United States
Department of
Agriculture

Forest Service

**Technology &
Development Program**

5100 Fire Management

0851 1809—SDTDC
September 2008

Comparison of Relocatable Commercial Vehicle Washing Systems

Comparison of Relocatable Commercial Vehicle Washing Systems

Joe Fleming, Mechanical Engineering Technician,

U.S. Department of Agriculture, Forest Service
San Dimas Technology & Development Center

San Dimas, California

September 2008

Table of Contents

Acknowledgements:

This project was funded by the Strategic Environmental Research and Development Program (SERDP), Project Number SI-1545. The Project is a joint venture between Montana State University (MSU), Bozeman, MT, San Dimas Technology and Development Center (SDTDC), and the U. S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Champaign, IL.

Note: The wash system contractors are listed alphabetically, which does not coincide with the Contractor numbers used in this report.

Acme Endeavors

All Clean Water Solutions

Breezeco

Little Red Hen LLC

S-K Environmental

ABSTRACT

Many land management activities on Federal, State, and private lands involve the movement of vehicles and equipment at off-road locations where seeds and spores can be picked up, transported, and transplanted great distances from their place of origin. When relocated to new areas invasive and nonnative species of plants and fungi can become established where the native ecosystem cannot coexist without being compromised. Some species of prolific plants can dominate new environments and upset the natural balance of plant life and wildlife to the extent that it will endanger other species and resources. These are called nonnative invasive species.

Plant seeds and fungal spores are often transported in the soil that is picked up by vehicles and equipment. Other times, seeds are picked up directly by undercarriage components that strike the host plant. Several contractors have developed systems for cleaning vehicles and equipment that could carry invasive or nonnative species propagules (seeds, for instance) into areas where they could disturb or destroy the native ecosystem. The intent is to reduce the amount of propagules that might be transported and thereby reduce the threat of infesting new areas. The use of such systems is required by Executive Order 13112, signed in February of 1999, pertaining to instances when the Forest Service is operating vehicles in unpaved areas among other activities.

The San Dimas Technology & Development Center (SDTDC) of the U. S. Department of Agriculture, Forest Service partnered with the U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC), Champaign, IL; Montana State University (MSU), Bozeman, MT; California Department of Forestry and Fire Protection (Cal Fire); and the El Dorado National Forest to evaluate a range of systems with respect to efficacy, economics, waste containment, waste disposal, and the viability of any propagules that were collected in the cleaning process. The effort was the result of a proposal by this team of MSU, ERDC, and SDTDC colleagues, to the Department of Defense, Strategic Environmental Research and Development Program (SERDP). SERDP funded the project (PN: SI-1545) in early 2007.

SDTDC took the lead role in developing the equipment, testing methods, and protocols used in the part of the study described here, while MSU led the effort to evaluate the viability of propagules post-cleaning. ERDC had the primary oversight role and Cal Fire provided the location as well as some of the vehicles, machines, and logistical support to make this study possible. The El Dorado National Forest provided local support for the project. Many of the contractors made contributions and suggestions that were also valuable.

We assembled a core crew of seven workers to assist with system-efficacy testing while MSU sent two students to assist us in evaluating propagule viability and recycling-system performance. The testsite was located at the State of California Cal-Fire Training Academy in Ione, CA (figure 1). We tested equipment from five washing contractors over a 6-week period (June 18, 2007 to July 27, 2007).

Figure 1—Ione location photo.

TEST OBJECTIVES

The purpose of this evaluation is to provide contracting officers from various government agencies with guidance on the parameters for contract washing systems. Often we find that the actual decision about what type (if any) wash station to order is usually made by an incident response buying team member who may be simultaneously told to do contradictory things: including to get good equipment, get low-cost contracts, abide by all environmental regulations and best management practices, and get it done quickly. When the decisionmaking process is left entirely to the contracting officers, or party in charge, without providing any definition of what a washing system should include, the default guidance to the contracting officer becomes cost. They very likely will hire the lowest cost contractor who claims to have a system and has an Emergency Equipment Rental Agreement (EERA) on file with the government. For most types of equipment, when a contractor is listed with an EERA, the equipment has to meet certain requirements that are measurable or notable. In some cases they are required to give proof of compliance to the contracting agency. These systems are an exception because we do not have national standards for portable vehicle-washing systems. As a result some contractors will propose that a pressure washer and a tarp is a functional system. Other contractors who may be more conscientious about the overall objectives, the environment, and the related regulations governing waste disposal, will have made a significant investment in their equipment, but it is impossible for them to compete with the low-budget contractors on a strict daily cost basis.

As we are still in the process of defining what characterizes a bona fide washing system we limited the range of systems tested to those we considered to have the potential to conform to the underlying needs. This resulted in selecting a range of units of varying cost and performance. For now, we have adopted the term “Type 1” to define systems that recover and recycle the majority of the washwater. Naturally, it is impossible to recover all of the water as long as the vehicles drive away wet. As this technology evolves we may set standards for several optional types of systems and assign type designations to them as well.

Our objectives for the Ione test were to evaluate reasonably priced Type 1 contract vehicle cleaning systems for the following:

- **Cleaning system efficacy -** The amount of debris removed from the vehicles and equipment over a certain time period, compared to the total amount of debris that could be removed from the vehicles.

- **Recycling system performance -** The ability of the contractor’s recycling system to process a known amount of soil and seeds and extract all particles greater than 100 microns.

- **Waste containment -** The contract system’s ability to contain the waste from the cleaning system.

- **Seed viability -** The amount of viable seeds remaining in the system waste compared to the known quantity of seeds that each system processed.

Note: The seed-viability testing was performed by a team from MSU, Bozeman, MT, headed by Dr. Lisa J. Rew; (Weed Ecology).

Test Protocol

We developed a protocol for evaluating the various systems and we used the same procedures and equipment for each contractor. We tested the cleaning systems in the same location on a paved helipad.

We used three types of vehicles from the Forest Service fleet to perform the tests :

Vehicle Type 1. Wildland fire engines (three; only two were used for test cycles).

Figure 2—Wildland fire engines.

Vehicle Type 2. Light-duty trucks (two) and sport utility vehicle (one).

Figure 3—Light-duty trucks and sport utility vehicle.

Vehicle Type 3. Caterpillar D6 High-Track bulldozer (one).

Figure 4—Caterpillar D6.

Our weekly routine was to set up and test the contractor's equipment on Monday, ensuring that all components were functioning. We would run Type-1 vehicles on Tuesday; Type-2 vehicles on Wednesday; and soil-and-clean the Type-3 bulldozer on Thursday. We started the MSU seed-viability and recycling-system tests on Thursday afternoon and we let the contractor's recycling system settle overnight before collecting the captured waste. Fridays were for cleanup and travel home.

Test Location

The Cal-Fire Academy has more than 5,400 acres located in the Sierra Nevada foothills approximately 40 miles southeast of Sacramento, CA. The terrain is mostly gentle hills with some level open fields. We chose the paved helipad as a good solid footing where we could set up all of the contractor wash systems as well as our washing and inspection areas. Use of the helipad helps to minimize the introduction of soil to the wash systems from sources other than the vehicles we were using. Since we were going to be tilting vehicles, jacking up axles, and removing wheels we wanted a firm and fairly level work platform and the helipad satisfied that requirement.

Course and Soil Classification

We laid out the test course in a cleared, open, and level field with little or no surface vegetation. The soil in the test area is described in a survey by the U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) as "very deep, well-drained soils formed… from basic igneous and granite rocks." The clay content usually averages 6 to 12 percent. The NRCS classification report is included as appendix 2.

TEST CYCLES

The wheeled vehicles had somewhat different soiling-and-cleaning cycles than did the bulldozer, due to the operational and physical differences between the different types of machines. The entire soiling-and-cleaning process for each vehicle type is described in detail below.

