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EVALUATION OF CENTRALIZED VEHICLE WASH FACILITIES FOR INVASIVE SPECIES REMOVAL

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FACILITIES ENGINEERING
ENVIRONMENTAL

EVALUATION OF CENTRALIZED VEHICLE WASH FACILITIES FOR INVASIVE SPECIES REMOVAL

1. Purpose

a. The purpose of this Public Works Technical Bulletin (PWTB) is to transmit information on proposed improvements for Centralized Vehicle Wash Facilities (CVWFs) in removing propagules (biological material used to propagate via dispersal, i.e., roots, stems, leaves, etc.) of Non-native Invasive (plant) Species (NIS) from military vehicles. The efficiency of new CVWF technologies assessed by this evaluation could indicate potential for improved CVWF practices worldwide or alternative methods for areas with restricted water resources. This document defines efficiency as the increase in potential NIS removal and the minimization of water consumption throughout the removal process. This bulletin present the methodology used in data collection and study, as well as an analysis of the results.

b. All PWTBs are available electronically at the National Institute of Building Sciences' Whole Building Design Guide webpage, which is accessible through this link:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability This PWTB applies to all U.S. Army facilities, and is especially applicable to military training facilities in areas with known or probable populations of NIS.

3. References

a. Army Memorandum, “Army Policy Guidance for Management and Control of Invasive Species,” Memorandum from the Assistant Chief of Staff for Installation Management [ACS(IM)], ATTN: DAIM-ED-N. 26 June 2001.

b. Army Regulation (AR) 200-1. 2007. “Environmental Protection and Enhancement,” 28 August 2007.

c. Department of Defense Regulation 4500.9-R, DoD Customs and Border Clearance Policies and Procedures, 2006.

d. Executive Order (EO) 13112, “Invasive Species,” [64 CFR 6183], 9 February 9 1999.

e. Executive Order (EO) 13514, Federal Leadership in Environmental, Energy, and Economic Performance, 5 October 2009.

f. Federal Noxious Weed Act of 1974 (FNWA) as amended 1988 and 1994 [7 U.S.C., 2801-2814].

g. Unified Facilities Criteria (UFC) 4-214-03 “Central Vehicle Wash Facilities,” originally Army Technical Manual (TM) 5-814-9 (1992), 16 January 2004.

h. Technical Guide No. 31, “Retrograde Washdowns: Cleaning and Inspection Procedures,” 2004.

4. Discussion

a. EO 13112 (1999) established Federal agencies’ responsibilities and duties for mitigating damages caused by invasive species, including: preventing the introduction, providing control, and minimizing economic, ecologic, and human health impacts. Furthermore, DoD-R 4500.9-R (2006) specifies that the Department of Defense is responsible for the removal of NIS from military equipment before its movement from the continental United States (CONUS) to location(s) outside the continental United States (OCONUS), or vice versa. Additionally, EO 13514 establishes Federal governmental goals for implementing sustainable practices including water conservation.

b. NIS are becoming increasingly problematic on military installations and throughout the United States: over 50,000 NIS have been identified, causing over $120 billion in damages annually to native ecosystems, agriculture, and infrastructure (Cofrancesco et al. 2007). As military activities often require movement of large amounts of equipment and personnel over vast areas in a short period of time, it is critical that efficient removal methods are available at all military installations. Appendix A.1 provides additional detail on the negative impacts of NIS and the importance of controlling their spread, reducing their populations, and minimizing their impacts.

c. CVWFs are the first line of defense against the spread of NIS. The purpose of CVWFs is to facilitate improved vehicle longevity as well as NIS removal before the movement of military vehicles to non-infested areas, both within the installation and off base (Cofrancesco 2007, HQUSACE 2008). CVWFs have been used since 1980; standards for construction and operation were written in 1992 (TM 5-814-9) and updated in 2004 (UFC 4-214-03). Although the Department of the Army has not promulgated specific military vehicle washing standards (number of washes, duration of wash), it has made recommendations based on other agencies' guidelines and confirmed those recommendations with experimental field studies (Fleming 2008, Rew 2011). PWTB 200-1-55 recommended that High-Pressure, Low-Volume (HPLV) hoses be added to a CVWF to increase sediment removal and thereby prevent the spread of NIS (HQUSACE 2008). This PWTB physically quantifies that recommendation. In addition, HPLV equipment may increase water conservation, which corresponds with the stated sustainability goals set forth in EO 13514. Appendix A provides additional detail on the CVWF's value in controlling NIS.

d. The general purpose of this PWTB is to discuss and quantify lessons learned from a review of the use of Low-Pressure, High-Volume (LPHV) water cannons and HPLV wands. A more specific purpose was to determine if HPLV systems remove plant propagule from military vehicles better than LPHV water cannons. In January of 2012, a new CVWF was constructed at Pohakuloa Training Area, HI (PTA), which included HPLV wands; this facility became operational in March 2012. In May of 2012, a field study was conducted to determine the difference in soil and NIS propagule removal between this new CVWF and the existing CVWF equipped with LPHV water cannons. Appendix B. discusses the experimental design, results, conclusions, and recommendations from the field study in Pohakuloa.

5. Points of Contact

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APPENDIX A

BACKGROUND INFORMATION

Non-Native Invasive Plant Species (NIS)

NIS are also known as non-indigenous, exotic, alien, noxious, weed, or pest species. Over 50,000 NIS have been found in the United States. Many of these were originally introduced as crops, livestock, landscape materials, biological pest control, sport, pets, and/or food. NIS can affect human health and safety. They can be destructive to native ecosystems, agriculture, and infrastructure (Pimentel et al. 2005 in Cofrancesco et al. 2007). The U.S. Department of Agriculture (USDA) has documented annual losses of over $138 billion from effects and management of these introductions (USDA 2012). In the United States, 5000 NIS plant species invade approximately 700,000 hectares of wildlife habitat annually, and compete with 17,000 native plant species (Babbitt 1998, in Pimentel et al. 2004; Pimentel et al. 1999). Four hundred (42%) of the 958 U.S.-listed species are threatened by competition with or predation by NIS. Other regions of the world report that up to 80% of listed species are threatened by NIS (Pimentel et al. 1999, Westbrook et al. 2005 in Gundlach 2007). DoD owns and manages large tracts of land (25 million acres), and must reduce the risk of introducing or transporting NIS in CONUS and OCONUS locations. DoD needs to prevent and manage NIS to fulfill these responsibilities, and to reduce future financial expenditures and opportunity costs.

Military training activities often disturb soils and plant life and facilitate NIS spread (HQUSACE 2008, Rew 2011, Ustin et al. 2008). NIS themselves are a concern to military land managers because of the negative impacts of NIS on soil stability, water quality, and listed species' habitat. From the standpoint of military readiness, NIS reduce realistic training and testing opportunities. NIS hinders mission readiness by increasing soil erosion, thereby increasing required maintenance and management costs. NIS also lead to the listing of threatened and endangered species since they contribute to habitat loss and fragmentation (HQUSACE 2011, 2008; Gundlach 2007).

Figures A1 and A2 show how NIS can negatively affect a military vehicle's mechanical systems, and how NIS can potentially be spread when vehicles are not properly washed.

