Best Management Practices for Preventing *Phytophthora* Introduction and Spread:
Trail Work, Construction, Soil Import

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ABSTRACT

This document contains Best Management Practices (BMPs) for reducing the import and spread of soil-borne *Phytophthora* species in the Golden Gate National Recreation Area (GGNRA) during trail work, construction, and soil import. These BMPs were written based upon scientific understanding of *Phytophthora* biology and pathology, and existing BMPs already in use in the GGNRA. The BMPs were developed in consultation with GGNRA and Golden Gate National Parks Conservancy staff.

This document is organized in the following five sections.

1. Section 1 describes the overall concepts upon which the BMPs are based. It discusses how various plant, environmental, and management factors interact with *Phytophthora* to affect disease epidemiology. It presents a conceptual risk model that relates these factors to the likelihood that *Phytophthora* species will be introduced and establish an infestation. This section includes checklists for assessing the likelihood that a site is contaminated with one or more *Phytophthora* species and for assessing whether any part of a site has a high likelihood of becoming infested with soil-borne *Phytophthora* species.
2. Section 2 presents BMPs for activities associated with trail construction and maintenance as well as trail decommissioning. BMPs in this section emphasize activities mainly involving crews using hand tools and small equipment along trail corridors.
3. Section 3 presents BMPs for general construction activities, which may involve larger project areas and use of heavy equipment, which are not considered in Section 2.
4. Section 4 presents guidelines and BMPs for evaluating soil for import, handling of imported soil, and assessing the site where the imported soil will be used with respect to the potential for introducing *Phytophthora*. This section includes assessment checklists and flow charts related to selecting soil sources compatible with soil use locations.
5. Section 5 contains definitions for key terms referred to in Sections 1 through 4 as well as detailed procedures and specifications for some of the BMPs presented in Sections 2, 3, and 4. This section also contains a reference list of cited and related publications.

Sections 2 (trail work), 3 (construction) and 4 (soil import) can largely be used as stand-alone BMPs for their respective topics when combined with Sections 1 (introduction) and 5 (definitions and specifications).

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Cover photo: Along the Bolinas Ridge Trail, Golden Gate Natural Recreation Area.

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1.1. INTRODUCTION

Phytophthora species are microscopic Oomycetes (water molds). Previously considered fungi, these microorganisms are more closely related to the brown algae than to true fungi. More than 120 *Phytophthora* species have been described to date, and virtually all are plant pathogens. Diseases caused by *Phytophthora* species include root roots, stem cankers, and blights of fruit and leaves. Host ranges of individual *Phytophthora* species may be relatively narrow or very wide, encompassing thousands of plant species in many unrelated families. The potential host ranges of most *Phytophthora* species are unknown because relatively few of these pathogens have been studied in depth, and most studies focus on disease issues in agricultural crops. When introduced into native ecosystems, various exotic *Phytophthora* species have proven to be serious to devastating pathogens. Sudden oak death, caused by *Phytophthora ramorum* and root rot caused by *P. cinnamomi* are two notable examples.

Root disease and plant mortality caused by exotic *Phytophthora* species pose a threat to the health, functioning, and sustainability of both natural plant communities and urban landscapes. *Phytophthora* infestations can limit the ability of sites to sustain a variety of appropriate and desirable plant species. Introduction of these pathogens into habitat areas may directly or indirectly affect threatened or endangered plants and animals. Decline and mortality of vegetation caused by *Phytophthora* species can also result in the loss of ecosystem services such as erosion protection and reduction of stormwater flows.

Recent research has highlighted the importance of diseases caused by exotic *Phytophthora* species in the San Francisco Bay Area and other northern California native habitats. In particular, many *Phytophthora* species have been detected in nursery stock planted in habitat areas for restoration projects. This has greatly increased the chances that *Phytophthora* species will establish and spread in habitat areas, affecting the growth and survival of native species. *Phytophthora* species introduced with nursery stock in urban landscapes can also be inadvertently moved and spread along roads and trails, especially in operations that involve grading and soil transport.

The Best Management Practices (BMPs) described in this document focus on avoiding and preventing the introduction of *Phytophthora* species. Small changes in working practices can greatly reduce the risk of spreading *Phytophthora* species. These changes are based on recognizing likely sources of contamination and routes through which contamination many be spread. In addition, because the risk of introduction varies with site and environmental conditions, strategic timing of work activities can reduce the level of effort needed to minimize risks. It is also important to understand which plant communities and landscapes are most vulnerable to invasion by *Phytophthora* to help prioritize areas where prevention efforts need to be maximized.

Finally, it is important to remember that even in areas that may be infested with one or more *Phytophthora* species, introducing additional *Phytophthora* species can further degrade the site and complicate management. Hence, BMPs that prevent the introduction of *Phytophthora* species through the use of clean tools, equipment, and materials, should be followed even in areas that could have existing *Phytophthora* contamination.

1.2. FACTORS AFFECTING *PHYTOPHTHORA* ROOT ROT

The development of plant disease caused by organisms such as *Phytophthora* is commonly described through a simple conceptual model known as the plant disease triangle. This model indicates that disease development requires a favorable alignment of three factors: host plant, pathogen, and environment. Plant diseases develop when a susceptible host encounters a virulent pathogen under environmental conditions that are favorable for infection and disease development. For soil-borne pathogens such as *Phytophthora*, other factors also come into play. The presence of other agents that may either favor or suppress disease can strongly influence disease development. The overarching effect of time also needs to be considered because infection, disease, and dispersal processes all require time. For example, if

environmental conditions do not remain favorable long enough for infection and inoculum dispersal to occur, disease may be inhibited.

The plant disease triangle factors that influence *Phytophthora* root rots, and risk associated with different levels of these factors, are shown in Table 1-1. Considering **host factors** alone, the highest risk for *Phytophthora* root rot disease development and spread exists where roots of susceptible host species (either one or multiple host species) are relatively dense and interconnected. Host susceptibility can be increased by predisposing stresses. If we consider **pathogen-related factors**, *Phytophthora* species are most likely to successfully establish in an area if they are well-adapted to local conditions, have a relatively wide host range, and readily produce sporangia and zoospores as well as survival structures. Such characteristics will vary between *Phytophthora* species for given combinations of host and environment. **Environmental factors** that favor pathogen introduction and disease spread can be divided into abiotic and biotic factors. Disease development is favored by periods of soil saturation, which may occur only during precipitation events or may be associated with irrigation, subsurface drainage, water courses, ponds, or seeps. Although temperature can be a limiting factor, the moderate soil temperatures found in GGNRA lands over much of the year are likely to favor a variety of *Phytophthora* species. Nonetheless, different *Phytophthora* species may be more or less active seasonally based on their temperature preferences. The main biotic environmental factor that influences *Phytophthora* establishment, spread, and disease severity is the presence of effective microbial antagonists in the soil. If populations of such antagonists are low, risk of *Phytophthora* impacts are greater. Low populations of antagonists are often associated with poor soils with low organic matter, such as serpentine soils.

Table 1-1. Relative risk of *Phytophthora* introduction, disease development, and/or spread related to selected host, pathogen, and environmental factors.

Relative risk:	no risk	lower risk	higher risk
Host factors			
Density of susceptible host roots	no host roots	low density	high density
Continuity of susceptible host roots		wide spacing, low connectivity	highly interconnected
Host predisposition due to drought, salinity, low soil oxygen, or other stressors		little or no predisposing stress	high level of predisposing stress
Pathogen factors			
Host range	very narrow, no local hosts	narrow	wide
Adaptability	not adapted to local conditions	narrow, poorly adapted to local conditions	wide, well adapted to local conditions
Production of sporangia and zoospores (for rapid reproduction and spread)		low	high
Production of oospores, chlamydospores, and other survival structures (for persistence under unfavorable conditions)		not regularly produced or uncommon	readily produced, abundant
Abiotic Environmental factors			
Soil moisture	consistently dry	very well drained, seldom saturated	slow drainage (e.g., due to hardpan or claypan), frequent/extended periods of saturation
Temperature	above thermal kill levels	long periods at high temperatures (>30 C)	normal soil temperature range
Biotic environmental factors			
Organic matter and related microbial activity		high	low

1.2.1. Unassisted spread of *Phytophthora*

Once *Phytophthora* is introduced into a site and becomes established there, the infested areas can function as sources for further spread. *Phytophthora* spreads naturally in infested landscapes via two main routes: **surface water flow**, which moves zoospores and other spores and infected plant fragments, and **root-to-root spread** between and along host roots in soil.

Natural (unassisted) spread via surface water flow primarily occurs downslope but can occur throughout an area that becomes inundated. Spores moving in water can move great distances downstream at the rate that water flows, though inoculum typically becomes more dilute as the distance from the source increases. Flowing water can transport inoculum across gaps where no hosts may be present.

In contrast, unassisted spread along roots requires a fairly continuous network of host roots and will not normally occur across gaps that are devoid of host roots. Root-to-root spread can occur in any direction, regardless of slope, as long as an intertwining network of host roots is present. The rate of spread via this means is typically slow, commonly no more than about 1-2 m per year. Nonetheless, even with an expansion rate of 1 m per year along a disease front, infested areas can expand substantially each year. A small spot infestation with a 1 m radius (3.14 m^2, 6.3 m circumference) can increase over 120-fold in area (to 380 m^2, 69 m circumference) in 10 years by this route.

Because *Phytophthora* infestations can continue to spread through root-to-root contact or runoff in many sites, it is critical to prevent the initial introduction of *Phytophthora*. **This is accomplished by recognizing contamination risk pathways and following appropriate working practices that minimize the risk of introducing or spreading *Phytophthora*.**

1.3. GENERAL RISK MODEL FOR *PHYTOPHTHORA* INTRODUCTION AND SPREAD

Introduction of *Phytophthora* to a site that is not infested occurs through a process with three interrelated steps:

1. Viable *Phytophthora* inoculum is present at a source.
2. The inoculum is transported from the source to the noninfested site.
3. The transported inoculum is brought in contact with susceptible vegetation at the site and an active infection is established.

These steps and corresponding risk factors associated with each are illustrated in Figure 1-1 and discussed in more detail below. An understanding of these processes is the key to appropriately implementing practices to prevent *Phytophthora* introduction and spread. Note that planting *Phytophthora*-infected nursery stock at a noninfested site accomplishes all three steps: viable inoculum and host material are inserted directly into the landscape. If the infested stock is planted in or near the rootzone of susceptible vegetation at the site, all elements are in place to initiate an infestation. Other processes that move *Phytophthora* are less direct, and the likelihood of a successful *Phytophthora* introduction depends on the efficiency of each step in the process.

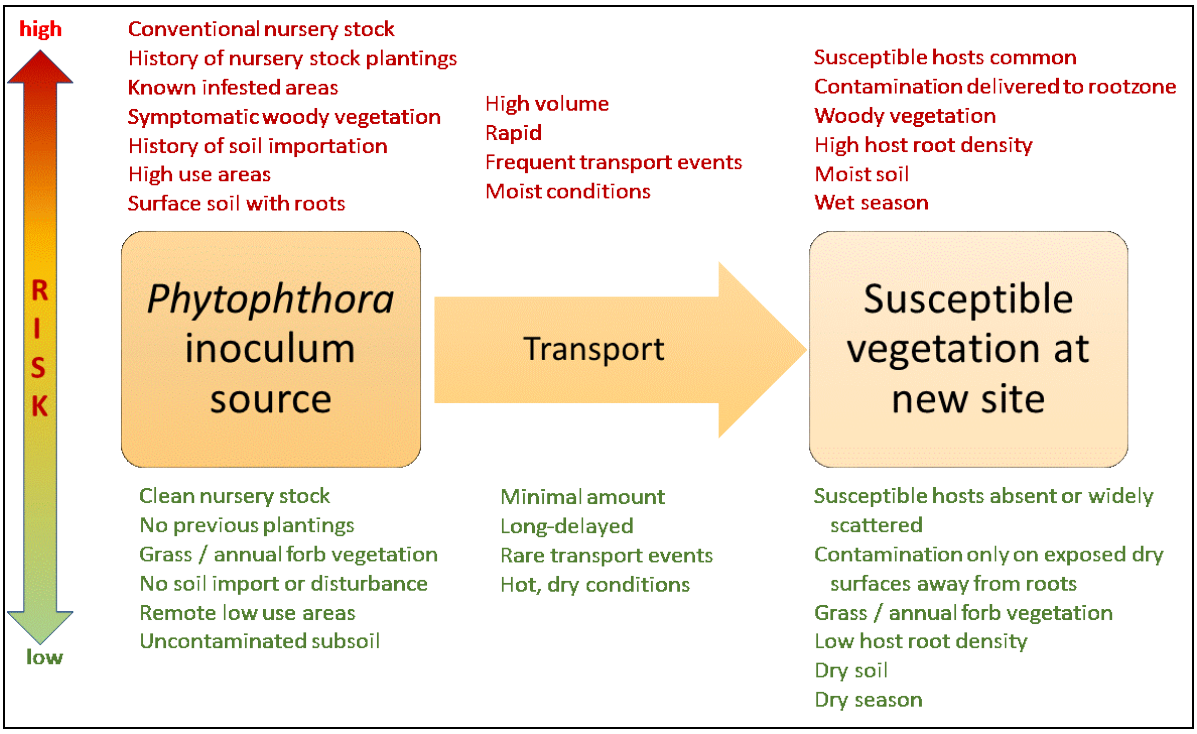


Figure 1-1. Diagram of the general risk model for introduction and spread of soil-borne *Phytophthora* species into uncontaminated sites.

1.3.1. Sources of *Phytophthora*

The first step in the risk model relates to the presence of a source of *Phytophthora*. If an activity intentionally or unintentionally moves soil or other materials to a receptive site, there is no risk if the transported materials are free of *Phytophthora*. For example, crushed rock from a known clean source that has been handled to prevent contamination can be imported to a clean site without risk.

Unfortunately, in most field sites and for many materials, information on the presence, abundance, and distribution of *Phytophthora* contamination will be unknown. If information is lacking, the safest default position is to assume that *Phytophthora* contamination is present and follow appropriate BMPs. However, in instances where it is not feasible or efficient to treat all sites and materials as infested, it is possible to use other observable factors to rate the relative risk of *Phytophthora* contamination.

Phytophthora infestations are found in some local areas, but soil-borne *Phytophthora* species are not generally distributed or ubiquitous in most locations. *Phytophthora* distribution is typically non-uniform because these pathogens are normally associated with host roots. Highly infested areas can exist in close proximity with areas with no detectable inoculum, depending on whether host roots are present or not and whether the pathogen has had time to spread to its potential limits at a site.

The ability of a site to act as a source of *Phytophthora* contamination is related to how *Phytophthora* is distributed across the site, and the density, type, and activity of the inoculum present within infested areas (Table 1-2). Considering these and additional factors that influence disease development, we can categorize the likelihood that a site may be contaminated based on site characteristics (Table 1-3). In general, past (e.g., previous plantings or land uses) or ongoing (e.g., via foot or vehicle entry) activities that can result in *Phytophthora* introductions increase the likelihood that a site will be contaminated.

Most developed areas should be considered potential sources of *Phytophthora*. This is due to the widespread use of nursery-grown landscape plants in urban and suburban areas. Conventionally-

produced ornamental nursery stock is commonly infected with a variety of *Phytophthora* species, making nursery stock one the most common *Phytophthora* reservoirs and an efficient vehicle for spread of these pathogens. Because of the wide variety of *Phytophthora* species circulating in nurseries, areas planted with conventional nursery stock may also have a relatively high diversity of *Phytophthora* species present. Agricultural lands are also considered potential sources of *Phytophthora*, though the risk and *Phytophthora* species present will vary with cropping history and other factors.

Finally, materials that are transported from a contaminated source can have varying amounts of *Phytophthora* inoculum. For most *Phytophthora* species, contamination is primarily associated with host material. For root-infecting *Phytophthora* species, the host roots and associated soil have the highest levels of inoculum. Deep subsoils with very few or no roots are unlikely to have substantial amounts of *Phytophthora* unless they are contaminated by mixing with infested surface soils. Leaves and branches are not commonly infected by root-infecting *Phytophthora* species unless they are exposed to spores in water (e.g., branches overhanging or in contact with streams or ponds or subject to splash from infested soil). Leaves and branches can be sources of inoculum for species such as *P. ramorum* that affect aerial plant parts.

