EPA/600/A-94/228

WETLANDS TREATMENT DATABASE

Jerry D. Waterman

Donald S. Brown

U.S. Environmental Protection Agency
Office of Research & Development
Risk Reduction Engineering Laboratory
Cincinnati, Ohio

ABSTRACT: The U.S. EPA sponsored a project to collect and catalog information from wastewater treatment wetlands into a computer database. EPA has also written a user friendly, stand-alone, menu-driven computer program to allow anyone with DOS 3.3 or higher to access the information in the database. The database and program were released to the general public in the summer of 1994. This paper discusses the database and the accompanying program.

The database contains information for 323 wetland cells at 178 locations in the U.S. and Canada. The information provided includes general information (e.g. names of contacts, dimensions, media and plants used, permit limits) as well as water quality data (BOD, TSS, N-series, P, DO, and fecal coliforms). The database is a collection of existing information; no new data were generated by this project.

KEYWORDS: Wetlands, Database, Water, Wastewater, Treatment of Wastewater

Introduction

Interest in the use of wetlands for the treatment of a variety of wastewaters is quickly growing in the United States and worldwide. In 1990, the U.S. Environmental Protection Agency (EPA), Office of Research and Development, began to collect information on existing wetlands in the United States which treated wastewater. The collection effort evolved into the Wetlands Treatment Database (North American Wetlands for Water Quality Treatment Database) described in this paper. Data collection ended in 1993. Papers discussing earlier phases of the project have been presented (Brown and Reed, 1992; Knight, Kadlec, and Reed 1992; Knight, Ruble, Kadlec, and Reed, 1993; Knight, 1994; Reed, 1991; Reed and Brown, 1992).

Because treatment wetlands are an emerging technology, design and performance data are limited and often difficult to obtain. Given the difficulty in locating and obtaining data, the primary purpose of the database was to compile existing data and make it readily available to the wastewater treatment community. During the compilation it became apparent that while some wetlands had been monitored extensively, many wetlands had little or no available data. In many cases data: 1) did not exist, 2) existed but were difficult to locate, 3) existed but had not been released by the owners, or 4) existed but were not collected due to funding limitations. Regardless of the lack of data for some systems, the database is thought to be the most

complete collection of information on wetland treatment systems available. Although EPA does not expect to update the database, the database will be useful as a framework for users to continue to compile information. The database also makes apparent data gaps which will help to focus new research and monitoring efforts.

Database Organization

Wetlands were entered into the database by geographic location or "site". Some sites had multiple "systems" (wetland treatment trains that were in parallel and that had individual outflows). Some systems had multiple "cells" (wetland areas that were clearly separated by dikes or uplands and had identifiable inlets and outlets). Multiple cells in a system were in series or in parallel. For example, the fictitious site shown in Figure 1 has two systems and seven cells.

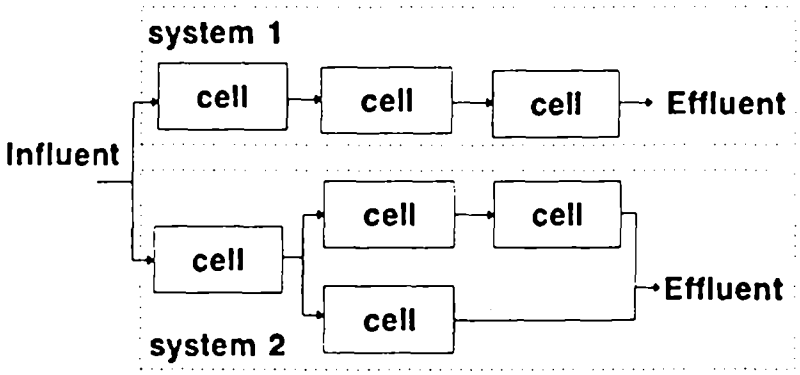

Figure 1. Relationship between "systems" and "cells"

The data were stored in nine files generated using dBASE IV™. Table I summarizes the file structure and size. To make an analogy to a spreadsheet or table format, "fields" and "records" can be thought of as columns and rows, respectively. More details about the data files can be found in the database program itself and elsewhere (Knight, Ruble, Kadlec, and Reed, 1993).