Type 1 and 2 Wheeled Vehicle: Test Course

We would drive the wheeled vehicles through a fabricated mud bog and then 2.75 times around a figure-8 course before returning them to the washing area on the helipad (figure 5). We know that it is very hard to control multiple natural and human-induced variables simultaneously so we tried to keep some of the human inputs, such as driving speed and course tracking constant, but our results seem to suggest that we may have experienced some form of boundary creep with respect to speed and tracking. We cannot know for sure how much variance there was since we did not have active speed and position monitoring.

Mud Bog. The mud bog was created by plowing a shallow trench 12-foot (ft) wide and 50-ft long with a maximum depth of 1 ft. We placed a heavy-duty tarp in the trench, and filled it with loose, excavated soil. We then used a Cal Fire watertruck to saturate the soil in the trench. We would recondition the mud bog between test periods for each of the different vehicle types by adding soil and water until it was saturated.

Figure-8 Section. After passing through the mud bog we drove the vehicles around a figure-8 course that was approximately a football field long (300 ft) and 100-ft wide. We loosened the soil in the figure-8 area with a roadgrader scarifier after each series of 18 soil-and-wash cycles for the Type 1 and 2 vehicles. In the early morning prior to running a test series with Type-1 or Type-2 vehicles, we applied a full load of water from a 3,000 gallon water truck to the figure 8. As the test progressed, typically after about 9 cycles, the figure-8 section would start to dry out somewhat and we would spray another 3,000-gallon (gal) load of water on the course. The lap distance around the figure 8 was approximately 761 ft and the distance from the helipad to the test course was approximately 1,254 ft. The road between the course and the helipad has a crushed-gravel surface. A trip from the helipad to the test course, including one pass though the mud bog and 2.75 laps around the figure 8, constituted the test distance.

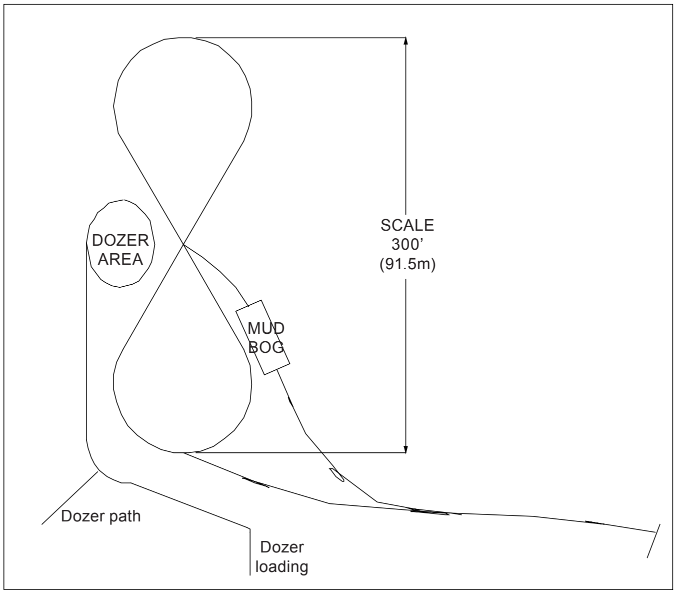


Figure 5—Figure-8 course drawing.

Type 1 and 2 Wheeled Vehicle: Wash Cycles

Each cycle of soiling-and-cleaning wheeled vehicles is outlined below:

Step 1. Drive through the mud bog at 10 to 15 miles per hour (mph).

Step 2. Enter the figure-8 course at the intersection and drive 2-3/4 laps around at 10 to 15 mph before exiting the course and returning to the washing area on the helipad.

The first two steps typically took about 5 minutes including the drive to-and-from the wash area.

Contractor Wash. Drive onto the contractor's wash-containment pad and allow up to 5 minutes for cleaning. During this time the vehicle is moved at the direction of the contractor if they desire. Soil removed here is "credited" to the contactor.

NOTE: We noticed early in the testing that if you turned the front wheels lock-to-lock it would often expose a significant amount of debris that might have otherwise missed. Some of the contractors were aware of this and used the wheel-turning procedure to better access hidden debris.

Post Wash. Drive onto our washrack (Hydropad®) and rinse further, concentrating on hard-to-reach areas and places that are often missed. This step typically took another 5 minutes but there was no time limit. Soil removed here is counted as "missed" by the contractor wash.

Step 3. Return to the course and repeat.

We ran 18 cycles of each wheeled-vehicle type through the course for each contractor and collected the soil and debris from both the contractor's wash containment and our second wash separately.

FINAL CLEANING

After the 18 daily soiling-and-cleaning cycles, we ran each vehicle once through a more meticulous, two-step cleaning and inspection process. All of the final cleaning phases were performed using fresh hydrant water and a pressure washer with a selection of spray nozzles. All material removed here was considered "missed" by the contractor as well.

Inspection Ramp

We built a 20-ft-long, 2-ft-wide, 18-in-high ramp that we could drive one side of the vehicle onto to get better access and view of the undercarriage. Raising each side of the vehicle separately allowed us to clean and inspect more meticulously without compromising safety. The ramp was made out of solid 6-in-square by 8-ft-long landscaping ties that were strapped and bolted together. See figures 6 and 7

Figure 6—Cleaning ramp photo.

Figures 7—SUV engine on inspection ramp.

Teardown

After cleaning each side of the undercarriage we put the vehicles over an adjacent containment mat and removed the wheels to get better access where debris could still be found on spindles, brake calipers, brake drums, springs, and between dual wheels. The containment mats for both the teardown and the inspection ramp were overlapped beneath the ramp with a downhill pitch toward the Hydropad®. During this phase, we raised the hood, removed battery covers, dropped the tailgate and lowered the spare tire, as applicable to the vehicle. All material removed here was considered "missed" by the contractor as well.

We collected debris from the final cleaning phases in dewatering bags and by pumping liquid waste through the same system we used for the more routine rinses that followed the contractor's wash cycle.

A diagram of our cleaning waste-recovery process is shown in figure 8.

Type 1 and 2 Vehicle: Debris Collection (Contractor). We noticed that each contractor tried to remove the heavy solids before pumping them through any filters. The first stage of solids separation is always right on the containment pad or in a sump that the pad drains into. We provided dewatering bags and support stands so the contactors could shovel the heavy solid waste from their pad directly into the bags. We tagged the bags and identified the contractor, vehicle type, and date. We used water-resistant yellow Tyvek® tags to distinguish samples taken from the contractor's system and green tags to identify debris removed from our subsequent washes. We zip-tied the dewatering bags to close them.

For these tests, each contractor used freshwater for all of the cleaning and none was recycled. We pumped all of the liquid waste from the contractor's containment pad to a 300-gal settling tank (described in more detail later). The wastewater from this settling tank was filtered to 100-micron particle size and then pumped into a dedicated 1,500 gal folding tank for further settling. We let the water settle overnight and used floating pool-