Root rot symptoms in vegetation

Root-rotting *Phytophthora* species commonly destroy fine roots that are important for water uptake. As a result, chronic water stress symptoms are often the first detectable symptoms of *Phytophthora* root rot in dry, nonirrigated sites, though such symptoms can also be related to factors other than *Phytophthora*. *Phytophthora* root rot symptoms commonly develop first in the growing points and higher in the plants, such as tops of trees. Mild symptoms including low vigor and stunting of entire plants or plant parts such as leaves. More severe symptoms include canopy thinning and dieback, chlorosis (yellowing) or reddening of foliage, marginal burn of leaves or dieback of leaf or needle tips, and premature or excessive leaf drop. In many species, especially various trees, symptoms such as thinning and dieback may start high in the canopy. In other species, especially drought tolerant species or those with evergreen leaves, older leaves may be shed prematurely, leading to an overall thin canopy. Dieback is commonly slow and progressive. However, under periods of high water demand, leaves may wilt and die quickly, and dead leaves may remain attached to the affected plants. Some *Phytophthora* species can cause bleeding cankers at the base of the trunk or main stems, similar to *P. ramorum* cankers seen in oaks affected by sudden oak death. In irrigated or moist sites, many chronic symptoms may be less severe or absent because the additional soil moisture offsets water stress associated with plant root loss due to disease. However, during periods of high water demand, the few remaining functional roots may be unable to supply enough water to meet the demand, leading to sudden death and rapid wilting and browning of most or all of the foliage.

Table 1-2. Factors that influence the likelihood that a site will serve as a source of *Phytophthora* contamination and risk ratings of materials as sources of *Phytophthora* contamination.

	Risk:		
Factor	**Low likelihood as source**	**Intermediate**	**High likelihood as source**
Inoculum density	very low	low to moderate	high
Pathogen distribution	one to a few localized areas	multiple limited infested areas	widespread, large areas
Survival structures present (oospores, chlamydospores, etc)	few or none		many
Pathogen activity level in source material	inactive		active
Materials			
Roots and debris	soil, no roots or infected debris	soil with roots or debris	conventionally-produced nursery stock
Soil	uncontaminated subsoils	surface soils from low risk areas	surface soils from developed, agricultural, or disturbed wet areas,
Water	potable water, subsurface water from large reservoirs	surface waters from edges of reservoirs, especially near stream inlets	water from runoff, creeks, streams, and ponds in potentially contaminated areas
Branches and leaves	branches and leaves more than 1 m above ground, not hosts of aerial species such as *P. ramorum*		branches and leaves in contact with soil or surface waters or infected with aerial species such as *P. ramorum*

Table 1-3. Site factors related to the risk of *Phytophthora* contamination.

	Risk:		
Factor	**Low likelihood**	**Intermediate**	**High likelihood**
Current vegetation	dry uplands with only annual grasses and forbs	woody hosts as scattered individuals or patches in grasslands or sparse vegetation	contiguous woody vegetation with dense, interwoven roots
Soil moisture regime	very well drained	subject to at least periodic saturation	commonly wet due to heavy irrigation, poor drainage, etc.
Vegetation symptoms	all species growing vigorously		one or more species showing decline typical of root diseases
Land use history	no history of developed uses, including planting, road building, grading, soil import	older history includes planting stock or other possible introduction with soil or plant material	recent or current uses known or likely to involve contaminated plant material, e.g., from landscape plantings
Presence of habitat restoration plantings not conducted according to recent *Phytophthora* BMPs	no nursery stock, no grading, minimal disturbance other than direct seeding	no nursery stock but significant soil grading or import of soil or mulch	planted with nursery stock, soil import or other soil-embedded materials (e.g., rootwads, fence posts) from possible contaminated sites
Current access to site	remote areas without trail /road access	low to moderate road/trail use, not directly accessed from potentially contaminated sites	high use unsurfaced trails or roads near landscaped, agricultural, or other likely contaminated areas
Urban development	hardscape only (no landscaping) or turf only, no other landscaping		urban landscaping with woody perennials
Agricultural uses	small grains, grass hay only		orchards

1.3.2. Transport of *Phytophthora*

The second step in the contamination risk model is movement of material that contains *Phytophthora* inoculum as spores or mycelium. The likelihood of a successful *Phytophthora* invasion increases with the number of viable spores that are introduced into the habitat. Several factors contribute to the movement of many viable spores, including the total volume of contaminated material that is moved and the density of *Phytophthora* propagules in this material (Table 1-4). Large volumes of infested material can be moved in single events, such as soil or mulch import, or in many smaller deliveries, such as soil adhered to hikers' shoes at a heavily-used trailhead. In Table 1-5, the general factors in Table 1-4 are translated into more specific factors and situations. In general, wet conditions tend to increase movement of soil and debris and also provide better conditions for *Phytophthora* survival and infectivity, so the risk of effective transport is much higher under wet than dry conditions.

Table 1-4. General factors that affect the likelihood that *Phytophthora* will be transported effectively via infected or infested material.

Factor	Low transport risk	Intermediate	High transport risk
Volume of infested or infected material	very low	low to moderate	high
Inoculum density in material	very low	low to moderate	high
Frequency of transport events	none or rare	periodic, repeated	frequent
Speed of transfer from source	long delayed (months to years)*		rapid (days to weeks)

*delay is most likely to reduce inoculum levels of short-lived propagules (such as zoospores); delay may also reduce levels of more resistant spores if the storage conditions are highly unfavorable (e.g., very hot)

Table 1-5. Specific factors related to the likelihood that *Phytophthora* will be transported effectively via infected or infested material.

Factor	Low transport risk	Intermediate	High transport risk
Conditions at time of transfer	dry, hot		moist, moderate temperature
Methods of transfer	shoes or small tires along unsurfaced road/trail with spotty or light soil moisture	surface soil on digging tools, in carts/wheelbarrows	surface soil import and grading with large equipment
	clean livestock moved in dry season		muddy livestock moved in wet season
Water movement	no water flow, drainage, or water transport from potentially-contaminated areas	infrequent flow or water transport (e.g., via wet equipment) from potentially-contaminated areas	seasonal or perennial water flow from potentially-contaminated areas
Total volume of contaminated material	small - up to a few hundred ml*		large – more than a few liters
	low-use trail sections far from potentially-contaminated areas	heavily used trail sections far from potentially contaminated areas	high use trails, trailheads, parking areas adjacent to contaminated areas

*Note: small amounts of inoculum can be high risk if delivered directly to rootzones of susceptible plants under conditions that favor infection

1.3.3. Delivery of *Phytophthora* to a receptive target

After *Phytophthora* inoculum is picked up from a contaminated source and transported effectively, it still needs to be delivered to a receptive site to initiate an infestation. Site receptivity is related to the host, environment, and time dimensions of the plant disease triangle model (Tables 1-1, 1-6). The likelihood that a root-infecting *Phytophthora* will become established at a site is greater if viable inoculum is introduced into the rootzone of susceptible plants. This can occur by mixing inoculum into soil (e.g., through grading). Inoculum deposited on the soil surface can also enter the rootzone via soil cracks or be washed into the rootzone by water. Under saturated conditions, *Phytophthora* species produce motile zoospores that actively seek and infect host roots. The movement of zoospores in soil pores is relatively limited, so inoculum needs to be placed close to existing roots, or where water will transport zoospores into the rootzone.

Site receptivity can vary seasonally. In general, receptivity increases in the wet season and decreases in the dry season. Wet conditions and free water provide more opportunities for inoculum to be washed into the rootzone and for infection to occur. Moist conditions also favor inoculum survival. Factors that decrease the viability of inoculum, such as prolonged dry periods, high temperatures, or the presence of antagonistic microbes, reduce the likelihood that inoculum will successfully infect host roots, and therefore decrease site receptivity (Table 1-6).

Table 1-6. General factors related to the likelihood that *Phytophthora* will be become established at a site where it has been introduced (site receptivity).

Factor	Low receptivity	Intermediate	High receptivity
Density of host roots	very low	low to moderate	high
Susceptibility of host	low	moderate	high
Soil moisture after transfer	dry for extended period	moist or with intermittent light rain	moist to wet, with periods of saturation
Environmental conditions after transfer	dry, hot for extended period	cool and intermittently moist	moist to wet, moderate temperatures
Suppressive microbiota in soil	present and abundant	variable in density by location	absent
Site where contamination is introduced	exposed, dry soil surface	onto shaded soil surface or into much or duff layer	incorporated into soil or introduced into water

Table 1-7 presents some specific factors and situations that influence site receptivity. Native vegetation land cover types currently considered to be at highest risk for *Phytophthora* invasion are those dominated by woody plants. Root density generally increases with increasing plant cover and density. However, root density and connectivity between root systems are often highly variable and can be difficult to assess. Riparian and wetland vegetation also has a high risk of being invaded by exotic *Phytophthora* species, many of which can persist and reproduce over much of the year on roots, leaves, and other substrates that are inundated or moist. Soil conditions that favor periodic saturation may vary across fine scales that may not show up on maps and may only be evident during wet weather.

Table 1-7. Specific factors related to the likelihood that *Phytophthora* will become established at a site (site receptivity) after introduction.

Factor	Low receptivity	Intermediate	High receptivity
Plant associations	upland annual grasslands	open savannah with annual understory	hardwood forest
	upland low density annual forbs	sparse shrubland	dense chaparral
		sparse tree/shrub mixtures	dense chaparral/forest mix
			dense scrub
		drainages that rarely have surface water flow	perennial or seasonal wetland and riparian
Host susceptibility and predisposition	relatively resistant hosts, no significant predisposing stresses		highly susceptible hosts, due to genetics or predisposing stresses
Cover of susceptible vegetation	low, scattered	moderate, at least some patches disconnected	complete or nearly complete cover
Uniformity of susceptible vegetation	susceptible species scattered, high diversity including multiple resistant or nonhost species	patchy distribution of susceptible species with gaps lacking hosts	stands of single susceptible species or of a few similarly susceptible species
Edaphic factors	high soil organic matter		low soil organic matter or fertility
Location where contamination is delivered	soil surface well away from host rootzone	soil surface in host rootzone	Incorporated or washed into rootzone
Soil moisture level	dry – well below field capacity		moist (near field capacity) to saturated
Soil moisture regime	very well drained, rarely if ever saturated	subject to at least periodic saturation	frequently saturated to constantly wet (e.g., stream edge)
Season	dry		wet

1.3.4. Implications of the risk model

The various factors described above contribute to the overall risk that a given activity may result in the introduction of *Phytophthora*. These factors interact in a multiplicative rather than additive fashion. This relationship can be illustrated in a simple mathematical model:

INTRODUCTION RISK = INOCULUM DENSITY × SOURCE VOLUME × SITE RECEPTIVITY

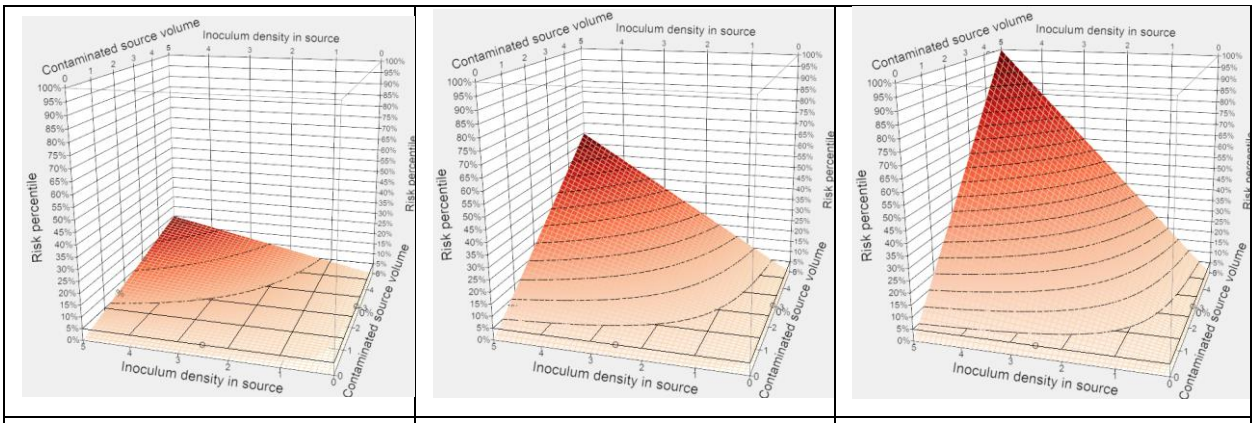
The factors in this model are related to each step in the risk model shown in Figure 1:

1. **Inoculum density of the source**: overall source risk increases with the density of *Phytophthora* inoculum in the source material. Because the actual inoculum density is normally unknown, the likelihood that a source is contaminated (Table 1-3) is used to estimate this factor.
2. **Volume of contaminated source material transported:** the total number of *Phytophthora* propagules transported increases in larger volumes of contaminated material.
3. **Target site receptivity:** as site receptivity increases, smaller amounts of inoculum are needed to initiate an infestation.

This simple model can be used to help rate the relative risk of various activities. If any of the factors is truly zero (no source inoculum, no material transported, or site completely unreceptive), the risk of *Phytophthora* introduction is also zero. **To minimize the overall risk of introduction, it is sufficient to reduce any one of these factors to zero.** For example, if there is no inoculum in the source material, transporting any volume of it to a susceptible site will not result in an introduction.

When all three factors are nonzero, risk is minimized by reducing the risk associated with one or more factors as much as possible. The factors that can be altered will vary with the activity involved. For example, import of fill involves a large volume of material by definition. Assuming that the target site contains susceptible vegetation, the only ways to minimize risk are by (1) ensuring that the source material is as pathogen-free as possible, i.e., reducing inoculum density, and (2) applying the material at a time that would be least favorable for pathogen establishment (e.g., beginning of the dry season), i.e., minimizing site receptivity. Within a site, risks associated with work activities are mainly reduced by not bringing in *Phytophthora* inoculum (e.g., starting with clean tools and equipment) and minimizing movement of potentially contaminated materials within a site (e.g., by working under dry conditions, or by working from areas with low contamination potential toward areas more likely to be contaminated).

Figure 1-2 compares INTRODUCTION RISK for three different levels of SITE RECEPTIVITY. It shows that for a given combination of INOCULUM DENSITY and SOURCE VOLUME, INTRODUCTION RISK increases as SITE RECEPTIVITY increases. If none of the three risk factors can be reduced to zero, maintaining two or all three factors close to minimum levels can keep the overall risk of introduction low. An acceptably low level of risk (represented as the flat gridded area to the outside of the 5% risk contour) is easier to achieve if site receptivity is low. Note that with low receptivity, a wide variety of combined INOCULUM DENSITY and SOURCE VOLUME levels will be below the 5% cutoff of the risk slope (Figure 1-2A). In contrast, in highly receptive sites, the floor area below the 5% cutoff of the risk slope is quite limited (Figure 1-2C). For instance, if source material has high INOCULUM DENSITY, the SOURCE VOLUME will need to be very low to keep overall risk low. Hence, highly receptive sites require the most stringent adherence to BMP avoidance measures.



A. SITE RECEPTIVITY: low - slightly receptive (e.g. dry, upland, widely separated woody hosts)	B. SITE RECEPTIVITY: moderate - moderately receptive (e.g. moist soil, seeps, moderate number trees/shrubs)	C. SITE RECEPTIVITY: high - highly receptive (e.g. riparian area, wet soil conditions, dense woody vegetation)

Figure 1-2. Risk of introducing *Phytophthora* from a source location to sites with low (left), moderate (center), and high (right) levels of site receptivity. Overall risk increases as inoculum density, contamination volume, and site receptivity increase. In the figures, the acceptable level of introduction risk is set to less than 5% (lowest contour line).

1.4. APPLYING THE RISK MODEL TO WORK ACTIVITIES

Introducing or spreading invasive plant pathogens such as *Phytophthora* can be an unintended consequence of various work activities. However, relatively minor changes to working practices can often greatly reduce the risk of this unwanted outcome. Deciding which practices are necessary or useful at a given site will require a basic analysis to identify the risks involved. The goal is to minimize risks while still allowing work crews to perform their work in a timely manner with a minimum of additional effort.

