U-C Energy Task Force

ENERGY OPTIMIZATION OF WATER DISTRIBUTION SYSTEMS

City of Detroit
Dennis W. Archer, Mayor

BACKGROUND AND ACKNOWLEDGMENTS

Public Technology, Inc. (PTI), is the non-profit technology organization of the National League of Cities (NLC), the National Association of Counties (NACo), and the International City/County Management Association (ICMA). PTI's mission is to bring technology to local governments. Through collective research and development efforts in its member jurisdictions, PTI creates and advances technology-based products, services, and enterprises for all cities and counties.

Four active task forces, each composed of members of PTI's Urban Consortium (UC)—which represents fifty of the nation's largest and most progressive cities and urban counties—drive PTI's research and commercialization efforts. One of these task forces is the Urban Consortium Energy Task Force (UCETF), which was established a quarter of a century ago to address critical energy needs of urban America.

About The Urban Consortium Energy Task Force

The UCETF is the nation's most extensive cooperative local government program to improve energy management and technology applications in local governments. Its membership is composed of local government officials from America's large urban centers. The four major goals established by UCETF members are to:

1. Act as the premier advocate group for local governments on energy technology;
2. Improve energy efficiency, reduce costs and develop revenue from local energy assets;
3. Address the overlap between energy and environmental policy issues; and
4. Act as the implementation arm for NLC and NACo policies.

Under an annual program sponsored by the U.S. Department of Energy (USDOE), the UCETF provides funding for a number of city and county projects that propose to meet these objectives. Projects selected for each year's program are organized in thematic units, such as Transportation, Sustainable Communities, Buildings, and Technology Transfer, to assure effective management and ongoing peer-to-peer exchanges. The results of these research projects are documented in reports such as this one, and made available for broad dissemination by PTI among other local governments.

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ENERGY OPTIMIZATION OF WATER DISTRIBUTION SYSTEMS

A Technical Report

Energy Task Force
of the Urban Consortium
for Technology Initiatives

CITY OF DETROIT
Dennis W. Archer, Mayor

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CHAPTER 1

OVERVIEW

1.1 Abstract

Energy costs associated with pumping treated water into the distribution system and boosting water pressures where necessary is one of the largest expenditures in the operating budget of a municipality.^{1,2} Due to the size and complexity of Detroit's water transmission system, an energy optimization project has been developed to better manage the flow of water in the distribution system in an attempt to reduce these costs.

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1. Clingenpeel, W.H., "Optimizing Pump Operating Costs," Journal AWWA, 75:10:502 (1983).
 2. Clark, T., "Reducing Power Cost for Pumping Water," Opflow, Vol. 13, No.10.

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The Detroit Water and Sewerage Department (DWSD) water distribution system provides drinking water to four million people in over 119 communities throughout Southeastern Michigan. The city's annual energy cost to operate the pumps at the water treatment plants and booster stations is approximately 20 million dollars.

The entire system is operated at a centralized facility located in downtown Detroit called the Water Systems Control Center (SCC). The existing operating strategy is to maintain system pressures at specified locations between prescribed values. The fact that the system operates on a daily basis without experiencing any major problems can be attributed to the knowledge and experience the DWSD operators possess of how their system operates. Unfortunately, the means by which operators choose to pump water throughout the system is typically accomplished without regard to energy cost.

To reduce energy consumption associated with pumping, a computer program has been developed to analyze different pumping combinations for specified system demands and identify the pump combinations that will use the least amount of energy. It is intended that this program be used by the SCC operators on a daily basis to assist them in selecting cost-effective pumping policies.

A guidebook has been developed to assist other municipalities and water utilities in developing their own energy optimization program. The guidebook discusses the procedure used to produce the computer program described in this report.

The Energy Optimization of Water Distribution System project for the City of Detroit was conducted in two parts,

each having a duration of approximately one year. The first year of the project was spent collecting data and general information on the water distribution system. The second year was spent developing and refining hydraulic models and producing the energy optimization computer program.

1.2 Project Purpose

The purpose of this project is to develop an energy optimization computer program that SCC operators can use to identify energy efficient pump combinations at individual treatment plants and designated booster stations capable of meeting system demands and pressures. It is envisioned that the program will eventually be incorporated into the Supervisory Control and Data Acquisition (SCADA) system which is currently in the process of being upgraded by DWSD. Linking the computer program to the SCADA System will give operators real-time data that will provide a more accurate description of the customer demands occurring at the time the analysis is being performed.

1.3 Report Organization

The following provides a brief description of the remaining chapters in this report:

Chapter 2 - General Background and Description

The reasoning behind the project and a description of how the program can be used to meet the project objectives is presented.

Chapter 3 - Project Description

This chapter describes the DWSD water distribution system and the development and application of the energy optimization program. Comparative results are provided to estimate the potential savings of using the program.

Chapter 4 - Summary

A summary of the results are presented, along with the suggested application of the program.

Appendices

Appendix A contains the help text that can be accessed automatically in the energy optimization computer program. Appendix B is the guidebook that was produced to assist other municipalities in developing their own energy optimization program.

CHAPTER 2

GENERAL BACKGROUND AND DESCRIPTION

2.1 Introduction

Energy costs associated with operating water distribution pumps is one of the largest expenditures for the Detroit Water and Sewerage Department (DWSD). In an effort to reduce this energy cost, a computer program to simulate and evaluate various pumping practices has been developed for the DWSD water distribution system. For a specified water demand, the computer program will evaluate several pumping combinations and select the optimal combination based on the lowest electrical power consumed.

Additionally, a guidebook has been produced to provide the methodology incorporated into the computer program. This book will provide guidance for other municipalities in the development of their own energy optimization program.

2.2 General Background and Description

As owner of one of the largest water supply systems in the nation, DWSD provides drinking water to over 4 million people living in more than 119 communities. Water is treated by a total of five water treatment plants and is delivered to consumers by high lift pumps located at each treatment plant and at 20 additional booster pumping stations. The existing operating strategy is to operate pumps at certain high lift and/or booster pumping stations so that pressures at specified locations are kept between prescribed values. Although the entire DWSD system is operated from one central location - the Systems Control Center (SCC), there are no general operating guidelines. Consequently, specific pumping strategies are based on each operator's experience. Even though the DWSD operators do a good job of operating the complex Detroit water system, the operators do not always know in advance how the pumping strategy selected for one area will affect adjoining areas of the system. Moreover, these strategies appear to have no direct regard for how they influence energy costs, which are approximately \$20 million dollars annually.

The approach being undertaken by DWSD to enhance operations is embodied in a computer program that will provide SCC operators with pumping strategies capable of maintaining pressures at specified locations. Furthermore, for the set of possible pumping schemes, the methodology will compute the relative pumping costs. This would allow system operators to select cost-effective operating strategies.

The energy optimization computer program developed by DWSD is comprised of three elements - a hydraulic simulation model (KYPIPE2³), a pump optimization program (KYPUMP⁴), and an interface program. The KYPIPE2 model communicates interactively with KYPUMP to generate pump groups at each of the pumping facilities capable of meeting or exceeding the operator's specified pressure requirements. The interface program is graphically-driven and provides a user-friendly environment for the operator to input data, execute the simulation, and view the results.

The input data required by the energy optimization program is that information which describes existing and proposed operating conditions. Existing conditions include those pumps currently on line, reservoir or suction well elevations, and pump station discharge pressures. Proposed operating conditions include the pressures that operators wish to meet and are identified in the program as "target pressures." Target pressures represent pressures at selected monitoring sites within the DWSD system and form the basis for selecting energy-efficient pump groups.

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3. Wood, D.J., "Comprehensive Computer Modeling of Pipe Distribution Networks: User's Manual," College of Engineering, Civil Engineering Software Center, University of Kentucky, Lexington (November 1991).
 4. Chase, D.V. & Ormsbee, L.E., "Computer-Generated Pumping Schedules for Satisfying Operational Objectives," Journal AWWA, 85:7:54 (July 1993).

The operator executes the analysis and the optimal pump groups for each station, along with their associated electrical consumptions, are displayed in order of increasing power demand. The operator selects a pump group for each station and a final hydraulic analysis is performed. The results of this analysis are displayed back to the operator in the form of a map showing the pressures at the target locations as well as all other monitoring locations in the system. This map allows the operators to view the results of their pumping strategy prior to actually implementing the changes in the system.

Because this type of project is applicable to other communities, a guidebook has been developed and included with this report. The guidebook discusses the methodology used to produce the energy optimization computer program.

CHAPTER 3

PROJECT DESCRIPTION

3.1 Introduction

The City of Detroit is located in the southeastern part of Michigan and borders Canada to the south and east. The DWSD system provides water to an area which includes more than 119 communities throughout the Detroit metropolitan area. Beyond the greater Detroit metropolitan area, water is delivered to Flint and its surrounding environs. With a service population of approximately four million people, DWSD provides water to almost half of Michigan's population. The current demand averages around 640 million gallons per day (mgd) and has peaked above 1.3 billion gallons per day (bgd) in the summertime.

3.2 Data Collection

In order to analyze pump operating scenarios for the system with the computer model, information on existing pumping equipment and the distribution system was collected. The information includes the following:

- Component description and design criteria for line booster stations, booster stations with reservoirs, and high lift pumps at the water treatment plants.
- Daily pump and pressure logs from SCC.
- Daily high lift pump logs from each water treatment plant.
- Annual reports from fiscal year 1987/1988 to fiscal year 1991/1992.
- A 1985 calibrated KYPIPE computer model of DWSD's water distribution system which included input data representing the maximum hour and average day demands on the system for that year. The flow demands were later revised using 1990 demands, which came from the most recent model of the system.