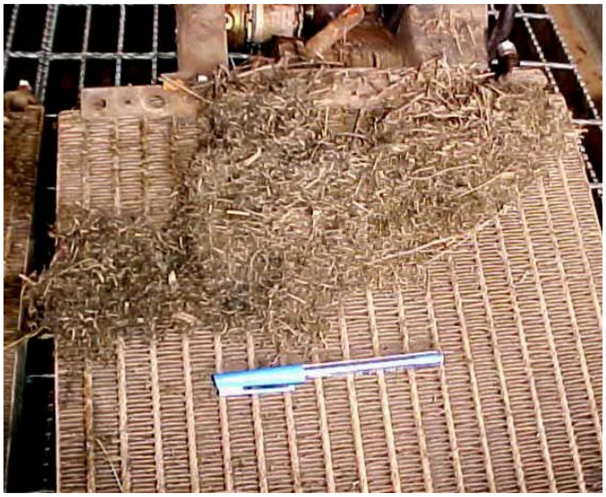

Figure A1. Siam weed (*Chromolaena odorata*) in the air filter of a military armored personnel carrier after washing (photo by Stuart Henson, AQIS).

Figure A2. Siam weed (*Chromolaena odorata*) in cooling system of a military armored personnel carrier after washing (photo by Stuart Henson, AQIS).

NIS act as pioneer species in newly disturbed areas and highly generalized habitat needs. Because any organism has the potential to become invasive when moved to a new environment with suitable habitat, it is easier and more efficient to control the pathways of movement, especially at points of embarkation and debarkation (Cofrancesco et al. 2007, NISC in Gundlach 2007). Human dispersal of NIS is especially problematic since humans often traverse large areas in short time periods. NIS have been documented on military personnel arriving at or leaving from Australia, Bosnia-Herzegovina, Germany, Italy, Kuwait, and the United States. Reducing introduction of a species to an area is the best means to control and manage NIS.

NIS Management through Use of CVWFs

The USDA inspects only a fraction of cargo, vehicles, and equipment entering the CONUS, but does not inspect interstate cargo to other states (with the exception of Hawaii) (Holst 2005). DoD is aware of the potential for NIS spread on its lands, and in accordance with EO 13112, the need to limit the introduction and spread of NIS. Additionally, actions have been taken to control existing NIS populations and removal of NIS, ensuring NIS are not brought into the United States or transported to other countries:

> It is DoD policy that equal vigilance will be exercised in preventing the export of agricultural pests to our foreign host nations (DoD 2006).

Cleaning vehicles to ensure removal of NIS before movement within CONUS or OCONUS is costly and consumes a tremendous amount of water. The USDA Animal and Plant Health Inspection Service (APHS) requires that the process to clean vehicles before deployment and on return ensure that no pathogen or NIS is transported back to U.S. soils. In Kuwait, during a 9-month period in 2003-2004 during Operation Iraqi Freedom, cleaning and inspection ran 24 hours per day, 7 days per week. Shipments out of Kuwait included 228,393 personnel, 65,541 vehicles, 7,385 conexes, 9857 containers, and 275,915 packages. All vehicles were washed, totaling a minimum 480,634 hours of wash time, $5-10 million in wash labor, and $6 million in inspection labor (Cofrancesco et al. 2007). If we assume that a LPHV hose was used and that, during all wash time, the LPHV was flowing at a rate of 25 gallons per minute, this event alone used over 720 Million gallons of water. The need to increase the efficiency and efficacy of cleaning procedures to reduce personnel and materials costs is paramount.

The consensus is that military vehicles have the ability to move soil debris and associated plant propagules, including those of NIS, and that they should be thoroughly cleaned before travel between sites (Cofrancesco et al. 2007, Gundlach 2007, Rew 2011). Personnel are typically advised to follow DoD Directive 4500.9-R, Part V, Chapter 505 (2006) for inspecting vehicles and complying with customs clearance procedures. Custom procedures require the prevention of “any movement that has the potential to introduce invasive species to a new area.” These guidelines are based on USDA recommendations. Additionally, the Armed Forces Pest Management Board’s Technical Guide No. 31 (2004) provides additional washdown guidelines specifically for vehicles traveling between countries.

Although there are standards for constructing and operating the wash facilities, there are currently no standardized wash procedures that prescribe such parameters as number and duration of washes. UFC 4-214-03 (2004) gives a wide range of wash times, from 6-15 minutes for wheeled vehicles and 6-20 minutes for tracked vehicles, solely based on CVWF construction requirements (U.S. Department of Army 2004, in Rew 2011). Fleming (2008) investigated the efficacy and economics of five MVWSs and found that mobile units removed up to 88% of plant propagules (mean = 77%). The wash times for this study were 5 minutes for fire engines and light-duty trucks, and 1 hour for bulldozers, based on U.S. Forest Service maximum average process time for wheeled vehicles (Fleming 2008). Fleming (2008) also found that a welltrained, experienced crew was critical to effective removal of debris and propagules.

Rew (2011) found that all three classes of military vehicles: tracked, tactical wheeled, and civilian pattern, had the capacity to spread NIS. Tracked vehicles had greater capacity than wheeled; vehicles that traveled on unpaved roads and off-road greater than those that traveled paved roads; and vehicles that had been operated in wet conditions more than those operated in dry conditions (21-46 times more propagules transported). She also found that all five MVWSs removed propagules well (mean = 80%) and destroyed 77% of seeds during wash facility containment procedures. Rew (2011) noted on the procedure that “It was visually apparent that some crew members were more effective with the pressurized wash hoses/wands. Adequate training on how to use a pressure hose would improve efficiency in the field.” Crewmembers specifically commented that undercarriage washers and HPLV wands performed much better than the LPHV water cannons. From the study results, Rew provided the recommended wash times listed in Table A-1.

Table A-1. Recommended wash times.

	200-1-138 April 2014	Tactical Wheeled - 6-10 wheel	Tracked
Evaluation of Centralized Vehicle Wash Facilities for Invasive Species Removal	6	12	18
Wet condition	12	18	36

CVWFs

The CVWF is a pollution-prevention technology designed and implemented by the U.S. Army Corps of Engineers (USACE) to perform two functions: washing tactical vehicles, and treating wash water before recycling it for future use. CVWFs were first constructed in the 1980s; the 25 facilities currently in operation save over 2.5 billion gallons of water every year (HQUSACE 2008, HQUSACE 2011). The wash system includes optional bath pre-washes and drive-through wash stations. The treatment system includes sedimentation basins, an optional sediment drying area (at newer facilities), secondary water treatment systems of sand filters or lagoons, and water storage areas.

Soldiers perform the actual washing procedures with hoses, water cannons, or high-pressure wands. Wash water is treated with sedimentation and sand filtration; chemical and advanced biological treatment are not used so that personnel do not require specialized training. A small CVWF can be operated by one person who gives prewash briefing to soldiers washing vehicles, starting and stopping pumps, controlling basin water levels and supervising wash areas. Larger CVWFs may require a lead operator with two or more assistants. Maintenance is usually limited to replacing worn hoses and nozzles, and to repairing mechanical items such as valves, pumps, and motors. The treatment system requires little monitoring, being controlled by timers and water-level sensors. Its purpose is to remove soil particles and floating oil from the wash water before recycling.