1.4.1. Step 1: Identify areas within the job site that have a high risk of *Phytophthora* contamination.

To minimize risk of spreading *Phytophthora* contamination while still allowing normal construction and maintenance activities to proceed, it is preferable to reserve the most stringent precautionary measures for areas where they are most needed. As illustrated in Figures 1-1 and 1-2, the greatest risk of spreading *Phytophthora* involves moving infested soil and materials from contaminated sites to non-contaminated sites. Checklist 1-1 below can be used to assess the likelihood that a site is contaminated with *Phytophthora*. Sites that do not have any of the risk factors noted in Checklist 1-1 have a low likelihood of being contaminated.

Not all sites that are currently free of *Phytophthora* contamination are equally likely to become contaminated. If some areas of a site are potentially contaminated and others are not based on checklist 1-1, use checklist 1-2 to rate the receptivity of the non-contaminated areas (i.e., likelihood that these sites may become contaminated).

In larger job sites, areas may differ widely with respect to *Phytophthora*-related risks. Risk of spreading contamination can be reduced by starting work in lowest risk areas and proceeding toward higher risk areas. To the degree possible, large job sites should be divided into smaller subsites that are appropriate for the scale of scheduled work activities. Cleaning and decontamination should be conducted when

moving between these subsites. Decontamination is simplified by starting in the least contaminated areas and progressing toward more contaminated areas.

Small work sites may not have separate areas that differ with respect to contamination potential or receptivity. In such sites, risks are minimized largely by avoiding unnecessary movement of soil, roots, and materials contaminated with either soil or roots.

1.4.2. Step 2. Select and implement risk-minimizing work practices based on activities and conditions.

Step 1 focuses on the first and last steps of the process illustrated in Figure 1-1. Step 2 focuses on the middle step, the transport of contamination from a source to a new site.

Many work activities can involve a variety of separate components. Each of these components has its own associated risk or range of risks depending on how they are implemented (Table 1-8). Risks associated with these activity components are related to:

- The amount of contaminated material (typically soil, roots, or materials contaminated with these) that can be moved by each activity. This generally increases as amount of soil disturbance increases. In general, the risk of moving contamination greatly increases under wet conditions compared to dry conditions.
- The likelihood that contamination could be delivered to rootzones of host plants. Plant rootzones of susceptible hosts are considered to be highly receptive sites. Activities that occur close to existing plants typically have a higher likelihood of delivering contamination to the rootzone than activities in non-vegetated areas.

Table 1-8 shows the risk of introducing and/or spreading *Phytophthora* that is associated with common work activities. These are the risks posed if BMPs are not followed. These ratings assume that (1) imported materials (tread, hardware, timbers, etc.) are clean and (2) some source(s) of contamination are present in the jobsite. Table 1-8 can be used to evaluate which components of an activity are associated with the greatest risk of spreading contamination. Most of the risk is associated with moving significant amounts of soil, especially excavated soil that may contain roots. Risk can be reduced most effectively by applying BMPs that prevent or minimize transfer of contamination from high risk sites to highly receptive sites. If contamination is moved directly into the receptive sites, such as rootzones of susceptible vegetation or into waterways, contamination risk can be high even if the total amount of contaminated material moved is small.

Table 1-8. Risks of spreading *Phytophthora* contamination associated with various components of work activities under dry and wet site conditions. Risks are rated in 5 overall classes from very low (VL) through moderate (M) to very high (VH). Risk ranges (e.g., M-H) are given for activities that may be associated with a range of risks depending on specific conditions.

	Site conditions	
	Dry	**Wet**
Risk-generating components	Risk rating VL - VH	
shoes, clothes	VL-L	L-M
small vehicles and equipment	M-H	M-VH
large vehicles and equipment	M-VH	H-VH
tools	VL-M	L-H
cut brush and wood	VL-L	M-H
excavated / graded soil	L-H	M-VH
Removed materials or items that have been in contact with or embedded in soil	M-H	M-VH
imported reused materials (timbers, forms, etc)	M-H	M-VH
imported clean fill, tread, or other earth material	VL	VL-L
imported clean hardware, etc. (timbers, fabric)	VL	VL-L

1.4.3. High *Phytophthora* contamination likelihood - quick assessment

This checklist can be used to assess whether any part(s) of a job site are likely to be contaminated or infested with soil-borne *Phytophthora*. For any area identified as having a high likelihood of contamination, additional special condition BMPs for infested sites will apply. In addition, special attention should be paid to BMPs pertaining to direction of work flow and avoiding spread of contamination from these areas.

Checklist 1-1. Quick assessment for high likelihood of *Phytophthora* contamination. Check all risk factors that apply for specific areas. A check in any category indicates a high likelihood of contamination, multiple checks indicate a greater likelihood. For areas that have a high likelihood of *Phytophthora* contamination, follow additional BMPs that are listed for infested sites in Sections 2 (Trails), 3 (Construction), and 4 (Soil Import) in addition to the standard BMPs. This checklist is formatted for up to 4 areas. Use additional copies as needed for additional areas.

	Area 1	**Area 2**	**Area 3**	**Area 4**
Short description of area: Enter additional details about each area in the table below the checklist				
Contamination risk factor				
1. Within or directly adjacent to known infested areas (contact Natural Resources staff for known locations)				
2. Areas landscaped with conventionally - produced (non-BMP) nursery stock including:				
a. urban landscaped areas				
b. landscaped parking areas				
c. plantings around buildings				
d. agricultural or forestry plantings of nursery-grown trees or shrubs				
e. older (pre-2016) habitat restoration plantings that used nursery stock				
3. At least seasonally wet from:				
a. storm runoff, especially from areas noted under 1 and 2 above				
b. perennial or seasonal watercourses, especially those flowing through areas noted under 1 and 2 above				
c. ponds, especially in areas used by livestock				
4. At least some of the woody or semi-woody vegetation at site showing decline and/or mortality				
5. High-traffic, unsurfaced trails directly adjacent to sites matching 1, 2, 3, or 4 above and with woody or semi-woody vegetation present at moderate or high density.				

Area	Location/description
1	
2	
3	
4	

1.4.4. High *Phytophthora* receptivity likelihood - quick assessment

This checklist can be used to assess whether any part of a job site has a high likelihood of becoming infested with soil-borne *Phytophthora*, i.e., is highly receptive to introduced contamination. Conduct this assessment for areas that have a low risk of being already contaminated or infested with soil-borne *Phytophthora* based on checklist 1-1. For areas identified as being highly receptive, additional special condition BMPs for sensitive sites will apply. Special attention should also be paid to BMPs pertaining to direction of work flow and avoiding spread of contamination into these highly receptive areas.

Checklist 1-2. Quick assessment for high *Phytophthora* receptivity. Check all risk factors that apply for specific areas. A check in any category indicates potentially high receptivity, multiple checks indicate greater receptivity, follow the additional sensitive site BMPs listed in Sections 2 (Trails), 3 (Construction), and 4 (Soil Import) in addition to the standard BMPs. This checklist is formatted for up to 4 areas. Use additional copies as needed for additional areas.

	Area 1	Area 2	Area 3	Area 4
Short description of area: Enter additional details about each area in the table below the checklist				
Receptivity risk factor				
1. Stand(s) of woody and semi-woody perennial vegetation present in area				
a. continuous stand(s) with overlapping root systems				
b. known highly susceptible species* present				
c. one or more known highly susceptible species* common to dominant				
2. Perennial or seasonal wetland and riparian areas with woody or nonwoody perennial vegetation (e.g. rushes, sedges)				
3. Low fertility or otherwise poor soils (e.g., serpentine, calcareous, thin)				
a. As above, but with areas of poor surface or subsurface drainage, including hardpans or other impermeable strata				
4. Introduced contamination would be incorporated (e.g., by excavation) or washed into plant rootzones (within 1.5 X canopy radius) or deposited on the soil surface under plant canopies				
5. Contamination would be introduced into moist or wet soil				

Area	Location/description
1	
2	
3	
4	

***** The degree to which most California native plants are susceptible to the many species of *Phytophthora* is mostly unknown. Some common families/genera with known susceptible hosts include Asteraceae (*Artemisia, Baccharis*), Ericaceae (*Arbutus, Arctostaphylos, Rhododendron, Vaccinium*), Fabaceae (*Lupinus*), Fagaceae (*Chrysolepis, Notholithocarpus, Quercus*), Lamiaceae (*Salvia*), Lauraceae (*Umbellularia*), Phrymaceae/Scrophulariaceae (*Diplacus*), Rhamnaceae (*Ceanothus, Frangula*), Rosaceae (*Heteromeles*). Many conifers are also susceptible to various *Phytophthora* species.

SECTION 2. TRAIL WORK ACTIVITIES

Trail work can spread *Phytophthora. Phytophthora cactorum* was baited from this freshly-constructed earth waterbar on a park trail in Contra Costa County.

CONTENTS

2.1. INTRODUCTION

Virtually all practices for preventing *Phytophthora* introduction and spread are based on preventing the following:

- movement of contaminated materials into a work site;
- spread of contaminated materials within a site; and
- movement of contaminated materials to other sites.

These objectives are largely addressed by following a set of best management practices (BMPs) for minimizing spread of *Phytophthora* and other soil-borne agents. The BMPs below are applicable to the trail work activities listed in Table 2-1 below. Note that:

- BMP Sections T1 through T4 apply to every type of work activity.
- BMP Section T5 applies to the use of structural materials and imported fill or tread materials, and therefore applies to trail work activities E through I in Table 2-1.
- BMP Section T6 addresses the use of clean water. It applies to the use of water for dust abatement or wetting of soil or tread material for compaction. It may not apply if soils are moist and additional water is not required. It is unlikely to apply to trail work activities A, B, or H in Table T2-1.

Many of the BMPs are common-sense practices involving basic levels of cleanliness and sanitation that can minimize the spread of soil-borne *Phytophthora*, as well as soil insects and weeds. Because *Phytophthora* contamination is not visible, BMPs are followed to minimize the movement of soil into, out of, and within work areas to minimize the likelihood of spreading contamination. Furthermore, each *Phytophthora* species poses a unique set of threats to native vegetation. Even in areas that may be infested with one or more *Phytophthora* species, introducing additional *Phytophthora* species can further degrade the site and complicate management. Hence, BMPs to prevent additional introductions of *Phytophthora* species apply even in sites that may be infested.

Some additional or modified BMPs apply to situations where risks are elevated because of site characteristics. These are essentially more stringent versions of certain BMPs. The more stringent versions are needed to mitigate higher risks and are noted under the **special conditions** headings in the tables below. These special conditions include the following situations:

1. **sensitive sites**: sites with especially sensitive plant resources, including special status plant species (including rare, threatened, or endangered); highly susceptible species such as manzanita (*Arctostaphylos*), Pacific madrone (*Arbutus menziesii*), and *Ceanothus* species; and remote stands that may have multiple host species but are far from likely sources of contamination.
2. **infested sites**: sites where plants are known or suspected to be infected by one or more species of *Phytophthora*. Likely infested sites include areas planted with woody plant nursery stock that was not produced under current nursery BMPs to prevent *Phytophthora* contamination.

Checklists 1-1 and 1-2 (Sections 1.4.3 and 1.4.4) can be used to assess the likelihood of *Phytophthora* contamination and *Phytophthora* receptivity of different parts of the work site to determine whether the corresponding more stringent BMPs (infested and sensitive site BMPs, respectively) apply.

2.1.1. Overall risks associated with trail work activities

Table 2-1 below shows risk ratings associated with various trail work activities under dry and wet soil conditions. Risk ratings for these activities are mostly influenced by the degree to which significant amounts of soil are moved away from the point of origin and deposited along other portions of the trail or into vegetated areas beyond the trail. Most ratings are shown as ranges because risk varies with details of the site and working conditions. Risks associated with all activities increase when working under wet

conditions because more incidental soil movement occurs when soil is wet; site receptivity is also increased under wet conditions.

Table 2-1. Risk of introducing and spreading *Phytophthora* contamination associated with trail work activities under dry and wet site conditions. Risk ratings assume some potential sources of *Phytophthora* contamination are present in areas involved in work activities. Risks are rated in 5 overall classes from very low (VL) through moderate (M) to very high (VH). Risk ranges (e.g., M-H) are given for activities that may be associated with a range of risks depending on specific conditions.

	Site conditions	
Activity	**Dry**	**Wet**
A. Brush cutting along trail edges with loppers, hand saws	VL	L-H
B. Brush cutting along trail edges with power brush cutters	L	M-H
C. Cleaning drainages	L-M	M-VH
D. Removing berms along trail edges	L-M	M
E. Importing clean material to restore tread	L	M
F. Installing new trails	M	H-VH
G. Decommissioning old trails	M	H-VH
H. Repair and replace fence posts on existing trails	L-M	M-H
I. Repair and replace water bars or staircases on existing trails	M	M-H

Understanding the overall risk of introducing or spreading *Phytophthora* through various trail work activities is the key to selecting appropriate practices to reduce or eliminate these risks. This is accomplished by first

- **planning to conduct activities in a way that minimizes *Phytophthora* risks**, and then
- **following the appropriate BMPs to mitigate risks that cannot be entirely avoided.**

The trail work BMPs are based on the following general strategies for minimizing risks of introducing or spreading *Phytophthora.*

1. **Minimize risk-generating activities** – KEEP HIGH RISK ACTIVITIES TO THE MINIMUM needed to accomplish the task, including minimizing the area of disturbance and amount of soil and roots moved.
2. **Segment operations spatially across the site** – separate projects into smaller activity areas where possible to minimize long range spread or spread from infested areas to noninfested areas. This may include directional controls (working from noninfested toward infested areas).
3. **Phase operations over time across site** – separate project activities over time to minimize spread from infested areas to noninfested areas or avoid working in high-risk areas under wet conditions.
4. **Use clean or sanitized materials** – ensure that materials used in construction activities, including earth materials, mulches, erosion control materials, and coarse woody debris are free of contamination.
5. **Decontaminate more frequently** – more frequent cleaning and sanitizing of tools and equipment may be needed where risks cannot be otherwise reduced. Note that some cleaning and decontamination is normally needed in conjunction with the above strategies.

When planning trail work, use Checklist 2-1 below to determine if planned activities are associated with a high *Phytophthora* introduction risk and how the activity can be modified to avoid or minimize these risks. After risks have been avoided to the degree possible though planning (e.g., timed to avoid wet soil

conditions), following all other applicable trail work BMPs will minimize or effectively eliminate remaining risks.

Even though the amounts of contamination moved via trail work may be small compared to heavy construction activities, trail work activities can transport *Phytophthora* inoculum directly into the rootzones of host plants, which is a high-risk situation. *Phytophthora* introduction risks increase where trail work activities span between more-developed areas that are more likely to be infested and areas that are relatively undisturbed. Activities that involve soil excavation and grading have the greatest potential to spread contamination, especially when they involve surface soils with roots of woody or perennial plants that may be *Phytophthora* hosts. By recognizing risks and planning appropriately, it may be possible to **adjust the timing or direction of work activities**, and thereby minimize movement of potentially-contaminated soil or materials.

Checklist 2-1. Factors that increase the risk of introducing and spreading *Phytophthora* through trail work activities and mitigations to reduce or eliminate these risks. Use this checklist when planning trail work activity to minimize risks to the degree possible before starting work.

Risk factor	No	Yes→	If yes: mitigations to reduce risk rating
Is the soil wet enough to stick to footwear, tools, and equipment in part or all of the site?			If possible, delay or reschedule until at least surface soil dries out. Segment or phase operations to minimize movement of soil, roots, and plant debris by working in drier areas first.
Are you planning to import potentially-contaminated materials to the site?			Use clean or sanitized materials.
Is at least part of site likely to be contaminated or infested with *Phytophthora*?			Avoid or minimize soil-disturbance activities in contaminated or infested areas. Segment or phase operations to minimize movement of soil, roots, and plant debris from contaminated or infested areas.
Does the project area connect between potentially contaminated or infested areas and noninfested areas?			Segment or phase operations to minimize connectivity, e.g., complete work in noninfested area first or use different personnel in infested and noninfested areas.
Will soil, roots, or other potentially contaminated materials be moved?			Minimize one or both of the following: - the **distance** that roots and soil are moved low risk: 6 ft or less; high risk: 30 ft or more - the **volume** of soil that is moved low risk: up to a cup or two; high risk: multiple shovels full or more These factors interact, so that if one factor is minimized, the overall risk is minimized (e.g., the risk of moving a large soil volume is negated if the distance is minimal). Conversely, risk is intensified as both volume and distance increase. Phase or direct movement to minimize spread of contamination toward noncontaminated areas Decontaminate more frequently to minimize incidental movement.
Will root disturbance, excavation, or grading occur within rootzones of potential host roots? Use 1.5X canopy spread to estimate the extent of the rootzone for this evaluation.			Avoid or minimize activities within host root zones if possible: low risk: 6-15 ft or more from rootzone, excavation disturbs no more than a few small (<⅛ inch diameter) woody roots high risk: under plant canopy, high root density; excavation disturbs many small roots, few to many larger roots Minimize the overall footprint of the disturbed area to what is needed. Segment or phase operations to avoid movement of soil, roots, and plant debris into host root zones.

