use of lavatories, bathtubs, showers, and other fixtures containing nonhuman or nonfecal wastes. Some literature sources refer to treated secondary effluent as greywater, however, this study considers such waters as reclaimed water, acceptable for reuse without further treatment. All other wastes are then "black" wastewater returned to the sanitary sewer for conveyance to the treatment plant. As an added benefit, large scale greywater systems can reduce sewage loads to the treatment facility.

The use of such systems was preliminarily screened for applicability to the study area. First, an assessment of probable commercial generators of commercial greywater and quantities of greywater versus onsite reuse demand is required. Commercial development in the Fairfield project is expected to be similar to the types found in other, primarily residential, communities. For the most part, these types of commercial development consist of strip shopping centers, including food markets, gas stations, small retail outlets, movie theaters, banks, day-care centers, pharmacies, and full-service and fast-food restaurants. Medical services and other miscellaneous small or medium business operations may be included. Exceptions to this type of development is the proposed regional shopping mall and commercial car washes. With few exceptions, notably the car washes, establishments of this type are not expected to generate significant quantities of greywater nor are they likely to have a large need for reclaimed greywater. Large commercial car washes usually recycle cleaner rinse waters to reduce operating expenses.

The potential for reuse in these types of commercial development is most likely limited to landscape irrigation along perimeter set backs, for toilet flushing, for recycling as noted above, or in a few instances, for air conditioning cooling towers. Perimeter landscaping would be distant from greywater sources, requiring considerable piping and possibly pumping of any collected wastewaters. Cooling water applications are discussed in the next section. The remaining potential application is water for local toilet flushing, however, if the proposed project is implemented, there are two reliable sources for this use, i.e., the potable water system and the nonpotable treated effluent system. Both are pressurized sources, negating the need for re-pumping.

Regardless of the final uses, the literature reports some form of treatment is usually required. The lowest level of treatment includes filtration followed by disinfection. If the source water contains a high percentage of soaps and foaming is a problem, then addition of a defoaming agent is advisable. Makeup water for cooling towers that is high in dissolved solids or organic material requires dilution with a higher purity water or higher blowdown rates and special condenser water treatment to control biological growths in the tower.

Given the limited quantities of greywater expected to be generated by the proposed commercial establishments, the additional treatment required for possible uses, and the potential availability of two water sources for potential needs, the use of separate greywater/blackwater systems appears limited in the planning area systems.

Potential for Cooling Reuse

Cooling water systems can be classified as "once-through" systems or as "recirculating" systems. Once-through systems, as the name implies, use water for only one cooling cycle before discharge. The water does not need to be of high quality, in fact, seawater and polluted river waters are often adequate for once-through systems. Large scale industrial users and power generating plants are typical users of these systems. This type of development is not anticipated in the planning area, therefore, there is little potential for once-through cooling reuse.

Recirculating evaporative cooling systems, on the other hand, can be found in almost any city or larger commercial establishments. Recirculating systems continually recirculate cooling water for many cycles by using cooling towers to cool the water following each heat-exchange cycle. Because the water is recycled and there are losses to evaporation, contaminants can build-up in the recirculating stream. To prevent unacceptable contaminants build-up, a certain portion of the stream is wasted as "blowdown." The water lost is replaced with "make-up" from the water supply source. Because contaminants are concentrated in the cooling process and because organic nutrients in the make-up water provide a source of food for microorganisms, make-up water must be of the highest quality.

Highly-treated reclaimed water is successfully used in recirculating cooling systems at several installations throughout the United States. Generally, the water 1) must not form scale; 2) must not be corrosive; 3) must not supply nutrients conducive to slime growth; 4) must not foam excessively; and 5) must not cause the wood in cooling towers to deteriorate. Besides secondary treatment, additional treatment is sometimes required dependent on the quality of the reuse supply. Table III-5 summarizes water quality criteria for recirculating systems. The treatment steps most commonly encountered to achieve this quality include lime addition which softens the water and removes phosphorous, some metals, ions, and organic compounds; filtration, to remove suspended solids; and disinfection, to control slime and reduce pathogens that are dispersed in the cooling tower plume. Hardness is not anticipated to be a problem in the Fairfield effluent nor are heavy metals or significant concentrations of ions expected due to the absence of industrial dischargers. The remaining processes, filtration, and disinfection, with the exception of phosphorous removal, will be employed at the Fairfield regional wastewater treatment plant. Thus, the potential for recirculating cooling tower reuse appears very good in the planning area.

In the literature review of cooling water reuse potential, one area of concern was noted. Recirculating cooling towers are natural breeders of bacteria, regardless of the make-up supply. One researcher estimated that a 100-ton cooling tower operating at maximum load with a 3-gpm evaporation rate dumps 1.2 billion bacteria into the air every minute. In 1979, an outbreak of Legionnaire's disease caused by the bacterium *Legionella pneumophila* was discovered in Philadelphia. Another outbreak occurred in Jamestown, New York, and was associated with cooling tower water from an industrial manufacturing plant. Other outbreaks have occurred, but were traced to other species of *Legionella* in potable water supplies from hospitals in Chicago and Los Angeles. The association with cooling towers is of some concern with a water reuse project, however, it is important to note that several of the reported cases originated from potable supplies.

Bacteria generation in cooling towers can be controlled with proper maintenance, i.e., regular cleaning to remove organic growth, addition of biocides and algaecides, confirmation of bacterial counts with laboratory testing, and installation of onsite sand filters to remove generated organic debris. As a precautionary measure, these methods probably should be required at cooling towers using nonpotable water supplies.

Other Potential Reuses

Three additional areas of potential reuse are considered applicable to the study area: water needs for construction related activities, firefighting needs, and toilet flushing requirements. Each is discussed below.

In growing developments such as Fairfield, the construction industry uses significant quantities of water in the building of roads and bridges; in construction of water, wastewater, and stormwater systems; and in home building activities. Typical uses include water for concrete mixing, washdown of construction areas, dust control, and compaction of soils in road beds, water and sewer trenches, and soils beneath home foundations prior to construction.

The issue of water quality and concrete mixing has been raised and investigated by others concerned with the "impurities" in reclaimed water and its effect on concrete strength. Researchers have found through laboratory testing, however, that reclaimed water is equivalent to potable water when used to mix concrete. Other than possible health risks, if any, water quality would not appear to be a deterrent for the other uses as well.

Yet, the question remains whether such uses are allowed under current reclaimed water-use regulations, since these uses are not specifically addressed. Water applied to the ground, as is the case in compaction and washdown activities, might be considered "irrigation" water, however, application presumably would be limited to rates established by a water balance and may not be sufficient for the intended use. Additionally, such uses might be construed as "unauthorized" or, rather, uncontrolled, and a "threat to groundwater sources," each of which is specifically prohibited. Until these questions are answered, the potential for reuse in construction activities appears limited.

The current State criteria also appear lacking in addressing the potential of reuse waters for firefighting needs since such uses are not specifically identified in the regulations. Such use would seem to be an ideal candidate; high quality waters are definitely not needed, there is limited public health risk, and the frequency of use is extremely low, thus minimizing environmental concerns from runoff. Additionally, reuse for irrigation, the thrust of the newly adopted regulations, applies to relatively high-flow, high-volume situations. It would seem logical to include similar high-flow, high-volume, but less frequent demands, such as firefighting, in the nonpotable side of a new dual distribution system rather than oversize the potable system for such needs. For these reasons, firefighting needs are considered as applicable to the study area. It is anticipated that a waiver or variance will be required from the Executive Administrator of the TWC to include such uses.

Another potential reuse application with significant implications is reuse for toilet flushing. The literature reports a substantial amount of the total daily potable water demand is allocated for this activity and the new TWC regulations allow reclaimed water for this use. The current scope of services does not include detailed investigation of this reuse possibility, however, a limited discussion is included in later sections.

TABLE III-1 - TYPICAL MUNICIPAL UNTREATED WASTEWATER QUALITY

Contituent	Conentration Range			U.S. Average
	Strong	Medium	Weak	
Solids, Total:	1,200	720	350	
Dissolved,Total	850	500	250	-
Fixed	525	300	145	-
Volatile	325	200	105	-
Suspended	350	220	100	192
Fixed	75	55	20	-
Volatile	275	165	80	-
Settleable Solids, ml/L	20	10	5	-
Biochemical Oxygen Demand, 5-day; 20 C	400	220	110	182
Total Organic Carbon	290	160	80	102
Chemical Oxygen Demand	1,000	500	250	417
Nitrogen (total as N)	85	40	20	34
Org-N	35	15	8	13
NH3-N	50	25	12	20
NO2-N	0	0	0	-
NO3-N	0	0	0	0.6
Phosphorous (total as P)	15	8	4	9.4
Organic	5	3	1	2.6
Inorganic	10	5	3	6.8
Chlorides	100	50	30	-
Alkalinity (as CaCO3)	200	100	50	211
Grease	150	100	50	-
Total Coliform Bacteria, MPN/100 ml	-	-	-	22x106
Fecal Coliform Bacteria, MPN/100 ml	-	-	-	8x106
Viruses, PFU/100 ml	-	-	-	3.6

Source: Water Reuse; A Report to the Clear Lake City Water Authority, 1987

TABLE III-2 - CONSTITUENTS OF CONCERN IN WASTEWATER TREATMENT AND USE AS IRRIGATION WATER

Constituent	Method of Measurement	Reason for Concern
Suspended Solids	Suspended Solids, including Volatile and Fixed Solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment. Excessive amounts of suspended solids can cause plugging in irrigation systems.
Biodegradeable Organics	Biochemical Oxygen Demand, Chemical Oxygen Demand	If discharged into the environment, biological decomposition can lead to depletion of dissolved oxygen in the receiving waters and to the development of septic conitions.
Pathogens	Indicator Organisms, Total and Fecal Coliform Bacteria	Communicable diseases can be transmitted by the pathogens in wastewater: bacteria, viruses, and parasites.
Nutrients	Nitrogen, Phosphorous, Potassium	Nitrogen, phosphorous, and potassium are essential nutrients for plant growth, and their presence normally enhances the value of the water for irrigation. When discharged to the aquatic environment, nitrogen and phosphorous can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, nitrogen can lead to the pollution of groundwater.
Stable (Refractory) Organics	Specific Compounds (e.g., phenols, pesticides, chlorinated hydrocarbons)	These organics tend to resist conventional methods of wastewater treatment. Some organic compounds are toxic in the environment, and their presence may limit the suitablity of the effluent for irrigation.
Hydrogen Ion Concentration	pH	The pH of wastewater affects metal solubility as well as alkalinity of soils. Normal range in municipal wastewater is 6.5-8.5, but industrial waste can alter pH significantly.

TABLE III-2 - CONSTITUENTS OF CONCERN IN WASTEWATER TREATMENT AND USE AS IRRIGATION WATER (con't)

Constituent	Method of Measurement	Reason for Concern
Heavy Metals	Specific Elements (e.g., Cd, Zn, Ni, Hg)	Some heavy metals accumulate in the environment and are toxic to plants and animals. Their presence may limit suitability of effluent for irrigation.
Dissolved Inorganics	Total Dissolved Solids, Electrical Conductivity, Specific Elements (e.g., Na, Ca, Mg, Cl, B)	Excessive salinity may damage some crops. Specific ions such as chloride, sodium, and boron are toxic to some crops. Sodium may pose soil permiabilty problems.
Residual Chlorine	Free and Combined Chlorine	Excessive amount of free available chlorine (greater than 0.05 mg/l) may cause leaf-tip burn and damage some sensitive crops. However, most chlorine in reclaimed wastewater is in a combined form which does not cause crop damage. Some concerns are expressed as to the toxic effects of chlorinated organics in regard to groundwater contamination.

Source: Water Reuse; A Report to the Clear Lake City Water Authority, 1987

TABLE III-3 - SUMMARY OF EFFLUENT QUALITY FROM SELECTED ADVANCED WASTE TREATMENT FACILITIES

Effluent Quality Parmeter	Plant Location: Long Beach	Los Coyotes	Pamona	Dublin San Ramon	Liver-more	Simi Val. CSD
Biochemical Oxygen Demand (5-day)	5	9	4	2	3	4
Suspended Solids	-	5	-	1	-	-
Total Nitrogen	-	-	-	-	-	19
NH3-N	3.3	13.6	11.4	0.1	1.0	16.6
NO3-N	15.4	1.1	3.0	19.0	21.3	0.4
Org-N	2.2	2.5	1.3	0.2	2.6	2.3
Total-P	-	-	-	-	-	-
Ortho-P	30.8	23.9	21.7	28.5	16.5	-
pH (unit)	-	-	-	6.8	7.1	-
Oil and Grease	-	-	-	-	-	3.1
Total Coliform Bacteria, MPN/100 ml	-	-	-	2	4	-
Cations:						
Ca	54	65	58	-	-	-
Mg	17	18	14	-	-	-
Na	186	177	109	168	178	-
K	16	18	12	-	-	-
Anions:						
SO4	212	181	123	-	-	202
Cl	155	184	105	147	178	110
Electrical Cond., micro mhos/cm	1,352	1,438	1,018	1,270	1,250	-
Total Diss. Solids	867	827	570	-	-	585
Soluble Sodium, %	63.2	59.2	51.7	-	-	-
Sodium Adsorbtion Ratio	5.53	4.94	3.37	4.6	5.7	-
Boron (B)	0.95	0.95	0.66	-	1.33	0.6
Alkalinity (CaCO3), total	-	256	197	150	-	-
Hardness (CaCO3), total	212	242	206	254	184	-

Note: All units in milligrams per liter unless noted.

Source: Water Reuse; A Report to the Clear Lake City Water Authority.

TABLE III-4 - SUMMARY OF HCMUD No. 322 EXISTING EFFLUENT QUALITY

Date	Flow (MGD)		BOD5 (mg/L)		Total Suspended Solids (mg/L)		Ammonia-Nitrogen (NH3-N in mg/L)		pH		Chlorine Residual (mg/L)	
	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.	Avg.	Max.
May 1989	0.058	0.165	2.0	2	2.5	3	0.1	0.1	7.5	7.7	1.0	4.0
Jun	0.064	0.232	3.0	4	3.0	4	0.2	0.2	7.3	7.7	1.1	3.7
Jul	0.029	0.074	2.7	3	4.7	6	0.2	0.2	7.8	7.9	1.0	3.9
Aug	0.038	0.063	2.0	2	7.5	10	0.4	0.7	7.7	7.9	1.1	4.0
Sep	0.043	0.141	3.7	6	4.7	7	0.1	0.1	7.0	7.4	1.1	4.0
Oct	0.041	0.062	1.3	2	8.0	12	0.1	0.1	7.5	7.5	1.1	4.0
Nov	0.042	0.065	2.0	2	5.0	5	0.1	0.1	7.5	7.7	1.0	4.0
Dec	0.051	0.066	2.0	2	3.5	5	0.1	0.1	7.4	7.7	1.1	4.0
Jan 1990	0.053	0.062	2.0	3	5.0	6	0.1	0.2	7.4	7.4	1.0	4.0
Feb	0.058	0.135	2.5	4	4.0	5	0.2	0.3	7.4	7.6	1.0	4.0
Mar	0.061	0.120	2.3	3	1.7	2	0.2	0.3	7.4	7.5	1.0	4.0
Apr	0.054	0.233	1.5	2	3.5	6	0.1	0.1	7.5	7.5	1.0	4.0
Permit Limitation	0.100		10.0	25.0	15.0	40.0	3.0	10.0	6.0	9.0	1.0 (minimum)	4.0
Maximum Reuse Limitation	-		5.0		10.0		-	-	-	-	Trace	-

Source: TWC Self-Reporting Data

TABLE III-5 - RECOMMENDED COOLING WATER CRITERIA FOR MAKE-UP WATER IN RECIRCULATING COOLING SYSTEMS

Parameter	Recommended Limit 1	Recommended Limit 2	Comments
Cl	500	100-500	
TDS	500	500-1,650	
Hardness (CaCO3)	650	50-130	
Alkalinity (CaCO3)	350	20	
pH	**	6.9-9.0	Preferably 6.8-7.2
COD	75	75	Preferably below 10
TSS	100	25-100	Preferably below 10
Turbidity	-	50	Preferably below 10
BOD5	-	25	Preferably below 5
Organics (Methylene blue active subsances)	1	2	2 is good
NH4	**	4	Preferably below 1
PO4	-	1	1 is good
SiO2	50	-	
Al	0.1	0.1	
Fe	0.5	0.5	
Mn	0.5	0.5	
Ca	50	50	
Mg	**	0.5/**	
HCO3	24	24	
SO4	200	200	

Notes: Recommended limits from two sources
* Required limits in mg/L, except pH
** Accepted as received

Source: EPA Guidelines for Water Reuse, 1980

SYSTEM DESIGN CONSIDERATIONS

REGULATIONS GOVERNING DESIGN OF WATER SYSTEMS

A number of agencies are involved, directly or indirectly, in the design of potable water and water reuse systems in Texas. At the federal level, the Environmental Protection Agency (EPA) has published guidelines for water reuse projects, however, there are no federal regulations relative to reuse. At the State level, minimum potable system design standards are under the jurisdiction of the Texas Department of Health (TDH) and the newly adopted nonpotable standards will be regulated by the Texas Water Commission. At the local level, Fairfield is within the extraterritorial jurisdiction of the City of Houston and is required to follow certain design standards, primarily directed at system construction, since the City may, at some time in the future, annex the area.

Minimum drinking water (potable) standards are also in effect and are enforced by both the EPA and TDH. The reuse project proposed for implementation does not include reuse for potable supply, therefore, these regulations do not affect the project. Summarized in the following sections are State and Local regulations which influence development of a dual distribution system project.

TDH Regulations for Potable Water Supplies

In 1988, TDH adopted revised rules and regulations for construction of public (potable) water system supplies. According to these rules, certain minimum standards must be followed for an acceptable public supply system. The following minimum system capacity requirements are in effect for the proposed Fairfield potable water system. According to the TDH regulations, both the existing and potentially revised systems as the result of a reuse project must abide by these certain minimum standards.

- Total storage capacity of 200 gallons per connection must be provided.
- Elevated storage in the amount of 100 gallons per connection is required for systems in excess of 2,500 connections.
- Well capacity must be such that two or more wells having a total capacity of 0.6 gpm per connection are provided.

- Service (booster) pump capacity must be such that each pump station or pressure plane have two or more pumps having a total capacity of 2.0 gpm per connection or total capacity of 1,000 gpm and be able to meet peak demands, whichever is less.
- Auxiliary power must be such that it is sufficient to deliver a minimum of 0.35 gpm per connection to the distribution system in the event of loss of normal power supply.

The TDH recognizes a wide variation in per capita water consumption throughout the State. Therefore, in addition to the minimum criteria, certain pressure requirements must be considered. Accordingly, the determining factor for water system facilities is the ability of the system to maintain a minimum residual pressure of 20 pounds per square inch (psi) at all points in the distribution system under peak-demand conditions. In analyses conducted by Turner Collie & Braden Inc, "peak-demand conditions" are considered the larger of peak-hour or peak-day-plus-fire conditions. Additionally, the TDH "minimum" system must be designed to maintain a least a pressure of 35 psi at all points within the distribution network at flow rates of 1.5 gpm per connection.

TDH criteria further specify minimum required water main sizes which, in some special instances, might affect the size of waterlines in a dual distribution system. Table IV-1 summarizes these criteria. The minimum sizes do not consider fire flows. Besides these criteria, TDH rules address many other areas, including general provisions and prohibitions, potable water sources, potable water treatment and storage, acceptable operating practices, and various construction standards. All of these additional criteria, however, apply to potable supplies regardless of capacity requirements and do not have a significant bearing on implementation of a reuse project.

TWC Regulations for Nonpotable Supplies

The Texas Water Commission (TWC) has recently adopted rules governing the use of reclaimed water. The preamble to the rules states the TWC's belief that "reclaimed water may be used safely and beneficially for many purposes, some of which include irrigation of vegetation, source of water for landscape impoundments, restricted recreational impoundments or ornamental fountains, and commercial and industrial uses, such as cooling water and flush water for toilets." Enacting this new legislation provides a broader based approach for its application and is intended "... to encourage the conservation of water resources by reusing water where possible and appropriate."

The general requirements pertaining to water reuse for irrigation purposes (or other potential uses) to be utilized at Fairfield Village are as follows:

- Irrigation with untreated wastewater is prohibited.
- Food crops which may be consumed raw by humans may not be spray-irrigated. Other types of irrigation which minimize contact between reclaimed water and edible portions of crops are acceptable.
- There shall be no nuisance conditions resulting from use or storage of reclaimed water.
- There shall be no offsite discharge of reclaimed water unless authorized by permit.
- Use of reclaimed water shall not threaten groundwater.
- Reclaimed water piping shall be separated from potable water piping when trenched by a distance of at least ten feet.
- Storage ponds must be constructed in a manner which prevents groundwater contamination. In some cases, this may require a special soil liner for the pond.

The following quality requirements apply to the use of reclaimed water for irrigation. All parameters are based on a 30-day average, unless otherwise noted. Not all of these uses are proposed in Fairfield.

- For irrigation of food crops:
  - BOD less than ten milligrams per liter (mg/l)
  - Turbidity less than 3 Nessler Turbidity Units (NTU)
  - Fecal coliform not to exceed 75 coliform forming units per 100 milliliters (cfu/100 ml)
- For irrigation of fodder, fiber, and seed crops:
  - BOD less than 30 mg/l
- For irrigation of pastures for animals milked for human consumption:
  - BOD less than 20 mg/l
  - Fecal coliform not to exceed 800 cfu/100 ml
- For irrigation of unrestricted access landscaped areas (the majority of proposed consumption in Fairfield):

- BOD less than 5 mg/l
- Turbidity less than 3 NTU
- Fecal coliform not to exceed 75 cfu/100 ml

• For irrigation of restricted access landscaped areas:

  - BOD less than 20 mg/l
  - Fecal coliform not to exceed 800 cfu/100 ml

Reclaimed water must be disinfected prior to transfer. If the user stores the water prior to use, the water must be chlorinated to provide a trace chlorine residual.

Application rates shall be based either on a figure contained in the regulations, which provides for an application rate of 2.0 feet per year for the study area, or as is determined by a detailed water balance.

Irrigation can only be performed when the area is not in use by humans or animals milked for human consumption, and reclaimed water applied to land with public access must be re-disinfected following storage and prior to use. There shall be no application of effluent if the ground is saturated or frozen.

Distribution systems must be designed to prevent operation by unauthorized personnel.

The following quality requirements apply to use of reclaimed water for landscape impoundments, restricted recreational impoundments, or ornamental fountains:

• BOD less than 10 mg/l
• Turbidity less than 3 NTU
• Fecal coliform not to exceed 75 cfu/100 ml

Swimming is prohibited in these impoundments.

• For commercial and industrial use of reclaimed water:

  - BOD less than 20 mg/l
  - Fecal coliform not to exceed 200 cfu/100 ml

• For use of reclaimed water as toilet flush water:

  - BOD less than 5 mg/l
  - Fecal coliform not to exceed 75 cfu/100 ml

The TWC requires that reclaimed water used as toilet flush water be dyed to distinguish the source from potable supplies.

The adopted rules also contain sampling and analysis and record keeping provisions to ensure compliance with quality and other requirements. Rules applicable to the planning area require a minimum frequency of once per week for distribution for irrigation of unrestricted access areas and once per month for irrigation of restricted access areas and other commercial uses.

City of Houston Regulations for Potable Water Distribution Systems

While potable water quality and supply system capacity are primarily regulated by the TDH, City of Houston regulations control the sizing and construction of distribution waterlines. The City's design specifications are comprehensive, having been developed from practical experience and generally accepted guidelines over a number of years. As would be expected, the City currently has no criteria for construction of nonpotable water systems, although many of the potable system standards are applicable. Those criteria considered of direct interest to this study are summarized in Table IV-2. It is important to note that the City's waterline sizing criteria, unlike the TDH criteria, do consider fire flows. Most importantly, if the potable system is to be utilized for firefighting, then the minimum potable line size is set by the City at six inches. This size is almost predetermined from the practical standpoint that fire hydrant fittings are almost universally six inches by industry standards and smaller lines cannot deliver the necessary fire demand without excessive head losses. It follows that smaller potable line sizes in a dual distribution cannot be effectively utilized for fires.

Legal and Administrative Constraints

With the adoption of the new nonpotable reuse regulations by TWC, legal and administrative constraints to implementing a reuse project are essentially limited to the issue of water rights. The TWC Water Quality Division is responsible for issuing Secondary Use Permits which authorize permit holders to divert wastewater effluent originating from surface waters for nonpotable uses. In water poor areas, upstream dischargers often dischargers often provide at least a portion of the raw water supply for downstream users, therefore, diversion of effluent originating from surface water might have a pronounced effect on the downstream user's supply. Secondary Use Permits, however, are not required for diversion of effluent from groundwater sources, because these sources are considered private water in Texas. Additionally, preliminary discussions with the TWC's Water Rights and Uses Division indicates that the original distributor of water to a system has the sole right to reuse water as long as it is used in lieu of potable water. Considering this information, Fairfield Village could begin using water from its wastewater treatment plant, to make beneficial use of this resource. The issue of water rights may "surface" in the future if the Fairfield community converts to a surface water supply or if the definition of State water is expanded to include groundwater.

DEVELOPMENT OF WATER DEMANDS

The Water Balance

As discussed above, the TWC requires that application rates for reclaimed water used for irrigation be based on a detailed water balance. The total annual application, then, is used in conjunction with the permit to discharge water from the treatment facility. A water balance for the study area has been developed based on the average historical precipitation data presented earlier and is presented in Table IV-3. Based on average precipitation and a "crop" of lawn grasses and landscape plantings typical to the area, the planning area maximum annual application rate is 29.77 inches per year. If open reservoirs provide storage, additional quantities of reclaimed water is necessary to replace evaporation losses, however, this amount does not affect the volume of water applied to the ground.