CVWFs help prevent the spread of NIS by removing propagules carried by vehicles from training areas (HQUSACE 2008). To prevent the spread of NIS by increasing sediment removal, as well as reducing water usage, HQUSACE (2008) recommended an update to UFC 4-214-03 “Central Vehicle Wash Facilities” to require installation of high-pressure hoses designed to deliver a maximum pressure of 800 psi at a flow of 3 to 4 gpm, as well as undercarriage wash systems. Subsequent studies have reiterated these recommendations (Fleming 2008, Rew 2011). HPLV wands are being incorporated into new CVWF designs and retrofits to address NIS risk to reduce water use.

APPENDIX B

STUDY METHODOLOGY, RESULTS, CONCLUSIONS, RECOMMENDATIONS

Wash Methodology

To compare the efficacy of the HPLV and LPHV techniques, the vehicle wash procedure began with an initial wash from a high-pressure sprayer wand. This gave a clean basis to start the study. Per recommendation of UFC 4-214-03, pressure in the sprayer was set to 1000 pounds per square inch (psi) at a flow rate of 4 gallons per minute (gpm). The hose was not used in this portion since it was a preparation step. Each High-Mobility Multipurpose Wheeled Vehicle (HMMWV) received a 5-minute wash from a two-person team, total of 10-minute wash (Figures B-1 and B-2). The Strykers received a 7-minute wash from a three-person team for a total of 21 minutes(Figure B-3). To perform the wash, the vehicles were pulled into a concrete basin with a trough in the center (Figures B-4 and B-5). The trough was dammed on the lowest side to capture all debris and water used in the cleaning process (Figures B-6 and B-7). The water and debris were then pumped out of the trough and through a 125-micron filter bag using a sump pump (Figures B-8 through B-11). The pump used has the capacity to move 1730 gallons per hour at 10 ft of elevation change.

After an initial wash, Vehicle Dynamics Monitoring and Tracking System (VDMTS) units were installed (Figures B-12, B-13, and B-14). Using a Global Positioning System (GPS) and Micro Electrical Mechanics System (MEMS), the VDMTS records the vehicle location and dynamics of the journey. The units were fixed to the HMMWVs under the rear hatch, or rear passenger seat if no hatch was present, via rubber tarp straps (Figure B-15). The antennas were placed above the rear passenger on the roof (Figure B-16). Similarly, the units were affixed to each Stryker in the rear right gear rack. The vehicles were then tracked over their routine routes for 19 days.

Once the Unit mission was completed, travel data were collected and VDMTS units were removed from the vehicles. The vehicles were immediately washed following a similar procedure to the initial wash, using two persons for HMMWVs and three persons for Strykers (Table B-1)). A LPHV hose was used to wash HMMWVs 1 and 3, and Strykers 3, 4, and 6. A HPLV wand was used to wash HMMWVs 2 and 4, and Strykers 1, 5, and 7. Wash times for the Strykers varied slightly. Strykers 1-3 were washed for 8 minutes (total 24 minutes); Strykers 4-7 were washed for 5 minutes (total 15 minutes). Per UFC 4-214-03, the hose was pressurized to 75 psi and a flow rate of 25 gpm was maintained. Wash contents were collected using the pump and filter bag method.

Table B-1. Post-travel vehicle wash record.

Vehicle	Vehicle ID	Identifier	Wash Time		Wash Method
HMMWV	HQ 36	1	10	Final	hose
HMMWV	HHC 7	2	10	Final	wand
HMMWV	HQ 80	3	10	Final	hose
HMMWV	HHC 54	4	10	Final	wand
HMMWV	HQ 3	5	10	Final	hose
Stryker	C-65	1	24	Final	wand
Stryker	HHC 71	2	24	Final	wand
Stryker	C-41	3	24	Final	hose
Stryker	C-42	4	15	Final	hose
Stryker	C-11	5	15	Final	wand
Stryker		6	15	Final	hose
Stryker	C-21	7	15	Final	wand

Laboratory Methodology

The original filter bag used for the washing process containing the collected wash debris was double bagged, labeled, and shipped back to the laboratory. On receipt at the laboratory, the sample was weighed and the following data were recorded:

- site location
- vehicle type
- vehicle number
- “initial wash” or “final wash”
- date collected
- weight.

Each sample was then split into two approximately equal fractions, half as an archive and the other half as the working sample. Samples were refrigerated for storage.

Analysis Process

Each working sample was wet sieved using 2000µm, 600µm, and 300µm standard test sieves. Each sieve fraction (sample that did not pass through that sieve) was transferred into pre-weighed glazed ceramic evaporating dishes for analysis.

The remaining portion of the sample larger than 2000µm was classified into categories of: seeds, roots, organic fraction (leaf, branches, etc.), and inorganic fraction (rock, bottle caps, paint chips, etc.). Visible seeds and roots were counted and measured, and recorded. The remaining sieve fractions (2000µm or less) were sorted and classified by material type. Categories included: paint chips, plastics, and various other materials known to be inconsistent with the natural environment (miscellaneous human debris (sunflower seed hulls, aluminum can pull-tabs, etc.). The fractions were then oven dried in an uncovered, pre-weighed evaporating dish, at 105 °C for 24 hours, with fan on low (Figure B-17). After drying, the sample was cooled in the desiccator for 1 hour. Cooled samples were weighed and dried sample weight calculated.

Due to the large amount of material collected from each wash, it was not feasible to process and categorize all the collected material. A sub-sampling strategy was established allowing a random sampling for scanning. From each of the 600µm and 300µm sieve dried samples three 2.5g subsamples were placed into pre-weighed glazed ceramic crucibles. These were then sub-sampled again with a 0.5g portion placed into a clear Petri dish. Using a microscope with a camera, the number of seeds, roots, and pieces of debris were counted and recorded for each of these 0.5g subsamples (Figure B-18). Five representative photographs of each Petri dish were taken (Figures B-19 and B-20).

The 0.5g samples were reduced to ashes, uncovered in a muffle furnace at 375°C for 1 hour, and then increased to 550°C for 16 hours (Figure B-21). The crucibles were cooled to less than 200°C, transferred to the desiccator, and allowed to cool to room temperature. The cooled samples were weighed, then the matter was removed and the empty crucibles were weighed.

Figure B-1. Two-person team washing HMMWV.

Figure B-2. Thoroughly washing HMMWV.

Figure B-3. Three people Stryker wash team.

Figure B-4. CVWF concrete wash basin with trough in middle.

Figure B-5. Clean trough before washing.

Figure B-6. Sand bag dam set up.

Figure B-7. Setup of the dam and sump pump in trough.

Figure B-8. Sump pump emerged in trough.

Figure B-9. Water being pumped through filter bags.

Figure B-10. Water being pumped through filter bag.

Figure B-11. Filling a filter bag.

Figure B-12. Packing VDMTS unit.

Figure B-13. Preparing VDMTS units.

Figure B-14. VDMTS unit ready for installation.

Figure B-15. VDMTS location in rear passenger area on HMMWV.