The information collected was used to develop and test the energy optimization computer program.

3.3 System Inventory

3.3.1 General. The distribution system consists of approximately 730 miles of transmission mains (24" and larger), 20 booster stations, and five water treatment plants. The water treatment plant capacities and their maximum day demands for fiscal year 1991/1992 are as follows:

<u>Water Treatment Plants</u>	<u>Plant Capacity (mgd)</u>	<u>Maximum Day Demand (mgd)</u>
Works Park	320	190
Springwells	540	388
Northeast	300	281
Southwest	240	125
Lake Huron	240	214

Four of these plants, Water Works Park, Springwells, Northeast, and Southwest are located strategically within the metropolitan area of Detroit. The Lake Huron Plant is located near Lake Huron, 50 miles north of Detroit, some five miles north of the city of Port Huron.

There is a total of approximately 363 million gallons (mg) of ground storage throughout the system. Except for a .25 mg elevated tank at Farmington, there is no elevated storage within the DWSD system. The communities served along with the water treatment plants, booster stations, and selected transmission mains are shown in Figure 3-1.

Due to the size and topography of the system, the distribution system is divided into three pressure districts. Each plant is equipped with high lift pumps which supply water to these pressure districts, at the following average pressures:

- Low pressure: 45 to 60 psi
- Intermediate pressure: 65 to 85 psi
- High pressure: 40 to 180 psi

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The different pressure districts are interconnected to facilitate the continuity of service and to meet the flow and pressure demands occurring during peak load periods or emergencies. Figure 3-2 represents an approximate delineation of the three pressure districts.

The 20 booster stations are strategically located throughout the system to maintain adequate water pressures for remote area customers or those at higher elevations. Five of the stations are line-booster stations, two stations have only reservoirs, and the rest are booster stations with reservoirs, as follows:

1. Line booster stations:

Adams Road
Newburgh
Orion
Roseville
Ypsilanti

2. Booster Stations with only reservoirs:

Eastside (Canyon)
Northwest

3. Booster stations with reservoirs:

Electric Avenue
Farmington
Ford Road
Franklin
Imlay
Joy Road
Michigan Avenue
North Service Center
St. Clair Shores

Figure 3-2

Schoolcraft
West Chicago
West Service Center
Wick Road

Booster stations with reservoirs are equipped with line pumps and reservoir pumps. The line pumps are used to maintain pressures at remote areas and higher elevations in the system, while the reservoir pumps are used to supply additional water from the reservoirs when required.

3.3.2 Pressure Districts. The low pressure district includes the downtown central business area and the lower east area of the City of Detroit. This service area is completely separated from other pressure districts by closed valves.

The low pressure district is supplied by the high lift pumps at Water Works Park, which are designed to serve the intermediate pressure district. Water Works Park is equipped with two pressure reducers capable of reducing the normal high lift output of 70-80 psi down to 50-60 psi which is then available for the low pressure district. If necessary, the low pressure district can be supplied from Springwells which normally serves the intermediate and high pressure districts.

Back-up from Springwells for the low pressure district is provided through cone valves at three locations in the distribution system connecting the intermediate and low pressure districts. The three locations are Chene and Maple, Porter and Sixth, and Park and Elizabeth. The cone valves are automatically opened

at approximately 40 psi in the event that pressure supplied from Water Works Park drops below the normal operating pressure.

The intermediate pressure district generally includes southwest Detroit (excluding the downtown area) and the downriver suburban areas. This pressure district is served by three plants at the following pressures:

- Water Works Park: 70 psi to 80 psi
- Springwells Plant: 65 psi to 75 psi
- Southwest Plant: 70 psi to 85 psi

The high pressure district covers the largest land area and includes the northern portion of the City of Detroit, and the north and northwest suburbs. In addition, water is delivered as far north as Pontiac and Flint. This pressure district is supplied by three plants at the following pressures:

- Springwells Plant: 75 psi to 85 psi
- Northeast Plant: 70 psi to 85 psi
- Lake Huron Plant: 160 psi to 180 psi

The Lake Huron plant supplies treated water through a 120 inch transmission main, approximately 25 miles west to the Imlay booster station. The Imlay booster station is currently not in service because, since the water demand for higher flow rates have not yet developed in this area, the pressure does not need to be boosted.⁵

⁵ Energy Task Force of the Urban Consortium for Technology Initiatives, "Hydraulic Waste Energy Recovery, A Technical Report," December 1990, p. 8 - 13.

3.4 Energy Optimization Computer Program

3.4.1 Program Description. The approach developed to manage the energy consumption of the Detroit water supply system represents a unique and innovative blend of well-established procedures for modeling water distribution systems and newly developed algorithms for optimizing pumping operations. The vehicle which fuses the modeling and optimization algorithms is a user-friendly interface program which will be used by SCC operators to reduce pumping expenditures and possibly improve overall operations. The following paragraphs describe the methodology incorporated into the interface program.

The existing means by which the DWSD water system is operated is quite simple. There are over 60 pressure monitoring locations transmitting data back to SCC. When system operators notice that pressures fall or rise to unacceptable values, pumps are placed on line or shut off. There is no systematic operation of specific pumps; pressures are simply increased or decreased at monitoring points to acceptable values.

In the proposed energy optimization approach (shown schematically in Figure 3-3), a mathematical model of the DWSD system is used to find the pressure and discharge required from a pump station so that the pressure at a monitoring point is increased or decreased to an acceptable user-defined value. There are no pumps in the model used to accomplish this task. Instead all pump

Figure 3-3

stations are modeled as Fixed Grade Nodes (FGN's). Herein after this approach is called the "FGN Model". FGNs are locations in the system where both the pressure and elevation are known. Using a monitoring site as a constrained node (nodes are locations where two or more pipes meet), the parameter calculation feature of KYPIPE2 is used to find the pump station characteristics which will satisfy the pressure constraint. These monitoring points are identified in the interface as "target pressures."

For example, suppose that the pressure at a monitoring site falls to an unacceptable value and the operator wishes to increase the pressure at the site up to 80 psi. The operator will input the value of 80 psi as the target pressure into the interface program. The interface program will then convert the pressure to a pressure head and add the elevation at the monitoring point so that a total hydraulic grade line (HGL) at the monitoring location can be found. The HGL represents the energy inside the pipe in feet of water. At this point the interface program will create a KYPIPE2 data file complete with the value of the desired HGL at the monitoring site. In addition, an appropriate assignment of FGN with the constrained node is made in the KYPIPE2 data file. KYPIPE2 will use the HGL setting together with the FGN Model to determine the necessary FGN setting at the pump station associated with the monitoring site.

By virtue of running the KYPIPE2 simulation, the pressure at and discharge from the FGN representing the pump station is found. A new mathematical model, called the "Local Model," will now be used in conjunction with

the KYPUMP program to determine the least expensive means of delivering the pump station discharge found from the KYPIPE2 simulation. Because the time required to complete a KYPUMP simulation is dependent upon the number of pipes in the mathematical model of the system, the new model representing a much smaller prototype of the system is used. This smaller model is nothing more than a number of pipes with pumps in them all pumping to a common discharge node. The demand at this node is equal to the previously found discharge from the FGN Model required to meet the pressure at the monitoring site.

The objective of the KYPUMP simulation is to determine the most cost-effective group of pumps which will deliver the discharge at or above the FGN head found from the simulation. Because there are no elevated storage tanks within the Detroit system the pumps collectively will deliver the amount of flow equal to the demand. Consequently, the economic analysis reduces to one of finding the least expensive pump group which will meet the pressure requirement placed at the pump station.

The means by which KYPUMP performs the optimization is outlined below. For a particular pumping facility, a set of pump groups is defined from the total number of pumps located at the facility. It is possible that a very large number of pump groups can be produced. In such cases, it is best to exploit the presence of multiple identical pumps to reduce the number of groups. This has been done for the DWSD system. Once all pump groups are identified, KYPUMP will call the KYPIPE hydraulic simulation routine for each individual pump group telling the routine to operate only those pumps

contained in the group. All other pumps are assumed to be not running. Using the Local Model, KYPIPE will compute the hydraulic response of the system so that pump characteristics (pump pressure and discharge) can be determined. KYPIPE will pass this information back to KYPUMP where pumping costs are computed and pressure constraint feasibility is checked.

After KYPUMP has completed its computation and checked pressure constraints, a set of results is generated in tabular form which relates the cost of pumping and the pump station pressure for each pump group. The interface program will read the results and display the feasible ones (those that meet the pressure requirement) so that the pump station operator may select from a particular pump group and put it into service. However, before placing the pump group into action, a KYPIPE data file will be generated by the interface program to describe the DWSD system. Unlike the FGN Model, this model ("Pump Model") will include all pumps selected by the operator at the various pumping stations. A final simulation is then conducted to determine the hydraulic impact of placing the proposed pump groups into service. The results of the pump model analysis are displayed by the interface program on a system map. The system map not only displays the pressures at the target locations, but at the other pressure monitoring stations as well.

3.4.2 Electrical Power Analysis. The local utility rate structure was obtained in order to identify other cost savings besides those realized from lower energy consumption. In reviewing the rate structure, two possible charges were identified. One of these charges

is related to a discount offered by the utility for power used during off-peak periods (7:00 p.m. to 11:00 a.m.). However, technically speaking, DWSD does not have elevated storage and must use pumps to meet system demands as they occur. Since these demands vary throughout the entire day, pumps cannot be limited during peak periods (11:00 a.m. to 7:00 p.m.).