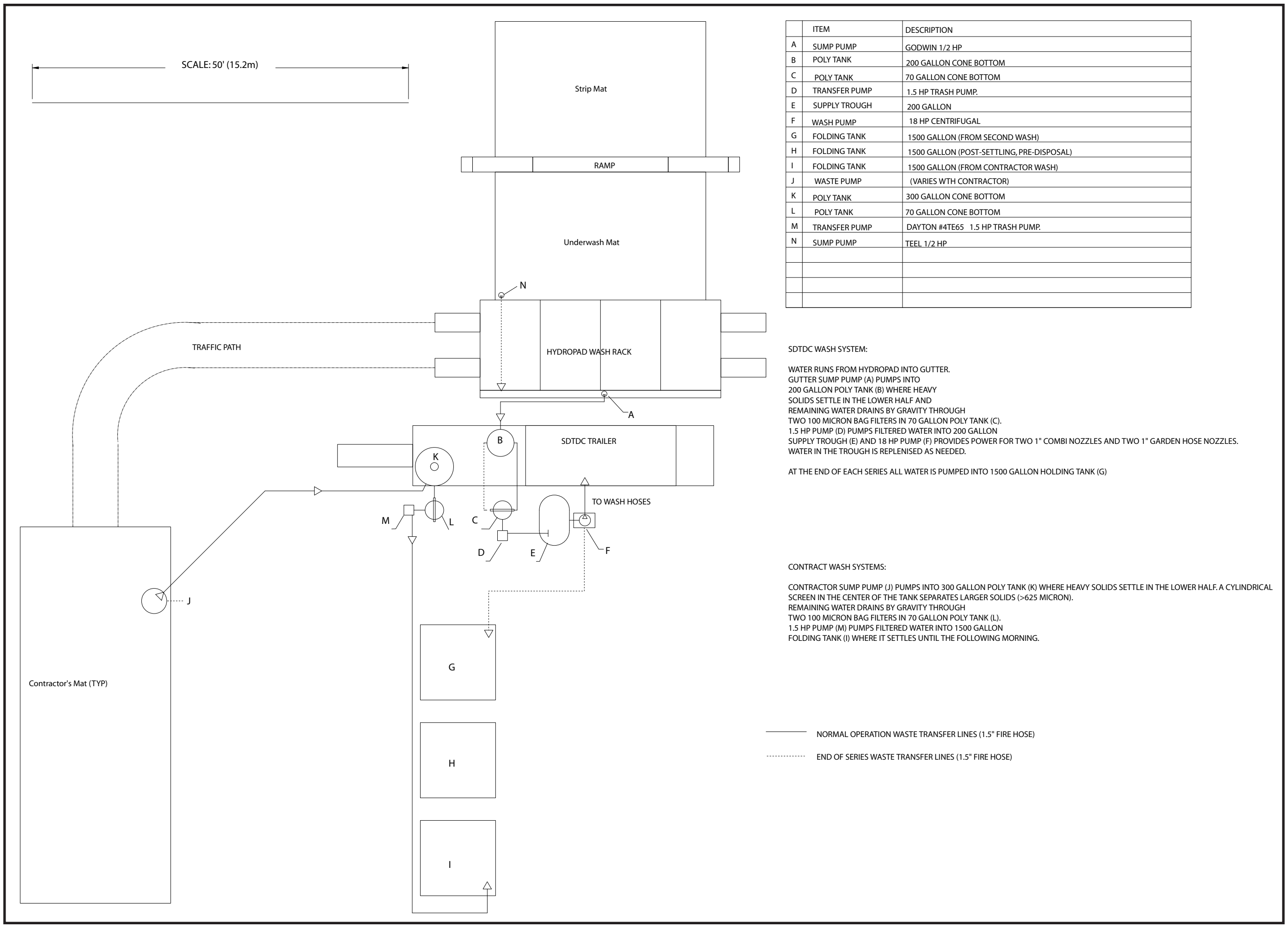


Figure 8—Waste recovery drawing.

skimmer pumps to remove water from the top down the following morning. The wastewater was put in a separate holding tank for disposal. We then “mucked” out the 1,500-gal holding tank. Our crew vacuumed or shoveled out the residual sediment and dumped it into dewatering bags. All of the bags we used to collect solid and liquid waste were tagged with the contractor’s name, vehicle type, and date.

We recorded sediment retrieved only from the primary 1,500 gal holding tank but we also saved liquid samples from the final holding tank for each contractor.

Type 1 & 2 Vehicle: Debris Collection (Investigator). We set up a secondary rinsing station where vehicles would drive onto our Hydropad® following the contractor’s wash. The Hydropad® is a commercially available washrack designed specifically for cleaning vehicles and equipment. We used low-pressure water, 60 to 80 pounds per square inch (psi), through garden-hose nozzles and 1-in combination fire nozzles to remove as much remaining debris as we could reasonably access without taking too much time. We recycled water for the secondary rinse, filtered it to 100 microns, and added freshwater as necessary to compensate for overspray, residual water on vehicles and evaporation. Our secondary rinsing system is diagramed in more detail in appendix 4.

We collected the debris from our rinsing station in a similar fashion to the contractor, though we used a smaller 200-gal settling tank for the first stage of particle separation. We drained water from the upper half of the settling tank and filtered it though 100-micron filter bags. At the end of each test period we pumped the filtered wastewater into a 1,500-gal holding tank to settle overnight. We used the same procedure for collecting residual sediment as we did with the contractor's residual. We did not use flocculent to accelerate settling.

Type-3 Vehicle (Bulldozer): Test Course. We used an area near the intersection of the figure-8 course for the bulldozer workout routine (figure 5). We sprayed the area with approximately 700 gal of water, 1 to 2 hours before starting. Our bulldozer "workout" regimen described below included plowing, back-dragging, ripping, pivoting, and moderate-speed traversing.

- Drive the dozer from the loading area to the workout area in second speed, high throttle. Once in the workout area, change to first speed and three-quarter throttle.
- In the workout area, drop the blade and push up a pile of soil until the tracks start to slip.
- Raise the blade over the pile and then reverse, dragging the pile back. Repeat.
- Drop rippers and drag for a short distance forward, then raise the rippers, drop the blade, and reverse over the same area.
- Return to the middle of the workout area and rotate forward with the right side-track locked for 360 degrees. Repeat rotation with the left side-track locked.
- Rotate in reverse for 360 degrees with the right side-track locked and repeat with the left side-track locked.
- Return dozer to the trailer in second speed, high throttle and load onto trailer. Sweep away any soil that fell from the dozer onto the trailer but do not remove any soil from the dozer. Return to helipad.

Type-3 Vehicle (Bulldozer): Wash Cycles. We granted the contactors discretion over how they wanted to wash the bulldozer; either loaded on the trailer or directly on their washing pad. Their choice was driven by the nature of each equipment array, as well as their past experience with similar equipment. We let them use any tools at their disposal and we would move the dozer back and forth at their request.

First wash (cleaning) cycle: We allowed each contractor 1 hour to remove as much soil as possible from the bulldozer, noting the number of people working and the amount of time spraying with wands or nozzles they would normally use. During the first 1-hour wash we did not credit the contractor with any soil that was removed from the bulldozer but remained on the trailer.

We cleaned the contractors wash pad completely after the first attempt at cleaning the bulldozer and collected all of the debris.

Second wash (cleaning) cycle: After the first cycle our crew joined with the contractor's crew and we used all available tools including our pressure washers and 1-in combination nozzles to remove any remaining soil. We put the machine back on or over the contractor's containment pad for the second cleaning attempt. We moved the machine as necessary to access all areas of the machine including all parts of the blade, rippers, and tracks. There was no time limit on the second attempt and we continued washing and inspecting until we did not see any more debris. The second attempt typically took another hour with an additional two to four crewmembers as well as the contractor's crew.

Note: *Even when the dozer appeared to be completely free of debris while wet, we would always find a little more once it dried, but a very small and insignificant amount as a percentage of the total. We never attempted to collect debris remaining after the second washing attempt since it seemed we would never get it totally cleaned even after three attempts and there was not enough time to wash and dry the machine three or more times. The residual debris was virtually invisible when the machine was wet and therefore we would no longer see it once the machine was wet again. We made the decision not to clean the machine more than twice per contractor as a matter of practicality and we will never know exactly how much debris was remaining on the machine beyond that, but we speculate it did not amount to enough that it would change the results by even one tenth of 1 percent. Still, we are aware that even a few grams of plant propagules could cause the start of an infestation.*

Type-3 Vehicle (Bulldozer): Debris Collection (Contractor). We did not screen or prefilter any of the wastewater from the bulldozer washing cycles. Most of the debris was put directly into dewatering bags as it came off the machine or the contractor's cleaning pad. We pumped all of the wastewater into a dedicated 1,500-gal holding tank and let it settle overnight in the same manner as we did with the Type 1 and 2 vehicles. We then collected the residual sediment in the same manner as we had for the other vehicles by pumping the top water off and putting the sediment in dewatering bags.

Type-3 Vehicle (Bulldozer): Debris Collection (Investigator). We used the same method described above for collection of debris from the second cleaning cycle. We bagged and tagged all solids and pumped all liquid waste into a separate 1,500-gal holding tank to settle overnight. We used floating pool-cover pumps to draw the settled water off the top of the tanks and then collected the residual fines using wet vacuums and shovels.