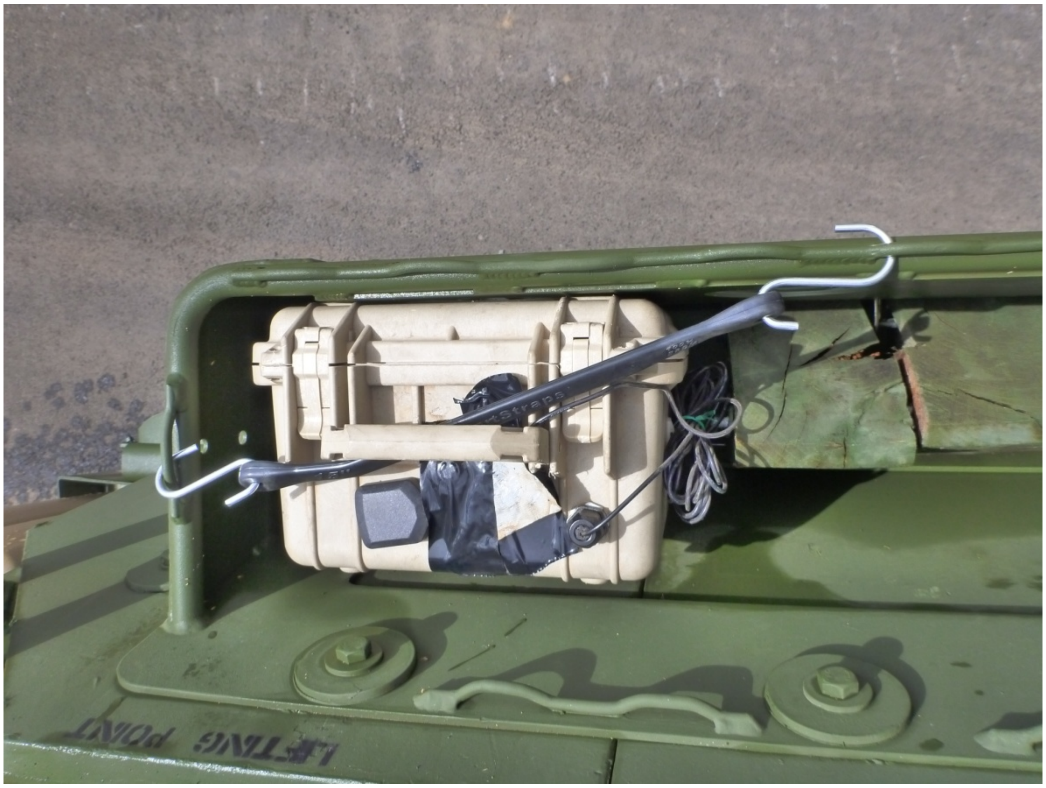

Figure B-16. VDMTS location on roof of a Stryker.

Figure B-17. Evaporating dishes in oven.

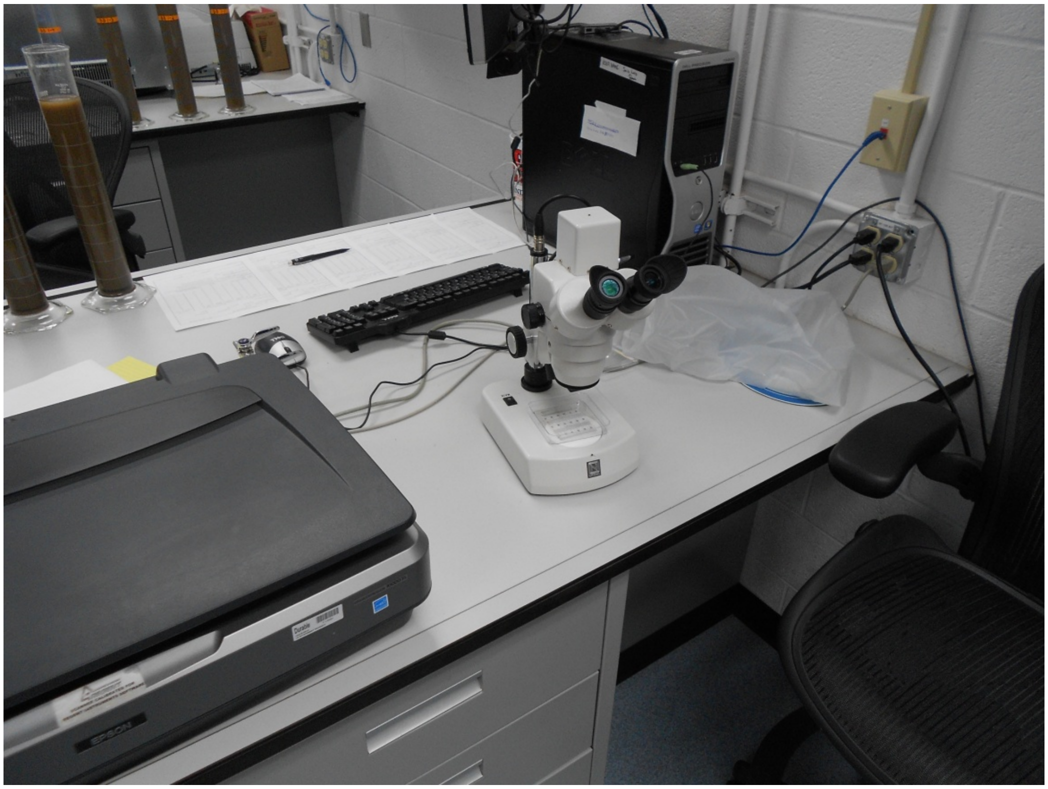

Figure B-18. Microscope with digital camera looking at Petri dish.

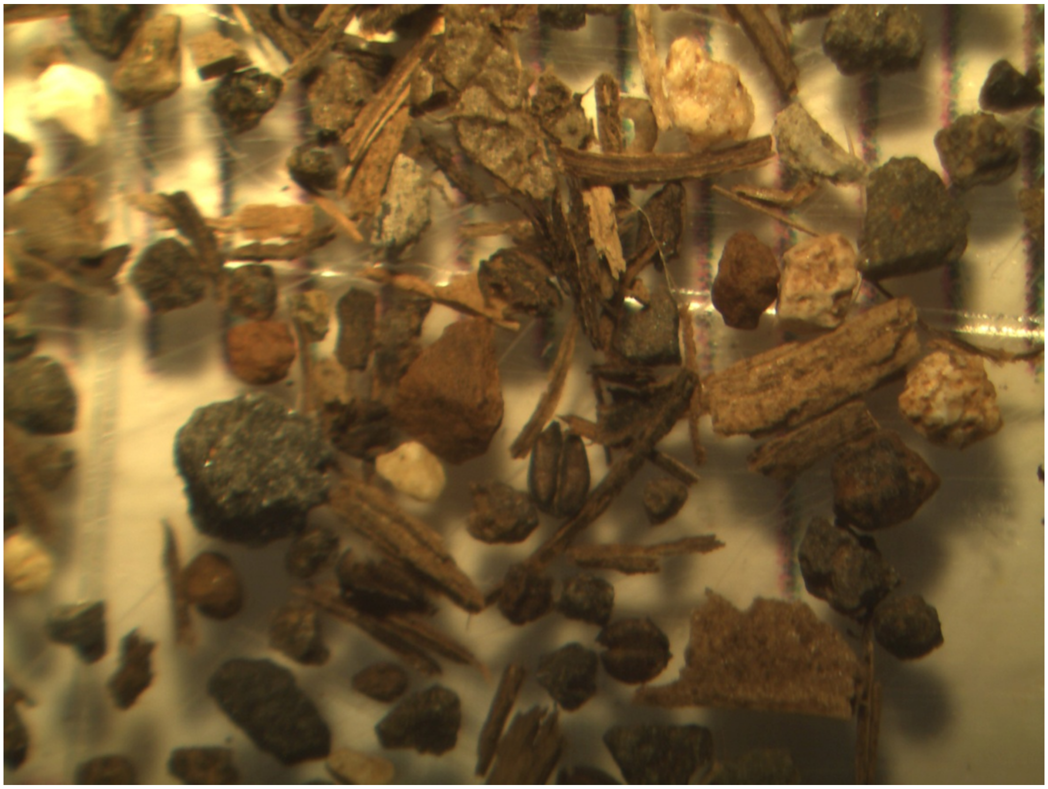

Figure B-19. Close-up view of 600µm sub-sample 1 of HQ36.