The other charge identified was the maximum demand.

The maximum demand charge is associated with the highest power consumption at a station for any 30-minute period occurring within the current month or the previous eleven months. This demand is applicable to all the treatment plants and North Service Center. The rate structure for Eastside, Electric Avenue and Northwest do not have a maximum demand charge, but are charged at a flat rate for the power consumed. Each month the local utility compares the maximum 30-minute demand to the contract capacity (the amount of electricity the utility must contractually make available to each station). If the 30-minute demand period is greater than 50 percent of the contract capacity, the 30-minute demand becomes the maximum demand charge, otherwise 50 percent of the contract capacity is the maximum demand charge.

The maximum demand was incorporated by comparing the power consumed by each feasible pump group to the contract capacity and the current maximum demand for the station. Any pump group whose estimated power consumption would set a new maximum demand is identified to the operator and a warning is displayed if the operator tries to select it.

Since the maximum demand is based on the total power used at a station, an estimate of the percentage of power consumed by only the high-lift pumps was calculated from existing power bills. The percentage of electrical power consumed by the pumps is based on a yearly average and varies between 70 and 95 percent.

By incorporating this option into the program, further cost savings could be achieved by lowering the maximum demand charges for the stations.

3.4.3 Program Limitations. Although the energy optimization program uses a complex procedure to identify cost-effective pumping combinations, the entire analysis is based on one steady-state input file that represents average day demand(i.e. the water demands do not vary with time or space). Because the DWSD system contains effectively no elevated storage tanks and since operators must identify pumps which are currently operating, a total system flow rate can be calculated from pump curves based on the existing head conditions at each station. This enables a system demand factor to be computed. Using the Global Demand Factor (GDF) feature of KYPIPE2, the average day demands are adjusted so that the system demand used in the analysis reflects the actual demand placed on the DWSD system at any given time.

Due to the concern that the steady-state globally adjusted input file, that uses pump curves rather than SCADA data to estimate flow, may not exactly match the current demands, a study is being performed to see how sensitive DWSD's water system is to the spatial distribution of demands. Thus far, the preliminary findings look promising; the distribution system is

apparently not very sensitive to varying spatial demand patterns. In the future this concern can be addressed in one of two ways. One option is to have multiple input demand files. Each file could represent a different loading pattern. For example, there could be separate files to simulate summer and winter demands, or week day versus weekend demands, or even night time conditions when the reservoirs are being filled. Using the interface program, the operators would select the appropriate file prior to running the simulation. The other option would be to link the program directly to DWSD's Supervisory Control and Data Acquisition (SCADA) system. The city is currently upgrading their SCADA system by updating existing controls and adding new monitoring stations. If the energy optimization program is linked to the SCADA system, real-time data could be used to provide a more accurate description of initial conditions.

Another limitation is that the program does not presently cover the entire DWSD system. As shown in Figure 3-4, the extreme western portion of the system has been omitted from the analysis. Instead, the energy optimization program currently focuses on that part of the system which contains the five water treatment plants and their associated high lift service pumps. This boundary was selected because approximately half of the energy used by DWSD is consumed by the high lift pumps at the treatment plants. Hence, it was assumed that initially optimizing the largest energy users would offer the greatest potential for savings.

Because a number of different models are used in this analysis, it is possible that hydraulic information

Figure 3-4

and pump power data generated by combined use of the "FGN Model" and the "Local Model" will not be entirely consistent with the "Pump Model." In other words, the actual pump station pressure head required to change the pressure at a monitoring site may be higher or lower than the value provided by the KYPIPE2 Pump Model simulation. Additionally, the resulting power consumption for a selected pump combination may be higher or lower since the power calculations are also based on the Local Model analysis. This discrepancy exists because pump stations are initially modeled using FGNS as opposed to pump curves and on/off status. The impact of this discrepancy on the KYPUMP simulation is currently under investigation. Moreover, due to the sheer size of the DWSD system, simultaneously considering all possible pump groups from all pump stations would result in an unmanageably large problem. Consequently, the optimal solution from KYPUMP may not represent the "global" optimum solution for the entire system. However, it is expected that the program developed by DWSD will produce tangible monetary benefits. It is hoped that a new phase of the project will be implemented to address the limitations described.

The accuracy of some of the results may also be limited to assumptions made related to the pumps. For some of the facilities (Lake Huron, Southwest, Water Works Park and North Service Center), water-to-wire efficiencies (combined efficiency of the motor and pump) were assumed because the motor efficiencies were unknown. Motor efficiency assumptions were based on generally accepted values relating to the sizes and types of motors. Lake Huron also seems highly sensitive to the pressure regulating values at North Service Center. As

a result, the model tends to under predict the pressure at Lake Huron. Furthermore, two of the pumps at Northeast have variable speed drives. Since KYPUMP can only analyze constant speed pumps, each of the two pumps were modeled for the high and low speed as separate pumps. Care has been taken in developing the combinations at Northeast so that both speeds of the same pump cannot be selected in a pump group. Finally, typical suction well elevations and average reservoir depths were assumed for the Pump Model. Because the pumps are high-head pumps, the difference between the actual depth and assumed depth in the reservoirs or suction wells is considered negligible.

3.5 Operating the Energy Optimization Program

This program was developed for the Microsoft Windows operating system and is graphically-driven to provide a user-friendly environment to input data and view the results. On-line help screens are also available to assist the operators. The help screen text is included in Appendix A as reference for the reader.

Since the program does not use data provided by the SCADA system, operators will be required to manually select the recommended pump groups. This is done by design, because at no time does DWSD want their system to be operated automatically. A brief description of selected screens from the program are provided to illustrate its use.

Detroit Treated Water Transmission System - Figure 3-5.
The map screen shows the limits of the DWSD system represented in the program. Major transmission mains are shown to illustrate the general connectivity between the

Figure 3-5

stations. The operator uses this screen to select each station for which input data is required. This is accomplished by simply using the pointing device (mouse to click on the station icons. Other required input such as valve operations and the Flint flow rate (shown as arrow button in top, left-hand corner) are described in more detail in Appendix A.

Electrical Power Data - Figure 3-6. The electrical power data is accessed from the menu bar located at the top of the system map screen. Required input, for applicable stations, includes the contract capacity, the current maximum demand and the billing data associated with the maximum demand. This information should be checked monthly to maintain the correct maximum demand in the program.

Station Screen - Figure 3-7. Once a station is selected, a graphical representation of the pump configuration at that station is displayed. The layout in this figure depicts the Northeast Water Treatment Plant. The operator uses this screen to identify the current status of the pumps (on, off, or red tag), the suction well or reservoir elevation, and the discharge pressure at the station. A pump which has been "red-tagged" indicates that this unit is unavailable for service due to maintenance reasons. This information is necessary so that pump groups which include red-tagged pumps will not be selected as possible solutions for meeting the station requirements.

The pressure gauge shown in the lower right-hand corner is the target pressure. Target pressures represent the locations of actual pressure monitoring

Figure 3-6

Figure 3-7

sites within the DWSD system. As shown in Figure 3-7, the pressure at 8 Mile Road and Gratiot is used to select pumping policies for the Northeast Water Treatment Plant high service pump station. The operator must set this gauge to select the target pressure.

The DWSD system is operated based on pressure. Since the operators have no convenient means of viewing the flow rate in the system, an option was added to allow them to view the estimated flow rate at the stations based on the pumps that are currently running. The operator simply clicks on the "Calculate Est. Flowrate" button and the flow is displayed in a information box in the middle of the screen. The estimated flowrate from each station is used to calculate the GDF for the FGN Model analysis.

After providing the existing and proposed operating conditions for a selected pumping facility, the operator selects the "Done" button. At this point the input map screen is redisplayed so that operating conditions for other pumping stations can be supplied. This process is repeated for each pumping station until the existing and proposed operating conditions for the entire Detroit water system have been identified.

The booster station screens are similar to the one shown in Figure 3-7. However, the operators are also prompted as to whether or not they want to consider the reservoir pumps in the analysis. This was added because the operators may not want to use the reservoirs to meet the demand in a low demand period.

Estimated Flow Rate - Figure 3-8. The optimization analysis is executed from the map screen by selecting "Run Simulation" from the menu bar. Prior to executing the analysis, the interface displays the estimated flow rate from each station and the total system demand. The flow rate summary allows the operator to verify that the initial conditions have been properly set at each station prior to the analysis. The program also uses this information to calculate the GDF total by taking the flow rate shown and dividing it by a constant default value that is equal to the average day system demand.

Results of Preliminary Analysis Screen - Figure 3-9. Once the existing conditions at every station and all target pressures are identified, the operator initiates the analysis. Upon completion of the optimization, the results screen is displayed. For a selected pumping facility, the screen shows a ranking of pump groups capable of meeting or exceeding the target pressure. The predicted pressure shown is for the pump group selected (2*G1 in this example). The ranking is given in order of increasing estimated kilowatt consumption. As an example, Figure 3-9 shows that the most cost-effective means of meeting the specified pressure at 8 Mile Road and Gratiot is to operate one pump from Group 1 (pump 9, 10, 15, 16 or 17) and one pump from Group 3 (pump 14 or 18 at high speed). However, this combination is shown in light gray because the pump combination is not available due to pumps 14 and 18 being red-tagged. The next combination (1*G2 and 1*G2) is available and is approximately the same cost as the first combination. The ability to choose from a list of pump groups offers great flexibility while simultaneously allowing system

Figure 3-8

Results of Preliminary Analysis

Water Treatment Plants

LH

NE

SPWH

SPWI

SW

WWP

Booster Stations

BSS

EAS

NWS

NSC-I

NSC-T

?

