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# Evaluating the Potential for Vehicle Transport of Propagules of Invasive Species

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## Background

Federal land managers have a responsibility to comply with the Presidential Executive Order on invasive species.* Invasion by non-indigenous species, both plants and animals, is a global-scale problem, recognized in the directive as threatening the ecological integrity of native communities and ecosystems nationwide. The propagules of invasive plants, largely seeds but also other plant parts, are introduced to new areas by a variety of natural and human actions. Roads and vehicles, including military vehicles and off-road recreational vehicles, are often regarded as important dispersal vectors. The danger of introducing new species following overseas deployments is a known aspect of this problem, and has been the subject of recent rulemaking. Less well appreciated is the potential hazard in transporting these species among Continental U.S. (CONUS) training sites or even from area to area on one installation. The U.S. Forest Service (USFS) has recently instituted rules requiring that vehicles entering and leaving forest fire management areas be washed to help minimize such transfer from one National Forest to another.

Not just training activity, but also many silvicultural and other land management activities involve the movement of vehicles and equipment at off-road locations where seeds and spores can be picked up, transported, and introduced great distances from their place of origin. When invasive and non-native species of plants and fungi are relocated to new areas, they can become established where the native ecosystem cannot coexist without being compromised. Some prolific plant species 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.

Plant seeds and fungal spores are often transported in the soil and mud picked up when vehicles are operated off paved roads. The quantity of soil that adheres to a vehicle is highly variable. This study shows that 50 pounds is a common load for a moderately soiled vehicle, and that 100 pounds (dry weight) is not uncommon. Anecdotally, a tank may well carry a ton of soil out of the field. The number and variety of seeds that may be carried in this quantity of soil is not known. Seeds and larger plant parts are also entangled directly and torn off by undercarriage components that strike the host plant. The number and variety of plant propagules transported by vehicles, and how this varies with driving surface, soil type, and vehicle type is poorly understood. More propagules are likely to be collected by vehicles driven off-road than on paved roads, and by tracked or all-terrain vehicles than civilian pattern vehicles, but there are no quantitative data to support this hypothesis. Nor is it known how effective current vehicle washing procedures are in removing soil and (potentially) any associated propagules.

## Objective

The objectives of this work were to acquire data on soil adhering to vehicles driven off road, and to evaluate several relocatable commercial vehicle cleaning systems for:

- *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)
- *Waste Containment* (the contract system's ability to contain the waste from the cleaning system)
- *Seed Viability* (the number of viable seeds remaining in the system waste compared to the known quantity of seeds that each system processed).

* Executive Order 13112. 3 February 1999. *Invasive Species.* Federal Register, 8 February 1999 (64)25.

# Approach

The U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (CERL), The U.S. Forest Service San Dimas Technology & Development Center (SDTDC), Montana State University, Bozeman (MSU) and the California Department of Forestry and Fire Protection (Cal Fire) joined forces to evaluate a range of relocatable vehicle cleaning systems. These systems were among many that are now being used by the Forest Service to wash vehicles at forest fire sites, and were selected to represent a range of equipment types now in use. All are contractor-owned and operated, and their services are typically leased on a daily basis. They were evaluated for cleaning efficacy, waste containment, and waste disposal. The viability of any propagules collected in the cleaning process was also examined. The relative economic effectiveness was also a factor in the Forest Service's evaluation.

SDTDC took the lead role in developing the equipment and methods used in this phase of the study, while MSU led the effort to evaluate the post-cleaning viability of propagules. CERL held primarily a planning and oversight role and Cal Fire provided the location and also some of the vehicles, machines, and logistical support to make this study possible. Many of the contractors made valuable contributions and suggestions.

## Test Location

SDTDC and CERL formed a working partnership with Cal Fire, whose cooperation permitted researchers to stake out a test course, a travel route, and a solid, paved cleaning location. The Cal Fire Academy site of over 5400 acres is located in the foothills of the Sierra Nevada Mountains approximately 40 miles southeast of Sacramento, CA. A paved helipad was made available for the duration of the project where each of the contractor wash systems and the team's washing and inspection areas could be set up. Use of the paved helipad minimized the introduction of soil from sources other than the vehicles, such as foot traffic.

