USACERL Technical Report N-91/29
August 1991

US Army Corps of Engineers
Construction Engineering Research Laboratory

Evaluation of Alternatives for Secondary Treatment at Central Vehicle Wash Facilities

by
Gary L. Gerdes
Joseph E. Matherly
Susan J. Bevelheimer
Douglas D. Suits
Michelle J. Westfall
Joshua S. Van Tassel
Edward L. Obermiller

The U.S. Army Corps of Engineers designed and built several successful Central Vehicle Wash Facilities (CVWFs) to allow the exterior of tactical vehicles to be cleaned in an efficient and environmentally safe manner. Because designers believe the guidance for secondary treatment design was too restrictive, research was initiated to investigate alternatives for CVWF treatment systems.

The objective of this study was to evaluate alternatives or modifications to existing design guidance for CVWF secondary treatment. Research revealed that intermittent sand filtration, lagoons, and constructed wetlands are acceptable for secondary treatment. All three alternatives will function with little attention from the CVWF operator. Lagoons and constructed wetlands will require little maintenance. Sand on the surface of intermittent sand filters will need to be removed periodically. All three types of secondary treatment provide water that should be discharge quality in most states and will not be a hazard to the troops using the facility.

Approved for public release; distribution is unlimited.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave Blank)

2. REPORT DATE
August 1991

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Evalution of Alternatives for Secondary Treatment at Central Vehicle Wash Facilities

5. FUNDING NUMBERS
PE 4A162720
PR A896
TA Area B
WU T10

6. AUTHOR(S)
Gary L. Gerdes, Joseph E. Matherly, Susan J. Bevelheimer, Douglas D. Suits, Michelle J. Westfall, Joshua S. Van Tassel, and Edward L. Obermiller

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratory (USACERL)
2902 Newmark Drive, PO Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR N-91/29

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
HQUSACE
ATTN: CEMP-RT
20 Massachusetts Avenue, NW.
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The U.S. Army Corps of Engineers designed and built several successful Central Vehicle Wash Facilities (CVWFs) to allow the exterior of tactical vehicles to be cleaned in an efficient and environmentally safe manner. Because designers believe the guidance for secondary treatment design was too restrictive, research was initiated to investigate alternatives for CVWF treatment systems.

The objective of this study was to evaluate alternatives or modifications to existing design guidance for CVWF secondary treatment. Research revealed that intermittent sand filtration, lagoons, and constructed wetlands are acceptable for secondary treatment. All three alternatives will function with little attention from the CVWF operator. Lagoons and constructed wetlands will require little maintenance. Sand on the surface of intermittent sand filters will need to be removed periodically. All three types of secondary treatment provide water that should be discharge quality in most states and will not be a hazard to the troops using the facility.

14. SUBJECT TERMS
Central Vehicle Wash Facilities
Design guidance

15. NUMBER OF PAGES
32

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

FOREWORD

This report was prepared for the Directorate of Military Programs, Headquarters, U.S. Army Corps of Engineers (HQUSACE), under Project 4A162720A896, "Environmental Quality Technology"; Task Area B, "Environmental Design and Construction"; Work Unit T10, "Treatment Alternatives for Vehicle Maintenance Pollution Control." The applicable Mission Area Deficiency Statement (MADS) is 4.02.003. The HQUSACE technical monitor was Fred Eubank, CEMP-RT.

The study was conducted by the Maintenance Facility Pollution Abatement Team, Environmental Division (EN), U.S. Army Construction Engineering Research Laboratory (USACERL). Dr. Edward W. Novak is Acting Chief, USACERL-EN. The technical editor was Gloria J. Wienke, USACERL Information Management Office.

Valuable contributions were made during this study by: Dave Hanke and Brian Spindor, Directorate of Engineering and Housing (DEH), Fort Lewis, WA; Robert Cory and Rusty Jordon, DEH, Yakima Firing Center, WA; Larry Ness and Robert Hoover, DEH, Fort Riley, KS: and Leon Howard, DEH, and CPT John Ciesla, Preventive Medicine, Fort Hood, TX. Wastewater sampling and/or analysis was performed by Richard Ray, Killeen, TX; Fran Swim, DEH, Fort Lewis, WA; Melissa Schlenker, Yakima, WA; Christopher White, Junction City, KS; Dave Haygood and K.C. Kunselman, Fort Hood, TX; Keith Smith, Jeff Pike, John Hollingsworth, and Pat Kemme, USACERL, Champaign, IL.

COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

CONTENTS

FIGURES

TABLES

EVALUATION OF ALTERNATIVES FOR SECONDARY TREATMENT AT CENTRAL VEHICLE WASH FACILITIES

1 INTRODUCTION

Background

Most major Army installations need to perform maintenance and repair on large numbers of tactical vehicles. An important element of vehicle maintenance is cleaning, including washing the exterior of the vehicles. The exterior of a vehicle must be clean to find any leaks or damaged parts, and to make necessary repairs. It must also be clean for transport from one installation to another or to travel within an installation cantonment area. (During wet weather, a tracked vehicle may carry 1000 lb* of mud back from the training area.)

The concept for Central Vehicle Wash Facilities (CVWFs), developed at the U.S. Army Construction Engineering Research Laboratory (USACERL) in the late 1970's, allows the exterior of tactical vehicles to be cleaned in an efficient and environmentally safe manner.[1] A CVWF consists of various structures for washing tactical vehicles and a wastewater treatment system for recycling the wash water. The recommended recycle treatment is primary sedimentation with floating oil removal, followed by intermittent sand filtration.

It was assumed that minimal resources would be available to operate and maintain the facilities. The treatment system had to be simple to operate, inexpensive to maintain, cost effective, and provide a discharge quality water for recycle. The secondary treatment had to be compatible with the specific treatment needs of CVWFs (i.e., be able to remove excess suspended solids, petroleum products, and organics that would not be removed in primary treatment). Processes that required constant monitoring, skilled operators, chemicals, large amounts of energy, and would otherwise be a resource drain on Directorate of Engineering and Housing (DEH) budgets were ruled out. Intermittent sand filtration was chosen as the most feasible process for secondary treatment.

Fort Lewis, WA, built the first successful CVWFs following the USACERL concept in 1980. The facilities consisted of drive-through washing stations and a recycle treatment system that used intermittent sand filtration. Figure 1 shows a flow schematic of one Fort Lewis CVWF, which is typical of the CVWF concept. In 1982, a second successful CVWF was built at Fort Polk, LA. The facility used lagoon treatment for recycling the wash water.

When Fort Lewis and other CVWFs were under design, research and development (R&D) funding to further develop and refine the USACERL CVWF concept was discontinued. USACERL was then instructed to prepare guidance to assist future CVWF planners and designers. In 1982 and 1983, draft Engineering Technical Letters (ETLs) were written to transfer the CVWF technology. That guidance was

*A metric conversion table is on p. 27.

[1] S.R. Struss, et al., *Preliminary Guidelines for Safe and Effective Use of Hot, High Pressure Washers for Maintenance Cleaning of Army Vehicles*; Technical Report N-138/ADA122762 (U.S. Army Construction Engineering Research Laboratory [USACERL], November 1982); Susan J. Bevelheimer, *Analysis of Usage Data for Central Vehicle Wash Facilities at Three Army Installations*, Technical Report N-89/04/ADA203520 (USACERL, January 1989).