2.2. TRAIL WORK BMPS

T1. Worker training and preparation

BMPs	Notes
T1.1. Before entering the job site, field workers shall receive training that includes information on *Phytophthora* diseases and how to prevent the spread of these and other soilborne pathogens by following approved phytosanitary procedures. Such training shall have been conducted within the previous 12 months.	
T1.2. Workers shall receive instruction and training on any site-specific phytosanitary practices before work commences.	Where applicable, instruction shall include information on the phasing and direction of work activities between higher- and lower-risk areas.
T1.3. Workers should be provided with equipment and supplies (e.g., brushes, spray bottles with alcohol) needed to clean and sanitize shoes, hands, or equipment as needed in the course of the specified work.	Supervisors should ensure that all workers have received instructions and training on the use of these supplies before the start of work at the job site.
T1.4. Mark boundaries of known *Phytophthora*-infested areas before work begins. Provide signage and/or other instructions indicating how work crews are to operate in the infested areas.	Marking of infested areas will be conducted by natural resources staff or other designated personnel.

T2. Cleaning and sanitation required before entering a job site.

Phytophthora contamination can be present in a variety of sites and materials, including commercial nursery stock, landscaped and agricultural areas, and some infested native or restored habitat areas. Contamination can be spread via soil, plant material and debris, and water from infested areas**. Arriving at the site with clean vehicles, equipment, tools, footwear, and clothing helps prevent unintentional contamination of the job site from outside sources.** The objective in cleaning and sanitation is to prevent the transfer of potentially contaminated soil, roots, plant debris, or water to the job site.

All cleaning activities in this section should be carried out away from the job site, preferably in a facility that allows for capture and proper disposal of debris and contaminated water, such as a commercial vehicle washing facility or a wash-down pad.

T2.1. Footwear and clothing

BMPs	Notes
T2.1.1. Soles and uppers of footwear must be free of debris and soil before arriving at the job site. Clean and sanitize footwear as described in Section 5.	
T2.1.2. At the start of work at each new job site, worker clothing shall be free of all mud, soil, and debris. If clothing is not freshly laundered, all debris and adhered soil should be removed by brushing with a stiff brush.	
Special conditions: sensitive sites	
T2.2.3. For work that involves handling plant material or working in soil in the rootzones of susceptible host plants, clothes and gloves should be clean (laundered or sanitized) at the start of each work day.	

T2.2. Vehicles, equipment, and tools

BMPs	Notes
T2.2.1. Equipment and vehicles should be free of soil and debris on tires, wheel wells, vehicle undercarriages, and other surfaces before traveling to the work site. Use a high-pressure washer, compressed air, brushes, or other means to ensure that soil and debris are completely removed.	See Section 5.2 for specifications on cleaning and sanitizing.
T2.1.2. The interior of equipment (cabs, etc.) must be free of mud, soil, plant parts, and organic debris. Interior floors, mats, and seats should be cleaned to remove potentially contaminated material.	See Section 5.2 for specifications on cleaning and sanitizing.
T2.1.3. Staff will inspect all vehicles and equipment prior to their entry into the Park for EMs and invasive species. Staff will inspect vehicles before they move from one project area to another.	See Section 5.2 for specifications on cleaning and sanitizing.
T2.1.4. Hand tools, shovels, picks, compactors, and other small equipment must be clean and free of soil and debris.	See Section 5.2. for details on cleaning tools and small equipment. Does not apply to tools used only in connection with asphalt or concrete.
Special conditions: infested sites, sensitive sites	
T2.1.5. If equipment, vehicles, or tools have been used at a known infested site or will be used at a designated sensitive site, exterior cleaning should include the use of a detergent solution (such as dishwashing liquid, e.g. Palmolive®, Dawn®, Joy®, etc.) or cleaning of contaminated parts should be followed with treatment by a sanitizing agent. Washed / sanitized equipment should be allowed to dry before being used at a new site.	

T3. Minimize incidental movement of soil and plant material within and beyond the job site.

Movement of soil that could be contaminated with *Phytophthora* is incidental to various trail work activities. In other words, soil movement is not needed to conduct the activity, but may occur as a side effect. Examples include cutting brush away from trails and replacing fence posts. For these activities, risks are minimized by avoiding work activities that disturb or move soil and leaving soil and associated debris in place when removing items that have been in contact with soil.

Thorough cleaning and sanitizing cleaned surfaces may be required to minimize risks before moving from infested sites or into sensitive sites. The objective in cleaning and sanitation is to prevent the transfer of potentially contaminated soil, roots, plant debris, or water to the job site. Cleaning should emphasize aggregations of soil and debris that could fall off or be knocked off when moving from a potentially contaminated work area to an area that is less likely to be contaminated.

BMPs	Notes
T3.1. If possible, avoid vehicle traffic and field work when soil at the job site is wet enough to stick readily to shoes, tools, equipment, and tires.	Working under wet conditions increases the potential for spreading potentially-contaminated soil and time required to clean vehicles, equipment, tools, gloves, and shoes.

T3.2. Vehicles

BMPs	Notes
T3.2.1 Do not bring more vehicles into the job site than necessary and keep vehicles on surfaced or graveled roads whenever possible to minimize potential for soil movement.	
T3.2.2. Do not drive off established roads unless absolutely necessary	
T3.2.3. If it is necessary to travel unsurfaced roads or off road, avoid doing so when soil or road surfaces are wet enough that soil will stick to vehicle tires and undercarriages.	Even during rainy periods, one to a few days of dry weather can allow the soil surface to dry and firm up substantially.

T3.3. Tools and materials

BMPs	Notes
T3.3.1. Do not drag tools and materials on the soil surface in a way that can move and distribute soil and associated debris.	Because risk of incidental soil and debris transport is increased under wet conditions, dragging of tools and materials should be entirely avoided under wet conditions.
T3.3.2. For tools not intended for soil use (e.g. saws, pruners, brush trimmers), avoid tool contact with soil, especially when soil is wet. Clean tools by brushing off soil and debris. Sanitize cleaned tools by rinsing with isopropyl alcohol.	Cleaning/sanitizing cutting tools frequently can minimize risk of spreading stem-infecting pathogens. See Section S5.2 for more details about cleaning and sanitizing.
Special conditions: infested sites, sensitive sites	
T3.3.3. Clean and sanitize tools contaminated with soil or roots before moving across gaps or moving more than 15-30 ft.	More frequent decontamination is needed to mitigate these elevated risk situations. When working under dry soil conditions, the effort needed to periodically decontaminate tools is minimal.

T3.4. Building materials or other items removed from site

BMPs	Notes
T3.4.1. When removing items that have been in contact with the soil (posts, water bars, stair treads, pipes, etc.), adhering soil and roots should be brushed off and left as close to the point of origin as possible.	Avoid spreading excavated soil and roots beyond their area of origin.
T3.4.2. Transport materials being removed on/in tarps or other containment.	Some residual soil and debris may remain on removed materials. Prevent soil and associated debris from being distributed along the route during transport.
T3.4.3. Soil and debris collected in tarps, etc., should be disposed of following guidelines for earth materials contaminated with invasive species (typically Class II designated landfill waste)	Check the Earth Material Management (EMM) SOPs (GGNRA, NPS 2015a) for disposal guidelines and any other applicable standards.
Special conditions: infested sites	
T3.4.4. Adhering soil and roots should be brushed off and left within 6 ft of origin (adds to T3.4.1.)	Keep excavated soil and roots within 6 ft of point of origin to mitigate elevated risk situation.

T3.5. Cut / removed vegetation

BMPs	Notes
T3.5.1. Cast vegetation should not be moved along trail corridors or away from the area where it was growing.	Consistent with Trail Construction & Maintenance Guidelines (GGNRA, NPS 2015b).
T3.5.2. If cast vegetation must be moved from its site of origin, avoid contact with soil, especially under wet conditions. Carry or load directly onto vehicle, trailer, etc., for transport.	Risks of incidental soil movement on cut vegetation are greatly reduced under dry conditions.
Special conditions: infested sites	
T3.5.3. Soil-contaminated vegetation and excavated roots should be left within 6 ft of origin (adds to T3.5.1.)	Keep near point of origin to mitigate risks associated with these contaminated materials.
T3.5.4. If 3.5.3 above is not feasible, remove soil-contaminated vegetation and excavated roots for off-site disposal. Ensure all soil and associated debris is contained, preferably in bins or on tarps and is not spilled during transport (adds to T3.5.1, T3.5.3).	Prevent soil and associated debris from being distributed along the route during transport.

T4. Avoid large-scale movement of soil and debris from known or potentially-infested areas to noninfested areas within and beyond job site.

In contrast to incidental soil movement covered under Section 3 above, purposeful movement of soil is an integral component of many trail work activities. Examples include installing or decommissioning trails, removing trail edge berms, and cleaning drainages. These activities typically involve moving larger amounts of soil and therefore have a higher risk of introducing or spreading *Phytophthora* in the soil. For these activities, risks are minimized by keeping soil that is moved as close to its source as possible. If soil must be moved, the direction of movement should be from clean (noninfested) areas toward areas that are more likely to be infested and not the reverse in sites where these differences are identified (Checklists 1 and 2, Section 1.4.3 and 1.4.4). Also, because *Phytophthora* inoculum naturally moves more readily downslope, potentially infested soil should not be moved upslope appreciable distances or moved laterally far enough to allow contamination to spread into different watersheds or sub-watersheds.

T4.1. Work planning and flow

BMPs	Notes
T4.1.1. Phase work to minimize movement of contamination by working from clean areas toward known or potentially-infested areas, not the reverse direction. Where possible, start work in areas less likely to be infested and work toward areas that are more likely to be infested.	Check with natural resources for delineated areas or guidance in completing Checklists 1-1 and 1-2 (Section 1.4.3 and 1.4.4).
T4.1.2. Where feasible, work directionally from upslope to downslope along a given length of trail.	*Phytophthora* naturally spreads more readily downslope with flowing water. Risk of spread by trail work is increased if soil is moved uphill.
T4.1.3. Where feasible, work directionally from more remote areas back toward trailheads, developed areas, and other higher-risk sites.	In the absence of other risk factors (Section 1.4.3, Checklist 1-1) remote areas along trails or away from existing trails and roads are less likely to be infested or contaminated with *Phytophthora* than roadsides, trailheads, parking areas, and developed areas.
T4.1.4. If possible, restrict personnel to working in a single contamination potential zone (high or low) at a time to minimize travel between zones and reduce the need for decontamination.	Avoid situations in which personnel or equipment are repeatedly crossing between infested and noninfested areas.

T4.2. Clean and sanitize within the job site and before leaving the job site

BMPs	Notes
Cleaning	
T4.2.1. Do not move soil or debris further than is needed to accomplish the task. Clean off excess soil or plant debris on an ongoing basis whenever excess material is being moved unnecessarily.	Dislodge loose soil and organic debris in place whenever possible before moving to a new spot to avoid unnecessary carryover of soil to more distant areas.
T4.2.2. Cleaning is generally adequate when moving to different areas along a trail with relatively uniform risk of contamination, particularly when working under dry soil conditions.	Clean means free of soil, mud, and organic debris (see Definitions in Section 5.1). Cleaning should emphasize parts of equipment, tools, or vehicles that may shed debris or soil particles when used. See Section 5.2 for cleaning specifications.
T4.2.3. Under dry working conditions, cleaning can typically be accomplished by brushing, wiping, sweeping, blowing with compressed air, etc.	Thin deposits of dry dust on materials have a low risk of transferring contamination.
T4.2.4. Under wet conditions, dislodge moist soil or mud to degree possible and apply additional water while brushing to remove adhered material. Finish with a rinse of clean water.	Cleaning is much more difficult and time consuming when working with sticky, wet soils.
T4.2.5. Conduct cleaning as close as possible to the source of the material. Do not deposit soil, roots, or rinse water around potential host plants beyond where the material originated. If soil and roots have been moved from their source area, collect potentially-contaminated material using tarps or containers for later offsite disposal (landfill).	Clean frequently in high contamination risk areas to minimize soil movement or the need to collect and dispose of contaminated material.
Sanitizing	
T4.2.6. Sanitize tools, equipment, and footwear when moving from areas of higher to lower contamination risk including: - before moving into sensitive (high receptivity) areas; - when moving out of known or suspected infested areas; - when moving from downslope to upslope areas; - when moving from developed or heavily used areas to remote areas; - when moving from wetlands and watercourses to uplands.	Sanitizing includes cleaning, followed by an approved sanitizing agent, such as 70% isopropyl alcohol. See Section 5.2.2 for complete sanitizing specifications.
T4.2.7. Gloves should be sanitized or exchanged for clean gloves when moving to new work areas when there is a risk that contamination will be moved.	See Section 5.2.2 for sanitizing specifications
T4.2.8. Sanitize tools, equipment, and footwear when leaving the job site to move to new work areas or when exiting the job site.	Items that stay in place at the job site for later reuse there do not need to be sanitized except in situations described in T4.2.6.
Special conditions: infested sites, sensitive sites	
T4.2.9. Clean and sanitize tools contaminated with soil or roots before moving across gaps in vegetation or moving distances of more than 15-30 ft.	See Section 5.2.2 for sanitizing specifications.

T4.3. Soil-moving activities

BMPs	Notes
T4.3.1. **Excess soil**: If approved for onsite spreading, all cast soil should be kept on the same side of the trail from which it originated from and as close as possible to the source location.	Consistent with Trail Construction & Maintenance Guidelines (GGNRA, NPS 2015b).
T4.3.2. **Trail berm soil**: When removing trail edge berms, keep removed soil as close as possible to the source location.	
T4.3.3. **Removed rocks**: If approved for onsite spreading, rocks, and other removed trail obstacles should be left as close as possible to point of origin.	
T4.3.4. **On-site fill soil**: If approved for use, on-site soil used for fill should be sourced as close as possible to the site of use. Do not move fill soil from areas that are more likely to be contaminated, uphill from the source, or between watersheds or sub-watersheds.	Source on-site fill soils as close to the site of use as possible. Moved soils should have very low risk of contamination if moved substantial distances. See Soil Import and Management BMPs (Section 4) for more information.
Special conditions: infested sites	
T4.3.5. **Excess soil, trail berm soil, removed rocks**: Keep within 6 ft of origin on same side of trail from which it originated (adds to T4.3.1, T4.3.2, T4.3.3).	Keep near point of origin to mitigate risks associated with these contaminated materials.
T4.3.6. If 4.3.5 above is not feasible, remove for off-site disposal. Ensure all soil and associated debris is contained, preferably in bins or on tarps and is not spilled during transport (adds to T4.3.1, T4.3.2, T4.3.3).	Prevent soil and associated debris from being distributed along the route during transport.
T4.3.7. **Trail berm soil**: Do not move likely contaminated soil with host roots from berms into trail. Dispose of as noted under T4.3.5. and T4.3.6 and use clean material to restore trail tread. .	Risk of moving contamination that may be spread by trail users is greatest if infected host roots from berms are placed in the trail.
T4.3.9. **On-site fill soil**: Use clean fill whenever possible. Do not move potentially-contaminated soil more than 6 ft from point of origin (adds to T4.3.4).	Clean soil should be sourced and handled according to Soil Import and Management BMPs (Section 4). Clean fill has low contamination potential until mixed with site soil, at which time the contamination potential is related to the potential contamination of the site soil.

T4.4. Maintaining appropriate moisture for grading and compaction

BMPs	Notes
T4.4.1. Water used for dust control or other construction purposes shall be from clean sources or treated.	See T6 for clean water BMPs.
T4.4.2. Where possible, schedule grading activities and other earth work when soil moisture is near the optimum range to minimize the need for added water.	
T4.4.3. Adjust the amount of water applied and time between wetting and equipment use as appropriate for soil and site conditions to minimize amount of soil or tread material that adheres to tools and equipment.	Wetting soil or earth materials for compaction or grading increases risk of spreading contamination if wet soil adheres to equipment and tools.
T4.4.4. Avoid excessive water application that results in runoff or puddling.	