The water balance provides the maximum application rate under average rainfall conditions without allowing for any runoff as required by State regulations. According to the regulations, there does not appear to be a variance for below average rainfall years when irrigation needs are sometimes much higher. Presumably, the balance was developed for relatively simple reuse systems. A golf course, for example, with a simple "one-line" connection to the treatment facility and a single usage can be more easily controlled.

Including an absolute value in a discharge permit, however, may present some problems for an entity with a dual distribution system unless extremely rigorous record keeping is maintained. For example, certain reclaimed water flows, such as unaccounted water (fire flows, line losses, meter under-registration, etc.) and evaporative losses from cooling tower reuse, which are rather significant quantities, are not accounted for in the water balance computation. Also, regardless of how carefully irrigation water is applied, there will almost certainly be some runoff in a widespread distribution system from wind-driven spray drift, sprinkler head malfunction, or other similar causes. Reuse for toilet flushing complicates the issue, since the water is recirculated. If the water balance value is included in the discharge permit as a means of accounting for total wastewater volume, some provision for these losses and uses, likewise, should be included.

Variations in Water Demands

Notwithstanding regulatory design considerations, perhaps the single most important criteria in developing capacity requirements for dual distribution systems is an estimation of water demands and disaggregation into potable and nonpotable needs. The literature contains several examples and general guidelines for determining average water demands for dual distribution systems. These sources tend to be site specific and vary widely in categorical (residential, commercial, industrial, public, and unaccounted) and total needs. The variations in average water-use allocation are directly related to the economics of reuse. When public or industrial use is proportionately higher, it is possible that cost savings obtained from implementation of a water reuse project also will be higher. For these reasons, it is necessary that water use patterns be investigated in some detail for each particular reuse application.

Probably every community exhibits distinct water-use cycles: seasonal cycles, weekly cycles, and daily cycles. Seasonal variations in water-use are climatically related. The water balance, for example, indicates that higher irrigation water needs occur, on the average, in June. In the Houston area, demand patterns indicate that more water is consumed in the summer months than in the winter months and, most often, irrigation demands are responsible for the higher consumption. As evidenced in later sections, residential irrigation with potable supplies does not necessarily follow the water balance example, as typically more water is consumed in the months of July, August, and September, than in June. If irrigation is not restricted, watering occurs on an "as-perceived", rather than an "as-required" basis.

Weekly cycles in water-use, on the other hand, are often related to work schedules. Experience has shown that suburban communities with a high percentage of residential land-use, like the proposed Fairfield development, will typically use more water on a Saturday or Sunday than on a weekday. This phenomena might be related to certain water use activities being "reserved" for weekends, such as clothes washing, car washing, etc., and in many cases, lawn irrigation.

Daily cycles in suburban residential communities are often related to work schedules as well. Weekday water-use cycles will often exhibit a double crest: one between 5 a.m. and 9 a.m., corresponding to personal hygiene and culinary activities, and another in the evening, corresponding to after-work activities. Lawn irrigation activities and other miscellaneous uses can influence either peak. Experience in the Houston area shows that weekend water use patterns frequently display only one crest: in the evening after increasing steadily all day.

When designing a dual use water system, it is important to consider all of these water-use fluctuations. Not only are peak system demands important from the standpoint of potable water delivery, but minimum uses and subsequent return flows are directly related to the amount and need for storage in the nonpotable system. Thus, there are many inter-related considerations in the design of a dual use system.

Average Total Water Needs

For this study, water use patterns and total water requirements were investigated in detail for two well-established, yet growing, communities in the Houston area. Each community exhibits characteristics similar to those expected in Fairfield. Each community was the subject of previous engineering analyses to determine peak system potable water demands. These analyses were initiated following summertime operating experiences when peak needs (primarily irrigation) were just met by existing facilities. As such, the resulting computed system demands closely approximate "unconstrained" water consumption, that is, all "perceived" demands were satisfied. These perceived demands are the result of irrigation and other uses without an established effort to conserve or otherwise reduce peak system consumption. It is important to note that emergency demands, such as those caused by a fire, probably could not have been satisfied by the respective water systems at the time of analysis. For purposes of discussion, the communities are called "A" and "B".

Community A is located in northeast Harris County. The area is primarily residential, with attendant commercial development. In 1987, the water system consisted of two water plants with booster pump stations, six groundwater wells, and ground storage. Two elevated storage tanks provided a total of 2.25 million gallons of elevated storage. All water facilities exceeded minimum TDH design capacities.

Water demand data for Community A were gathered for the one-year period prior to the time of analysis -- from August 1986 to July 1987. During this period, there was an average of about 11,100 active equivalent single-family water connections, with an estimated five percent related to commercial development. The data indicate that September 1986 was the peak month of consumption, however, peak-day demands occurred on a weekend in July 1987. On the basis of billed usage, annual average consumption for the data period was 112.1 gallons per equivalent capita per day (GPECD) and peak-day consumption was estimated to be 346.3 GPECD. Peak-hour demand rate, which occurs on the peak day was about 521.9 GPECD. Table IV-4 summarizes the community's monthly water use pattern and Table IV-5 shows the peak-day consumption pattern for the data period. Figures IV-1 and IV-2 provide graphic comparisons.

Examination of aerial photographs of the area indicates a significant number of private swimming pools which, theoretically, tend to increase the average water demand. Most residential lots are also well-wooded which probably decreases average irrigation and total water demands. The community does not maintain special, highly manicured landscaped areas as are planned in Fairfield. Nevertheless, peak demands (attributable to irrigation) experienced in the summer of 1987 were well above what, until then, were considered "typical" for the area.

Rainfall would also be expected to influence water consumption in the community. Normal summer rainfall at nearby Houston Intercontinental Airport, averages about 11.1 inches for the months of June, July, and August. In the summer of 1987, coincident with the peak days of consumption, total summer rainfall was reportedly above normal, however, with a total of 15.6 inches recorded for the period. Extreme system peaks for the community, therefore, might be even higher.

Community B is located in west Harris County and consists of four municipal utility districts, each with a separate water supply plant consisting of booster pumps, a groundwater well, and ground storage. Elevated storage is not provided. The systems are interconnected with interconnections normally open, thus, the system functions as a single, integrated system. Three of the Districts are primarily residential and the fourth is primarily commercial.

Water demand data for Community B also was gathered for the one-year period prior to the time of its analysis -- from November 1987 to October 1988. During this period, there was an average of about 3,600 active equivalent single family water connections of which about 21 percent were commercially related. In Community B, July 1988 was the peak usage month with the highest single day of consumption similarly occurring on a July weekend. By comparison, average annual water demands for the period were 138.2 GPECD (billed consumption) and the peak-day demand was about 313.5 GPECD. The peak-hour demand rate was 530.1 GPECD. Analogous to Community A, actual peak-system demands were found to be significantly higher than those expected. Tables IV-6 and IV-7 provide the community's consumption patterns on a monthly and peak-day basis, respectively. Figure IV-1 and Figure IV-2 compare the information graphically for the data period with the results from Community A's analyses.

West Harris County developments characteristically are void of large numbers of trees, since historically these areas have been utilized for agriculture. The absence of wooded lots, and a corresponding increase in turfed areas, appears to contribute to higher annual average water demands than those in Community A. Community B also does not have extensive landscaping in its land plan although some common setback areas along major thoroughfares are maintained and irrigated by community associations. Rainfall totals at IAH for the summer of 1988 also were investigated to determine potential effects on consumption patterns in Community B. In this year, summertime total rainfall was 2.3 inches below the norm of 11.1 inches and probably contributed to higher demands. Despite the differences in summer rainfall, the water use patterns of the two communities appear quite similar.

The proposed Fairfield development, with the exception of the specially landscaped areas, could be considered a composite of these two existing communities. The total number of future equivalent connections, about 12,800, or alternately, the relative size of the proposed water system which influences peak system demands, approximates the size of Community A. Compared to Fairfield, the high residential land use component would tend to increase water demands, especially peak consumption. On the other hand, the land-use mix, also which influences system demands, more closely approximates Community B although Fairfield's future commercial equivalent connections is higher and will account for about 38 percent of the total development. A higher percentage of commercial development tends to decrease overall consumption, especially peak demands. Nevertheless, the inherent similarities provide a unique opportunity to utilize the available detailed water use information to estimate future water needs for the Fairfield community.

Disaggregation of Water Uses

Water consumption and water pumping records for the two communities were examined in detail to define "essential use", "irrigation", and "other use" demands. Water pumping records were included in the analysis to determine quantities of unaccounted water, that is, water loss due to waterline flushing, firefighting needs, watermain leaks, under-registration of meters, and unmetered connections. These losses were found to be well below "acceptable" limits of 10 to 15 percent of water production (see Tables IV-4 and IV-6), indicating few losses or unmetered uses were experienced in the systems. Such losses are experienced in almost all systems and must be considered when estimating total system supply needs.

Minimum "essential use" needs were estimated for each community on the basis of the month with the lowest usage. In both cases, the minimum usage month is December.

Essential uses are defined as water necessary for preparation of meals, house cleaning, laundry, toilet flushing, and bathing. Next, the essential uses were adjusted to include "other" needs for the remaining months to include water for swimming pools, carwashing, and miscellaneous outdoor activities. In the absence of local data for these needs, an allowance of five percent of the essential use needs was assumed for the cooler months of November, January, and February and ten percent was assumed for the remaining months. The addition of the minimum essential needs to the water demand associated with other needs constitutes the total essential needs. The difference between the essential needs and the total consumption yields the estimated irrigation and other miscellaneous "lumped" needs, for example cooling tower uses, construction activities, etc. of the community. Cooling water may be considered an essential need. However, as is true for irrigation needs, the demand for cooling water fluctuates by season and is minimal in the winter months. Similarly, construction activities are typically lower in winter months. Tables IV-4 and IV-6 present the results of these analyses on a monthly and annual average basis for Community A and Community B, respectively.

For comparison, monthly wastewater plant effluent data are provided for each community. The daily average wastewater flow of 93.5 GPECD for Community A compares well with the accepted engineering design standard of 100 GPECD. Community B's average wastewater flow of 61.6 GPECD is much lower than this value. This may be attributed to the relative newness of the collection system which would result in minimal infiltration and inflow. As the system ages, the average flow can be expected to increase.

Estimation of Water Needs in Fairfield (Non-Reuse System)

In order to estimate the future annual average "essential", "irrigation" and "other use" needs of a non-reuse, i.e., totally potable, system in Fairfield, an average of the two communities' results was prepared. Table IV-8 and Figure IV-3 present these data. Including unaccounted water demands (estimated at seven percent of production), adjustments for implemented water conservation measures, as well as adjustments for special irrigation needs of the Fairfield development, total an annual average water demand that is approximately 140.4 GPECD. Of this total, 83.2 GPECD are essential needs and the remainder, or 57.2 GPECD, are the estimated irrigation and other use category needs. Special irrigation needs assume one-third of areas identified as greenbelts, esplanades, and landscaped entryways will be "polished lawn areas" requiring sprinkling systems, and likewise, one-third of all park areas will be irrigated. The special areas irrigation application rate is based upon an analysis of needs in similar areas by commercial irrigators. It is important to note that these rates are developed from "practical time clock settings" for a completely automated sprinkling system and include an allowance for runoff. Irrigation and outdoor uses of residential areas follow the averaged, observed pattern in Communities A and B.

A similar analysis was completed to evaluate the future peak-day needs for the Fairfield community. Peak-system requirements are important, since they provide the basis for water system design. Table IV-9 and Figure IV-4 present the results of this analysis. Peak-day demand, in terms of consumption, is estimated to be about 329.9 GPECD or roughly 2.5 times the annual average daily consumption of 130.5 GPECD. Peak-hour demand rate is about 495.4 GPECD or approximately 3.8 times the annual average daily rate. It is extremely important to differentiate the results of these tables with the water needs of a dual use system. As noted in previous discussion, the basis of these estimates is "unconstrained" water consumption based on perceived needs of the consumer. For this reason, these demands represent water use on an as-needed basis and probably include water wasted as the result of over-irrigation and run-off from lawn and special use irrigation areas. In a dual use system, irrigation would at least be partially be controlled by a managing authority at application rates determined from the water balance analysis with little or no run-off as required by State regulations. As a result, system peaks are dampened considerably and significantly less water is lost to runoff.

Total required annual water volume for the non-reuse alternative can be easily computed from the consumption analyses tables by multiplying the number of equivalent capita at full development (44,807) times the average per equivalent capita rate times 365 days per year. This computation yields a future, total, annual water production of about 2.29 billion gallons. A similar computation for required peak-day needs yields 15.89 million gallons.

Estimation of Water System Needs in Fairfield (Reuse System)

Tables IV-10 and IV-11 present the results of comparable analyses considering the special requirements of a reuse system with dual distribution waterlines. Similar in-house potable water conservation measures have been assumed as presented for the non-reuse alternative in Table IV-8. Primary adjustments include a reduction in the special needs irrigation rate based on the water balance table and an allowance for only "front yard" watering with the nonpotable supply if a dual use system is implemented. This practice follows the example of the Irvine Ranch dual use system and provides residents an area that has been irrigated with potable water for outdoor recreational activities in the back yards. As noted above, system peaking factors and total water use would be reduced considerably if a reuse alternative were to be implemented. Table IV-10 and Figure IV-5 present annual average consumption and production for the potable and nonpotable uses in terms of GPECD. In comparison with Table IV-8, potable system production is reduced from 140.4 GPECD to 79.6 GPECD, or by about 40 percent. The average required nonpotable production is about 25.2 GPECD. Comparison of Table IV-9, peak-day consumption for the non-reuse alternative, and Table IV-11, peak-day consumption for the reuse alternative, reveals that peak-day uses are similarly reduced. Figures IV-4 and IV-6 provide graphic comparisons. The requirements for potable water production during peak-day potable is 124.9 GPECD instead of 354.7 GPECD. Non-potable water needs of 59.6 GPECD on a peak day would be acquired from the wastewater effluent.

Under the reuse alternative, the potable system peak-day factor reduces from 2.5 (non-reuse alternative) to 1.09 and the peak-hour factor reduces from 3.8 to 1.40. These factors are important from an engineering design standpoint, because they are the basis of system design. Comparison of total annual volume requirements, however, provides a measure of the beneficial effects of water conservation. For example, implementation of the irrigation reuse system, requires a total annual production volume of only 1.36 billion gallons or about 59 percent of the non-reuse alternative. Of this quantity an estimated 379.4 million gallons, or about 28 percent, would be recovered and utilized for irrigation and other uses.

Inclusion of Toilet Flush Water In a Reuse Alternative

One area of reuse not fully investigated, but which could be implemented in the study area, is the use of reclaimed water for toilet flushing. The literature indicates that 35 to 40 percent of total interior water use is for toilet flushing. Assuming that this value is reduced to 25 percent following implementation of water conservation measures, the study area essential use demands would be reduced by about one-fourth with a corresponding increase in the nonpotable reuse demand. For the study area, this approach equates to a reduction in the "Minimum Essential Use" column from Table IV-10 of 19.9 GPECD (0.25 x 79.6 GPECD) and an increase in the average "Total Nonpotable Water Needs" column of 19.9 GPECD. Thus, total potable needs would be decreased to an annual average daily rate of 63.3 GPECD (production of 83.2 - 19.9) and total nonpotable demand would be increased to 45.1 GPECD (production of 25.2 + 19.9). Again in comparable terms of total annual water volume, implementation of reuse, including toilet flushing needs, requires approximately 1.04 billion gallons of potable water, of which 737.6 million gallons, or about 71 percent is reclaimed. Considering peak-system variations, including fire demands, and the high average percentage of reuse volume, implementation of reuse for toilet flushing and irrigation in the study area is most likely the practical limit of reuse possibilities.

Firefighting Demands

As noted previously, water systems are generally designed to accommodate the expected peak demands imposed on the system. Usually, these demands are considered the peak-hour demand or the peak-day-plus-fire demand. In relatively small systems, peak-hour demands govern system design. In larger systems, like Fairfield, the peak-day-plus-fire demand is often higher.

Required firefighting flow rates and fire duration for Fairfield have been determined in earlier master planning studies based on criteria published by Insurance Services Offices (ISO). This non-profit agency assists in the determining fire insurance rates in 44 states in the U.S. At present, Texas' insurance rates are determined using a "Key Rate Schedule" adopted and published by the State Board of Insurance. Both schedules list minimum needed fire flows to calculate fire insurance rates, however, the two sources provide different requirements. The distinction is important because the design fire flow and duration affect various water system capacities. The Texas Key Rate Schedule, for example, provides for a fire flow of 3,000 gallons per minute (gpm) with an unspecified duration in "principal mercantile areas". The ISO schedule, on the other hand, considers needed fire flows on the basis of building material construction, contents, communications between buildings, and exposure to other buildings. By contrast, the proposed regional shopping mall, a principal mercantile area, presents the highest fire demand for the study area at 6,000 gpm for a six-hour duration. Differences also exist in the needed fire flow in residential areas. The Texas schedule considers 750 gpm (unspecified duration) as adequate in "congested residential areas", while the ISO schedule estimates a more conservative figure of 1,500 gpm (two-hour duration) as adequate.

Newspapers report that many consider the Texas schedule to be outdated, and there is current debate over adoption of the ISO schedule in its place. Since the ISO schedule provides conservative estimates, and because the current Texas schedule may be replaced, fire flows of 6,000 gpm for the regional mall and 1,500 gpm for single-family residential areas as reported in previous studies are utilized in subsequent analyses.

OTHER DESIGN CONSIDERATIONS

Nonpotable Storage Requirements

As discussed in earlier sections, the variations in demand in the potable and nonpotable systems versus return wastewater flow are important considerations in the design of a dual use system. When nonpotable demand exceeds return flow rate, storage must provide the difference. Potable demand, in turn, influences the quantity of wastewater effluent. Anticipated storage of non-potable water needs are proposed to be provided by open earthen reservoirs, since this type of facility is much less expensive than closed systems and could serve as attractive amenity lakes for the development. An entryway lake, already planned, could easily be converted to a nonpotable storage reservoir by provision of appropriate liners, if liners are determined as necessary. Open reservoirs are used successfully at area golf courses for reclaimed water storage.

Nonpotable Pressure Maintenance

Fluctuations in nonpotable demand may cause a water hammer in the distribution system, unless provisions are included in the system design to dampen these effects. Pressure can be maintained by elevated storage tanks or hydro-pneumatic tanks. Elevated storage is often recommended in potable systems to provide a pressurized water source in the event of electrical or mechanical system failure. The pressurized source usually prevents air entrapment in the waterlines, minimizing the potential for contamination of the public drinking water supply. Hydro-pneumatic tanks are much smaller in size and cannot prevent air entrapment in the waterlines in the event of power failure or booster pump malfunction. This is a primary argument for TDH's recommendation of elevated storage in larger potable systems. Elevated storage, while much more reliable than hydro-pneumatic storage, is also much more expensive and is probably not necessary in a nonpotable system since drinking water quality is not of concern. For these reasons, hydro-pneumatic tanks are recommended for pressure maintenance of the nonpotable system.

Auxiliary Power

Since the nonpotable system is to be relied upon for firefighting needs, auxiliary power should be provided in the event of power failure. Auxiliary power is required by TDH for the potable system. Similar facilities are proposed for the nonpotable distribution system.

Special Considerations

Implementation of dual use systems in other communities has been preceded by adoption of special design codes aimed at protecting against unauthorized or mistaken use of the nonpotable supply. Primary steps implemented at Irvine Ranch and/or St. Petersburg include the following:

- Special staff training and ongoing staff education programs
- Special supervision of new reclaimed water system construction
- Color-coded pipe or stenciled pipe for potable and/or nonpotable waterlines

- Different shaped water valves or burying of nonpotable waterline valves below ground and special markings on hydrants
- Non-standard pipe threading
- Prohibition of hose bibs and use of special connectors between the street connection and sprinkler grid
- Use of conspicuous warning signs at ponds and lakes
- Additional measures to prevent the breeding of flies, mosquitos, and other vectors. It is anticipated similar measures would be employed in the local area.

Additional Wastewater Treatment Needs

The proposed regional wastewater treatment plant will be permitted to discharge effluent with water quality of 10 mg/L BOD_5, 15 mg/L TSS, and 3 mg/L NH_3-N. Irrigation of restricted access areas requires a higher quality effluent containing only 5 mg/L BOD_5, turbidity of 3 NTU and a fecal coliform limit of 75 CFU per 100 ml. BOD_5, turbidity, and fecal coliform levels are related to the TSS concentration, although disinfection also controls the level of viable microorganisms. To consistently achieve these limits, effluent filtration is proposed to remove additional suspended material. It should be noted that many permittees with the same discharge limits as Fairfield are installing effluent filtration units purely as insurance against process upsets which might cause discharge violations. Others are providing space for the units in plant expansion plans, since future waste load evaluation studies for receiving streams may dictate higher levels of treatment. Nevertheless, the filters currently are required to polish the effluent for a reuse application and are included in the cost analysis.

TABLE IV-1 - MINIMUM TEXAS DEPARTMENT OF HEALTH WATERLINE SIZES

Maximum Number of Connections	Minimum Main Size (in inches)
2	1
5	1.5
10	2
25	2.5
50	3
100	4
150	5
250	6
>250	8 and larger

Source: Rules and Regulations for Public Water Systems, Texas Department of Health, 1988.

TABLE IV-2 - CITY OF HOUSTON MINIMUM WATERLINE SIZING CRITERIA

WATERLINE SIZE (inches)	NOTES
2	May serve a maximum of 8 lots when supported on both ends by a larger main. Dead-ended 2-inch mains may serve no more than 5 lots.
4	May serve a maximum of 26 lots when supported on both ends by a larger main. A deadend line may supply a maximum of 16 lots.
6	Mains to be a maximum of 1200 feet long when supported on both ends by 8-inch mains or larger and shall have no more than one intermediate flushing valve or fire hydrant. Deadend 6-inch mains shall not be more than 500 feet in length.
8	Required size for lines over 1200 feet long or when more than one intermediate flushing valve or fire hydrant is required.
12	12-inch and larger mains to be determined by Engineer and verified by City of Houston Water Division Engineering.

Source: COH Engineering Design Criteria for the Preparation of Plan and Profile Drawings for the Design and Expansion of the Water System, Dept. of Public Works, 1979.

TABLE IV-3 - WATER BALANCE FOR ULTIMATE DEVELOPMENT IN FAIRFIELD VILLAGE

MONTH (1)	AVERAGE PRECIP. (2)	AVERAGE RUNOFF (3)	AVERAGE INFILTRA. RAINFALL (2)-(3) (4)	EVAPO - TRANSP - IRATION (5)	REQUIRED LEACHING (6)	TOTAL WATER NEEDS (5)+(6) (7)	EFFLUENT NEEDED IN ROOT ZONE (7)-(4) (8)	EVAPORA. FROM RESERVOIR SURFACE (9)	EFFLUENT TO BE APPLIED TO LAND (8)/K (10)	CONSUMPTION FROM RESERVOIR (9)+(10) (11)
January	3.64	1.36	2.28	0.4	0.00	0.40	0.00	-0.014	0.00	-0.01
February	3.78	1.45	2.33	0.7	0.00	0.70	0.00	-0.014	0.00	-0.01
March	2.50	0.61	1.89	2.6	0.08	2.68	0.79	0.063	0.87	0.93
April	3.82	1.48	2.34	3.8	0.16	3.96	1.62	0.063	1.80	1.86
May	4.98	2.35	2.63	6.7	0.44	7.14	4.51	0.070	5.01	5.08
June	4.39	1.90	2.49	7.6	0.56	8.16	5.67	0.133	6.30	6.43
July	3.13	1.01	2.12	7.2	0.55	7.75	5.63	0.169	6.26	6.43
August	3.11	0.99	2.12	5.0	0.31	5.31	3.19	0.183	3.54	3.72
September	5.39	2.69	2.70	5.6	0.32	5.92	3.22	0.098	3.58	3.68
October	4.19	1.75	2.44	4.4	0.21	4.61	2.17	0.126	2.41	2.54
November	3.78	1.45	2.33	2.2	0.00	2.20	0.00	0.035	0.00	0.04
December	4.53	2.01	2.52	1.1	0.00	1.10	0.00	-0.007	0.00	-0.01
Total	47.24	19.05	28.19	47.3	2.63	49.93	26.80	0.905	29.77	30.68

COLUMN NOTES:

2. Precipitation obtained from NOAA - Climatography of the United States No. 81 for Texas from 1951 to 1980.
3. Runoff was determined with a weighted curve number of 74.
5. These data are from the TWDB - Bulletin 6019, "Consumptive Use of Water by Major Crops in Texas," using the alfalfa crop data. The units for the total are IN-AC/AC-YR.
6. The input data for electrical conductivity of the effluent (Ce) was determined to be 0.98 millimhos/cm at 25 C and the maximum allowable conductivity of soil solution (Cl) was 10.0 for St. Augustine grass, shrubbery, and trees.
9. Utilized Lake Houston net evaporation data from the Texas Water Oriented Data Bank. These data are adjusted to 5.9% for reservoir to irrigation areas.
10. Irrigation efficiency (K) is 90% (efficiency of application rate towards infiltrating into the soil with only evaporation and no runoff). The maximum application rate of 29.77 IN/YR is used in conjunction with a permit to discharge treated wastewater.

(All Column Units are Inches of Water per Acre of Irrigated Area.)