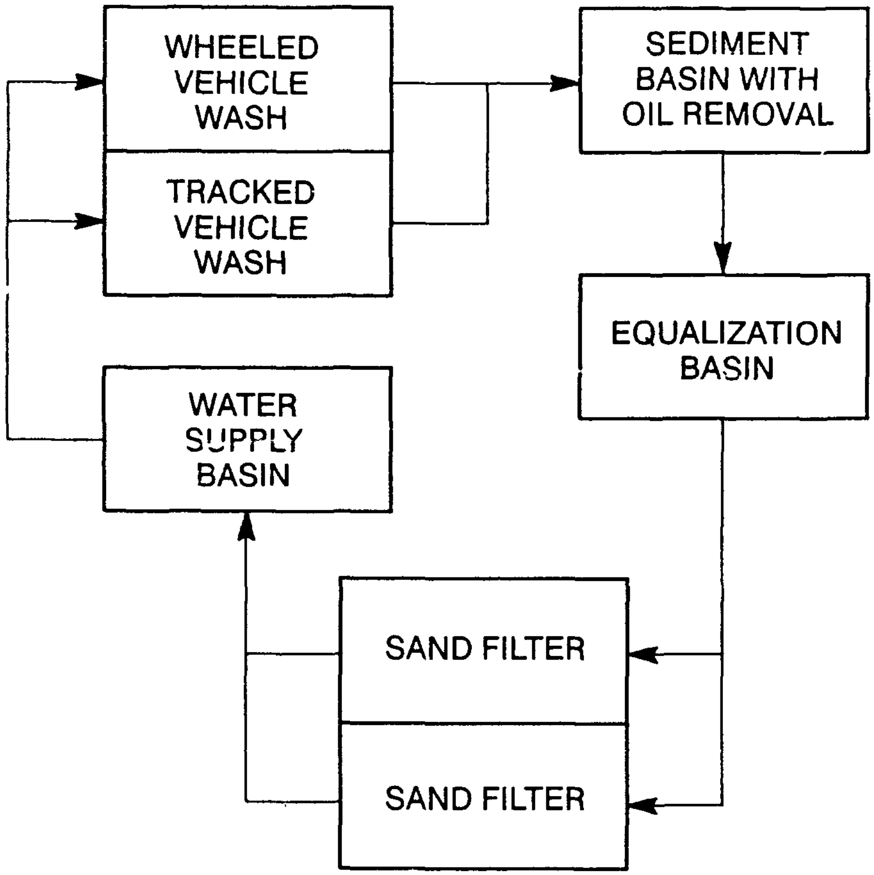


Figure 1. Flow schematic for a Fort Lewis CVWF.

limited to findings from incomplete USACERL investigations and a brief history of lessons learned at two successful, but completely different, CVWFs. Draft Technical Manual (TM) 5-814-9, *Central Vehicle Wash Facilities*, which is soon to be distributed, contains a consolidation of all CVWF design guidance contained in the ETLs, and incorporates lessons learned from several CVWFs now operational.

The Corps of Engineers designed and built several CVWFs during the mid-1980's using the draft ETLs as guidance. However, many Corps and architect/engineer (A&E) designers felt that the guidance for the secondary treatment design was too restrictive. Because of these concerns, new research was initiated to investigate alternatives for CVWF treatment systems.

Objective

The objective of this study was to evaluate alternatives or modifications to existing design guidance for CVWF secondary treatment.

Approach

Current design guidance for CVWF secondary treatment is limited to two types of treatment: intermittent sand filtration and lagoon These were the only two processes that met the selection criteria (i.e., able to remove excess suspended solids, petroleum products, and organics that would not be removed in primary treatment). To respond directly to the concerns of CVWF designers, the focus of this study was divided into three thrusts:

1. An investigation to maximize the recommended dosing rates for intermittent sand filters,

2. An investigation to confirm the effectiveness of lagoon treatment, and if possible, provide additional design criteria, and

3. An investigation of other alternative treatment methods not included in the design guidance. Resources for this project limited the third thrust to one alternative — constructed wetland treatment.

Mode of Technology Transfer

It is recommended that the findings in this report be incorporated into updates of TM 5-814-9 *Central Vehicle Wash Facilities.* A draft Engineer Technical Letter containing these findings will also be prepared by USACERL. Preliminary results of this study were presented at the Users's Group Meeting on Central Vehicle Wash Facilities held in September 1988, and at the User's Group Conference for Centralized Vehicle Wash Facilities held in May 1990. Final results will be presented at a future User's Group Meeting.

U.S. Army Corps of Engineers (USACE) Louisville District is the Mandatory Center-of-Expertise (MCX) for Central Vehicle Wash Facilities. Louisville District will ensure that the recommendations made in this report are considered and/or incorporated into all future CVWF designs. Future R&D efforts will develop an interactive computer program that will assist in the design of CVWFs.

2 EVALUATION CRITERIA

Following are descriptions of the criteria used to evaluate the treatment alternatives. Other than the treatment performance, the evaluations are largely subjective. They are based on observations by operation and maintenance personnel, and by USACERL personnel when on site. Treatment performance was evaluated quantitatively using water quality data generated by on-site USACERL studies.

1. Operational Requirements. What resources are required to operate the treatment system? Is any special training required for the operators? How much attention must the operator normally give to the treatment system?

2. Maintenance Requirements. What resources are required to maintain the system? What daily maintenance is required? What major maintenance actions can be expected? What is the experience at existing facilities?

3. Design and Construction Requirements. Will the design tax the expertise of either the designer or construction contractor? How do the design and construction costs compare to the other alternatives?

4. Treatment Performance. Does the treatment system produce water of a quality that will not be a hazard to the troops using the facility and that could be discharged to the environment if necessary?

3 INTERMITTENT SAND FILTRATION

Description and Existing Design Guidance

Intermittent sand filtration incorporates both physical and biological treatment. Constructed as a sand filter, the layer of sand physically removes contaminants from the water. Further, the filter is dosed intermittently. Dosing involves applying a predetermined amount of water to the sand and allowing it to completely percolate through the sand before a succeeding amount of water is applied. Intermittent dosing allows the full depth of the sand to be aerated and encourages a microbial growth around the sand particles. The microbial growth provides a biological treatment by removing dissolved organic material from the water.

Draft TM 5-814-9 contains the most recent design guidance for intermittent sand filters. The latest version has incorporated interim findings from this study, which were presented at the May 1990 User's Group Conference. A brief summary of the design parameters follows.

• The design daily loading rate is between 490,000 and 650,000 gallons per acre per day. Generally, the amount of clay in the soil washed off the vehicles determines the loading rate. High clay content means the suspended solids loading on the filter is likely to be higher, therefore a daily loading rate in the low end of the range is recommended

• Dosing frequency shall be three doses per day. Each filter, or isolated section of a filter (cell), receives a dose every 8 hours.

• Dosing rate, or flow to the filter, shall be 95 to 190 gallons per minute (GPM) per 1000 sq ft of filter surface. A dose shall be applied in 20 to 40 minutes.

• Filter media will meet the criteria shown in Figure 2.

The intermittent sand filters are always preceded by an equalization basin. Equalization is needed because flow from the wash structures fluctuates greatly. The basin is also needed for extended sedimentation of the wash water following primary treatment. While this study does not address design of the equalization basin, it is considered a secondary treatment structure.

Pilot Studies at Fort Lewis

Filtration experiments were conducted at Fort Lewis, WA, to determine if the recommended loading rates could be increased. The existing filters at the two main CVWFs were used for full-scale pilot studies. The surfaces of both filters at each of the facilities were partitioned to limit the usable filter area (Figure 3). The distribution piping was then altered so all water was directed to the partitioned areas. The area of each filter to be partitioned was calculated using actual water use data and the daily loading rates to be tested.

