

<i>Title:</i> NEON Standard Operating Procedure (SOP): Decontamination of Sensors, Field Equipment and Field Vehicles		<i>Date:</i> 04/12/2018
<i>NEON Doc. #:</i> NEON.DOC.004257	<i>Author:</i> C. Bohall, et al	<i>Revision:</i> B

NEON STANDARD OPERATING PROCEDURE (SOP): DECONTAMINATION OF SENSORS, FIELD EQUIPMENT AND FIELD VEHICLES

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	04/14/2017	ECO-04461	Initial release; consolidates and replaces NEON.DOC.001154 AOS Protocol and Procedure: Aquatic Decontamination and information for NEON Tower Sensors Decontamination Procedures, which was never a released document.
B	04/12/2017	ECO-05148	Numerous updates to clarify requirements; added special considerations and NEON best management practices for Hawaii

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1 DESCRIPTION

1.1 Purpose

Regular and routine activities performed by National Ecological Observatory Network (NEON) staff have potential to increase the spread of invasive species within and across NEON sites. The purpose of this document is to describe standard operating procedures (SOPs) that NEON will follow to prevent the spread of invasive species. It covers inspection and decontamination methods for equipment, personal gear, rubber-tired and tracked land vehicles and watercraft; focusing on the most common methods used to prevent the introduction and spread of nonindigenous species and pests. In some locations, quarantines may be in place for certain insect pests – such as the emerald ash borer (*Agrilus planipennis*) (ER[29]).

This document also outlines specific decontamination protocols for Domain 20 (Hawaii) to prevent the spread of a new fungal disease that is spreading in Hawaii and killing the native ‘ōhi‘a (*Metrosideros polymorpha*) tree. This disease is called “Rapid ‘Ōhi‘a Death” (ROD) and is caused by the fungus, *Ceratocystis fimbriata*. (See ER[30-32]; and Appendices E and F.)

1.2 Scope

This document provides a change-controlled version of an Observatory procedure. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

The SOPs described in this document are applicable to all NEON AOS and TOS protocols (RD[28]), as well as operation and maintenance of AIS, TIS and related infrastructure and activities

1.3 Background

Invasive species have a significant disruptive impact on native flora and fauna; costing the US billions of dollars per year (ER[01-04]). Invasive species also represent one of the seven Grand Challenges addressed by NEON (AD[01]). Proactive efforts to prevent the spread of invasive species are necessary to avoid impacts on the environment and infrastructure, and to avoid exacerbating species invasions that NEON is attempting to observe over the next 30 years.

NEON’s 34 aquatic and 47 terrestrial sites are located in a diverse array of ecological communities in 20 eco-climatic regions across the US and are subject to a variety of land use practices and levels of disturbance. NEON field crews routinely visit these sites to operate and maintain instrumental and observational sampling infrastructure, thereby increasing the risk of invasive species spreading within and across sites.

At all NEON sites, irrespective of land ownership and management, NEON will mitigate these risks by employing the procedures outlined in this document and following procedures that may be specified in

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applicable site host land use agreements. Field operations personnel will report any notable encounters with invasive species on a NEON site to the site host and to NEON HQ via the trouble ticketing system, including the discovery of exotic species heretofore unreported from the host site.

Prevention, the first line of defense against the spread of invasive species, can be a significant challenge. Invasive species use various means and media to invade new locations, such as soil and mud accumulated on clothing, boots, or vehicles; seeds lodged on equipment; invasive plant fragments; adhesion to boats and other in-water equipment; and other viable material that is not easily recognizable by casual inspection. NEON will utilize best management practices employed by several federal land management agencies and others (ER[05-18]).

Our intent is to address requirements of Executive Order 13112 (ER[19]), and several federal laws (ER[20-22]) designed to prevent the introduction and impact (economic, ecological, and human health) of invasive species; and recommendations of the National Invasive Species Council for their management (ER[23]).

Standard Operating Procedures (SOPs) in section 6 of this document provide detailed systematic directions and best practices for decontamination of *in situ* sensors, field equipment, personal gear and vehicles. NEON’s problem reporting system will be used to resolve any issues associated with implementing these SOPs.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.000001	2011 Science Strategy: National Ecological Observatory Network
AD[02]	NEON.DOC.004300	EHSS Policy, Program and Management Plan
AD[03]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[04]	NEON.DOC.000727	Chemical Hygiene and Biosafety Plan
AD[05]	NEON.DOC.050005	Field Operations Job Instruction Training Plan

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Level 1, Level 2, and Level 3 Data Products Catalog
RD[04]	NEON.DOC.002984	Standard Operating Procedure: Minimizing Site Disturbance during Aquatic and Terrestrial Observation System Sampling
RD[05]	NEON.DOC.000481	TOS Protocol and Procedure: Small Mammal Sampling

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RD[06]	NEON.DOC.014045	TOS Protocol and Procedure: Tick and Tick-borne Pathogen Sampling
RD[07]	NEON.DOC.014048	TOS Protocol and Procedure: Soil Biogeochemistry and Microbial Sampling
RD[08]	NEON.DOC.014038	TOS Protocol and Procedure: Core Sampling for Plant Belowground Biomass
RD[09]	NEON.DOC.014050	TOS Protocol and Procedure: Ground Beetle Sampling
RD[10]	NEON.DOC.014049	TOS Protocol and Procedure: Mosquito Sampling
RD[11]	NEON.DOC.001711	TOS Protocol and Procedure: Coarse Downed Wood
RD[12]	NEON.DOC.001710	TOS Protocol and Procedure: Litterfall and Fine Woody Debris
RD[13]	NEON.DOC.014037	TOS Protocol and Procedure: Herbaceous Biomass Sampling
RD[14]	NEON.DOC.002136	TOS Protocol and Procedure: Bryophyte Productivity
RD[15]	NEON.DOC.002697	NEON Tower Sensors Infrastructure & Assembly Maintenance Procedure
RD[16]	TBD	Guide for Annual Sensor Refresh (Draft training material) https://neoninc.sharepoint.com/sites/fieldops/TIS/Shared%20Documents/Annual%20Sensor%20Refresh/Guide%20for%20Annual%20Sensor%20Refresh%20rev_c.pdf#search=Sensor%20Swap
RD[17]	NEON.DOC.002716	NEON Preventive Maintenance Procedure: AIS Nitrate Analyzer
RD[18]	NEON.DOC.001569	NEON Preventive Maintenance Procedure: AIS Surface Water Quality Multisonde
RD[19]	TBD	NEON Preventive Maintenance Procedure: AIS Level Trolls
RD[20]	NEON.DOC.001465	NEON Preventive Maintenance Procedure: Sun Photometer
RD[21]	NEON.DOC.004849	NEON Preventive Maintenance Procedure: TIS & AIS Secondary Precipitation Gauge
RD[22]	NEON.DOC.004757	NEON Preventive Maintenance Procedure: AIS & TIS Thermometrics Platinum Resistance Thermometer (PRT)
RD[23]	NEON.DOC.003505	NEON Preventive Maintenance Procedure: Particulate Analyzer - Mass
RD[24]	NEON.DOC.003633	NEON Preventive Maintenance Procedure: Soil CO ₂ Concentration
RD[25]	NEON.DOC.003593	NEON Preventive Maintenance Procedure: Soil Temperature Profile
RD[26]	NEON.DOC.003622	NEON Preventive Maintenance Procedure: Soil Water Content and Salinity Profile
RD[27]	NEON.DOC.000769	Electrostatic Discharge Protection Procedure
RD[28]	NEON.DOC.002180	Configured Item List – NEON Observation Systems Protocols
RD[29]	NEON.DOC.003496	NEON Preventive Maintenance Procedure: Particulate Analyzer - Size
RD[30]	NEON.DOC.001458	NEON Preventive Maintenance Procedure: 2D Sonic Anemometer
RD[31]	NEON.DOC.001457	NEON Preventive Maintenance Procedure: Aspirated Air Temperature Shield
RD[32]	NEON.DOC.001459	NEON Preventive Maintenance Procedure: Barometric Pressure Sensor
RD[33]	NEON.DOC.004134	NEON Preventive Maintenance Procedure: Eddy Covariance Systems
RD[34]	NEON.DOC.003342	NEON Preventive Maintenance Procedure: Primary Precipitation Gauge and Double Intercomparison Reference (DFIR)
RD[35]	NEON.DOC.004934	NEON Preventive Maintenance Procedure: Particulate Analyzer – Humidity and Temperature Sensor

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RD[36]	NEON.DOC.004429	NEON Preventive Maintenance Procedure: Radiation Sensors
RD[37]	NEON.DOC.001882	NEON Preventive Maintenance Procedure: TIS & AIS Digital Network Camera
RD[38]	NEON.DOC.004849	NEON Preventive Maintenance Procedure: TIS & AIS Secondary Precipitation Gauge
RD[39]	NEON.DOC.003495	NEON Preventive Maintenance Procedure: Wet Deposition

2.3 External References

ER[01]	Pimentel, D., Lach, L., Zuniga, R., Morrison, D., 2000. Environmental and Economic Costs of Nonindigenous Species in the United States. <i>Bioscience</i> 50: 53-65
ER[02]	Pimentel, D., Zuniga, R., Morrison, D., 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. <i>Ecological Economics</i> 52(2005:: 273-288
ER[03]	Crowl, T., et al. 2008. The spread of invasive species and infectious disease as drivers of ecosystem change. <i>Frontiers in Ecology and Environment</i> 6 (5), 238-246
ER[04]	Vila, M., et al. 2011. Ecological impacts of invasive alien plants: a meta-analysis of their effects on species, communities and ecosystems. <i>Ecology Letters</i> 14 (7), 702-708
ER[05]	DiVittorio, Grodowitz, and Snow, Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species, <i>Technical memorandum No. 86-68220-07-05</i> , US DOI 2010 https://www.usbr.gov/mussels/prevention/docs/EquipmentInspectionandCleaningManual2010.pdf
ER[06]	Kenai Peninsula CWMA. 2013. Preventing the Spread of Invasive Species: Procedures for Field Researchers on the Kenai Peninsula, Alaska. Kenai Peninsula Cooperative Weed Management Area http://www.kenaiweeds.org/user_images/Prevention%20Guidelines.pdf
ER[07]	Malecki, R.A., B. Blossey, S.D. High, D. Schroeder, L.T. Kok, and J.R. Coulson. 1993. Biological control of purple loosestrife. <i>Bioscience</i> 43 (10): 680-686.
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ER[13]	USEPA. 2007. National Rivers and Streams Assessment: Field Operations Manual. EPA-841-B-07-009. U.S. Environmental Protection Agency, Washington, DC.

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ER[15]	US Forest Service. 2016. Aquatic Invasive Species Guide to Preventing Transport by Wildland Fire Operations. Appendix B. Aquatic Invasive Species of Concern to Firefighters Nationwide and Methods of Control. http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3806222.pdf , June 2016.
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ER[19]	Executive Order 13112 (Dec 5 2016) Safeguarding the Nation from the Impacts of Invasive Species. Retrieved from https://www.invasivespeciesinfo.gov/laws/execorder.shtml , January 2017
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ER[22]	Federal Noxious Weed Act of 1974, as amended (16 USC §1531 et seq.)
ER[23]	National Invasive Species Council (2016). National Invasive Species Council Management Plan. Retrieved from https://www.doi.gov/invasivespecies/management-plan , January 2017
ER[24]	Federal Insecticide, Fungicide, and Rodenticide Act (7 USC §136 et sq.). Retrieved from https://www.gpo.gov/fdsys/pkg/USCODE-2010-title7/pdf/USCODE-2010-title7-chap6.pdf , January 2017
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ER[30]	Rapid ‘Ōhi‘a Death, ROD (<i>Ceratocystis fimbriata</i>). Retrieved from http://dlnr.hawaii.gov/hisc/info/species/rapid-ohia-death/ , December 2017
ER[31]	Rapid ‘Ōhi‘a Death, Part 1: 2017-2019 Strategic Response Plan, November 2016 http://www.ctahr.hawaii.edu/dl/rod/strategicresponseplanfinal.pdf
ER[32]	Guidance Document for Rapid ‘Ōhi‘a Death: Background for the 2017-2019 ROD Strategic Response Plan.

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ER[34]	Vaisala (2013) User’s Guide: Vaisala CARBOCAP Carbon Dioxide Probe GMP343, Version M210514EN-E. Vaisala Oyj., Helsinki, Finland. https://www.vaisala.com/sites/default/files/documents/GMP343%20User%27s%20Guide%20in%20English%20M210514EN.pdf
ER[35]	US Department of Labor, Occupational Safety and Health Administration. Occupational Safety and Health Standards, 29 CFR Standard No. 1910.242(a). https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=9849#1910.242(b)
ER [36]	MSDSOnline (NEON Project Access) URL: https://msdsmanagement.msdsonline.com/ec04e43d-e72d-4174-9369-c81635eb9493/ebinder/?nas=True

2.4 Acronyms

Acronym	Definition
DAS	Data Acquisition Systems
DO	Dissolved Oxygen
DSF	Domain Support Facility
EHS	Environmental Health and Safety
EPA	Environmental Protection Agency
ESD	Electrostatic discharge
IAW	In Accordance With
PPE	Personal Protective Equipment
PRT	Platinum Resistance Thermometer
QUAT	Quaternary ammonium solution; household strength ammonium cleaning solution
ROD	Rapid ‘Ōhi’a Death
SDS	Safety Data Sheets
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
v/v	Volume-to-volume percentage

2.5 Definitions

Allelopathic: Describes a plant (or other organism) that inhibits germination or growth of another via the release of chemical inhibitors.

Aquatic nuisance species (ANS): Includes “...nonindigenous species that threatens the diversity and abundance of native species or the ecological stability of infested waters, or commercial, agricultural or recreational activities dependent on such waters.” (ER[20])

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Biofouling: The accumulation of water borne organisms -- such as bacteria, protozoans, algae, and crustaceans -- on the surfaces of engineering structures (e.g., sensors and equipment) in water that leads to corrosion and inefficiency of moving parts.

Equipment: Items used for sampling at NEON sites that are not installed permanently at the site -- they are carried to and from the site each sampling day (e.g., waders, nets, tick drag cloth, buckets, boats, backpacks).

Exotic Species: A species introduced from outside of its historic range via deliberate or accidental human activity, including any such organism transferred from one country into another. Also known as alien, non-indigenous or non-native.

Invasive Species: "...an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health." (ER[19])

Non-indigenous species: See definition of **Exotic Species** above.

Noxious weed: "...any plant or plant product that can directly or indirectly injure or cause damage to crops (including nursery stock or plant products), livestock, poultry, or other interests of agriculture, irrigation, navigation, the natural resources of the United States, the public health, or the environment." (ER[22]). Most are also non-indigenous.

Pest: "... (1) any insect, rodent, nematode, fungus, weed, or (2) any other form of terrestrial or aquatic plant or animal life or virus, bacteria, or other micro-organism (except viruses, bacteria, or other micro-organisms on or in living man or other living animals) which the [EPA] Administrator declares to be a pest." (ER[24])

Plant Pest: "... any living stage of any of the following that can directly or indirectly injure, cause damage to, or cause disease in a plant or plant product..." protozoan, nonhuman animal, parasitic plant, bacterium, virus, infectious agent or other pathogen. (ER[21])

Veligers: Planktonic larvae of snails and mussels.

Weed: A native or non-native plant that is unwanted in a particular place at a particular time.

3 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices (see (AD[01-02])).

Personnel working at a NEON site must be compliant with safe fieldwork practices as outlined in the Operations Field Safety and Security Plan (AD[03]) and the EHSS Safety Policy, Program and Management Plan (AD[02]). The Field Operations Manager and the Lead Field Technicians have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

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Personal protective equipment (PPE) may be required in some decontamination procedures to maintain safe working conditions and for the proper application of disinfectants. For this reason, personnel should be trained and familiar with the cleaning solutions, tools and equipment (e.g., power washers and air compressors) used.

Be sure to wear eye protection and gloves while cleaning with chemicals such as bleach, QUAT, vinegar and Hydrochloric Acid (HCl). Follow proper chemical disposal guidelines in the Chemical Hygiene and Biosafety Plan (AD[04]). Everyone must be familiar with the Safety Data Sheets (SDS) for each chemical used, particularly hydrochloric acid (HCl). HCl is used in a very low concentration and there is great detail in how to achieve the low concentration inside the safety of a fume hood included in this document. Take special care not to burn skin when using hot water. It is the responsibility of each supervisor and team leaders to ensure that field technicians know proper chemical safety protocols for all chemicals used.