TABLE IV-4 - COMMUNITY "A" ANNUAL WATER CONSUMPTION ANALYSIS

DATE	AVERAGE DAILY WATER CONSUMPTION (Billed - MG/MONTH)	EQUIVALENT SINGLE FAMILY CONNECTIONS (ESFC)	AVERAGE DAILY WATER NEEDS (GPECD)	MINIMUM ESSENTIAL USE (1) (GPECD)	OTHER ESSENTIAL NEEDS (2) (GPECD)	AVERAGE DAILY ESSENTIAL NEEDS (GPECD)	ESTIMATED IRRIGATION AND OTHER DEMAND (3) (GPECD)	RECORDED AVERAGE DAILY WASTEWATER FLOW (4) (MGD)	RECORDED AVERAGE DAILY WASTEWATER FLOW (GPECD)
AUG 1986	212.6	11,125	176.1	68.2	17.6	85.8	90.3	3.33	85.5
SEP	232.3	11,433	193.5	68.2	19.4	87.6	105.9	3.64	91.0
OCT	139.0	11,124	115.2	68.2	11.5	79.7	35.5	3.78	97.1
NOV	104.1	10,991	90.2	68.2	4.5	72.7	17.5	3.87	100.6
DEC	80.6	10,888	68.2	68.2	0.0	68.2	0.0	4.05	106.3
JAN 1987	95.5	10,974	80.2	68.2	4.0	72.2	8.0	3.97	103.4
FEB	84.2	10,990	78.2	68.2	3.9	72.1	6.1	3.95	102.7
MAR	100.4	10,944	84.6	68.2	8.5	76.7	7.9	3.47	90.6
APR	147.3	11,125	126.1	68.2	12.6	80.8	45.3	3.26	83.7
MAY	137.2	11,391	111.0	68.2	11.1	79.3	31.7	3.48	87.3
JUN	141.1	11,262	119.3	68.2	11.9	80.1	39.2	3.62	91.8
JUL	126.4	11,336	102.8	68.2	10.3	78.5	24.3	3.26	82.2
Total	1,600.7	---	1,345.4	818.4	115.3	933.7	411.7	43.7	1,122.2
Average	133.4	11,133	112.1	68.2	9.6	77.8	34.3	3.64	93.5 (6)
Average Production(5)	142.4		119.6	72.8	10.2	83.0	36.6		

NOTES:
(1) Minimum Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing, and bathing and equals the lowest monthly 'Average Daily Water Consumption' (gallons per equivalent capita per day).
(2) Other essential needs: Pools, carwashing, and miscellaneous outdoor activities. Assumes 5% of 'Minimum Essential Needs' in November, January and February and 10% in remaining months (except December).
(3) Estimated irrigation and other demand: Water used for lawn, garden, and other irrigation needs. Includes ot commercial uses, i.e., cooling tower uses, etc.
(4) Measured wastewater effluent rates provided for comparison.
(5) Water loss ratio for record period was 6.3% of total water produced.
(6) Wastewater system is older that Community "B" resulting in more infiltration/inflow.

TABLE IV-5 - COMMUNITY "A" PEAK-DAY WATER CONSUMPTION ANALYSIS

TIME (HOUR)	PEAK-DAY WATER CONSUMPTION (Billed - GPM)	PEAK-DAY WATER NEEDS (1) (GPECD)	PEAK-DAY ESSENTIAL NEEDS (2) (GPECD)	ESTIMATED IRRIGATION AND OTHER DEMAND (3) (GPECD)	RECORDED WASTE-WATER FLOW (MGD)	RECORDED WASTE-WATER FLOW (GPECD)
0	3,590	130.3	76.3	54.0	2.73	68.7
1	3,640	132.1	56.0	76.1	2.00	50.4
2	3,290	119.4	63.0	56.4	2.25	56.7
3	3,300	119.8	49.7	70.1	1.78	44.7
4	4,930	178.9	47.6	131.3	1.70	42.8
5	5,700	206.9	57.4	149.5	2.05	51.7
6	6,960	252.6	53.2	199.4	1.90	47.9
7	8,840	320.8	70.0	250.8	2.50	63.0
8	10,830	393.1	85.4	307.7	3.05	76.9
9	11,910	432.3	105.7	326.6	3.78	95.1
10	11,880	431.2	128.1	303.1	4.58	115.3
11	12,390	449.7	127.4	322.3	4.55	114.7
12	12,840	466.0	123.9	342.1	4.43	111.5
13	12,930	469.3	110.7	358.6	3.95	99.6
14	13,050	473.6	111.3	362.3	3.98	100.2
15	13,170	478.0	112.0	366.0	4.00	100.8
16	14,180	514.6	106.4	408.2	3.80	95.8
17	13,940	505.9	107.8	398.1	3.85	97.0
18	14,380	521.9	112.0	409.9	4.00	100.8
19	12,670	459.8	100.1	359.7	3.58	90.1
20	12,000	435.5	104.3	331.2	3.73	93.9
21	10,120	367.3	103.7	263.6	3.70	93.3
22	8,040	291.8	107.8	184.0	3.85	97.0
23	4,440	161.1	86.8	74.3	3.10	78.1
Total	229,020.0	8,311.9	2,206.6	6,105.3	78.80	1,986.0
Average	9,542.5	346.3	91.9	254.4	3.30	82.8
Average Production (4)	10,184.1	369.6	98.1	271.5		

NOTES:

(1) GPECD: Gallons per equivalent capita per day.

(2) Peak Day Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing and bathing as well as carwashing, pools, and miscellaneous outdoor activities and assumes a 90% return wastewater flow.

(3) Estimated Irrigation and Other Demand: Water used for lawn, garden, and other irrigation needs. Includes other commercial uses, i.e., cooling tower uses, etc.

(4) Constant annual water loss ratio was 6.3% of total water produced.

TABLE IV-6 - COMMUNITY "B" ANNUAL WATER CONSUMPTION ANALYSIS

DATE	AVERAGE DAILY WATER CONSUMPTION (Billed - MG/MONTH)	EQUIVALENT SINGLE FAMILY CONNECTIONS (ESFC)	AVERAGE DAILY WATER NEEDS (GPECD)	MINIMUM ESSENTIAL USE (1) (GPECD)	OTHER ESSENTIAL NEEDS (2) (GPECD)	AVERAGE DAILY ESSENTIAL NEEDS (GPECD)	ESTIMATED IRRIGATION AND OTHER DEMAND (3) (GPECD)	RECORDED AVERAGE DAILY WASTEWATER FLOW (4) (MGD)	RECORDED AVERAGE DAILY WASTEWATER FLOW (GPECD)
NOV 1987	40.2	3,354	114.1	79.7	5.7	85.4	28.7	0.82	70.1
DEC	29.0	3,353	79.7	79.7	0.0	79.7	0.0	0.83	70.7
JAN 1988	33.5	3,399	90.8	79.7	4.5	84.2	6.6	0.79	66.4
FEB	29.6	3,430	88.1	79.7	4.4	84.1	4.0	0.80	66.6
MAR	40.2	3,467	106.9	79.7	10.7	90.4	16.5	0.84	69.6
APR	41.8	3,517	113.2	79.7	11.3	91.0	22.2	0.86	69.5
MAY	58.1	3,544	151.1	79.7	15.1	94.8	56.3	0.87	70.3
JUN	58.0	3,584	154.1	79.7	15.4	95.1	59.0	0.90	72.0
JUL	90.4	3,696	225.4	79.7	22.5	102.2	123.2	0.93	71.6
AUG	72.4	3,782	176.4	79.7	17.6	97.3	79.1	1.03	77.6
SEP	82.1	3,820	204.7	79.7	20.5	100.2	104.5	1.05	78.2
OCT	64.2	3,845	153.9	79.7	15.4	95.1	58.8	1.04	77.2
Total	639.5	---	1,658.4	956.4	143.1	1,099.5	558.9	14.77	859.8
Average	53.3	3,566	138.2	79.7	11.9	91.6	46.6	1.2	71.7 (6)
Average Production(5)	57.8		149.9	86.4	12.9	99.3	50.5		

NOTES:
(1) Minimum Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing, and bathing and equals the lowest monthly 'Average Daily Water Consumption' (gallons per equivalent capita per day).
(2) Other essential needs: Pools, carwashing, and miscellaneous outdoor activities. Assumes 5% of 'Minimum Essential Needs' in November, January and February and 10% in remaining months (except December).
(3) Estimated irrigation and other demand: Water used for lawn, garden, and other irrigation needs. Includes other commercial uses, i.e., cooling tower uses, etc.
(4) Measured wastewater effluent rates provided for comparison.
(5) Water loss ratio for record period was 7.8% of total water produced.
(6) Wastewater sytem is newer than Community "A" resulting in less infiltration/inflow.

TABLE IV-7 - COMMUNITY "B" PEAK-DAY WATER CONSUMPTION ANALYSIS

TIME (HOUR)	PEAK-DAY WATER CONSUMPTION (Billed - GPM)	PEAK-DAY WATER NEEDS (1) (GPECD)	PEAK-DAY ESSENTIAL NEEDS (2) (GPECD)	ESTIMATED IRRIGATION AND OTHER DEMAND (3) (GPECD)	STUDY AREA RECORDED WASTE-WATER FLOW (MG/HR)	STUDY AREA RECORDED WASTE-WATER FLOW (GPECD)
0	1,541.6	171.6	78.3	93.3	0.038	70.5
1	1,431.5	159.4	61.9	97.5	0.030	55.7
2	1,431.5	159.4	43.3	116.1	0.021	39.0
3	1,459.0	162.4	37.1	125.3	0.018	33.4
4	1,459.0	162.4	30.9	131.5	0.015	27.8
5	1,459.0	162.4	30.9	131.5	0.015	27.8
6	1,844.4	205.3	30.9	174.4	0.015	27.8
7	2,092.2	232.9	43.3	189.6	0.021	39.0
8	2,340.0	260.5	61.9	198.6	0.030	55.7
9	2,918.1	324.8	90.7	234.1	0.044	81.6
10	2,890.5	321.8	96.9	224.9	0.047	87.2
11	3,386.1	376.9	103.1	273.8	0.050	92.8
12	3,413.6	380.0	109.2	270.8	0.053	98.3
13	3,413.6	380.0	109.2	270.8	0.053	98.3
14	3,441.1	383.1	103.1	280.0	0.050	92.8
15	3,468.6	386.1	103.1	283.0	0.050	92.8
16	3,523.7	392.2	96.9	295.3	0.047	87.2
17	3,661.3	407.6	96.9	310.7	0.047	87.2
18	4,211.9	468.9	90.7	378.2	0.044	81.6
19	4,762.5	530.1	90.7	439.4	0.044	81.6
20	4,652.4	517.9	90.7	427.2	0.044	81.6
21	4,184.4	465.8	84.6	381.2	0.041	76.1
22	2,863.0	318.7	84.6	234.1	0.041	76.1
23	1,734.3	193.1	84.6	108.5	0.041	76.1
Total	67,583.3	7,523.3	1,853.5	5,669.8	0.899	1,668.0
Average	2,816.0	313.5	77.2	236.2	0.037	69.5
Average Production (4)	3,054.2	340.0	83.7	256.2		

NOTES:

(1) GPECD: Gallons per equivalent capita per day.

(2) Peak Day Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing and bathing as well as carwashing, pools, and miscellaneous outdoor activities and assumes a 90% return wastewater flow.

(3) Estimated Irrigation and Other Demand: Water used for lawn, garden, and other irrigation needs. Includes other commercial uses, i.e., cooling tower uses, etc.

(4) Constant annual water loss ratio was 7.8% of total water produced.

TABLE IV-8 - FAIRFIELD VILLAGE ANNUAL WATER CONSUMPTION ANALYSIS: NON-REUSE ALTERNATIVE

	ESSENTIAL NEEDS					IRRIGATION AND OTHER NEEDS				
MONTH	AVERAGE DAILY WATER CONSUMPTION (GPECD)	MINIMUM ESSENTIAL USE (1) (GPECD)	OTHER ESSENTIAL NEEDS (2) (GPECD)	EXPECTED CONSERVATION ADJUSTMENT (3) (GPECD)	AVERAGE DAILY NEEDS (GPECD)	ESTIMATED UNCONSTRAINED DEMAND (4) (GPECD)	SPECIAL AREAS RATE (5) (GPD/AC)	SPECIAL AREAS NEEDS (6) (GPECD)	TOTAL IRRIG. AND OTHER NEEDS (GPECD)	TOTAL WATER NEEDS (GPECD)
JAN	85.5	74.0	4.3	(7.4)	70.9	14.6	0.0	0.0	14.6	85.5
FEB	83.1	74.0	4.2	(7.4)	70.8	12.3	0.0	0.0	12.3	83.1
MAR	95.7	74.0	9.6	(7.4)	76.2	19.5	364.6	0.8	20.3	96.5
APR	119.7	74.0	12.0	(7.4)	78.6	41.1	1,514.2	3.2	44.3	122.9
MAY	131.0	74.0	13.1	(7.4)	79.7	51.3	4,080.1	8.6	59.9	139.6
JUN	136.7	74.0	13.7	(7.4)	80.3	56.4	7,750.5	16.3	72.7	153.0
JUL	164.1	74.0	16.4	(7.4)	83.0	81.1	6,997.0	14.7	95.8	178.8
AUG	176.3	74.0	17.6	(7.4)	84.2	92.1	5,799.0	12.2	104.3	188.5
SEP	199.2	74.0	19.9	(7.4)	86.5	112.7	2,978.2	6.3	119.0	205.5
OCT	134.6	74.0	13.5	(7.4)	80.1	54.5	1,111.2	2.3	56.8	136.9
NOV	102.2	74.0	5.1	(7.4)	71.7	30.5	0.0	0.0	30.5	102.2
DEC	74.0	74.0	0.0	(7.4)	66.6	7.4	0.0	0.0	7.4	74.0
Total	1,502.1	888.0	129.4	(88.8)	928.6	573.5	30,594.8	64.4	637.9	1,566.5
Average	125.2	74.0	10.8	(7.4)	77.4	47.8	2,549.6	5.4	53.2	130.5
Required Production(7)	134.6	79.6	11.6	(8.0)	83.2	51.4	2,741.5	5.8	57.2	140.3

NOTES:
(1) Minimum Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing, and bathing and equals the lowest monthly 'Average Daily Water Consumption' (gallons per equivalent capita per day).
(2) Other essential needs: Pools, carwashing, and miscellaneous outdoor activities. Assumes 5% of 'Minimum Essential Needs' in November, January and February and 10% in remaining months (except December).
(3) Expected conservation adjustment is 10% of 'Minimum Essential Use' due to installation of water conservation methods.
(4) Estimated demand includes water used for lawn, garden, and other irrigation needs. Includes other commercial uses, i.e., cooling towers, etc.
(5) Special Area Rate: Monthly irrigation rate based on analysis of needs by an irrigation company for "practical time clock settings".
(6) Special Area Needs: Per equivalent capita conversion of special area irrigation needs for 94.3 acres of parks, esplanades, greenbelts, etc.
(7) Assumes a 7% water loss ratio.

TABLE IV-9 - FAIRFIELD VILLAGE PEAK-DAY WATER CONSUMPTION ANALYSIS
NON-REUSE ALTERNATIVE

TIME (HOUR)	PEAK-DAY WATER NEEDS (1) (GPECD)	PEAK-DAY ESSENTIAL NEEDS (2) (GPECD)	ESTIMATED IRRIGATION AND OTHER DEMAND (3) (GPECD)	WASTE-WATER FLOW (GPECD)
0	151.0	77.3	73.7	69.6
1	145.8	59.0	86.8	53.1
2	139.4	53.2	86.2	47.9
3	141.1	43.4	97.7	39.1
4	170.7	39.2	131.5	35.3
5	184.7	44.2	140.5	39.8
6	229.0	42.1	186.9	37.9
7	276.9	56.7	220.2	51.0
8	326.8	73.7	253.1	66.3
9	378.6	98.2	280.4	88.4
10	376.5	112.6	263.9	101.3
11	413.3	115.3	298.0	103.8
12 Noon	423.0	116.6	306.4	104.9
13	424.7	110.0	314.7	99.0
14	428.4	107.2	321.2	96.5
15	432.1	107.6	324.5	96.8
16	453.4	101.7	351.7	91.5
17	456.8	102.3	354.5	92.1
18	495.4	101.3	394.1	91.2
19	495.0	95.4	399.6	85.9
20	476.7	97.6	379.1	87.8
21	416.6	94.1	322.5	84.7
22	305.3	96.2	209.1	86.6
23	177.1	85.7	91.4	77.1
Total	7,918.3	2,030.6	5,887.7	1,827.6
Average	329.9	84.6	245.3	76.2
Average Production (4)	354.7	91.0	263.8	

NOTES:
(1) GPECD: Gallons per equivalent capita per day.
(2) Peak-Day Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing and bathing as well as carwashing, pools, and miscellaneous outdoor activities and assumes a 90% return wastewater flow.
(3) Estimated Irrigation and Other Demand: Water used for lawn, garden, and other irrigation needs. Includes other commercial uses, i.e., cooling tower uses, etc.
(4) Constant annual water loss ratio was 7% of total water produced.

TABLE IV-10 - FAIRFIELD VILLAGE ANNUAL WATER CONSUMPTION ANALYSIS: REUSE ALTERNATIVE

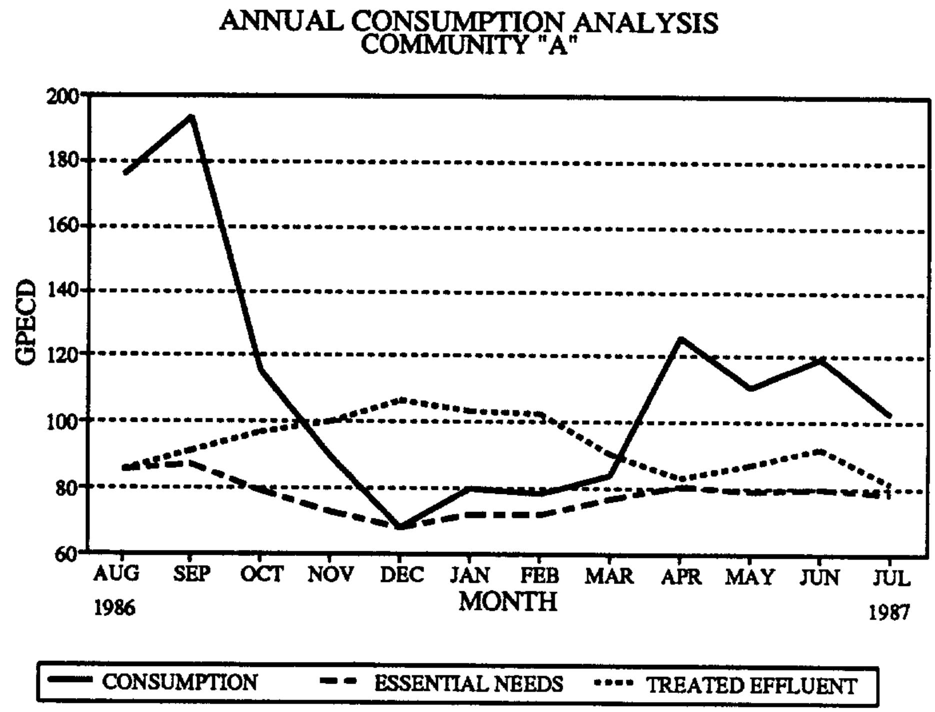
MONTH	POTABLE NEEDS AND POTABLE IRRIGATION					NONPOTABLE USES			
	MINIMUM ESSENTIAL USE (1) (GPECD)	OTHER ESSENTIAL NEEDS (2) (GPECD)	POTABLE IRRIGATION DEMAND (3) (GPECD)	EXPECTED CONSERVATION ADJUSTMENT (4) (GPECD)	AVG. DAILY POTABLE NEEDS (GPECD)	IRRIGATION AREAS RATE (5) (GPD/AC)	IRRIGATION AREAS NEEDS (6) (GPECD)	OTHER NONPOTABLE USES (7) (GPECD)	TOTAL NON-POTABLE WATER NEEDS (GPECD)
JAN	74.0	4.3	0.0	(7.4)	70.9	0.0	0.0	3.5	3.5
FEB	74.0	4.2	0.0	(7.4)	70.8	0.0	0.0	3.5	3.5
MAR	74.0	9.6	0.7	(7.4)	76.2	776.5	6.9	3.8	10.7
APR	74.0	12.0	3.6	(7.4)	82.2	1,606.7	14.2	4.1	18.3
MAY	74.0	13.1	7.7	(7.4)	87.4	4,471.8	39.5	4.4	43.9
JUN	74.0	13.7	14.5	(7.4)	94.8	5,623.3	49.6	4.7	54.3
JUL	74.0	16.4	13.1	(7.4)	96.1	5,587.6	49.3	4.8	54.1
AUG	74.0	17.6	10.9	(7.4)	95.1	3,159.7	27.9	4.8	32.7
SEP	74.0	19.9	5.6	(7.4)	92.1	3,195.5	28.2	4.6	32.8
OCT	74.0	13.5	2.1	(7.4)	82.2	2,152.5	19.0	4.1	23.1
NOV	74.0	5.1	2.1	(7.4)	73.8	0.0	0.0	3.7	3.7
DEC	74.0	0.0	2.1	(7.4)	68.7	0.0	0.0	3.4	3.4
Total	888.0	129.4	62.4	(88.8)	990.3	26,573.6	234.5	49.4	283.9
Average	74.0	10.8	5.2	(7.4)	82.5	2,214.5	19.5	4.1	23.7
Ave Production(8)	79.6	11.6	5.6	(8.0)	88.7	2,381.2	21.0	4.4	25.4

NOTES:
(1) Minimum Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing, and bathing and equals the lowest month daily average from Tables IV-3 and IV-5 (gallons per equivalent capita per day).
(2) Other essential needs: Pools, carwashing, and miscellaneous outdoor activities. Assumes 5% of 'Minimum Essential Needs' in November, January and February and 10% in remaining months (except December) from Tables IV-4 and IV-6.
(3) Adapted from rates provided by commercial irrigators.
(4) Expected conservation adjustment is 10% of 'Minimum Essential Use' due to implementation of water conservation measures.
(5) Irrigation Area Rate: Monthly irrigation rate based on water balance table analysis.
(6) Irrigation Area Needs: Per equivalent capita conversion of special area irrigation needs for 94.3 acres of parks, greenbelts, esplanades, etc. and 301.1 acres of residential lawns.
(7) Assumes 5 percent of 'Average Daily Potable Needs'; (8) Required production assuming a 7% water loss ratio.

TABLE IV-11 - FAIRFIELD VILLAGE PEAK-DAY WATER CONSUMPTION ANALYSIS
REUSE ALTERNATIVE

	POTABLE NEEDS AND POTABLE IRRIGATION				NONPOTABLE IRRIGATION AND OTHER NONPOTABLE USES			
TIME (HOUR)	WASTE-WATER FLOW (1) (GPECD)	PEAK-DAY ESSENTIAL NEEDS (2) (GPECD)	ESTIMATED POTABLE IRRIGATION DEMAND (3) (GPECD)	TOTAL PEAK-DAY POTABLE NEEDS (GPECD)	IRRIGATION AREAS NEEDS (4) (GPECD)	OTHER NONPOTABLE NEEDS (5) (GPECD)	TOTAL NONPOTABLE WATER NEEDS (GPECD)	TOTAL WATER NEEDS (GPECD)
0	69.6	77.3	9.5	86.8	198.4	4.3	202.7	289.5
1	53.1	59.0	11.2	70.2	198.4	3.5	201.9	272.1
2	47.9	53.2	11.1	64.3	198.4	3.2	201.6	265.9
3	39.1	43.4	12.6	56.0	198.4	2.8	201.2	257.2
4	35.3	39.2	16.9	56.1	198.4	2.8	201.2	257.3
5	39.8	44.2	18.1	62.3	0.0	3.1	3.1	65.4
6	37.9	42.1	24.0	66.1	0.0	3.3	3.3	69.4
7	51.0	56.7	28.3	85.0	0.0	4.3	4.3	89.3
8	66.3	73.7	32.6	106.3	0.0	5.3	5.3	111.6
9	88.4	98.2	36.1	134.3	0.0	6.7	6.7	141.0
10	101.3	112.6	34.0	146.6	0.0	7.3	7.3	153.9
11	103.8	115.3	38.3	153.6	0.0	7.7	7.7	161.3
12 Noon	104.9	116.6	39.4	156.0	0.0	7.8	7.8	163.8
13	99.0	110.0	40.5	150.5	0.0	7.5	7.5	158.0
14	96.5	107.2	41.3	148.5	0.0	7.4	7.4	155.9
15	96.8	107.6	41.8	149.4	0.0	7.5	7.5	156.9
16	91.5	101.7	45.2	146.9	0.0	7.3	7.3	154.2
17	92.1	102.3	45.6	147.9	0.0	7.4	7.4	155.3
18	91.2	101.3	50.7	152.0	0.0	7.6	7.6	159.6
19	85.9	95.4	51.4	146.8	0.0	7.3	7.3	154.1
20	87.8	97.6	48.8	146.4	0.0	7.3	7.3	153.7
21	84.7	94.1	41.5	135.6	0.0	6.8	6.8	142.4
22	86.6	96.2	26.9	123.1	0.0	6.2	6.2	129.3
23	77.1	85.7	11.8	97.5	198.4	4.9	203.3	300.8
Total	1,827.6	2,030.6	757.6	2,788.2	1,190.4	139.4	1,329.8	4118.0
Average	76.2	84.6	31.6	116.2	49.6	5.8	55.4	171.6
Required Production(6)	81.9	91.0	34.0	124.9	53.3	6.2	59.6	184.5

NOTES:
(1) GPECD: Gallons per equivalent capita per day. Average from Communites A and B.
(2) Peak Day Essential Use: Water needed for kitchen, house cleaning, laundry, toilet flushing and bathing as well as carwashing, pools, and miscellaneous outdoor activities and assumes a 90% return wastewater flow.
(3) Potable irrigation for residential back lawn areas.
(4) Nonpotable irrigation for front lawns, esplanades, parks, greenbelts, etc.
(5) Includes uses for cooling towers, etc. Assumes 5 percent of ' Peak-Day Potable Needs'.
(6) Assumes a 7% water loss ratio.