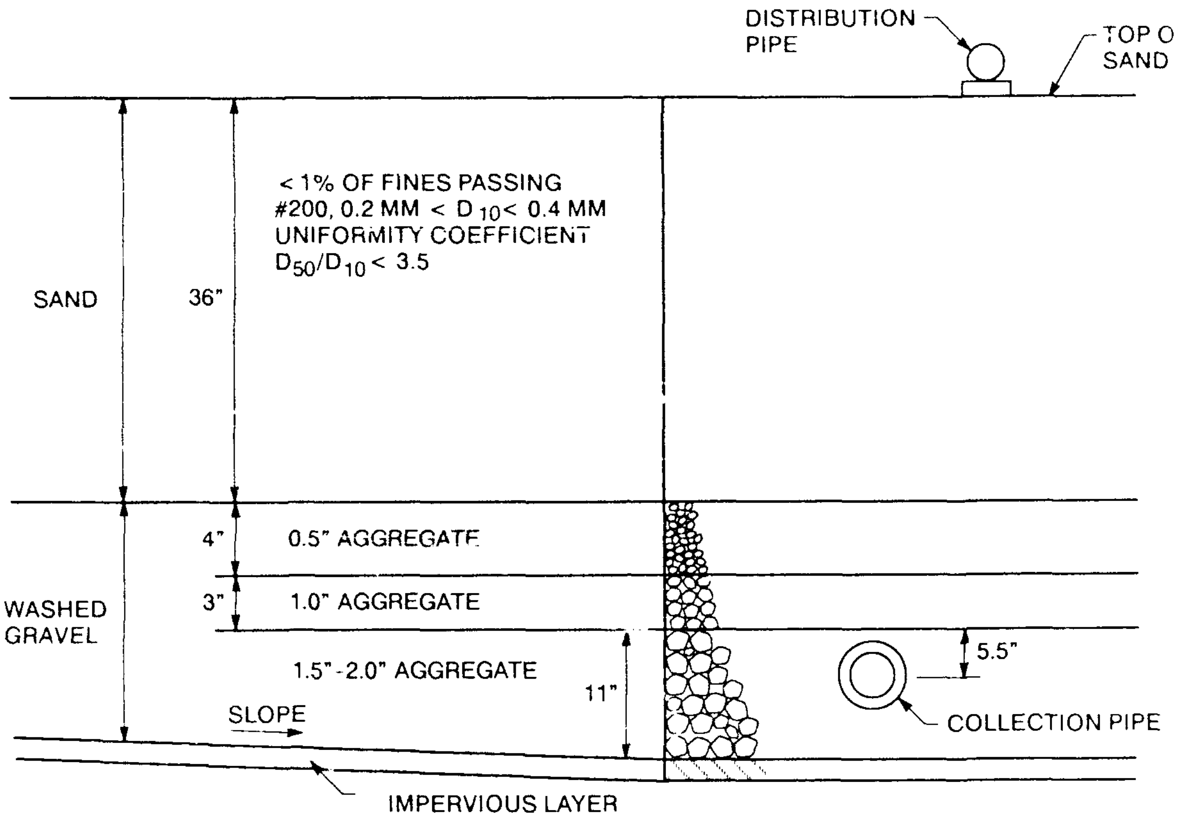


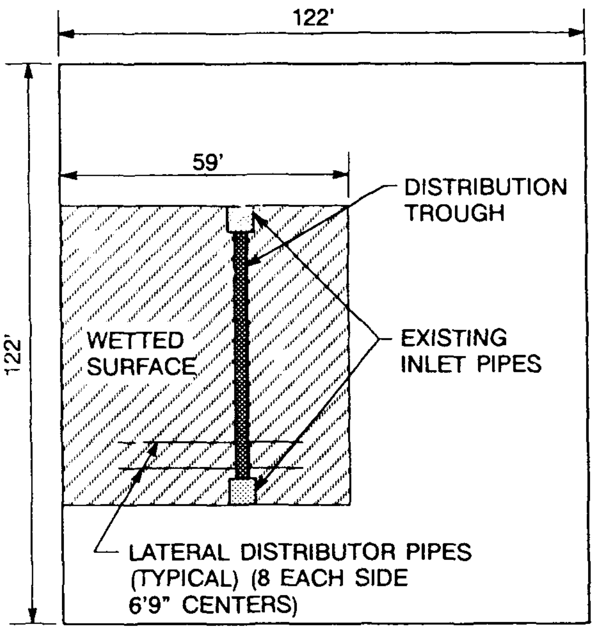
Figure 2. Media for an intermittent sand filter.

Three daily loading rates were tested at Fort Lewis: 650,000 gal/acre/day; 1,000,000 gal/acre/day; and 1,300,000 gal/acre/day. The filters at Fort Lewis were designed for a loading rate of 490,000 gal/acre/day. However, the number of vehicles washed and the amount of water needed at the Fort Lewis CVWFs is much less than predicted in the design analysis. That is why the partitioned areas used in the experiment are much smaller than the original filter surface area of 1/3 acre per filter.

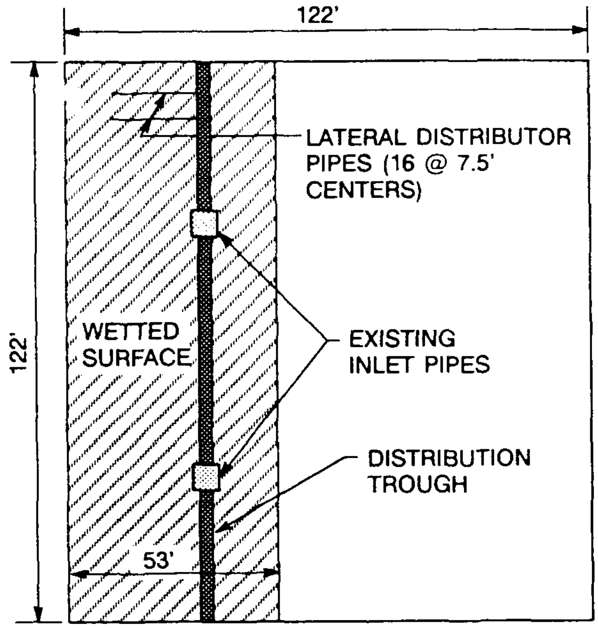
Vehicle soiling at Fort Lewis was consistently light. The soils in the training areas are sandy with little cohesive material. This type of soil is very easily removed from the vehicles and requires less water per vehicle cleaned than at most other installations.

Observations from the filtration studies follow.

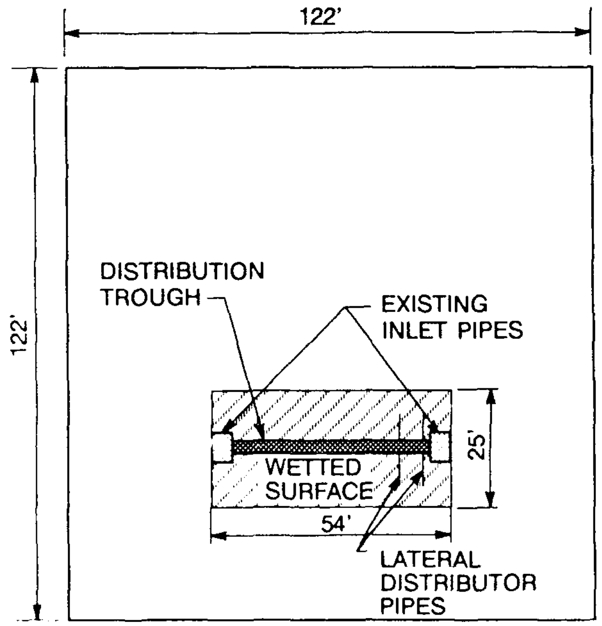
- The performance of the intermittent sand filters was never severely tested during the study. The water pumped to the filters from the equalization basin often was already discharge quality. There were three primary reasons for the low levels of contaminants in the equalization basin effluent. First, the sandy soil in the Fort Lewis training areas is easily removed from the wash water by sedimentation. Second, because the facility was designed for greater use, the equalization basin was somewhat larger than required. Third, because of large water losses due to leaks in the equalization basin liners, much of the wash water used was potable makeup water. Table 1 shows a summary of suspended solids (ss) concentration in grab samples obtained during the study to monitor filter performance.