Wastewater disposal. We stored the remaining water that had been pumped from the top of the settling tanks into another 1,500-gal holding tank. At the conclusion of the test series for each of the first two contractors we would pump the remaining wastewater through a 50-micron cartridge element and then through a 5-micron oleophilic element to remove any oil or hydrocarbons. The 50-micron and 5-micron elements never came close to being clogged even though turbid water was still passing through them. After final filtration the water was trucked back to the test area and sprayed on the ground.

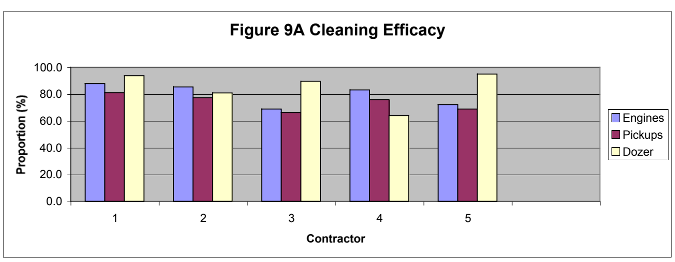
Our water samples taken after the first two contractors did not show any visible signs of oil contamination and since all of the wheeled vehicles had been washed 36 times by the time the first two contractors were finished we decided it was not necessary to filter the wastewater. The oleophilic elements are rather expensive and in this case we felt they were not necessary. Instead, we set oil-absorbing pads on the water surface in the holding tanks just to be sure, but we did not notice any oil or grease collecting on the pads.

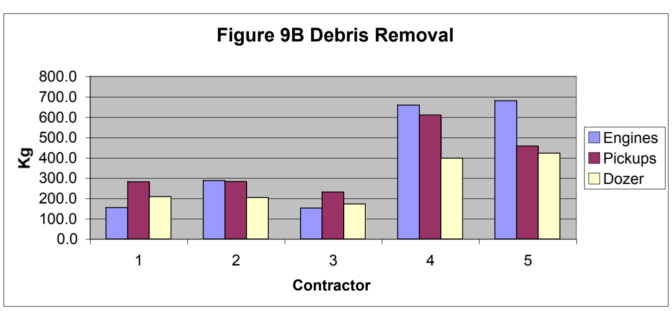
GENERAL REVIEW

All five systems tested in Ione were fairly successful at removing the majority of debris from the vehicles and heavy equipment. However, even the most effective system could not remove more than about 88 percent of the debris from the wheeled vehicles and the average proportion of removal was around 77 percent. If we had allowed more time, the results would likely have been better but we decided to limit the vehicle washes to 5 minutes each to reflect fire-incident conditions. For the bulldozer we allowed a full hour for the contractors to clean it, and while some of them got better than 90 percent of the debris in that timeframe, we spent another hour cleaning it with five or more people and still did not get 100 percent of the remaining debris.

Cleaning Efficacy

Figures 9a and 9b show what each contractor removed from each vehicle type and what our crew removed afterward. The difference between the proportion removed and 100 percent is what our crew removed afterward. You will note that as the test progressed the vehicles seemed to pick up more debris from the same course. We believe that the repeated tilling and driving over the course broke up some of the larger soil clumps to where they could more easily adhere to the vehicles. The more pulverized soil also created more of a dust cloud and we had to increase the amount of water we were using for dust abatement as the test progressed. Therefore the later contractors, who may have recovered a lower percentage of debris from the vehicles, had a much larger amount of debris to remove and in some cases almost five times as much.





Figures 9a and 9b—Contractor efficacy chart.

Water Usage

Although many of the contractors will provide all of the water for their washing system, there are cases where water is scarce, so we looked at the actual water use by each contractor on a per-wash basis. Some contractors have made the point that water recycling ends up being more costly than it's worth since it requires a lot of additional equipment and if the recycled water is still somewhat contaminated it can cause premature failure of pumps, valves, and nozzles. Even if water is in abundant supply it all has to be filtered to the point where it contains no invasive plant propagules before disposal. All wastewater must be contained and disposed of in accordance with the provisions of the Clean Water Act and any additional requirements of the water resource authority having jurisdiction for a given area.

We tested the contractors spray bars and wands individually prior to testing to see their performance. In some cases the systems did not deliver what was expected, so we made note of the actual output and proceeded to test. We had an observer timing the entire wash process, noting how long the spray bar(s) and wands were used. There were brief periods when a wand would not be spraying for a couple of seconds while the operator inspected an area, but generally the wands would spray whenever they were held and the underbody spray bar was off. We also estimated water usage by the level of recovered water in the portable holding tanks, but that does not take into account overspray, evaporation, and water that is carried off by the vehicles. Our water-use estimates by time and flow rating do seem consistent with the amounts recovered in the holding tanks, with some allowance for over spray, leakage, etc**.** Figure 10 lists water usage by contractor.

Note: *Water use represents only the amount of water that was sprayed onto the vehicles. Since all of the systems tested have containment, recovery,* *and recycling systems, this does not equate to wastewater that would actually have to be disposed of at a field site where recycling was practiced.*

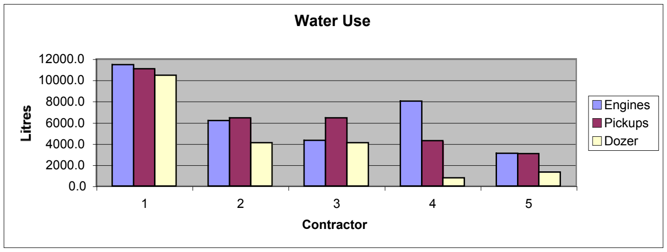


Figure 10—Water use by contractor.

Wastewater

We collected water samples from the settling tanks after they had settled overnight. The purpose was to get an estimate of the solids still suspended in the wastewater when we disposed of it. The samples were analyzed for suspended solids and turbidity by Accurate Testing Labs, LLC, in Coeur d'Alene, ID. Suspended solids ranged from 1,460 to 8,320 milligrams per liter. Any nonbuoyant suspended solids in the holding tank water were most likely below the 1-micron size since anything larger would have settled after 12 hours. Since we did not record the water use and wastewater amounts from the secondary and final cleaning phases, we did not add the suspended solids to the recovered waste amounts for determining efficacy.

Process Rate

We limited the contractors to 5 minutes per wash cycle for the wheeled vehicles and 1 hour for the bulldozer. Process rate is very important when you have many vehicles that all need cleaning at more or less the same time and if the wash cycle takes too long many drivers and operators often bypass the wash cycle because of a backlog of equipment waiting to be washed. Excessive delays cost in labor hours for the drivers, operators, and engine crews as well as fuel and morale.

The Forest Service has adopted a maximum average process time for wheeled vehicles in some regions. The interim standard for Region 1 (MT, ND, ID, WY, SD) requires that any wash system used on an EERA be capable of washing wheeled vehicles in no more than 5 minutes per vehicle on an average of 10 vehicles. We adopted the 5-minute limit for wheeled vehicles in our testing in Ione. Occasionally a contractor would run beyond the 5-minute mark, but we made note of that and stopped them as soon as possible afterward. We also note that the number of personnel employed in the washing varied from two to five, another variable that was not controlled here. Those who used a larger number of personnel appear to have taken less time per vehicle, which seems logical.

Figure 11 compares the five systems with regard to the average process rate per vehicle.

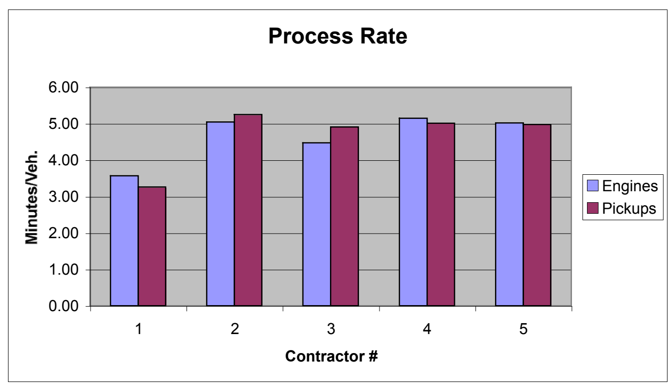


Figure 11—Process rate.