Table I. Database File Structure

File Name	Description	No. of Fields	Number of Records	Total File Size (Kb)
SITES.DBF[a]	General site (location) information	56	178	37
SITES.DBT[b]	General notes about site Data quality statements	1	173	143
SYSTEMS.DBF	System specific information	16	203	28

a) .DBF is a standard database file
b) .DBT is a database memo file

Table I (continued). Database File Structure				
File Name	Description	No. of Fields	Number of Records	Total File Size (Kb)
CELLS.DBF	Cell specific information	21	323	83
PEOPLE.DBF	Contact people for the site	8	287	83
LITERAT.DBF	References for the site	11	286	140
PERMITS.DBF	Permit information for a system/cell	10	475	60
OPERATE.DBF	Water quality data for a system/cell	79	3229	2240
OPERATE.DBT	Notes about water quality data	1	123	70

Existing wetlands treating stormwater or municipal or industrial wastewater in North America were included in the database. Both subsurface flow (SF) and free water surface (FWS) wetlands, and both natural and constructed wetlands were included. (SF wetlands were referred to as vegetated submerged beds (VSB) in some of the earlier references to the database.) Agricultural and mining wastewater systems were specifically excluded. Figure 2 shows the location of the database systems in the U.S.; five locations in Canada were also included. As shown in Figure 3, the majority of the systems treated municipal wastewater. The "Other" category includes systems where the source of wastewater was unknown, and unique systems such as the Des Plaines River experimental project which was used for improving river water quality.

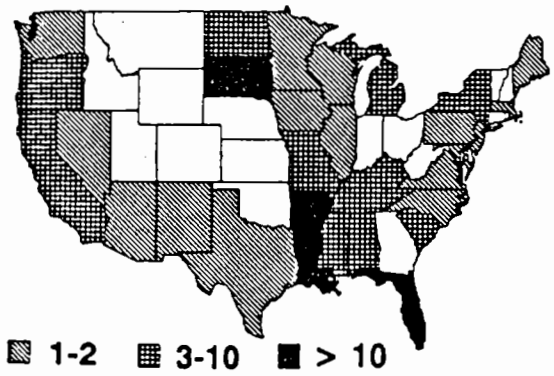

Figure 2. Location of treatment wetlands in the U.S.

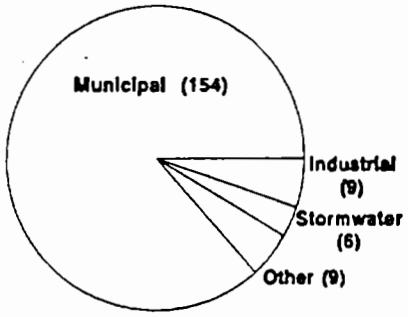

Figure 3. Type of Wastewater Treated

In general, only systems that treated greater than 38 m^3/d (10,000 gpd) were included. A few smaller pilot scale systems were included, but individual home systems were excluded.

Figure 4 shows the range, mean, and median for actual flows (rather than design flows) for five types of wetlands. These five types (CSM = constructed SF marsh, CFM = constructed FWS marsh, NFM = natural FWS marsh, CHM = constructed hybrid (combination of SF and FWS) marsh, and NFF = natural FWS forest) account for most of the systems in the database. Figure 5 shows the distribution of wetlands by origin (natural or constructed), and within each origin, distribution by hydrologic type (FWS, SF or hybrid). "Other" in Figure 5 includes unknown and hybrid (combination of natural and constructed) wetlands.