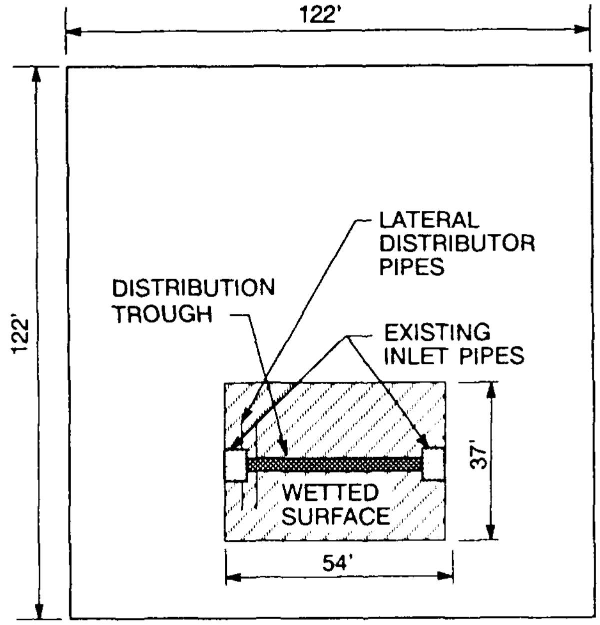
FORT LEWIS SOUTHWEST CVWF
FILTER #2 WETTED SURFACE AREA = 3010 SQ FT
DAILY LOADING RATE = 1,300,000 GAL/ACRE/DAY



FORT LEWIS SOUTHWEST CVWF
FILTER #1 WETTED SURFACE AREA = 6020 SQ FT
DAILY LOADING RATE = 650,000 GAL/ACRE/DAY



FORT LEWIS SOUTHEAST CVWF
FILTER #2 WETTED SURFACE AREA = 1340 SQ FT
DAILY LOADING RATE = 1,000,000 GAL/ACRE/DAY



FORT LEWIS SOUTHEAST CVWF
FILTER #1 WETTED SURFACE AREA = 2010 SQ FT
DAILY LOADING RATE = 650,000 GAL/ACRE/DAY

Figure 3. Partitioning of filters.

Table 1

Suspended Solids Removal

Sample Location	SS Concentration (mg/L)				% Removal	
	Influent		Effluent			
	Range	Average	Range	Average	Range	Average
SW Filter 1	7-24	12	3-19	9	-90 to 75	26
SW Filter 2	7-34	17	2-22	7	-57 to 82	48
SE Filter 1	7-63	22	1-7	3	57-98	82
SE Filter 2	4-53	18	1-12	3	25-98	77

- Before this study, the filter surfaces showed little or no crusted or matted material after 7 years of use. Some sections of the filter surfaces looked like they had never been wetted.

- The dose applied to the filter would pass through in about 2 hours. A water surge came from the filter about 15 to 20 minutes after the beginning of a dose application. A peak occurred in the effluent flow about 20 minutes after the initial surge.

- The suspended solids in the filter effluent varied greatly during the filtration of a single dose. The first water surge often had a higher concentration of solids than did the filter influent. The variation in the solids concentration for the effluent of a single dose seemed to be dependent on the velocity of the water through the filter.

- The water quality in the effluent was influenced more by the dosing frequency than by the daily loading rate. Several smaller doses per day came out cleaner than the same amount of water applied in 2 or 3 doses per day. Changing the dosing schedule from 3 doses per day to 6 doses per day seemed to minimize the effect of surging through the filter. Surging must be minimized for intermittent sand filtration to be an effective secondary treatment.

- Filter influent was generally homogeneous.

- Biological oxygen demand (BOD) concentration was less than 10 milligrams per liter (mg/L) for almost all influent and effluent samples.

- The filter effluent often had a green tint, indicating the presence of algae. The color was not present in the filter influent. However, volatile solids tests indicate that algae did not significantly contribute to the suspended solids in the filter effluent.

• The filter influent distribution system seemed to work very well. It consisted of a wooden trough feeding parallel distributions pipes. Influent water was pumped into the trough and flowed to the filters by gravity.

Monitoring Study at Fort Hood

The 2nd Armored Division (2AD) CVWF at Fort Hood went on line in 1987. That CVWF has three 1.1-acre filters designed for a loading rate of 650,000 gal/acre/day. Soiling conditions at Fort Hood are much more variable than at Fort Lewis. Some parts of the training areas have very clayey soil. During wet weather, tracked vehicles carry in hundreds of pounds of cohesive soil that is difficult to remove. Water use at the 2AD CVWF appears to be much closer to what was predicted in the design analysis than it was at Fort Lewis. Figure 4 shows a schematic of the 2AD CVWF.

USACERL began studies to monitor the performance of the filters in the summer of 1989. The monitoring study consisted of water quality testing before and after the filters, sand analysis, and flow analysis. Periodic water sampling and analysis occurred from March 1990 through August 1990. Table 2 provides a summary of water quality data obtained at the 2AD CVWF.

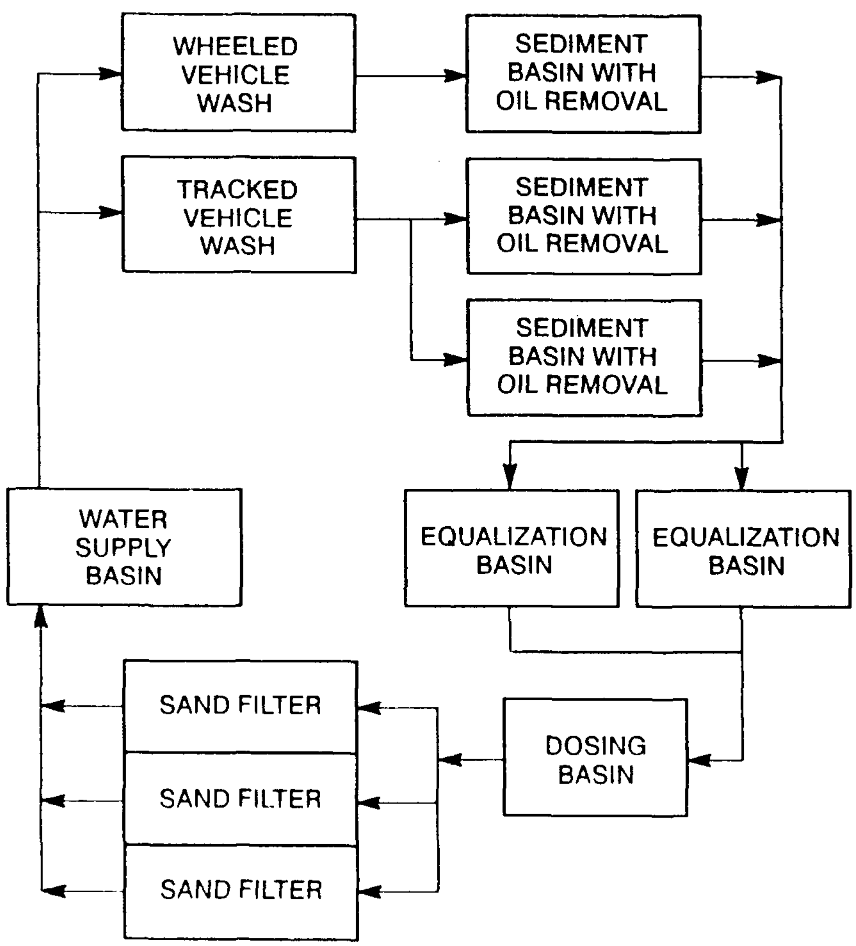


Figure 4. Flow schematic for the 2AD CVWF.

Table 2

Fort Hood 2AD - CVWF Water Quality Data

Parameter	Equalization Effluent		Filter Effluent	
	Range	Average	Range	Average
Suspended Solids (mg/L)	5 - 210	37	0 to 10	2
COD (mg/L)	2 - 34	14	0 to 15	5
Oil & Grease (mg/L)	0 - 0.4	0.1	0 to 0.4	0.1
pH	6.0 - 7.4	6.7	6.2 to 7.0	6.5

Observations from the monitoring follow.