## Procedures

All testing took place in the same location on a paved helipad at the Cal Fire Training Center in Ione, CA. Each system was tested over a separate 5-day period between 18 June and 27 July 2007. The test course was laid out in a cleared, open, level field with little or no vegetation above the surface (Figure 1). The area had been graded recently, so the surface was fairly smooth. The soil in the test area is a Honcut silt loam described by the Natural Resources Conservation Service as "very deep, well drained soils that formed in moderately coarse textured alluvium from basic igneous and granite rocks." In this USFS-focused phase of the study, three types of vehicles were used:

- Wildland (Class 3) Fire Engines (two were used for test cycles)
- Light 4x4 vehicles (two pickup trucks and 1 sport utility vehicle [SUV])
- Bulldozer (one Caterpillar D6R high track bulldozer).

Wheeled vehicles were driven 15 m through a fabricated mud bog (Figure 2) and then 2.75 times around the figure-8 course (Figure 1) before returning them to the washing area on the helipad. Total distance driven on the figure-8 soil was ~650 m. This varied slightly, because successive drivers could not travel the exact path of the previous vehicles, but the exact total soil adhering was not a measured variable in any case. The road distance, on a gravel road, from the helipad to the test course was ~382 m. The paved helipad segment of the test course measured 135 m. The total distance driven for each test, on all surfaces, including transitions, was ~1720 m.

**Figure 1. Test Driving area at Cal Fire Academy, Ione, CA.**

Figure 2. Constructed muddy driving area.

Figure 3. Class 3 fire engine on course.

Figure 4. Four-by-four pickup on wash pad.

## Scheduling

The weekly routine was to set up as follows. On Monday, the contractor's equipment was tested to ensure that all components were functioning. On Tuesday, Class 3 fire engines (Figure 3) were studied; on Wednesday, light 4x4s (Figure 4) were tested; and on Thursday, the bulldozer was soiled and cleaned. On Thursday afternoon, the MSU seed viability and recycling system tests were begun. The contractor's recycling system was allowed to settle overnight before collecting the captured waste. Fridays were dedicated to cleanup and travel home.

Vehicles were cleaned meticulously prior to driving at a set speed around the predefined course, and then washed by the wash unit. This was replicated 18 times each for both light 4x4 vehicles and fire engines. Tracked vehicles were washed only once. At the end of this process, the vehicles were stripped down and cleaned again to quantify the amount of debris missed by the commercial wash units. To quantify how much seed was lost in the wash and filtering system process, a known amount of soil and seed were placed in a water trough and taken into the wash unit's filtering system. Samples were left overnight, as is normal practice, and filtered according the individual unit's protocol. Waste samples (greater than 75μ) were collected and placed in the MSU greenhouse and germination was recorded. These data and those from future experiments will be used to develop protocols that will aim to reduce the movement of non-indigenous plant propagules within and between Department of Defense installations.

## Cleaning Efficacy

All five of the systems tested in Ione were at least fairly successful at removing the majority of debris from the vehicles and heavy equipment. Figure 5 shows the efficacy of each contractor for each vehicle type. The total was the amount they removed plus that which the research crew removed in the post-wash. Even the most effective system could not remove more than about 88 percent of the debris from the wheeled vehicles. The average proportion of removal was around 77 percent. If more time had been allowed, the results would likely have been better; however, it was decided to limit the vehicle washes to 5 minutes each to reflect fire-incident conditions. The bulldozer was allowed a full hour for the contractors to clean it, and the best removed more than 90 percent of the debris in that time frame. As the test progressed, the vehicles picked up more debris from the same course, apparently related to increases in the amount of water applied to the course for dust abatement. Therefore, the later contractors had a much larger mass of debris to remove, in some cases more than 4 times as much (Figure 6). This might be reflected in a somewhat lesser efficacy in some cases.

## Seed Viability

Seed viability was tested before the experiment (Table 1, col. 2). In the Ione, CA studies, the seeds and some soil were passed through each vehicle wash system. Soil and seed water retained at the end of the process was placed in cold storage while transporting the samples from California to the greenhouse, causing a loss of seed viability which was quantified (Table 1, col. 3). The number of seedlings of each species germinating from samples that had passed through wash units was recorded and corrected for seed viability and loss due to transport. The percent viability lost for each species (Table 1, col. 4) thus represents the percent of viable seeds of each species lost as a direct result of passing through the wash units. These values will be used to correct for seed viability losses in future field studies.