BMPs	Notes
Special conditions: infested sites	
T4.4.5. Brush or rinse adhered soil and debris from equipment and tools as needed to minimize movement from point of origin (adds to T4.4.3).	Keep contaminated soil or tread as close to near point of origin as feasible.

T5. Use clean materials

A variety of materials may be installed during trail work. To prevent risks associated with *Phytophthora,* and other invasive species, all materials need to be protected from contamination during storage and transport. Many materials, including dimensional lumber, pressure-treated wood products, and metal hardware, are free from *Phytophthora* because of their composition or the way they are sourced or produced. Protecting these materials from contamination maintains their no-risk status. If these same materials have been in service and are removed for reuse, they can pose a risk if they have become contaminated with soil or debris that contains *Phytophthora*, so additional practices are needed to mitigate this risk. Other materials, including earth materials (EM), mulches, coarse woody debris, and straw wattles, may or may not be free of *Phytophthora* or other exotic agents of concern, depending on their source. These materials should either come from sources that are free of *Phytophthora* or should be treated (e.g., with heat – see Section 5) in a way that will eliminate viable *Phytophthora* or other agents of concern.

T5.1. New materials

BMPs	Notes
T5.1.1. Use only approved clean earth materials (EM), mulches, erosion control materials, etc.	Clean means sanitized, heat-treated, or free of contamination due to manufacturing conditions or sourcing, and maintained in a way to prevent subsequent contamination.
T5.1.2. Load new clean materials directly into thoroughly cleaned vehicles, carts, trailers, etc., and unload directly at point of use onto clean, dry surfaces. Do not place materials on the ground, especially under wet conditions.	
T5.1.3. Store new materials to be used at a job site on carts, platforms, or clean tarps. Do not place stockpiles in places they will be exposed to runoff. Cover and install perimeter protections if inclement weather is likely. Cover if inactive for at least 14 days.	Minimize time between material delivery and subsequent installation. See GGNRA EMM SOPs (GGNRA, NPS 2015a) and Soil Import BMPs (Section 4) for more details on constructing stockpiles. Requirement for covering after 14 days is from the GGNRA EMM SOP.
T5.1.4. Clean and sanitize tarps, bins, etc., before using at another site.	
T5.1.5. **Spreading clean fill or tread material**: To the degree possible, distribute clean fill/tread along length of repaired section in amount needed. Spread and grade side to side across trail rather than extended distances along trail.	Objective is to minimize movement of fill or tread once it becomes contaminated with site soil.
Special conditions: sensitive sites	
T5.1.6. Any hardware or lumber that becomes contaminated with soil shall be cleaned to remove soil and plant debris and then sanitized before being brought to the job site (adds to T5.1.3)	Sanitizing reduces contamination risk to a greater degree, which is appropriate for sensitive sites.
Special conditions: infested sites	
T5.1.7. Do not move or redistribute clean fill/tread that has been mixed with site soil beyond immediate area of soil contact (adds to T5.1.5).	Once clean fill or tread is mixed with contaminated soil, further movement of the material can spread contamination.

T5.2. Reused materials

Note: Trail Construction & Maintenance Guidelines (GGNRA, NPS 2015b) and GGNRA EMM SOPs (GGNRA, NPS 2015a) encourage reuse and recycling of used materials where possible.

BMPs	Notes
Reused materials - general	
T5.2.1. All used hardware and materials being transported for immediate reuse or stockpiling should be handled to minimize the spread of soil and debris from the removal site. Remove loose adhering soil and debris and leave it where the materials originated (e.g., fence post hole) if materials will be moved more than 6 ft from the site of origin.	
T5.2.2. Load and unload materials to be reused directly into sanitized vehicles, carts, trailers, etc. Clean and sanitize vehicles, carts, trailers, etc., before using at another site.	Staging materials on the ground before or after transport provides an opportunity for depositing or picking up contaminated soil or debris.
Materials reused directly on-site in the same contamination potential zone	
T5.2.3. Keep reused materials as close to site of origin as possible.	
Special conditions: infested sites	
T5.2.4. On-site reuse of materials with soil contamination is not allowed at distances more than 6 ft from the site of the original use (adds to T5.2.3).	
Materials reused directly on-site in a different contamination potential zone	
T5.2.5. Materials reused on-site may only be moved from cleaner zone (low contamination potential) to a more contaminated zone (higher contamination potential).	Check with natural resources for delineated areas or guidance in completing Checklists 1 and 2 (Section 1.4.3 and 1.4.4).
T5.2.6. Clean, or clean and sanitize, materials before reuse as specified by Natural Resource staff based on site specifics.	
Special conditions: infested sites	
T5.2.7. Do not reuse materials from an infested area in a clean / noninfested area (adds to T5.2.5).	

BMPs	Notes
Materials reused from a location outside the job site.	
T5.2.8 Re-used materials (timbers, fence posts, etc.) from nearby areas with similar *Phytophthora* risk profiles may be installed with Natural Resource staff approval. Reused hardware shall be thoroughly cleaned to be free of soil and plant debris before being brought to the job site. Washed materials shall be allowed to dry before being transported to the job site.	The degree of contamination with soil, other invasive species, and other contamination factors are considered before approving reuse.
T5.2.9. Previously used materials (timbers, fence posts, etc.) that have been stockpiled must be completely cleaned of soil and plant debris. If required by Natural Resource staff based on site specifics, reused materials may need to be sanitized or subjected to heat treatment (e.g., steaming, solarization) sufficient to kill pathogens and other agents of concern (e.g., invasive plant propagules) in soil and debris that is adhered to or embedded in the material.	Nonporous, readily cleaned items taken from low risk areas may be reused after cleaning. Porous materials such as wood may require additional sanitizing treatment, especially if they were removed from higher risk sites. Heat treatment is described in Section 5.3.
Special conditions: sensitive sites	
T5.2.10. If possible, use only clean, new materials, especially for porous materials such as wood, in sensitive sites. Use of any reused materials must be approved by Natural Resource staff (adds to T5.2.9).	

T6. Use clean water

Water may be used in trail work to control dust, adjust earth materials to proper moisture for compaction, and other purposes. Surface waters, including untreated water from streams or ponds and runoff, are known sources of *Phytophthora* contamination. Only uncontaminated water or water that has been effectively treated (Section 5) to remove or kill *Phytophthora* should be used for trail work purposes.

BMPs	Notes
T6.1. Water used for dust control or other construction purposes shall be from treated municipal water supplies or wells. Tertiary-treated municipal recycled water is acceptable for pathogen BMPs, check with Natural Resources for suitability regarding other chemical properties.	
T6.2. If well water is used, wellheads shall be protected from contamination by surface water sources.	
T6.3. Untreated surface waters shall not be used. If it is necessary to use surface waters, treat water to eliminate *Phytophthora* propagules. Treatment may be via lethal heating or by chlorination if approved by Natural Resource staff.	See Section 5.2 for specifications on cleaning and sanitizing. See Section 5.3 for specifications on heat treatment.
T6.4. Water shall be transferred through clean intact pipes or hoses with appropriate backflow prevention devices. Tanks or other vessels used for transporting water shall be clean and sanitized before use.	
T6.5. Vessels, tanks, pipes, hoses, pumps and other items use to store or transfer untreated surface waters or other potentially contaminated water must be sanitized before being used for clean water.	Where possible, use dedicated clean equipment for water storage and transport to avoid the need for decontamination.

SECTION 3. CONSTRUCTION ACTIVITIES

Large amounts of *Phytophthora*-contaminated soil can be moved unintentionally on construction equipment. This piece of equipment was in use at a Sonoma County location where *Phytophthora cambivora* was causing manzanita mortality in multiple sites near graded earth roads and test trenches.

CONTENTS

3.1. INTRODUCTION

Virtually all practices for preventing *Phytophthora* introduction and spread are based on preventing the following:

- movement of contaminated materials into a work site;
- spread of contaminated materials within a site; and
- movement of contaminated materials to other sites.

These objectives are largely addressed by following a set of best management practices (BMPs) for minimizing spread of *Phytophthora* and other soil-borne agents. The BMPs below are applicable to the construction activities listed in Table 3-1 below.

Many of the BMPs are common-sense practices involving basic levels of cleanliness and sanitation that can minimize the spread of soil-borne *Phytophthora*, as well as soil insects, and weeds. Because *Phytophthora* contamination is not visible, BMPs are followed to minimize the movement of soil into, out of, and within work areas to minimize the likelihood of spreading contamination. Furthermore, each *Phytophthora* species poses a unique set of threats to native vegetation. Even in areas that may be infested with one or more *Phytophthora* species, introducing additional *Phytophthora* species can further degrade the site and complicate management. Hence, BMPs to prevent additional introductions of *Phytophthora* species apply even in sites that may be infested.

Some additional or modified BMPs apply to situations where risks are elevated because of site characteristics. These are essentially more stringent versions of certain BMPs. The more stringent versions are needed to mitigate higher risks and are noted under the **special conditions** headings in the tables below. These special conditions include the following situations:

3. **sensitive sites**: sites with especially sensitive plant resources, including special status plant species (including rare, threatened, or endangered); highly susceptible species such as manzanita (*Arctostaphylos*), Pacific madrone (*Arbutus menziesii*), and *Ceanothus* species; and remote stands that may have multiple host species but are far from likely sources of contamination.
4. **infested sites**: sites where plants are known or suspected to be infected by one or more species of *Phytophthora*. Likely infested sites include developed areas planted with nursery stock that was not produced under current nursery BMPs to prevent *Phytophthora* contamination.

Checklists 1-1 and 1-2 (Section 1.4.3 and 1.4.4) can be used to assess the likelihood of *Phytophthora* contamination and *Phytophthora* receptivity of different parts of the work site to determine whether the corresponding more stringent BMPs (infested and sensitive site BMPs, respectively) apply.

3.1.1. Overall risks associated with construction activities

Table 3-1 below shows risk ratings associated with various construction activities under dry and wet soil conditions. Risk ratings for these activities are mostly influenced by the degree to which significant amounts of soil are moved away from the point of origin and deposited in other areas, especially near *Phytophthora*-susceptible vegetation. Most ratings are shown as ranges because risk varies with details of the site and working conditions. Risks associated with all activities increase when working under wet conditions because more incidental soil movement occurs when soil is wet and site receptivity increases under wet conditions.

Table 3-1. Risks of introducing and spreading *Phytophthora* contamination associated with construction activities under dry and wet site conditions. Risk ratings assume some potential sources of *Phytophthora* contamination are present in areas involved in work activities. Risks are rated in 5 overall classes from very low (VL) through moderate (M) to very high (VH). Risk ranges (e.g., M-H) are given for activities that may be associated with a range of risks depending on specific conditions, including footprint of work area.

	Site conditions	
Activity	**Dry**	**Wet**
J. Grading – surface soil	M-VH	H-VH
K. Grading – imported clean soil and subsurface soil	L-M	M-H
L. Decompaction – surface soil	M-VH	H-VH
M. Soil trenching and deep excavation	L-H	M-VH
N. Hydrological recontouring of drainages/creek beds	H-VH	VH
O. Installation of large woody debris into streams/creeks	M-H	H-VH
P. Culvert removal or replacement	M	M-H
Q. Erosion stabilization; repair of rills, gullies, or channelization	M-H	H-VH
R. Tree removal or vegetation clearing	L-H	M-VH
S. Non-designated trail removal	M-H	H-VH
T. Demolition of asphalt or concrete roads/structures	L-M	M-H
U. Building concrete structures such as overlooks or plazas	L-M	M

Understanding the overall risk of introducing or spreading *Phytophthora* through various construction activities is the key to selecting appropriate practices to reduce or eliminate these risks. This is accomplished by first

- **planning to conduct activities in a way that minimizes *Phytophthora* risks**, and then
- **following the appropriate BMPs to mitigate risks that cannot be entirely avoided.**

The construction BMPs are based on the following general strategies for minimizing risks of introducing or spreading *Phytophthora.*

6. **Minimize risk-generating activities** – KEEP HIGH RISK ACTIVITIES TO THE MINIMUM needed to accomplish the task, including minimizing the area of disturbance and amount of soil and roots moved.
7. **Segment operations spatially across the site** – separate projects into smaller activity areas where possible to minimize long range spread or spread from infested areas to noninfested areas. This may include directional controls (working from noninfested toward infested areas).
8. **Phase operations over time across site** – separate project activities over time to minimize spread from infested areas to noninfested areas or avoid working in high-risk areas under wet conditions.
9. **Use clean or sanitized materials** – ensure that materials used in construction activities, including earth materials, mulches, erosion control materials, and coarse woody debris are free of contamination.
10. **Decontaminate more frequently** – more frequent cleaning and sanitizing of tools and equipment may be needed where risks cannot be otherwise reduced. Note that some cleaning and decontamination is normally needed in conjunction with the above strategies.

When planning construction activities, use Checklist 2-1 below to determine if planned activities are associated with a high *Phytophthora* introduction risk and how the activity can be modified to avoid or

minimize these risks. After risks have been avoided to the degree possible though planning (e.g., timed to avoid wet soil conditions), following all other applicable construction BMPs will minimize or effectively eliminate remaining risks.

Phytophthora introduction risks associated with construction increase as the overall footprint of the construction-impacted area increases. Hence, risks can be reduced by minimizing the area disturbed by construction activities. The amount of contamination moved via construction activities can be large, which increases the risk of spreading *Phytophthora* if it is present. However, even activities that move smaller amounts of soil can be high risk if they transport *Phytophthora* inoculum directly into the rootzones of host plants. *Phytophthora* introduction risks also increase where construction activities span between more-developed areas that are more likely to be infested and areas that are more remote or undeveloped. Activities that involve soil excavation and grading have the greatest potential to spread contamination, especially when they involve surface soils with roots of woody or perennial plants that may be *Phytophthora* hosts. By recognizing risks and planning appropriately, it may be possible to **adjust the timing or direction of work activities**, and thereby minimize movement of potentially-contaminated soil or materials to other portions of the work area. Advance planning can be used to locate ingress and egress points, parking, and turn-around areas where they pose minimum risk.

Checklist 3-1. Factors that increase the risk of introducing and spreading *Phytophthora* through construction activities and mitigations to reduce or eliminate these risks. Use this checklist when planning construction activities to minimize risks to the degree possible before starting work.

Risk factor	No	Yes→	If yes: mitigations to reduce risk rating
Is the soil wet enough to stick to footwear, tools, and equipment in part or all of the site?			If possible, delay or reschedule until at least surface soil dries out. Segment or phase operations to minimize movement of soil, roots, and plant debris by working in drier areas first.
Are you planning to import potentially-contaminated materials to the site?			Use clean or sanitized materials.
Is at least part of site likely to be contaminated or infested with *Phytophthora*?			Avoid or minimize soil-disturbance activities in contaminated or infested areas. Segment or phase operations to minimize movement of soil, roots, and plant debris from contaminated or infested areas.
Does the project area connect between potentially contaminated or infested areas and noninfested areas?			Segment or phase operations to minimize connectivity, e.g., complete work in noninfested area first or use different personnel and equipment in infested and noninfested areas.
Will soil, roots, or other potentially contaminated materials be moved?			Minimize one or both of the following: - the **distance** that roots and soil are moved - the **volume** of soil that is moved These factors interact, so that if one factor is minimized, the overall risk is minimized (e.g., the risk of moving a large soil volume is negated if the distance is minimal). Conversely, risk is intensified as both volume and distance increase. Phase or direct movement to minimize spread of contamination toward noncontaminated areas Decontaminate more frequently to minimize incidental movement.
Does grading or other soil movement involve surface soils (upper 2 ft of soil profile)?			Minimize the distance that surface soils are moved. Use low risk subsoils (more than 2 ft below the surface in areas without deep woody roots) where possible instead of surface soil. Segment or phase operations to minimize mixing of higher-risk surface soil with lower-risk subsoil. Decontaminate more frequently when moving between different areas.
Will root disturbance, excavation, or grading occur within rootzones of potential host roots? Use 1.5X canopy spread to estimate the extent of the rootzone for this evaluation.			Avoid or minimize activities within host root zones if possible: low risk: 6-15 ft or more from rootzone, excavation disturbs no more than a few small (<⅛ inch diameter) woody roots high risk: under plant canopy, high root density; excavation disturbs many small roots, few to many larger roots Minimize the overall footprint of the disturbed area to what is needed. Segment or phase operations to avoid movement of soil, roots, and plant debris into host root zones.