- The surface of the filters became very crusty with little vegetation except algae. The crust was apparently caused by dissolved solids left by evaporation in combination with suspended solids deposited on the surface.

- The velocity of the water through the filters was much slower at Fort Hood than at Fort Lewis. A dose took several hours to pass through the surface. The dose would completely pass through the filters after 12 or more hours.

- Ponding on the surface of the filters due to slow infiltration has encouraged a growth of algae. This algal growth probably has further slowed the rate of infiltration.

- There was no evidence of algae in the effluent from the filters.

- Two of the motorized valves that directed water to specific filters were inoperable during the study. The automatic dosing system could not be used; the filters were dosed by operating the valves and pump controls manually.

- During the course of the study, a new program to allow troops to purge their petroleum transport tanks at the 2AD CVWF was initiated. This program had minimal impact on the quality of water in the filter effluent, though small amounts of emulsified oil (less than 5 ppm) passed through the filters. Purging of tankers was not allowed at the other CVWF at Fort Hood because the DEH Environmental Office was not confident that lagoons could effectively treat wastewater from the purging operation.

Monitoring Study at Yakima Firing Center

Yakima Firing Center is used as a maneuver and firing area by Fort Lewis and Army Reserve units. The Yakima Firing Centei CVWF was constructed soon after the Fort Lewis CVWFs and used approximately the same design. Vehicle soiling at the training ranges is more severe than at Fort Lewis. Use of the Yakima CVWF has been much greater than predicted.

The water quality throughout the recycle treatment system was monitored by USACERL. This study occurred between March 1988 and November 1988. Table 3 summarizes the results.

Observations from the monitoring follow.

• Deposition of solids was much greater on the filters at Yakima than on the filters at Fort Lewis. This is because primary treatment is inadequate at Yakima, and because of the unexpectedly large number of vehicles washed.

• After 8 years of operation, Yakima DEH is in the process of replacing the top layer of sand on the filters because of plugging.

Aberdeen Proving Ground Study

The CVWF at Aberdeen consists of a one-lane bath, final wash stations, and a treatment system almost identical to the Fort Lewis design. The facility is used primarily by the Ordnance Center and School for washing retrievers and retrieved vehicles that have been used for training exercises. The training area soils are mostly clay, and every vehicle brings a great deal of soil back to the wash facility. Severe suspended solids loading is present in the recycle treatment system.

Aberdeen DEH and USACE Baltimore District asked USACERL to evaluate problems with the treatment system. Some of the findings of that short-term study were appropriate for the evaluation of intermittent sand filtration, and are described in the following paragraphs.

Table 3

Yakima Firing Center CVWF Water Quality Data

Parameter	Equalization Basin		Filter Influent		Filter Effluent	
	Range	Average	Range	Average	Range	Average
Suspended Solids (mg/L)	3-532	49	15-331	122	0-49	7
Volatile Suspended Solids (mg/L)	0-140	12	5-50	19	0-30	1.9
COD (mg/L)	5-136	62	5-50	36	5-100	35
BOD (mg/L)	0-29	11	4-27	13	0-23	5
pH	6.4-9.9	7.8	6.8-8.8	7.6	6.2-8.7	7.4

• Severe problems with secondary treatment are caused by improper operation of the primary treatment. Large amounts of solids were pumped onto the filters, causing continuous ponding on the surface. Eventually the filters became completely plugged after only a few years of service. The top 8 in. of sand was replaced.

• When the ponding occurred, there was significant algal growth on the filter surface, contributing to the flow problems.

• After the sand was replaced, flow through the filters was restored, though percolation rates were somewhat slower than expected. Problems with the underdrain system may be causing the slow percolation.

• Filter effluent from the replaced sand showed some of the same flow and water quality characteristics observed at Fort Lewis. High concentrations of suspended solids were present at the beginning of a water surge that passed through the filter.

• The daily loading rates for the filters were much less than predicted in the design analysis. Actual loading rates were probably 300,000 and 400,000 gal/acre/day. At this location, a higher loading rate is not recommended.

• Inoperable filter dosing valves have prevented normal automatic dosing.

• One of the dosing pumps has lost significant pumping capacity, possibly because of the high concentration of solids that have been pumped.

Evaluation of Intermittent Sand Filtration

Operational Requirements

When the automatic dosing system is fully functional, intermittent sand filtration can operate with little attention. But when the automatic system is not functioning, filter operation depends on the initiative of the facility operators. Fort Lewis, Fort Hood, and Aberdeen have had problems with the automatic dosing systems. At all three installations, because of inconvenience or lack of training, the filters were not operated properly in the manual mode. To eliminate some of the problems with system downtime, it is recommended that each filter have a separate automatic control for dosing. Although it may add to project costs, a dosing tank in the filter system design is also recommended.

Improper operation of the primary treatment can lead to premature plugging of the filters. Inefficient primary treatment has a more significant negative effect on intermittent sand filters than on lagoons or wetlands.

Operation of intermittent sand filters requires much more training of the operators than the operation of lagoons or wetlands.

Maintenance Requirements

Experience at existing CVWFs is that all motor-operated valves are potential maintenance or repair problems, particularly those that are opened and closed often. This has been the case for filter dosing valves, as is evidenced by the large amount of downtime.

When filters become plugged, the top few inches of sand must be removed. The frequency of removal depends on how well the primary treatment structures are operated and maintained, but may be every 5 to 10 years. Sand may be removed 3 or 4 times until there is only 24 in. of sand left in the filter. Then new sand must be added to regain the original 36 in. depth. Removing the top layer of sand can be very labor intensive, depending on the design of the influent distribution piping.

Filters have very little solids storage capacity compared to lagoons or constructed wetlands, and solids removal is required much more often. Inefficient primary treatment will cause more frequent maintenance of the filter surfaces.

Most of the suspended solids removal occurs in the top 2 in. of the filter sand. Thus, storage of the removed solids is limited to pore space between sand particles in this top 2 in. layer. Filters have very little potential solids storage volume compared to lagoons or constructed wetlands.

Algae contributes to filter plugging. A treatment program is necessary to keep algal growth from plugging the surface. At Aberdeen, researchers initiated a program of periodic treatments with swimming pool chlorine chemical. However, research has not yielded enough information to give specific guidance for algae control. Further work is needed in this area.

Design and Construction

Intermittent sand filters are more difficult to design and construct than either lagoons or wetlands. The automatic dosing controls at existing facilities have not allowed enough flexibility to allow dosing to continue when a pump or valve is not functioning.

Construction costs for intermittent sand filters (according to USACE Fort Worth District) are at least 10 percent higher than for lagoons. The graded layers of aggregate are a significant portion of the construction cost.

The influent distribution systems constructed to date (other than those at Fort Lewis and Yakima) are very complex and costly. Gravity flow through distribution pipes is adequate.

Sand filters require less area than lagoons or wetland treatment.

Although no severe problems have occurred to date, blockages in the filter underdrain system could be very expensive to locate and correct. It is recommended that new designs include "cleanouts" on all lateral underdrain pipes, as have been installed at Fort Carson, CO.

Treatment Performance

All filters studied during this project provided an exceptional quality water to be recycled.

The results of the increased dosing study at Fort Lewis are inconclusive because the filters were never severely tested. However, it may be concluded that in areas where vehicles train in sandy soils, primary treatment of wash water will be very effective. Intermittent sand filters at these locations may safely be designed for loading rates of 1,300,000 gal/acre/day.

Experience at the Aberdeen CVWF indicates there may be situations where a daily loading rate as low as 400,000 gal/acre/day is necessary. When training area soils are very cohesive with a large fraction of clay, primary treatment cannot be expected to be efficient.