Safety goggles should always be used when mixing chemicals. Safety glasses, at least, should be used when applying chemicals

Power washers operate at very high pressures and are capable of causing serious bodily harm. Operators should be familiar with the equipment before attempting its use. Do not use compressed air for cleaning purposes except where reduced to less than 30 PSI, and then only with effective chip guarding and PPE – i.e., use of safety glasses, at a minimum (ER[35]).

3.1 Hazard Communication Safety Data Sheets (SDS)

Safety Data Sheets (SDS)s can always be accessed via the NEON Project’s account on [MSDSOnline \(ER \[36\]\)](#).

If in the field and have internet connectivity, access to [MSDSOnline](#) can also be accessed via the following Quick Response (QR) code.



Neon Inc.
Scan to access an
MSDS

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4 PERSONNEL AND EQUIPMENT

4.1 Equipment

The items needed to implement the procedures in this document are organized by task in Table 1,

Table 2, and Table 3. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

4.2 Training Requirements

All technicians must complete training for proper and safe implementation of the procedures described herein, in accordance with the Field Operations Job Instruction Training Plan (AD[05]). This includes training in lab chemical safety and recognition of invasive species likely to be encountered – aquatic and terrestrial. Emphasis is on domain-specific species of concern likely to be encountered and the most appropriate inspection and cleaning techniques. As such, domain staff should familiarize themselves with known and potential invasive species likely to occur at field sites. Educational and outreach materials should be posted in highly visible locations at the support facility and locations such as truck binders, and be made readily available to seasonal staff and visitors. See, for example, fact sheets published by the US Forest Service:

- https://www.na.fs.fed.us/fhp/invasive_plants/weeds/index.shtm.

Domain staff must inform visitors about the risks and proper protocols while on site, such as removing material from their personal gear that might harbor invasive species.

4.3 Specialized Skills

No specialized skills are required to implement these SOPs.

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Table 1 Equipment list – Decontaminating sensors

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Quantity	Special Handling
Durable Items							
MX108279	Forestry Suppliers	89158	R	Hand-held thermometer	Measuring water temperature for the bleach cleaning method	1	N
MX101740	Uline	S-7914	R	5 gal Bucket	Wash solution container	4	N
MX100570	Fisher Scientific Company	10020F	R	1 L Volumetric flask	Preparing a 5% (v/v) hydrochloric acid (HCl) solution	1	N
MX100381	Fisher Scientific Company Thomas Scientific, Inc.	085726D 3571A25	R	100 mL Graduated cylinder	Preparing a 5% (v/v) hydrochloric acid (HCl) solution	1	N
	Fisher Scientific Company	0340610F	R	1 L Wash bottle	Wash solution and rinsing container	4	N
MX100665	Fisher Scientific Company Thomas Scientific, Inc.	033134F 1709C04	R	1 L Nalgene bottle	Storing a 5% (v/v) hydrochloric acid (HCl) solution	2	N
MX110311	Fisher Scientific Company	1043736	R	10 L Nalgene carboy	Acid waste container	1	N
MX107552	Thomas Scientific, Inc.	1227T93	R	Soft, antistatic brush	Removing debris from sensors	1	N
MX105381	Fondriest Environmental, Inc.	599470	R	YSI EXO conductivity cell cleaning brush	YSI Sonde decontamination	1	N
			R	Large plastic tarp or plastic sheeting	Laying out sensor cables and infrastructure components for spraying and decontamination	1-2	N
Consumable Items							
MX100635	Grainger, W.W.	4TKE5	R	Phosphate-free detergent (Alconox or Liquinox)	Decontaminating aquatic sensors (except uPAR)	1 gal	N
MX100581	Fisher Scientific Company	A142212	R	Hydrochloric acid, 37%	Preparing a 5% (v/v) hydrochloric acid (HCl) solution for decontaminating aquatic sensors (except uPAR)	4 L	Y
MX107542	Fisher Scientific Company	435571	R	Isopropyl alcohol, 70%	Decontaminating aquatic and terrestrial sensors (except uPAR, PQS1, and Quantum Line Sensor (QLS))	4 L	Y

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Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Quantity	Special Handling
MX100587	Grainger, W.W.	41H893	R	Household bleach (5-6% NaClO)	Used to make various bleach solutions	½ gal	Y
MX100586	Grainger, W.W.	3WVGK6	S	Quaternary ammonium disinfectant (ADBAC + DDAC)*	Ammonium-based solution	1 gal	Y
MX100213	Fisher Scientific Company	4355601	R	Ethyl Alcohol 95%	Decontaminating terrestrial sensors	4 gal	Y
			R	Deionized water	Rinsing sensors	4 gal	N
MX107541	Amazon Capital Services Inc.	B0056QWLBY	R	White vinegar (5% acetic acid)	Softening mineral deposits	1 gal	N
MX100676	Fisher Scientific Company	23400118	R	Cotton Swab	Removing large debris from sensor housings	1 box	N
MX100642	Thomas Scientific, Inc.	1234Z63	R	Kimwipes	Applying cleaning solutions to sensors	3 boxes	N
MX107548			R	Compressed air (keyboard) duster	Drying conductivity cells of the Aqua and Level Trolls; remove debris from sensors	1	N
			R	Wood or plastic toothpicks	Remove debris terrestrial sensors	1 box	N
MX104751	Grainger, W.W.	2AJP4	R	Soft camel hair brushes	Remove debris terrestrial sensors	Assorted sizes	N
MX108694	Fisher Scientific Company	NC0842601	R	Soft lint-free or microfiber cloth	Wipe radiation sensors	As needed	N
MX103142	Fisher Scientific Company	19027438	R	Soft toothbrush	Remove debris terrestrial sensors	1	N
MX100355	Amazon Capital Services Inc.	B00WC1X8MC	R	Soft bristle scrub brushes (small and medium sizes)	Remove debris terrestrial sensors	2 sizes	N
			R	Bottle brush for Cimel collimating tubes	Decontaminate Cimel	1	N
MX105696	VWR	17227-044	R	Pipe cleaners	Decontaminate Apogee IR radiometer	12	N
MX104783	Grainger, W.W.	16W486	R	Plastic wrap	Sealing open connector ends	As needed	N

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R/S=Required/Suggested

Table 2 Equipment list – Decontaminating equipment

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items								
MX106234	Grainger, W.W.	2ZV91	S	1 gallon home and garden compression sprayer	Applying bleach or ammonium-based solution	All	1	N
MX104772	Grainger, W.W.	3LFU8	S	24 oz. hand sprayer	Applying bleach or ammonium-based solution	All	1	N
MX104772	Grainger, W.W.	3LFU8	S	24 oz. hand sprayer	Applying 70% isopropyl solution	All	1	N
			R	Plastic mixing/catch basin	Containing bleach or ammonium-based solution	All	2	N
MX101220	Grainger, W.W.	2RWC7	R	Nylon-bristled kitchen brush (separate from the brush used for macroinvertebrate sampling)	Removing debris from equipment	All	1	N
MX104786	Fisher Scientific Company	19181504	R	Safety goggles	Safe mixing of chemicals	All	1	N
			R	Safety glasses	Safe application of chemical mixtures	All	1	N
MX104452	Grainger, W.W.	4T299	S	Splash Apron	Safe handling of chemicals	All	1	N
			R	Nitrile gloves	Safe handling of chemicals	All	1 box	N
			R	White label tape	Labeling solutions	All	1 roll	N
MX102002	Grainger, W.W.	1JU51	R	Black marker (Sharpie)	Labeling solutions	All	1	N

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*Also used for cleaning small mammal traps

Table 3 Equipment for vehicle inspection

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Quantity	Special Handling
Durable items							
			R	Flashlight	Inspecting equipment and vehicles	1	N
MX101693	Grainger, W.W.	1VUA3	R	Under vehicle mirror	Inspecting under vehicles	1	N
			R	Invasive Species list	Reference	1	N
			R	Portable lighting	Inspecting during night work	1	N
	Amazon Capital Services Inc.	B00CPGMUXW	R	Pressure Washer	Dislodging soil, plant and animal material	1	N

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4.4 Estimated Time

The time required to implement an SOP will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, level of domain/site-specific risk and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by skilled personnel (i.e., not the time it takes at the beginning of the field season). Note that more time may be needed if and when contamination is obviously excessive; domain personnel are expected to use good judgement to determine if and when more or less time is required – i.e., depending on domain/site-specific circumstances. Use the framework in Table 4 for assessing progress:

Table 4 Estimated time and frequency required for decontamination

Item	Inter-site transport of invasive species <u>IS NOT</u> a significant concern	Inter-site transport of invasive species <u>IS</u> a significant concern
Fixed Sensors	1-2 people; 30 minutes per site at the field site and 30-90 minutes at the DSF, depending on reagent.	Same
Handheld sensors	1-2 people; 30 minutes at the DSF prior to use at another site	Same
AOS/TOS Equipment	1-2 people; 30-45 minutes prior to use at another site**	1-2 people; 30-90 minutes prior to use at another site**
Personal Gear	10-15 minutes prior to use at another site**	20-30 minutes prior to use at another site**
Vehicle Exterior	Light wash as needed; thorough cleaning monthly*	Light wash weekly; before traveling to a new site if needed; thorough cleaning at least monthly*
Vehicle Interior	Light cleaning as needed; thorough cleaning monthly	Light cleaning weekly; before traveling to a new site if needed; thorough cleaning at least monthly

* A light wash may include running the vehicle through a car wash if available and feasible, a hose wash at the DSF, or something equivalent. If not feasible for any reason, submit a problem ticket. If possible, when using a car wash, get a standard exterior wash and undercarriage wash.

** For aquatic sites, equipment and gear subject to bleach decontamination must dry prior to next use (e.g., overnight)

5 CONTINGENCIES AND NOTES

Site Host Requirements: Individual site hosts may require additional procedures and Preventive measures, as specified in relevant land use agreements and/or Domain Site-Specific EHS Plans. Local site host requirements override the procedures outline in this document. Check with the site host and the NEON Permitting Office to confirm requirements.

 **NOTE:** Domain 20, Pu'u Maka'ala (PUUM) Natural Area Reserve (NAR) has specific requirements for all work within Hawaii's Natural Area Reserve -- see Appendices E and F for further information.

Duration: If a task is taking significantly longer than the estimated time (see Table 4), or if cleaning procedures appear to be ineffective or are not feasible for any reason, submit a problem ticket.

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Incident weather: Delay inspection and cleaning until weather conditions are favorable and safe.

Field Emergencies: Emergencies involving the health and safety of personnel take precedence over decontamination. Inspection and decontamination should proceed after the emergency is rectified.

6 STANDARD OPERATING PROCEDURES

SOP A covers general procedures applicable at both aquatic and terrestrial sites. SOP B and SOP C go into more depth for aquatic and terrestrial decontamination procedures, respectively.¹ These SOPs cover NEON project equipment and vehicles as well as contractor and associated researcher-owned equipment and vehicles. A quick reference and reminders are provided in Appendices A and B.

The inspection, cleaning, and decontamination procedures presented here are designed for sites where the status of invasive species is unknown (i.e., invasive species have not yet been documented). Heightened vigilance is recommended at sites where invasive species have been identified and documented and are at risk of spreading to new sites, or where current land use agreements require it. A lesser effort may be warranted where invasive species are already well established across sites within a domain.

Selected non-indigenous aquatic and terrestrial species of concern are presented in Appendices C and D. These do not comprise a complete list of invasive species potentially occurring on NEON sites. NEON will update these listed over time as new information emerges. Table 5 lists several additional sources of information on non-indigenous and pest species that occur in the US.

NEON does not plan to apply biological control measures -- although some site hosts may include them as part of their land management practices. In any case, these methods are not covered here.

Table 5 Selected invasive species information sources

Information Sources	Web Link
Global Invasive Species Database	http://issg.org/database/welcome
National Invasive Species Information Center	https://www.invasivespeciesinfo.gov/index.shtml
US Forest Service	http://www.fs.fed.us/research/invasive-species/insects/
USDA Agricultural Research Service	https://www.ars.usda.gov/
List of federal noxious weeds	http://plants.usda.gov/java/noxious
Plant pests and disease programs	https://www.aphis.usda.gov/aphis/ourfocus/planthealth/plant-pest-and-disease-programs/pests-and-diseases

¹ The procedures for TIS are applicable to the Mobile Deployment Platform (MDP) as well.

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SOP A General Decontamination Considerations for all Subsystems at all Sites

All gear, equipment and vehicles brought on to a NEON site should be inspected under adequate day lighting for soil, mud and vegetation on personal gear, equipment and vehicles. Be sure to examine vehicle wheel wells, behind bumpers, on radiators, on vehicle tracks, storage areas, passenger and driver seats, and above drivetrain belly pans. This is especially important at sites known to harbor one or more invasive species and where risk of establishment at new sites is high – i.e., the species is not already well established at other NEON sites in the domain. If contamination is observed, thoroughly clean prior to moving to a new site.

A.1 Frequency

NEON’s field-based operating procedures require inspection and cleaning of personal gear, equipment and vehicles in accordance with Table 4 above. Personnel are expected to use good judgement to determine if and when more or less frequent or thorough cleaning may be necessary. For example, longer or more frequent cleaning may be required where the threat of invasive species transport and invasion is a major concern; lesser time and frequency when and where this is not the case. Please consult the local Domain Manager, Permitting, or submit a problem ticket should questions arise. For any equipment returning to the same site the next day, decontamination generally is not necessary.²

Instruments installed for long-term deployment require inspection, cleaning and decontamination only when removed from the field for repairs and/or calibration at NEON HQ and redeployments. Hand-held sensors, tools, and equipment require decontamination between sampling events at different sites within the Domain. These items should be decontaminated at the DSF or other approved location.

A.2 Inspection and Cleaning of Equipment

If contamination is found upon inspection, particularly when and where invasive species transport is a significant concern, do not move the equipment to a new site until it has been cleaned and decontaminated. Several key considerations follow:

1. Remove heavy accumulations of soil, mud, seeds and other debris with appropriate tools and techniques while still at the field site; reducing the amount of cleanup required at the DSF.
2. Pressurized water – if available at the DSF or car wash -- may be appropriate for use on some large equipment, such as boats and vehicles.

² Further domain/site-specific guidance is being developed and will be included in a future revision of this document



3. Compressed air (canned or compressor set to <30 psi) is more suitable for equipment, such as wired equipment, easily damaged by water. DO NOT use compressed air above 30 PSI; and then use only with an chip guarding and safety glasses at a minimum (ER[35]).
4. Certain invasive species will require chemical decontamination. This may necessitate extra care for disposal of chemical rinsate and other waste liquids. See the Chemical Hygiene and Biosafety Plan (AD[04]) for guidance on chemical hygiene procedures. The use of some chemicals requires certification or licensing, depending on State applicator laws.
5. One alternative when and where invasive species transport is a concern is to designate common-use DSF equipment (e.g., backpacks) as site specific in weekly blocks or even for an entire field season if that is logistically and economically feasible.

A.3 Personal Gear

Inspect all personal gear for soil and plant material before departing the DSF for the day (e.g., Figure 1). While most of the inspection and cleanup can be done at the DSF, field personnel should remove obvious contamination on personal gear before leaving the field site using portable equipment such as brushes and scrapers. This will reduce the amount of cleanup required at the DSF (see Table 6). When the most thorough cleaning is needed, proceed as follows:



1. Clothing: Turn out pockets; remove seeds and burrs from all socks, shoelaces, and shoe tongues. Be sure to inspect all clothing (i.e., hats, gloves, and coat).
2. Gear bags, Hip packs and Backpacks: Remove all seeds and burrs from outer material and straps. Check all pockets as a potential reservoir for transporting foreign material.
3. Examine for vegetation, soil, mud, insects, and other invertebrates.
4. Physically remove contaminated materials with a stiff brush, lint remover, compressed air, vacuum, or pressurized hot water. Normal washing in a washing machine might not be sufficient to remove all seeds and burrs.
5. Give special attention to species with seeds that have hooks and hairs that are difficult to remove from gear.



Figure 1 Invasive plant material can be transported via shoes and clothing

Table 6 Cleaning personal gear at the field site and at the domain office.