Cost

One of our primary objectives in this effort is to determine, as best possible, the value of various systems with regard for cost. What is the "best bang for the buck?"

The percentage of debris removed is presumably proportional to the percentage of invasive species propagules removed, so one would think that would be the key issue. But when the soil loads on the vehicles vary a great deal and the time limit to clean the vehicles off remains constant, we cannot say that the removal percentage alone is a fair gauge of system efficacy or value. In the field, it is likely that some contractors would elect to clean a vehicle beyond our arbitrary 5-minute requirement. Since it can take as little as one propagule to start an infestation, you have to wonder what the value difference between 95-percent effective and 65-percent effective really is. Mathematically, of course, there's a simple answer but it does not address the real question. True, the additional remaining soil may well hold more seeds, so it may be a proportional issue, or it may not. Containment of the soil and debris removed is also important if the goal is to prevent spread of invasives, and not just to clean vehicles.

Beyond the value of efficacy between one system and another, we still need to determine the lower threshold where a system might be considered worthless. At this point we do not have a clear answer but other phases of this project are still in process and we may be able to get some answers upon their completion. Still, we will have to combine and prioritize the following factors to make a fair and objective value rating for any system:

- Cleaning efficacy.
- Containment ability.
- Waste treatment and disposal.
- Additional support required (water, power, etc).
- Deployment cost.
- Daily cost.
- Process rate.

Figure 12 gives a comparison of the five different systems in terms of total cost to run the test at Ione. Some contractors were stationed within a few hours of Ione while others had to travel for days to get there. Some carried all of their equipment in light-duty trucks while others needed heavier vehicles like a flatbed semitrailer, forklifts, or multiple-cargo trailers. We did not factor in the initial cost of bringing the contractor's equipment to Ione in cost figures 12 and 13, instead we used their daily rate for EERA rental divided by 5 days; one for set-up, 3 vehicle-washing days, 1 for cleanup and teardown.

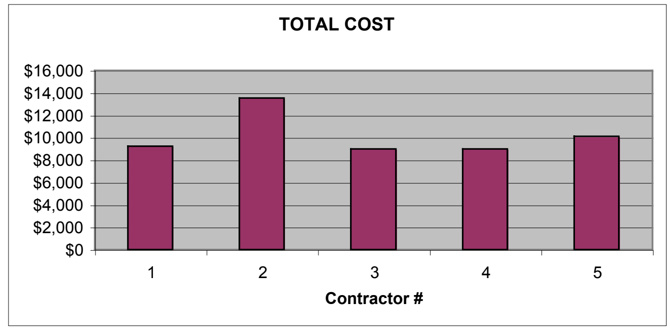


Figure 12—Total cost.

Figure 13 shows a cost comparison of the daily rates without any travel or lodging expenses. This is typically what the contractor would charge on an EERA.

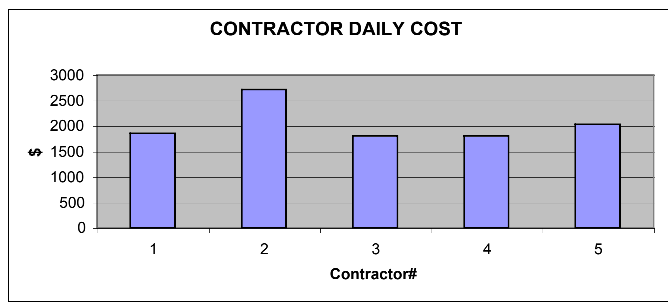


Figure 13—Daily cost.

Figure 14 compares cost with regard for cleaning efficacy in terms of dollars spent per average percent removed from all three vehicle types.

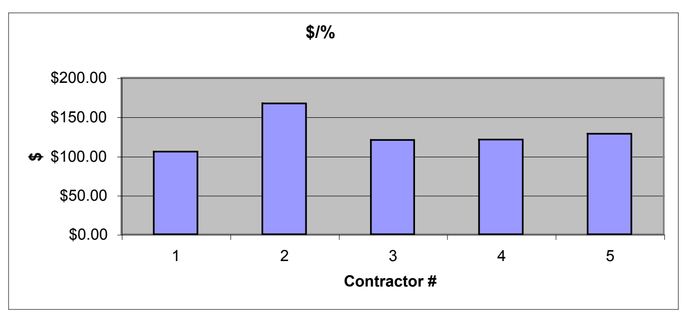


Figure 14—Cost versus percent removal.

OTHER ISSUES

We have heard comments from wash-service contractors, engine crews, equipment operators, government contracting officers, ecologists, and other concerned parties, regarding the cost, efficacy, cycle time, and overall practicality of washing vehicles and equipment for the purpose of mitigating the spread of invasive and nonindigenous plant species. A few of the points that have surfaced are mentioned below:

Contract Cost versus Equipment Provided

The Forest Service does not have any agency-wide guidelines that delineate just what the minimum equipment requirements are for a vehicle washing system and results from this study should help give some guidance for future contracts and EERAs. Naturally, the more elaborate a wash system is, the more it will cost to transport and operate, but we are still trying to define what we really need as a baseline for system performance and equipment criteria.

Given that there have not been any specific guidelines for the most part, entrepreneurs have developed washing systems based upon what they believe will do the best job of washing in a reasonably short time, while still safely containing all spoils and waste for proper disposal.

Traditionally, contractors who are listed in the EERA system, are dispatched on the basis of proximity to the need, with the closest being the first to get called in. Sometimes contractors are called in strictly on the basis of low bid. In either case we could be paying a lot for a system of unknown value and perhaps inferior performance. It is almost impossible for a contractor with a developed, completely self-contained system, and a well-trained experienced crew to compete with a minimally prepared contractor who has only a small financial investment and untrained labor.

Waste Disposal

All of the contractors we tested in Ione showed great concern for proper waste-disposal practices. Waste from vehicle washing stations usually comes in two forms; liquid and solid, and there are different guidelines for the proper disposal of either. Often the waste is really neither truly liquid nor solid, but rather a sludge.

We understand that one of the common methods for sludge disposal involves settling at a wastewater treatment facility. The remaining sludge is pumped into tanktrucks that spread it on farm fields that are to be planted in nonvegetable crops like hay. By U.S. Environmental Protection Agency regulation, farmers must plow the sludge into the soil to a minimum of 6 inches within 8 hours. Unless the waste has all been prefiltered to a small enough particle size that guarantees no plant propagules remain in it, there is a strong possibility that this disposal process could actually end up cultivating the very plants we were trying to eliminate. This is patently counter-productive.

Wastewater can contain hydrocarbons in toxic or dangerous quantities and in some cases unacceptable to the wastewater authority or treatment facility in a given location. The most commonly encountered hydrocarbons in vehicle washing are oils and grease. All five systems we tested have some removal mechanism for hydrocarbons but we did not test them with regard for that feature. Contractor number 5 had his wastewater tested in 2004 after working at a fire incident and even though the system is designed to remove the hydrocarbons from the waste it still contained trace amounts. However, these levels were acceptable to the waste treatment or disposal facility the contractor used. We do not have any objective data on the typical hydrocarbon loading of wastewater from mobile-vehicle washing stations. As funding allows, we may gather some samples from a variety of mobile-washing facilities deployed under various circumstances such as fires, construction projects, and military operations for chemical analysis.

Solid waste from vehicle washing systems can contain invasive species propagules and the current most common practice for disposal is burial in a landfill. If you properly contain the waste in a fairly air-tight opaque bag or container the seeds should not germinate, and if they are buried deep enough that they will never see the light of day, you should not have to worry about starting an infestation.