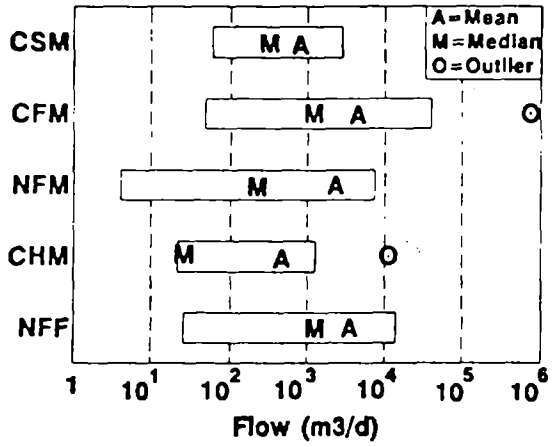

Figure 4. Size (flow) by wetland type

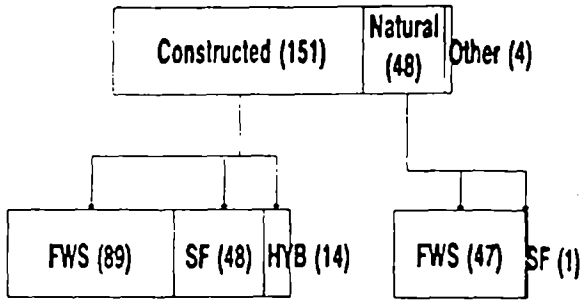

Figure 5. Distribution by origin and hydrologic types

As stated earlier, treatment wetlands are an emerging technology and data did not exist for some systems. Table II summarizes the availability of data. The "Number of Sites" column shows how many sites had information for each data file. For example, there were 286 records for LITERAT.DBF, indicating that there were 286 literature citations. However, these citations pertained to only 80 of the wetland sites. By comparing the number of sites (in this case, 80) with the total number of 178 sites in the database, or with the number of data file records (in this case, 286), the reader can get an indication of the availability of each type of data.

Table II. Availability of Data

File Name	Number of Records	Number of Sites	% Full
SITES.DBF	178	178	80
SYSTEMS.DBF	203	178	71
CELLS.DBF	323	128	67
PEOPLE.DBF	287	164	96
LITERAT.DBF	286	80	73
PERMITS.DBF	475	85	88
OPERATE.DBF	3229	94	50

The "Percent Full" column of Table II also gives an indication of data availability by showing the percentage of data fields that contain information. For example, 50% of the fields in OPERATE.DBF are empty. This does not mean that 50% of the sites did not have data. It means that for the 94 sites that did have data, 50% of the fields are empty. However, the numbers in this column can be misleading. Some of the empty fields can explained by the redundancy of some of the fields (i.e. mass loading and concentation), as discussed below.

Description of the Database and WTS Program

The database files include general site information, system specific information, information for individual cells, names and addresses of people who are involved with or have relevant knowledge about the wetland, literature references for wetland sites in the database, permit information, and operational flow and water quality data for individual cells and/or systems. To make the database information more accessible to the user, the EPA created a user friendly, stand-alone computer program ("Wetland Treatment Systems" or WTS) to allow anyone with DOS 3.3 or higher to access the information in the database. A minimum of 640K of memory and 4MB of free disk space is required to run the software.

The WTS program is an interface that allows the user to look at most of the information in the wetlands treatment database without purchasing additional software. To access the complete database, to sort or search the data files, or to do in-depth analyses of the data, the user will have to use one of the several commercially available software packages that can access files generated by dBASE IV™.

The WTS program begins with three opening screens, including a Disclaimer on Data Quality (see discussion of Data Quality below). The Welcoming Menu screen comes next and gives the user seven menu choices. The first five menu choices lead to important information about the database background, data quality, acknowledgements, database description, and summary information. This information is presented on the monitor rather than as a hardcopy manual or a "READ.ME" file. The last two choices let the user begin the program or return to DOS.

When the user chooses to begin the program, the program presents a list of the wetlands in the database and lets the user scroll through the list to pick the wetland of interest. Sites are listed in alphabetical order by state and then by site name within each state. The list also includes the source of the wastewater. After a site has been chosen, the user can choose from a list of menu items on the "Site Menu", which access the various database files: Site Description, People & Literature, Permits Information, Choose Another Site, Print Option, or Return to Main Menu.

Site Description. The user can choose Site Description to view general information about the site, including geographic location, total number of systems and cells at the site, type of pretreatment, and design flow. Also included in this section is a comment field that may have comments about the site history, anecdotal information, or general observations relative to the site. The comments range from one short sentence up to several paragraphs. Narrative statements about data quality, if available, are presented here. For all sections of the program, if a site has no information, then a window appears on the screen to indicate that "No Data was

found for this site". Conversely, multiple screens are automatically displayed in sequence if they are needed to present all of the information pertinent to a site.