	Clean up at Site	Clean up at DSF
Clothing	Shake out and brush clothing	Use compressed air or vacuum to remove debris from cuffs and folds
Treads of boots	Use a small scraper, or similar tool, and pressurized water as needed	Setting up a boot brush and mats at the DSF can be helpful
Zipper and snap closures	Brush off loose debris and soil	Use a stiff brush on zippers, belts, laces or ties, buckles, straps, Velcro, buttons, fasteners, rivets, etc.

NOTE: Domain 20, Pu'u Maka'ala (PUUM) Natural Area Reserve (NAR) has specific requirements for all work within Hawaii's Natural Area Reserve see Appendices E and F for further information.

A.4 Vehicles – Areas to Check and Clean

Field vehicles, whether used for operation and maintenance of terrestrial or aquatic infrastructure, need to be inspected and decontaminated in accordance with Table 4 above. The following guidance is adapted from the *Plant Dispersal Information System* (ER[25]). One option to minimize the amount of decontamination needed is to assign individual rental trucks to specific sites during the field season.



Figure 2 Power washing can be an effective way to clean equipment. Inspect after cleaning.

A.4.1 Vehicle Exterior

Power washing is the most effective means to decontaminate the exterior of rubber-tired and tracked vehicles (Figure 2), but many car washes may be suitable as well. The key areas to inspect and decontaminate are listed in Table 7 and illustrated in . A general inspection of these areas should occur at each washing event – i.e., for the most obvious contamination. A more thorough inspection and deep cleaning should be conducted during monthly vehicle checks.

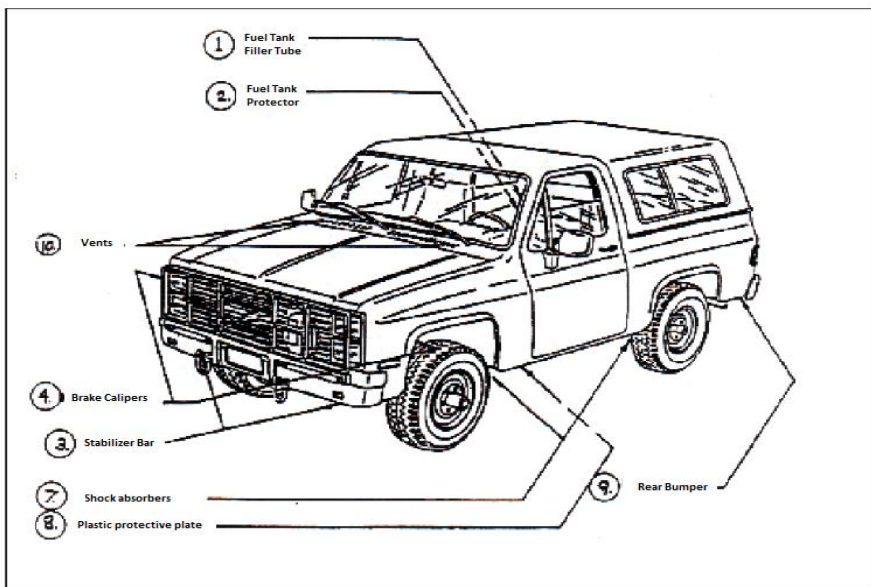
Table 7 Key areas to inspect on rubber-tired vehicles

Rubber-tired Vehicles	
<ul style="list-style-type: none"> • Crevices in upper surface and panels • Tires, rims, and fender areas • Spare tire mounting area • Bumpers • Front and rear quarter area • Around and behind grills • Bottom of radiator vent openings • Brake mechanisms 	<ul style="list-style-type: none"> • Transmission • Stabilizer bar • Shock absorbers • Front and rear axles • Beds • Suspension units • Exhaust systems • Light casings and mirrors
Tracked Vehicles	
<ul style="list-style-type: none"> • Crevices in upper surface and panels • Top of axles and tensioners • Support rollers • Between rubber or gridded areas 	<ul style="list-style-type: none"> • Beneath fenders • Hatches • Under casings • Grills

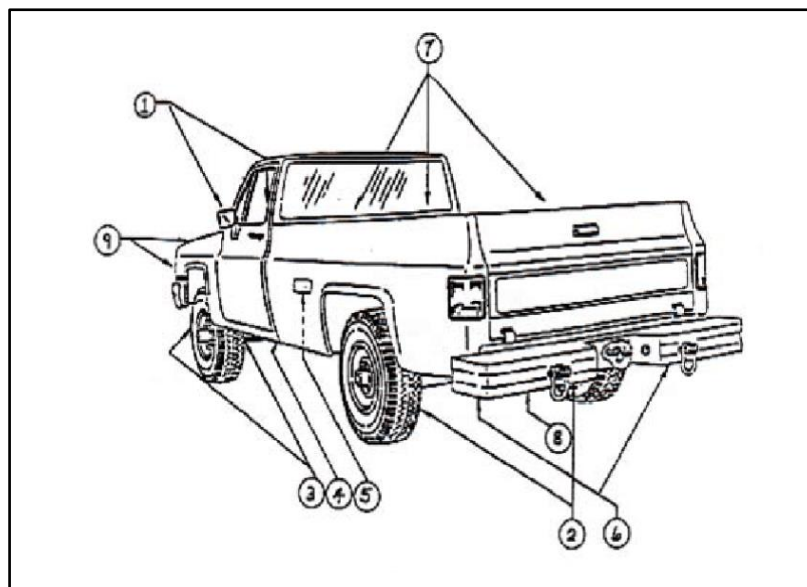
A.4.2 Vehicle Interiors

Vehicle interiors are most effectively decontaminated using a combination of a vacuum cleaner and a stiff brush. Use a scraper to dislodge caked on mud. Key areas to inspect and clean include beneath seats, pedals and floor mats, upholstery, and inside folds of gearshift cover. A general inspection of these areas should occur at each cleaning event – i.e., for the most obvious contamination. A more thorough inspection and deep cleaning should be conducted monthly at the time of monthly vehicle checks.

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(1) Fuel Tank Filler Tube; (2) On top of Fuel Tank Protector; (3) Stabilizer Bar and shackles; (4) Top of brake calipers; (5) Inside the cab, under floor mats and storage areas; (6) On top of the transmission; (7) Bottom of shock absorbers; (8) Above the plastic protective plates at each wheel well; (9) Rear bumper area; (10) Hood vents. (ER[05]).



(1) Debris in vent openings; (2) Rear wheel drums and brakes; (3) Suspension components; (4) On top of transmission; (5) Underneath the fuel tube; (6) Rear bumper area; (7) Bed of vehicle; (8) On top of spare tire; (9) Front area of grill. ER[05])

Figure 3 Example inspection locations for truck

A.5 Cleaning Solution Concentrations

Various solution concentrations are specified throughout this document. Table 8 provides a conversion of percent concentration to a ratio of parts of water to parts of the solute (assuming a volume to volume concentration). This would be applicable, e.g., in preparing bleach solutions using household bleach (5-6% NaClO).

Table 8 Table of conversions of solution concentration (%) to a ratio of parts water to parts solute (e.g., bleach) at varying levels of bleach effectiveness. Assumes a total mixture of 1 L.

Concentration	Simple Ratio	Water:Solute (mL)	Water:Solute (mL)	
% Effectiveness >>	100%	100%	80%	70%
1%	99:1	990:10	988:12	986:14
2%	49:1	980:20	975:25	972:28
3%	32:1	970:30	963:37	958:42
4%	24:1	960:40	950:50	944:56
5%	19:1	950:50	938:62	930:70
6%	16:1	940:60	926:74	916:84
7%	13:1	930:70	914:86	903:97
8%	12:1	920:80	902:98	890:110
9%	10:1	910:90	890:110	876:124
10%	9:1	900:100	878:122	863:137

Example formulations follow:

1. 1% Bleach Solution (approximately 500 ppm of available chlorine)
 - a. Start with 990mL water
 - b. Add 10 mL fresh (5.25%) bleach to water
 - c. Stir
 - d. Ready to use

2. 2% Bleach Solution (approximately 1,000 ppm of available chlorine): same as above using 980mL water and 20mL fresh bleach

In the case of cutting a solution concentration from one percentage to another (e.g., 37% HCl to 5% HCl), a simple formula can be applied:

- Final Concentration ÷ Original concentration x total volume of solution desired
- Example: 5% ÷ 37% x 1000mL = 135mL, i.e.,
- 135 mL of 37% HCl is mixed with 865 mL water to obtain 1000mL of a 5% HCl solution

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TWO CAUTIONS:

1. Unless otherwise directed by your supervisor, always use the least concentrated formulation necessary to satisfy the decontamination requirement. Why?: (1) your safety, (2) to avoid exceeding manufacturers guidelines, and (3) to minimize corrosion and degradation of field equipment.

2. NEVER MIX CLEANING SOLUTIONS unless otherwise directed by your supervisor and approved by NEON Safety. For example, mixing bleach with ammonia or with vinegar will release toxic chlorine and chloramine gases. Bleach also reacts with ethanol or isopropyl alcohol to produce chloroform, hydrochloric acid, and other compounds, such as chloroacetone or dichloroacetone. If ever in doubt about use and mixing of chemicals for cleaning or other purposes, contact the NEON Safety Office and bring the issue to your manager’s attention.

Several considerations follow with respect to the use of bleach in particular:

1. Bleach has a relatively short shelf life (see NEON-3512). For example, the Clorox Company claims a one-year shelf life, and it recommends replacing unopened containers after one year. Do not use unopened bleach that is more than 12 months old; and do not use bleach that has been opened for more than 3 months. The “born-on” date can be read as follows:
 - a. For Chlorox: their code looks like this: A314168. A3 = factory ID. Next one or two digits = year of production. Last three digits = calendar day (n/365) of production. Example: A314168 = June 17, 2014
 - b. For Grainger/Tough Guy: their two-line code looks like this: 15206 00:32 CP2 33NT68 072315-5. ONLY the first five digits (15206) are used. 15 = the year of production. 206 = calendar day (n/365) of production. Example: 15206 = July 24, 2015 (Don’t be fooled by the 2nd line (072315) that looks suspiciously like a date—Grainger said it isn’t.)
2. It is best to buy only as much bleach as you think you need; avoid stockpiling several bottles of bleach. You may contact the supplier to ensure that the bleach you are ordering is close to the “born-on” date and has not been sitting on the suppliers shelf.
3. Also, mark bleach containers with the date received by the domain support facility. A good practice is to replace bleach that was received more than 6 months prior.
4. It may be possible to use bleach (unopened) that is older than 6 months, but a higher proportion of the bleach solute would be required. After 6 months, bleach degrades at approximately 20% per year and may be only 70-80% effective by 12 months. At 70-80% effectiveness, the bleach solute would need to be increased by 43% to 25%, respectively -- i.e., $1/0.70=1.43$ and $1/0.80 = 1.25$. See Table 8 for actual mixtures that would be required.
5. Once opened, bleach may be less than 60% effective after 3 months; it is best to discard at this point.
6. If the bleach has lost most of its strong odor, is starting to get cloudy or is cloudy it has lost most of its strength and should not be used. If in doubt, discard and use a fresh supply.
7. Once the bleach solution is mixed it should be used immediately. Bleach will rapidly lose strength within 24 hours. A fresh mixture should be made each day that it is needed.

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8. Bleach is corrosive to metals and other materials. Always rinse thoroughly in order to minimize impact on equipment.

SOP B Aquatic Decontamination

B.1 Background

It is imperative that NEON staff and contractors follow best practices for decontamination of aquatic sensors and field equipment. Fresh water ecosystems are highly susceptible to aquatic nuisance species, which can cause economic or environmental harm, or degrade human health (ER[26]). These invasive species threaten aquatic habitats via shading, oxygen depletion, and predation, and by outcompeting and often extirpating native organisms. The US Fish and Wildlife Service reports that there are approximately 10,000 non-indigenous aquatic species in US waters, resulting in severe degradation of aquatic habitats throughout North America (ER[27]). These factors contribute to the risk of extinction of 37% of naturally occurring freshwater fish species and 67% of freshwater mussels (ER[28]).

The aquatic SOP is based on the protocols recommended by the US Forest Service (ER[15]), US EPA (ER[13]), USGS (ER[08]), and the National Park Service (ER[09]). These SOPs will be followed at all aquatic sites. However, sites confirmed to have aquatic nuisance species may be required to follow more stringent procedures – i.e., as mandated by site host and/or state regulations. The guidelines apply to all aquatic protocols and SOPs.

B.2 Aquatic Decontamination Frequency and Timing

All AIS sensors will return to NEON HQ at least once per year for repairs, calibration or redeployment. Decontamination will occur as soon as possible after sensor removal and prior to shipment of sensors to NEON HQ. Any further decontamination will occur on an as-needed basis.

Decontamination of equipment (e.g., handheld sensors, waders, nets, buckets, and boats and trailers) occurs in accordance with Table 4 -- generally before moving to a new body of water, and with enough time for equipment to completely dry. If returning to the same body of water upon the next sampling trip, full chemical decontamination will not be warranted; however, equipment should be manually cleaned and rinsed to remove organic matter.

Sampling of groundwater wells requires rinsing of the down-well pump and flow-through cell prior to sampling each well at the same site, and full decontamination before using at another site.

B.3 Decontamination: Aquatic Sensors

Operation and maintenance of NEON’s AIS comprises three main sources of invasive species risk. First, long-term deployment of these sensors provides many opportunities for the accumulation of multiple species of aquatic organisms. Second, all common sensors in the NEON network are calibrated under the same conditions at the same time to limit error and bias. This creates a potential for the spread of invasive

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species when sensors come into contact with one another. Finally, the newly calibrated sensors are rotated to a new site each year. As such, decontamination of aquatic sensors prior to transport to NEON HQ is crucial.

A combination of manual removal of debris, chemical cleaning and drying is typically effective for decontaminating sensors and equipment. In freshwater, biofouling is typically “soft” and easily addressed because there are few calcifying organisms. Likely contaminants include bacteria, protozoans and algae. Remove any organisms adhering to the surface of sensors. Deactivate bacterial spores and viruses using cleaning and disinfecting procedures both in the field and in the DSF.

Decontamination of aquatic sensors requires special considerations due to the sensitivity of construction materials. The information detailed in this document presents a decontamination protocol derived in part from the USGS National Water-Quality Assessment Program (NAWQA) (ER[08]), and from consultation with sensor manufacturers. The protocol takes into account the effectiveness of disinfectants and the safety of field personnel, the environment and the integrity of the sensors.

For all cleaning procedures, wear nitrile gloves and safety glasses, and ensure proper electrostatic discharge (ESD) protection in place before handling the sensors and Data Acquisition Systems (DAS; GRAPEs and CR1000 buoy) (RD[27]). Note that equipment must be removed from the GRAPE prior to decontamination.

B.3.1 On-Site Field Cleaning of Aquatic Sensors

1. Manually remove visible biological material and debris from sensors while at the site using soft bristle brush, Kimwipes or microfiber/ lint-free cloth. (e.g., technicians must wipe off biofilms, debris, etc.; see RD[17-19] for details). Take special care to not scratch optical parts of the sensors.
2. Remove any large debris from sensor housings at the field site with a dry, nylon-bristle brush or cotton swab, or vigorous rinsing with stream water or deionized water from a spray bottle.
3. Clean port and sensor. Visually inspect the port for contamination. If the port is dirty or wet, clean it with a clean, lint-free cloth or compressed air (≤ 30 psi). Apply a light coat of Krytox grease to the rubber mating surfaces of the connector (not the o-ring) and a small dab of Krytox grease on the threads of the locking nut.
4. Pack sensors in an ESD bag and transport sensors to the DSF for chemical decontamination in order to minimize chemical contamination at the field site. Ensure use of protective caps, handling, and storage to avoid sensor damage.

B.3.2 Domain Lab Cleaning of Aquatic Sensors

All sensors must be cleaned and decontaminated before being returned to HQ for servicing and calibration, or when being moved to a new body of water (though this situation is very unlikely as most sensors should be received from HQ). Typically, sensors are serviced at least once per year, but may be

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removed from the site more often if offsite troubleshooting and repairs or unscheduled calibrations are needed.

B.3.2.1 All Optical Sensors: SUNA, Turbidity, Total Algae, fDOM and DO

1. Wash the sensor with tap water; use mild detergent as needed; do not use any organic solvents)
 - a. Wet sensor with tap water from a wash bottle or spray bottle.
 - b. Use a mild detergent such as dish soap or Liquinox as necessary to remove fouling, films and debris. .
 - c. For the optics on both the SUNA and the Multi-sonde (Turbidity, Total Algae, fDOM and DO) only use isopropyl alcohol. If you need to remove calcium deposits, soak in a 50% diluted 5% white vinegar .
 - d. Remove all visible soils and organic materials.
 - e. Spray with tap water to remove any remaining debris.
2. Allow the sensor to air dry. NOTE: Ensure sensor connections are dry before connecting probes and sensor cables.
3. Package and ship sensors according to procedures provided by NEON CVAL.