ANNUAL CONSUMPTION ANALYSIS
COMMUNITY "A"
GPECD
200
180
160
140
120
100
80
60
AUG SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL
1986
MONTH
1987
CONSUMPTION
ESSENTIAL NEEDS
TREATED EFFLUENT

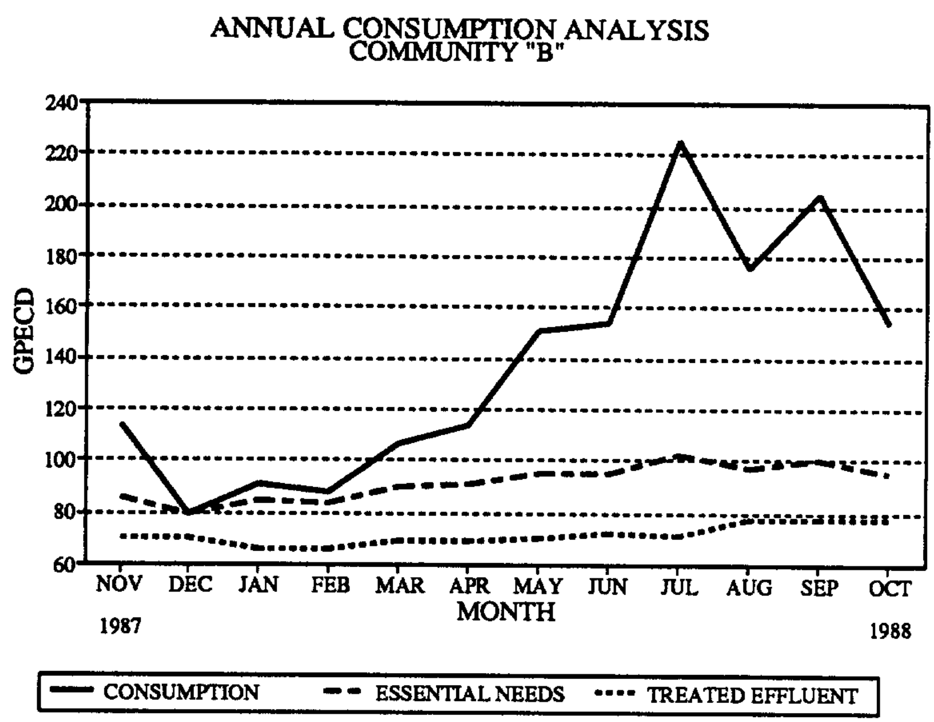
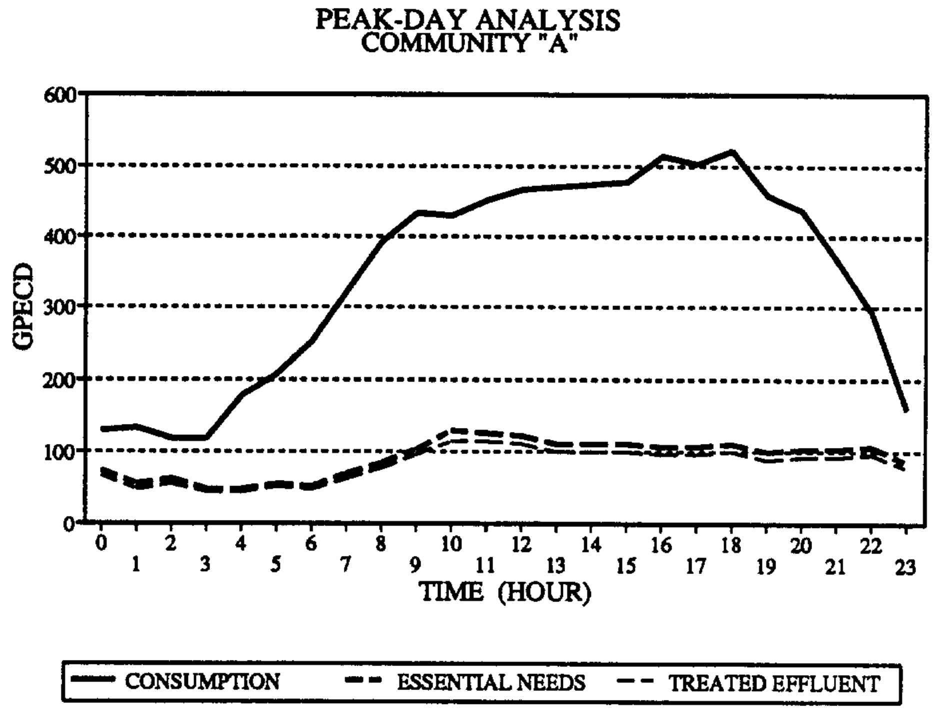

ANNUAL CONSUMPTION ANALYSIS
COMMUNITY "B"
GPECD
240
220
200
180
160
140
120
100
80
60
NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT
1987
MONTH
1988
CONSUMPTION
ESSENTIAL NEEDS
TREATED EFFLUENT

Figure IV-1


PEAK-DAY ANALYSIS
COMMUNITY "A"
GPECD
0
100
200
300
400
500
600
TIME (HOUR)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
CONSUMPTION
ESSENTIAL NEEDS
TREATED EFFLUENT

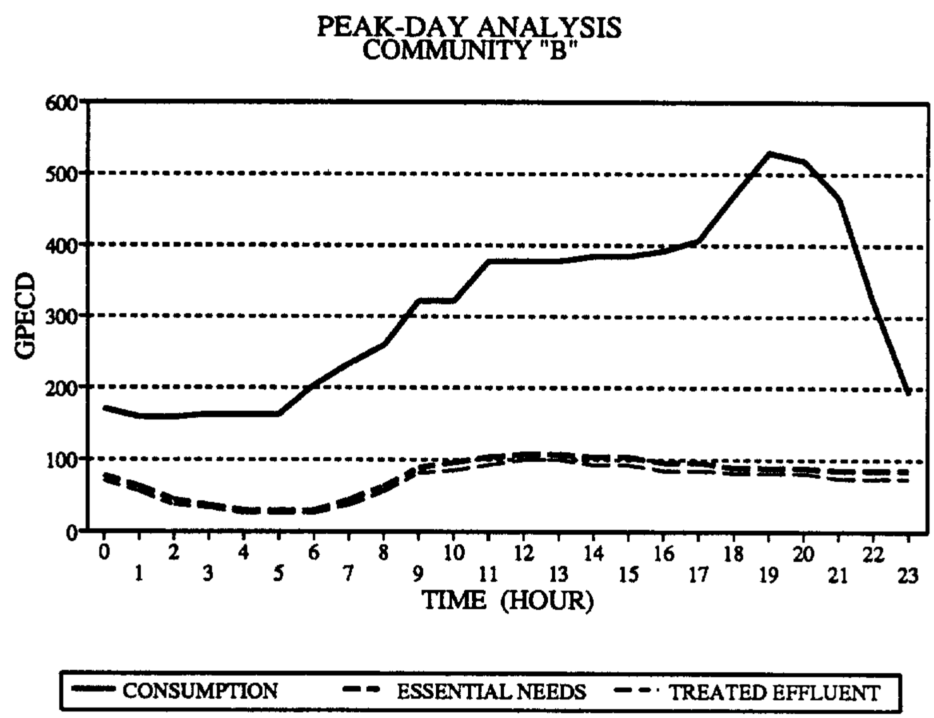
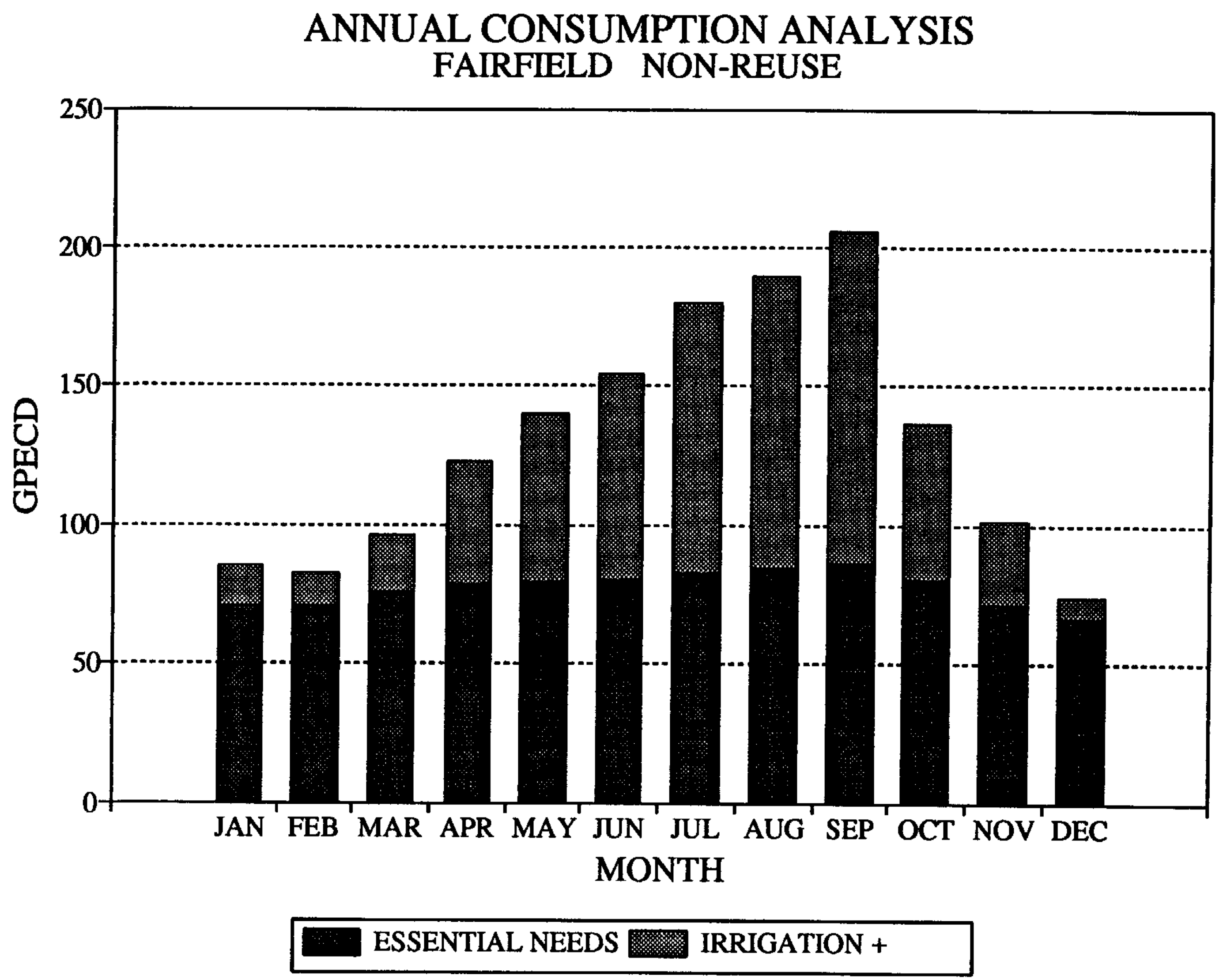

PEAK-DAY ANALYSIS
COMMUNITY "B"
GPECD
0
100
200
300
400
500
600
TIME (HOUR)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
CONSUMPTION
ESSENTIAL NEEDS
TREATED EFFLUENT

Figure IV-2


ANNUAL CONSUMPTION ANALYSIS
FAIRFIELD NON-REUSE
GPECD
0
50
100
150
200
250
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
ESSENTIAL NEEDS
IRRIGATION +

PEAK-DAY CONSUMPTION ANALYSIS
FAIRFIELD NON-REUSE

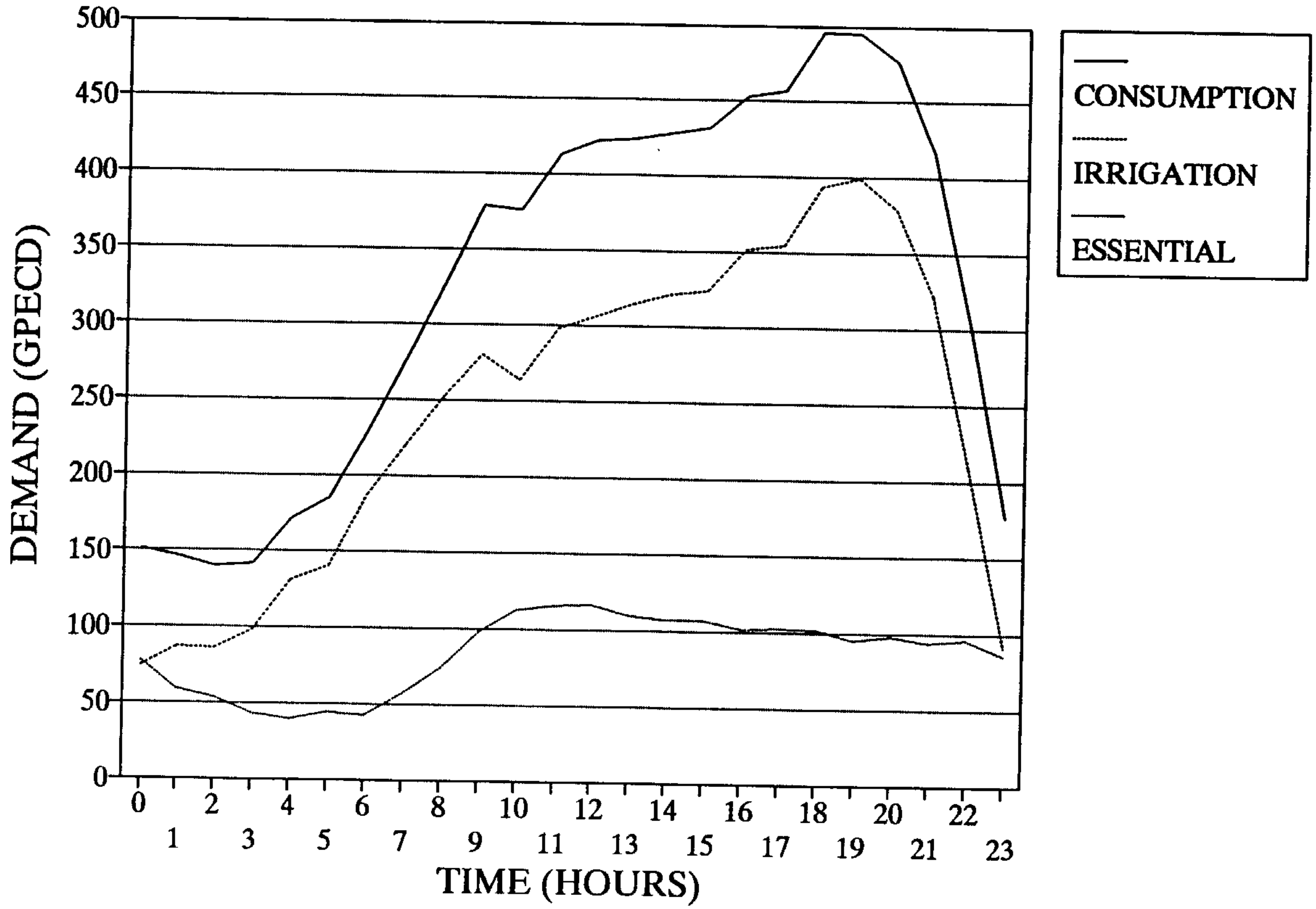


Figure IV-4

ANNUAL CONSUMPTION ANALYSIS
FAIRFIELD - REUSE

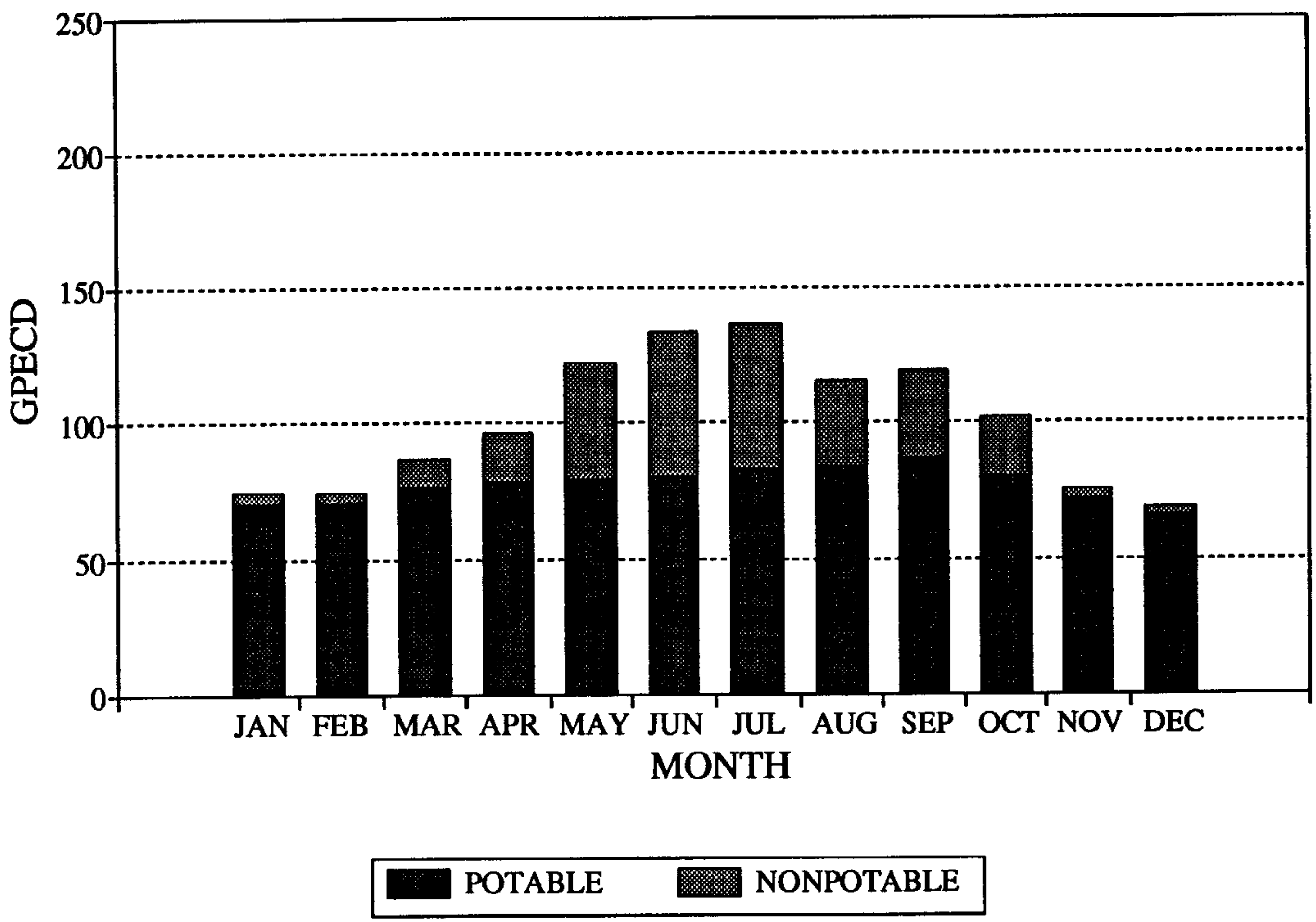


Figure IV-5

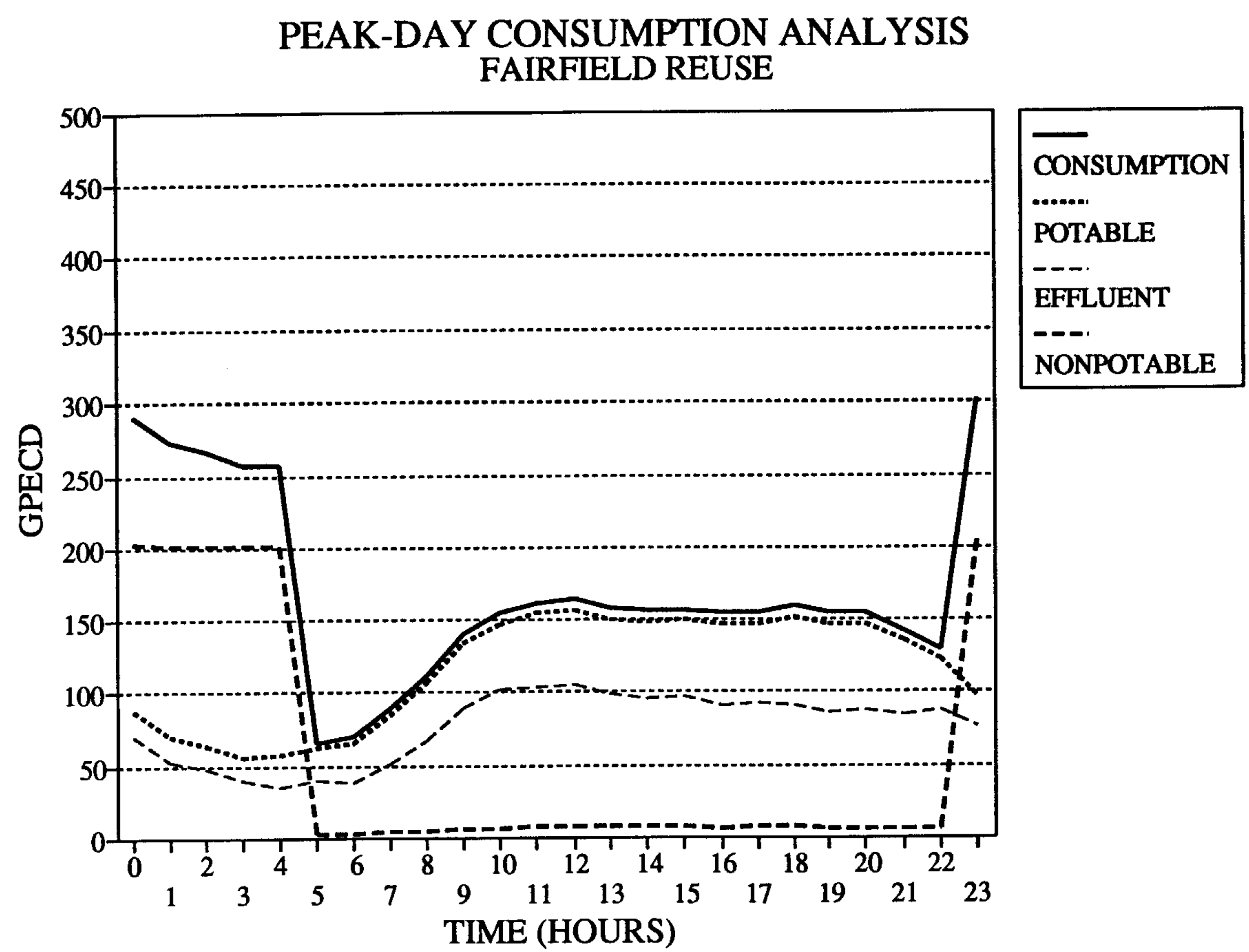

PEAK-DAY CONSUMPTION ANALYSIS
FAIRFIELD REUSE
GPECD
500
450
400
350
300
250
200
150
100
50
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
TIME (HOURS)
CONSUMPTION
POTABLE
EFFLUENT
NONPOTABLE

Figure IV-6

DEVELOPMENT OF ALTERNATIVES AND WATER SYSTEM ANALYSIS

SELECTION OF ALTERNATIVES

As noted previously, and discussed repeatedly in the literature, the cost-effectiveness of reuse projects is directly related to the volume of reclaimed water used. Generally speaking, the more water utilized, the more cost-effective the project. Irrigation, especially irrigation inclusive of residential areas, and fire demand provide the highest potential water demand in the study area. The addition of toilet flush water increases overall nonpotable demands and reduces potable consumptive needs, but not as extensively as reuse irrigation. Cooling water uses in the study area, while providing added nonpotable demands, are almost incidental compared to irrigation and toilet flush water needs. In the remaining discussions, "irrigation" should be considered to include cooling water and other potential low volume uses.

There exist three primary alternatives for implementation in Fairfield:

Alternative 1--	Irrigation of common and commercial landscaped areas
Alternative 2--	Irrigation of common, commercial, and residential areas
Alternative 3--	Irrigation of common, commercial, and residential areas plus fire protection

Implementating Alternative 1 involves the least capital expenditure and might prove cost effective if surface water conversion were pending with its expected significant increase in potable water cost. Estimates of water needs for the special irrigation areas alone are only about four percent of the total potable demand at full development. Commercial areas are spread along U.S. Highway 290 with remaining demand areas located throughout the development, necessitating an extensive distribution system to distribute the total demand. At the current relatively low cost of groundwater ($0.50 per thousand gallons for common irrigation areas) the cost of constructing and operating a large distribution system with relatively low demands probably would not offset expected savings.

Implementing Alternative 2, irrigation of public and private areas without fire protection, increases nonpotable water demand considerably, but is most likely not cost-effective for other reasons. First, effluent storage is almost certainly required due the increased volume and the fact that night-time watering periods coincide with low-flow periods at the wastewater treatment plant. Without fire protection, the potable and nonpotable pumping and distribution systems are essentially duplicated, since fire demands govern the size of the potable distribution system and peak irrigation demands control the size of the nonpotable system.