Help

Proceed

Northeast WTP

Predicted WTP Pressure =

81 psi

	Pump Combination	kW	Rel. Cost
1	1*G1, 1*G3	3652	100
2	1*G1, 1*G2	3687	100
3	2*G2, 1*G3	3925	102
4	2*G1	4048	1102
5	2*G2, 1*G3	4148	1132
6	3*G2	4199	1142

Current Max Demand

16392 kW

Current Billing Date

10-22-93

Choose

Unchoose

Pump Group	Available Pumps	Red Tagged Pumps
G1	9, 10, 15, 16, 17	
G2	11, 12, 13, 19, 20	
G3	none (High)	14, 18
G4	none (Low)	14, 18

Figure 3-9

operators to select operating strategies from an economic perspective.

Pressure Monitoring Points Screen - Figure 3-10. A final analysis is performed based on the pump combinations selected by the operator. This analysis uses the Pump Model to determine the pressures not only at the target monitoring locations but at all of the other pressure monitoring locations in the system. Since the program is executed off-line, the operators can view the results of their selections prior to actually implementing the changes.

If the operator wants to revise the system pressures, he has two options. The operator can either select different pump groups at the treatment plants and booster stations or the operator can go back to the beginning of the program and set new target pressures. With new pump groups or target pressures selected, the operator would once again analyze the system and view the system pressures.

After the operators have viewed their results, they are given the option to either analyze different pump groups for the same target pressures or run another analysis with different target pressures. After the operator has used the program to obtain acceptable pressures throughout the system, he could then implement the changes using the SCADA system.

3.6 Results and Future Plans

In order to estimate the amount of savings that may be achieved by using the energy optimization program, selected

Figure 3-10

days were identified to represent typical demands experienced by the system. A total of four days were selected, one day for each of the four seasons. Associated pump and pressure monitoring logs were then collected for these days to identify the pump combinations used and the resulting system pressures.

For each day, optimal pump combination results were obtained using the following procedure:

- 1) Turn on the same pumps in the model that were actually used by SCC. The optimization program uses this information to determine the system demand.
- 2) Set target pressures equal to the actual pressures at the same monitoring locations.
- 3) Select a resulting pump combination for each station from the optimization analyses.
- 4) Compare pressures shown on the Pressure Monitoring Points screen to actual pressures at the same locations.
- 5) Repeat steps 3 and 4 until the pressures at the monitoring points are approximately equal to the actual pressures. The resulting pump combinations were then considered to be optimal pump combinations.

The optimal pump groups found were compared to the actual pump combinations using the Pump Model. The results are shown on Tables 3-1 through 3-4 and indicate that a potential savings, based on power consumption, ranges from one to fourteen percent. Since the facilities identified in the model

Location	Recorded Pumps Used	Estimated KW	Recorded Pressure	Optimal Pump Combination	Estimated KW	Predicted Pressure
Eastside Station	1	264	62	No pumps req'd	0	65
Electric Avenue Station	3	142	69	No pumps req'd	0	66
Lake Huron WTP . . .	5, 6	7, 248	180	5, 6	7, 500	172
North Service Center (Line)	4L, 5L	1, 484	131	4L	956	123
North Service Center (Res.)	R1, R4	491	45	No pumps req'd	0	44
Northeast WTP	15, 20	3, 649	74	13, 14H	3, 025	74
Northwest Booster Station	2	280	45	No pumps req'd	0	49
Southwest WTP	1	1, 838	66	3, 4	2, 138	69
Springwells WTP (High)	23	1, 838	76	11, 23	3, 318	80
Springwells WTP (Int.)	18	1, 287	57	18	1, 304	60
Water Works Park WTP	7, 12	2, 683	74	9, 12	2, 688	73

Total Power - Actual = 21,204 KW
Total Power - Predicted = 20,929 KW
Estimated Savings = 1.3%

DWSD Water Distribution System
Pump Optimization Results
for January 5th

Location	Recorded Pumps Used	Estimated KW	Recorded Pressure	Optimal Pump Combination	Estimated KW	Predicted Pressure
Eastside Station	None	0	63	No pumps req'd	0	65
Electric Avenue Station	None	0	57	No pumps req'd	0	66
Lake Huron WTP	3, 6	7,202	174	3, 6	7,420	174
North Service Center (Line)	2L, 5L, 6H	2,293	130	2L, 4L	1,620	123
North Service Center (Res.)	R4	281	40	R1	205	39
Northeast WTP	9, 19, 20	5,191	77	9, 10	4,216	71
Northwest Booster Station	None	0	44	1, 2, 3	873	49
Southwest WTP	6	1,838	69	3, 4	2,421	71
Springwells WTP (High)	24, 26	3,766	83	13, 19	3,878	80
Springwells WTP (Int.)	16, 20	2,642	65	14	1,351	60
Water Works Park WTP	8, 12	2,682	74	5, 6	3,144	74

Total Power - Actual = 25,895 KW
Total Power - Predicted = 25,128 KW
Estimated Savings = 3.0%

DWSD Water Distribution System
Pump Optimization Results
for May 5th

Location	Recorded Pumps Used	Estimated KW	Recorded Pressure	Optimal Pump Combination	Estimated KW	Predicted Pressure
Eastside Station	1	277	64	1	267	67
Electric Avenue Station	4	198	70	No pumps req'd	0	69
Lake Huron WTP	3, 4, 5, 6	13, 876	192	3, 4, 5	10, 707	186
North Service Center (Line)	3H, 4H, 6H	4, 144	135	2L, 4L	1, 816	128
North Service Center (Res.)	None	0	50	R1, R2	394	49
Northeast WTP	12, 15, 19, 20	6, 500	84	9, 11, 12, 13	6, 508	80
Northwest Booster Station	None	0	39	1	279	42
Southwest WTP	1, 4, 5	3, 836	75	1, 3	3, 153	76
Springwells WTP (High)	13, 24, 26	5, 844	83	11, 13	5, 239	78
Springwells WTP (Int.)	16, 18, 22	3, 744	69	12, 16, 18	3, 750	69
Water Works Park WTP	3, 7	3, 838	74	5, 6, 9	4, 245	77

Total Power - Actual = 42,257 KW
 Total Power - Predicted = 36,358 KW
 Estimated Savings = 14%

DWSD Water Distribution System
 Pump Optimization Results
 for July 24th

Location	Recorded Pumps Used	Estimated KW	Recorded Pressure	Optimal Pump Combination	Estimated KW	Predicted Pressure
Eastside Station	None	0	69	No pumps req'd	0	63
Electric Avenue Station	None	0	70	R1	194	63
Lake Huron WTP	3, 4, 7	10, 875	183	3, 4	8, 100	171
North Service Center (Line)	5H, 6H	2, 796	135	2L, 4L	1, 510	137
North Service Center (Res.)	None	0	52	R1, R3, R4	788	51
Northeast WTP	11, 12	3, 074	73	9, 11	3, 573	77
Northwest Booster Station	None	0	45	No pumps req'd	0	45
Southwest WTP	6	1, 839	73	3, 4	2, 435	69
Springwells WTP (High)	15, 24	3, 310	80	11, 13	3, 315	79
Springwells WTP (Int.)	14, 22	2, 651	60	14	1, 340	58
Water Works Park WTP	6, 12	2, 686	76	5, 6	3, 146	72

Total Power - Actual = 27,231 KW
Total Power - Predicted = 24,401 KW
Estimated Savings = 10.4%

DWSD Water Distribution System
Pump Optimization Results
for September 25th

use over 250 million kilowatt-hours (KW-hr) per year at an average cost of approximately 7¢/KW-hr, the estimated savings is equivalent to between \$225,000 and \$2,500,000 annually.

The future plans for the project are to install the energy optimization program at SCC for the operator's use. Actually operating the system with the program will allow DWSD to realize the projected savings. DWSD also plans to incorporate the optimization program into the SCADA system, once it has been upgraded. Finally, it is hoped that in the future an additional phase of the project will be initiated to address the current limitations of the program.

3.7 Potential Benefits of Using the Energy Optimization Program

An operator's knowledge and experience of the system is a very powerful asset, but in the absence of a set of rules or guidelines, each operator tends to run the system based on their preferred approach. Whether or not one individual's approach is more cost-effective than that of another is not known since impacts of the alternative were not previously available. Using the program will help answer this question; now the operators have a tool to operate the system based on pressures and cost.

The ability of the program to display the results of an analysis also makes it a useful training tool. The program could be used to test new operators on how they would operate the system given a set of monitoring pressures. Their selections could then be compared to the program simulation results. By modifying the input demand file, the program could also be used to look at emergency situations. For example, three treatment plants (Water Works Park, Northeast,

and Springwells) receive their raw water from one common intake located in the Detroit River. One simulation could be to analyze a condition when the intake is damaged or otherwise out-of-service. Once again, the knowledge gained by new operators analyzing these types of varying and extreme simulations can only help them become more familiar with such a large and complex system.

3.8 Guidebook

A guidebook has been developed for this project and is included in Appendix B. The guidebook provides direction for other municipalities to follow in developing an optimization computer program for their own water distribution system. The guidebook covers data collection, hydraulic model development and calibration, and the logic used in the interface program for DWSD's water distribution system.