B.3.2.2 uPAR Sensor

The underwater PAR (uPAR) sensor housing is made of sensitive material that requires the uPAR-specific procedure as described in this section.



Do NOT use alcohol, organic solvents, abrasives, or strong detergents to clean the diffuser element on the uPAR sensor. The acrylic material is highly sensitive and alcohol, and organic solvents can cause crazing on the sensor and affect the sensor response. Avoid touching the sensor surface when cleaning to minimize the potential of scratching the sensor.

1. Wash the sensor with tap water
 - a. Submerge the sensor in tap water taking care to protect electrical ports.
 - b. Use a mild detergent such as dish soap or dilute Liquinox as necessary to remove fouling, films and debris.
 - c. Use a Kimwipe, microfiber cloth, or lint-free cloth to clean the exterior of the sensor.
 - d. Remove all visible soils and organic materials.
 - e. Spray the sensor with tap water to remove any remaining debris.
2. If mineral deposits are visible, use household white vinegar (typically 5% acetic acid) to soften them and repeat Steps 1-2.
3. Rinse thoroughly with tap water to avoid mixing vinegar and bleach.
4. Wash the sensor with a 2% bleach solution (see Table 8).
 - a. Fill a wash bottle with bleach solution and label it appropriately (see section B.5) .

- b. Working over a “BLEACH”-labeled catch basin, spray the sensor with bleach solution to disinfect.
- 5. Rinse the sensor with deionized water.
 - a. Using the wash bottle filled with deionized water.
 - b. Working over a catch basin, spray the sensor with water to remove bleach solution.
- 6. Allow the sensor to air dry.

B.3.2.3 All Other Sensors: pH, Conductivity and Temperature, PRT, LevelTroll, AquaTroll

When removing sensors from the site for servicing or calibration, follow the steps listed in

- 1. Table 9 and directions that follow.

Table 9 General cleaning methods for decontamination of aquatic sensors (all except uPAR)

Step	Action	Method	Solution	Delivery
1	Remove debris	Dry brush	N/A	Manual removal
2	Remove soils and organic material	Detergent solution wash	0.2% Liquinox (v/v) or Alconox (v/v)	Wash bucket; wetted Kimwipes and brush as needed
3	Rinse	Rinse	Tap water	Rinse bucket; wash bottle
4	Remove inorganic chemical contaminants, mineral deposits, and biofilms	Acid solution wash	HCl 5 % (v/v)	Wash bottle; wetted Kimwipes and brush as needed
5	Rinse	Rinse	Deionized water	Rinse bucket; wash bottle
6	Remove organic chemical contaminants, and disinfect surfaces	Alcohol solution wash	Isopropanol 70% (v/v)	Wash bottle
7	Rinse	Rinse	Deionized water	Rinse bucket; wash bottle

- 2. Prepare a 0.2% (v/v) detergent solution in a 5-gallon bucket.
 - a. Measure out either 378.5 mL of Liquinox or 37.85g Alconox phosphate-free detergent and pour into the 5-gallon bucket.
 - b. Fill the bucket with tap water, mixing halfway through filling (i.e., 5 gallons).
 - c. Label the bucket “SOAP”.
- 3. Use a 5% (v/v) hydrochloric acid (HCl) solution.. Assuming HCl is not purchased at that concentration, prepare the solution as follows using a starting solution of 37% HCl and store in a 1L Nalgene bottle. **NOTE:** 37% HCl quickly evaporates forming a gas that can be irritating to lungs and eyes, and it burns on contact. Handle HCl under a fume hood or, at the very least, a well-ventilated area. Safety goggles and gloves are required, and a splash apron is recommended.
 - i. Fill a 1L volumetric flask with approximately 600 mL of tap water.
 - ii. Measure out 135mL of 37% HCl using a 100 mL graduated cylinder (e.g. 100 mL & 35mL) and add to the volumetric flask.
 - iii. Swirl the volumetric flask to mix.
 - iv. Fill the volumetric flask to the 1 L line with tap water.



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- v. Pour the solution into an appropriately labeled 1 L Nalgene for storage.
4. Label a catch basin and a 10 L carboy as “ACID WASTE (NO BLEACH!)”.
5. Prepare wash and rinse stations.
 - a. Station 1. Add 3 gallons of tap water to a 5-gallon bucket and label it “SOAP RINSE”. Place the “SOAP” and “SOAP RINSE” buckets next to each other, with a wash bottle, a brush and Kimwipes.
 - b. Station 2. Add 3 gallons of deionized water to a 5-gallon bucket and label it “ACID RINSE”. Place the “ACID RINSE” bucket with a catch basin, the acid solution, a wash bottle, a brush and Kimwipes.
 - c. Station 3. Add 3 gallons of deionized water to a 5-gallon bucket and label it “FINAL RINSE”. Place the “FINAL RINSE” bucket with the alcohol solution, and a wash bottle. Place next to the catch basin from Station 2.
6. Wash the sensor with detergent solution at Station 1.
 - a. Protect sensor electrical ports throughout the process.
 - b. Submerge the sensing half of sensor in the “SOAP” bucket .
 - c. Use a brush and/or Kimwipe to clean the exterior of the sensor.
 - i. Remove all visible soils and organic materials.
 - ii. For YSI sonde, use the small brush to clean the conductivity cell.
7. Rinse the sensor with tap water (Station 1).
 - a. Fill a wash bottle with tap water and label it appropriately.
 - b. Submerge the sensing half of the sensor in the “SOAP RINSE” bucket taking care to protect electrical ports.
 - c. Working over the bucket, spray the sensor with tap water to remove any remaining detergent.
8. Wash the sensor with acid solution (Station 2).
 - a. Fill a wash bottle with acid solution (5% HCl) and label it appropriately.
 - b. Working over a catch basin, spray the sensor with acid solution.
 - c. If mineral deposits are visible, apply light scrubbing with a brush and/or Kimwipe wetted with acid.
8. Rinse the sensor with deionized water (Station 2).
 - a. Fill a wash bottle with deionized water and label it appropriately.
 - b. Working over the catch basin, spray the sensor with water to remove acid solution.
 - c. Submerge the sensing half of the sensor in the “ACID RINSE” bucket and lightly scrub with a Kimwipe.
 - d. Working over the catch basin, spray the sensor with deionized water to remove any remaining acid.
10. Wash the sensor with alcohol solution (Station 3).
 - a. Move the catch basin from Station 2 to Station 3.
 - b. Fill a wash bottle with alcohol solution (70% isopropanol) and label it appropriately.
 - c. Working over the catch basin, spray the sensor with alcohol solution.



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- d. You may want a separate catch basin for station 3 if disposal of materials is different from the catch basin at station 2.
- 11. Rinse the sensor with deionized water (Station 3).
 - a. Use the wash bottle filled with deionized water.
 - b. Working over the catch basin, spray the sensor with water to remove alcohol solution.
 - c. Submerge the sensing half of the sensor in the “FINAL RINSE” bucket and lightly scrub with a Kimwipe.
 - d. Working over the catch basin, spray the sensor with water to remove any remaining alcohol.
- 12. Pour the contents of the catch basin into the “ACID WASTE” carboy for disposal. (Acid waste can be neutralized with baking soda – one tablespoon at a time until the pH reads between 6 and 9.) The solution can then be poured down the lab drain with additional water from the faucet. If you are unsure of the proper disposal methods, contact Safety and/or notify your Manager. Regulations and procedures may vary by location (AD[04]).

Store sensors in accordance with

- 13. Table 9.

Table 10 Storage protocols for aquatic sensors

Sensor	Procedure
YSI EXO2 Multisonde (except long term storage of pH and DO probes³):	<ul style="list-style-type: none"> • Place wet paper towel inside the sonde guard. • Partially fill the YSI EXO2 calibration cup with tap water. Use enough water to cover the paper towel you put in the sonde guard. • Fasten the cup to the end of the sonde for storage and transport to site (not shipment back to HQ).
YSI EXO2 Multisonde pH probe	<ul style="list-style-type: none"> • pH probes must remain moist • Short term storage (up to 2 weeks) air saturated with water as outlined above. • Long term storage (> 2 weeks) 2M pH 4 buffer preferable, but can use tap water with a wash bottle.
YSI EXO2 Multisonde DO probe	<ul style="list-style-type: none"> • DO probes must remain moist • Storage: short term, air saturated with water as outlined above. • Long term, keep moist by either direct submersion in water, or use a hydrated sponge in the plastic cap that comes with the delivered sensor.
Aqua and Level Trolls	<ul style="list-style-type: none"> • Dry the cleaned sensor. • Wipe exterior with Kimwipes. • Place protective red dust cap on the cable end • Store the instrument where it will not fall onto a hard surface.
PRT	<ul style="list-style-type: none"> • Dry the clean sensor.

³ Sonde sensors will arrive from HQ with caps present. They are not meant to be submerged but rather are preventative for water intrusion during shipment scenarios.

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- Wipe exterior with Kimwipes.

14. Package and ship sensors as follows:

- a. Package dry sensors according to the guidelines of each sensor and/or subsystem in the preventive maintenance document. Ship sensors with pertinent protective hardware (e.g., caps/ESD bags/bubble wrap) in containers (e.g., pelican cases or similar) with exception of the met-station, 2D Wind Anemometer and SUNA. Ship these sensors in their original packaging. Secure any moving parts and loose cables that may incur damage or damage contents. If Domains are missing shipping containers or protective hardware, submit a problem ticket to request additional supplies from CVAL.
- b. Specific probes needing liquid or moist environments:
 - i. For YSI EXO2 Multisonde pH probes, insert sensing end into the bottle that the sensor was originally shipped in. Install the bottle's o-ring and tighten cap. This bottle should contain pH 4 buffer. If this solution is unavailable, users may store sensor in tap water. If bottle is not available, a last resort can be to cover the sensing end with moistened sponge/cap assembly or water soaked paper towel and secured with rubber band. Note: pH probes cannot go below freezing, so take special precaution when shipping in winter months.
 - ii. For YSI EXO2 Multisonde DO probes, cover the sensing end with moistened sponge/cap assembly or water soaked paper towel and secure with rubber band.



B.4 Decontamination: Aquatic Field Equipment



Thoroughly clean, disinfect, and dry field equipment between use at sites to prevent transport of invasive species from one site to another. This includes all boots, waders, backpacks, sensors, equipment (e.g., buckets, nets, clippers, meter tape, and motors), boats, vehicles, and trailers.

The basic premise of decontamination for aquatic invasive species is threefold:



Drain → Clean → Dry

Use a combination of draining, manual removal, chemical disinfection, and drying to remove and kill invasive species. Re-inspect after cleaning, especially at field sites, to reduce the risk of overlooking areas difficult to access.

Waders: Note that felt-soled waders and wading boots are prohibited for NEON field staff, NEON designated visitors and subcontracted personnel due to the difficulty of removing small invasive materials. Felt soles are also illegal in some states. Studded soles are allowed and may be helpful for slippery sites. Boot-foot, lug-soled waders are preferred by NEON because they are easier to clean. Stocking-foot waders with a separate wading boot are allowed, but must be dedicated to a single site due to the difficulty in cleaning laces, eyelets, and pebble guards or gaiters.

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Currently, there is no single standardized protocol available for cleaning equipment that targets all biofouling and aquatic invasive species of concern. In general, bleach-cleaning is most often effective (ER[08]). However, bleach is relatively ineffective against New Zealand mudsnails; in this case, quaternary ammonia (QUAT) should be used. NEVER use QUAT and bleach on the same gear. Use one or the other or make sure to thoroughly rinse and dry between uses. If mudsnails are in the area, DO NOT use bleach; use only QUAT. For guidelines on the application of these chemicals, see section B.5 and B.6 below.

Several states use hot water cleaning for boats and trailers – a relatively effective treatment for most aquatic invasive organisms. Allow equipment to completely dry after cleaning and before its next scheduled use.

B.4.1 On-Site Field Cleaning of Aquatic Field Equipment

If invasive species are present at the site, return ALL equipment to the DSF for thorough cleaning and drying before reuse at any other site, unless the site is in the same watershed and/or known to harbor the same species of concern. More limited decontamination may be appropriate if sites within the domain fall within the same watershed. If sampling multiple sites in one day, equipment must be bleach-cleaned (via a spray bottle or soaking tub in the truck) and thoroughly sun-dried in the field before moving to the next site. If equipment cannot be adequately cleaned and thoroughly dried in the field (e.g., it is raining and the equipment will not dry), return to the DSF to clean equipment and sample the next site another day. Alternatively, plan to use a second set of equipment when sampling at two sites within the same day.

1. Before leaving the site, DRAIN all buckets, coolers, waders, boots, and any other equipment that can hold water.
 - a. Remove the boat drain plug and drain transom well, bilges, and live wells (if present).
 - b. Follow factory guidelines for flushing water from the boat motor.
 - c. Empty water out of buckets, coolers, etc.
2. Clean all debris off equipment, including waders, nets, and brushes by hand. Leave debris at the site (discard on the shoreline or in the water).
 - a. Remove any visible plants or plant fragments, animals, mud, or other debris.
 - b. Check net seams and edges of sieve for hidden organisms.
 - c. You may rinse mud and debris off surfaces using water from the site and the nylon kitchen brush.
3. Clean all debris off boat, motor, and trailer by hand and leave debris at the site (discard on the shoreline or in the water). A lesser level of effort may be warranted if each site has its own boat or if a determination has been made that decontamination is not necessary – e.g., for sites within the same watershed harboring the same species of concern.
 - a. Remove any visible plants or plant fragments, animals, mud, or other debris.
 - b. You may rinse mud and debris off surfaces at the site using water from the site and/or the nylon kitchen brush.

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- c. Check trailer, axle, and wheel wells, as well as the boat, motor, propeller, anchor, ropes, and paddles.

B.4.2 Domain Lab Decontamination of Aquatic Field Equipment

B.4.2.1 Handheld Probes

Handheld probes (i.e., YSI temperature, conductivity, DO probe) follow manufacturer decontamination suggestions.

1. At the DSF, prepare a fresh 2% bleach solution (see Table 1).
2. Use tap water to rinse the probe and any other parts of the unit that have come in contact with water.
3. Wash unit in the 2% bleach solution and allow probe and cable to soak for ≥ 10 minutes. Do not remove the DO sensor.
4. Rinse entire unit with tap water.
5. Rinse probe and sensors with deionized water.
 - a. Do not allow the DO probe tip to dry completely as this will compromise its performance.
 - b. There is no need to replace the DO probe membrane after cleaning with 2% bleach solution.

B.4.2.2 Humminbird

DO NOT clean the Humminbird with bleach. This will eventually degrade the transducer. Follow manufacturer decontamination suggested cleaning procedure (ER[33]), which follows:

1. Decontaminate the transducer only (not the entire Humminbird unit).
2. Rinse the transducer in tap water.
3. Prepare a 0.2% (v/v) detergent solution (see B.3.2.3 Step 2 above).
4. Place transducer in soap solution. Clean with a soft brush or hands.
5. Allow transducer to soak in soap solution for ≥ 5 minutes.
6. Remove transducer and rinse with deionized water.
7. Allow transducer to thoroughly dry prior to using in a new body of water.

B.4.2.3 Boats and Trailers

1. At a commercial car wash, spray the boat and trailer with high-pressure hot water (no detergent). This is the best way to remove plant fragments or veligers. If washed at a car wash, proceed to Step 4. If car wash with hot water is not available go to Step 2.
2. At the DSF, use the pressure sprayer and a fresh 2% bleach mixture to spray any surface of the boat and trailer that came in contact with water from the site. See Table 11 for soaking/spraying times (ER[10, 14]).
3. Follow the bleach wash with a hot water (hottest tap water is fine, 50-60°C) wash using a pressure sprayer. This rinses bleach from the equipment and provides additional

decontamination. Check the temperature of hot water using a handheld thermometer. Spraying time varies; follow guidelines in Table 11.



4. Air DRY boat, trailer, and all associated equipment thoroughly. Allow 48 hours drying time at humidity <70%. Allow longer drying time at sites with higher relative humidity
5. Dry in direct sunlight as much as possible.