3.2. CONSTRUCTION BMPS

C1. Worker training and preparation

BMPs	Notes
C1.1. Before entering the job site, workers shall receive instruction and training as needed on applicable general and site-specific phytosanitary practices before work commences.	Where applicable, instruction shall include information on the phasing and direction of work activities between higher- and lower-risk areas.
C1.2. Copies of all applicable *Phytophthora* BMPs shall be made available at the jobsite for reference.	Copies may be available in hard copy or digital form readable on electronic devices in use at the job site.
C1.3. Workers should be provided with equipment and supplies (e.g., brushes, spray bottles with alcohol, air compressors, power washers) needed to clean and sanitize shoes, hands, or equipment as needed in the course of the specified work.	Supervisors should ensure that all workers have received instructions and training on the use of these supplies before the start of work at the job site.
C1.4. Mark boundaries of known *Phytophthora*-infested areas before work begins. Provide signage and/or other instructions indicating how work crews are to operate in the infested areas.	Marking of infested areas will be conducted by Natural Resources staff or other designated personnel.

C2. Cleaning and sanitation required before entering a job site.

Phytophthora contamination can be present in a variety of sites and materials, including commercial nursery stock, landscaped and agricultural areas, and some infested native or restored habitat areas. Contamination can be spread via soil, plant material and debris, and water from infested areas. Arriving at the site with clean vehicles, equipment, tools, footwear, and clothing helps prevent unintentional contamination of the job site from outside sources.

The objective in cleaning and sanitation is to prevent the transfer of potentially contaminated soil, roots, plant debris, or water to the job site. Cleaning should emphasize aggregations of soil and debris that could fall off or be knocked off at the job site. Thorough cleaning and sanitizing of cleaned surfaces is required to minimize risks when moving from contaminated sites or into sensitive sites.

All cleaning activities in this section should be carried out away from the job site, preferably in a facility that allows for capture and proper disposal of debris and contaminated water, such as a commercial vehicle washing facility. Off-site cleaning applies before initial entry to a job site or before subsequent re-entry if the items or equipment have become contaminated with soil or plant debris while away from the job site (e.g., by driving off pavement in wet conditions).

C2.1. Footwear and clothing

BMPs	Notes
C2.1.1. Soles and uppers of footwear must be free of debris and soil before arriving at the job site.	Procedures for cleaning and sanitizing footwear are described in Section 5.2.
C2.1.2. At the start of work at each new job site, worker clothing shall be free of all mud, soil, and detritus. If clothing is not freshly laundered, all debris and adhered soil should be removed by brushing with a stiff brush.	
Special conditions: sensitive sites	
C2.1.3. For work that involves handling plant material or digging or moving soil within the rootzones of plants, workers' clothes and gloves should be clean (laundered or sanitized) at the start of each work day.	

C2.2. Vehicles, equipment, and tools

BMPs	Notes
C2.2.1. Equipment and vehicles shall be free of soil and debris accumulations on tires, wheel wells, vehicle undercarriages, and other surfaces before traveling to the work site. Use a high-pressure washer, compressed air, brushes, or other means to ensure that soil and debris are completely removed.	See Section 5.2 for further information on cleaning and sanitizing.
C2.2.2. No soil or plant debris from the interior of vehicles or equipment (cabs, etc.) shall be deposited at the work site. If drivers/operators will be entering or exiting vehicles at the job site, the cab must be free of mud, soil, plant parts, and organic debris before arriving at the job site. Interior floors, floor mats, and seats must be free of potentially contaminated material.	See Section 5.2 for further information on cleaning and sanitizing
C2.2.3. Staff will inspect all vehicles and equipment prior to their entry into the Park for EMs and invasive species. Staff will inspect vehicles before they move from one project area to another.	See Section 5.2 for further information on cleaning and sanitizing
C2.2.4. Hand tools, shovels, picks, compactors, and other small equipment must be clean and free of soil and plant debris before entering the job site.	See Section 5.2. for details on cleaning tools and small equipment. Does not apply to tools used only in connection with asphalt, and concrete.
C2.2.5. Other items that have been in contact with soil elsewhere (e.g., barricades, traffic cones, temporary fencing, concrete forms, water tanks, portable toilets, etc.) must be completely cleaned of soil and plant debris before being delivered to the job site. Washed items should be allowed to dry before being delivered to the job site.	See Section 5.2. for cleaning/sanitizing specifications. Cleaning (Section 5.2.1) is suitable for nonporous, readily cleaned items used in non-sensitive areas or kept on paved surfaces. Porous materials such as wood may require additional sanitizing treatment (Section 5.2.2), as required by Natural Resource staff depending on the intended use and use location.
Special conditions: sensitive sites	
C2.2.6. If equipment, vehicles, or tools will be used at a designated sensitive site, thorough cleaning should be followed with a sanitizing treatment. These include treatment with a sanitizing agent (smaller tools and equipment) or pressure washing with a detergent solution or hot water (at least 180F) pressure-washing after cleaning (large equipment). Washed / sanitized equipment should be allowed to dry before being delivered to the job site.	See Section 5.2. for cleaning/sanitizing specifications. Always consult the owner's manual if in doubt as to tolerance of equipment or vehicles to heat treatment or sanitizing agents.

C3. Minimize risk-generating activities

Many construction projects involve activities that have a high potential to spread contamination, most commonly in disturbed or excavated surface soils that may be infested with *Phytophthora*. Although it may not be possibly to entirely avoid these activities, risk can be reduced by restricting these activities to the minimum needed to accomplish the task. In particular, the total area disturbed by construction activities (including stockpiling, vehicle traffic, and parking), soil grading/excavation, and associated root disturbance should be minimized to limit risks associated with these activities.

C3.1. Minimize the disturbed area footprint

BMPs	Notes
C3.1.1. Keep vehicles and equipment on established paved and gravel roads whenever possible, especially under wet conditions. Restrict travel and parking on unsurfaced roads and non-road areas to the minimum needed.	This is especially important under wet conditions. If operating in wet conditions, restrict parking and travel to paved or graveled areas where feasible.
C3.1.2. Minimize the number of vehicles at the job site to reduce the need for parking.	
C3.1.3. Where possible, maintain separation between soil-contaminated equipment that is actively working the site and equipment and vehicles that travel between work areas or off site	
C3.1.4. Minimize the number of entry/exit points, particularly for equipment that may be contaminated with soil. Select entry / exit points to minimize movement of soil out of project boundaries.	
C3.1.5. Where appropriate, use different entry/exit points for clean vehicles and equipment and those contaminated with soil.	Especially under wet conditions, using separate entrances can reduce soil contamination of vehicles not directly involved in soil grading.
C3.1.6. If operating under wet soil conditions in areas with high likelihood of contamination, use wash-down pads or racks at points where equipment and vehicles exit contaminated areas.	See Section 5.2 for general specifications for onsite wash-down areas.
C3.1.7. Avoid stockpiling materials on site where feasible by delivering materials directly to the site of installation/use or keeping materials in or on trailers or vehicles until needed.	Stockpiling at the job site can increase the total disturbance footprint and can increase the likelihood of contaminating stockpiled materials with soil. See also C6.
C3.1.8. Use signage, temporary fencing, gates, and other access control methods to mark boundaries of the disturbed area, special protection areas, entrances and exits.	Signage and markings should clearly indicate where access is restricted and decontamination is required.
Special conditions: infested sites	
C3.1.9. Consider use of vehicles that are restricted to the infested area for shuttling deliveries of materials into that area, especially under wet soil conditions	Because delivery vehicles will need to be cleaned when leaving infested areas, especially under wet soil conditions, a dedicated offloading vehicle that stays in the infested area can reduce the need for frequent decontamination.

C3.2. Clean or disinfest building materials or other items before removing them from job site
Materials that are removed from a potentially infested site could spread contamination if soil and debris are shed along the transport route.

BMPs	Notes
C3.2.1. When removing items that have been in contact with the soil (pavement, pipes, hardware) remove loose adhering soil and roots as close to the point of origin as possible. Avoid spreading soil from removed items beyond the minimum necessary footprint.	Avoid spreading excavated soil and roots beyond their area of origin.
C3.2.2. Transport soil-contaminated waste in trucks that will not allow dispersal of soil and debris along the route. Vehicles shall not be overfilled to the point that spillage may occur. Vehicle beds and gates shall not have gaps that allow soil and debris to spill. Loads should be covered to prevent loss of materials.	Some residual soil and debris may remain on removed materials. Transport vehicles should have adequate containment to prevent soil and associated debris from being spilled during transport.
C3.2.3. Soil and debris collected in tarps, etc., should be disposed of following guidelines for earth materials contaminated with invasive species (typically Class II designated landfill waste)	Check the Earth Material Management (EMM) SOPs (GGNRA, NPS 2015a) for disposal guidelines and any other applicable standards.
Special conditions: infested sites	
C3.2.4. In areas of limited excavation, adhering soil and roots should be brushed off and left within 6 ft of origin when possible (adds to 3.2.1.)	This helps minimize spread of contamination associated with trenching or similar limited excavation. It does not apply in areas that are extensively graded.

C3.3. Cut / removed vegetation
Activities include tree removal, vegetation clearing, trail obliteration, and placement of woody debris in the landscape.

BMPs	Notes
C3.3.1. Cut vegetation used or left on site should be placed as close as possible to site of origin.	Consistent with Trail Guidelines BMPs.
C3.3.2. If cut or removed vegetation must be moved from its site of origin, avoid contact with soil, especially under wet conditions. Carry or load directly onto vehicle, trailer, etc., for transport. Avoid dragging or shedding soil beyond area of origin.	Risks of incidental soil movement on cut vegetation are much reduced under dry conditions.
C3.3.3. Use only aerial logs and cut brush that are free of soil contamination for trail obliteration or as sources of woody debris. Plant material should be sourced as close to site of planned use as possible.	Greatest risk associated with moving vegetation is associated with incidental soil movement.
Special conditions: infested sites	
C3.3.4. Soil-contaminated vegetation and excavated roots should be left within 6 ft from the location of origin (adds to 3.3.1.)	Keep near point of origin to mitigate risks associated with these contaminated materials.
C3.3.5. If 3.3.4 is not feasible, remove soil-contaminated vegetation and excavated roots for off-site disposal. Ensure all soil and associated debris is contained, preferably in bins or on tarps and is not spilled during transport (adds to 3.3.1, 3.3.3.)	Prevent soil and associated debris from being shed along the route during transport.

C3.4. Soil excavation and grading

Activities include grading, trenching, decompaction, recontouring, culvert replacement, repairing erosion, removing trails, demolition of structures, removal of pavement, and building concrete pads.

BMPs	Notes
C3.4.1. Excavated soil to be reused (e.g., for backfilling) should be kept as close as possible to point of excavation. Place surface soil, especially if it contains woody plant roots, closest to hole or trench, subsurface soil can be paced further away.	Usually, risk of contamination is greatest in surface soil, is lower for subsurface soils.
C3.4.2. Refill holes and trenches with soil from same area as excavation; use surface soil first so that any excess soil will be the deepest subsoil.	Usually, risk of contamination is greatest in surface soil, is lower for subsurface soils.
C3.4.3. If necessary to remove excess excavated soil from the job site, transport in trucks that will not shed soil and debris along route. Vehicles shall not be overfilled to the point that spillage may occur. Vehicle beds and gates shall not have gaps that allow soil and debris to spill. Loads should be covered to prevent loss of materials.	Same requirement as C3.2.2.
C3.4.4. When grading, minimize long-distance movement of surface soils, especially if it contains woody plant roots. If it is necessary to move or soil spread local soil widely, use subsoil without woody roots instead of surface soil where possible.	Usually, risk of contamination is greatest in surface soil, is lower for subsurface soils.
Special conditions: infested sites	
C3.4.5. Work from less-contaminated areas toward more-contaminated areas where feasible.	Direction to work will depend on jobsite topography and location of contamination.
C3.4.6. Do not move excavated soil and roots beyond the immediate area of origin; keep within 6 to 15 ft of origin on site, or see C3.4.7. (adds to 3.4.1.)	Keep near point of origin to mitigate risks associated with these contaminated materials.
C3.4.7. If 3.4.6 above is not feasible, remove excavated soil for off-site disposal. Ensure all soil and associated debris is contained and is not spilled during transport (adds to 3.4.1, 3.4.3.)	Prevent soil and associated debris from being shed along the route during transport.

C3.5. Maintain appropriate moisture for grading and compaction

BMPs	Notes
C3.5.1. Water used for dust control or other construction purposes shall be from clean sources or treated.	See C7 for clean water BMPs, see Section 5.2.5 for water treatment specifications.
C3.5.2. Where possible, schedule grading activities and other earth work when soil moisture is near the optimum range to minimize the need for added water.	
C3.5.3. Adjust the amount of water applied and time between wetting and equipment use as appropriate for soil conditions to minimize amount of wet soil that adheres to tools and equipment.	Wetting soil or earth materials for compaction or grading increases risk of spreading contamination if wet soil adheres to equipment and tools.
C3.5.4. Avoid excessive water application that results in runoff or puddling.	

C3.6. Manage water runoff

BMPs	Notes
C3.6.1. Manage sites to minimize water runoff from exposed soils that could transport contamination into noninfested areas.	*Phytophthora* contamination can be moved directly as spores in flowing water or indirectly with infested soil or plant debris transported in flowing water.
C3.6.2. Where runoff is anticipated, keep water that flows through potentially contaminated areas from being directed into noninfested areas, sensitive areas, or into different watersheds or subwatersheds	
C3.6.3. Direct water flow to prevent movement of contamination via water runoff onto roads.	Clean vehicles before they enter a noninfested site if they have traveled through potentially contaminated runoff.
C3.6.4. Manage roads to minimize puddles or standing water; avoid use of roads when flooded or use additional washdown/decontamination.	Clean vehicles before they enter a noninfested site if they have traveled through potentially contaminated runoff.

C4. Segment operations spatially and phase operations over time across the site

For projects that span between potentially contaminated and clean (noninfested) areas, organize work activities in time and space to minimize movement of soil from contaminated to clean areas. Also note that *Phytophthora* inoculum naturally moves more readily downslope with water flow. To minimize this mode of spread, avoid moving potentially-contaminated soil and roots substantial distances up slopes and avoid moving contamination along slopes into different watersheds or sub-watersheds.

C4.1. Work planning and designing project area

BMPs	Notes
C4.1.1. In the planning phase of the construction, identify areas with high likelihood of infestation and sensitive areas to be protected from contamination, and plan entry/ exit points, parking and staging areas, travel routes, and decontamination points to minimize movement of contamination into clean areas.	See Section 1.4.3 and 1.4.4, Checklists 1-1 and 1-2, to assess contamination potential and receptivity. Work with Natural Resources to identify these areas.
C4.1.2. Phase work to minimize movement of contamination by working from clean areas toward contaminated areas, not the reverse direction. Where possible, start work in areas with no or low contamination potential and work toward areas that are more likely to be contaminated.	Check with Natural Resources for delineated areas or guidance in completing Checklists 1-1 and 1-2 (Section 1.4.3 and 1.4.4).
C4.1.3. Where feasible, work directionally from more remote areas back toward developed areas, and other higher-risk sites.	In the absence of other risk factors (Section 1.4.3, Checklist 1-1) remote areas are less likely to be contaminated with *Phytophthora* than roadsides, trailheads, parking areas, and developed areas.
C4.1.4. Where feasible, work directionally from upslope to downslope, unless known contaminated areas are located at higher elevations of the project area.	Because *Phytophthora* naturally spreads more readily downslope, moving contaminated soil uphill can enhance pathogen spread. However, if known or suspected contaminated areas are upslope from the project area, work should proceed from clean downslope areas toward the upslope contaminated area (see C4.1.2).

BMPs	Notes
C4.1.5. If possible, restrict personnel and equipment to working in a single contamination potential zone (high or low) at a time to minimize travel between zones and reduce the need for decontamination.	This can be achieved through timing (see also C4.1.1.) or using different equipment in spatially separate sites. Avoiding crossover is especially important if working in areas where *Phytophthora* infestation has been identified.
C4.1.6. Minimize or avoid scheduling construction activities during the rainy season where possible or apply work restrictions when soil conditions are wet (see C.4.1.7).	Wet conditions increase risk of spreading *Phytophthora* contamination and increase time needed to decontaminate.
C4.1.7. If possible, avoid vehicle traffic and soil excavation/grading work when soil at the job site is wet enough to stick readily to shoes, tools, equipment, and tires.	Even during rainy periods, one to a few days of dry weather can allow the soil surface to dry sufficiently to reduce soil contamination of vehicles and equipment.