Heavy Equipment Cleaning

Heavy earth-moving equipment can collect an enormous amount of debris in a very short time. These machines should be cleaned before they are loaded on their trailers to reduce the risk of spreading seeds along roadsides between deployment locations and fire camps. We may find that type-2 cleaning systems, which capture solid waste but do not recycle the water, are more appropriate for cleaning heavy equipment. During our tests in Ione we found that it seems more effective to remove most of the soil and debris from the bulldozer manually first, without using any water sprays, then follow up with washing. We noticed that the water spray would relocate a lot of the debris on the machine rather than remove it. The water also seemed to reduce the visual contrast between machine and mud so it was harder to see when the metal was clean. Contractors who dry cleaned the machine first removed a higher proportion of the debris. Again, our test conditions, where most of the soil and debris on the dozer was dry material rather than muddy, may have affected this observation, and this might not be true in all cases. We may find that cleaning systems, which capture solid waste but do not recycle the water are more appropriate for cleaning heavy equipment.

CONCLUSIONS

Overall there was little difference between the five vehicle wash units we field tested. Four of the five units had under carriage wash systems and pressure hoses; though they differed in delivered water volume and pressure. All removed a similar proportion of the soil and other waste. We did observe that a well trained, experienced crew is an important aspect of an effective washing system. Crews that know where to look for hidden debris and follow practices like turning the steering tires from lock to lock can make a significant difference in the end result. We did not standardize the crew size for the test, which could be another factor in cleaning effectiveness. In any case, oversight and inspection will be necessary to determine if a contract cleaning crew is performing adequately.

Data from the testing in Ione implied that it takes about 10 minutes to completely clean these wheeled vehicles. Looking at what the contractors removed in 5 minutes, and what our re-wash crew removed in approximately another 5 minutes, it seems likely that some systems could achieve upward of 95 percent removal in 10 minutes. Another facet of this test was later performed in another location using a vehicle wash unit with a 2-person crew. The vehicle was washed five times, each time for 3 minutes, and soil waste was collected after each wash. Most of the soil was removed in the first 3 minutes (approximately 60 percent) but significant amounts were also removed in the second (approximately 20 percent) and less so in the third wash (approximately 10 percent). Only very small amounts were removed by the fourth and fifth washes. These results suggested that the optimal wash should be at least 6 minutes long. In this later study the vehicles were not as heavily soiled as those in Ione, but the results were similar. Anecdotal evidence suggests that under fire situations only 1 to 1.5 minute washes are the norm. Another later experiment showed that a 1.5 minute wash only collected 42 percent of that collected in a 6 minute wash, or barely half the total soil. Managers will have to evaluate if that is sufficient.

Heavy equipment, particularly tracked vehicles like bulldozers, can pick up a tremendous amount of debris. We did not consider it practical to remove the skid pans and covers from the dozer in our test since we were focused on field washing situations with logistical limits on time, tools, and labor. However, we found that manually removing debris from the machines without water was the best first step since the water tends to relocate a lot of the debris without removing it.

Although we tested five systems that we considered to be representative of a wide range of equipment, we did not find any single mechanical feature that clearly ensured an effective system. We consider the presence of an undercarriage wash system to be advantageous, though have to state that the unit, which did not have them, performed similarly to the rest. The higher volume system did remove the debris very rapidly but the end result of all systems was similar. Therefore we do not have any data to support the specification of any particular piece of equipment or combination.

As we had to measure all the soil waste recovered from each vehicle wash unit and then measure what they had missed we could not specifically address how, under normal field conditions, each unit contained the waste. However, it was apparent that some contractors were much more prepared and concerned with reducing contamination at the site than others. The best approach was one where the soil waste was double bagged. This approach ensured that no waste could be left to contaminate the area. In addition the double plastic bagging meant that if the soil waste was left for a period of time (> a few days) many of the seeds were killed.

In some regions the Forest Service has already adopted system standards and practices based in part on the results of this test. The agency is assuming responsibility for final disposal of all solid waste to ensure that the primary objective of containing invasive species is met. All tested systems recycled the water after filtration, and we recommend that fresh water will be provided by the agency in an effort to help reduce the contract cost.

RECOMMENDATIONS

We should, as agencies of the Federal Government:

1. Evaluate a wider range of systems to develop minimum standards. Although we tested units with a range of water volumes and pressures (four units with undercarriage sprayers and one without) the overall performance was similar. If we had performance data on systems of lesser and greater cost and complexity, we would have a better basis upon which to determine what acceptable minimums should be.

2. Define washing systems by type with regard for water and waste containment, spray system, process rate, and cost range. We are still considering that there may be a cost advantage to systems that do not recycle the wash water but we do not yet have a definition of this type of system and we do not have any comparative data on the efficacy, productivity, and cost of these systems. We recommend formal comparative testing of the presumably less costly type 2 systems mentioned earlier.

3. Establish simple, easily followed test procedures to ensure that our minimum requirements are met by measurable, repeatable criteria. Testing suggested in recommendations 1 and 2 should first be completed.

4. Convert our contracting practices to a performance basis, where system efficacy and effectiveness, process rate, containment protocol, overall cost, and deployment time are all factored into the decision process. The resulting choice would represent the best value available.

5. Define specific acceptable guidelines for waste disposal that are universally acceptable. Some areas may allow variances but at least we would have a worst-case set of practices that contractors and contracting officers could revert to when there is no clear statute or rule governing disposal method and practices. In any case, we should at least define a particle size that all wastewater and sludge will be filtered to before disposal. At this point we recommend all particles larger than 100 microns must be removed from waste water prior to disposal and contained in some way, such as heavy plastic bags, to be discarded at an appropriate site.

6. Establish a wash time of at least 6 to 9 minutes per vehicle to ensure that the majority (60 to 90 percent) of available soil debris is removed, given a typical two-person crew with two high pressure spray wands, and preferably with undercarriage spray systems. These data are generated from two different site conditions.

Reviewed by:

SDTDC thanks Dr. Harold Balbach, U.S. Army Corps of Engineers, Engineer Research and Development Center and Ralph Taylor, Fire Program Leader (retired), San Dimas Technology and Development Center for their technical review of this publication.

SDTDC's national publications are available on the Internet at: http://www.fs.fed.us/eng/pubs/

Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and SDTDC's individual project pages on their internal computer network at: http://fsweb.sdtdc.wo.fs.fed.us/

For additional information on vehicle washers, contact Joe Fleming at SDTDC. Phone: 909–599–1267 ext 236. E-mail: {jfleming@fs.fed.us]

APPENDIX 1-CONTRACTOR SYSTEM DESCRIPTIONS

NOTE: *Since the technology is evolving, many details regarding system outputs, waste containment, and disposal practices have changed somewhat from what they were when tested in Ione, presumably for better or more economical practices and equipment. All values of water flow and pressure listed in appendixes 1 and 2 are in English units.*

Contractor 1
Crew size: 4 constant, 1 intermittent

This washing system: Consists of a flexible containment mat with berms, a high-volume underbody spray-bar system, and two 1-inch combi nozzles.

The design output of this system is: Combi nozzles (2) 25 gallons per minute (gpm) at 75 pounds per square inch (psi)

Spray bar: 100 gpm at 75 psi

A self-priming trash pump (model, horsepower (hp), gpm, etc) moves wastewater and debris to the recycling system. This system relies mostly on water volume to remove debris and the wastewater is pumped into several stages of settling and filtration before it is reused. An 80-micron shaker screen precedes three 25-gpm vortex separators before the water is returned to use or disposed of.

Solid waste containment: All solids placed in dewatering bags and in double plastic trash bags for landfill disposal.

Contractor 2
Crew size: 2 constant

Undercarriage wash system: Two remote controlled stationary undercarriage washers, each with four double-sets of free-rotating zero-degree nozzle washes (one entering, one leaving containment mat) at 18 gpm at 800 psi on a dual 6-inch elevated ramp system, over a 19- by 33-foot vinyl containment mat.

Hand detail wash system: Two manual dual-turbo nozzle detail spray wands, each operating at 9 gpm at 1,200 psi over a 19- by 33-foot vinyl containment mat.

High pressure system: Dual 9-gpm, 1,200 psi ceramic-plunger type pumps.

Fresh water supply: 3,000-gallon (gal) open, octagonal, external frame portable tank.

Waste and sediment containment system: Two sequential cone-bottom settling tanks, proprietary automated.