B.4.2.4 Other Equipment



Use a fresh 2% bleach solution to disinfect equipment from all sites if the status of invasive species is unknown, or no data are available. If specific invasive species are present at the site, use a higher concentration bleach or quaternary ammonia disinfectant (never together) following Table 11. Implement any additional procedures required by the NEON site host as needed.

Bleach cleaning can be hard on waders and equipment, and decontamination takes time. Some domains may consider using a separate set of dedicated waders or equipment for some sites, which would be cleaned and rinsed but not fully bleach-decontaminated.

B.5 Domain Lab Decontamination: Bleach Cleaning

If known invasive species exist at the site, treat following the specific guidelines in Table 11. Otherwise, treat using a fresh 2% bleach solution, followed by rinsing and drying. Use the least concentration necessary (1) for safety, (2) to avoid exceeding manufacturer's guidelines, and (3) to minimize corrosion and degradation of field equipment and other metals and plastics.



1. At the DSF, mix bleach solution as prescribed in Table 11 (see also Table 8) in compression sprayer or soaking tub. (NOTE: bleach solution is not an effective treatment for New Zealand mudsnails, see instructions in section B.6.) Bleach cleaning must occur at the DSF so bleach does not run into the body of water. You may either spray the equipment using a compression sprayer, or soak in a plastic tub.
 - a. Use 2% bleach if invasive status of the site is unknown (80 mL bleach in 3920 mL tap water for a total of 4L; or see Table 8).
 - b. Use a higher bleach concentration if chytrid fungi are known or suspected at the site (Table 11.)
 - c. As noted earlier, the shelf life of bleach is relatively short, and only remains at the expected concentration of chlorine for 6 months. Check the date on the production of the bottle, and plan accordingly when ordering. You may use bleach that is older than 6 months but will need to increase the concentration. (See additional discussion above in section A.5 Cleaning Solution Concentrations.)
 - d. Label sprayer or tub "2% bleach solution" (or other appropriate percentage).
2. Use the pressure sprayer or soaking tub filled with bleach mixture to clean all equipment and waders that came in contact with water.
 - a. Use the sprayer on equipment that will not easily fit in the soaking tub.

- b. Equipment such as boots and waders are best cleaned using the soaking tub, as it is a more thorough method. See Table 11 for soaking times.
 - c. Pay special attention to the laces and eyelets of lace-up wading boots, as these areas tend to stay damp longer than other equipment. Boot-foot waders are suggested by NEON, as they are easier to clean.
 - d. Make sure to clean the bottom of any gear that has come in contact with water at the site, such as the top-setting rod (discharge).
3. Follow the bleach wash with a hot water (hottest tap water is fine, preferred 50-60°C if available) rinse or soak. This rinses bleach from the equipment, adds another layer of decontamination, and helps avoid mixing of chemicals.

Table 11 Common invasive species and cleaning methods for equipment

Taxon	Step 1	Step 2: Choose one method				Step 3	Step 4
	Wash & remove mud & debris	Bleach*	Hot water rinse	Drying Time**	QUAT*	Rinse	Dry
Unknown	Yes	2% for 10 min	50-60°C for 5 min	24hr	N/A	Tap Water	>4 hours, sunlight preferred
Whirling disease	Yes	1% for 10 min	90°C for 10 min	24hr	≥4.4% for 10-15 min	Tap Water	>4 hours, sunlight preferred
Chytrid fungus	Yes	7% for 10 min	60°C for 5 min	3hr	0.15% for 30 seconds	Tap Water	>4 hours, sunlight preferred
New Zealand mudsnails	Yes	Not effective	50°C for 5 min	48hr	≥4.6% for 10 min	Tap Water	>4 hours, sunlight preferred
Zebra and Quagga mussels	Yes, pressure wash	0.5%	≥60°C water	3-5 days	≥3% for 10 minutes	Tap Water	>4 hours, sunlight preferred
Asian clams	Yes (See NEON-2995)	Unknown	43°C for 30 min	14-27 days (less in full sun)	Not effective	Tap Water	>4 hours, sunlight preferred
Didymo	Yes	2% for 1 min	60°C for 1 min	48 hr	2% for 1 min	Tap Water	>4 hours, sunlight preferred
Eurasian watermilfoil	Yes	N/A	N/A	N/A	N/A	Tap Water	>4 hours, sunlight preferred
Drawback to method	None	Hard on equipment	Could be difficult to get water hot enough	Depends on ambient humidity	Chemistry sample contamination	None	May be difficult to find sunlight

*Never mix bleach with QUAT or vinegar, which can result in dangerous gases; **Drying in direct sunlight is best.

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4. Air DRY all equipment thoroughly.
 - a. Allow ≥ 4 hours drying time. Dry in direct sunlight as much as possible.
 - b. If technicians are planning to sample two sites in one day and it will not be possible to dry equipment between sites, careful chemical decontamination of all equipment must occur.
5. Dispose of bleach wastewater at DSF down the drains as indicated by Chemical Hygiene and Biosafety Plan (AD[04]).

B.6 Domain Lab Decontamination: Ammonium-Based Cleaning

At sites where New Zealand mudsnails are present, QUAT will be used in place of bleach. **(CAUTION: Never mix chlorine bleach with ammonia; the mixture forms chlorine gas, which is extremely dangerous.)**



1. Mix a 3% solution of QUAT – i.e., 120 mL QUAT disinfectant topped to 4 L of tap water (or approximately 0.5 cup QUAT in a gallon of tap water) in the sprayer or plastic tub and label “3% QUAT”.
 - a. Mix fresh solution. When the liquid becomes cloudy as this indicates its effectiveness has been reduced. This is only applicable if you are using a tub to soak equipment.
2. Soak or spray equipment according to the guidelines in Table 11.
3. Follow the QUAT wash with a hot water (hottest tap water is fine, 50-60°C preferred) rinse or soak. This rinses QUAT from the equipment, and adds another layer of decontamination.
4. Air DRY all equipment thoroughly (≥ 4 hours, direct sunlight is best).
5. Dispose of wastewater at DSF down drains as indicated by the Chemical Hygiene and Biosafety Plan (AD[04]).

B.7 Ending the Day

1. Refresh the cleaning kit
 - a. Ensure that adequate supplies of bleach, QUAT, and other consumables are available for the next sampling trip.
2. Equipment maintenance, cleaning, and storage.
 - a. Triple rinse pressure sprayer and soaking tub with tap water to remove residual bleach, QUAT and debris.
 - b. Allow sprayer and tub to dry completely before storage.

SOP C Terrestrial Decontamination

C.1 Background

Invasive species can displace terrestrial communities composed of native species, altering ecological structure and function, and resulting in functional loss of habitat (ER[03, 04]). Degradation and loss of

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terrestrial habitats contributes significantly to the decline of many threatened, endangered and other at-risk species.

Operation and maintenance activities over a long period also have the potential to affect NEON sites (RD[04]). Specifically, vehicles, equipment, and personnel gear will spread invasive species if not properly decontaminated; anything that may contain soil or mud may harbor non-native seeds or microbes. The terrestrial SOP is based on the protocols of the Bureau of Reclamation (ER[05]), Kenai Peninsula Cooperative Weed Management Area (ER[06]), and the National Park Service Guidelines (ER[09]).

C.2 Terrestrial Decontamination Frequency and Timing

Decontaminate deployable sensors as soon as possible after sensor removal and prior to their return to NEON HQ for repairs, calibration or redeployment. Most of these terrestrial instruments return to NEON HQ on a regular basis. Additional cleaning events will occur on an as-needed basis.

Decontamination of field equipment should take place in accordance with Table 4 above. Use good judgement to determine if and when more frequent or thorough cleaning may be required, such as at sites where invasive species transport is a significant concern.

C.3 Terrestrial Sensors

C.3.1 On-site Cleaning of Terrestrial Sensors

1. Remove sensors as described in the appropriate maintenance procedure (RD[15]) and in accordance with the Guide for Annual Sensor Refresh (RD[16]); see also each specific Preventive Maintenance document for each sensor or assembly (see Reference Documents Section 2.2).
2. Put Amphenol caps on exposed GRAPE ports before removing the GRAPE to prevent ESD damage.
3. Remove visible soil, dirt and debris from sensors while at the site by hand or using a soft brush.
4. Inspect all holes for biological debris and clean with soft brush/pipe cleaner.
5. Place removed sensor in ESD bag, and then in a Pelican box or appropriate shipping container for transport to the DSF for further decontamination. Be sure that packing material is free of contamination.

C.3.2 Domain Lab Cleaning of Terrestrial Sensors

Clean tower or soil sensors after removing the sensor assembly; this simplifies the decontamination procedure. Clean biological debris from radiation sensors, there is no need to clean the sensor lenses to a streak-free surface. Use the following bullet points as a general guide when cleaning sensors (see Table 12).

1. Always wear nitrile gloves and safety glasses, and ensure proper ESD protection in place before handling the sensors and Data Acquisition Systems (DAS; Grapes and CR1000 buoy) (RD[27]).

2. Always soak to loosen any hardened biological debris from a surface rather than attempting to scrub.
3. With tap water and a soft brush, clean any biological debris off radiation sensor lens or dome.
4. Use soft bristled brushes, tap water, and compressed air (≤ 30 psi), unless otherwise indicated, as necessary to remove dust and dirt, bird droppings, insects, insect nests, and insect eggs, spider webs and any other biological debris or small trash.
5. Many sensor bodies can then be carefully wiped down with a clean dry microfiber or other lint-free cloth.
6. Use brushes and water as necessary to clean all sensor cables returning to HQ; they too can contain invasive species and dirt.
7. With any sensor, examine all areas for debris, especially in small and enclosed areas.



CAUTION: Only wipe radiation sensor lenses with a soft, lint-free cloth, and only after removing all traces of contamination from the surface with a tap water rinse.

8. Package dry sensors according to the guidelines of each sensor and/or subsystem in the preventive maintenance document. Ship sensors with pertinent protective hardware (e.g., caps/ESD bags/bubble wrap) in containers (e.g., Pelican cases or similar) with exception of the 2D Sonic Anemometer, 3D Sonic Anemometer and PICARRO Analyzers. Ship these sensors in their original packaging. Secure any moving parts and loose cables that may incur damage or damage contents. If Domains are missing shipping containers or protective hardware, submit an issue ticket to request additional supplies from CVAL.

Table 12 General cleaning procedures for decontamination of terrestrial sensors

Step	Action	Method	Solution	Delivery
1	Remove visible dirt and debris	Soft dry brush	NA	Manual removal on site
2	Remove soil and organic matter	Soak	Tap water	Wash bucket
3	Mineral or salt deposits	Soak, soft brush	White vinegar (5% acetic acid)*	Wash bucket
4	Remove soil and organic matter	Wipe, brush and dust	Tap water	Wash bottle, wetted Kimwipes, soft brush and compressed air as needed
5	Clean sensor cables that are returning to HQ	Brush	Tap water	Manual removal

*Note: a lesser concentration of acetic acid may be used if available. For example, a concentration of as little as 1% acetic acid (4 parts water and 1 part white vinegar) may be sufficient in some instances.

C.3.2.1 Salt and Mineral Deposits

Salt or mineral deposits can accumulate on Sensor surfaces. These deposits can be seen as a thin white film or white spots or accumulations. A heavy buildup may require the use of a solvent such as acetic acid to dissolve the deposits.

1. Follow the cleaning procedure in for each individual sensor (see External References).
2. If the salt deposits remain, or are caked on, soften up with white vinegar ($\leq 5\%$ acetic acid)
 - a. Place a catch basin, or towel underneath the sensor to catch any overflow.

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- b. Using a spray or squirt bottle, apply vinegar on to the areas with salt deposits. Allow the acetic acid to dissolve the salt deposits.
- c. Gentle scrubbing motion with a lint-free cloth, microfiber towel, or cotton swab may be used to help facilitate salt deposit removal.
- d. Repeat as necessary until salt deposits are removed.

The following sections provide specific instructions that apply to each sensor, based on the sensor’s physical characteristics.

C.3.3 Common Decontamination Procedures

C.3.3.1 Sensors

Routine decontamination of terrestrial sensors is very straightforward and typically requires use of a fresh 1% bleach solution (see Table 8). Always start with a rinse of the sensor with tap water to remove any loose dust, dirt, or residue that may inadvertently persist on the sensor surface. Use only gentle pressure when cleaning the surfaces of all sensors. The liquid should be allowed to do the cleaning, not mechanical force. The procedure is as follows:

1. Cap any open sensor connectors.
2. Debris Removal: Remove any biological debris (stems, leaves, etc.) by hand or using a soft brush.
3. Initial Rinse:
 - a. Place a small bucket or catch basin underneath the sensor to catch excess dirt, water, or bleach solution runoff.
 - b. Thoroughly rinse the sensor with tap water and allow the water to drain off. This should remove most loose dust, dirt, or residue.
 - c. Use a soft bristle brush or microfiber cloth to loosen any remaining dirt or residue. Rinse the area thoroughly with tap water.
4. Decontamination:
 - a. If there are mineral deposits on the sensor housing, use white vinegar as described above (C.3.2.1) to soften them up. Repeat Steps 4-5 as necessary. Rinse thoroughly with tap water to avoid mixing with bleach.
 - b. Place sensor over a “bleach”-labeled catch basin.
 - c. Using a 1% bleach solution, spray and saturate the entire surface of the sensor and **allow to soak for 5 minutes.**
5. Final Rinse:
 - a. Thoroughly rinse the sensor with tap water to remove the bleach from sensor.
 - b. Rinse a second time with deionized or distilled water to remove any remaining bleach solution.
6. Allow the sensor to air dry

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C.3.3.2 Cables

Routine decontamination of terrestrial sensor cables are similar to the decontamination procedure for sensors above. However, it may be unwieldy to hold a sensor cable over a bucket or catch basin, so a tarp or plastic sheeting may be used during the wash and rinse portions of the procedures. Be sure to protect the open sensor connectors with either their sealed caps, or plastic wrap so they don't get wet.

1. Cap and or seal any open sensor connectors.
2. Debris Removal: Remove any biological debris (stems, leaves, etc.) by hand or using a soft brush.
3. Remove any caked on dirt or debris.
4. Initial Rinse:
 - a. Lay out a tarp or suitable thick plastic sheeting on a table or ground.
 - b. Thoroughly rinse the cable with tap water and allow the water to drain off. This should remove most loose dust, dirt, or residue.
 - c. Use a brush or towel to loosen any remaining dirt or residue. Rinse the area thoroughly with tap water to avoid mixing with bleach.
5. Decontamination:
 - a. If there are mineral deposits on the cable, use white vinegar as described above (C.3.2.1) to soften them up. Repeat Steps 5-6 and necessary. Rinse thoroughly with tap water to avoid mixing with bleach.
 - b. Using a 1% bleach solution, spray and saturate the entire surface of the cable and **allow to soak for 5 minutes**.
6. Final Rinse:
 - a. Thoroughly rinse the cable with tap water to remove the bleach from sensor.
 - b. Rinse a second time with deionized or distilled water to remove any remaining bleach solution.
7. Allow the cable to air dry.

C.3.3.3 Exterior Surfaces

Routine decontamination of the exterior surfaces of terrestrial sensors and sensor housings could be done with a "Common Cleaning Procedure" for nearly all exterior surfaces following this 7-step procedure:

1. Cap and or seal any open sensor connectors.
2. Debris Removal: Remove any biological debris (stems, leaves, etc.) by hand or using a soft brush.
3. Initial Rinse:
 - a. Wet a microfiber cloth with tap water and clean the exterior surfaces of the sensor or sensor housing. This should remove most loose dust, dirt, or residue.

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- b. Continue using the wet microfiber cloth or a soft bristle brush to loosen and remove any caked on dirt or debris. Replace cloth as necessary to keep the surface clean.
- 4. Decontamination: Once all surfaces have been wiped down with a water dampened cloth, repeat Steps 2-3 with a cloth wetted with 1% bleach solution and **allow to soak for 5 minutes**.
- 5. Final Rinse:
 - a. With a fresh new cloth, wet with tap water and wipe down all the surfaces covered in Step 4 above.
 - b. Rinse a second time with deionized or distilled water. This should remove any remaining bleach solution.
- 6. Allow to air dry.

C.3.4 Sensor-Specific Cleaning Procedures

C.3.4.1 Radiation Sensors

When decontaminating terrestrial radiation sensors, care must be taken not to scratch the sensor’s receptor surface (glass domes or acrylic diffusers). Always start with a rinse of the sensor surface with tap water to remove any loose dust, dirt or residue that may inadvertently scratch sensor surface.