The third alternative, which includes use of non-potable water for fire protection, offers extensive water reuse possibilities, plus the potential of significantly reducing the capacity of the potable water system to minimum essential needs. Prudent planning would consider water for fire protection, which does not need to be of drinkable quality, to be included in the nonpotable system. The nonpotable irrigation distribution system, itself a high demand system component when considering watering of residential areas, can easily accommodate intermittent fire demands. Since the proposed system envisions the managing water or wastewater utility controlling the nonpotable system, irrigation demand can easily be terminated if water is required to battle high demand fires. Alternative 3 offers additional advantages. Sizing the nonpotable system to include fire demands allows the flexibility to include other uses, for example, toilet flush water at some future date. Additionally, when considering reuse in a new community, changes in land planning relative to reuse can be more easily accommodated.

Based on these considerations, Alternative 3 has been investigated in detail as a possible alternative to a totally potable water system. The following sections present the results of computer water network modeling to compare the two alternative systems.

RESULTS OF COMPUTER NETWORK MODELING ANALYSES

Computer network analysis techniques have been employed to verify operation of the possible potable and nonpotable pumping and distribution systems. The computer software selected for use in the analysis is the University of Kentucky's network modeling program, KYPIPE.

Careful computer modeling allows accurate determination of required pump sizes, waterline sizes, water well supply requirements, and ground and elevated storage tank volumes necessary for given demand conditions. Resulting distribution system pressures, water velocities, and head losses are then computed and tabulated relative to the demands. Extended period simulation (EPS) techniques, possible with KYPIPE, allow simulation of varying water demands throughout a specified analysis period. Often, the selected demand period is a 24-hour day. EPS modeling further allows confirmation of elevated and ground storage tank water levels as a function of water demands and pump energy input. Techniques developed by Turner Collie & Braden Inc. further allow automatic water well cycling depending on water tank levels. These techniques optimize storage levels, especially in systems where water wells feed directly to elevated storage, as has been proposed in Fairfield.

Existing Planned Freshwater System Analyses

The latest update to the Fairfield Village Water System Master Plan was completed in June 1990. Copies of the KYPIPE water system network computer analyses used in the master planning effort were obtained for use with this study. The computer models utilized peak-day-plus-fire-demands to simulate peak-stress conditions on the proposed water system. The data files were first modified to include the automatic well cycling feature described above, then updated to exclude a minor area not identified initially as part of the planning area and to include new peak-day water system demands developed for this study. Finally, the model was executed with these changes.

The resulting computer output revealed that the system as designed could not satisfy the revised peak-day (plus-mall-fire) demands. It is important to note that well capacity was initially determined based on the minimum TDH requirement of 0.6 gpm per equivalent connection which is not sufficient for proposed conditions. In order to maintain elevated or ground storage levels, well capacity should approximate the peak-day demand. Since the wells cannot pump 24 hours per day or provide the total peak-day demand (storage tanks are full for some period at night), storage is depleted by some measure even when the system is subjected to only peak-day conditions. It follows, then, that storage must provide greater than the maximum fire volume for a peak-day-plus-fire analysis in order to avoid complete storage depletion. Addition of too much storage can lead to stagnant water supplies during average-day conditions since the volume is not effectively utilized. Additional water wells, therefore, are necessary to satisfy the peak-day system demand. If booster pumps are sized for peak-day requirements, then elevated storage can provide higher peaks, for example peak-hour demands.

Following this reasoning, total well capacity was increased in the model to match the expected peak-day demand and the model re-executed. In essence, well supply was increased from 9 water wells providing approximately 9,000 gpm capacity to 11 wells providing 11,000 gpm capacity. Peak-day demand in the non-reuse system is about 11,036 gpm. In this scenario, the water system performed comparably to results prior to adjustment of the system demands. Thus, the revised water capacity requirements become the basis of comparison for the dual use distribution system. Exhibit V-1 presents the revised water system if water reuse is not implemented.

Proposed Potable Water System Analyses

Since fire flows are not considered for the proposed potable water system, waterline sizes can be reduced significantly, yet still provide sufficient delivery rates to customers. Any reduction in size, however, violates current City of Houston minimum waterline size criteria. Typical proposed line sizes in Fairfield, for example, which conform to City standards, include mostly eight- and some six-inch waterlines along major arterial streets. "Internal" distribution lines, including those serving individual homes or groups of homes along cul-de-sacs, include six-, four-, and, in some cases, two-inch waterlines. Computer modeling verifies that all previously proposed 8- and 12-inch lines can be reduced to at least a six-inch diameter. Although not modeled, review of the computer model output indicates that many lines could be reduced another standard diameter, i.e., to four inches as minimum residual pressures in the system are about 55 psi during peak-hour conditions. A compromise arrangement is considered in the cost-effectiveness analysis of the reuse system where potable waterlines in undeveloped areas along major streets are six inches in diameter and remaining lines are four- and two-inch. Additional computer modeling of discreet areas in the system would confirm the ability to reduce sizes further, however, these models are beyond the scope of a feasibility analysis. The compromise arrangement would allow redundant fire protection in some areas, as well as convenient locations for routine line flushing.

Seven water wells are modeled for the potable system, of which three are stand-by water wells and do not contribute to the system. These include one operating and one stand-by well at the central plant site, one well at each of the three elevated tank sites, and two (total) stand-by wells providing back-up to the elevated storage tank wells, for a total system capacity of 7,000 gpm. If well capacity is computed solely on the basis of peak-day requirements, a total of 2,831 gpm (or three wells at 1,000 gpm each) would be required. The present configuration of the potable system, unfortunately, does not allow further reduction in the number of wells without a loss in system reliability. Interestingly, the requirement of 3,000 gpm when converted to gpm per connection for the Fairfield community (12,800 equivalent connections) equates to 0.23 gpm per connection, well below TDH's minimum requirement of 0.6 gpm per connection. At a total well capacity of 7,000 gpm, about 0.55 gpm per equivalent connection is provided. Storage requirements also can be estimated based on the potable water system modeling, however, results are not as conclusive because ground and elevated storage relate as a function of the distribution system. Under average operating conditions, it is anticipated that the elevated tanks and their associated water wells will supply total water needs, as envisioned in the master plan. During periods of higher demand, the central plant, equipped with booster pumps and ground storage will assist in satisfying demand. For the peak system conditions analyzed, ground storage depletion at the central plant was approximately 400,000 gallons and the elevated storage remained essentially undepleted, although continuously replenished by the water wells. For modeling purposes, the minimum TDH requirements of 100 gallons per connection of each ground storage and elevated storage were assumed. The model indicates substantially less is required under peak-system conditions when potable demands are reduced to essential needs. For purposes of the cost-effectiveness analysis, the minimum standard is assumed. Additional computer modeling under a variety of operating conditions is required to determine an absolute minimum standard for the potable side of a dual distribution system.

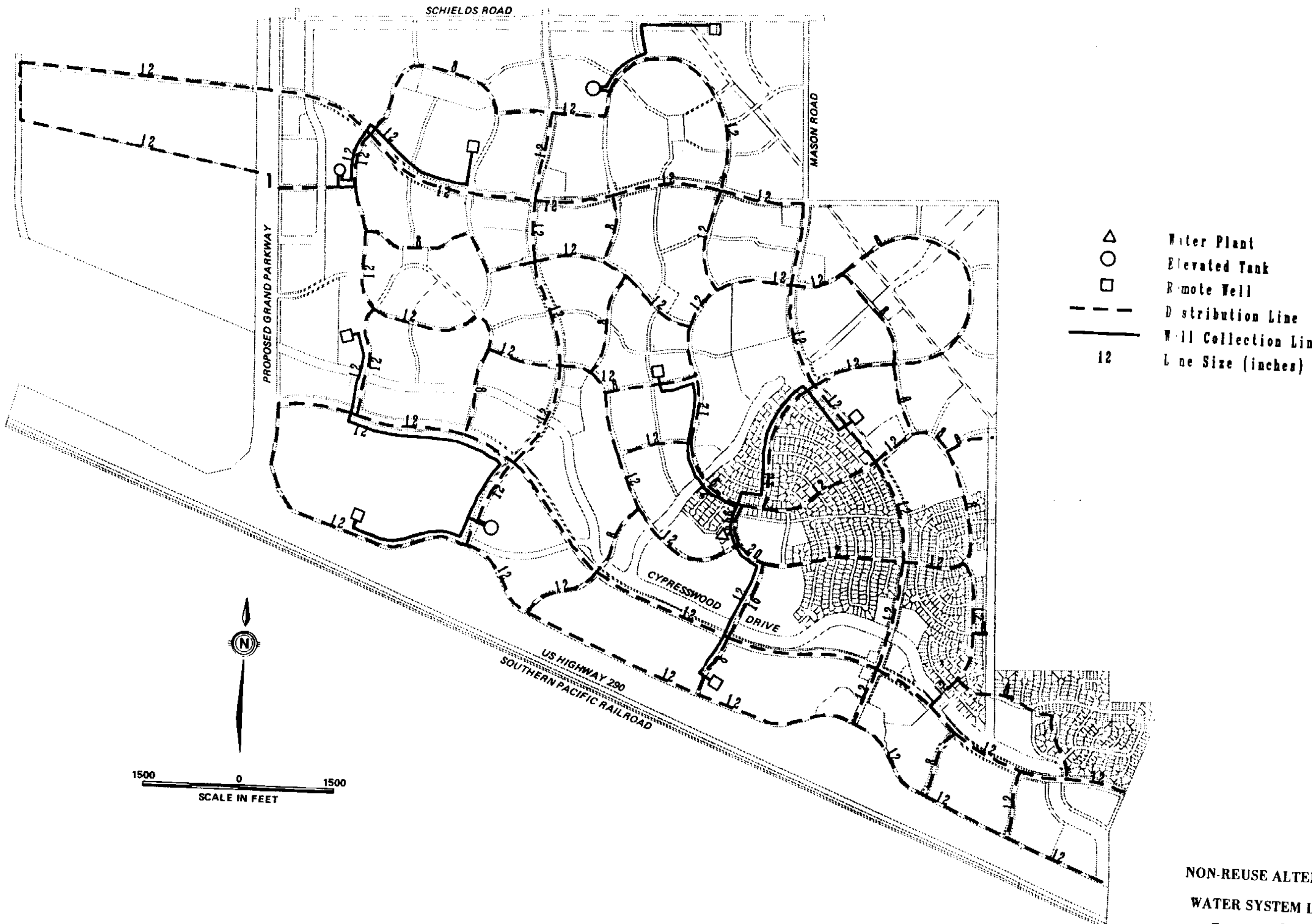
The minimum requirement for booster pump capacity is two or more pumps with a capacity of 2.0 gpm per connection or total capacity of 1,000 and ability to meet peak demands, whichever is less. Booster pumps already constructed at the central plant site exceed this minimum capacity. As might be expected, the existing capacity is not fully utilized in the potable system model. Since the existing capacity represents a sunk cost, it has no effect on the cost-effectiveness of the project.

Exhibit V-2 presents the potable system as modeled. Because current planning does not foresee the new regional wastewater plant online until approximately 1993, potable waterlines have been considered extended at the master plan size until that time. It is important to note that development within this area would be provided fire protection primarily from the potable system.

Analyses of Proposed Nonpotable Water System

Exhibit V-3 shows a possible nonpotable system configuration. Major system components include two nonpotable open storage reservoirs which will appear as amenity lakes at the entrances to Fairfield, each equipped with a booster pumping station. Additional booster pumps would be located near the disinfection basins at the regional wastewater treatment plant. Booster pumps are sized based on peak pumping requirements for the peak-day-plus-fire conditions with a 6,000 gpm, six-hour fire at the mall site at a rated operating pressure of 65 psi. Total reservoir storage volume of approximately four million gallons is based on a mass balance from the computer output of fire volume plus irrigation volume plus a ten percent factor of safety. The split in storage capacity is based on fire demand requirements at the mall site.

A monitoring and control system is planned for the nonpotable system to monitor system pressures and effluent turbidity as a measure of water quality, in addition to other routine water quality testing. The control system would include timing mechanisms for control of irrigation volumes and areas watered.

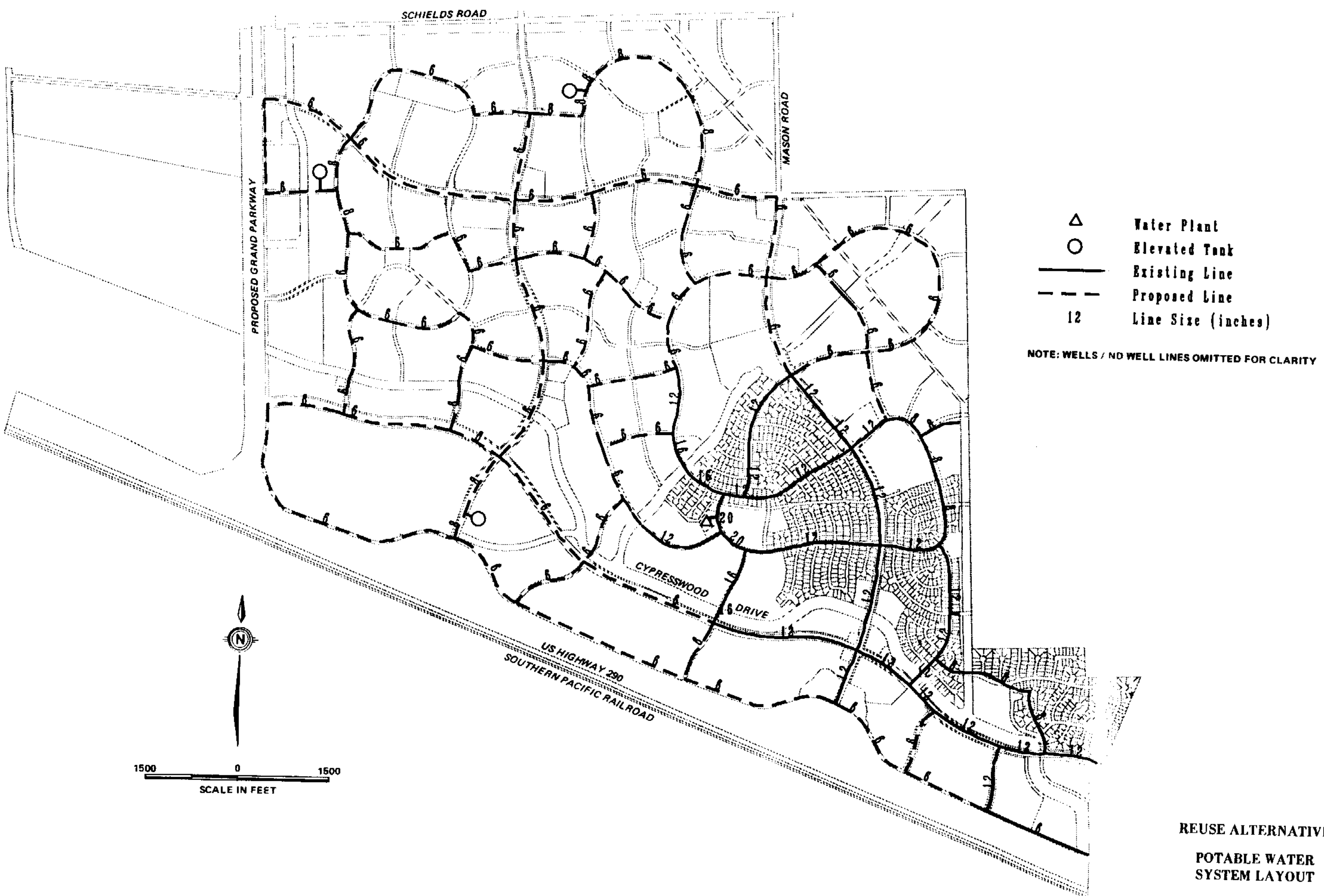


NON-REUSE ALTERNATIVE

WATER SYSTEM LAYOUT

Turner Collie & Braden Inc.

October 1990 Exhibit V-1



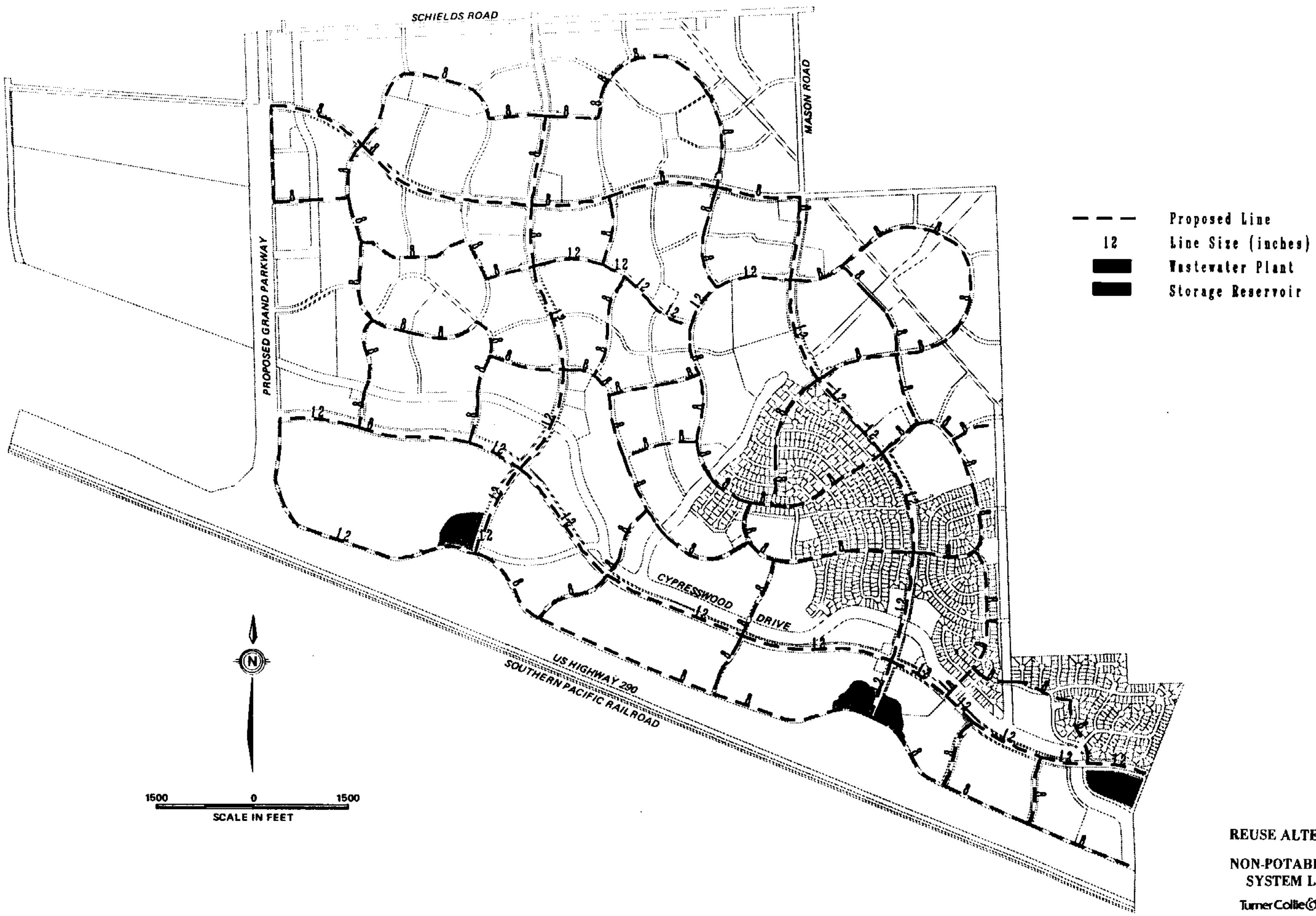
REUSE ALTERNATIVE

POTABLE WATER
SYSTEM LAYOUT

Turner Collie & Braden Inc.

October 1990

Exhibit V



REUSE ALTERNATIVE

NON-POTABLE WATER SYSTEM LAYOUT

Turner Collie & Braden Inc

October 1990

Exhibit V-3

SUMMARY OF PROBABLE COSTS AND COST-EFFECTIVENESS ANALYSIS

GENERAL

The probable cost of implementing a water reuse alternative requires the investigation of four primary cost components. These include both capital construction costs and operation-and-maintenance (O&M) costs for the following:

- Distribution of the reclaimed water
- Additional treatment at the wastewater plant, if required, above the requirements necessary to achieve water quality standards for discharge of the effluent
- Storage systems and pressure maintenance of the nonpotable supply
- Water quality monitoring and additional administration for maintaining two water systems

Comparing these costs with a similar compilation of costs for a freshwater supply system provides a measure of cost-effectiveness of a reuse project. Potentially, there are additional costs which may be incurred by end users of a reuse system. Examples include additional treatment and monitoring for use of reclaimed water in cooling towers, retrofited plumbing or installation of additional plumbing in new construction if considering toilet flush water reuse, and steps to ensure worker safety.

Potentially offsetting these costs is the possibility of a lower overall water system cost, either due to a reduction in the sizes and capacities of facilities, or to lower debt costs, especially if grants or low-interest financing are available to assist in project funding. Conversion to surface water might also be delayed indefinitely with effective implementation of this and other reuse projects, resulting in substantial savings to future water users.

On the other hand, there are certain intangible items, both benefits and detriments, which must be weighed in considering a reuse project. Change in normal personal routines, for instance, restricted access to irrigated areas, or control of volume and frequency of irrigation by a governmental agency, can be considered negative impacts. Compensating factors, however, include less time with irrigation activities and assurance of an adequate and reliable irrigation supply during drought periods. Naturally, a reduction in the rate of level groundwater declines and resulting subsidence would be realized. In some reuse communities, a sense of community pride has been noted in the literature. For the developer, the study area could be marketed as an "environmentally aware" community, an extension of waste recycling programs already in progress in the Fairfield community. While detailed analysis of these considerations is beyond the scope of this study, each should be considered by the community and other involved parties in any feasibility and cost-effectiveness decision.

SUMMARY OF PROBABLE CAPITAL COSTS

Table VI-1 presents the estimated capital construction cost for continuing a freshwater supply project, as outlined in previous master planning studies. The costs are modified to include the additional supply components (water wells and well collection lines) necessary to satisfy the water demands developed in this study, as well as a component for "internal distribution lines". The internal distribution cost component accounts for the smaller waterlines located along interior residential streets. The non-reuse alternative costs also permit a reduction in booster pumping capacity which was not required in the revised water system model, as well as allowances for system components which are already constructed, e.g., ground storage and other central plant facilities. Many of the unit costs for a potable system provided in the 1990 water master plan update have been utilized in this table. These unit costs are based on bid tabulations from similar work in the Houston area. Capital costs are divided into groundwater supply components and distribution system components for ease of comparison with the reuse alternative costs contained herein, as well as with other systems having different potable water production costs. The table includes only those capital costs required after 1993, the year the regional wastewater plant is expected to be operational. In summary, the total non-reuse capital cost is $18,443,800 with groundwater supply component costs of $6,785,100 and distribution system costs of $11,658,700.

Table VI-2 summarizes the Option 1 probable construction cost of a reuse alternative whose potable supply system components meet the current minimum TDH requirements for potable supplies. Like Table VI-1, the costs are separated into groundwater supply components, distribution system components, both potable and nonpotable, and a third category for additional wastewater plant improvements, e.g., effluent filtration. Total probable cost for Option 1 is $28,813,300 including $3,966,400 for groundwater supply components, $23,766,900 for the dual distribution system components, and $1,080,000 for effluent filtration. The distribution system category includes a line item, and significant cost, for residential sprinkler systems which has been imposed as a "requirement" of the reuse alternative. From the standpoint of operation of the reuse system by a regional authority, prudent planning would dictate uniformity in system design to ensure proper application rates and ease of maintenance activities. It can be argued that the non-reuse system should include a comparable sprinkler system component, which likewise contributes to high irrigation demands, although these systems are not mandatory. Since there is not a corresponding item in the non-reuse alternative, there may be some validity in removing this component from the reuse cost table and including the cost as a cost of the lot, or alternately, as an access fee to the reuse system.

Table VI-3 presents Option 2 for a reuse system and assumes that the cost of the sprinkler system is provided by some other means. Additionally, the supply system capacities and associated costs are reduced to reflect lesser requirements of the potable system, that is, they do not meet current TDH minimum requirements. For this case, the elevated and ground storage requirements are reduced from 100 gallons per connection by the ratio of the reuse potable demand (83.2 GPECD) to the non-reuse potable demand (140.3 GPECD), or about 59.3 gallons per connection. Water system modeling indicates that lower capacities are fully functional, however, minimum quantities were not absolutely defined. Nevertheless, well capacity and booster pump capacity can be reduced to the potable peak-day requirement, plus provide an additional unit for stand-by capacity. For well supply, this equates to a total requirement of 4,000 gpm. In Fairfield, an excess in ground storage and booster capacity based on these requirements already exists, therefore, additional capacity simply is not required. In summary, the total Option 2 cost is reduced to $17,964,700; $1,986,500 for groundwater supply, $14,898,200 for distribution system items, and $1,080,000 for effluent filtration.

Summary of Probable O&M Costs

The cost of operation and maintenance of a water system is a composite of both fixed and variable system costs and is relative to the size of the water system. Fixed costs can be divided into O&M costs for the distribution system, including waterlines and elevated and ground storage, and O&M costs for water production, including water well O&M or surface water treatment costs. Administrative costs are common to both components. These costs can encompass a variety of items including costs of meter reading, billing costs, postage, insurance, surety bonds, professional services fees (sometimes contract water system operation charges), rental fees, miscellaneous costs and other administrative services. Variable costs, on the other hand, are generally limited to the cost of treatment chemicals and pumping.