4 LAGOON TREATMENT

Lagoon Description and Existing Design Guidance

The lagoon is perhaps the simplest of all treatment structures. Treatment depends on a long detention time to allow sedimentation of suspended solids, and on suspended microorganisms to remove nutrients and organics from the water.

Lagoons are sized according to detention time. For secondary treatment at CVWFs, the required detention time is 14 days for peak hydraulic loading.

Fort Hood Study

The second large CVWF built at Fort Hood, used by the 1st Cavalry Division (1st Cav), has been in operation since February 1989. This facility uses two lagoons in series for secondary treatment in its recycle treatment system. Figure 5 shows a schematic of the 1st Cav CVWF. The vehicles washing at the facility train in the same conditions as the vehicles that wash at the Fort Hood 2AD CVWF.

USACERL began a study to monitor the performance and operation of the 1st Cav CVWF in the summer of 1989. Periodic analysis of the influent and effluent of each of the lagoons (cells) occurred from March 1990 through August 1990. Table 4 summarizes the water quality data at the 1st Cav CVWF during that period. Observations are listed below.

- The lagoons provided an exceptional quality of water for recycle.

- The flow was apparently short circuiting across Cell 1. The normal 7-day detention may have been as short as 1 day.

- Cell 2 provided little or no additional treatment. It appears that the designed detention time of 14 days is too long; 7 days or less may be adequate.

Evaluation of Lagoon Treatment

Operational Requirements

Very little knowledge or effort is required to operate a lagoon treatment system. Effluent structures must be checked for blockages. To check for leakage through a lagoon liner, the total volume of water in the recycle system should be monitored for losses.

Maintenance Requirements

No maintenance has been done to the lagoons at Fort Hood. Unless severe leaks appear in the basin liners, it is not likely there will ever be any significant maintenance or repair actions.

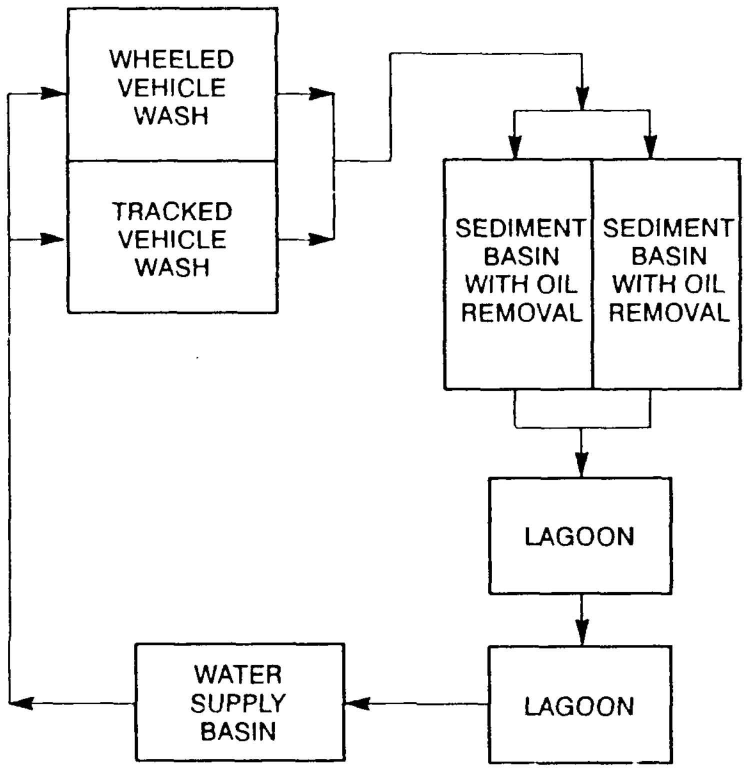


Figure 5. Flow schematic for 1st Cav CVWF.

Lagoons can be designed with enough solids storage capacity that, for all practical purposes, they may not need to be cleaned during the projected life of the facility.

Because of dissolved solids accumulation and evaporative losses, more makeup or replacement water will be required at CVWFs with lagoon treatment than at CVWFs with filters or wetlands.

Design and Construction

Requirements for design and construction of lagoons are minimal. Construction costs, generally dictated by the amount of earth moving required, are site dependent. Lagoons take up more area than intermittent sand filters, but less than wetland treatment.

Table 4

1st Cav CVWF Water Quality Data

Parameter	Primary Effluent		Cell 1 Effluent		Cell 2 Effluent	
	Range	Average	Range	Average	Range	Average
Suspended Solids (mg/L)	7-358	83	0-88	12	0-19	6
COD (mg/L)	15-75	30	5-35	20	4-32	19
Grease & Oil (mg/L)	0-0.7	0.2	0-0.4	0	0-0.3	0
pH	6.1-8.1	6.8	6.2-8.1	6.7	6.2-7.6	6.6

Treatment Performance

The limited experience at Fort Hood suggests that lagoons can provide an exceptional quality of water for recycle. However, the 1st Cav wash facility had a very closely controlled operation. It is not known how lagoon treatment will respond to occasional inputs of petroleum products or cleaning agents as have occurred at facilities with intermittent sand filters.

It is possible that as solids accumulate in the bottom of the lagoons, they may be brought back into suspension by severe wave action from storms, turnover caused by seasonal temperature changes, or by aquatic animals. Observations at Fort Riley, KS suggest that this may be happening in a basin there.

Feces from aquatic birds and mammals may also tend to degrade the water in lagoons. Lagoons are subject to algae blooms.

Because of the large, unshaded surface area, evaporation losses and dissolved solids accumulation may be greater for lagoons than for filters or wetlands. Though the 2AD CVWF at Fort Hood has been in operation longer, dissolved solids are already somewhat higher in the 1st Cav CVWF wash water.

5 CONSTRUCTED WETLAND TREATMENT

Description and Design Guidance

Several types of constructed wetland treatments incorporate overland flow, subsurface flow, and a variety of aquatic plants. The processes involved in pollutant removal within the wetland include: extended sedimentation, biological treatment, and filtration. Because the overland flow wetland is very shallow and has long detention times, it is ideal for sedimentation. Larger aquatic plants such as cattails and bulrushes provide an excellent surface area to support the microbial growth necessary for biological treatment. The slow velocity of wastewater through the wetland provides the opportunity for suspended and colloidal material to adhere to the surfaces of the aquatic plants, thus the wetland provides a form of filtration. Unfortunately, very little specific design or operational guidance is available for constructed wetlands since their use for wastewater treatment has a very short history. The guidance described in the next paragraph has been gleaned from a collection of papers published by Donald Hammer.[2]

Each wetland area or cell is usually configured as a long, narrow, shallow basin. Length was often about 330 ft from influent to effluent. Water depth was usually between 6 and 15 in. Loading rates were between 16,000 and 54,000 gal/acre/day. Detention times were kept at 6 to 7 days to allow enough time for biological assimilation of the nutrients in the wastewater. Initial planting of large plants such as cattails was at 3-ft intervals.

Fort Riley Study

The CVWF at Fort Riley serves a mechanized infantry division. The soils in the training area seem to be primarily silts and clays, and the soiling on the vehicles is average. The existing CVWF is a retrofit of a failed wash facility and a treatment system that had combined industrial wastewater with recycled wash water. Three of the four lagoons in the original treatment system were isolated for use only by the retrofitted wash facility. Figure 6 shows a flow schematic of the Fort Riley CVWF.

Because there was excess water treatment and storage capacity in the three-cell lagoon system, the water level in the first cell was allowed to drop. Eventually this cell, quite by accident, became one of the Army's first wetland treatment structures. The type of constructed wetland that evolved at Fort Riley was overland flow through rooted aquatic plants. The aquatic plants were primarily cattails.