DO NOT “dry” wipe a radiation sensor’s dome or acrylic diffuser. Use only gentle pressure when cleaning the surfaces of the radiation sensors. Sensor specific considerations are listed in See RD[30] and RD[33] for specific cleaning procedures.

Table 13. See RD[36] for specific cleaning procedures.

C.3.4.2 3D/2D Sonic Anemometers

Use the Common Decontamination Procedure – Sensors in sections C.3.3.1 and C.3.3.2 for the sensor and sensor cables, respectively. Component-specific considerations follow:

1. Transducers: The surface of the transducers are extremely delicate. Avoid touching the surface of the transducers when decontaminating the sensors.
2. Transducer Arms: The alignment of the transducer arms are critical for the accurate operation of this sensor. Avoid bumping or applying any force to the transducers arms during decontamination.

See RD[30] and RD[33] for specific cleaning procedures.

Table 13. Sensor-specific considerations for terrestrial radiation sensors.

Sensor	Special Considerations
Four-Component Net Radiometer (Hukseflux, NR-01)	There are four shields on this sensors that are removable. The sensor and shields should be decontaminated separately.

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Pyranometer (Kipp & Zonen, CMP22)	<p>The CMP22 is housed within a ventilator unit, both should be decontaminated.</p> <ol style="list-style-type: none"> 1. Remove the ventilator cover and decontaminate IAW with section C3.3.1. 2. Remove the CMP22 from the ventilator housing (DO NOT remove the cables) and decontaminate IAW section C3.3.1. 3. Remove any biological debris within the ventilator unit . 4. Remove the filter and decontaminate separately IAW section C.3.3.1. 5. Decontaminate the ventilator unit IAW section C.3.3.1. 6. Reassemble the unit. <p>Note: Use extreme care to avoid scratching the glass dome of the sensor during disassembly, handling and assembly of the ventilator.</p>
Sunshine Pyranometer (Delta-T, SPN-1)	None.
Biological Temperature (Apogee, SI-111)	<p>There is an external shield surrounding the sensor, and a gap between the external shield and the sensor.</p> <ol style="list-style-type: none"> 1. DO NOT remove the shield from the sensor, but the gap in between the two may house additional dirt and debris and insect nests. 2. Use pipe cleaners to clean the area between the sensor body and the inside of the external shield. 3. Use compressed air (≤ 30 psi) to blow any loosened dirt or debris. Blow air only from the cable end to protect the lens. 4. The lens on this sensor is recessed and could house an insect nest or additional dirt or debris. Use a Q-Tip to clean the recessed area surrounding the lens. DO NOT use a pipe cleaner to clean the lens or the lens cavity.
PAR Quantum (Kipp & Zonen, PQS-1)	There is a small channel around the dome that may accumulate dirt and debris. Use a soft bristle brush to loosen and dislodge any dirt or debris.
Line PAR Quantum (LiCOR, 191-01)	There are two long channels on the underside of the sensor that may house insect nests, and other dirt and debris. Use a soft bristle brush to remove insect nests and to loosen and dislodge any dirt and debris.

C.3.4.3 Aspirated Air Temperature Shield

1. Remove any biological debris (leaves, stems, insect nests, etc.) on the housing, or inlet.
2. Open the sensor housing and remove the sensors as necessary.
3. With the sensor housing open, use compressed air (≤ 30 psi) to blow out the interior tubes, and the fans. This should help remove any loose dirt or debris.
4. Remove any biological debris (particularly insect nests) from the space in between the inner and outer intake tube.
5. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.3
 - a. On all exterior surfaces and interior surfaces of the unit. Be sure to also clean the underside of the shield.
 - b. On the fans and interior housing as necessary.
6. Reassemble the aspirated shield.

See RD[31] for specific cleaning procedures.

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C.3.4.4 PRTs

1. Refer to RD[22] to remove the PRT’s from their respective sensor housing.
2. Use the Common Decontamination Procedure section C.3.3.1 and C.3.3.2 for the sensor and sensor cables, respectively.

See RD[22] for specific cleaning procedures.

C.3.4.5 Sun Photometer (Cimel) and Robot

Refer to RD[20] to remove the sensor body from the robot. Component-specific considerations follow:

1. Sensor: Use the Common Decontamination Procedure to clean the external surfaces of the sensor body (section C.3.3.3).
 - a. Remove the collimator from the sensor body (RD[20]).
 - b. Clean the collimator in accordance with detail instructions provided in RD[20]. **DO NOT** clean or touch the lenses on the sensor body. Dirty lenses are analyzed for drift corrections and calibrations. Re-attach the collimator to the sensor body.
2. Robot: Use the Common Decontamination Procedure for sensor cables (section C.3.3.2) and exterior surfaces (section C.3.3.3).

See RD[20] for specific cleaning procedures

C.3.4.6 Barometric Pressure Sensor

1. Remove the sensor shield.
2. Verify that the pressure ports on the sensor are not clogged by biological debris or dirt. If so clean with a small brush or pipe cleaner.
3. Inspect the boxes with port connections and heater box holes for biological debris or dirt. If so clean with a small brush or pipe cleaner.
4. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.3 on the exterior surface of the sensor body.

See RD [32] for specific cleaning procedures.

C.3.4.7 Tipping Bucket Precipitation Sensor

1. Remove any biological debris (stems, leaves, etc.) from the funnel and screens.
2. Refer to RD[21] to remove the sensor from the tower, and the outer cover from the cover from the sensor.
3. Use the Common Decontamination Procedure – Sensors in section C.3.3.1 to decontaminate the cover, funnel, and the screens. Be sure to also clean the inside surface of the cover and funnel.
4. Inspect the interior for any dirt, biological debris, or insect nests.

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5. Use a soft bristle brush to remove any debris. **DO NOT** use compressed air to blow off debris as high-pressure air will damage the sensitive components.
6. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.3 on the exterior surface of the sensor body.
7. Refer to RD[21] for instructions on how to secure the tipping buckets for shipment.
8. Re-attach the cover and funnel.

See RD [38] for specific cleaning procedures.

C.3.4.8 Humidity and Temperature Sensor

1. Use a soft-bristled brush to remove any dirt or biological debris (stems, leaves, spider webs, etc.) from the radiation shield.
2. Refer to RD[15] to remove the radiation shield and sensor from the tower, and the sensor from the radiation shield; set the sensor aside.
3. Use the Common Decontamination Procedure –to decontaminate the radiation shield (section C.3.3.1) and the exterior surface of the sensor body (section C.3.3.3).
4. Use gentle pressure on the top of the sensor -- there is a sensitive air-permeable membrane at the top of the sensor that can be damaged.

See RD [35] for specific cleaning procedures.

C.3.4.9 Particulate Analyzer - Mass

1. Refer to RD[23] to open the unit to access the interior components
 - a. Remove any biological debris (leaves, stems, insects, etc.) from the large screen.
 - b. Remove and package the filter and filter cassette.
2. Using compressed air, blow out the blower components (located at the base of the fiberglass intake, below the filter stage).
3. Use an appropriately sized bottle brush to clean any debris out of the nozzles inside the size-selective inlet.
 - a. A 1-inch brush is recommended for the small inlets.
 - b. A 1.5-inch brush is recommended for the larger inlets.
4. Using compressed air, blow out any remaining dirt and/or dust from within the unit. Also blow off any loose dust from the outside of the sensor housing.
5. Use the Common Decontamination Procedures to clean the interior and the exterior surface of the sensor body (section C.3.3.3).

See RD[23] for specific cleaning procedures.

C.3.4.10 Soil CO₂ Sensors


1. Remove any biological debris (stems, leaves, etc.) from the top of the sensor housing.

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2. Refer to RD[24] to remove the sensor from the sensor housing.
3. Handle the filter with care to prevent contaminants or mechanical stress from damaging the filter. Avoid touching the filter unless it is dirty or stained.
4. If the filter appears clean and unstained, place the plastic sensor cap (filter cover) over the filter. The mirror and other internal components of the sensor do not need to be cleaned.
5. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.3 on the interior and the exterior surface of the sensor body.
6. If debris/stains are present on the filter follow the manufacturers cleaning process below (see ER[34]):
 - a. Holding the frame of the diffusion filter pull it off the sensor’s body. Beware of the threads on the sensor body, as they are sharp.
 - b. Use clean compressed air to blow any loose debris from the inside of the sensor.
 - c. If the mirror and/or window (located opposite the mirror) appear dirty, pour 95% ethanol or 70% isopropyl alcohol on them and swish it around to clean the dirt. Then pour out the excess liquid and let the surfaces dry before proceeding to the next step.
 - d. Place plastic cap (filter cover) over sensor.
7. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.3 on the interior and the exterior surface of the sensor body.
8. Place sensor in an individual sealed ESD bag for shipping.

See RD[24] for specific cleaning procedures.


C.3.4.11 Soil Temperature Sensors

 NOTE: Do not return the sensors installed in the plastic tubes to HQ unless specifically requested to do so. The earlier version of the hardware set up included a PVC outer tube and a removable interior sensor array. The latest revisions requires direct burial in which sensor arrays are typically not removed from the ground once installed. Refer to RD[25] for more information.

1. Refer to RD[25] to remove the sensor from the sensor housing.
2. Use the Common Decontamination Procedure – Sensors in section C.3.3.1 to decontaminate the soil temperature sensors.

See RD[25] for specific cleaning procedures.

C.3.4.12 Soil Water Content Sensors

 NOTE: These sensors are housed in a PVC pipe in the ground and the interior sensor array removed. There are numerous electronics that should not get wet, so be careful when decontaminating this sensor. Decontaminate the exterior metal sensor area. Refer to RD[26] for more information regarding this sensor.

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1. Refer to RD[26] to remove the sensor from the sensor housing.
2. Use the Common Decontamination Procedure – Exterior Surfaces in section C.3.3.2 on the exterior surface of the sensor bodies.

See RD[26] for specific cleaning procedures.

C.4 Terrestrial Field Equipment

C.4.1 On-site Decontamination of Terrestrial Field Equipment

Perform an initial inspection and manual removal of visible invasive species/propagules and debris from all equipment while at the site.

1. If invasive species are present at the site, return all equipment to the DSF for thorough cleaning and drying before reuse at any other site.
2. When sampling multiple sites in the same day, thoroughly clean and dry (preferably sun-dry if possible) equipment in the field before moving to the next site.
3. Clean all debris off equipment by hand. Leave debris at the site.
 - a. Remove any visible plants or plant fragments, animals, mud, or other debris.
 - b. Check seams and edges of sampling equipment for hidden organisms.
 - c. Use a nylon kitchen brush to scrub mud, soil and debris off surfaces at the site. Decontaminate brush when back at the DSF or make the brush site specific.
 - d. Make sure all equipment is dry before placing it in storage.

C.4.2 Domain Lab Decontamination of Terrestrial Equipment

Terrestrial equipment cleaning and maintenance guidelines are detailed in each of the relevant TOS Protocol and Procedure documents, and SOPs therein. Refer to those documents for details. The remainder of this section presents only a summary and applicable reference documents.

C.4.2.1 Small Mammal Traps

Equipment cleaning and disposal procedures described in the Small Mammal Sampling protocol (RD[05]) serve to prevent transport of nonindigenous species between sites. This includes cleaning any equipment known to have been in contact with small mammals and traps that are extremely soiled, full of bait, contaminated by ants, slugs, etc. Clean all traps prior to transport and use at another site.

C.4.2.2 Tick Drag Cloth

Decontaminate the drag cloth used for tick sampling prior to use at other plots and sites. The cleaning guidelines in the Tick Sampling protocol (RD[06]) will suffice:

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1. Place the drag cloth in a -20°C freezer for at least 30 minutes to kill any tick larvae attached to the cloth – along with other arthropods and gastropods that may be of concern.
2. Remove seeds stuck to the drag cloth by hand or with duct tape.
3. The drag cloth may also be washed using fragrance-free laundry detergent and bleach if necessary, and hung out to dry.
 - a. If a laundry drier is used, select a medium heat setting to prevent the drag cloth from shrinking.
 - b. Always make sure the drag cloth is completely dry and in good condition (i.e., same size as at the beginning of the season, free of holes) before placing in storage.

Alternatively, a separate cloth can be used for each sampling site and should be labeled and stored separately.

C.4.2.3 Soil Sampling Equipment

Clean any tools in contact with soil prior to use at another site. This includes soil coring devices, trowels, soil knives and other digging tools used in soil sampling (RD[07-08]) and digging pits for ground beetle pitfall traps (RD[09]). Warm water and a stiff brush are adequate for removing soil and debris. However, the soil sampling procedures for biogeochemistry and microbes are more stringent to minimize contamination between sampling locations (RD[07]). See Table 14 for additional details.

Table 14 Summary of cleaning protocols for soil sampling equipment

Sample Type	Water	Brush	70% ETOH	Nitrile Gloves
Joint Soil Microbe/Biogeochemistry (RD[07])	Deionized or distilled water	Yes	Yes	Reusable
Soil Nitrogen Transformations (RD[07])	Deionized or distilled water	Yes	Yes	New
Plant Belowground Biomass (RD[08])	Tap water	Yes	No	Not required
Beetle Pit Fall Traps (RD[09])	Tap water	Yes	No	Not required

1. Clean soil-sampling tools with deionized or distilled water. Scrub the soil core barrel using a toothbrush or toilet brush.
2. Sterilize with 70% alcohol wipes or 70% ethanol from a squirt bottle and wiped down prior to re-use within and across sites.
3. Use new nitrile gloves when going to a new site – i.e., do not reuse nitrile gloves. It is not necessary to change gloves between sampling plots at a site.

C.4.2.4 Mosquito Traps

Make sure all trap components are as clean and free as possible of insect parts and other debris prior to use at another site. Clean in accordance with guidelines in the Mosquito Sampling Protocol (RD[10]).

1. If mesh sleeves/collection cups are wet or dirty following trapping, gently wash them by hand using fragrance-free laundry detergent and hang/stack to dry.
2. Clean fans as necessary as follows:

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- a. Remove the fan assembly from the rain cover.
- b. Fill a small tray with warm soapy water to just below the fan motor of one or more fan assemblies.
- c. Soak fan assemblies for 10-20 minutes, then remove from the water tray and clean with bottlebrush.
- d. Once clean, set the fan assemblies on paper towels to dry before reattaching the rain cover.

C.4.2.5 Plant Material

Several TOS protocols require the collection of plant material for analysis (e.g., biomass and bulk density) at the DSF (RD[11-14]). These samples are oven dried at varied temperatures for a length of time needed to achieve a constant weight (typically 2-5 days) (Table 15). This should suffice to minimize the risk of transporting non-native species and pests. If you suspect the presence of exotic arthropods or gastropods in litterfall and fine woody debris samples, place the samples in a -20°C freezer for 30 minutes prior to oven drying. Any plant material remaining post-analysis should be disposed of in a sealed trash bag and disposed of at a sanitary landfill and/or in accordance with site host requirements.

Take extra care when handling equipment that may be contaminated with *Toxicodendron* species, such as poison ivy. Tecnu or an equivalent cleanser may be used to clean such equipment. See the applicable TOS protocol for protocol specific information.

Table 15 Oven drying temperatures used in selected vegetation sampling and analysis protocols

Sample Type	Oven drying temperature
Coarse Down Wood Sampling (RD[11])	105°C
Litterfall and Fine Woody Debris (RD[12])	65°C
Herbaceous Biomass (RD[13])	65°C
Bryophytes (RD[14])	65°C

APPENDIX A QUICK REFERENCES

A.1 General Decontamination

- Inspect and clean all personal gear, hand held sensors, tools, equipment and vehicles as follows:

Item	Inter-site transport of invasive species IS NOT a significant concern	Inter-site transport of invasive species IS a significant concern
Fixed Sensors	1-2 people; 30 minutes per site at the field site and 30-90 minutes at the DSF, depending on reagent.	Same
Handheld sensors	1-2 people; 30 minutes at the DSF prior to use at another site	Same
AOS/TOS Equipment	1-2 people; 30-45 minutes prior to use at another site	1-2 people; 30-90 minutes prior to use at another site
Personal Gear	10-15 minutes prior to use at another site	20-30 minutes prior to use at another site
Vehicle Exterior	Light wash as needed; thorough cleaning monthly*	Light wash weekly; before traveling to a new site if needed; thorough cleaning at least monthly*
Vehicle Interior	Light cleaning as needed; thorough cleaning monthly	Light cleaning weekly; before traveling to a new site if needed; thorough cleaning at least monthly

* A light wash may include running the vehicle through a car wash if available and feasible, a hose wash at the DSF, or something equivalent. If not feasible for any reason, submit a problem ticket. If possible, when using a car wash, get a standard exterior wash and undercarriage wash.