Many of the sites had water quality data that can be accessed from the Site Description section of the program. The water quality data were entered by system or cell and by time period. The database contains fields for the water quality parameters listed in Table III. For each parameter there were six available fields for entering data (see Table IV). Although it resulted in redundancy for some wetlands, six fields were necessary because the database compilation depended on existing data. For example, some wetlands reported data only in terms of mass loading, but did not report enough additional information to allow computation of concentrations. Therefore, restricting the database to concentration data only would have left some information unavailable. The data for each parameter were entered into as many of the six fields as possible. Some wetlands had data for all three fields for either mass loading or concentration, but not enough information was available to report both. Therefore, these wetlands had 50% of their data fields blank, and yet had data for influent, effluent, and percent removal (see Table II). Other wetlands had data for only one field (e.g. concentration percent removal).

Table III. Water Quality Parameters
Biochemical Oxygen Demand (BOD)
Total Suspended Solids (TSS)
Total Kjeldahl Nitrogen (TKN)
Ammonia Nitrogen(AMN)
Nitrate Nitrogen (NO3)
Total Nitrogen (TN)
Organic Nitrogen (OGN)
Dissolved Phosphorus (DP)
Total Phosphorus (TP)
Fecal Coliforms (FEC)
Dissolved Oxygen (DO)

Table IV. Water Quality Data Fields	
mass loading (kg/ha/d)	concentration (mg/L)
Influent	Influent
Effluent	Effluent
Percent Removal	Percent Removal

Figure 6 shows the number of sites for which water quality data were available for each parameter. Figure 7 shows that the amount of water quality data available for a given site varied considerably from no data to over 100 data records.

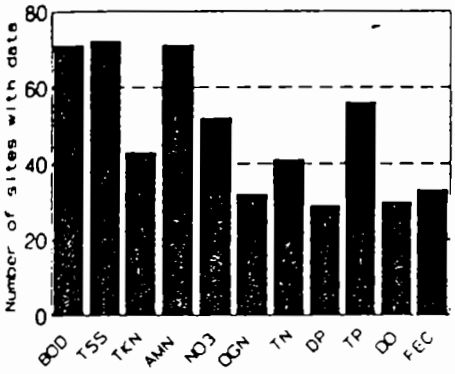

Figure 6. Extent of Water Quality Data

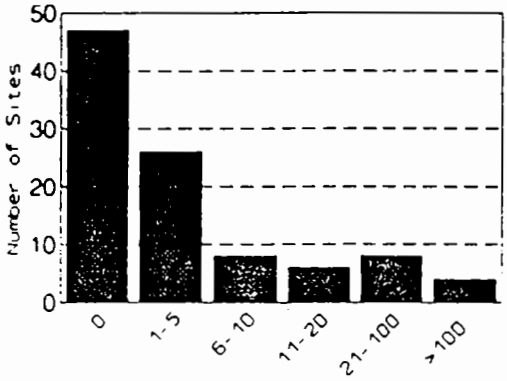

Figure 7. Distribution of water quality data

After viewing the water quality data screens, the user can see more specific information about the systems and cells. Some of the sites have multiple screens to show the multiple systems and/or cells at a site. The screen(s) with system data include origin type, hydrologic type, vegetation type, area (ha), flow (m3/d), start date, down date, and cost information. The screen(s) with cell data include vegetation species, length, width, depth, substrate, aspect, and for subsurface flow wetlands, media, bottom slope and top slope.

People, Permits, Printing. After the user has reviewed the Site Description information the "Site Menu" will reappear. The user can then view additional information about the current site, select another site to view, or choose the print option. Additional information about the current site includes either People & Literature or Permits Information. On the People & Literature screen(s), information is shown about people familiar with the site including name, address, and phone number. Next, literature information is shown with the author(s), title, year, and the citation for the article. A comprehensive literature search was not done in the compilation of the database. The reports included were often the type of gray literature (e.g. student theises and reports to regulatory agencies) that are difficult to locate. These literature citations can be consulted for more detailed information about systems in the database.

Using the Permits Information option the user can view the permit information for that site. Information on the permit screen(s) includes design flow, limit, units, duration, parameter, season, and comments for each permitted condition. Figure 8 shows the types of parameters for which permit limits had been written for treatment wetlands. The N/P column includes all types of nitrogen and phosphorus limits. The miscellaneous (MISC) column included a wide range of site specific limits including metals, ultimate oxygen demand, and synthetic organics. Because most permits had limits for several parameters, and often had different limits, durations, or seasons that applied for a given parameter, a wetland system usually had more than one record. Figure 9 shows that the types of permits written vary considerably from permits with one record (i.e. limit) to permits with over 20 records.