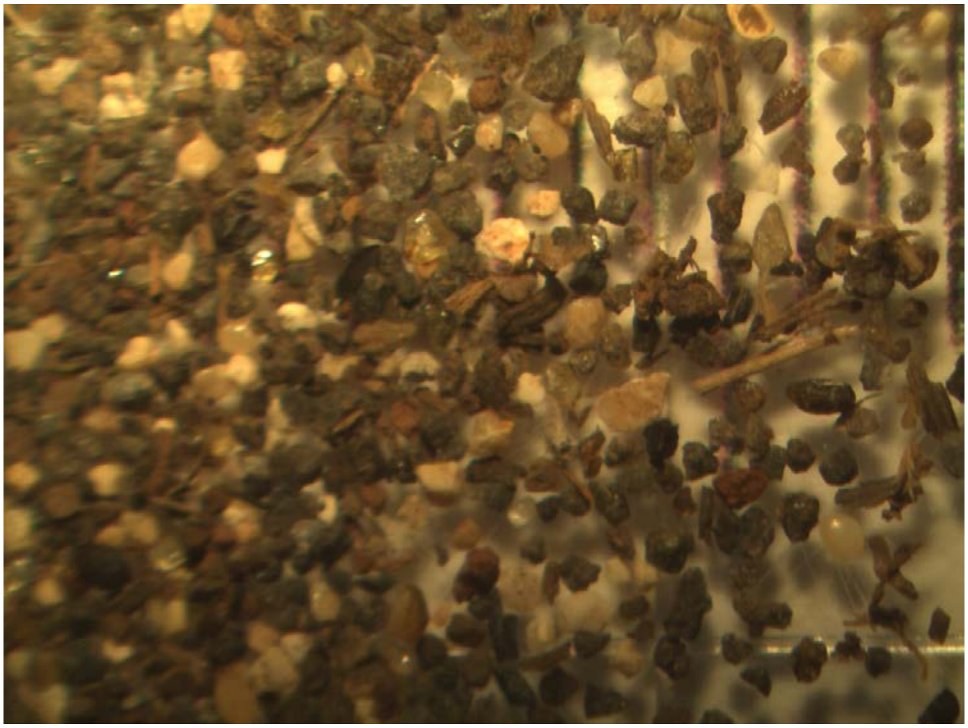

Figure B-20. Close-up view of 300µm sub-sample 1 of HQ36.

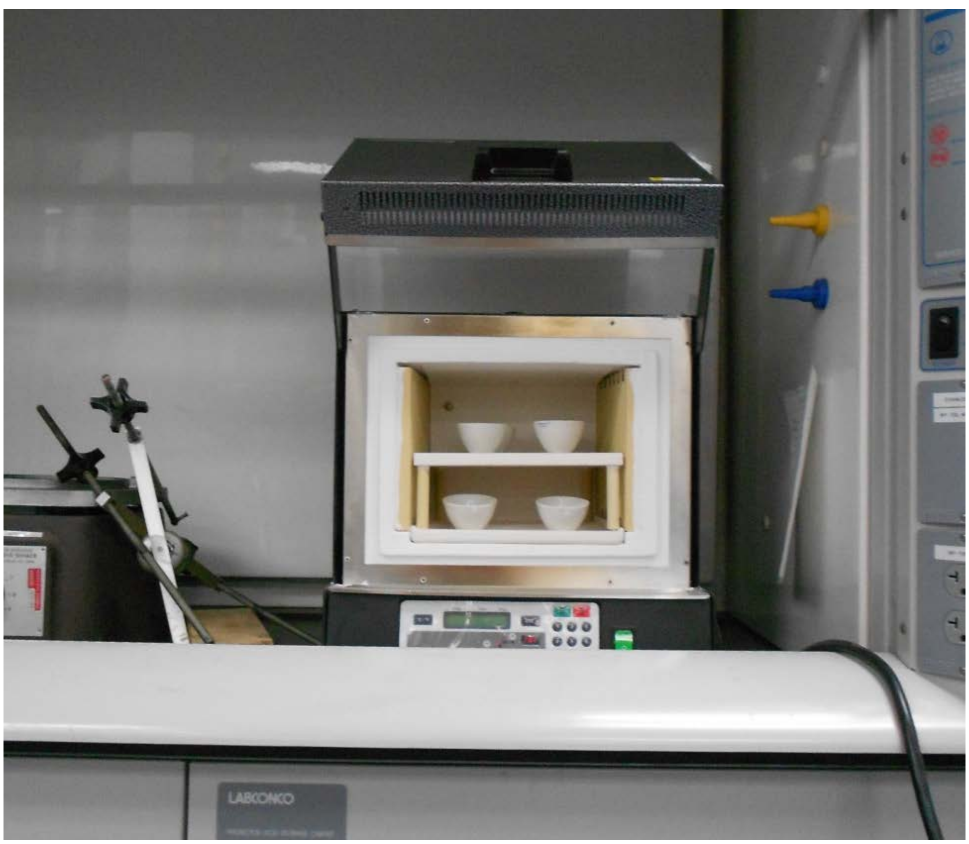

Figure B-21. Crucibles in muffle furnace.

APPENDIX C

CALCULATIONS

Water Efficacy

Water use was calculated by:

$$\text{number of washers} * \text{individual washing time} = \text{total time washed} \quad (1)$$

$$\text{total time washed} * \text{gallons per minute} = \text{total gallons used} \quad (2)$$

$$\frac{\text{filter mass}}{\text{gallons used}} = \text{mass removed per gallon} \quad (3)$$

Organic Mass

Assumed organic material was calculated in micro units by:

$$\frac{\text{processing mass}}{\text{filter mass}} = \text{percent processing of total mass} \quad (4)$$

$$\begin{aligned}&(\text{dry mass of } 2000\mu \text{ seeds and roots dry mass of } 2000\mu \text{ organic matter}\\ &+ \text{dry mass of } 600\mu \text{ organic matter}\\ &+ \text{dry mass of } 300\mu \text{ organic matter}) / \text{total dry mass}\\ &= \text{estimated percent of organic matter}\end{aligned} \quad (5)$$

$$\begin{aligned}&\text{filter mass} * \text{percent processing of total mass}\\ &* \text{estimated percent of organic matter}\\ &= \text{estimated total organic mass}\end{aligned} \quad (6)$$

Seeds and Roots

Seed and root material was ca`lculated by:

$$\begin{aligned}&\frac{\text{estimated dry mass}}{\text{sub-sample mass}} * \text{number of roots}\\ &= \text{estimated roots in } 600\mu \text{ sieve}\end{aligned} \quad (7)$$

$$\begin{aligned} &\textit{roots counted in } 2000\mu \textit{ sieve} \\ &\quad + \textit{estimated roots in } 600\mu \textit{ sieve} \\ &\quad + \textit{estimated roots in } 300\mu \textit{ sieve} \\ &\qquad = \textit{estimated roots in sample} \end{aligned} \tag{8}$$

Results

This work assessed efficacy based on a technology's ability to increase its potential for NIS removal while minimizing water consumption throughout the debris removal process. An analysis of the results of this work found that the measures that most comprehensively compared the efficiencies of the LPHV hose and HPLV wand technologies are expressed as calculated grams of "organic debris removed per gallon of water used" and "roots and seeds removed per km driven off-road."