C5. Prevent spread of contamination from tools, equipment, and wearables when moving between contaminated and clean areas or removing them from the job site

BMPs	Notes
C5.1.1. Remove visible accumulations of soil and plant debris from tools, small and large equipment, fencing, barricades, gloves, clothes, and footwear before removing these items from the job site for use at other sites.	Applies to items moved to areas that differ in contamination risk potential. Items that stay in place at the job site for continued use there do not need to be cleaned until they leave unless other decontamination BMPs apply.
C5.1.2. If it is impractical to clean contaminated items on site, remove loose soil and debris and transport items offsite for cleaning before use elsewhere. Transport soil-contaminated items in a way that prevents dispersal of soil and debris along the route.	
C5.1.3. Under dry working conditions, cleaning can be accomplished by brushing, wiping, sweeping, blowing with compressed air, etc.	Thin deposits of dry dust on materials have a low risk of transferring contamination. See Section 5.2 for cleaning specifications.
C5.1.4. Under wet conditions, dislodge moist soil or mud to degree possible and rinse using a minimum of water with additional brushing to remove adhered material. Finish with a rinse of clean water.	Cleaning is much more difficult and time consuming when working with sticky wet soils. See Section 5.2 for cleaning specifications.
C5.1.5. Cleaning followed by sanitation should occur before moving from areas of higher to lower contamination risk. This includes: - before moving into sensitive (high receptivity) areas; - when moving out of known or suspected infested areas; - when moving from developed or heavily used areas to remote areas; - when moving from wetlands and watercourses to uplands.	See Section 5.2 for cleaning and sanitizing specifications.
C5.1.6. Gloves should be sanitized or exchanged for clean gloves when moving to new work areas when there is a risk that contamination will be moved.	See Section 5.2 for cleaning and sanitizing specifications.

Special conditions: infested sites	
C5.1.7. Cleaning followed by sanitation should occur before tools, equipment, footwear, etc., are used beyond the infested area. Vehicles should be washed before leaving the job site and treated by pressure washing with a detergent solution or hot water (at least 180 F) before being reused (large equipment). Washed / sanitized equipment should be allowed to dry before being used elsewhere. Wash contaminated clothing and gloves before they are used beyond the infested area.	See Section 5.2 for cleaning and sanitizing specifications. Always consult the owner's manual if in doubt as to tolerance of equipment or vehicles to heat treatment or sanitizing agents.

C6. Use clean materials

A variety of materials may be installed during construction. To minimize risks associated with *Phytophthora* and other invasive species, all materials need to be protected from contamination during storage and transport. Many materials, including dimensional lumber, pressure-treated wood products, and metal hardware, are free from *Phytophthora* because of their composition or the way they are sourced or produced. Protecting these materials from contamination maintains their no-risk status. If these same materials have been in service and are removed for reuse, they can pose a risk if they have become contaminated with infested soil or debris, so additional practices are needed to mitigate this risk. Other materials, including imported earth materials (EM), mulches, coarse woody debris, and straw wattles, may or may not be free of *Phytophthora* or other exotic agents of concern, depending on their source. These materials should either come from sources that are free of *Phytophthora* or be treated (e.g., with heat) in a way that will eliminate viable *Phytophthora* or other agents of concern.

C6.1. Use and handling of new materials

BMPs	**Notes**
C6.1.1. Use only approved clean earth materials (EM), mulches, erosion control materials, etc. that have a low risk of *Phytophthora* contamination.	See Soil Import BMPs (Section 4) for information on low risk soil materials.
C6.1.2. Load new clean materials directly into clean vehicles, carts, trailers, etc., and unload directly at point of use onto clean, dry surfaces whenever possible. Do not place materials directly on the ground except at site of use, especially under wet conditions.	See Soil Import BMPs (Section 4) for more details on handling of soil.
C6.1.3. Minimize time between material delivery at the job site and subsequent installation to avoid need for stockpiling and potential contamination.	Applies to sites where soil contamination is likely or difficult to prevent. May not apply to sites where materials can be staged on clean dry pavement. See BMP SI2 in Section 4 if soil stockpiling is necessary.
C6.1.4. Do not allow clean materials to become contaminated with soil or plant debris during storage and handling. Contaminated hardware should be cleaned and sanitized before use, especially in sensitive sites. Contaminated materials that cannot be sanitized may be rejected for use.	The advantages of using clean materials are lost if these materials become contaminated through storage and handling.
C6.1.5. When spreading clean fill, gravel, mulch, and other soil-applied materials, distribute material to target areas directly from vehicles or loaders to the degree possible to minimize the need for redistribution by grading over extended areas.	Objective is to minimize movement of soil-applied materials once they are mixed with potentially-contaminated site soil.
Special conditions: infested sites	
C6.1.6. Do not move or redistribute clean soil-applied materials that have been mixed with site soil beyond immediate area of soil contact (adds to C6.1.5)	Once clean fill or tread is mixed with contaminated soil, further movement of the material can spread contamination.

C6.2. Stockpiling of clean materials

To the degree possible, avoid stockpiling materials in situations where the potential for contamination with soil or runoff is possible. BMPs in this section apply where stockpiling is necessary.

BMPs	Notes
C6.2.1. Select the stockpile location to minimize potential for contamination of stockpile.	
C6.2.2. Place stockpiled materials on clean pavement, platforms, tarps, or in clean bins. Do not place stockpiles directly on soil or where they are exposed to surface water runoff. Cover and install perimeter protections if runoff-generating rain is likely. Cover if inactive for 14 days.	Requirement for covering comes from the GGNRA EMM SOP.
C6.2.3. Clean and sanitize tarps, bins, etc., before using at another site.	
C6.2.4. Stockpiled clean earth materials and mulches that are transported or spilled beyond the pile onto soil, etc., are considered contaminated and should not be returned to the pile. Such contaminated materials may be left in place, if approved, or collected for disposal or heat-treatment before use.	Initially clean materials are considered contaminated once mixed with potentially-contaminated soil, plant debris, or runoff. Material flow from a clean stockpile is one-way, from the pile to the use location, with no returns, including excess in carts, wheelbarrows, etc.

C6.3. Use and handling of reused materials

Note: Trail Construction & Maintenance Guidelines (GGNRA, NPS 2015b) and GGNRA EMM SOPs (GGNRA, NPS 2015a) encourage reuse and recycling of used materials where possible.

BMPs	Notes
Materials reused directly on-site in the same contamination potential zone	
C6.3.1. Keep reused materials as close to site of origin as possible.	
C6.3.2. Remove all adhering soil and debris and leave it where the materials originated (e.g., fence post hole) if materials will be moved more than 6 - 15 ft from the site of origin.	
Special conditions: infested sites	
C6.3.3. On-site reuse of soil-contaminated materials is not allowed at distances more than 6 ft from the site of the original use (adds to C6.3.1).	
Materials reused directly on-site in a different contamination potential zone	
C6.3.4. Materials reused on-site may only be moved from cleaner zone (low contamination potential) to a more contaminated zone (higher contamination potential). Do not reuse materials from an infested area in a clean / noninfested area.	
C6.3.5. Clean and sanitize materials before reuse as specified by Natural Resource staff based on site specifics.	

BMPs	Notes
Materials reused from a location outside the job site.	
C6.3.6 Re-used materials from nearby areas with similar *Phytophthora* risk profiles may be installed with Natural Resource staff approval. Reused hardware or lumber shall be thoroughly cleaned to be free of soil and plant debris before being brought to the job site. Washed materials shall be allowed to dry before being transported to the job site.	Consider other invasive species and other contamination factors before approval.
C6.3.7. Previously used materials (timbers, fence posts, etc.) that have been stockpiled must be completely cleaned of soil and plant debris and, if required by Natural Resource staff based on site specifics, treated with a sanitizing agent or subjected to heat treatment (e.g., steaming, solarization) sufficient to kill pathogens and other agents of concern (e.g., invasive plant propagules) in soil and debris that is adhered to or embedded in the material.	Nonporous, readily cleaned items taken from low risk areas may be reused after cleaning. Porous materials such as wood may require additional sanitizing treatment, especially if they were removed from higher risk sites.
Special conditions: sensitive sites	
C6.3.8. If possible, use only clean, new materials, especially for porous materials such as wood, in sensitive sites. Use of any reused materials must be approved by Natural Resource staff.	

C7. Use clean water

Water may need to be used to control dust, adjust earth materials to proper moisture for compaction, and other purposes. Surface waters, including untreated water from streams or ponds and runoff, are known sources of *Phytophthora* contamination. Only uncontaminated water or water that has been effectively treated (Section 5) to remove or kill *Phytophthora* should be used for construction purposes.

BMPs	Notes
C7.1. Water used for dust control or other construction purposes shall be from treated municipal water supplies or wells. Tertiary-treated municipal recycled water is acceptable for pathogen BMPs, check with Natural Resources for suitability regarding other chemical properties.	
C7.2. If well water is used, wellheads shall be protected from contamination by surface water sources.	
C7.3. Untreated surface waters shall not be used. If it is necessary to use surface waters, treat water to eliminate *Phytophthora* propagules. Treatment may be via lethal heating or by chlorination if approved by Natural Resource staff.	See Section 5.2 for specifications on cleaning and sanitizing. See Section 5.3 for specifications on heat treatment.
C7.4. Water shall be transferred through clean intact pipes or hoses with appropriate backflow prevention devices. Tanks or other vessels used for transporting water shall be clean and sanitized before use.	
C7.5. Vessels, tanks, pipes, hoses, pumps and other items use to store or transfer untreated surface waters or other potentially contaminated water must be sanitized before being used for clean water.	Where possible, use dedicated clean equipment for water storage and transport to avoid the need for decontamination.

SECTION 4. SOIL IMPORT AND MANAGEMENT

Phytophthora cinnamomi was detected at this and other sample locations from this potential soil export site at the Presidio in San Francisco.

CONTENTS

4.1. INTRODUCTION

Phytophthora species are a diverse group of microscopic plant pathogens, including more than 120 described species, and a number of apparent hybrids. These introduced pathogens have varying host ranges, temperature preferences, and other adaptations that can affect their ability to infest an area and infect vegetation. Hence, different *Phytophthora* species and even strains within species need to be considered as separate threats, much in the same way that different weed species pose different threats. For this reason, even if areas are suspected or known to be contaminated with one or more *Phytophthora* species, practices that may introduce additional *Phytophthora* species should still be avoided to the degree possible. More diverse assemblages of *Phytophthora* species have greater potential to affect a wider variety of vegetation. In addition, mixed *Phytophthora* infestations provide more chances for genetic exchange that could give rise to better-adapted and more pathogenic strains. Beyond this, the more thoroughly contaminated an area becomes, the more likely it is to serve as a source of *Phytophthora* inoculum that can initiate satellite infestations.

A key practice for preventing *Phytophthora* introduction and spread is preventing the movement of contaminated materials into a work site. For this reason, imported soil used in connection with construction and maintenance activities should be free of *Phytophthora* contamination to the degree possible. This standard applies even if the receiver site could have existing *Phytophthora* contamination, because it is unlikely in most cases that the introduced pathogens will match the *Phytophthora* species or genotypes already present.

Current GGNRA standards (GGNRA EMM SOPs) require that all earth materials be tested for contaminants and soil be screened for invasive species before being imported into the park (GGNRA, NPS 2015a). The purpose of the BMPs presented here is to extend existing standard operating practices for soil import to specifically address risk related to *Phytophthora* contamination.

Imported soils that are free of *Phytophthora* are preferable to use in all situations because they do not pose a risk of introducing or spreading *Phytophthora.* If *Phytophthora* contamination is potentially present in imported soil, the soil should either be:

- heat-treated to eliminate *Phytophthora* before use (Section 5.3), which is typically feasible only for limited soil volumes, or
- used only in very low risk applications (low site receptivity), in which spread of the pathogen to susceptible vegetation is very unlikely (Section 4.3). Subsurface fill under pavement in areas devoid of woody vegetation is an example of a low risk application. Consult with GGNRA Natural Resources for assessing the receptivity of a job site.

The scope of these BMPs is specifically limited to soil. Among various earth materials used in construction, soil generally has the highest risk of *Phytophthora* contamination. Although other earth materials are not specifically addressed in these BMPs, the factors related to *Phytophthora* contamination in soil can be used to evaluate risks associated with other earth materials. This is especially the case when soil mixed with these materials is the most likely source of contamination.

Import soils and other earth material can become contaminated with *Phytophthora* during handling, transport, and storage. BMPs provided in this document reduce the risk of introducing contamination during these activities.

4.1.1. *Phytophthora* in imported soils

Information on the presence and abundance of *Phytophthora* contamination in imported soil may be difficult to obtain, especially if soils are stockpiled. It is much easier to assess the likelihood of contamination and conduct appropriate testing if the soil source can be viewed and sampled before the soil is excavated for export. Informed sourcing of soil can both identify soil that is unlikely to be contaminated with *Phytophthora* and minimize the chances that clean soil sources will be unintentionally contaminated in the process of extraction.

By definition, mixing clean and *Phytophthora*-contaminated soils together results in contaminated soil. For chemical soil contaminants, dilution can be used to lower the concentration of the contaminant to a level that is below the adverse effects level. However, biological agents such as *Phytophthora* are capable of propagating and increasing in numbers under favorable conditions in the presence of susceptible hosts. Hence, even if *Phytophthora* propagules are diluted to low concentrations in soil, they can still pose a significant threat that can increase over time.

Localized *Phytophthora* infestations are found in numerous locations in California, but widespread infestations of soil-borne *Phytophthora* species are not common. Soil-borne *Phytophthora* contamination is normally associated with host roots. Highly-infested areas can exist in close proximity with areas with no detectable inoculum if host roots are present in only some areas, or if the pathogen has not yet spread to infect all hosts at a location.

The ability of a site to act as a source of *Phytophthora* contamination is related to how widely the contamination is spread, and the density, type, and activity of the inoculum (Section 1.3.1, Table 1-2). By considering these and additional factors that influence disease development, we can rate the likelihood that a site may be contaminated based on site characteristics (Section 1.3.1, Table 1-3). Various activities and land uses can serve to introduce *Phytophthora* to a site.

Most developed areas should be considered potential sources of *Phytophthora.* This is mostly related to the widespread use of nursery-grown landscape plants in urban and suburban areas. Conventionally-produced ornamental nursery stock is commonly infected with a variety of *Phytophthora* species. Conventional nursery stock is one of the most common *Phytophthora* reservoirs and an efficient vehicle for spread of these pathogens. Agricultural lands are also considered potential sources of *Phytophthora*, though the risk varies with cropping history and other factors. However, even in high-risk developed areas, *Phytophthora* contamination is likely to be associated with host material and is commonly patchy. *Phytophthora* may not be present at detectable levels in urban/suburban areas with few or no hosts, such as open turf areas.

Soil sourced from a potentially contaminated area can be infested with *Phytophthora* to varying degrees. For root-infecting *Phytophthora* species, host roots and closely associated soil have the highest levels of inoculum. In most areas, deep subsoils with very few or no woody roots are unlikely to have substantial amounts of *Phytophthora* unless they are contaminated by mixing with infested surface soils. One exception to this generalization can occur in very well-drained soils (e.g., coarse sandy soils) that have an underlying impermeable layer that creates a perched water table. Deep-rooted species can have higher *Phytophthora* infection levels in roots near the perched water table than in roots in the dry surface soil.

Leaves and branches can be sources of inoculum for species such as *P. ramorum* that affect aerial plant parts. However, most root-infecting *Phytophthora* species are unlikely to be associated with leaves or branches in California except under unusual situations (e.g., branches overhanging or in contact with streams or ponds, sprinkler irrigation of plants with contaminated water).

4.1.2. Can *Phytophthora* be detected in imported soils?

Several methods can be used to assay soil for the presence of soil-borne *Phytophthora* species. Only very limited volumes of soil are actually assayed in all of these tests. Because *Phytophthora* is not uniformly distributed in soils, sample selection, sample size, and the number of samples can all affect test outcomes. Among the various *Phytophthora* assays, baiting with unwounded green pears is among the most sensitive methods for detecting viable *Phytophthora* in soil samples (http://phytosphere.com/soilphytophthora/pearbaitingPhytophthora.htm). For pear baiting, a single sample consists of up to about 1.5 L of soil with host roots, which is a much larger sample than can be tested with most other methods. The following discussion assumes pear baiting will be used as the testing method.