CHAPTER 4

SUMMARY

4.1 Lessons Learned

The results show that using an energy optimization program to operate a water distribution system can provide cost savings for a municipality. However, the greatest challenge to realizing the savings is getting the operators to actually use the program. In developing the computer program, DWSD operators were initially reluctant to use the program. It was not certain whether they were concerned about computers replacing humans or that they believed a computer could not accurately manage a system that continuously changes.

What the City of Detroit found to be extremely helpful was getting operators involved early on in the project. This was done by working with one of the SCC supervisors. Soliciting his opinions and concerns assisted Detroit in providing a computer program that is more customized to the operator's needs than what was originally intended. Additionally, working with the supervisor helped him to understand how the program functioned and that it would not

replace operators, but provide them with a tool to perform their job more efficiently.

4.2 Conclusion

A general-purpose computer program has been developed by the Detroit Water and Sewerage Department to assist water supply system operators in selecting cost-effective pumping policies. The methodology marries the widely-used KYPIPE hydraulic simulation routine and the KYPUMP pump optimization algorithm within a user-friendly graphically-driven interface program. Once existing operating conditions have been established, system operators can use the energy optimization program to select cost-effective pumping strategies capable of meeting specified pressure requirements at designated locations.

Very few water utilities have investigated computerized pumping operations. Fortunately, the program represents a significant advancement in this area. The energy optimization program will equip water supply system operators with a powerful tool which will help to improve overall system operations at a reduced cost. Given that DWSD operating costs are approximately \$20M per year, the potential savings are likely to be well-received. When combined with a SCADA system, the whole may be greater than the sum of its parts since real-time data can then be used within a real-time operating environment.

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Energy Optimization
Computer Program
Help Text

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1.0 DETROIT TREATED WATER TRANSMISSION SYSTEM SCREEN

1.1 Description

The System Map Screen shows the limits of the DWSD system represented in the program in the upper left hand portion of the screen. The remainder of the screen displays the portion of the system in the program for the Detroit metropolitan area, including four of the five water plants. Skeletonized transmission mains are shown to illustrate the general connectivity between the stations.

1.2 Required Input

1.2.1 Water Treatment Plant & Booster Station Selection.

The existing conditions must be identified for all five water treatment plants and the booster stations to determine the existing system demand. The existing conditions can be identified for a water treatment plant (WTP) or booster station (BST) by clicking on the desired location's icon. The high-lift and reservoir pump status must be identified for the current system demand to be determined. BST line pump status is not required since they do not add to the system flow. Once a station has been updated, the station's icon will change color from light to dark blue.

1.2.2 State Fair Valve Status. The status of the valve can be toggled between open and closed by clicking on the State Fair Valve button. The status will be maintained in the optimization of the system.

1.2.3 Eight Mile & Kelly RV Setting. The pressure can be set by clicking on the valve icon located directly east of Northeast WTP. The RV setting can be changed by either clicking on the up or down arrows or by highlighting the current value using the mouse and then entering the desired value. The RV setting will be maintained in the optimization analysis of the system.

1.2.4 Current Flint Flow. The current Flint flow can be set by clicking on the arrow button located in the upper left-hand corner of the system map screen. The current Flint flow can be set by either clicking on the up or down arrows or by highlighting the current value using the mouse and then entering the desired value.

1.3 Menu Bar

1.3.1 Quit. Exits the program.

1.3.2 Run Simulation. Runs the simulation using the conditions set by the operator for the system. After the operator has chosen to run the simulation, a table showing the estimated flows from the WTP's and BST's will appear. The values of the flows are shaded or dashed to indicate the following:

BLACK - the operator wants the station considered in the optimization.

GREY - the operator does not want the station considered in the optimization.

DASHED - the initial conditions of the station have not been set.

1.3.3 Power. Allows the operator to view and edit the electrical power data for stations that have a maximum demand charge included in their rate structure.

1.3.4 Help Topic. A list of help topics related to the System Map Screen is produced to aid the operator.

2.0 ELECTRICAL POWER DATA SCREEN

2.1 Purpose

The purpose of the Power Screen is to view and edit the electrical power data for stations that have a maximum demand charge included in their rate structure. Northwest Station, Eastside Station, and Electric Avenue Station are not shown because their rate structures do not include a maximum demand charge. The electrical power data is used to determine if an available pump combination identified by the optimization analysis will set a new maximum demand charge.

2.2 Station Icon

The electrical power data for a station can be viewed by clicking on the desired station's icon. The electrical power data includes the contract capacity, the current maximum demand, and the billing date from which the current information has been obtained. The data can be edited by clicking on the desired data field.

2.3 Done

Returns the operator to the system map input screen.

3.0 EASTSIDE BOOSTER STATION SCREEN

3.1 Reservoir Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

3.2 Reservoir Elevation

The default reservoir elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

3.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the reservoir elevation. The default value shown is based on the pressure required for an average day system demand.

3.4 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

3.5 Done

Returns to the system map input screen. Upon exiting the Booster Station Screen, the operator has the option whether or not to consider the reservoir pumps at the station in the optimization analysis of the system.

4.0 ELECTRIC AVENUE BOOSTER STATION SCREEN

4.1 Reservoir Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

4.2 Line Pump Status

The status of a line pump (available or red-tagged) may be changed by clicking on the desired pump. A line pump can not be turned on since it does not contribute to the system demand (see Help section for System Map Screen). However, the status of the pump is required to determine the optimal pump groups to meet the target pressures identified.

4.3 Reservoir Elevation

The default reservoir elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

4.4 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

4.5 Target Pressure

The target pressure for the pressure monitoring point shown can be set by using either method described above for modifying the reservoir elevation. The default value shown is based on the pressure required for an average day system demand.

4.6 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

4.7 Done

Returns to the system map input screen. Upon exiting the Booster Station Screen, the operator has the option whether or not to consider the reservoir pumps at the station in the optimization analysis of the system.

5.0 NORTH SERVICE CENTER BOOSTER STATION SCREEN

5.1 Reservoir Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

5.2 Line Pump Status

The status of a line pump (available or red-tagged) may be changed by clicking on the desired pump. A line pump can not be turned on since it does not contribute to the system demand (see Section 1.0). However, the status of the pump is required to determine the optimal pump groups to meet the target pressures identified.

5.3 Reservoir Elevation

The default reservoir elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

5.4 I-Valve Pressure

The current I-valve pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand. This setting is maintained in the optimization of the system.

5.5 Target Pressure

The target pressure for the pressure monitoring point shown can be set by using either method described above for modifying the reservoir elevation. The default value shown is based on the pressure required for an average day system demand.

5.6 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

5.7 Done

Returns to the system map input screen. Upon exiting the Booster Station Screen, the operator has the option whether or not to consider the reservoir pumps at the station in the optimization analysis of the system.

6.0 NORTHWEST BOOSTER STATION SCREEN

6.1 Reservoir Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

6.2 Reservoir Elevation

The default suction well elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

6.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well

elevation. The default value shown is based on the pressure required for an average day system demand.

6.4 Target Pressure

The target pressure can be set by using either method described above for modifying the reservoir elevation. The default value shown is based on the pressure required for an average day system demand.

6.5 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

6.6 Done

Returns to the system map input screen. Upon exiting the Booster Station Screen, the operator has the option whether or not to consider the reservoir pumps at the station in the optimization analysis of the system.

7.0 LAKE HURON, NORTHEAST, AND SOUTHWEST WATER TREATMENT PLANT SCREENS

7.1 High-Lift Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump. Either high or low speeds may also be selected for Pump No. 14 and 18 at Northeast.

7.2 Suction Well Elevation

The default suction well elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

7.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

7.4 Target Pressure

The target pressure for the pressure monitoring site shown can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

7.5 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

7.6 Done

Returns to the system map input screen.

8.0 SPRINGWELLS WATER TREATMENT PLANT HIGH PRESSURE OPERATION SCREEN

8.1 High-Lift Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

8.2 Suction Well Elevation

The default suction well elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

8.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

8.4 Target Pressure

The target pressure for the pressure monitoring site shown can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

8.5 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

8.6 Switch to Intermediate Pressure Operation

Allows the operator to update the current conditions for the Springwells Water Treatment Plant intermediate pressure zone operation.

8.7 Done

Returns to the system map input screen.

9.0 SPRINGWELLS WATER TREATMENT PLANT INTERMEDIATE PRESSURE OPERATION SCREEN

9.1 High-Lift Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged. The option to turn all pumps on or off is also available upon clicking on an individual pump.

9.2 Suction Well Elevation

The default suction well elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

9.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

9.4 Target Pressure

The target pressure for the pressure monitoring site shown can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

9.5 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

9.6 Switch to High Pressure Operation

Allows the operator to update the current conditions for the Springwells Water Treatment Plant high pressure zone operation.

9.7 Done

Returns to the system map input screen.

10.0 WATER WORKS PARK WATER TREATMENT PLANT SCREEN

10.1 High-Lift Pump Status

The status of a pump may be changed by clicking on the desired pump. A pump can be turned on, turned off, or red-tagged.

The option to turn all pumps on or off is also available upon clicking on an individual pump.

10.2 Suction Well Elevation

The default suction well elevation can be modified by two different methods. The value can be increased or decreased by clicking on the up or down arrow, respectively. Also, the value can be highlighted using the mouse and the desired value can then be entered. The default value is based on the typical elevation maintained.

10.3 Current Discharge Pressure

The current discharge pressure can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

10.4 Low Pressure Cone Valve Setting

The pressure setting for this cone valve can be set by using either method described above for modifying the suction well elevation. The cone valve setting will be maintained in the optimization analysis of the system.