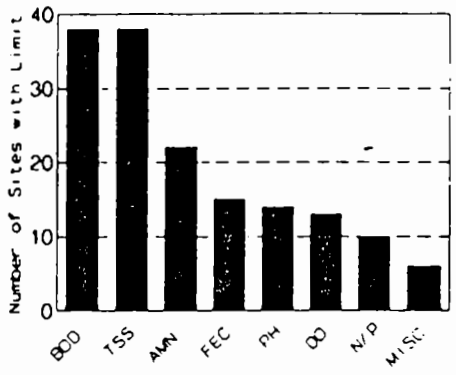

Figure 8. Types of permits written

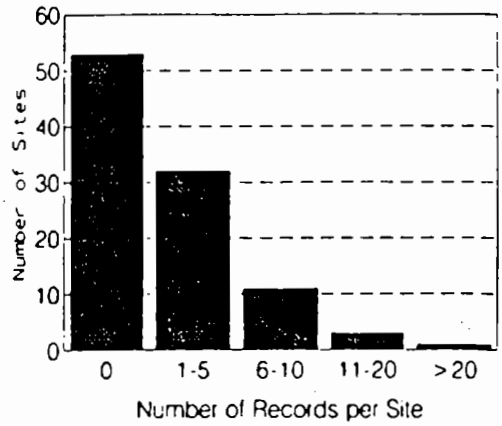

Figure 9. Distribution of permit records

Finally, using the Print option the user can print some or all of the information about the selected site to a printer or to an ASCII text file. If the user sends the information to a text file, the user can review the information later, incorporate it into a report, or import it into a spreadsheet or other software application that will accept ASCII files.

Data Quality

Much of the information in the database had been collected over the past 15 years by the principal database team members (see acknowledgements). Information was requested or retrieved for all sites; however, most systems had only a limited amount of design or operational data. As information was obtained it was converted, as necessary, to the units used by the database. Data reduction and entry into the database was conducted by the principal team members or under their direct supervision. All data were reviewed by the principal team members for apparent aberrant values before entry into the database. Any values suspected of being in error were confirmed with the original source of the information or were discarded. The principal team members carefully reviewed the data for which they were responsible as well as the data entered by the other team members. No other quality control checks were conducted on the database.

The quality of the data in the OPERATE data file was not always known. For those sites where it was known, the quality was sometimes difficult or impossible to verify. Data quality depended on all of the people involved with the collection, transportation and analysis of water samples. Procedures to document and control this process (quality assurance and quality control, QA/QC) at wetland treatment systems were highly variable. Many systems, especially at smaller facilities, had no written QA/QC procedures and used relatively simple analytical methods. Although the people involved in the process may have been conscientious and used great care, there was usually no documentation of data quality. Some systems, however, were larger or better funded and had very credible QA/QC procedures and documentation of data quality.

Due to the variable nature of data quality and data validation, users should exercise caution when interpreting and applying these data. The original sources of the data should be

contacted for more information about the quality of the data. Conservatism must be included in design and operation of new systems when using these data, because data errors can be difficult to detect. Also, it is important to note that: 1) actual operational parameters were not fully described in the database; and 2) start-up data may not be representative of long-term operation.

Data Analyses

Due to the large number of variables included in the database, analysis of data in the database was beyond the scope of this paper. Wetlands varied by origin, hydrologic type, age, climate (e.g. temperature, precipitation, and evaporation), design criteria (e.g. aspect, area, and hydraulic detention time), vegetation, source and strength of influent wastewater, and treatment objectives. The variablility of data quality also complicates data analysis. Preliminary analyses of the database have been done by Knight, Ruble, Kadlec, and Reed (1992, 1993, 1994), and additional analyses have been included in this paper for illustrative purposes. This type of analysis, which points toward general data trends is too preliminary and too broad in scope to be used to design or evaluate an individual treatment wetland, but it does add to the general understanding of treatment wetlands. More detailed analyses of the data should be forthcoming with the release of the database as more people have access to the data.