The analysis of the volume of water used to clean showed that the wand was more efficient at removing organic material than the hose. For combined vehicle types, results showed a 95% statistical significance in favor of the wand. Mean values for "organic grams removed per gallon of water used" were 0.53 for wands technology and 0.47 for hoses with standard deviations of 0.02 and 1.01, respectively (Figure C-1).

The analysis of the measure of "seeds removed per km driven off-road," revealed that there was an error with the tracking device that had been fixed to Stryker C-42. The tracking unit for Stryker C-42 encountered a malfunction during the study period. The median value for the remaining Strykers was used for C-42 to normalize the data results.

Results for "roots and seeds removed per km driven off-road" proved to be insignificant for combined vehicle types. However, for the wand, the overall mean was slightly higher (0.23) than for the hose (0.17) (Figure C-2).

All other tests of the capability to remove plant propagule showed little difference in performance between the wand and hose technologies. Figure C-3 shows that the mean total grams removed per km off-road were 0.61 for the hose and 0.64 for the wand. Figure C-4 shows the same average organic grams per km removed for both the hose and wand, 0.05. Test results did not differ significantly enough to conclusively show one technology to be more efficient at plant propagule removal, without regard for water usage.

Both HPLV and LPHV systems removed approximately the same amount of paint and fiberglass from both vehicle types (HMMWVs 15g and Strykers 17g). When processing the subsamples of 600µm and 300µm material, the pieces of paint and fiberglass melted into the glazing of the crucible in the muffle furnace (Figure C-5). These samples were reprocessed to avoid compromising the data.

Results showed an inverse correlation between the total distance that a vehicle traveled off-road and the amount of material removed from the vehicle per km driven (Figure C-6). On average, the HMMWV washed by the wand had been driven off-road a total of 56.54 km; those washed by hose had been driven off-road a total of 68.96 km. The HPLV wand removed 0.92 grams/km, and the LPHV removed 0.33 g/km.

Results for Strykers were similarly inversed. Strykers washed by wand had been driven off-road an average of 45.80 km; those washed by hose had been driven off-road an average of 40.06 km. The HPLV wand removed 0.46 g/km, and the LPHV removed 0.83 g/km.

This inverse correlation trend can possibly be considered as a contributor to the discrepancies found within the grams removed per km datasets as an unconsidered outside variable. However, this hypothesis cannot be made certain with the limited dataset.

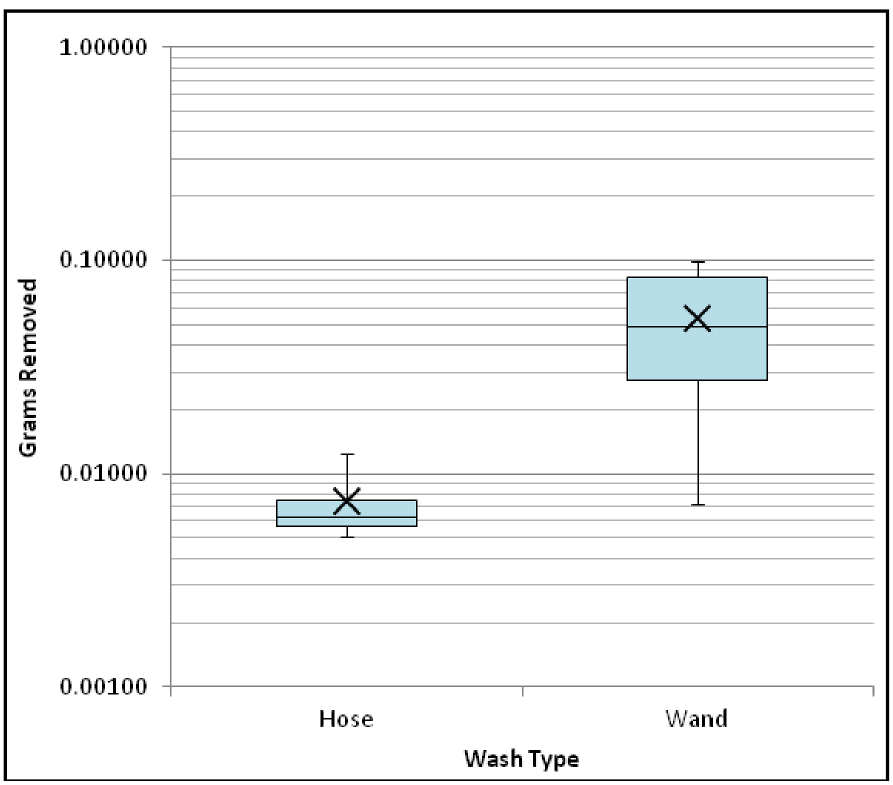

Figure C-1. Organic grams collected per gallon.

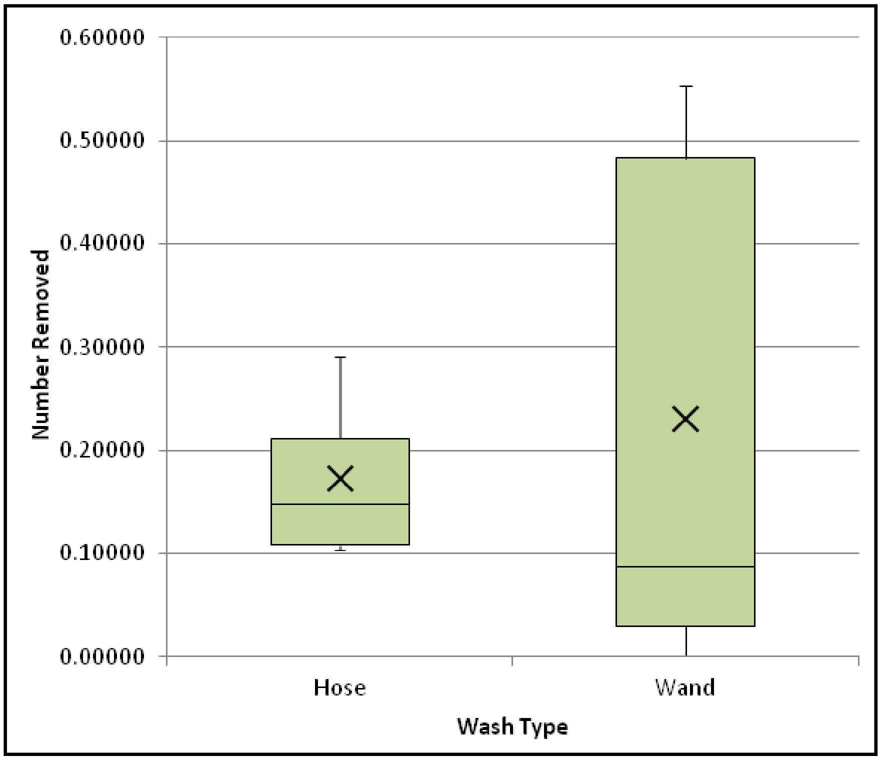

Figure C-2. Roots and seeds removed per kilometer.