10.5 Target Pressure

The target pressure for the pressure monitoring site shown can be set by using either method described above for modifying the suction well elevation. The default value shown is based on the pressure required for an average day system demand.

10.6 Calculate Est. Flowrate

Identifies the estimated flowrate based on the conditions set by the operator.

10.7 Done

Returns to the system map input screen.

11.0 RESULTS OF PRELIMINARY ANALYSIS SCREEN

11.1 Description

The Results of Preliminary Analysis Screen allows the operator to choose pump combinations at the water facilities based on both their predicted pressures and relative costs. The left portion of the screen contains icons for the WTP's and BST's. In order to choose a pump group at each facility, simply click on an icon. Once a facility has been chosen, the optimal pump groups and their associated estimated power consumption and relative cost are displayed for the selected facility.

11.2 WTP/BST Selection

An operator can choose a water facility by clicking on the desired station's icon.

11.3 Pump Group Selection

A pump combination may be highlighted by clicking the mouse on the desired combination. The Choose and Unchoose buttons can be used to select and unselect the highlighted pump combination. If a combination is not available due to red-tagged pumps, the group is shaded grey. If the operator chooses a combination which contains red-tagged pumps, a

warning message will appear to alert the operator. The following information is also provided:

11.3.1 Power Consumption. If the estimated power consumption of a pump combination is greater than the current maximum demand charge, the KW value is highlighted. If the operator chooses such a combination, a warning message will be given to alert the operator.

11.3.2 Station Pressure. The predicted pressure for the highlighted pump group combination appears in the upper right-hand portion of the screen.

11.3.3 Pump Group Listing. A listing of the pumps within each pump group at the facility is located on the bottom right portion of the screen. Available pumps and red-tagged pumps for each group are shown.

11.4 Proceed

Continues the simulation.

12.0 PRESSURE MONITORING POINTS SCREEN

12.1 Description

The Pressure Monitoring Points Screen displays the pressures obtained from a hydraulic analysis of the distribution system using the pump groups selected by the operator. In the upper left-hand portion of the screen is a map of the entire system. The right portion of the screen displays a magnified view of an area within the DWSD water system. The magnified view is represented by a highlighted box and can be changed by clicking the mouse near the desired view. The magnified view shows the pressures at the monitoring locations within that

view. The operator can click on any pressure box and the location and its associated pressure gauge is displayed.

Note that the pressures shown for the WTP's and BST's on the Pressure Monitoring Points Screen may vary from the pressures displayed on the Results of Preliminary Analysis Screen. This is because the Pressure Monitoring Points Screen displays the pressures based on the WTP's and BST's interacting with the network, whereas the pressures shown on the Results of Preliminary Analysis Screen reflect the WTP or BST acting independent of the system. This discrepancy is explained in detail in the Energy Optimization of Water Distribution Systems report, dated February, 1994.

12.2 Print Results

Prints a summary of the predicted pressures at the water facilities and pressure monitoring locations and the pump groups chosen at each water facility. The operator also has the option to print a listing of the pumps contained in each pump group for all facilities.

12.3 Choose Different Pump Combination

Returns the operator to the Results of Preliminary Analysis Screen. This option allows the operator to view the system pressures based on different pump groups for the same system demand.

12.4 Run Another Simulation

Returns the operator to the System Map Screen. This option allows the operator to modify either the pump status at the facilities or the target pressures.

12.5 Quit

Exits the program.

Appendix B
Energy Optimization
of Water
Distribution
Systems Guidebook

**ENERGY OPTIMIZATION
OF
WATER DISTRIBUTION SYSTEM
GUIDEBOOK**

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CHAPTER 1

OVERVIEW

1.1 Abstract

Typically, energy costs associated with municipal water distribution systems are one of the municipality's largest operating expenditures. Optimizing the use of these pumps would save energy and thereby reduce operating costs.

Thus was the impetus behind the Energy Optimization of Water Distribution Systems project. This project has developed a computer program that identifies energy efficient pump combinations for the Detroit Water and Sewerage Department (DWSD) water distribution system. The guidebook is based on the experience gained from this project.

1.2 Guidebook Purpose

The purpose of the guidebook is to provide direction for other municipalities in developing an energy optimization computer program for their own water distribution system. The

procedure described in the guidebook is based on the experience gained by Detroit in producing our energy optimization computer program.

1.3 Guidebook Organization

The following provides a brief description of the remaining chapters in the guidebook:

Chapter 2 - Data Collection

This chapter describes the data needed for an energy optimization computer program. Data sheets are provided to assist the user of the guidebook in collecting the necessary information.

Chapter 3 - Energy Optimization Computer Program

Three basic components were used to develop the computer program for the City of Detroit - hydraulic models, a pump optimization program, and an interface program. The chapter describes how each component is developed and how they all work together. Computer hardware and software requirements are also identified.

CHAPTER 2

DATA COLLECTION

2.1 Introduction

The energy optimization computer program, used to reduce energy costs at pumping facilities, interfaces with hydraulic computer models of the water distribution system. Since hydraulic computer models simulate the flows and pressures in a water distribution system due to customer demands and pump and tank operations, the data collection phase consist of the information required as input for the hydraulic models. Sources of information for this phase of the project are typically the municipality and the local utility company.

The energy optimization project for the City of Detroit was fortunate in that DWSD already had a hydraulic model of their system. Although some work was involved in calibrating the model, starting with an existing hydraulic model substantially reduced the data collection effort. However, since other municipalities may not be as fortunate, this

chapter describes the information needed if a hydraulic model is not available.

2.2 Water Distribution Pipe Network

The initial step in preparing the input data for the computer model is to develop a plan for describing specific information on the pipe network and pumping and storage facilities. The methods suggested are described below and should be used as a preliminary attempt to collect and tabulate necessary information. These methods should be modified as required to include other information that may be specific to the system being modeled.

In order to compile the pipe data, a map depicting the water distribution system should be used. This map can usually be acquired from the municipality and typically indicates the size, location, and length of pipes, as well as size and location of valves and meters. Information on the pipe's age and material and valve settings can be obtained from operation and maintenance logs and as-built drawings. Pipe age and material information is used to estimate the pipe friction coefficients.

Once the information described above is compiled, a coordinate system should be established. Nodal points (locations where one or more pipes meet) would then be identified and coordinates assigned to each node.

There are a number of components in a system, such as valves, bends, junctions, etc., that would be classified as minor losses, but should be accounted for since they may produce significant head losses. Although it is necessary to account for this information in the data collection phase, the need for actually including these minor losses in the model

should depend on the degree of accuracy the person developing the model wishes to obtain.

Consideration should be made to simplify the model to the extent that the solution will not significantly be affected. Reducing the size of the computer file, especially for large systems, will reduce the analysis time and staff hours required to obtain and input the information. Typically, this is accomplished by reducing the number of pipes in the model and is referred to as "skeletonizing" the system. Commonly this is accomplished by only considering pipes above a certain minimum size. Network skeletonizing may be difficult in certain cases and the user is referred to AWWA Manual M32, "Distribution Network Analysis for Water Utilities," for additional information.

2.3 Water Storage and Pumping Facilities

Energy optimization programs are usually based on two types of scenarios. For a specified time interval, the user wants to determine the most cost effective pump combinations that would be required to either produce desired water elevations in the storage tanks or to meet a required system demand. In order to collect information required to analyze these scenarios, two data summary forms were developed and are shown in Figures 2-1 and 2-2.

Figure 2-1 provides a space for the dimensions of the tanks or reservoirs and their operating ranges. This information should be collected if the energy optimization project is trying to determine cost effective pumping combinations to produce desired water elevations in the storage tanks.

WATER STORAGE FACILITY
DATA SUMMARY FORM

I. GENERAL

STATION: _____

LOCATION: _____

GROUND ELEV: _____

II. TANKS/RESERVOIR

OVERFLOW OPERATING					
NO.	CAPACITY	CROSS SECTIONAL	HEIGHT	ELEVATION	RANGE
_____	(mg)	AREA (sf)	(ft)	(ft)	(ft)
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____

RECORDED BY: _____

DATE: _____

FIGURE 2-1

PUMP DATA SUMMARY SHEET

I. GENERAL

STATION: _____

LOCATION: _____

GROUND ELEV: _____

TYPE: _____ RESERVOIR
 _____ IN-LINE BOOSTER
 _____ HIGH LIFT

If reservoir pump, indicate reservoir number. _____

II. PUMP

Pump No. _____

Mfg. _____

Rated Head _____

Rated Flow _____

Imp. Size _____

Speed _____

Is pump curved attached? _____

III. MOTOR

Mfg. _____

Type _____

Horsepower _____

Voltage _____

Speed _____

RECORDED BY: _____

DATE: _____

FIGURE 2-2

Pump curve data for each pump is essential for developing an energy optimization model. Selected points from the pump curves are entered into the model to describe the head-flow characteristics of each pump. The pump curves also provide pump efficiency and brake horsepower data which is required to calculate the overall or "wire-to-water" efficiency. The wire-to-water efficiency is used to calculate the energy cost for each pump. This information would be recorded on the form shown in Figure 2-2.

2.4 Demand Allocation

Demand allocation is the process of assigning water demands in the system to nodes in the distribution model. Meter records from the municipalities can be obtained to determine water demands as well as various flow meters located in the system. The process requires a good working knowledge of the system water usage. Additional information is provided in AWWA Manual M32.