A 50-micron roll paper-filter system, 50-micron bag filter, and a final 100-micron discharge hose bag for filtered water discharge. A 1,000 gal “overflow” bladder tank is also available for very high traffic days (100+ vehicles) or as a backup containment system.

Water recycling system: 500-gal supply tank receives double-filtered water from sediment-removal system and gravity feeds high-pressure pumps.

Solid waste containment and disposal: All liquid waste material is filtered to solid waste, then placed in two independently sealed 4-mil black plastic trash bags, then sealed in a 40-pound poly "sandbag" marked for landfill disposal.

Liquid waste disposal: No liquid waste except triple-filtered (50 micron) silty water. Hydrocarbons are removed by bilge boom bags in all recycling and sediment tanks. Under normal operating conditions (50+ washes per day at 40 to 50 gal per wash), about 200 to 300 gal per day of silty filtered water is drained by hose onto dry (grassy) ground, and about 100 to 200 gal per day is lost to evaporation and carry off.

Contractor 3

Crew Size: 2 constant, 2 intermittent on dozer only
Stationary dual spray bars 20 gpm each at 2,000 psi
Dual manual detail spray wands (3 gpm each at 2,000 psi each)

Flexible mat containment (14- by 50-foot)

Water tanks: 340-gal supply tank; 340-gal settling tank; 80-gal effluent-accumulation tank; 135-gal sludge tank

Recycling system: Dual filtration, 200-micron and 20-micron bags, 1-1/4 inch specially engineered hydrocyclone, 340-gal settling tank, 20-gpm effluent-processing capacity.

Solids and wastewater disposal: Effluent effectively separates heavy solids into sludge cell and lighter particulate into settling cells, which can be periodically drained, flushed, and disposed of in approved monitored sites. Finest particulate and the majority of organic matter and seeds are captured in the filter bags, which are periodically removed and disposed of by burning or deep burial. Sludge can either be collected in landfill-only bags or collected by the greywater tender onsite for fires.

Contractor 4

Crew size: 2 constant, 1 intermittent.

Two movable spray bars with rotating and stationary nozzles.

Two manual detail spray wands, 6.3 gpm at 240 psi. (Note: Contractor has since changed to approximately 9.5 gpm at 230 psi.)

Water supply: Two 1,800-gal tanks; one with reclaimed filtered water and one tank with clean water.

Recycling system: Settling tanks, geotextile filter bags. (Note: Contractor has since changed to 100-micron nylon filter bags.)

Solids containment: Geotextile bags placed in heavy plastic bags for landfill disposal. (Note: Contractor has since changed to dewatering bags for solids containment.)

Waste water disposal: One baffled settling tank followed by filter bags. Skimmer pads are utilized in the settling tank to remove hydrocarbons. The water leaving the settling tank will be acceptable to most wastewater treatment facilities.

Contractor 5

Crew size: 2 constant, 1 intermittent

Elevated wash rack: Hydropad®

Manual pressure washers (2): 2 gpm @2,000 psi

Water supply:

Recycling system: Hydroclean® patented recycling system

Solid waste: Contained in heavy plastic bags, dewatering bags, with final deposition in a landfill.

Liquid waste: Disposal in municipal waste-treatment facility.

LOCATION HONCUT CA

Established Series
Rev. RCH-GWH-RWK-MAV-ET
02/2003

HONCUT SERIES

The Honcut series consists of very deep, well drained soils that formed in moderately coarse textured alluvium from basic igneous and granitic rocks. Honcut soils are on floodplains and moderately sloping alluvial fans and have slopes of 0 to 9 percent. The mean annual precipitation is about 12 inches and the mean annual air temperature is about 62 degrees F.

TAXONOMIC CLASS: Coarse-loamy, mixed, superactive, nonacid, thermic Typic Xerorthents

TYPICAL PEDON: Honcut loam - pasture. (Colors are for dry soil unless otherwise noted.)

A--0 to 13 inches; brown (7.5YR 5/2) loam, dark brown (7.5YR 4/2) moist; weak fine granular structure; hard, friable, slightly sticky and slightly plastic; many fine roots; many pores and insect burrows; low in organic matter; slightly acid (pH 6.5); gradual smooth boundary. (6 to 22 inches thick)

C--13 to 72 inches; brown (7.5YR 5/3) loam with few thin strata of fine sandy loam in lower part of the horizon, dark brown (7.5YR 4/3) moist; massive; hard, friable, slightly sticky and slightly plastic; roots and pores decreasing gradually with depth, a few roots penetrate deeper than six feet; neutral (pH 6.7).

TYPE LOCATION: Merced County, California; gravel pit on north side of Bear Creek, sec. 16, T.7S., R.15E.

RANGE IN CHARACTERISTICS: The mean annual soil temperature at a depth of 20 inches is 59 to 68 degrees F. and the soil temperature is not below 47 degrees F. for any significant period. The soil between depths of 8 to 24 inches is usually dry all of the time from late April until November and is usually moist in some or all parts all the rest of the year. The 10 to 40 inch control section averages sandy loam, coarse sandy loam, fine sandy loam, loam or gravelly equivalents of each. Rock fragments range from 0 to 25 percent. The control section has little or no stratification. Clay content usually averages 6 to 12 percent. Organic matter is less than 1 percent, decreases regularly with increasing depth and is below 0.2 percent at a depth of 60 inches. Some pedons have unrelated strata of sand, gravel or buried soils below depth of 40 inches. Reaction ranges from moderately acid to slightly alkaline. The profile is noneffervescent to depth of 40 inches or more.

The A horizon is 10YR 5/2, 5/4, 5/3, 5/6, 4/2, 4/3, 4/4; 7.5YR 5/2, 5/4, 5/6, 4/2, 4/4. Moist values are generally one unit less. This horizon is sandy loam, fine sandy loam, loam or gravelly equivalents of each.

The C horizon is 10YR 4/4, 4/6, 5/2, 5/3, 5/4, 4/3, 6/3, 6/4; 7.5YR 5/6, 6/4, 5/2, 5/4, 4/2, 4/4. Moist values are generally one unit less.

COMPETING SERIES: These are the Hanford, Pollasky (T), and Saugus series. Hanford soils have A horizons with a dry value of 6 or more. Saugus soils have a paralithic contact at depths more than 40 inches and are on irregular slopes of more than 9 percent.

GEOGRAPHIC SETTING: Honcut soils are on flood plains and alluvial fans at elevations less than 2,000 feet. Slopes are 0 to 9 percent. The soils formed in alluvium dominantly from basic rocks but are derived from acid igneous rocks in some places. The climate is dry subhumid mesothermal with hot dry summers and cool, moist winters. Mean annual precipitation is 9 to 25 inches. Mean annual temperature is 60 to 62 degrees F., average January temperature is about 45 degrees F., and average July temperature is about 80 degrees F. Frost-free period is about 200 to 280 days.

GEOGRAPHICALLY ASSOCIATED SOILS: These are the Burchell, Ryer, Yokohl and Wyman soils. All of these have argillic horizons. Also, Yokohl soils have a duripan at depths less than 40 inches.

DRAINAGE AND PERMEABILITY: Well drained; slow to medium runoff; moderately rapid permeability.

USE AND VEGETATION: Honcut soils are highly productive under irrigation. Crops are alfalfa, small grains, forage crops, apricots, peaches, grapes, prunes, apples, oranges, pears and berries. Some areas are dry farmed. Vegetation consists of open parklike areas of annual grasses, herbs and scattered oaks.

DISTRIBUTION AND EXTENT: They occur on the east side of the Central Valley and in the intermountain valleys of southern California. These soils are moderately extensive in MLRA-17.

MLRA OFFICE RESPONSIBLE: Davis, California

SERIES ESTABLISHED: Marysville Area, Sutter and Yuba Counties, California, 1909.

REMARKS: The activity class was added to the classification in February of 2003. Competing series were not checked at that time. - ET

Diagnostic horizons and features recognized in this pedon are:

Ochric epipedon - the zone from the surface to a depth of 13 inches (A)

National Cooperative Soil Survey
U.S.A.