While capital costs are relatively straightforward to compute, O&M costs are more difficult to estimate for any particular system, due primarily to the variability in age of components and differing sources of water supply. In either a groundwater or surface water system, a utility with new system components has relatively lower O&M costs, whereas operators of the older water system are often faced with increasing O&M costs as more components require repair or replacement. If considering two separate distribution systems, the difficulty in estimating O&M costs becomes more complex. Nevertheless, some allowance for future operating costs must be included in a cost-effectiveness analysis of alternative water systems.

In order to estimate probable O&M for the alternative systems under investigation, current rate structures for several utility districts which maintain groundwater systems were evaluated. The water systems are of varying age and complexity, but provide a reasonable basis for estimating future O&M costs. Based on this analysis, an annual average equivalent single-family-per-connection charge of $118.83 was computed, or about $9.90 per connection per month. For the Fairfield non-reuse alternative, this equates to an annual O&M cost of $1,521,200 assuming 12,802 ESFC, including both fixed and variable costs for a non-reuse system.

O&M costs for the reuse system alternative are anticipated to be higher for several reasons. Considering the various component O&M costs detailed above, many costs are non-reuse option is approximately $3,400,100 at an interest rate of eight percent. By comparison, the Option 1 reuse alternative interest rate must be slightly over zero percent to be cost competitive to implement in the Fairfield community since zero percent interest provides an annual cost of $3,374,900. Because, realistically, such rates do not exist and O&M costs cannot be reduced, capital expenditures must be lowered to implement a reuse alternative in Fairfield.

Option 2 of the reuse alternative reduces capital expenditures by minimizing the capacity and cost of required groundwater facilities and by shifting some capital expense (the sprinkler systems) to the homeowner in return for added property value. The effects of reducing capital expense are also presented in the table. By comparison, the reuse project becomes cost-effective, that is, reaches a breakeven point, at an interest rate between four and eight percent. By interpolation, the rate is about 5.7 percent, within the range of current rates offered by the TWDB.

In order to extend the results of this analysis to other systems of comparable size and development, the data from Table VI-6 is presented graphically in Figures VI-1 and VI-2 and is plotted on the basis of potable water cost in dollars per 1,000 gallons versus annual cost in terms of equivalent single-family connections. Both the capital cost and O&M cost associated with water production have been excluded from the plots, so that the curves can be applied to surface water supplies as well as groundwater supplies for potable systems such as Fairfield. Thus, the curves represent only the capital and O&M costs relative to the distribution systems, plus additional treatment costs.

likely to almost double. These include O&M costs of the distribution system and O&M costs for water plant and storage components, since essentially two separate systems are provided. Some costs, for example administrative costs, which would include the costs of administering a second water system, might vary either way. On the one hand, there is duplicity in some administrative items, such as professional services and other miscellaneous costs, resulting in only minor cost increases. On the other hand, there are additional unaccounted costs, most notably significant water quality testing expenses and an increase in operation staff, resulting in major cost increases. At least one cost category would decrease, that is, the cost of operating and maintaining significantly fewer water wells. It would seem reasonable that overall system O&M costs would increase by at least a factor of 1.5 to 2.

Based on these assumptions, Table VI-4 presents estimated annual O&M costs for the non-reuse and Option 1 reuse systems as previously described in terms of cost per 1,000 gallons of production. O&M costs are divided into various distribution and water production components. The reuse system contains an added O&M component for effluent filtration at the regional wastewater plant, plus a reduction in dechlorination costs for the reclaimed water volume. As evidenced in the table, O&M cost for the reuse system is about 1.65 times as much as the non-reuse system in terms of unit production, as might be expected. Interestingly, annual O&M costs, which are volume related, increase only by a factor of 1.27. Table VI-5 summarizes similar costs comparing the non-reuse and Option 2 reuse systems.

Cost-Effectiveness Analysis

Table VI-6 combines capital construction costs for the non-reuse alternative, annualized at eight percent interest over a 20-year planning period, and capital costs for the reuse alternative, Options 1 and 2, annualized at interest rates of eight, four, and zero percent, plus annual O&M costs to compare the two alternatives on an equivalent annual cost basis. The various interest rates shown on Table VI-6 were evaluated to determine what impact an incentive from a State or Federal agency in the form of low interest rates might have on the feasibility of implementing a dual system. The total annual cost for the non-reuse option is approximately $3,400,100 at an interest rate of eight percent. By comparison, the Option 1 reuse alternative interest rate must be slightly over zero percent to be cost competitive to implement in the Fairfield community since zero percent interest provides an annual cost of $3,374,900. Because, realistically, such rates do not exist and O&M costs cannot be reduced, capital expenditures must be lowered to implement a reuse alternative in Fairfield.

Option 2 of the reuse alternative reduces capital expenditures by minimizing the capacity and cost of required groundwater facilities and by shifting some capital expense (the sprinkler systems) to the homeowner in return for added property value. The effects of reducing capital expense are also presented in the table. By comparison, the reuse project becomes cost-effective, that is, reaches a breakeven point, at an interest rate between four and eight percent. By interpolation, the rate is about 5.7 percent, within the range of current rates offered by the TWDB.

In order to extend the results of this analysis to other systems of comparable size and development, the data from Table VI-6 is presented graphically in Figures VI-1 and VI-2 and is plotted on the basis of potable water cost in dollars per 1,000 gallons versus annual cost in terms of equivalent single-family connections. Both the capital cost and O&M cost associated with water production have been excluded from the plots, so that the curves can be applied to surface water supplies as well as groundwater supplies for potable systems such as Fairfield. Thus, the curves represent only the capital and O&M costs relative to the distribution systems, plus additional treatment costs.

TABLE VI-1 - TOTAL PROBABLE CONSTRUCTION COST OF NON-REUSE ALTERNATIVE

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
GROUNDWATER SUPPLY COMPONENTS				
Remote Wells (1 Existing Well)				
Well, motor, and electrical	10	Ea.	350,000	$3,500,000
Auxillary Power	10	Ea.	50,000	500,000
Well Lines				
12-inch	21,950	L.F.	21.00	461,000
Remote Well Sites	7	Ea.	70,000	490,000
Sand Separation Equipment (Elevated Tanks)	1	L.S.	75,000	75,000
SUBTOTAL				$5,026,000
Engineering (15 percent)				753,900
Contingencies (20 percent)				1,005,200
GROUNDWATER SUPPLY SUBTOTAL				$6,785,100
DISTRIBUTION SYSTEM COMONENTS				
Storage				
Elevated	2,200,000	Gallons	1.25	$2,750,000
Ground (0.75 MG Existing)	1,750,000	Gallons	0.25	437,500
Elevated Storage Sites	3	Ea.	70,000	210,000
Distribution Pumps (2,800 gpm Existing)	2,500	GPM	15.00	37,500
Distribution Lines (After 1993)				
8-inch	19,300	L.F.	16.00	308,800
12-inch	86,500	L.F.	21.00	1,816,500
16-inch	5,500	L.F.	35.00	192,500
Subtotal				$2,317,800
Appurtenances (20%)				463,600
ROW/Crossings (5%)				115,900
Internal Distribution Lines				
2-, 4-, & 6-inch	1,141.0	Ac.	1,800	2,053,800

TABLE VI-1 - TOTAL PROBABLE CONSTRUCTION COST OF NON-REUSE ALTERNATIVE (cont'd)

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
Regional System Monitoring and Controls	1	L.S.	250,000	250,000
SUBTOTAL				$8,636,100
Engineering (15 percent)				1,295,400
Contingencies (20 percent)				1,727,200
DISTRIBUTION SYSTEM SUBTOTAL				$11,658,700

PROBABLE CONSTRUCTION COST SUMMARY

GROUNDWATER SUPPLY COMPONENTS	$6,785,100
DISTRIBUTION SYSTEM COMPONENTS	11,658,700
ALTERNATIVE GRAND TOTAL	$18,443,800

TABLE VI-2 - TOTAL PROBABLE CONSTRUCTION COST OF REUSE ALTERNATIVE
OPTION 1: MEETS TDH MINIMUM CRITERIA

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
GROUNDWATER SUPPLY COMPONENTS				
Remote Wells (1 Existing)				
Well, motor, and electrical	6	Ea.	350,000	$2,100,000
Auxillary Power	6	Ea.	50,000	300,000
Well Line (12-inch)	12,050	L.F.	21.00	253,100
Remote Well Sites	3	Ea.	70,000	210,000
Sand Separation Equipment (Elevated Tanks)	3	Ea.	25,000	75,000
SUBTOTAL				$2,938,100
Engineering (15 percent)				440,700
Contingencies (20 percent)				587,600
GROUNDWATER SUPPLY SUBTOTAL				$3,966,400
DISTRIBUTION SYSTEMS COMPONENTS				
Storage				
Elevated	1,300,000	Gallon	1.25	$1,625,000
Ground (0.75 MG Existing)	600,000	Gallon	0.25	150,000
Nonpotable Reservoir at Lake Site	2.0	MG	25,000	50,000
Nonpotable Reservoir at Mall Site	3.0	MG	25,000	75,000
Elevated Storage Sites	3	Ea.	70,000	210,000
Distribution Pumps (Includes Structures)				
Nonpotable - WWTP Site	3,200	GPM	20.00	64,000
Nonpotable - Lake Site	3,000	GPM	20.00	60,000
Nonpotable - Mall Site	5,000	GPM	20.00	100,000
Auxillary Power	3	Ea.	50,000	150,000
Pressure Tanks				
Nonpotable - Lake Site	50,000	Gallon	0.40	20,000
Nonpotable - Mall Site	50,000	Gallon	0.40	20,000
Central Distribution Lines				
Potable				
6-inch	85,900	L.F.	12.00	1,030,800
8-inch	9,400	L.F.	16.00	150,400
Nonpotable				
8-inch	108,300	L.F.	16.00	1,732,800
12-inch	35,400	L.F.	21.00	743,400

TABLE VI-2 - TOTAL PROBABLE CONSTRUCTION COST OF REUSE ALTERNATIVE (cont'd)
OPTION 1: MEETS TDH MINIMUM CRITERIA

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
Subtotal Central Distribution Lines				$3,657,400
Appurtenances (20%)				731,500
ROW/Crossings (5%)				182,900
Residential Sprinkler Systems	5,758	Ea.	1,000	5,758,000
Potable Internal Distribution Lines (2- and 4-inch)	1,141.0	Ac.	1,250	1,426,300
Nonpotable Internal Distribution Lines (2-, 4- and 6-inch)				
Undeveloped Areas	1,141.0	Ac.	1,800	2,053,800
Retrofit in Developed Areas	385.6	Ac.	2,000	771,200
Regional System Monitoring and Controls	2	Ea.	250,000	500,000
SUBTOTAL				$17,605,100
Engineering (15 percent)				2,640,800
Contingencies (20 percent)				3,521,000
DISTRIBUTION SYSTEMS SUBTOTAL				$23,766,900
WASTEWATER TREATMENT PLANT IMPROVEMENTS				
WWTP Effluent Filtration	1	L.S.	800,000	$800,000
Engineering (15 percent)				120,000
Contingencies (20 percent)				160,000
WASTEWATER TREATMENT PLANT IMPROVEMENTS SUBTOTAL				$1,080,000
PROBABLE CONSTRUCTION COST SUMMARY				
GROUNDWATER SUPPLY COMPONENTS				$3,966,400
DISTRIBUTION SYSTEMS COMPONENTS				23,766,900
WASTEWATER TREATMENT PLANT IMPROVEMENTS				1,080,000
ALTERNATIVE GRAND TOTAL				$28,813,300

TABLE VI-3 - TOTAL PROBABLE CONSTRUCTION COST OF REUSE ALTERNATIVE
OPTION 2: LESS THAN TDH MINIMUM CRITERIA

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
GROUNDWATER SUPPLY COMPONENTS				
Remote Wells (1 Existing)				
Well, motor, and electrical	3	Ea.	350,000	$1,050,000
Auxillary Power	3	Ea.	50,000	150,000
Well Line (12-inch)	6,025	L.F.	21.00	126,500
Remote Well Sites	1	Ea.	70,000	70,000
Sand Separation Equipment (Elevated Tanks)	3	Ea.	25,000	75,000
SUBTOTAL				$1,471,500
Engineering (15 percent)				220,700
Contingencies (20 percent)				294,300
GROUNDWATER SUPPLY SUBTOTAL				$1,986,500
DISTRIBUTION SYSTEMS COMPONENTS				
Storage				
Elevated	770,900	Gallon	1.25	$963,600
Ground (0.75 MG Existing)	0	Gallon	0.25	0
Nonpotable Reservoir at Lake Site	2.0	MG	25,000	50,000
Nonpotable Reservoir at Mall Site	3.0	MG	25,000	75,000
Elevated Storage Sites	3	Ea.	70,000	210,000
Distribution Pumps (Includes Structures)				
Nonpotable - WWTP Site	3,200	GPM	20.00	64,000
Nonpotable - Lake Site	3,000	GPM	20.00	60,000
Nonpotable - Mall Site	5,000	GPM	20.00	100,000
Auxillary Power	3	Ea.	50,000	150,000
Pressure Tanks				
Nonpotable - Lake Site	50,000	Gallon	0.40	20,000
Nonpotable - Mall Site	50,000	Gallon	0.40	20,000
Central Distribution Lines				
Potable				
6-inch	85,900	L.F.	12.00	1,030,800
8-inch	9,400	L.F.	16.00	150,400
Nonpotable				
8-inch	108,300	L.F.	16.00	1,732,800
12-inch	35,400	L.F.	21.00	743,400

TABLE VI-3 - TOTAL PROBABLE CONSTRUCTION COST OF REUSE ALTERNATIVE (cont'd)
OPTION 2: LESS THAN TDH MINIMUM CRITERIA

Item	Quantity	Unit	Unit Cost ($)	Probable Cost
Subtotal Central Distribution Lines				$3,657,400
Appurtenances (20%)				731,500
ROW/Crossings (5%)				182,900
Residential Sprinkler Systems	0	Ea.	1,000	0
Potable Internal Distribution Lines (2- and 4-inch)	1,141.0	Ac.	1,250	1,426,300
Nonpotable Internal Distribution Lines (2-, 4- and 6-inch)				
Undeveloped Areas	1,141.0	Ac.	1,800	2,053,800
Retrofit in Developed Areas	385.6	Ac.	2,000	771,200
Regional System Monitoring and Controls	2	Ea.	250,000	500,000
SUBTOTAL				$11,035,700
Engineering (15 percent)				1,655,400
Contingencies (20 percent)				2,207,100
DISTRIBUTION SYSTEMS SUBTOTAL				$14,898,200
WASTEWATER TREATMENT PLANT IMPROVEMENTS				
WWTP Effluent Filtration	1	L.S.	800,000	$800,000
Engineering (15 percent)				120,000
Contingencies (20 percent)				160,000
WASTEWATER TREATMENT PLANT IMPROVEMENTS SUBTOTAL				$1,080,000
PROBABLE CONSTRUCTION COST SUMMARY				
GROUNDWATER SUPPLY COMPONENTS				$1,986,500
DISTRIBUTION SYSTEMS COMPONENTS				14,898,200
WASTEWATER TREATMENT PLANT IMPROVEMENTS				1,080,000
ALTERNATIVE GRAND TOTAL				$17,964,700

TABLE VI-4 - SUMMARY OF PROBABLE OPERATION AND MAINTENANCE COSTS
OPTION 1

DESCRIPTION	ANNUAL O&M COSTS	O&M COST* ($/1000 GAL)
NON-REUSE SYSTEM		
Distribution	$741,100	0.32
Water Production	780,100	0.34
Total	$1,521,200	0.66
REUSE SYSTEM		
Distribution		
Potable	$571,400	0.32
Nonpotable	$590,000	0.33
Water Production		
Potable	421,400	0.24
Nonpotable	268,800	0.15
Effluent Treatment	82,700	0.05
Total	$1,934,300	1.09

* - Per 1,000 gallons of total production; 140.3 GPECD for non-reuse alternative and 108.4 GPECD for reuse alternative.

TABLE VI-5 - SUMMARY OF PROBABLE OPERATION AND MAINTENANCE COSTS
OPTION 2

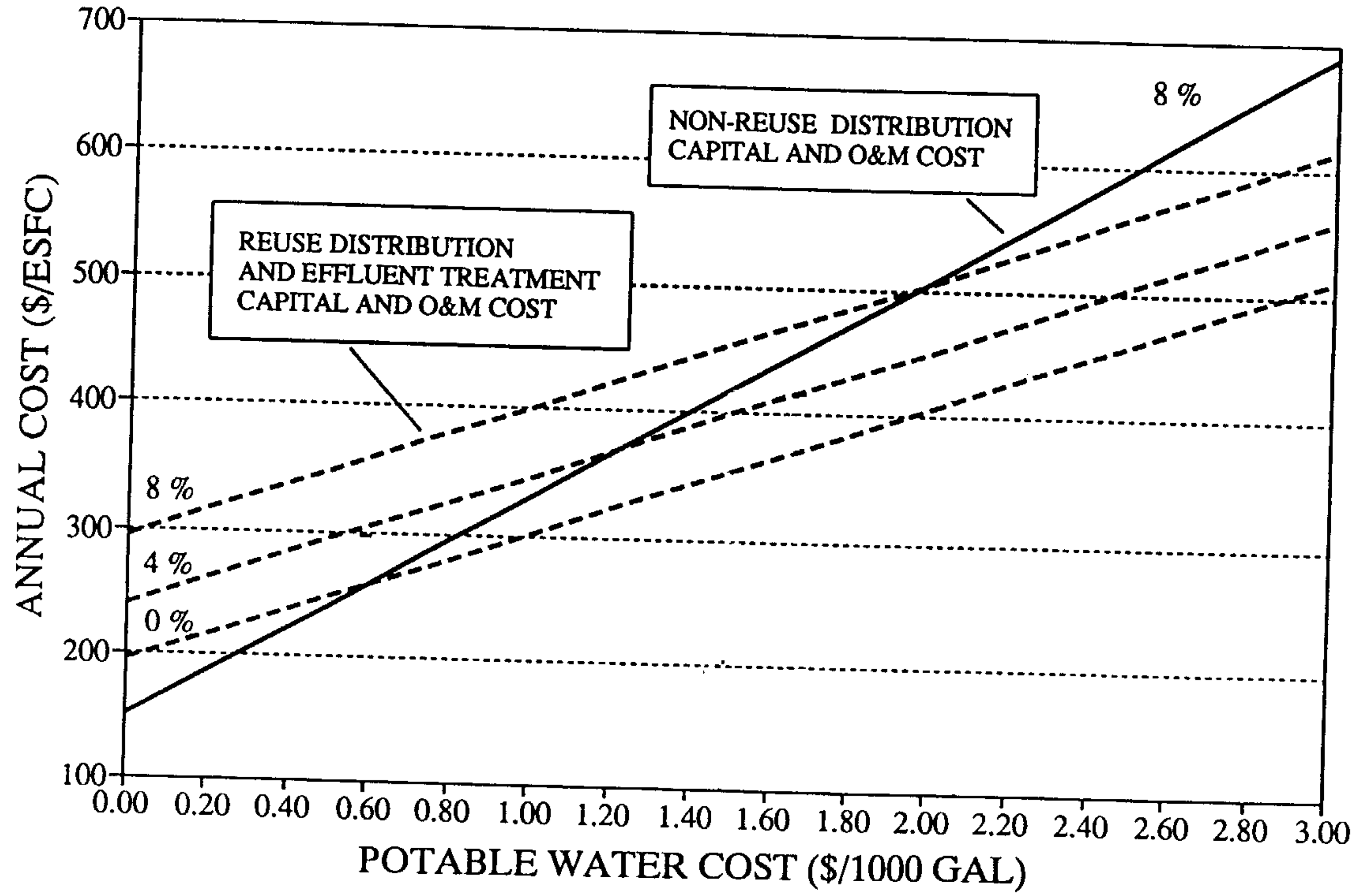
DESCRIPTION	ANNUAL O&M COSTS	O&M COST* ($/1000 GAL)
NON-REUSE SYSTEM		
Distribution	$741,100	0.32
Water Production	780,100	0.34
Total	$1,521,200	0.66
REUSE SYSTEM		
Distribution		
Potable	$571,400	0.32
Nonpotable	$590,000	0.33
Water Production		
Potable	347,200	0.20
Nonpotable	268,800	0.15
Effluent Treatment	82,700	0.05
Total	$1,860,100	1.05

* - Per 1,000 gallons of total production; 140.3 GPECD for non-reuse alternative and 108.4 GPECD for reuse alternative.

TABLE VI-6 - SUMMARY OF CAPITAL AND O&M COSTS

ALTERNATIVE DESCRIPTION	CAPITAL COSTS			O&M COSTS			TOTALS		
	GROUNDWATER SUPPLY	DISTRIBUTION SYSTEM	EFFLUENT TREATMENT	GROUNDWATER SUPPLY	DISTRIBUTION SYSTEM	EFFLUENT TREATMENT	GROUNDWATER SUPPLY	DISTRIBUTION + EFFLUENT TRMT.	GRAND TOTAL
NON-REUSE SYSTEM									
8 % Interest									
Annual Cost	$691,100	$1,187,500	0	$780,100	$741,400	0	$1,471,200	$1,928,900	$3,400,100
$/1000 Gal	0.30	0.52	0	0.34	0.32	0	0.64	0.84	1.48
REUSE SYSTEM									
Option 1									
8 % Interest									
Annual Cost	$404,000	$2,420,700	$110,000	$690,200	$1,161,400	$82,700	$1,094,200	$3,774,800	$4,869,000
$/1000 Gal	0.23	1.37	0.06	0.39	0.66	0.05	0.62	2.14	2.76
4 % Interest									
Annual Cost	$291,900	$1,748,800	$79,500	$690,200	$1,161,400	$82,700	$982,100	$3,072,400	$4,054,500
$/1000 Gal	0.16	0.99	0.04	0.39	0.66	0.05	0.55	1.74	2.29
0 % Interest									
Annual Cost	$198,300	$1,188,300	$54,000	$690,200	$1,161,400	$82,700	$888,500	$2,486,400	$3,374,900
$/1000 Gal	0.11	0.67	0.03	0.39	0.66	0.05	0.50	1.41	1.91
Option 2									
8 % Interest									
Annual Cost	$202,300	$1,517,400	$110,000	$616,000	$1,161,400	$82,700	$818,300	$2,871,500	$3,689,800
$/1000 Gal	0.11	0.86	0.06	0.35	0.66	0.05	0.46	1.63	2.09
4 % Interest									
Annual Cost	$146,200	$1,096,200	$79,500	$616,000	$1,161,400	$82,700	$762,200	$2,419,800	$3,182,000
$/1000 Gal	0.08	0.62	0.04	0.35	0.66	0.05	0.43	1.37	1.80
0 % Interest									
Annual Cost	$99,300	$744,900	$54,000	$616,000	$1,161,400	$82,700	$715,300	$2,043,000	$2,758,300
$/1000 Gal	0.06	0.42	0.03	0.35	0.66	0.05	0.41	1.16	1.57

COST-EFFECTIVENESS ANALYSIS
REUSE OPTION 1



COST-EFFECTIVENESS ANALYSIS
REUSE OPTION 2

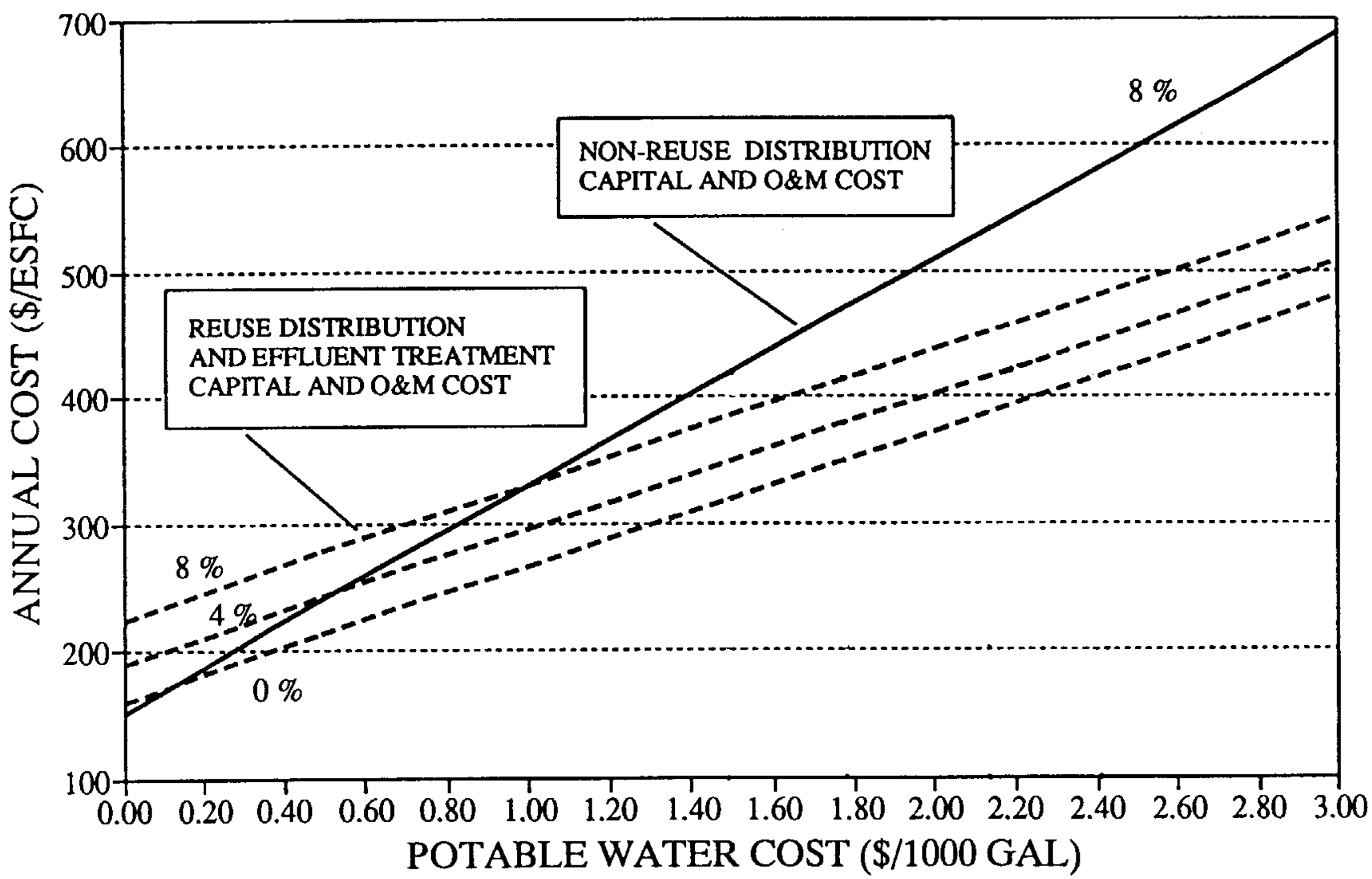


Figure VI-2

FINANCING OPTIONS

SECTION VII - INVESTIGATION OF FINANCING METHODS

FUNDING OVERVIEW

As indicated in earlier sections of the report, funding and management of a water reuse system is a key element of feasible implementation. Without a workable funding and management component, any capital development program obviously remains only a plan.