Unaccounted-for water is also a water demand and is present in all systems. Although unaccounted for water results from many factors, typical ones are pipe leaks, main breaks, unauthorized use, unmetered services, and non-functioning meters. One way to estimate the amount of unaccounted-for water is to calculate the difference between flow out of the system (customer demands) and flow into the system (treatment plants, booster stations, reservoirs and tanks). The total amount of unaccounted-for water is then generally distributed equally to all of the nodes in the model since it is usually difficult to identify specific locations.

2.5 Energy Charges

The final piece of information needed to develop an energy optimization project is the energy cost associated with the operation of each pump. The electrical rates charged by the utility company can usually be separated into two categories, (1) electrical usage charges and (2) demand charges. Electrical usage charges are direct charges for the volume of electricity consumed. Demand charges are based on the maximum amount of power consumed in a short time during the billing period, typically 30 minutes.

The electrical power rate structure can be obtained from the local utility company as well as from billing statements for individual pumping stations. This information is used to estimate the cost of each pump combination.

The City of Detroit obtained the rate structure from the local utility (Detroit Edison) and identified charges that could be reduced and therefore included in the optimization program. Unfortunately, only the demand charges for the water treatment plants and selected booster stations could be incorporated into the program. Detroit Edison does provide discounts to its customers for use of power during off-peak periods. However, DWSD effectively has no elevated storage and therefore must use pumps to meet the system demands. Since these demands vary throughout the entire day, the pumps cannot be limited to off-peak periods.

CHAPTER 3

ENERGY OPTIMIZATION COMPUTER PROGRAM

3.1 Introduction

Chapter Two described the data necessary for creating a hydraulic model. This chapter will discuss how the energy optimization program was developed for the DWSD system and how similar steps could be followed by other municipalities to create their own program.

The energy optimization program for the DWSD system is composed of three basic components - hydraulic models of the water distribution system, a pump optimization program, and an interface program. This chapter will describe how each component was developed and how all of the components work together to form the energy optimization program.

3.2 Water Distribution System Models

In most cases, a municipality will have a hydraulic computer model of their water distribution system. However, if a municipality is starting from scratch, the data collected in Chapter Two must first be inputted into a program in accordance with the program's users manual. Regardless of whether the municipality starts from scratch or with an existing model, the model needs to be tested to ensure that the results provide an accurate representation of the existing system.

It should be noted that there are actually three kinds of hydraulic models used in the energy optimization program - the Fixed Grade Node (FGN) Model, the Pump Model, and the Local Models. Since the guidebook is an appendix to the Energy Optimization of Water Distribution Systems report, it is not intended to repeat the methodology behind the use of these models. Instead, the reader is referred to Chapter Three of the report.

3.2.1 Calibration. Calibrating a hydraulic model is the procedure used to compare the model predictions of the distribution system to recorded observed and measured system conditions. In order to do this, operational information is required to describe pressures throughout the system as well as flows entering and leaving the system. There are several locations within a distribution system that can be utilized to collect pressure data. Examples of these location include pressure monitoring stations, pump stations, tanks or reservoirs, and fire stations. Locations for flow data include flow meters at individual and large-demand customers, water treatment plants, reservoirs, and tanks.

Fire hydrants are also good locations for measuring both pressures and flows.

Calibration of a hydraulic model is more of an art than a science. Multiple adjustments of nodal demands in the model or pipe-friction factors may be necessary to adjust the model so that its results match the operational data within an accepted level of confidence over a wide range of operating conditions. Once again, the reader is referred to AWWA Manual M32, for additional information on model calibration.

In calibrating the DWSD model, pressure data from over 60 pressure monitoring stations located throughout the distribution system and flow data from the treatment plants, reservoirs, and booster stations were used. Initially, flow data from the booster and reservoir stations were not available. However, since DWSD records the pump operations (when each pump is on or off), pump curves were used to estimate the flows out of the stations. The stations were then calibrated by performing flow testing at the individual stations. If flow testing is required by the municipality, the user is referred to the Hydraulic Institute, "Hydraulic Institute Standards for Centrifugal, Rotary, and Reciprocating Pumps," for additional information.

The pump curves of the plants were then calibrated based on data from pumping logs. These logs represent each treatment plant's high lift pumping flows and discharge pressures.

After the pump curves were calibrated, five days of system data were used, covering all four seasons, to calibrate all three groups of models (FGN, Pump, and

Local). The system was determined to be calibrated when the predicted pressures at the monitoring locations were within ten percent of the recorded data.

3.2.2 Hydraulic Model Software. The energy optimization program is based on identifying energy efficient pump combinations that meet the system demand and pressure requirements. This means that, for a given demand, a hydraulic analysis for each possible pump combination must be conducted in order to obtain pump characteristics and operating costs.

The optimal pump combinations that meet the system requirements are then ranked in order of energy efficiency. Therefore, either the hydraulic model software must be able to analyze multiple pump combinations for a single system demand or the software must be able to interface with another software package that can perform the pump optimization.

The City of Detroit's project uses two software programs, KYPIPE2 and KYPUMP. KYPIPE2 is a hydraulic computer program for water distribution systems developed by Dr. Donald J. Wood, Department of Civil Engineering, at the University of Kentucky. KYPUMP is a pump optimization program that interfaces with KYPIPE2 and was developed by Dr. Donald V. Chase, Department of Civil and Environmental Engineering, at the University of Dayton.

An additional advantage to using KYPIPE2 is the parameter calculation option. The parameter calculation allows for pressures to be specified at various locations (nodes) within the distribution system. Once each node has been specified, KYPIPE2 determines the discharge pressure needed at an associated water treatment plant or

booster station. This option is used in the FGN Model and allows the operators of the system to identify what pressures they want their distribution system to be at for the optimization analysis.

3.3 Pump Optimization Program

As indicated in the previous section, the pump optimization program used for the City of Detroit's project is KYPUMP. KYPUMP has the capability of either finding energy efficient pump combinations that produce desired water elevations in storage tanks or meet a specified system demand. Although the City of Detroit's project did not use the first option, it may be applicable to other municipalities with elevated tanks.

One other benefit in using KYPUMP is the minimum pressure verification option. The minimum pressure verification option checks the resulting station discharge pressure for each pump combination analyzed. If the pump combination does not meet the minimum pressure identified for each station, KYPUMP removes the combination from the analysis. This option assures that only combinations that meet the required pressures and flows are identified as optimal combinations.

3.4 Energy Optimization Program

The energy optimization program is comprised of three components. The previous sections described two of the components - the hydraulic model and the pump optimization program. The third component is the interface program. The interface program was developed using Microsoft's Visual Basic for Windows, Professional Version 3.0. The interface provides a user-friendly environment for the operator to identify the current status of the water distribution system, input the desired pressures at selected locations in the system, and view the results of the energy optimization analysis. The logic by which this is accomplished is shown in flowchart format in Figure 3-1.

As seen by the flowchart, the methodology used in the development of the interface program can be applied to any distribution system. The hydraulic models (KYPIPE2) and pump optimization program (KYPUMP) are separate components. Therefore, another municipality could follow the same logic shown in the flowchart using a KYPIPE2 hydraulic model of their system and a KYPUMP pump optimization program containing the characteristics of their pumps. Other changes uniquely related to the DWSD system would also have to be changed in the interface to represent a different system. These changes include modifying the individual water treatment plant and booster station input screens, modifying the map screens, and identifying different constraint node locations.

Furthermore, a "global" energy-efficient pump combination may be obtainable for a system with a smaller amount of pumps than the DWSD system. If the total number of pump combinations is within a manageable range, one pump model could be developed combining the Local Model and Pump Model.

FLOWCHART OF OPERATION

FLOWCHART OF OPERATION (Continued)

FLOWCHART OF OPERATION (Continued)

FLOWCHART OF OPERATION (Continued)

3.5 Computer Equipment

The City of Detroit is using a 486DX2 50 Mhz computer with 8 Mb of RAM, standard VGA with 1Mb video memory, and a 205 Mb hard drive. The suggested minimum requirements for analyzing a distribution system of comparable size would be a 486SX/33 Mhz computer with 4 Mb RAM, standard VGA (512 Kb video memory), and a 120 Mb hard drive. The system should also be optimized for Windows 3.1 running in enhanced mode.

Since the program is computation-intensive, a fast computer with a large processing capacity is necessary. Also, the program contains a good amount of graphics and requires enough space for variable storage (8 Mb or more of RAM is recommended).

Several software packages have been identified in the guidebook including Visual Basic for Windows, KYPIPE2 and KYPUMP. However, additional software programs were used to create and enhance the graphics displayed in Detroit's project. This software includes AutoCad Release 12, Corel Draw Version 3.0, Corel Photo Paint, HiJack Pro, and the Graphics Workshop, Version 6.0. The run-time associated with the optimization process is dependent on the computer equipment as well as the size of the water distribution system and number of pumps. For the DWSD system, the computation time to run an optimization analysis averages approximately two minutes.

3.6 Summary

Optimizing pumping operations used to transmit water throughout a distribution system will save energy and reduce operating costs. The guidebook has described an approach that municipalities can follow to produce a computer program for

their communities that will identify energy efficient pumping combinations to meet specified system demands and pressures.

The process described in the guidebook has been considered by some to be on the leading edge of technology. It is hoped that the City of Detroit's experience in developing the optimization program will be followed by other communities to assist them in saving energy and thereby conserving our country's natural resources.