APPENDIX 3. DAILY FOOTNOTES

This section lists the comments and issues noted on a daily basis for each of the contractors and vehicle types.

Contractor 1

Initial setup: 06/18/2007: We tested the spray bar system for flow and pressure but found it was delivering roughly half what the contractor expected. Since we could not find anything conspicuously wrong with the setup, and since we did not know for sure that it really should be delivering a lot more water pressure and flow, we decided to just make note of the hydraulic output and run the system as it was, developing 50 pounds per square inch (psi) and 65 gallons per minute (gpm) through the spray bar.

After returning to his home base the contractor found a problem with his pump impeller that was reducing the output. He repaired the pump and brought his spray bar system back to be retested on 7/18/2007 and we found that it could deliver 75 psi at 100 gpm when run in the normal throttle range or 100 psi at 117 gpm with the throttle held wide open. Unfortunately we did not have the resources to perform even an abbreviated retest of this system.

Type-1 Fire Engines: 06/19/2007: Even though the system was not delivering water at its full potential it still used more water than we could contain in a single 1,500-gallon (gal) (5,678-liter [L]) holding tank. We borrowed one of the contractor's 2,100-gal (7,950-L) tanks to contain the balance of the post-filtered waste from his system. We let the water in both tanks settle overnight before removing the residual fines.
The average depth in the 1,500-gal (5,678-L) holding tank at the end of the day was 22.5 inches (in) (57 centimeters [cm]) or approximately 1,400 gal (5,323 L). The average depth in the larger tank was 9.9 in (25 cm) or about 886 gal (3,355 L).

While 24 replications had been planned, we noticed after 18 cycles that the course was starting to pack down and dry up, and that the liquid waste collection tanks were filled. When we looked at all of the soil we had collected up to that point, as well as the time of day, we decided 18 cycles was plenty and we would need time to finish cleaning the vehicles and preparing the course for the next day.

Type-2 Pickup/SUV: 06/20/2007: We surveyed the test course and the amount of debris collected after 18 cycles and although we decided the test should stop at that point one of the drivers did not get the message and proceeded to run through the course making a total of 19 cycles for type-2 vehicles.

We also noticed that the pickups and SUV seemed to collect more debris than the type-1 vehicles did. We believe this is due to lower ground clearance bringing more of the underbody into contact with the mud bog. It may also be the case that it is more difficult for operators to direct their nozzles under the lower chassis of the smaller vehicles.

We used the contractor's 2,100-gal holding tank again due to the large volume of water that the system uses. Not only does the spray bar deliver 65 gpm, the manual cleaning nozzles were delivering 23 gpm each and the crew was using two, and sometimes even three, simultaneously. We also pumped liquid waste into one of our 1,500-gal (5,678-L) tanks and the lacing that holds up the sidewall on our tank started to unravel, lowering the wall height by 3 in (7.6 cm). The 1,500-gal (5,678-L) holding tanks measure 120 in

(305 cm) square so we estimate they hold about 62 gallons (235 L) for every inch of depth. We estimate that 186 gal (704 L) of filtered wastewater spilled onto the pavement when the tank wall failed.

The average depth in the 2,100-gal tank at the end of the day was 6 in (15 cm) or approximately 538 gal (2,040 L). The average depth in the 1,500-gal (5,678 L) tank was 21.625 in (55 cm) or approximately 1,350 gal (5,100 L).

Type-3 Dozer: 06/21/2007: Nothing noted during the wash cycles.
The levels in the holding tanks were either not recorded or the record was lost.

Contractor 2
Type-1 Fire Engines: 06/26/2007: LRH does not usually clean the tire treads. The battery box was never opened during cleaning and it was heavily soiled upon inspection.

The average water level in the 1,500-gal (5,678-L) holding tank was 22.69 in (57.6 cm) or approximately 1,407 gal (5,324 L). Our estimate for water use based on time and output was 1,634 gal (6,185 L). This could mean almost 227 gal (859 L) of water was lost to overspray, evaporation, and residual on the vehicles and that would mean an average loss of 12.6 gal (48 L) per wash.

Type-2 Pickup/SUV: 06/27/2007: One of the Dodge pickup trucks quit after the first wash but it was revived with a jump start. We replaced the battery and it continued to run for the rest of the day.
This contractor did not lower the spare tires during the wash cycle and there was a considerable, though unrecorded, amount of debris lodged there.

The average depth in the holding tank was 18.5 in (47 cm) or approximately 1,150 gal (4,353 L) but it was measured the following morning.

Dozer: 06/28/2007: The dozer was washed on the trailer and moved as requested by LRH workers.
During the second cleaning we used one LRH cleaning pistol, two of our crew with the LRH dual wands, and one using our own pressure washer.

The average depth in the holding tank was 12.4 in (31.5 cm) or approximately 775 gal (2,935 L).

Contractor 3
Type-1 Fire Engines: 07/10/2007: Sump pickup problems caused some down time. Generator expired.
Average depth of water in holding tank at the end was15.875 in (40 cm) or approximately 989 gallons (3,746 L).

Type 2-Pickup/SUV: 07/11/2007: Average depth in holding tank at the end of the day was 20.2 in (51 cm) or approximately 1,258 gal (4,763 L).

Type 3-Dozer: 07/12/2007: Crew of four manually removed debris without water for 45 minutes then continued with two pressure washers and two trowels. Final underbody rinse with both spray bars zip-tied together dragging them fore and aft several times.

A hollow section on the lower part of the dozer blade could be a place where soil is trapped.
Second cleaning took 51 minutes with two contractor sprayers and our pressure washer.

Average depth in the holding tank after washing was 2.63 in (6.7 cm) or approximately 163 gal (619 L).

Contractor 4

Type-1 Fire Engines: 07/17/2007: There appears to be a lot of overspray from the underbody system. Considerable amount of debris were removed from between the wheels and in the tread after the contractor wash.

Hose delivering waste to holding tank from the contractor blew out briefly.

Brief overflow of our 200-gal (757 L) holding tank spilled an estimated 10 to 20 gal (38 to 76 L) of wastewater.

We pumped approximately 124 gal (469 L) off the top of the contractor's holding tank to allow room for the rest of the wastewater.
The average depth in the holding tank at the end was 23.63 in (60 cm) or approximately 1,473 gal (5,575 L).

Type-2 Pickup/SUV: 07/18/2007:
The average depth in the holding tank at the end was 23.63 in (60 cm) or approximately 1,473 gal (5,575 L).

Type-3 Dozer: 07/19/2007: Two workers manually removed soil without water for 30 minutes, and then used one wand running 4,000 psi and 4 gpm, and one wand at 240 psi and 6 gpm.

Some of our crew said the 240 psi wands were not aggressive enough to get the soil off.

There was a lot of overspray within 3 feet of the contractor's mat and I had intended to collect it separately, but the crew started collecting it with the first-wash debris before I could stop them.

At the end of the day the average depth in the first-wash holding tank was 5.38 in (14 cm) or approximately 335 gal (1,268 L).

Contractor 5

Type-1 Fire Engines: 07/24/2007:
The grader we were using to scarify the course was gone so we used the bulldozer instead, which may have affected the amount of soil collected by vehicles this week.

The average depth in the holding tanks at the end of the day was 13.13 in (33 cm) or approximately 818 gal (3,097 L).

Type-2 Pickup/SUV: 07/25/2007:
The crew was well trained. They took extra steps like dropping the tailgate and turning the front wheels from lock-to-lock.

The average depth in the holding tank was 12.5 in (32 cm) or approximately 779 gal (2,965 L).

Type-3 Dozer: 07/26/2007:
We put the dozer directly on the contractor's Hydropad for cleaning. The cleat spacing on the tracks did not mesh well with the cap-connector length, causing damage to the connectors.

A crew of three manually removed soil without water for 13.5 minutes, and then one worker started using a pressure washer. Both wands were in use after 30 minutes.

No record of wastewater depth in holding tanks but based on time and volume outputs recorded we estimate that they used 344 gal (1,303 L) of water for the first cleaning.