- Remove heavy accumulations of soil, mud, seeds and other debris with appropriate tools and techniques to save time and effort.

	Clean up at Site	Clean up at DSF
Clothing	Shake out and brush clothing	Use compressed air or vacuum to remove debris from cuffs and folds
Treads of boots	Use a small scraper, or similar tool, and pressurized water as needed	Setting up a boot brush and mats at the DSF can be helpful
Zipper and snap closures	Brush of loose debris and soil	Use a stiff brush on zippers, belts, laces or ties, buckles, straps, Velcro, buttons, fasteners, rivets, etc.

- Key areas of vehicles to inspect and decontaminate are illustrated in the following table.

Rubber-tired Vehicles	
<ul style="list-style-type: none"> • Crevices in upper surface and panels • Tires, rims, and fender areas • Spare tire mounting area • Bumpers • Front and rear quarter area • Around and behind grills • Bottom of radiator vent openings • Brake mechanisms 	<ul style="list-style-type: none"> • Transmission • Stabilizer bar • Shock absorbers • Front and rear axles • Beds • Suspension units • Exhaust systems • Light casings and mirrors

Tracked Vehicles	
<ul style="list-style-type: none"> • Crevices in upper surface and panels • Top of axles and tensioners • Support rollers • Between rubber or gridded areas 	<ul style="list-style-type: none"> • Beneath fenders • Hatches • Under casings • Grills

A.2 Aquatic

- Before leaving the site, DRAIN all buckets, coolers, waders, boots, and any other equipment that can hold water.
- CLEAN all debris off sensors AND equipment, including waders, nets, and brushes by hand. Leave debris at the site (discard on the shoreline or in the water).
- CLEAN all debris off boat, motor, and trailer by hand. Leave debris at the site (discard on the shoreline or in the water).
- All sensors must be cleaned and decontaminated at the DSF before being returned to HQ for servicing and/or calibration, or when being moved to a new body of water.
 - Decontaminate optical sensors using tap water, isopropyl alcohol, and, if needed, diluted white vinegar.
 - Decontaminate the uPAR sensor with tap water, white vinegar, if necessary, and 2% bleach, being careful to not mix vinegar and bleach.
 - Decontaminate all other aquatic sensors using detergent, tap water, HCl, isopropyl alcohol, and dionized water as illustrated in the following table.

Step	Action	Method	Solution	Delivery
1	Remove debris	Dry brush	N/A	Manual removal
2	Remove soils and organic material	Detergent solution wash	0.2% Liquinox (v/v) or Alconox (w/v)	Wash bucket; wetted Kimwipes and brush as needed
3	Rinse	Rinse	Tap water	Rinse bucket; wash bottle
4	Remove inorganic chemical contaminants, mineral deposits, biofilms	Acid solution wash	HCl 5 % (v/v)	Wash bottle; wetted Kimwipes and brush as needed
5	Rinse	Rinse	Deionized water	Rinse bucket; wash bottle
6	Remove organic chemical contaminants, disinfect surfaces	Alcohol solution wash	Isopropanol 70% (v/v)	Wash bottle
7	Rinse	Rinse	Deionized water	Rinse bucket; wash bottle

- Decontaminate all equipment with 2% bleach solution if the status of invasive species is unknown or no data are available. If specific invasive species are present at the site, use a higher concentration of bleach, hot water, or quaternary ammonia disinfectant as instructed.
- At the DSF or a commercial car wash, spray the boat and trailer with high-pressure hot water.

A.3 Terrestrial

- Before leaving the site, remove all visible soil and debris from equipment by hand using a soft brush. Discard debris at the site.

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- Decontaminate tower or soil sensors after removing the sensor assembly; this simplifies the procedure.
- Clean and decontaminate all sensors at the DSF before being returned to HQ for servicing and/or calibration, or when being moved to a new site. Generally, use water, kimwipes, a soft brush and compressed air as needed, as illustrated in the following table.

Step	Action	Method	Solution	Delivery
1	Remove visible dirt and debris	Soft dry brush	NA	Manual removal on site
2	Remove soil and organic matter	Soak	Tap water	Wash bucket
3	Mineral or salt deposits	Soak, soft brush	White vinegar (≤5% acetic acid)*	Wash bucket
4	Remove soil and organic matter	Wipe, brush and dust	Tap water	Wash bottle, wetted Kimwipes, soft brush and compressed air as needed
5	Clean sensor cables that are returning to HQ	Brush	Tap water	Manual removal

*Note: a lesser concentration of acetic acid may be used if available. For example, a concentration of as little as 1% acetic acid (4 parts water and 1 part white vinegar) may be sufficient in some instances.

- Do not wipe any radiation sensor lenses or domes with a rag. Use only a soft, lint-free cloth, and only after removing all traces of contamination from the surface.
- Clean all small mammal traps prior to transport and use at another site using QUAT or a 10% bleach solution. (**NEVER** mix chlorine bleach and QUAT)
- Decontaminate tick drag cloths by placing in a -20°C freezer for 30 minutes, removing seeds by hand and/or with duct tape, and, if especially dirty, wash using fragrance-free laundry detergent and bleach.
- Clean all soil sampling equipment prior to use at a new site; the procedure used depends upon the sampling type, as illustrated in the following table.

Sample Type	Water	Brush	70% ETOH	Nitrile Gloves
Joint Soil Microbe/Biogeochemistry (RD[07])	Deionized or distilled water	Yes	Yes	Reusable
Soil Nitrogen Transformations (RD[07])	Deionized or distilled water	Yes	Yes	New
Plant Belowground Biomass (RD[08])	Tap water	Yes	No	Not required
Beetle Pit Fall Traps (RD[09])	Tap water	Yes	No	Not required

- Make sure all mosquito trap components are clean and free of insect parts and other debris to the extent possible prior to use at another site. Gently wash mesh sleeves and collection cups by hand using fragrance-free detergent.
- Oven drying as specified in these protocols will decontaminate plant samples. If you suspect presence of non-native arthropods or gastropods in litter and fine woody debris samples, place them in a -20°C freezer for 30 minutes.

Consider posting reminders at the DSF and in truck binders about the importance of minimizing the spread of invasive species. See e.g., <http://dnr.wi.gov/topic/Invasives/documents/pedestrian1.pdf>

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APPENDIX B REMINDERS

B.1 General Considerations

- Thoroughly inspect and clean (as needed) all personal gear, equipment and vehicles IAW Table 4, or as otherwise needed.
- Never mix bleach with QUAT
- Never mix bleach and vinegar directly (undiluted by water)
- Always wear safety goggles when mixing chemicals and safety glasses when applying chemical solutions. As a general rule, if nitrile gloves are required, safety goggles or safety glasses are also required.

B.2 Aquatic

General Decontamination:

- The basic premise of decontamination for aquatic invasive species is threefold:
 - Drain → Clean → Dry.
- Felt-soled waders and wading boots are prohibited for NEON field staff; NEON designated visitors, and subcontracted personnel. Bootfoot waders are preferred.

Aquatic Sensor Decontamination:

- All sensors must be cleaned and decontaminated before being returned to HQ for servicing and/or calibration, or when being moved to a new body of water.
- Handle hydrochloric acid under a fume hood or at the very least a well-ventilated area. Acid causes burns on contact and safety glasses and gloves are required
- Do NOT use alcohol, organic solvents, abrasives, or strong detergents to clean the diffuser element on the uPAR sensor.
- Clean handheld probes and Humminbird transducer following manufacturer guidelines.

Aquatic Equipment Decontamination:

- Use a 2% bleach solution to disinfect equipment at all sites if the status of invasive species is unknown, or no data are available.
- Rinse and air DRY all equipment thoroughly.
- Rinse and air DRY all boats and trailers thoroughly.

B.3 Terrestrial

General Decontamination:

- Clean and dry

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Terrestrial Sensor Decontamination:

- All sensors must be cleaned and decontaminated before being returned to HQ for servicing and/or calibration, or when being moved to a new site. A 1% bleach solution is typically used unless otherwise directed.
- Do not wipe any radiation sensor lenses or domes with a rag. Use only a soft, lint-free cloth, and only after removing all traces of contamination from the surface.
- Use extreme care when wiping down the 2D and 3D sonic anemometer sensor arms. Avoid any excessive force that might misalign them.

Terrestrial Equipment Decontamination:

- Perform an initial inspection and manual removal of visible invasive species/propagules and debris from all equipment while at the site.
- If invasive species are present at the site, return all equipment to the DSF for thorough cleaning and drying before reuse at any other site.
- Clean tools used for soil sampling or digging prior to use at another site.
- A -20°C freezer may be used to decontaminate plant material samples or equipment that is suspected of harboring nonindigenous invertebrates

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APPENDIX C SELECTED AQUATIC NUISANCE SPECIES OF CONCERN

Whirling disease (*Myxobolus cerebrali*) – Whirling disease is caused by a myxospore parasite and primarily affects salmonid fishes. Spores are generally transported through fish parts and organic matter. Flushing of equipment and removal of debris and organic material significantly decreases the number of spores on equipment.

Chytrid fungus (*Batrachochytrium dendrobatidis*) – Chytridiomycosis, or chytrid disease, has caused a massive decline in amphibian diversity since 1998. Chytrids are microscopic and transported in water, but can be destroyed using bleach and hot water.



Figure 4 New Zealand mudsnails spread easily due to their small size

New Zealand mudsnails (*Potamopyrgus antipodarum*) – New Zealand mudsnails were introduced to North America in 1987. They are small (4-6 mm) outside of their native range and thrive in disturbed, silted streams (Figure 4). Because of their small size, they are easily transported in waders and nets. Bleach treatment is not effective; in mudsnail-infested waters use stronger ammonium compounds.



Figure 5 Quagga mussels have spread into Western U.S. waters; and are resistant to desiccation

Zebra (*Dreissena polymorpha*) and Quagga (*Dreissena rostriformis bugensis*) mussels – Ecologically similar and closely related, zebra and quagga mussels entered the Great Lakes in ballast water in 1988. Quagga mussels were first discovered in Lake Mead, NV, and represent the first confirmed introduction of a dreissenid species in the western United States (ER[18]). Individuals are relatively small (<1.5 inches) and can survive 3-5 days of desiccation (Figure 5). Bleach cleaning and hot water are effective in killing mussels on equipment.

Asian clam (*Corbicula fluminea*) – Corbicula is a common invasive freshwater clam in streams across North America, especially in the eastern United States (Figure 6). Immigrants likely brought it to the US in the 1920s as a food source. Adults are relatively small at about 5 cm.



Figure 6 Asian clams are common in streams in the eastern US

“Didymo”, rock snot (*Didymosphenia geminata*) – Although native to many cold-water streams in North America, the range of Didymo has been expanding, and it was listed as a nuisance species in 2005. Large mats of the diatom

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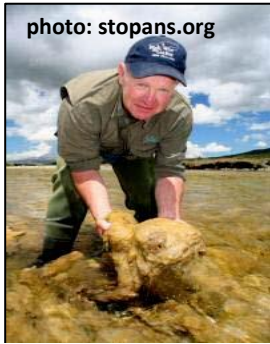


photo: stopans.org
Figure 8 Didymo is a stalked diatom that forms large mats in streams

plant fragments on boat motors or equipment (Figure 8). Fragments easily regenerate in freshwaters. Thorough cleaning and inspection of equipment and boats, along with high-pressure wash, are the most effective treatment.

filter water and alter stream habitat (Figure 7). *Didymo* is microscopic and can be spread in a small amount of water, so bleach cleaning of equipment and waders is important in restricting its spread. It occurs at West St. Louis Creek (D13) (see JIRA ticket NEON-3870). Other stalked diatoms such as *Cymbella* spp. may also function as a filter in some streams such as Blacktail Deer Creek (D12) (see JIRA ticket NEON-3494). In the absence of information, treat similar growth of other stalked diatoms species with caution.

Eurasian watermilfoil (*Myriophyllum spicatum*) – Eurasian watermilfoil was introduced to North America in the 1940s, and quickly spreads in lakes by



photo: dnr.wi.gov UGA1 624031
Figure 7 Eurasian watermilfoil spreads easily among lakes and ponds due to fragmentation

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APPENDIX D SELECTED TERRESTRIAL INVASIVE SPECIES OF CONCERN

Emergent Riparian Plants

Flowering rush (*Butomus umbellatus* L.) – Aquatic herbaceous plant that grows along shores in shallow water. Reproduces by seed and rootstock.

Purple loosestrife (*Lythrum salicaria* L.) – Erect, emergent, much-branched perennial growing to 2 meters tall. It grows in marshes, along the wet margins of ponds, lakes, rivers, canals, meadows, prairies and ditches. A single plant can produce 2.5 million seeds annually (Malecki *et al.* 1993).

Giant Reed (*Arundo donax* L.) – Clump-forming grass that can be 7-8 meters tall. It grows rapidly and propagates from rhizomes, forming dense stands. The large biomass left after each seasonal die-off creates a fire hazard.

Common Reed (*Phragmites australis*) – A perennial with a large, dense, terminal panicle that grows up to 4.5 meters tall. It is found in marshes, along the edges of lakes, ponds, swamps, ditches, streams, canals, rivers, and estuaries.

Saltcedar (*Tamarix* spp.) – A shrub or small tree with irregularly spreading – ascending, elongate branches with leafy branchlets. Leaves are normally deciduous but may persist through mild winters. Species habitat includes rivers, streams, ditches, lakes, coastal areas, salt flats, and waste places. Saltcedar forms excessive stands and creates water loss-drought conditions, displacing native plant communities.

Terrestrial Plants

Brazilian pepper (*Shinus terebinthifolius* Raddi) – A dioecious shrub or tree reaching 10 meters. Seeds are easily dispersed by birds, and people and retain high variability for months. It out-competes and displaces native plants, forming monocultures and destroying native communities.

Russian olive, autumn olive, cherry silverberry (*Eleagnus* spp.) – These small tree species are capable of nitrogen fixation, changing the biogeochemistry of the ecosystem. They grow in disturbed areas, successional fields, pastures, roadsides, and shelterbelts where they may have been purposefully planted. They invade prairies, woodlands, and forest edges. *Eleagnus* spp. Interrupts natural plant succession and nutrient cycling and resprout vigorously following cutting or burning.

Russian knapweed (*Acroptilon repens*) – Bush perennial, growing up to 80 cm tall. It is deeply rooted with a long lifespan, forming dense colonies in fields, orchards, pastures, and along roadsides.

Spotted knapweed (*Centaurea stoebe* L. *subsp. micanthos*) – Different from Russian knapweed in that it is a biennial or short-lived perennial. It also invades pastures, rangeland, dry meadows, flood plains, roadsides, and other dry, gravelly, or sandy sites. Seeds are prolific and viable for years. Grazing lands

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are at particular risk as grazing animals pass over knapweed, which gains an advantage over preferred grazing crops.

Diffuse knapweed (*Centaurea diffusa*) – Can be annual or biennial herb. It is allelopathic and disruptive to native communities. It rapidly invades disturbed rangeland and other disturbed sites, but can also colonize undisturbed communities.

Giant hogweed (*Heracleum mantegazzianum*) – This federally noxious weed is a perennial that grows up to 4-5 meters tall, typically in rich, moist soils along roadsides, stream banks and disturbed areas. Its sap can cause severe skin and eye irritation.

Leafy spurge (*Euphorbia esula* L.) – A widespread weed in grazing lands. Seeds are spread by animals and water. It has a milky fluid that can cause irritation to some animals.

Yellow starthistle (*Entaurea solstitialis* L.) – A short plan with yellow flowers and deep taproot. It reproduces by seed, estimated as high as 29,000 seeds per square meter with 95% viability. It invades fields, roadsides, rangelands, pastures, and waste areas. It is allelopathic.

Perennial pepperweed (*Lepidium latifolium* L.) – A perennial herb that grows to about 1 meter tall. It is common in fields in the western United States. The root system persists year round and spreads widely.

Canada thistle (*Cirsium arvense*) – This herbaceous thistle forms thick communities in pastures, ditches, bottomlands, and other moist areas. It spreads through horizontal roots and fragmentation.