The area of the Fort Riley wetland is about 5.5 acres. Assuming an average depth of 9 in., and a vegetation concentration of 20 percent by volume, the available treatment volume in the wetland is about 1.1 million gallons. According to the design analysis, the average daily flow was predicted to be 774,000 gal/day. The design loading rate on the wetland is 140,000 gal/acre/day and the detention time is 1.4 days.

USACERL conducted a study to monitor the effect this wetland had on water quality from March 1989 through July 1989. Table 5 shows a summary of the results of that study. Observations are listed below.

---

[2] Donald A. Hammer, "Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural," *Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment*, Chattanooga, TN, June 13-17, 1988 (Lewis Publishers Inc., Chelsea, MI, 1989).

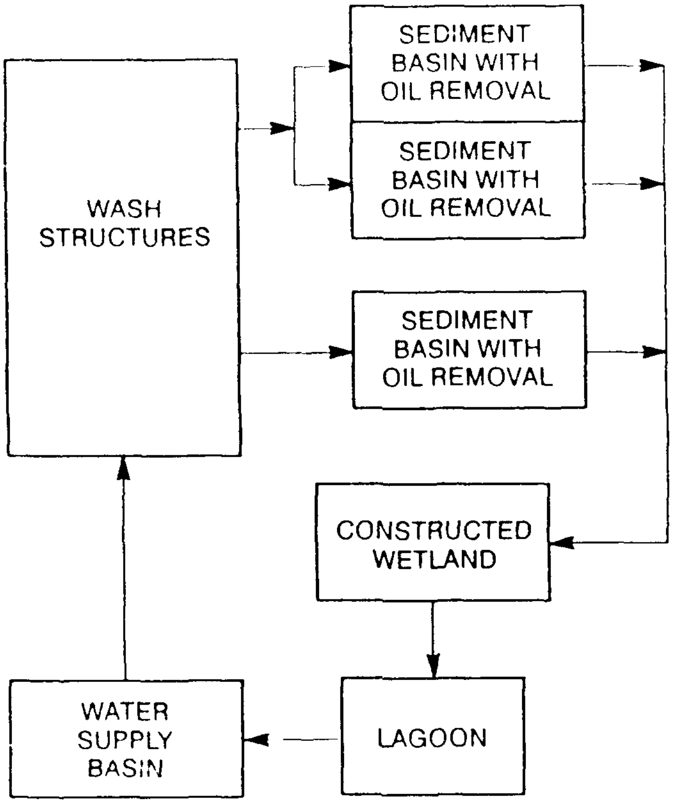


Figure 6. Flow schematic for Fort Riley CVWF.

Table 5

Fort Riley CVWF Constructed Wetland Treatment Water Quality Data

Parameter	Wetland Influent		Wetland Effluent	
	Range	Average	Range	Average
Suspended Solids (mg/L)	46 - 1124	259	0 - 75	12.2
Volatile Suspended Solids (mg/L)	6 - 159	37	0 - 73	7
COD (mg/L)	12 - 130	41	9 - 50	25
BOD (mg/L)	10 - 39	22	8 - 23	13
Oil & Grease (mg/L)	0 - 23	2	0 - 1	0.09
pH	7.8 - 8.6	8.1	7.3 - 7.9	7.6

• The effluent from the wetland was actually the highest quality water in the recycle system. The quality of water in the effluent of the two lagoons downstream of the wetland was normally worse.

• Floating debris tended to accumulate near the effluent structure of the wetland; after several years of use, the debris did not interfere with flow. In future applications of wetland treatment it is recommended that screens be used to prevent floating debris from entering the recycle detention basin.

• Although wetland literature mentions that mosquitoes may be a problem, researchers did not notice any problems with mosquitoes after working very close to the wetland.

• Despite the fact that suspended solids in the influent to the wetland were above 200 mg/L on many days, effluent consistently had less than 30 mg/L, and normally was less than 20 mg/L. Suspended solids concentration in the wetland influent was exceptionally high because of inadequate primary treatment at the final wash stations.

• Algae was not apparent in the wetland, nor in the wetland effluent samples. Algae was obvious in the effluent of the two lagoons downstream from the wetland. It has been observed at other wetland treatment locations that aquatic plants shade the water and prohibit algal growth.

• Several factors inhibited long term water quality at the Fort Riley CVWF. Water from the adjacent industrial wastewater treatment lagoon was often used for makeup water. Some unknown influences caused the water in the supply basin to be of much lesser quality than the wetland effluent. The suspected causes are: natural occurrences that disturb the bottom sediment in the basin, such as wave action, fish, aquatic animals, and turnover due to temperature changes. It is also suspected that leakage from the industrial lagoon was somehow infiltrating the supply basin. Chemical oxygen demand (COD) concentrations throughout the CVWF treatment system were abnormally high.

• Wetlands have become a very popular type of treatment. Politically, it is very desirable to construct new wetlands because of the positive environmental image. Further, because of the "no net loss" policy the Corps of Engineers is enforcing, constructing a wetland treatment system at a CVWF may be of benefit to another construction project where filling a small wetland area is necessary.

Evaluation of Constructed Wetland Treatment

Operational Requirements

Very little training or effort are required to operate a constructed wetland system. The operator will need to periodically check the wetland effluent structure screen to ensure that debris is not blocking the flow.

Maintenance Requirements

Other than periodically cleaning the effluent structure screen, a constructed wetland should require little or no maintenance or repair work. Because of the shallow water depth, leakage through the basin liner should not be a problem. Losses would be much less than in lagoons or other deep basins.

Deep rooted plants must be kept out of the wetland. At Fort Riley some deep rooted plants had to be cut off along the edge of the wetland, but no deep rooted plants have grown within the wetland.

Thus far, there had been no apparent need to remove live or dead vegetation from the wetland. Unless serious flow blockages occur, or aerobic conditions cannot be maintained, there should be no need to remove vegetation. However, long term maintenance requirements are not known.

Design and Construction

Design and construction of a wetland will be almost identical to construction of a lagoon. Because of the shallow depth and smaller volume required, earth work will be significantly less for a wetland than for a lagoon. However, planting cattails may be new to many construction contractors.

It is recommended that design criteria for new facilities be patterned after the Fort Riley wetland; a 9-in. water depth and a daily loading rate of 140,000 gal/acre/day. Though this loading rate may be conservative, further research is necessary to provide more accurate criteria.

The designer must allow for the water depth at the effluent structure to be variable. As solids and vegetation accumulate on the bottom, the elevation of the water surface must be raised to maintain an optimum depth and detention time.

If enough depth is allowed for sediment and debris storage, the wetland may never need to be cleaned out during the life of the facility.

Though removal of vegetation is not known to be a requirement, the design should allow for this maintenance to be done efficiently. The bottom of the wetland basin should be designed to support earth moving equipment, or the basin should be configured so that a bucket of a backhoe could reach any point on the bottom of the basin.

Treatment Performance

The constructed wetlands at Fort Riley provided an excellent quality of water, especially considering the inadequate primary treatment and occasional contamination from the industrial treatment system.

The constructed wetland has provided adequate treatment of slugs of suspended solids that have bypassed primary treatment. Wetlands may be considered best for excess solids removal because they are not prone to plugging as are filters.

It should be expected that a wetland will also adequately treat slugs of petroleum products that may bypass primary treatment. Wetlands should perform better than lagoons in this capacity, but not as well as intermittent sand filters.

Algae may not be a problem at constructed wetlands using cattails or bulrushes.

6 CONCLUSION AND SUMMARY

Conclusion

All three alternatives considered (intermittent sand filtration, lagoons, and constructed wetlands) are acceptable for secondary treatment at CVWFs.

Summary

Operational Requirements

All three alternative secondary treatments will function with little attention from the CVWF operator. However, if the automatic dosing system for the intermittent sand filters goes down (as has often occurred), system operation becomes a test of the operator's understanding and attentiveness. Operation of intermittent sand filters requires more operator training than the other two treatment types.