Figures 2 through 5, 10, and 11, update information provided by Knight, Ruble, Kadlec, and Reed (1993). The size distribution based on area for the five major types of wetlands is shown in Figure 10. SF wetlands, on the average, are one to two orders of magnitude smaller than FWS wetlands. Figure 11 shows the primary types of vegetation used. As expected, the most common vegetation species found in treatment wetlands were cattail (Typha spp.) and bulrush (Scirpus spp.). In contrast to European systems, only a small percentage of wetlands had Phragmites (common reed) as the primary species.

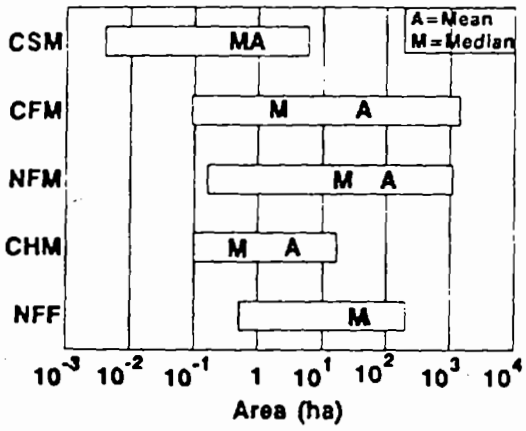

Figure 10. Size (area) by wetland type

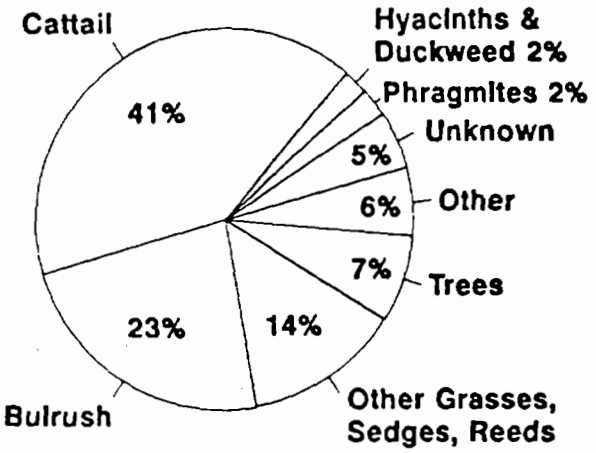

Figure 11. Primary types of vegetation

The low cost of construction and annual operation has been one of the major factors behind the growth in interest in treatment wetlands. As shown in Figures 12 and 13, the database provides construction cost information for 67 wetlands, and annual operating cost information for 15 wetlands. The categories of wetlands shown in these figures are:

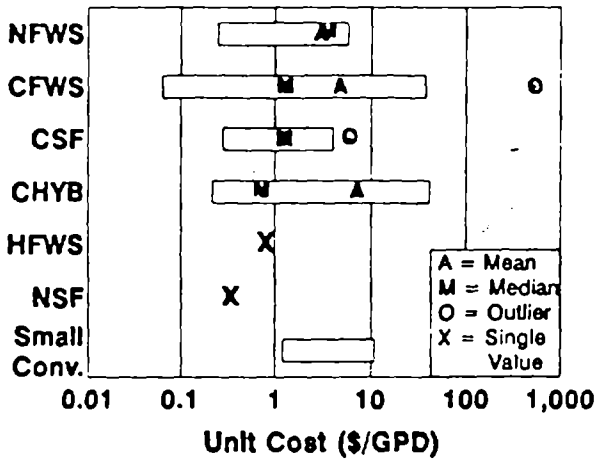

Figure 12. Construction Costs

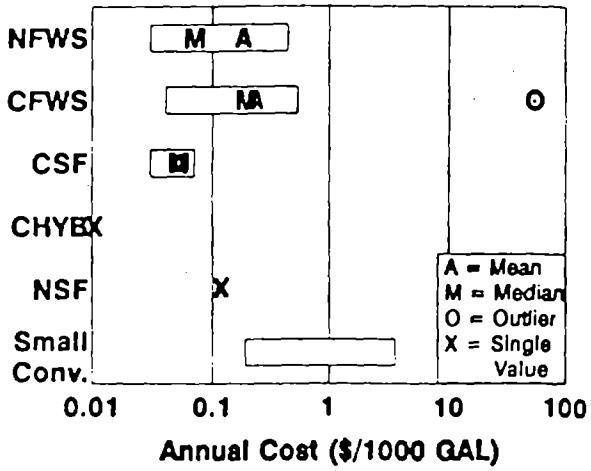

Figure 13. Annual Operating Costs

NFWS = natural FWS; CFWS = constructed FWS; CSF = constructed SF; CHYB = constructed hybrid; and NSF = natural SF. The year of the cost data was reported in the database to allow users to update the costs to the present. Because of the wide range in costs, and because the year of the cost data was not always known, the costs shown in Figures 12 and 13 were not updated. For Figure 12, the year of the cost data was reported for 36 of the 67 wetlands, and the year ranged from 1972 to 1993. For Figure 13, the year of the cost data was reported for 11 of the 15 wetlands, and the year ranged from 1978 to 1993. For comparison, the category "Small Conv." refers to a variety of conventional, natural and mechanical, small community wastewater treatment technologies (package plants, trickling filters, oxidation ditches, sequencing batch reactors, aerated lagoons, sand filters, and land application)(SAIC, 1992). As expected, costs for treatment wetlands of all types are equivalent or less than conventional treatment methods.

Conclusion

The Wetlands Treatment Database was released in the summer of 1994 to the general public. To request a copy or for questions about the database contents, contact Donald Brown, Project Officer, (513) 569-7630. For questions about the software program, contact Jerry D. Waterman, Software Developer, (513) 569-7834. Both can be reached at the Risk Reduction Engineering Laboratory (RREL), U.S. EPA, 26 W. Martin L. King Dr., Cincinnati, OH 45268; FAX: (513) 569-7787.

Acknowledgements

The data collection and database creation was done under contract by: Robert L. Knight, Ph.D. and Richard W. Ruble of CH2M HILL, Gainesville, Florida; Robert H. Kadlec, Ph.D. of Wetland Management Services, Chelsea, Michigan; and Sherwood C. Reed, P.E., Environmental Engineering Consultants, Norwich, Vermont. The WTS program was developed by Jerry Waterman, U.S.EPA, RREL. Technical support was provided by Richard Olson, ManTech Environmental Technology, Corvallis, Oregon. Project oversight was provided by

Donald Brown, U.S.EPA, RREL, and William Sanville, U.S. EPA, Environmental Research Laboratory, Duluth, Minnesota.

Disclaimer

The database has been funded wholly or in part by the United States Environmental Protection Agency under contracts 68-C0-0021 with Technical Resources, Inc., 68-C0-0027 with Montgomery Watson Americas, Inc., and 68-C8-0006 with ManTech Environmental Technology, Inc. The database and this paper have been subjected to the Agency's peer and administrative review, and have been approved for release as EPA documents. The data are presented for review by the user. Therefore, the conclusions and opinions drawn from the data are solely those of the user and are not necessarily the views of the EPA. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
EPA/600/A-94/228		

4. TITLE AND SUBTITLE	5. REPORT DATE
Wetlands Treatment Database	6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Jerry D. Waterman and Donald S. Brown	

9. PERFORMING ORGANIZATION NAME AND ADDRESS	10. PROGRAM ELEMENT NO.
U.S. Environmental Protection Agency Risk Reduction Engineering Laboratory--Cincinnati, OH Office of Research and Development Cincinnati, OH 45268	11. CONTRACT/GRANT NO. 68-C0-0021,68-C0-0029, 68-C8-00

12. SPONSORING AGENCY NAME AND ADDRESS	13. TYPE OF REPORT AND PERIOD COVERED
Risk Reduction Engineering Laboratory--Cincinnati, OH Office of Research and Development U.S. Environmental Protection Agency Cincinnati, OH 45268	Abstract & Proceedings 14. SPONSORING AGENCY CODE EPA/600/14

15. SUPPLEMENTARY NOTES Jerry D. Waterman, (513) 569-7834 ; Proceedings of the Water Environment Federation, 67th Annual Conference & Exposition , VIII, Chicago, IL, 10/15-19/94, p:79-89

16. ABSTRACT

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
WATER WASTE WATER	WETLANDS DATABASE WASTEWATER TREATMENT	

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES
RELEASE TO PUBLIC	UNCLASSIFIED	13
	20. SECURITY CLASS (This page) UNCLASSIFIED	22. PRICE