REPORT AND INFORMATION SOURCES

Additional copies of this "*Energy Optimization of Water Distribution System*" from the Building and Safety Engineering Department, Detroit, MI, are available from:

PTI Publications Center
Tel: 301/490-2188
Fax: 301/604-0158

For additional information on the process and the results of the work described in this report or for information on the overall energy management programs in the City of Detroit, please contact:

Bob Dickerson
Chief
Building and Safety Engineering Department
Building Inspection Division
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ABOUT THESE PUBLICATIONS

These publications were produced through research conducted by the Urban Consortium Energy Task Force (UCETF) of Public

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UCETF membership includes elected officials, management, and technical professionals from urban cities and counties. It links through the Urban Consortium and PTI to national organizations, such as the National Association of State Energy Officials (NASEO), the National League of Cities, the National Association of Counties, and the International City/County Management Association to ensure the widespread exchange of information and technology.

For more information about the Urban Consortium Energy Task Force (UCETF) or these guidebooks, contact Jack Werner, PTI Business Director, at 202/626-2421.

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SAN JOSE, CA - *Negotiating a Demand-Side Bid*
Remove the mystery from the energy conservation-bidding process. Get general background

information on demand-side bidding information; learn advantages and disadvantages of participation; and, discover alternative and "ideal" scenarios for bidding. In addition, preview potential pitfalls and lessons learned from a municipal jurisdiction that has already been through the process and offers its transferable model for your benefit.

92-322. \$12.00

ALSO AVAILABLE:

PTI URBAN CONSORTIUM ENERGY TASK FORCE - *Video: Variable Frequency Drives: SAVING ENERGY!* Also, ask for PTI's other free videos, entitled the Urban Consortium Energy Task Force, and Cleaner Fueled Vehicles.
92-401. FREE

SMALL BUSINESSES

NEW ORLEANS, LA - *Reducing Impact of Energy Costs on Small Businesses*
88-312. \$15.00

UTILITY MANAGEMENT

PTI - *Electric Utility Franchise Conference Proceedings*
Details from the first conference of its kind includes research results, negotiating experiences, technological advancements, and regulatory changes.
89-307. \$20.00

ALSO AVAILABLE:

CHICAGO, IL - *A Municipal Guide to Least Cost Utility Planning*
90-323. \$18.00

CHICAGO, IL - *The Electric Utility Franchise Expiration and Renewal Process*
87-322. \$15.00

KANSAS CITY, MO - *Use of Cogeneration System to Control Electrical Demand*
90-305. \$15.00

HOUSTON, TX - *Electric Utility Franchise Guide*
87-311. \$20.00

WATER DISTRIBUTION

DETROIT, MI - *Energy Optimization of Water Distribution System*
Looking to cut your water transmission costs? An energy optimization project, such as that developed by Detroit, may help your jurisdiction cut one of its highest expenditures. Development of a computer program used to develop energy strategies and planning guidelines helped Detroit minimize power consumption and improve pumping efficiency at its pumping facilities. A guidebook identifying the transferable methodology used to develop the computer program will assist you in developing an energy optimization program for your municipality.
92-301. \$7.50

ALSO AVAILABLE

DETROIT, MI - *Computer Assisted Control for Municipal Water Distribution*
87-313. \$20.00

ENVIRONMENTAL MANAGEMENT

HAZARDOUS WASTE

ALBUQUERQUE, NM - *Hazardous Waste as an Energy Manager's Issue*
88-317. \$15.00

HENNEPIN COUNTY, MN - *Household Batteries: Evaluation of Collection Methods*
89-309. \$7.50

PTI - *Communicating with the Public about Environmental Risks*
89-314. \$13.00

SEATTLE, WA - *Evaluating Program Effectiveness of Household Hazardous Waste Collection*
90-330. \$15.00

SEATTLE, WA - *Evaluation and Comparison of Selected Household Hazardous Materials*
89-313. \$15.00

RECYCLING

MEMPHIS, TN - *Recycling and Composting Demonstration Projects for the Memphis Area*
91-332. \$25.00

MONTGOMERY COUNTY, MD - *Yardwaste Recycling Study: A Pilot Study for Composting Yard Waste with Existing Leaf Composting Program*
89-311. \$15.00

NEW ORLEANS, LA - *Waste Tire Recycling by Pyrolysis*
90-328. \$20.00

SAN DIEGO, CA - *Multifamily Recycling Program Program Data and Implementation Guidelines*
91-334. \$20.00

SOLID WASTE

DADE COUNTY, FL - *Maximization of Revenues for Power Sales from a Solid Waste Resources Recovery Facility*
Learn how to maximize electricity revenues from resource recovery plants through Metro-Dade County's contract with Florida Power & Light Company to sell excess energy produced by burnin municipal solid waste.
91-303. \$20.00

SO AVAILABLE

HOUSTON, TX - Solid Waste Integrated Cost Analysis Model (Parts I and II)
306. \$15.00; 91-331. \$15.00

MEMPHIS, TN - Sludge Storage Lagoon Biogas Recovery (Phases I and II)
310. \$15.00; 90-327. \$10.00

HYDRAULIC WASTE

TROIT, MI - Hydraulic Waste Energy Recovery: A Technical Report
331. \$15.00

TROIT, MI - Hydraulic Waste Energy Recovery: A Technical Report - Phase II
311. \$15.00

HOUSTON, TX - Wastewater Treatment Process Energy Optimization
303. \$13.00

TRANSPORTATION

BUQUERQUE, NM - Alternative Vehicle Models in Municipal Duty: A Demonstration Project

Comparison of the comparative benefits of CNG, electricity, oxygenated fuels and gasoline as primary fuels for automobiles, with emphasis on environmental impact and fleet integration.
316 \$15.00

SAN ANGELO, CO - Technical Comparison between Hythane, CNG and Gasoline Fueled Vehicles

Study demonstrating performance of Compressed Natural Gas (CNG) as compared to Hythane, a mixture of CNG and Hydrogen. Hythane was shown to have the potential to meet California's Ultra-Low Emissions Vehicle (ULEV) standard, a criterion currently met only by electric vehicles.
324. \$12.00

CONNEC - Refueling Alternatives Fuel Vehicles: Lessons Learned from the Marketplace

Study supported by DOE, public officials and energy companies has been conducted by the Coalition of Northeast Governors (CONEG) Policy Research Center, Inc. The findings conclude that information and refueling are two critical needs if fleet managers are to operate alternative fuel vehicles. The study surveyed fleet operators in the northeast states. This report provides useful quantitative information for decision makers to make preliminary assessments of potential market demand for the development of refueling infrastructure to serve alternative fuel vehicles.

Copies of the report are available from CONEG (202)624-8450 for \$50 for the two volume set, \$30 for Volume I and \$40 for Volume II.

HOUSTON, TX - Compressed Natural Gas Fueled Vehicles: The Houston Experience
A feasibility study with additional focus on refueling infrastructure.
90-320 \$22.00

LONG BEACH, CA - NGV Fleet Fueling Station Business Plan

Promote compressed natural gas vehicle use in your municipality's fleet. In this report, based on the City of Long Beach's experience, market barriers as well as an econometric model for the implementation of a CNG infrastructure are addressed. This transferable model may help your municipality effectively address issues associated with the implementation of such an infrastructure.
93-310. \$18.00

NEW YORK, NY - Alternative Transportation Fuels: Financing Issues

This study examines methods of financing alternative fuel vehicles which do not include government subsidies. Learn how high costs can be spread among a number of parties in the private sector.
91-310 \$12.00

SAN DIEGO, CA - California Clean Air Act - A Compliance Strategy

The full cost of acquiring and operating a fleet of low emission vehicles is cited in San Diego's compliance strategy report. Learn from this jurisdiction's experience how to create a well-planned approach to changing over to a low emission fleet with minimal municipal service interruption, and improve air quality in your region.
92-330. \$20.00

PTI UCETF - Cleaner Fueled Vehicles (Video)

Uncertain fuel costs and environmental pressure make alternative fuel fleets increasingly important. Decide which Cleaner Fueled Vehicle is right for your city or county.

92-400 FREE!

ALSO AVAILABLE:

BROWARD COUNTY, FL - Dual Fuel Conversion Demonstration and Technology Transfer Project
89-323 \$10.00

DETROIT, MI - Analysis of Operational, Institutional and International Limitations for Alternative Fuel Vehicles and Technologies
90-311 \$18.00

DETROIT, MI - Fleet Assessment for Opportunities to Effectively Deploy Light Duty Alternative Fuel Vehicles
89-326 \$15.00

MEMPHIS, TN - Feasibility Study of Transportation Management Strategies
88-301. \$15.00

NEW YORK, NY - Alternative Transportation Fuels: Infrastructure Issues
89-327 \$18.00

PHOENIX, AZ - Analysis of Programmatic Fleet Conversion to Ethanol Blends
89-330 \$15.00

PTI - Economic Evaluation Guide for Alternative Transportation Fuels
91-501 \$27.00

PTI'S ENERGY PROGRAM AIMS TO:

- Improve Energy Efficiency
- Create Sustainable Communities
- Enable Practical Energy Management
- Reduce Pollution
- Save Money

The Urban Consortium Energy Task Force of Public Technology, Inc. is chaired by Mike Lindberg, Commissioner, City of Portland, Oregon.

Task Force Members: Albuquerque, NM; Austin, TX; Chicago, IL; Columbus, OH; Denver, CO; Hennepin County, MN; Houston, TX; Memphis, TN; Metro-Dade County, FL; Montgomery County, MD; Orange County, FL; Philadelphia, PA; Phoenix, AZ; Norfolk, VA; San Diego, CA; San Francisco, CA; San Jose, CA; Seattle, WA; Washington, DC.