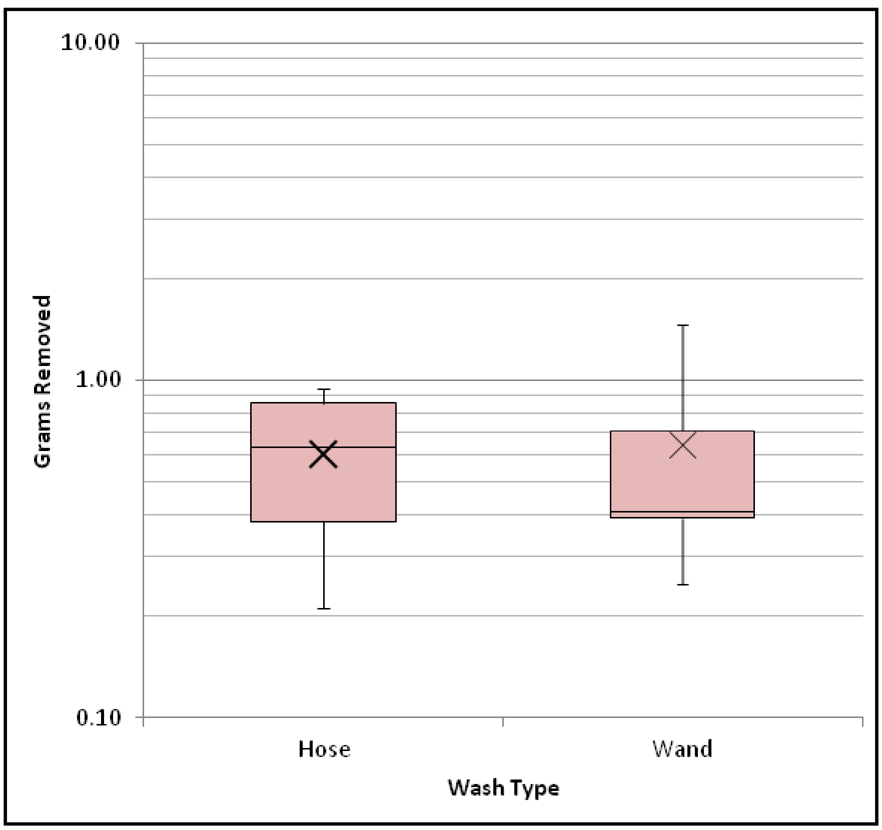

Figure C-3. All grams per kilometer off-road.

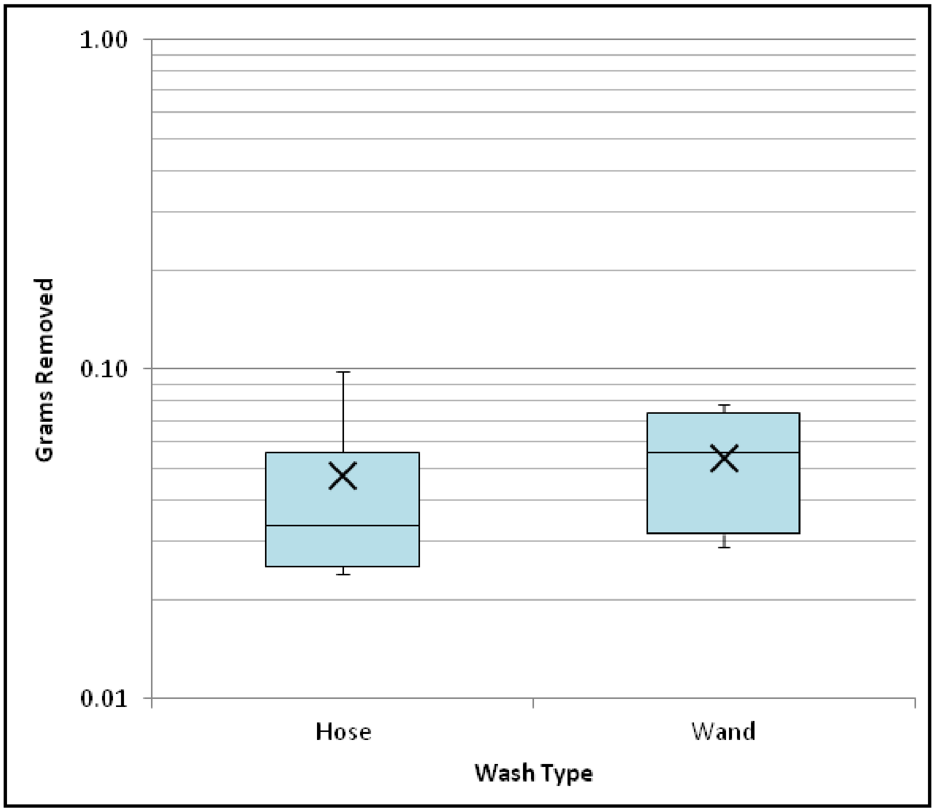

Figure C-4. Organic grams per kilometer off-road.

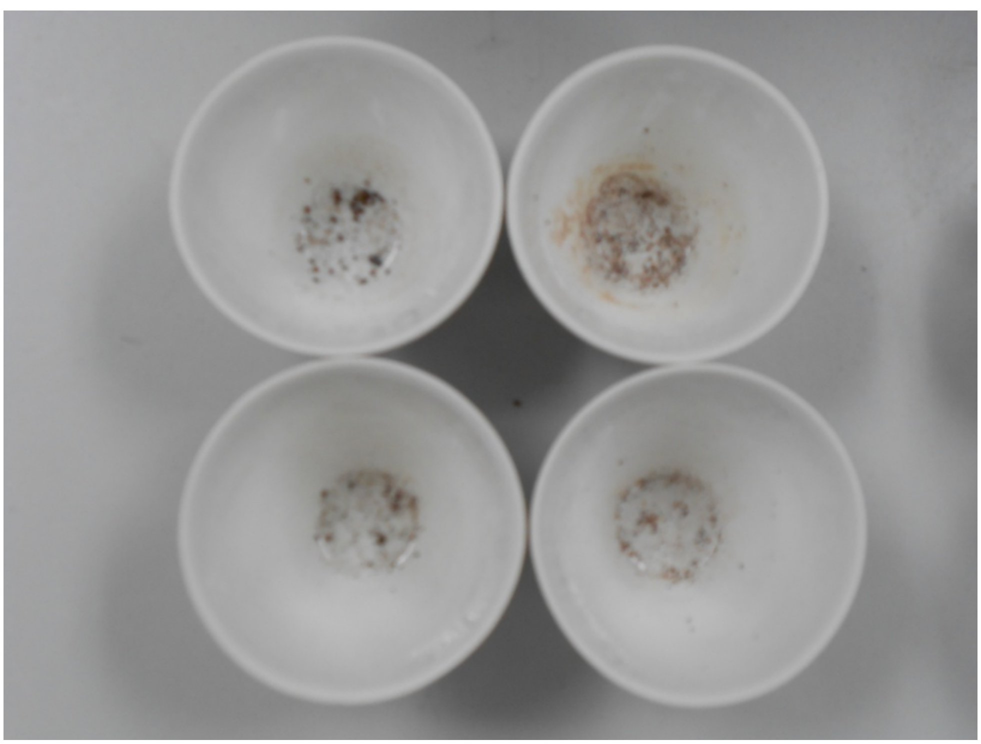

Figure C-5. Paint and fiberglass melted into crucible glazing.