Water and wastewater development programs historically have been funded with general tax revenues and general obligation debt, often with funding assistance at the Federal level. Most major water impoundments constructed throughout the country during this century have been financed with Federal funding, often as flood control and conservation projects. Since 1972, the Federal Water Pollution Control Act (amended as the Clean Water Act) has provided billions of dollars of Federal money, in the form of grants for the construction of wastewater treatment plants, in an effort to improve water quality and pollution control. This program has now been revised as a Federally assisted loan program and is administered by the TWDB as the State Revolving Loan program.

On the other hand, transmission and collection lines and annual operation and maintenance expenses of both water and wastewater systems traditionally have been the financial responsibility of state and local governments or of the utilities themselves. Most of these costs, in turn, are passed on to the utility user in some form of user charge. In analyzing the options available for financing the proposed improvements presented in this study, several factors must be considered. Centralized water supply and distribution or centralized wastewater collection and treatment, for example, require relatively high initial costs with fewer recurring costs (operation, maintenance, and replacement). Some costs may qualify for various financial programs, while others do not. Ability, or inability, to pay may significantly limit user charges as a potential revenue source, thus limiting the participation in loan or grant programs. Existing municipal and utility service areas, facilities, and financial commitments also influence the choice of financing and management structures and determine which procedures appear most reasonable for future development. This section of the report examines some of the financing options available to implement the proposed water reuse project.

POTENTIAL PROGRAMS FOR FINANCING CAPITAL IMPROVEMENTS

There are some State and Federal programs that have been used or potentially could be used to assist in financing a water reuse project in Fairfield. The following is a brief description of the programs which appear to have the greatest potential.

Federal Programs

Clean Water Act Construction Grants For Wastewater Treatment Works

Historically, the most important program providing assistance for the financing of wastewater treatment facilities has been the Federal construction grants program administered by the EPA. This program has been the major financial participant in new wastewater treatment plant development throughout the country since its inception in 1972. The language of the Clean Water Act of 1977 clearly supports water reuse projects through several provisions. St. Petersburg, Florida for example, was able to obtain Federal funding for a significant portion of its water reuse system. However, in recent years lack of available funding has essentially limited the program's participation to assisting in the completion of projects currently under development. The Clean Water Act grant program is being phased out and replaced by a revolving loan fund. Initial "seed" money for the loan program comes from Federal capitalization grants, however, with the loan program now established, Federal participation is expected to cease after 1991.

State Programs

The State Water Pollution Control Revolving Fund

The State Revolving Fund (SRF) is a perpetual fund through which the TWDB provides low interest loans to Texas communities for the construction of wastewater treatment works. Eligible projects historically have included only construction of new treatment plants, interceptor sewers, and repairs to existing collection systems, however preliminary discussions with TWDB indicate this program might be available for financing a water reuse project. In addition to construction funding, loans can also include funds for planning and design. As noted above, the SRF program replaces the Federal construction grants program and is managed by the State with minimal federal oversight. The fiscal year 1989 interest rate was 5.5 percent with the maximum term of SRF loans as twenty years after project completion.

In order to apply for assistance, "an entity must be an interstate agency, city, town, county, district, river authority, association, or other public body created by or pursuant to State law which has the authority to treat sewage." The entity also must be or have applied to become a designated waste management agency before the TWC. Among other requirements the applicant additionally must satisfy the following:

1. Have a cost-effective, eligible project which is included on the Project Priority List
2. Prepare a water conservation plan and SRF engineering report
3. Document the existence of a dedicated source of funds for repayment
4. Implement a user charge system and demonstrate that it has the financial and managerial capability
5. Obtain an environmental determination in compliance with the National Environmental Policy Act

Recent changes to the SRF legislation allow for a reserve fund to be established from SRF repayments for loans to eligible applicants which qualify as "hardship" cases. In evaluating hardship, the TWDB considers severity of the public health problem, alternative funding sources imposing a hardship on the community, median household income, and area unemployment. Should an entity qualify, certain priority ranking and project rating requirements of the program can be waived, as well as the completion of the SRF engineering plan. In fiscal year 1989, approximately $200 million dollars was earmarked for SRF projects with funding requests from around the state in excess of this amount. In 1990, additional projects were added to the list, however, Congress may reduce program funding, further limiting the numbers of loan recipients. Thus, there are numerous projects which will remain unfunded this year.

TWDB's Financial Assistance and Water Bond Insurance Programs

Under the Texas Water Code, the TWDB administers programs of financial assistance for projects involving "water conservation, water development, and water quality enhancement", as well as flood control and drainage. These programs are for loans and loan insurance and do not currently include construction grants. Matching grants are available for planning and engineering for some of these facilities. These programs are separate from the SRF which was initiated at the Federal level. The TWDB's financial assistance and bond insurance programs are available to any "political subdivision" of the State. The Board has considerable latitude regarding the terms and conditions of loans made, including interest deferral or the capitalization of interest and can make loans for durations of 50 years.

The TWDB can acquire, lease, construct, or reconstruct projects with funds from the so-called "State participation account" and thus own up to 50 percent of a project. In turn, the state can "sell, transfer, or lease its ownership" to an eligible applicant. This can be undertaken so long as the TWDB can reasonably "expect that the State will recover its investment in the facility."

Funding Requirements

Because the ultimate use of funds will often influence the method best suited for securing the funding, the financial needs of a water reuse project should be examined by use category. In this way, a financial program can be established which may comprise a variety of financing sources, each designed to accommodate a separate funding need.

Funding Operations and Maintenance Costs

The costs of operating and maintaining a water reuse project are daily costs that require a continuous flow of funds. The anticipated O&M expenses for a fiscal period are generally budgeted prior to the beginning of the period. These budgeted funding needs are then converted to per-unit costs for collection purposes.

If the O&M expenses are to be financed through user charges, the budgeted figures can be converted into monthly charges per gallon of water used or per service connection.

Revenues derived from these charges are then used to finance the O&M expenses incurred during the period. Obviously, the ability of this financing method to accurately generate needed funds is dependent on the accurate projection of O&M expenses, volume of water consumed, and number of active connections during the budget period. Since the volume of water used is often related to weather conditions, long-term demand projections and, therefore, derived revenue can be lesser or greater than anticipated.

If O&M expenses are to be subsidized with tax revenues, the budgeted O&M expenses need to be added to other financing needs to be covered by the specific tax involved. While tax generated revenue is not considered to be as "fair and equitable" as user charges in paying for utility operations and such revenue sources are prohibited by most State and Federal agencies, taxes are generally a more reliable and predictable form of revenue generation.

Debt financing is almost never used to finance O&M expenses. In fact most bond covenants will specifically prohibit bond funds from being used for O&M expenses.

Capital Funding of New Regional Systems

The major funding need of a new utility system is for financing design and construction of new facilities. These new facilities may be an entirely new facility or expansion to an existing system. Some characteristics that are common to all facility financing will tend to influence the funding alternatives to be considered. First, during construction, there is generally a requirement for a relatively large capital funding commitment over a relatively short time period. Second, the amount of funds required for a specific project can usually be accurately estimated before a financing commitment is made. Third, most new facilities will be useful and productive over an extended time period far beyond the initial funding time frame.

Because of these common characteristics, most financing of new facilities will involve some form of debt. By issuing debt, the utility can obtain the relatively large initial investment required for construction and amortize repayment of the debt over the estimated useful life of the system. In this way, the repayment of the debt takes the form of annual payments similar to the annual depreciation expense of the newly financed facility. Those entering the system after it is built are required to share its initial cost in the form of amortized debt service as part of their annual user fees.

Debt for districts such as those comprising Fairfield most often is from the sale of general obligation or revenue bonds. General obligation bonds are those which are paid back through general property taxes (ad valorem taxes), while revenue bonds return payment based on collection of service charges. The major source of district revenue is the ad valorem property tax.

While grants may become available to help fund a portion of the capital costs, some of these costs will likely require local debt financing. It follows that most, if not all, of the customers' affordable monthly charge will need to be allotted to paying O&M costs, little, if any, user charge revenue is left with which to amortize the local share of the capital costs.

An alternative to general tax support to fund facility improvements is to require developers to pay for the capital facilities. This approach has the effect of having the buyer of the property pay, as the developer's costs are passed on to the buyer in terms of a higher purchase price.

Capital Funds for Repair and Replacement of Existing Systems

Probably the most ignored or abused funding requirements of water and wastewater utility systems are those required for facility repair and replacement (R&R). Wastewater systems in particular often are in need of facility replacement or repair that goes unfulfilled due to lack of required funding. This type of financial oversight generally results in a system which operates ineffectively.

Financing system R&R needs generally differs from new facility financing. While the funding needs for R&R can be significant, especially as a system ages, R&R funding is not as predictable or preplanned as funding new or expanded facilities. Therefore, R&R financing usually makes use of a reserve fund created by periodic contributions until the fund reaches some preset balance. Thereafter, contributions are made only as necessary to retain the preset balance.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Based on the discussions presented in previous sections of the text, the following conclusions can be drawn relative to implementation of a water reuse system in Fairfield:

1) The study area, in northwest Harris County, lies within the jurisdiction of the Harris-Galveston Coastal Subsidence District and is subject to conversion from current groundwater supply to surface water supply in the future. Existing studies indicate surface water conversion is at least 40 years away, therefore, groundwater will remain the only available supply source unless other supply strategies are implemented. At present, adequate quantities of groundwater are available, however, continued groundwater withdrawal will increase subsidence in the area.

2) A literature review indicates that reuse systems using dual water distribution systems, one for potable and the other for nonpotable supplies, have been successfully implemented in other parts of the United States. There have been few problems associated with such systems. The newly adopted Texas Water Commission Rules for Nonpotable Reuse Systems will allow implementation of a water reuse system in Texas.

3) The study area encompasses the new development of Fairfield Village and is a good candidate for implementation of a water reuse project since construction of a dual distribution system is less expensive in undeveloped areas. The study area will contain approximately 12,800 equivalent single family connections at full development.

4) Detailed analyses of similar local groundwater systems have been completed with results applied to the Fairfield community. Without implementing a reuse alternative, these analyses indicate that total annual water demands in the study area will reach 2.29 billion gallons per year (6.27 million gallons per day) by the end of the planning period in 2020. Peak-day demands will reach 15.89 million gallons per day.

5) Potential reuse applications have been investigated for the study area. The Fairfield land use plan indicates extensive landscaping will be a theme of the development and will require significant quantities of irrigation water. The water system analyses above further indicate that the residential component of similar developments also utilize substantial quantities of water for irrigation. Since TWC rules will allow such uses with reclaimed water, this is a primary potential use in the study area. Use of reclaimed water for other applications, such as in cooling towers were also found to be applicable to the study area. Use of reclaimed water for toilet flush water can be included but

has not been investigated in detail. Other uses not addressed in current regulations, such as fire-fighting needs and reuse in certain construction activities, can be included if allowed by the TWC.

6) It is estimated that implementation of a reuse alternative will reduce annual potable water production to about 1.36 billion gallons (3.73 mgd) with irrigation and cooling water reuse and about 1.04 billion gallons (2.85 mgd) if toilet flush water reuse is included.

7) Potable and nonpotable water system networks have been modeled using computer analysis simulation techniques to determine required waterline and water system component sizes. These analyses indicate that potable water system requirements for the potable side of a dual distribution system are significantly lower than current minimum sizes required by regulatory agencies. These data indicate a revision to current potable water system standards may be warranted for dual distribution systems.

8) Capital and O&M costs have been compared for non-reuse and reuse systems for the Fairfield area to determine the cost-effectiveness and feasibility of a water reuse alternative. Capital costs were estimated for reuse systems considering conformance to current minimum potable water system standards and to reduced standards. Additional analyses are required to determine acceptable reduced potable standards for dual use systems. A significant cost component of the reuse system alternative is the cost to construct sprinkler systems in residential areas.

9) The capital and O&M costs were compared on an annual cost basis at a constant interest rate for the non-reuse alternative and varying interest for the reuse alternative, assuming the reuse alternative could be funded with a TWDB low interest loan. The reuse alternative is cost-effective only with a loan rate of about 5.7 percent, provided lower potable water standards are approved by the City of Houston and the Texas Department of Health. Certain water uses germane to the analysis, e.g., fire-fighting needs, also must be approved by the Texas Water Commission. Additionally, the cost of residential sprinkler systems must be borne by the developer or residents in the form of a connection or access fee to the regional reuse system.

RECOMMENDATIONS

From the above conclusions, the following recommendations are presented for consideration:

1) The draft report be submitted to the regulatory agencies and other affected parties for review and comment.

2) If key provisions are acceptable, conduct a public meeting to solicit comments from the general public, especially the existing residents of Fairfield.

3) Revise the draft report to include all responses, provided there is not overwhelming opposition to implementation dual of distribution system alternative.

4) If the total project alternative remains cost-effective following any revisions, develop an implementation plan and schedule and determine a Phase 1 demonstration project. Present the project to TWDB for consideration of funding with a low interest loan.

5) Construct the Phase 1 project if funds are available, simultaneously with construction of the regional wastewater plant or shortly thereafter.

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WATER CONSERVATION AND DROUGHT CONTINGENCY PLAN

Purpose and Goals of the Program

Harris County Municipal Utility Distict (HCMUD) No. 322 and Harris County Water Control and Improvement District (HCWCID) No. 155 are completing a regional planning study to investigate the feasibility of implementing a water reuse project in northwest Harris County. The study area is a new residential and commercial development known as Fairfield Village. The study is funded, in part, by a grant from the Texas Water Development Board (TWDB). As part of the grant requirements, the applicants must prepare a water conservation and drought contingency program for adoption if the plan is implemented. The origin of these requirements is action taken by the 69th Texas Legislature in 1985. Conservation requirements established by House Bill (HB) 2 and House Joint Resolution 6 were approved by Texas voters on November 5, 1985 by ratification of an amendment to the Texas Constitution, which implements HB 2.

The objective of a conservation program is to reduce the quantity of day-to-day water use activities, insofar as practical, through the implementation of efficient water-use practices. Day-to-day water uses include water used for drinking, bathing, cooking, toilet flushing, fire protection, lawn watering, swimming pools, laundry, dishwashing, car washing, and sanitation.

A drought contingency program provides procedures for voluntary and mandatory actions to be implemented to temporarily reduce water demands during a water shortage emergency. Drought contingency procedures include conservation but may also prohibit certain water uses.

The purpose of this report is to present background information on the proposed water and wastewater utility systems and to discuss alternatives and elements selected for Water Conservation and Drought Contingency Plan.

Description of the Planning Area

The study area is a proposed community known as Fairfield Village and is located between Cypress, Texas and Hockley, Texas approximately 30 miles northeast of downtown Houston in northwestern Harris County. The area is presented on Exhibit II-1. US Highway 290 bounds the study area on the south, Schields Road on the north, future Grand Parkway to the west, and undeveloped land to the east. The area lies within the Cypress Creek and Little Cypress Creek watersheds. These streams are tributaries to the west fork of the San Jacinto River.

The study area, which encompasses about 2,595 acres, is a master planned development initially opened in 1988, primarily as a residential suburban community of Houston. Proposed development will occur in several planned municipal utility districts.

Description of the Project

The regional planning study examines the potential benefits of using treated wastewater effluent for irrigation of selected common areas, as well as the potential for a dual water supply system serving individual households and/or commercial establishments within the study area boundaries. Besides irrigation, the nonpotable system would be utilized for firefighting needs. Potential irrigated areas include esplanades, park areas, greenbelts, drainage channels and homeowner landscapes.

The purpose of the study is to determine if such reuses are feasible, thereby reducing the requirement for new groundwater developments. Besides utilizing an otherwise wasted resource, long-term potential benefits include extension of the life of existing or planned supply facilities and reduction or elimination of wastewater effluent discharges to receiving streams.

The project, if implemented, in itself represents a major step toward conservation and might be considered the conservation plan for the study area. Nevertheless, other conservation measures have been considered and are included in this Plan. Ironically, implementation of some of these measures would serve to reduce return wastewater flow to the sewage treatment plant and reduce available quantities for reuse.

Surface and Groundwater Resources

The study area lies within the H-GCSD Regulatory Area 8 which currently does not have a specified timetable for conversion to surface water. At present, there are no surface water resources available for Fairfield Village. The most recent long-range alternative plans for northwest Harris County's conversion to surface water are presented in the draft "Implementation Plan" completed by the West Harris County Surface Water Supply Corporation (WHCSWSC) in November, 1988. The most cost-effective alternative developed in the plan describes completion of surface water supply lines along US Highway 290 by year 2030. The proposed surface water supply source is a surface water treatment plant obtaining water from the Brazos River, approximately 25 miles south of Fairfield. At best, then, surface water availability and conversion is at least 40 years away.

Until such time as surface water becomes available, or alternative water strategies are implemented, all water needs of the study area are reliant upon groundwater resources. The current Fairfield Water Master Plan calls for development of groundwater wells and related facilities to be constructed in phase with planned growth.

Land Use and Population Projections

Detailed master planning and land planning studies provide the basis of land uses for the Fairfield development. Projected development includes single-family, multi-family, commercial, and institutional (parks, schools, churches, and utility sites) uses. Part of the commercial development includes a regional shopping mall planned in the southwest corner of the development.

Certain reserves have been set aside as drill sites for possible oil and gas exploration and a significant portion of the area is provided for drainage channel rights-of-way. Somewhat unique to the character of the Fairfield development and an impetus for investigating water reuse for the area are special areas for highly manicured landscaping and greenbelt areas for recreation and park access.

Population projections for the study area are provided by the developer, Friendswood Development Company and are based on a housing density of 3.5 persons per single-family connection, consistent with similar developments in the Houston area. Multi-family development is based on a projection of 20 equivalent single-family connections (ESFC) per acre. Based on the current land use plan, the total actual population for the study area is about 25,158 actual persons. The estimated equivalent population, including other types of land-use development, is 44,807 equivalent persons. Equivalent population projections include 10 equivalent single-family connections per acre of commercial and retail development, plus an allowance for institutional and other uses. Equivalent population projections are presented in the next section.

Water Demands

Water demands for the study area will vary dependent on whether or not a water reuse project is implemented and the extent of water reuse practices. Figures IV-3 and IV-5 present graphically the difference in expected annual water use patterns between a non-reuse alternative and a reuse alternative at full development conditions. In terms of volume, the non-reuse alternative will require 2.29 billion gallons of water annually, whereas a reuse, irrigation alternative would reduce the annual water requirement to approximately 1.36 billion gallons. These volumes correspond to annual average gallons-per-equivalent-capita-per-day (GPECD) rates of 140.3 GPECD for a non-reuse system and 79.6 GPECD for the proposed reuse system.

Coupled with the equivalent population projections, estimated water demands are summarized below.

Year	Equivalent Population	Non-Reuse Alternative Water Use (gpd)	Reuse Alternative Water Use (gpd)
1990	1,866	261,800	148,500
1995	16,757	2,351,000	1,333,900
2000	34,776	4,879,100	2,768,200
2005	40,609	5,697,400	3,232,500
2010	42,791	6,003,600	3,406,200
2015	44,276	6,221,900	3,524,400
2020	44,807	6,286,400	3,566,600

Water Rate Structure

HCMUD No. 322 charges its customers to recover costs for operation and maintenance of water and wastewater facilities. Presently, these rates are $10.00 for the first 2,000 gallons; $0.50 per 1,000 gallons for the next 8,000 gallons, and $1.00 per 1,000 gallons, thereafter, for water service. These rates are expected to change with implementation of a water reuse project.

Public Involvement in the Planning Process

A public meeting is planned to discuss results of the planning study and to determine if the existing community residents are in favor of implementing a water reuse project. The public will also be provided the opportunity to comment on the Water Conservation and Drought Contingency Plan.

The following items have been considered and, when appropriate, incorporated into the Plan.

Assessment of Supply and Demand Management Potentials

Water conservation measures are often evaluated under two management categories--demand management and supply management. Demand management methods consider water use downstream of the service connection; that is, user-oriented conservation. Demand management provides for education or incentives, such as overall lower water costs, to reduce water consumption by the consumer. This method of conservation generally reduces water revenues since less water is purchased from the water utility.

Supply management methods consider water supply upstream of the customer's service connection. The goal of supply management is to reduce water waste and improve efficiency within the production, treatment, and distribution system. Supply management usually results in decreased cost to the water utility as water system losses are reduced. Both demand and supply management techniques were considered in development of The Water Conservation Plan.

Demand Management Alternatives

Education and Information

The most readily available and lowest cost method of promoting water conservation is to inform water users about ways to save water inside homes and other buildings, in landscaping and lawn uses, and in recreational uses. An effective education and information program can be easily and inexpensively administered. Materials available from the American Water Works

Association, the TWDB, and other similar associations can easily be acquired for distribution to customers through handouts, mail-outs, bill stuffers, and other sources. Distribution of materials to school children, another feasible method, promotes conservation at an early age. The local newspaper can be used for public service announcements and publication of articles concerning water conservation. The use of radio stations in the area, together with public and cable television systems, also can be utilized for this purpose.

Plumbing Codes

Water-saving plumbing codes for new construction and replacement of existing plumbing are effective methods of reducing water demands. Water-saving plumbing codes, however, must be adopted and enforced by building inspection to be effective. An alternative to regulation and enforcement is the extension of the education and information program to include information about water-saving devices on a voluntary basis. This alternative is a viable method and has been considered for adoption into the Water Conservation Plan. If, in the future, the participating districts implement a plumbing code and inspection system, that code will include water conservation plumbing fixture standards.

Retrofit Programs

Information can be made available through an education program for plumbers and customers to use when purchasing and installing plumbing fixtures, lawn watering equipment, or water-using appliances. Information regarding retrofit devices, such as low-flow shower heads or toilet dams which reduce water use by replacing or modifying existing fixtures or appliances, can also be provided.

Alternately, kits can be provided at cost for installation by the homeowner.

Water Rate Structures

A water conservation-oriented rate structure usually takes the form of an increasing block rate, although continuously increasing rate structures, peak or seasonal load rates, excess use fees, and other rate forms can be used. The increasing block rate structure is the most commonly used water conservation rate structure. Separate rate structures are usually used for residential, commercial, institutional, and industrial customers.

HCMUD No. 322 currently uses an increasing rate structure. Other districts in the study area, as yet unformed, may chose different rate structures. Implementation of a water reuse project is anticipated to significantly alter rate structures due to the nature of the project. It is expected that a flat rate may be charged for the nonpotable irrigation system. If a reuse project is implemented, potable water needs in the study area would be based on essential needs that do not include irrigation, a primary cause of high consumption and water waste. Thus, water conserving rate structures are probably not warranted in the study area.

Water-Conserving Landscaping

In order to reduce the demands placed on a water system by landscape irrigation, the water utility should consider methods that either encourage (by education and information) or require (by regulation) water-conserving landscaping by residential customers and commercial establishments engaged in the sale or installation of landscape plants or watering equipment. As much as 35 percent of total residential water use can be traced to exterior uses such as lawn watering and car washing. Even with a water reclamation project, such practices could reduce irrigation demands and reduce the cost of operation and maintenance of the system.

Supply Management Alternatives

Universal Metering

All potable water users, including the water utility and other public facilities, should be metered. A regularly scheduled maintenance program of meter repair and replacement should be established to maintain meter accuracy. Most important, metering can provide an accurate accounting of water uses throughout the system. In addition, the water utility may be able to locate and bill previously unbilled users. Metering and meter repair and replacement, coupled with an annual water audit, can be used in conjunction with other programs such as leak detection and repair, and thereby save significant quantities of water.

State regulation requires that nonpotable system operation be restricted to authorized personnel for reasons of public safety and to reduce the potential cross-connections, runoff, and other undesirable consequences. Other entities outside of Texas which have successfully implemented reuse programs maintain complete control of watering activities. In many instances, a flat fee is charged to recover cost of operation of the system and to reduce administrative costs of nonpotable meter reading and bill collecting. Nonpotable meter repair is similarly eliminated. A flat fee rate structure is being considered for the reuse project. If implemented, household metering of the nonpotable supply would be unnecessary.