All three systems require proper operation of the primary treatment. Improper operation of the primary treatment can lead to premature plugging of filters and can negatively affect treatment performance of lagoons and constructed wetlands. Inefficient primary treatment has a more significant negative effect on intermittent sand filters than on lagoons and wetlands.

Maintenance Requirements

With proper design and construction, lagoons and constructed wetlands should require very little maintenance during the projected life of the CVWFs.(p 29) Constructed wetlands will have a screen at the effluent structure that will remove floating debris. This screen will have to be cleaned every few days by the operator.

Because of plugging, sand on the surface of intermittent sand filters will need to be removed periodically during the life of the facility, perhaps every 5 to 10 years. Inefficient primary treatment will cause more frequent plugging of the filters. It is suspected that algae contributes to plugging of filters. An algae control program is necessary to prevent premature plugging.

Many of the existing CVWF automatic filter control systems have experienced problems with motorized valves and other electrical equipment.

Design and Construction

Intermittent sand filters will be more difficult and more costly to design and construct than will lagoons and wetlands. Though there is little data to compare costs, it is expected that filters will be at least 10 percent more costly than lagoons. Costs for lagoons and wetlands should be approximately the same.

Treatment Performance

All three types of secondary treatment provide water that should be discharge quality in most states and would not be a hazard to the troops using the facility.

Intermittent sand filters should be best able to handle occurrences of unusually high suspended solids loading or slugs of petroleum products. Wetland treatment should adequately handle slugs of solids and petroleum products. Lagoons may minimally treat slugs of solids and petroleum products.

Lagoons may be subject to resuspension of settled solids due to environmental influences, and may be subject to algae blooms.

Design loading rates for intermittent sand filters and lagoons (as stated in the draft TM 5-814-9) may be changed as described in chapters 3 and 4, respectively. The Fort Riley constructed wetland should be used as a model for future use of constructed wetlands at CVWFs.

METRIC CONVERSION TABLE

1 acre	=	0.4047 hectare
1 ft	=	0.305 m
1 gal	=	3.78 L
1 in.	=	25.4 mm
1 lb	=	0.448 kg
1 ppm	=	1 mg/L
1 sq ft	=	0.093 m^3

CITED REFERENCES

Bevelheimer, Susan J., *Analysis of Usage Data for Central Vehicle Wash Facilities of Three Army Installations*, Technical Report N-89/04/ADA203520 (U.S. Army Corps of Engineering Research Laboratory [USACERL], January 1989).

Hammer, Donald A., "Constructed Wetlands for Wastewater Treatment: Municipal, Industrial, and Agricultural," *Proceedings from the First International Conference on Constructed Wetlands for Wastewater Treatment*, Chattanooga, TN, June 13-17, 1988 (Lewis Publishers, Inc., Chelsea, MI, 1989).

Struss, S.R., et al., *Preliminary Guidelines for Safe and Effective Use of Hot, High Pressure Washers for Maintenance Cleaning of Army Vehicles*, Technical Report N-138/ADA122762 (USACERL, November 1982).

Technical Manual (TM) 5-814-9, Draft, *Central Vehicle Wash Facilities*.

UNCITED REFERENCES

Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment, EPA/625/1-88/022 (U.S. Environmental Protection Agency [USEPA], Center for Environmental Research Information, September 1988).

Miller, I.W.G., and S. Black, "Design and Use of Artificial Wetlands," in *Ecological Considerations in Wetland Treatment of Municipal Wastewaters* (Van Nostrand Reinhold Co., NY, 1985) pp 26-37.

S.E. Huey Co., *Final Design Analysis for Washrack Pollution Abatement, Phase II, FY80 - MCA Project No.-269.3 Fort Riley, Kansas* (U.S. Army Engineer District, Kansas City, MO, July 1984).

USEPA *Report on the Use of Wetlands for Municipal Wastewater Treatment and Disposal* (USEPA, Office of Municipal Pollution Control, submitted to Sen. Q. Burdick, October, 1987).

USACERL DISTRIBUTION

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CERD-L
ATTN: CECC-P
ATTN: CECW
ATTN: CECW-O
ATTN: CECW-P
ATTN: CECW-RR
ATTN: CEMP
ATTN: CEMP-C
ATTN: CEMP-E
ATTN: CEMP-RT
ATTN: CERD
ATTN: CERD-C
ATTN: CERD-M
ATTN: CERM
ATTN: DAEN-ZCZ
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCE

CEHSC
ATTN: CEHSC-ZC 22060
ATTN: CEHSC-F 22060
ATTN: CEHSC-TT-F 22060
ATTN: DET III 79906

US Army Engineer Districts
ATTN: Library (41)

US Army Engr Divisions
ATTN: Library (14)

US Army Europe
ODCS/Engineer 09403
ATTN: AEAEN-FE
ATTN: AEAEN-ODCS
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (16)
21st Support Command
ATTN: DEH (12)
USA Berlin
ATTN: DEH (9)
Allied Command Europe (ACE)
ATTN: ACSGEB 09011
ATTN: SHIHB/Engineer 09055
USASETAF
ATTN: AESE-EN-D 09019
ATTN: ACSEN 09168
ATTN: AESE-VE 09168

8th USA, Korea
ATTN: DEH (19)

ROK/US Combined Forces Command 96301
ATTN: EUSA-HHC-CFC/Engr

USA Japan (USARJ)
ATTN: DEH-Okinawa 96331
ATTN: DCSEN 96343
ATTN: HONSHU 96343

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

416th Engineer Command 60623
ATTN: Facilities Engineer

US Military Academy 10996
ATTN: Facilities Engineer
ATTN: Dept of Geography & Environmental Engr
ATTN: MAEN-A

AMC - Dir., Inst., & Svcs.
ATTN: DEH (23)

DLA ATTN: DLA-WI 22304

DNA ATTN: NADS 20305

FORSCOM (28)
FORSCOM Engr, ATTN: Spt Det. 15071
ATTN: Facilities Engineer

INSCOM - Ch, Instl. Div.
Vint Hill Farms Station 22186
ATTN: IAV-DEH
Arlington Hall Station 22212
ATTN: Engr & Hsg Div

USA AMCCOM 61299
ATTN: Library
ATTN: AMSMC-IS

NARADCOM, ATTN: DRDNA-F 01760

TARCOM, Fac. Div. 48090

TRADOC (19)
HQ, TRADOC, ATTN: ATEN-DEH 23651
ATTN: DEH

TSARCOM, ATTN: STSAS-F 63120

USAIS
Fort Ritchie 21719
Fort Huachuca 85613
ATTN: Facilities Engineer (3)

WESTCOM
Fort Shafter 96858
ATTN: DEH
ATTN: APEN-A

HQ USEUCOM 09128
ATTN: ECJ 4/7-LOE

Fort Belvoir, VA
ATTN: Australian Liaison Officer 22060
ATTN: Water Resource Center 22060
ATTN: Engr Studies Center 22060
ATTN: Engr Topographic Lab 22060
ATTN: ATZA-TE-SW 22060
ATTN: CECC-R 22060

CECRL, ATTN: Library 03755

CEWES, ATTN: Library 39180

HQ, XVIII Airborne Corps and
Ft. Bragg 28307
ATTN: AFZA-DEH-EE

NAVFAC
ATTN: Division Offices (11)
ATTN: Facilities Engr Cmd (9)
ATTN: Naval Public Works Center (9)
ATTN: Naval Civil Engr Lab 93043 (3)
ATTN: Naval Constr Battalion Ctr 93043

Engineering Societies Library
New York, NY 10017

National Guard Bureau 20310
Installation Division

US Government Printing Office 20401
Receiving/Depository Section (2)

US Army Env. Hygiene Agency
ATTN: HSHB-ME 21010

Nat'l Institute of Standards & Tech 20899

Defense Technical Info. Center 22304
ATTN: DTIC-FAB (2)

324
03/91