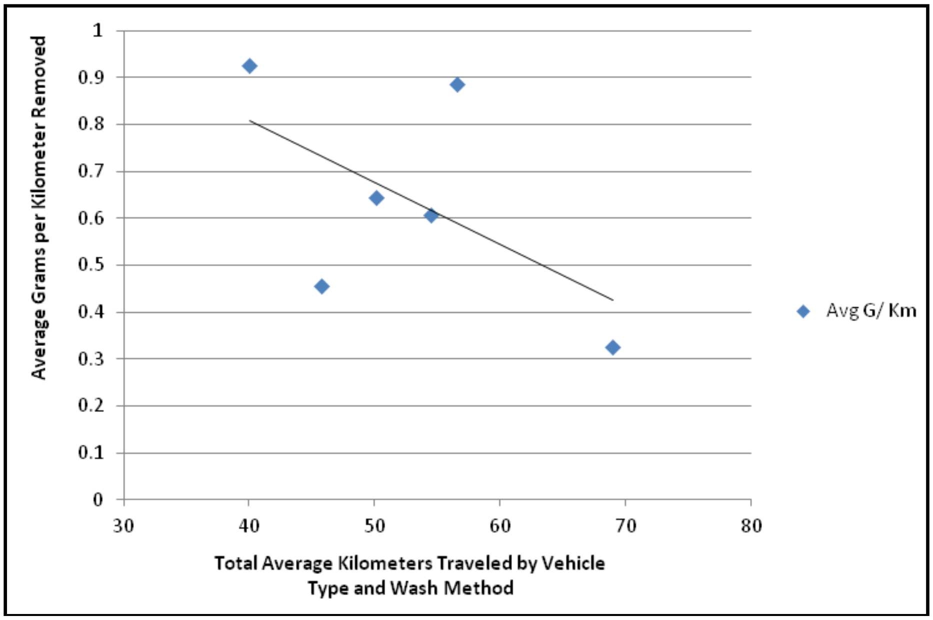

Figure C-6. Average grams per kilometer by total kilometer.

Conclusions

Due to its greater efficacy in water consumption, the HPLV has shown itself as the preferred method to remove NIS from military vehicles for bases with limited water resources. Data show that the HPLV uses less than 100 gallons per wash, which is clearly more water efficient that LPHV technology, which used 375 gallons or more per wash.

However, the results of this study were similar to those of Rew (2011) in the relationship between vehicle type and matter removal. Both washing techniques removed nearly the same amounts of dry mass of human debris, for both vehicle types. Neither method showed itself to be conclusively better at removing debris, or at preventing NIS contamination.

The study identified more seeds and roots in the LPHV samples than in the HPLV samples. This might suggest that the LPHV was more efficient at removing seeds and roots. On the other hand, it might be hypothesized that the high pressure of the HPLV technique destroyed more of the adhered roots and seeds during the washing process therefore they were not present in the analysis. While the data do not conclusively prove this occurrence, high pressure could negatively affect seed and root integrity and compromise their viability. Additionally, scanned images of the debris showed more fine roots in the LPHV samples than in the HPLV samples, indicating that the HPLV wand method impacts/destroys propagules better than the LPHV method.

Recommendations

Both the HPLV (wand) and the LPHV (hose) technologies are efficient at debris removal. However, the hose requires significantly larger amounts of water than does the wand to remove the same amount of debris. Additionally, data suggest that the HPLV method more effectively destroys propagules than does the LPHV method. It is therefore recommended that CVWFs with LPHV be converted to HPLV technology for its combined water conservation and environmental benefits.

To reduce the introduction and spread of NIS, it also recommended that installations develop a standard operational practice for washing of vehicles and equipment before mobilizing to other training areas and/or installations. This cultural practice will reduce the risk of NIS spread from one training area to another. It is further recommended that installations:

- Install HPLV that can deliver a flow rate of 800 psi at 3 to 4 gpm (HQUSACE 2008, Rew 2011).

- Provide adequate training and periodic monitoring of soldiers in proper operation of the CVWF and MVWS per UFC 4-214-03 (Fleming 2008, Rew 2011).

- Remove dried debris first from tracked and heavy equipment and follow with a wash time of at least 20-minutes. For wheeled vehicles, use a 10-minute wash time (Fleming 2008).

- Remove dirt and debris from the wash rack pad and dispose of the grit chamber materials (soil, seed, propagules, etc.) in a manner that will not encourage spread of NIS. Some installation compost grit chamber debris and maintain a temperature of at least 180 °F for 7-days to ensure that weed seed and propagules are no longer viable.

Finally, further investigation is recommended to expand the data set begun in this work, to better analyze the trends and tracking malfunctions noted in this bulletin, which may be partly attributed to the small sample size used here.

APPENDIX D

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APPENDIX E

ACRONYMS AND ABBREVIATIONS

Term	**Definition**
APHIS	Animal and Plant Health Inspection Service
AR	Army Regulation
CECW	Directorate of Civil Works, U.S. Army Corps of Engineers
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CEMP	Directorate of Military Programs, U.S. Army Corps of Engineers
CERL	Construction Engineering Research Laboratory
CFR	Code of the Federal Regulations
CONUS	Continental United States
CVWF	Central Vehicle Wash Facility
DA	Department of the Army
DoD	U.S. Department of Defense
DPW	Directorate of Public Works
EO	Executive Order
ERDC	Engineer Research and Development Center
FNWA	Federal Noxious Weed Act of 1974
GPS	Global Positioning System
HMMWV	High-Mobility Multipurpose Wheeled Vehicle
HPLV	High-Pressure, Low-Volume
HQUSACE	Headquarters, U.S. Army Corps of Engineers
LPHV	Low-Pressure, High-Volume
MEMS	Micro Electrical Mechanics System
MVWS	Mobile Vehicle Wash Systems
NIS	Non-native Invasive (plant) Species
NISC	National Invasive Species Council
OCONUS	Outside Continental United States
POC	point of contact
PTA	Pohakuloa Training Area, HI
PWTB	Public Works Technical Bulletin
SBCT	Stryker Brigade Combat Team
SERDP	Strategic Environmental Research and Development Program
SON	Statement of Need
TM	Army Technical Manual
TR	Technical Report
UFC	Unified Facilities Criteria
U.S.	United States
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
VDMTS	Vehicle Dynamics Monitoring and Tracking System

APPENDIX F

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