Leak Detection and Repair

A continuous leak detection, location, and repair program can be an important part of a water conservation plan. An annual water accounting or audit should be part of the program. Sources of unaccounted-for water include defective hydrants, abandoned services, unmetered water used for fire fighting or other municipal uses, inaccurate or leaking meters, illegal hook-ups, unauthorized use of fire hydrants, and leaks in mains and services. Once located, corrective repairs or actions need to be undertaken.

A master water utility is expected to maintain the potable and nonpotable water distribution systems in Fairfield. It is anticipated that waterline breaks will be reported by citizens or discovered during routine inspections by the master district personnel. Such leaks could then be promptly corrected. In addition, computerized potable water billing systems can flag above-normal water usage at individual connections, thus alerting the water utility of inaccurate or leaking meters. These measures can be incorporated as part of the Conservation Plan.

Recycling and Reuse

Any water utility should evaluate the potential of recycling and reuse because these methods may be used to increase water supplies within the service area. Reuse can be especially important where the use of treated effluent from an industry or a municipal system or agricultural return flows replace an existing use that currently requires fresh water from a utility's supply. Recycling of in-plant process or cooling water can reduce the amount of fresh water required by many industrial operations.

Reuse or recycling of treated wastewater effluent within Fairfield will be accomplished if a water reuse project is implemented. As noted earlier, the project is planned to conserve significant quantities of groundwater reserves.

Plan Description

Based on the evaluation of alternatives available to the water utility for conserving water, the following elements have been selected as those best suited for water conservation.

- Demand Management
  - Public Education and Information
  - Retrofit Programs
  - Water-Conserving Landscaping

- Supply Management
  - Universal Metering
  - Meter Repair and Replacement
  - Leak Detection and Repair
  - Recycling and Reuse

Public Education and Information

A program of public education and information to promote water conservation and educate new residents about the reuse system (if implemented) will be initiated. At a minimum, methods that will be used to distribute first-year information to the public are as follows:

1. An initial fact sheet explaining the water conservation program, the drought contingency plan, and key elements of the reuse system;

2. Pamphlets on the reuse system and the beneficial effects of water conservation issued through mail-outs, bill stuffers, door hangers, or other method of direct issuance;

3. Print water conservation tips on water bills during the year or implement other information activities;

During subsequent years of the program, technical information on water conservation will be provided semi-annually directly to the public in the form of pamphlets or bill stuffers. In addition, water conservation information and information about reuse system operation and benefits will be made available to new customers when they apply for water service. The managing water utility will include information about insulating pipes to prevent freezing in cold weather, retrofitting of existing plumbing fixtures and devices, and landscaping conservation methods. The energy savings associated with the reuse and water conservation programs also will be emphasized.

Assistance in obtaining publications and materials for the program will be obtained from:

- Texas Water Development Board
- American Water Works Association
- American Public Works Association

Individual pamphlets and flyers will be selected for the specialized needs of Fairfield.

Retrofit Programs

The water utility will make information available through its education program for plumbers and customers to use when purchasing and installing plumbing fixtures, lawn watering equipment, or water-using appliances. Information regarding retrofit devices such as low-flow shower heads or toilet dams that reduce water use by replacing or modifying existing fixtures or appliances also will be provided. Water conservation kits containing retrofit devices easily installed by the homeowner can be made available upon request and at cost at the water district office.

Water-Conserving Landscaping

Water-conserving landscaping in the development will be promoted as a method to reduce operating costs of the reuse system as well as reduce water consumption in those areas which will continue to be irrigated with the potable system.

Universal Metering

The districts comprising Fairfield will meter all potable water sales in the system. In addition, the managing water authority will meters all water well production. State regulations will require metering of reused water to monitor application rates within the study area. Additionally discharged wastewater flows will be monitored at the regional wastewater treatment plant. This program of universal metering will made part of the Water Conservation Plan.

Meter Repair and Replacement

A program of meter repair and replacement will be implemented and will include the following:

- Replacement of all residential meters at 1,000,000 gallons.
- Annual testing of all meters 2 inches and larger.

Accuracy of all smaller meters, including those smaller than one inch, will be monitored continuously through water billing procedures. Unusually high or low readings will be investigated, followed by testing, repairs, or replacement as needed. This program will be initiated as part of the Water Conservation Plan.

Leak Detection and Repair

A leak detection program will be implemented to include:

- Bi-monthly water-use billing to identify high water use and potential meter leaks.
- Visual inspection by utility employees to uncover abnormal conditions indicating leaks.
- An adequate maintenance staff and budget to repair any leaks.

Recycling and Reuse

The most significant aspect of the water conservation plan will be implementation of the proposed reuse project. Successful implementation will conserve potable water supplies many times over all other components of the Plan. As noted previously, approximately 1 billion gallons of water per year can be conserved under full development conditions by implementing the project.

Implementation/Enforcement

It is anticipated that the master utility district will assume authority for implementation and operation of the proposed project and Water Conservation Program. The administrator will oversee the execution and implementation of all elements of the program. He also will be responsible for maintaining adequate records for program verification. Each member utility district will be responsible for furnishing all information needed and requested by the master district.

In addition to the above, the administrator will be responsible for the submission of an annual report to the TWDB on the Water Conservation Plan and record keeping requirements of the Texas Water Commission. The water conservation report will include the following elements.

- Progress made in the implementation of the program.
- Response to the program by the public.
- Quantitative effectiveness of the program.

In order to achieve the benefits of an effective water conservation plan, it is necessary for the customer districts to adopt the proposed plan and play a key role in its implementation. The program will be adopted by resolution of the member Districts. Since the reuse project will be utilized by the entire community, implementation of the Plan will be essentially automatic, supported and reinforced by a public information program.

SECTION IV - DROUGHT CONTINGENCY PLAN

Introduction

Drought, or a number of other uncontrollable circumstances, can disrupt the normal availability of community or utility water supplies. Even though a city may have an adequate water supply, the supply can become contaminated, or a disaster can disrupt or destroy the supply. During drought periods, consumer demand is often significantly higher than normal. Some older systems, or systems serving rapidly growing areas, may not have the capacity to meet higher than average demands without system failure or other unwanted consequences. System treatment, storage, or distribution failures also can present a city or utility with an emergency demand management situation.

It is important to distinguish drought contingency planning from water conservation planning. While water conservation involves implementing permanent water use efficiency or reuse practices, drought contingency plans establish temporary methods or techniques designed to be used only as long as an emergency exists.

An effective Drought Contingency Plan includes the following six elements:

- Trigger conditions signaling the start of an emergency period.
- Drought contingency measures.
- Information and education.
- Initiation procedures.
- Termination notification actions.
- Means of implementation.

Trigger Conditions

For the purposes of this Plan, trigger conditions will be based on Fairfield as one system, rather than individual triggers for each MUD and considered only for the potable distribution system, since individual customers will have little influence on operation or control of the nonpotable system. A description of conditions considered mild, moderate, severe, and critical for the potable system follow.

- Mild conditions are oftentimes discretionary, based on daily monitoring of water demands and weather forecasts and the water plant operator's judgment.

- Moderate conditions occur when combined pumpage from water plants is in excess of 85 percent of firm capacity for three days, or 90 percent of firm capacity for one day, or when continually falling elevated storage tank levels occur and storage cannot be replenished over 70 percent of maximum tank volume overnight.

- Severe conditions occur when combined pumpage from water plants is in excess of 90 percent of firm capacity for three days, or 95 percent of firm capacity for one day, or when continually falling elevated storage tank levels occur and storage cannot be replenished over 50 percent of maximum tank volume overnight.

- Critical conditions are reached when water plant pumpage exceeds 95 percent of firm capacity for three days, or 100 percent of firm capacity for one day, or a major line break or a pump or system failure occurs which causes pressures to drop significantly. Prolonged power outage also constitutes a critical condition.

Emergency Management Program

The following actions shall be taken by the water utility, as noted, when trigger conditions are reached.

Mild Conditions

- Request customers to voluntarily limit the amount of water used.

- Increase monitoring of water supply versus demand.

- Increase leak detection and repair efforts.

- Request customers implement policy of no swimming pool refilling or car washing.

- Request customers cease operation of ornamental fountains unless equipped with recycling system or are operated from the nonpotable system.

Moderate Conditions

- Continue implementation of all Stage 2 restrictions.
- Prohibit all unnecessary outside water use.
- If the above restrictions do not produce the desired results, the water utility will reduce water plant operating pressure to reduce water demand during peak periods if possible.
- The water utility will maintain normal pressure during off-peak hours to fill elevated storage tanks.

Severe Conditions

- Prohibit all public water uses not required for health or safety.
- Continue prohibition of all outside water uses.
- Reduce plant operating pressures to maintain a minimum residual of 40 psi in the system when excessive water demands are the cause of critical conditions.

Information/Education

As a component of the Information/Education section in the Water Conservation Plan, the purpose and effect of the Drought Contingency Plan will be communicated to the public through articles in local newspaper, supplemented by pamphlets distributed at the same time and public service announcements on local television.

When trigger conditions appear to be approaching, the public will be notified through publication of articles in local newspaper with information on water-conserving methods. During critical conditions, signs may be posted at major entrances to Fairfield.

When trigger conditions have passed, the local newspaper will publish notification that drought contingency measures are abated for that condition, and, if applicable, will outline measures necessary for the reduced condition.

Throughout the period of a trigger condition, regular articles will appear to explain and educate the public on the purpose, cause, and methods of conservation for that condition.

Implementation/Enforcement

It will be the responsibility of the Plan Administrator to monitor the status of the water supply and distribution systems. When a trigger condition is reached, officials will notify each District of implementation of the Drought Contingency Plan.

The water utility administrator will continue to monitor the water emergency until it is determined that the trigger condition no longer exists. When this occurs, he will notify the member Districts and the Drought Condition Abatement procedures will be implemented.

Update of Trigger Conditions

Once a year, the water utility will examine the production requirements and ability to maintain these requirements to determine if trigger conditions need to be re-established. Consideration will be given to each District's usage in relation to the aggregate usage and any anticipated increase in production of the water supply facilities.

COMMENTS ON STUDY

TEXAS WATER DEVELOPMENT BOARD

February 6, 1991

Members of the Boards of Directors
Harris County Municipal Utility District No. 322
and Harris County Water Control & Improvement
District No. 155
c/o Fulbright & Jaworski
1301 McKinney
Houston, Texas 77010

Dear Members of the Boards of Directors:

Re: Review Comments on Draft Final Report for the Harris County MUD No. 322 and Harris County WCID No. 155: TWDB Contract No. 90-483-768

Staff members of the Texas Water Development Board and the Texas Water Commission's Water Quality Division have completed a review of the referenced document under TWDB Contract No. 90-483-768 with Harris County MUD No. 322 and Harris County WCID No. 155. The review comments presented in Attachment A should be considered before the report is finalized.

The Board looks forward to receiving the Final Report on this planning project. Please contact Ms. Carolyn L. Brittin, the Board's Contract Manager, at (512) 475-2056 if you have any questions about the Board's comments.

Sincerely,

Tommy Knowles
Director of Planning

Attachment (1)

P.O. Box 13231 Capitol Station • 1700 N. Congress Avenue • Austin, Texas 78711-3231
Telephone (512) 463-7847 • Telefax (512) 475-2053

Attachment A
Review Comments on Draft Final Report
TWDB Contract No. 90-483-768

1. The feasibility study provides a good analysis of the potential for re-use in a developing area.

2. A direct comparison of TWDB population projects with the developer's population projections was not possible. However, based on census tract projections from the Houston Water Master Plan and the Houston-Galveston Area Council and the current economic situation in the Houston area, the developer's projected population increase for Fairfield Village during the 1990's appears optimistic.

2. Re-examine savings for essential use obtained through the water conservation plan in Section IV. The draft final report assumes a 10 percent savings in essential use due to water conservation. This is lower than the 15 percent savings projected in the 1990 Texas Water Plan.

3. In the development of the water conservation plan in Appendix A, the section on Plumbing Codes or regulations is left out of the plan description beginning on page III-6 even though it is discussed on Page III-2 of the Appendix.

4. While it is largely the prerogative of the district to establish a "flat rate" for sale of non-potable water, charging for treated effluent on a volume basis would encourage more efficient use of the water and would help prevent abuse of this system which would result in excessive water demands that may exceed the capacity of the system.

5. Metering of the non-potable system would help determine if excessive losses in the system or major unauthorized uses are occurring and will provide a much more accurate analysis of the system.

6. For a true comparison of alternatives on a cost basis, all alternatives should be compared at an equivalent interest rate. The varying interest rate analysis equates total expenditures for certain alternatives at about a 5.7 percent rate and indicates the 5.7 percent rate to be within the range of current rates offered by TWDB. Note that at this time only the State Revolving Fund (SRF) program has a rate this low and that SRF funding would not be available for the potable water portion of the project. Other state funds with rates of a higher value would possibly be available for the potable water portion.

7. The sprinkler system component cost of the re-use alternatives (Page IV-4) should not be removed as it is a necessary component for proper disposal of the wastewater.

RESPONSES TO REVIEW COMMENTS ON DRAFT FINAL REPORT
FOR FAIRFIELD WATER REUSE STUDY
TWDB CONTRACT NO. 90-483-768

February 18, 1991

1. The favorable response to the study's content and conclusions is appreciated.

2. As noted in the review comments and the study report, use of the developer's projected populations and land use assumptions were necessary due to a lack of other location-specific sources. We agree that these projections appear optimistic given the current economic situation in the Houston area. In fact, Fairfield's growth has not materialized at as fast a pace as projected. However, the developer's track record in other master-planned communities, specifically communities such as the Kingwood, Copperfield, and Clear Lake developments are not typical of local conditions. These areas demonstrate continued growth or stability in their respective areas despite lower growth trends in other areas of the region. Accordingly, there is sufficient reason to believe the Fairfield community will develop as planned, although at a delayed or slower start. The net effects of slower development will be an extension of the timetables presented in the study and revisions to debt retirement schedules.

3. The net projected water savings of 15 percent presented in the Texas Water Plan is an overall water savings of <u>total</u> water consumption. The total consumption includes irrigation and other potential reuse opportunities as defined in the study report. As noted in the review comments, the estimated 10 percent savings applies only to <u>essential</u> water use. Irrigation demand, perhaps the highest single water use in suburban Houston-area communities, is not included in the "essential" consumption figure. Within the study area, lawn irrigation of residential front-yards and other public areas will be a controlled application based on the estimated water balance rates. The controlled application provides an additional savings of otherwise wasted water not included in the 10 percent essential use water savings.

   Assuming a water reuse project is implemented in the Fairfield community, annual total water savings can be estimated as follow:

(Total Water Consumption of Non-reuse Project less Total Water Consumption of Reuse Project) x 100 Total Water Consumption of Non-reuse Project

= Percent Total Water Savings, or

$$\frac{(130.5\ \text{GPECD} - 105.7\ \text{GPECD})}{130.5\ \text{GPECD}} \times 100 = 19.0\%$$

GPECD is gallons per equivalent capita per day. Thus, total projected water savings are 4 percent in excess of the 1990 Texas Water Plan.

4. The section on plumbing codes was inadvertently left out of the plan description. The final report will include this section.

5. It is our opinion that the concept of charging for treated water on an individual basis is the better approach in the study area. Consequently, the flat rate is presented for a number of reasons. First, metering of individual connections adds a significant addition to the overall project cost, increasing the capital, O&M, and administration costs. These increases result in a less cost-effective project. Second, the Texas Water Commission Rules specifically prohibit "unauthorized" use of reclaimed waters. The managing authority, that is, the governing body responsible for treatment, distribution, and administration of the project, must be substantially in control of distribution and application rates to prevent unauthorized discharges from entering waters of the State and to protect the public from inadvertent uses. In an uncontrolled system, or one in which individual users have access to the reuse supply, such uses might include excessive runoff and accidental consumption. Third, water reuse consumption is dictated by the water balance expressly as a measure to prevent excessive or abusive uses. Finally, a mandatory flat rate approach encourages acceptance and use of the system as a type of "take or pay" fee. Customers not wishing to use the reuse water would use potable water as an alternative and would incur higher water bills. For these reasons, the flat rate approach is preferable. As noted in the report, this approach appears successful in other dual distribution communities, for example, in St. Petersburg, Florida.

6. Metering of the reuse system is essential to assure compliance with application rates provided by the water balance. Metering of the system is not specifically mentioned in the study report, however "master" or regional meters and system pressure devices are necessary to monitor for leaks, major unauthorized uses, etc. It should be noted that metering of discharged effluent at

the treatment plant and metering of reuse water to storage ponds historically are requirements of the Texas Water Commission for water reuse projects. A line item in the cost tables includes the cost of metering and monitoring outside of the treatment plant as "Regional System Monitoring and Controls." Supervisory Control and Data Acquisition (SCADA) systems are proposed for both potable and nonpotable use monitoring.

6. The alternative costs are presented using an equivalent basis of comparison, but not necessarily an equivalent interest rate. If a reuse project is <u>not</u> implemented, the assumed interest rate for potable water facilities is about 8 percent, near current market rates. On the other hand, the interest rate for all future water facilities (both potable and nonpotable) must be lower for the project to be cost-competitive. This is the result of higher capital and O&M costs for the nonpotable alternatives. The cost analysis determines that rate necessary to be a cost-effective project. With the Option 1 alternative, the rate is slightly over 0 percent and, with Option 2, the rate is about 5.7 percent.

7. As noted in the report, the sprinkler system effectively becomes an amenity that is included in the purchase of the house. If sprinkler systems are included in the nonpotable alternative it seems there should be a corresponding line item in the potable system alternative. When equal numbers of sprinkler systems for either alternative are included, the net effect is the same as if no sprinkler systems are considered. This is the case represented by the Option 2 alternative referenced on Page IV-4.

HARRIS - GALVESTON COASTAL SUBSIDENCE DISTRICT
1660 West Bay Area Blvd. Friendswood, Texas 77546-2640 (713) 486-1105

January 20, 1991

Mr. Donald R. Sarich, P.E.
Turner Collie & Braden, Inc.
P.O. Box 130089
Houston, Texas 77219

Re: Draft - Feasibility Study for the Implementation of a Water Reuse Project in Fairfield Village

Dear Mr. Sarich:

We appreciate the opportunity to review the above mentioned report. Although, we do not feel we are qualified to perform a technical review of the report, we feel the report thoroughly covers all the various possibilities for water reuse and addresses concerns the public may have regarding the proposed reuse program.

The Subsidence District feels that a project of this type has great potential in reducing the overall water demand for the area. The District will encourage these types of conservation programs.

If you have any questions, please feel free to contact me.

Sincerely,

Robert E. Thompson
District Engineer

RET/ct

Texas Department of Health

Robert Bernstein, M.D., F.A.C.P.
Commissioner

Robert A. MacLean, M.D.
Deputy Commissioner
Professional Services

Hermas L. Miller
Deputy Commissioner
Management and Administration

Public Health Region 4
10500 Forum Place Drive
Suite 200
Houston, Texas 77036
(713) 995-1112

John N. Bogart, M.D., M.B.A.
Regional Director

February 28, 1991

Don Sarich, P.E.
Turner Collie and Braden, Inc.
P.O. Box 13089
Houston, Texas 77219

Subject: Fairfield Village Water Re-use Feasibility Study

Dear Mr. Sarich:

Reference is made to our several meetings concerning the subject study. As you requested, I have transmitted a copy of the report to the Plan Review Branch and the On-Site Sewage Facilities Branch of the Division of Water Hygiene in Austin for their review and comments, which are attached as a separate memorandum.

In addition to the information attached, I would also like to reiterate several points that were made in the discussion during our last meeting. They are as follows:

1. The piping of reclaimed wastewater into the interior of a dwelling raises considerable concern for the Department of Health, since we require that water piped into any dwelling be of potable quality. It is our understanding that portion of the proposal has already been dropped.

2. The use of reclaimed wastewater for fire-fighting purposes is also of concern, since firefighters are often protected from the heat by hosing them down. Given the danger of burns, cuts and puncture wounds faced by firefighters in the course of their normal duties, and the subsequent risk of infection from same, it would seem that the use of reclaimed effluent could result in an increased risk to the firefighters.

3. Although not specifically stated in the study, it is to be assumed that there will be contact sport practice and game fields that would be present in this area. Irrigation of such fields which are subject to numbers of players being shoved to the ground, as in soccer, football, and others, gives rise to increased concern about risk of infection from abrasions, cuts, and from getting material in the eyes, nose, and mouth.

4. The subject of irrigating residential property lawns on a large scale with spray irrigation is also worrisome. From a public health standpoint, we would much prefer to see sub-surface drip irrigation as an alternative to surface application, although we do realize that there are problems related to the plugging of such systems. It was also not clear to me that the utilization of the reclaimed effluent was controlled by the district and not by the individual homeowner, although this intent was stated to me at the time of the meeting.

The above information is provided for your guidance and use as you continue to develop re-use scenarios. Please be assured that this Department remains committed to the conservation of and maximum utilization of all resources in the state.

If we may provide further information or clarification of any of the above or the attached material, please let us know.

Very truly yours,

Mark V. Lowry

Mark V. Lowry, P.E.
Regional Director of Environmental
and Consumer Health Protection

MVL/mvl

ccs: Harris Co. Health Dept.
Plan Review - Austin
OSSF Branch - Austin

TEXAS DEPARTMENT OF HEALTH
AUSTIN TEXAS
INTER-OFFICE

FROM: James E. Pope, P.E., Director
Division of Water Hygiene

THRU: Associate Commissioner for Community
and Rural Health Services

TO: Robert A. MacLean, M.D.
Acting Regional Director of Public Health
Public Health Region 4

ATTN: Mark V. Lowry, P.E., Regional Director of
Environmental and Consumer Health Protection

SUBJECT: Review of Fairfield Village Water Reuse
Project by OSSF Staff

Per your request, OSSF staff members have completed a review of the above-referenced draft study.

Their comments on this study are attached for your information.

SWH:re

Attachments

SIGNED James E. Pope

DATE January 28, 1991

DATE: 1/21/91

TO: S. Hart
J. Salgado

FROM: S. Ferns SF

SUBJECT: Review of "Feasibility Study for the Implementation of a Water Reuse Project in Fairfield Village" by Turner Collie & Braden Inc.

I feel that there are some deficiencies in the methodology used in this study that make it of questionable use as a feasibility study for a water reuse project. My chief concerns center around the adequacy of the assessment of the irrigation and agronomic aspects of the project. My points can be summarized as follows:

(1) Adequate data on existing wastewater quality is not provided.
(2) Adequate data on soil physical and chemical properties are not provided.
(3) Analyses based on the above information and standard methods in the agricultural, wastewater irrigation and environmental literature are not conducted in the areas of:
- (a) soil/wastewater system interactions,
- (b) hydraulic and chemical loadings,
- (c) groundwater and surface water pollution potential.

(4) Irrigation of wastewater should be based on an engineering analysis using standard methods and not on anecdotal information.
(5) A more detailed consideration of Alternative 2 (Fire protection in the potable instead of the non-potable water system) should be made. The effect of improved water conservation on irrigation demand in the non-reuse scenario should be considered.

These points are expanded below.

(1) Existing Wastewater Quality. Table III-4 presents some data on the existing effluent quality. While some changes in the treatment process would be made, no information is presented on the magnitude of existing levels of parameters of concern when irrigating with wastewater such as sodium, potassium, calcium, electrical conductivity. Similarly, no mention is made of the existence of an industrial pretreatment program or of the results of testing for industrial pollutants and heavy metals. This information would be used to predict the type of additional treatment that might be needed, and, in conjunction with additional soils data (see Point 2 below), the suitability of the wastewater for irrigation purposes.

(2) Soil Data. Soils are briefly described on page II-6. None of the detailed soil physical or chemical parameters that are necessary to determine the suitability of a soil/wastewater system are presented.

(3) Soil/Wastewater System Suitability, Loading Rates and Groundwater Pollution Potential. As mentioned above, there are

no data presented to base a determination of the soil/wastewater system suitability for irrigation and there appears to be no discussion of this in the feasibility study. Similarly, loading rates of nutrients and chemicals are not calculated and the ground and surface water pollution potential is not addressed. The procedures for doing these calculations are quite standard and are readily available in the agricultural, irrigation, and environmental engineering literature. If these areas are not considered, the potential exists for the failure of the irrigation system due to wastewater induced soil property changes; overloading the ability of the soil system to absorb/treat nutrients, heavy metals and other chemicals; and the pollution of the groundwater which is to be used for drinking water purposes until the year 2030. It should be emphasized that I am not saying that such problems will occur, but only that standard methods for determining the possibility of occurrence should be followed.

(4) Water Conservation and Irrigation Scheduling. The consideration of irrigation procedures relies to heavily on anecdotal information. Page IV-17 refers in general to "an analysis of needs in similar areas by commercial irrigators." Limited information is presented as to what this analysis entailed an what the results were. Furthermore, it is possible to conduct an engineering analysis of this problem based on standard irrigation engineering principles. Not to do so in an engineered feasibility study is a disservice to the client and does not lead to sound decision-making.

(5) Development of Alternatives. Section V begins with a brief discussion of three primary alternatives. Only the third alternative is analyzed in detail. A more thorough analysis of the second alternative should be provided because it offers a viable alternative (Potable system: drinking and fire protection; Non-potable: irrigation) vs. the third alternative (Potable: drinking; Non-potable: irrigation and fire protection). Since savings due to pipe downsizing would be possible under both alternatives and there are regulatory problems with downsizing the potable water lines (as pointed out in the feasibility study), the second alternative should be considered in detail as well. Since the study of alternatives is based on the use of a Hardy-Cross based computer program, KYPIPES, it should not be too difficult to do these additional studies.

In a related area, the comparison of the reuse vs. non-reuse option is flawed because water conservation due to improved irrigation scheduling is not considered for the non-reuse option. While as complete control as in the reuse option is probably not possible, some level of conservation should be achievable.