## Conclusions

Preliminary conclusions show both positive and negative aspects to the vehicle washing procedures. On one hand, in this severe set of tests (in which each wash was time limited), the best systems removed from 80 to almost 90 percent of the soil. On the other hand, these were all systems believed to be the best of their types, with experienced operators. Many of the systems actually being used by the USFS likely do not achieve these levels of soil removal in field use.

This means that large amounts of soil are routinely *not* removed during cleaning stops at forest fire sites. While the soil removed surely reduces the number of propagules of invasive species, there are just as surely large numbers that are not removed. These results will be used by the Forest Service to help develop specifications for relocatable washing systems.

In terms of the relevance of these results to the Army and other services—they do show that there are systems that could be used to remove soil and other debris from vehicles when they are moved among different training areas. At this time, only a few installations routinely require that off-post vehicles be washed before entering, and fewer before leaving. The washing facilities used for this purpose are typically wash racks and tank baths, the location of which is fixed. Relocatable systems could serve to make such requirements more flexible by providing cleaning at as many locations as necessary to serve large and small units. The study also shows, however, that the efficacy is much less than 100 percent; while the process would reduce the risk of seed transport, it would not eliminate it.

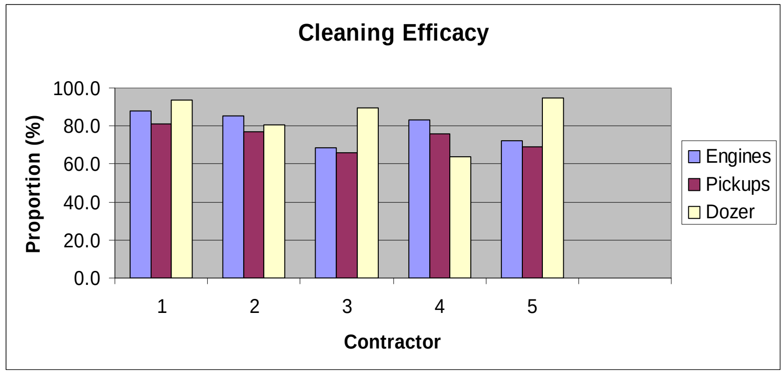


**Figure 5. Cleaning efficacy, by contractor.**

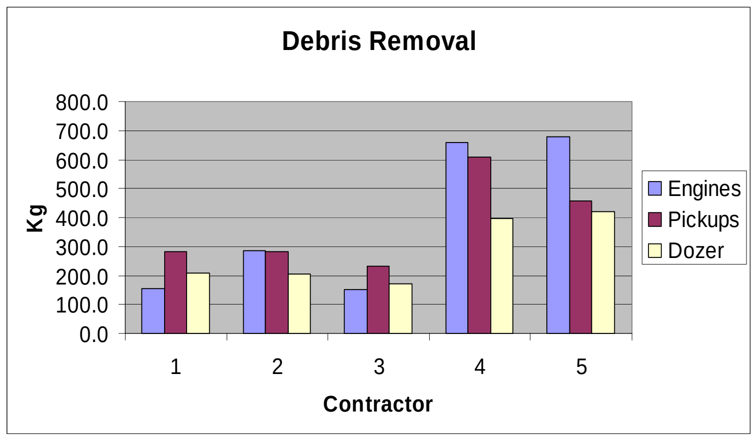


**Figure 6. Amount of debris removed, by contractor.**

**Table 1. Seed viability.**

| Seed Common Name | Initial % seed viability | Corrected % seed viability | %viability lost in washing process |
|---|---|---|---|
| Field Oats | 90 | 78 | 91.6 |
| Slender Wheatgrass | 96 | 87 | 56.4 |
| Kentucky Bluegrass | 80 | 74 | 32.9 |
| Field Buckwheat | 81 | 65 | 67.1 |
| Purple Coneflower | 76 | 88 | 87.4 |
| Cultivated Flax | 94 | 37 | 90.7 |
| White Mustard | 98 | 92 | 79.0 |
| Yellow Sweet Clover | 86 | 77 | 65.9 |
| Kochia | 70 | 18 | 65.0 |

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