Cheatgrass (*Bromus tectorum* L.) – This annual grass occurs along roadsides, banks, fields, and waste areas and throughout the U.S. The tufted fruit seeds are barbed and can cause inflammation and injury. The dry plants are fire hazards.

Kudzu (*Pueraria montana* var. *lobate*) – An aggressive vine that can grow 60 feet per year, forming dense blankets which choke out native vegetation. Early introduction to the Southeast United States to control agriculture erosion. Risks include damage to ecosystems and NEON infrastructure.

Privet (*Ligustrum* spp.) – A shrub species that easily escapes cultivation and forms dense monocultural thickets. This deciduous plant grows up to 5 meters high, growing from seed or stump sprouts. Privet is a particularly active primary species following disturbance of an ecosystem.

Honeysuckles (*Lonicera* sp.) – Nonindigenous honeysuckles are deciduous shrubs adapted to a wide variety of habitats in much of the eastern and Midwestern portions of US. These upright, multi-stemmed plants consistently produce a large number of seeds that are easily dispersed by birds and small mammals

Black Locust (*Robinia pseudoacacia*) – This tree may be 75 feet tall and spread through seedlings, root sprouts, and fragmentation. While native to the Appalachian Mountains, it has invaded the Northeast

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and forms dense monocultures. It fixes nitrogen in the soil and can change the biogeochemistry of fragile ecosystems, such as inland pine-barrens.

Garlic Mustard (*Alliaria petiolata*) – A biennial herb that poses significant threat to lowland areas in the Eastern United States. First year growth is up to 4 inches and subsequent years may reach 1 meter. While removing the plant from equipment is effective, use special care when handling plants that have seeded. Seeds should be bagged and disposed.

Crown Vetch (*Coronilla varia* L.) – This low growing vine is commonly used for erosion control in roadside planting and soil rehabilitation. As such, it is common threat to NEON sites.

Tree-of-Heaven (*Ailanthus altissima*) – This tree is a persistent and aggressive weed, quickly growing in disturbed areas. It can grow to 2.5 meters in the first year and up to 30 meters later. It reproduces from seed and root sprouts. Seeds are easily windblown and largely viable. Mechanical removal methods can cause spreading by fragmentation.

Japanese stiltgrass (*Microstegium vimineum*) – A sprawling, annual grass that grows to 0.5-3.5 ft. in height. It is a common invader of forested floodplains, and also occurs in ditches, forest edges, fields, and trails. It is very shade tolerant and can completely displace native vegetation.

Marsh thistle (*Cirsium palustre*) – Can be a biennial or monocarpic perennial. Typically found along roadsides and in a variety of wetlands, marshes, wet forests, forest edges and open fields. Of particular concern in the Great Lakes region.

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APPENDIX E SPECIAL CONSIDERATIONS FOR DOMAIN 20 -- PU'U MAKA'ALA NATURAL AREA RESERVE (PUUM)

DOMAIN 20, PU'U MAKA'ALA NATURAL AREA RESERVE (NEON SITE ID: PUUM) – INVASIVE PEST PREVENTION STANDARD OPERATING PROCEDURES (SOPS)

This SOP has been given to NEON from the Site Host (date: 02/02/2016). NEON must adhere to adhere to this SOP while doing any work within the Domain 20, Pu'u Maka'ala Natural Area Reserve.

This document lists protocols for preventing the introduction of harmful invasive pests including coqui, ants, weeds, and rapid ohia death into State NARS lands on the Island of Hawaii. It mirrors Hawaii Volcanoes National Park SOPS as they were the most comprehensive. It is the project leader's, contractor's, or concessioner's responsibility to ensure compliance with these protocols.

1. All work vehicles, machinery, and equipment must be clean and free of debris prior to entering NARs.

- a. Vehicles, machinery, and equipment must be thoroughly pressure washed and visibly free of mud, dirt, plant debris, frogs and frog eggs, insects and other debris. A hot water wash is preferred. Areas of particular concern include bumpers, grills, hood compartments, areas under the battery, wheel wells, undercarriage, cabs, and truck beds.
- b. The interior and exterior of vehicles, machinery, and equipment must be free of rubbish and food. The interiors of vehicles and the cabs of machinery must be vacuumed clean. Floor mats will be sanitized with a solution of >70% isopropyl alcohol or a freshly mixed 10% bleach solution.
- c. Store all equipment and gear in areas routinely treated for invasive species prevention
- d. Adhere to routine treatment protocols. Vehicles will be fumigated with Pyrethren foggers every six months, or sooner as routine inspections dictate.
- e. All work vehicles, machinery, and equipment may be subject to inspection.
- f. Any vehicles, machinery, and equipment that do not pass inspection will be turned away.
- g. Vehicles, machinery, and equipment leaving the NARs for any reason must be cleaned prior to re- entry into the NARs, and may require re-inspection at the NARS Staff's discretion.

2. Inspection of work vehicles, machinery, and equipment for invasive ants prior to entering NARs.

- a. In addition to visual inspection for plant debris, insects, soil, frog and frog eggs, testing for invasive ants is part of the inspection prior to entry into the park or at a predetermined location in the park. To expedite the process, make sure vehicles, machinery, equipment, and staging areas used are clean as described in (1) above.
- b. Test for invasive ants by placing chopsticks baited with a dab of peanut butter and jelly for 30 minutes to 1 hour throughout the equipment being tested. About 6 chopsticks will be used to test most personal vehicles and trucks, larger vehicles and heavy machinery may require up to 10-20 baits. Baits will be placed in the shade, inside the cab, engine compartment, and truck bed if applicable. Please note baits are only good for detection and do not control ants, and the bait will not be left in the vehicle for over 1 hour as this may attract ants from beyond the area of concern.

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- c. Any ants found will be collected, bagged and labelled for identification, and the equipment will not be allowed to enter the NARs until it is sanitized and re-tested following a resting period. Infested vehicles will be sanitized following recommendations by the Hawaii Ant Lab (<http://www.littlefireants.com/>) or other ant control expert and in accordance with all State and Federal laws. Control records will be required to confirm treatment. Treatment is the responsibility of the equipment or vehicle owner.
- d. Gravel, building materials, or other equipment such as portable buildings will also be tested, using the same method as above, however, baited chopsticks will be placed every 10-20 feet around the area, in the shade, and the immediate surrounding area will be searched for 2 minutes for ants. These monitoring stations must be left out for 1 hour, and any ants found will be collected for identification. The vehicle base yard and quarries may also be tested using these methods if deemed necessary by the NARS Staff.
- e. The NARS Staff reserves the right to conduct additional tests for ants at any time during the course of the project.

3. Base yards and staging areas inside and outside the park must be kept free of invasive pests

- a. Base yards and staging areas may be inspected for invasive pests at the beginning of the project.
- b. Pest control records may be requested anytime at the NARS Staff’s discretion.
- c. Project vehicles or equipment stored outside of a base yard or staging area, such as a private residence, should be kept in a pest free area. Such vehicles or equipment may be subject to additional inspection as described in (1d) above and will be turned away if infested.

4. All cutting tools must be sanitized to prevent rapid ohia death (ROD)

- a. All cutting tools, including machetes, chainsaws, and loppers must be sanitized to remove visible dirt and other contaminants prior to entry into the park, and when moving to a new project area in the park. Tools may be sanitized using a solution of >70% isopropyl alcohol or a freshly mixed 10% bleach solution. One minute after sanitizing, you may apply an oil based lubricant to chainsaw chains or other metallic parts to prevent corrosion.
- b. Only dedicated tools and chainsaws will be used to sample known or suspected ROD infected trees.
- c. Vehicles, machinery, and equipment must be cleaned as described in (1) above.

5. Imported firewood:

- a. All firewood imported into the NARs facilities must be sourced from a DOFAW approved site free of ROD, invasive weeds, coqui and ants.

SCHEDULING AN INSPECTION FOR A NARS APPROVED PROJECT:

Projects may be required to provide their own trained inspectors and to document records of inspection. Requests for inspections should be made via email to Nicholas.R.Agorastos@hawaii.gov and should include the project lead and contracting officer. Requests must be made a minimum of 3 business days prior to inspection. We may be unable to accommodate requests made on shorter notice, though you

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may contact the following staff via email to try to arrange an inspection. Please make sure to also copy your project lead on this correspondence. Additional points of contact include the following:

- lan.w.cole@hawaii.gov 974-4383
- Jennifer.A.Randle@hawaii.gov (phone number not provided)
- ziudd@hawaii.edu 430-8464 (Waimea)
- Lisa.M.Shizuma@hawaii.gov 974-4385

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APPENDIX F NEON BEST MANAGEMENT PRACTICES FOR DOMAIN 20, PU'U MAKA'ALA NATURAL AREA RESERVE (NEON SITE ID: PUUM)

The following BMPs are part of the NEON Operating Plan for Domain 20, Pu'u Maka'ala Natural Area Reserve. Contact NEON Permitting for additional questions regarding these BMPs.

Best Management Practices

The following Best Management Practices (BMPs) were developed in coordination of DOFAW, NARS, USFWS, NSF and the NEON project.

1. The NEON project will follow the biosecurity (decontamination) protocols outlined by the DOFAW NARS.
2. Tools used for cutting infected 'ohi'a trees should be cleaned with a 70% rubbing alcohol solution (or 10% bleach solution as long as tools are oiled afterward)
3. Vehicles used off-road in infected forest areas should be thoroughly cleaned. The tires and undercarriage of the vehicle should be cleaned with detergent if they have travelled from an area with ROD or travelled off-road.
4. Shoes and clothing used in infected forests should be cleaned. Shoes should be decontaminated by dipping the soles in 10% bleach or 70% alcohol solution. Other gear can be sprayed with the same solution. Clothing can be washed in hot water and detergent.
5. Wood of affected 'ohi'a trees should not be transported to other areas of the Hawaiian Islands or interisland. All cut wood should be left on-site to avoid spreading the disease. The pathogen may remain viable for over a year in dead wood. The HDOA has passed a new quarantine rule that prohibits interisland movement, except by permit, of all 'ohi'a plant or plant parts.
6. All construction vehicles and equipment will be maintained in proper tune according to manufacturer's specifications.
7. The number of vehicles accessing and moving within the project area will be limited to the extent possible. Vehicles speed on unpaved roads within the proposed project area will be limited to 15 miles per hour or less.
8. Vehicles and equipment would not be allowed to idle for extended periods of time (i.e., greater than 20 minutes).
9. The extent of ground disturbance will be minimized where possible. Temporarily disturbed areas will be stabilized and revegetated as quickly as possible.
10. All trucks hauling soil or other loose materials will be covered.
11. The entrance to the proposed project site will be stabilized to avoid offsite tracking of sediment.
12. Construction equipment would be properly tuned and balanced, and maintenance will be performed in accordance with the manufacturer's specifications.
13. Noise barriers, mufflers, or both will be used on diesel and gasoline engines.
14. Construction activities will be restricted to typical working days/hours.
15. Unnecessary noise will be kept to a minimum.

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16. Erosion and sediment control measures (for example, silt fences) will be installed before earth moving activities are initiated, and will be inspected and properly maintained throughout the construction period.
17. Disturbance of soil will be minimized during periods of heavy rain.
18. Vehicles and equipment will be inspected for leaks and contamination on a daily basis.
19. In the event of a spill or leak of fuel or lubricants from onsite equipment, the materials will be cleaned in a timely manner and disposed of at an approved site.
20. Preconstruction surveys will be conducted throughout the construction limits. In the event that a protected plant species is identified, the NEON project team would work directly with DOFAW and NARS staff to adjust the construction limits or implement design modifications to avoid potential impacts.
21. Temporary protective fencing will be erected around any protected plant species located in close proximity to the access road or construction limits.
22. Vehicles, equipment, materials and boots would be inspected for foreign matter (including dirt, seeds, eggs, larvae or other propagules) before entry into the site then will be cleaned to remove all foreign matter.
23. All workers will be instructed on specific procedures to prevent the introduction and spread of invasive species in the project area.
24. All trash, including food waste, will be placed into appropriate containers, removed from the project site, and properly disposed.
25. NEON domain staff will conduct regular monitoring for invasive species within the project area throughout the operational period. If invasive species are detected, removal and control will be coordinated with the NARS site manager.
26. A biologist familiar with the nesting behavior of the nēnē will survey suitable habitat within the construction area before the initiation of any construction activities, or after any subsequent delay in work of 3 or more days (during which time, the birds could attempt nesting). If a nest is discovered, USFWS will be contacted.
27. All NEON staff will be trained to identify nēnē, 'lo (Hawaiian Hawk), threatened and endangered honeycreeper species and 'alalā and know the appropriate steps to take if the species are present within the project area or encountered in transit to sampling locations.
28. If a nēnē is encountered within the project area, the bird would not be approached, and all activities within 100 feet of the bird will cease until the bird leaves the area of its own volition.
29. If a nēnē is encountered while in transit to a sampling location, the researcher(s) will stop and remain in place until the bird moved more than 100 feet from the travel route of its own volition or slowly retreat and return for sampling at a later time.
30. Vegetation clearing or construction will not be conducted during the Hawaiian hawk breeding season (March through September). If it is not possible to avoid vegetation clearing or construction during these months, a nest survey will first be conducted by a qualified biologist. The survey would be conducted no more than 14 days before the start of vegetation clearing or construction, and would include all areas within 1,600 feet of the construction area. Appropriate survey methodology

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(including avoidance and minimization measures in the event a nest is found) will be coordinated with USFWS.

31. If vegetation clearing or construction occurs during the honeycreepers breeding season (February through July), a nest survey will first be conducted by a qualified biologist. The survey would be conducted no more than 14 days before the start of vegetation clearing or construction, and would include all areas within 500 feet of the construction area. Appropriate survey methodology (including avoidance and minimization measures in the event a nest occurs) would be coordinated with USFWS.
32. If vegetation clearing or construction occurs during the ‘*alalā* breeding season (February through July), a nest survey will first be conducted by a qualified biologist. The survey would be conducted no more than 14 days before the start of vegetation clearing or construction, and would include all areas within 1,600 feet of the construction area. Appropriate survey methodology (including avoidance and minimization measures in the event a nest occurs) will be coordinated with USFWS.
33. The use of shiny materials would be minimized and shiny surfaces will be masked to decrease their attractiveness to ‘*alalā*. Specifically, the tower will be constructed of materials that are a dull, galvanized gray. An exterior treatment involving dark/dull colors will be added to any shiny surfaces, such as power boxes and communication equipment.
34. All trash will be placed into appropriate containers and promptly removed from the project site, to avoid inadvertent discarding of shiny materials or other items that may be of interest to ‘*alalā*.
35. The guy wires for the research tower may be fitted with bird flight diverters, as needed, to increase their visibility to birds.
36. The beetle traps will be fitted or retrofitted, depending on timing of ‘*alalā* releases, with chicken wire to limit the extent to which ‘*alalā* could access the traps. Any preservatives used in the beetle traps will be verified to be non-toxic to birds.
37. Construction activities will be restricted to daylight hours to avoid the use of nighttime lighting that could attract seabirds.
38. Installation of outside lighting will be avoided, to the extent possible. If outside lights are required for safety or security purposes, directional lighting or shielded lighting will be used to prevent upward radiation. The shields will be completely opaque, sufficiently large, and positioned so that the bulb is only visible from below. Outside lights that are not needed for security and safety will be turned off from dusk through dawn during the seabird fledging season (September 15 to December 15).
39. The guy wires for the research tower will not extend above the top of the tree canopy to minimize the potential for bird strikes.
40. No trees taller than 15 feet will be trimmed or removed as a result of this proposed project between June 1 and September 15, when juvenile bats that are not yet capable of flying may be roosting in the trees. However, if a limited number of trees need to be trimmed or removed during that time period, a qualified biologist shall use appropriate protocols to ensure no juvenile bats are in the affected trees before trimming or cutting.
41. No loulou or wet montane forest habitat will be cleared or trimmed, nor would vegetation biomass be harvested as part of sampling within areas that are designated critical habitat for *Drosophila*

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mulli. If loulu is to be cleared, trimmed or harvested in portions of the project area that are not within designated critical habitat, they will first be inspected for *D. mulli* by a qualified biologist. If *D. mulli* are found, the NEON project team will work directly with DOFAW and NARS staff to adjust the construction limits or implement design modifications to avoid impacts to the occupied loulu. Protective fencing would be installed around the occupied loulu, as appropriate.

42. Mosquito traps will not be installed within 1,000 feet of critical habitat for *D. mulli* or any location where the species was previously documented within Pu'u Maka'ala NAR.