Detection in intact field soils

Detecting or delineating *Phytophthora* infestations in the field involves determining whether inoculum is present in very large volumes of soil. In these situations, careful selection of samples at several levels is needed to maximize detection likelihood. At the first level, sample locations should generally be determined using in-field observations of host plant distribution and condition, and the presence of other risk factors. Sample sites should be selected within rootzones of symptomatic vegetation or other areas (e.g., riparian areas, among or near planted nursery stock) where *Phytophthora* is more likely to be associated with host roots. At the next level, each sample should consist of subsamples taken at several points to increase the odds of encountering infected roots. Subsample sites that have no roots should be rejected in favor of sites where host roots are encountered. Finally, material from each subsampled site should be selected to consist primarily of potential host roots, along with associated soil that may contain decayed root fragments and *Phytophthora* spores. Simple grab samples from holes dug without attention to host roots are likely to have low detection efficiency.

Even with such careful selection, the success of detecting *Phytophthora* in root/soil samples taken from known infested areas is normally less than 100%. Detection success rates may be 20% or less where inoculum levels are low or seasonal conditions are unfavorable for detection. As the dry season progresses, some *Phytophthora* species become more difficult to bait from soil samples. Samples collected in dry, non-irrigated sites in late summer and fall, before soils are wetted by rainfall, are most likely to yield false negatives. Detection efficiency will generally be greater if soils are sampled after the onset of winter rains through late spring.

Phytophthora-infested areas can be detected using only a few well-selected sample locations, but such a high rate of success is not guaranteed. Fairly intensive sampling, including samples collected at different times, may be required to confirm the presence of *Phytophthora* in field soils. A lack of detection, especially from a small number of samples, does not guarantee that *Phytophthora* is absent from a field location.

It is not possible to set a single standard for the number of samples that should be taken because of the wide variety of field situations in which sampling may occur. Multiple samples should always be collected if possible to account for the often-spotty distribution of *Phytophthora* in the field. Depending on the characteristics and size of the site, around 20-25 samples is close to the maximum number of carefully-selected root/soil samples that can be collected in a day by one to two experienced samplers.

Detection in stockpiled or graded soil

Compared with sampling of intact field soils, sampling of graded or stockpiled soils is much less likely to result in a *Phytophthora* detection. Visual cues that can be used to select more efficient field sample locations are lacking in stockpiles, because the relationship between the original host material and the soil cannot be observed. If the entire stockpile is accessible for sampling, sampling is essentially random. This is very inefficient unless inoculum is both uniformly distributed and present at very high concentrations. In the field, infestations are commonly limited in area and may have a patchy

distribution. When such soils are excavated and stockpiled, it is unlikely that they will be mixed to the degree that inoculum will be evenly distributed in the pile.

If the stockpile is large, only the surface of the pile may be readily accessible for sampling without the use of heavy equipment. In large stockpiles, the readily accessible portion of the stockpile (easily reached by digging with a shovel) is a small fraction of the entire pile. Inoculum that is located in the interior or bottom of a large pile, beyond the accessible depth, has a zero likelihood of being sampled. Hence, a highly-contaminated stockpile could be extensively tested and yield only false negative results if the inoculum was present in the inaccessible portions of the pile.

From a statistical standpoint, a large number of samples is required to detect a low level of *Phytophthora* that is unevenly distributed in a large stockpile. For example, if any 1.5 L sample taken from the accessible portion of the stockpile has a 1 in 100 chance of having detectable *Phytophthora* levels, at least 100 samples (150 L) would need to be tested (on average) before a single positive sample was likely. To have a 95% chance of detecting *Phytophthora* (assuming that the entire pile is accessible for sampling), about 300 samples (450 L) would be needed. These numbers assume that the test is always effective, which we know is not the case. If testing is 50% effective, the sample number would need to be doubled to 600 (900 L).

It is clear that an excessively high number of samples is required to have high confidence in the test outcome. The 1% detectable *Phytophthora* level in this example would be a significant amount of contamination. However, even a high number of samples could be noninformative if the contamination was limited to portions of the stockpile that were inaccessible. Except under unusual situations (inoculum levels are consistently very high throughout the pile, or pile volume is small and a high proportion of the pile can be tested), soil testing is not practical for detecting *Phytophthora* in stockpiled soil.

4.2. ASSESSING *PHYTOPHTHORA* CONTAMINATION POTENTIAL OF IMPORTED SOIL

Soil likely to be free of significant *Phytophthora* contamination is always the preferred material to use for import. However, it is necessary to have detailed data on where the soil was taken from and how it has been handled and stored to assess whether it is likely to be contaminated or not.

Use Checklist 4-1A below to evaluate the *Phytophthora* contamination risk of a potential source of import soil. Even when the highest risk situations are avoided, the *Phytophthora* contamination status of a soil source site can still be difficult to determine. Targeted *Phytophthora* testing can be used to help provide additional data for identifying contaminated areas before soil removal occurs. Checklist 4-1B notes additional modifying factors that increase or decrease the likelihood that soil taken from a given site will have *Phytophthora* contamination.

In summary, to obtain soil that has a minimum likelihood of *Phytophthora* contamination:

- **Use checklist 4-1A**: Avoid using soil from high and very high contamination risk situations.
- ***Phytophthora* Testing**: Conduct in-field *Phytophthora* testing for candidate soil sample locations with intermediate or low contamination risk from checklist 4-1A. If *Phytophthora* is detected, reclassify as very high risk. Also, note that sites may still have *Phytophthora* even if it is not detected through testing.
- **Use checklist 4-1B:** Select soil excavation areas within the source site that have the lowest modifying risk factors.

Checklist 4-1A. Primary factors that increase the likelihood a soil source is contaminated with *Phytophthora* and recommendations for use. If more than one primary factor is present, the recommendation for the highest contamination risk factor applies. Risks for other invasive species are not covered by this checklist.

Primary factor	*Phytophthora* contamination risk	Recommendation
1. Within or directly adjacent to known infested areas (contact Natural Resources staff for known locations)	Very high	Generally not suitable for use as import.
2. Areas landscaped with conventionally - produced (non-BMP) nursery stock including:	High	Generally not suitable for use as import.
a. urban landscaped areas		
b. landscaped parking areas		
c. plantings around buildings		
d. agricultural or forestry plantings of nursery-grown trees or shrubs		
e. older (pre-2016) habitat restoration plantings that used nursery stock		
3. Areas that are at least seasonally wet from storm runoff, perennial or seasonal watercourses, or ponds and:	High	Generally not suitable for use as import.
a. water in these area flows from areas noted under 1 and 2 above		
b. areas are used by livestock that have access to the wet areas		
4. Areas that are at least seasonally wet from storm runoff, perennial or seasonal watercourses, or ponds but water does not flow through areas with high contamination risk.	Intermediate	Harvest soil from lower-risk situations (Checklist 4-1B). Do not use in sensitive sites. May be suitable for low sensitivity sites.
5. Areas connected to very high and high-risk sites (factors 1,2, and 3 above) by unsurfaced, high-traffic roads and trails	Intermediate	Harvest soil from lower-risk situations (Checklist 4-1B). Do not use in sensitive sites. May be suitable for low sensitivity sites.
6. At least some of the woody or semi-woody vegetation at site showing decline and/or mortality.	Intermediate	Harvest soil from lower-risk situations (Checklist 4-1B). Do not use in sensitive sites. May be suitable for low sensitivity sites.
7. No identifiable site risk factors	Low	Harvest soil from lower-risk situations (Checklist 4-1B). May be suitable for sensitive sites if all modifying factors are low risk.

Checklist 4-1B. Modifying factors that affect the likelihood a soil source is contaminated with *Phytophthora*. Use this checklist to identify the lowest risk soil from a source that has a low to intermediate risk of *Phytophthora* contamination based on Checklist 4-1. Soils selected for import should not be high risk for any of these factors. Risks for other invasive species are not covered by this checklist.

	Risk rating				
Modifying factors	**Lower risk**	**L**	**M**	**H**	**Higher risk**
Vegetation type	nonvegetated or annual grasses and forbs only				woody hosts common to abundant
Vegetation symptoms	plants uniformly healthy				mortality or decline consistent with root rot observed in area
Woody roots of potential hosts	absent or rare				abundant in soil
Depth in soil profile	subsurface soil (>60 cm depth)[1]				surface soil (0-60 cm)[1]
Hydrology	dry uplands				perennial or intermittent wetlands, watercourses, creeks, drainages, ditches, ponds, irrigated areas

[1]Most *Phytophthora* inoculum is associated with fine roots in near-surface soil horizons where oxygen levels are greater, but this depth varies with soil type and condition, rooting patterns, and soil hydrology. The 60 cm cutoff is given as a general reference, but the distribution of host roots may provide a more appropriate cutoff for a given location. In some soils with deep rooted hosts and subsurface hardpans, *Phytophthora* inoculum can be found deeper than 60 cm.

4.2.1 Harvesting soil to minimize *Phytophthora* contamination

A potential soil source location may have both zones with little or no likelihood of *Phytophthora* contamination and zones with a definite risk of contamination. When harvesting soil for export from a site, the objective is to minimize potential contamination of the target low-risk soils. The main practices for minimizing contamination are:

1. Conduct soil harvest operations under conditions where the soil is dry enough to work without excessively adhering to equipment. Do not harvest soil during rainy weather.
2. Allow a suitable buffer distance between harvested low-risk soils and areas that have some potential for contamination, such as roads, trails, and woody host vegetation.
3. When harvesting subsoils, determine the likely depth of contamination based on root density, the depth of soil cracks, and related factors. Remove the likely contaminated layer first; then clean the equipment used to remove the contaminated soil. Next, remove a buffer layer of at least 10 to 15 cm depth to better remove remnants of the contaminated layer. Clean equipment again before excavating the subsoil for export. It may be useful to allow the newly-exposed subsurface soil several days to dry out between the successive excavations.

4.2.2. Evaluating *Phytophthora* risk for existing stockpiles

As discussed above in section 4.1.2, while testing soil from stockpiles is possible, it is not practical for detecting *Phytophthora* infestations in most situations. If complete data on the sourcing of the soil stockpile is available, checklists 4-1A and 4-1B can be used to determine whether the stockpile was originally from a low-risk source. If the source risk can be assessed, handling and storage practices (see BMPs below) should also be reviewed to assess whether contamination could have been introduced in these processes.

For stockpiles that consist of mixed sources, available information on sourcing, handling, and storage of stockpiled soil may be insufficient to determine its *Phytophthora* contamination potential. In such cases,

the stockpile should be considered to be potentially contaminated. If a high *Phytophthora* contamination likelihood cannot be ruled out, soil stockpiles should not be used or should be heat-treated before use (see Section 5.3). *Phytophthora* propagules can persist in soil for many years even in the absence of a host, so long-term storage alone does not eliminate *Phytophthora* contamination from soil.

4.2.3. Other earth materials

The risk factors shown in Checklists 4-1A and 4-1B above can be used to help assess the risk of *Phytophthora* contamination in other earth materials. Based on Checklist 4-1B, sand and rock quarried from subsurface sources have a low intrinsic risk of *Phytophthora* contamination because they are extracted at significant depths well beyond the extent of host roots. The main risk of contamination for such low-risk materials depends on the degree to which they may be mixed or otherwise contaminated with surface soils, whose contamination potential can be assessed using the checklists. For surface-mined materials (e.g., sand from river quarries), risk factors in Checklists 4-1A and 4-1B will serve to identify possible sources of contamination (e.g., surface waters).

4.3. AVOID USE OF ANY POTENTIALLY-CONTAMINATED SOILS IN SENSITIVE / RECEPTIVE SITES

Checklist 4-2A below presents a list of very sensitive and potentially receptive sites where the use of possibly *Phytophthora*-contaminated import soil should not be considered. This is only a partial list. Natural resources staff should consider additional site factors and potential risks before considering the use of potentially-contaminated import soil at any site. Only heat-treated soils (*Phytophthora*-free) or soils with a minimum risk of *Phytophthora* contamination (Checklist 4-1A low risk, Checklist 4-1B all low risk) should be considered for use in sensitive /receptive sites listed in Checklist 4-2A.

Checklist 4-2A. Primary factors related to the sensitivity and receptivity of a site to *Phytophthora* infestation via contaminated imported soil. If any response is "yes", do not import soil that is potentially contaminated with *Phytophthora* into the site; use only soil with the lowest risk ratings in Checklists 4-1A and 4-1B).

High site sensitivity / receptivity factors	No	Yes
1. Site is habitat or potential habitat for plant species that are endangered, special status, have limited range, or have other conservation status concerns, or provide critical or important habitat for other special status species.		
2. Site contains plant species that are known to be susceptible to *Phytophthora* species that have been detected elsewhere in California causing mortality of wildland species. Highly susceptible species include *Arctostaphylos* species, *Ceanothus* species, *Arbutus menziesii*, *Chrysolepis chrysophylla*, *Frangula californica,* and *Heteromeles arbutifolia,* but many other plants are susceptible to various *Phytophthora* species.		
3. Site is unlikely to have been contaminated with *Phytophthora* species as the result of previous land uses or management practices, most commonly undeveloped and relatively remote areas.		

Checklist 4-2B. Modifying factors that affect receptivity of a site to *Phytophthora* infestation via contaminated imported soil. Soils with higher receptivity should use the cleanest (lowest contamination likelihood) soils possible. In non-sensitive sites with low receptivity risk ratings, import soils with some intermediate contamination risk factors may be considered.

	Receptivity risk rating				
Modifying factors	**Lower receptivity**	**L**	**M**	**H**	**Higher receptivity**
Vegetation type where applied	nonvegetated or not near woody hosts				around, adjacent to, or upslope from sensitive woody species
Woody roots of potential hosts where applied	absent or rare				abundant in soil
Exposure of applied soil	fill under pavement or other stable unvegetated surfaces				surface use, top dressing or incorporated into surface soil
Depth of application	deep fill subsurface soil (>60 cm depth)				soil surface or upper 30 cm of the soil profile
Hydrology of area where applied	dry uplands				perennial or intermittent wetlands, watercourses, creeks, drainages, ditches, ponds, irrigated areas
Timing of application	dry soils during dry season				wet soil conditions during the wet season

4.4. USING LOW CONTAMINATION RISK SOILS IN LOW RECEPTIVITY SITES

As noted above, if adequate supplies of clean import soil (minimum *Phytophthora* contamination potential) are available, these soil sources are preferred. However, soils meeting these standards may not be available in sufficient supply for some projects. In non-sensitive sites with low receptivity, it may be necessary to use soils with a low risk of *Phytophthora* contamination.

A similar scenario involves finding appropriate uses for stockpiled soils that have a low risk of *Phytophthora* contamination. These include soils from sites that have low to intermediate risk of contamination based on Checklist 4-1A above, have low modifying risk factors based on Checklist 4-1B above, and have no *Phytophthora* positive test results for any field sampling. Stockpiles should not be used, or should be heat-treated before use (see Section 5.3), if it not possible to determine whether they include soil from high-risk sites.

As described in Section 1, to initiate a *Phytophthora* infestation, *Phytophthora* contamination must be introduced into a situation where it can infect and multiply on susceptible hosts. Not all sites where import soils are used have the same potential to be colonized by *Phytophthora*. Hence, there are situations where soil with some risk of *Phytophthora* contamination may be used without a significant risk of initiating a new infestation.

If sites do not have the high receptivity risk factors listed in Checklist 4-2A above, use of import soil that has some risk of *Phytophthora* contamination may be considered. Such soils may be suitable for situations that have the lowest receptivity, i.e., the lowest potential for allowing *Phytophthora* survival and reproduction. Factors that affect receptivity are shown in Checklist 4-2B above. These modifying factors increase or decrease receptivity in a quantitative way. For instance, because root-rotting *Phytophthora* species are most active in the rootzone of susceptible plants, potentially-contaminated import soil should not be used where it will come into contact with host roots.

In summary, to minimize *Phytophthora*-related risks if using import soil with some risk of *Phytophthora* contamination:

A. Always use the cleanest (least contaminated) import soil available (Checklists 4-1A, B).
B. Do not import soils from sites with very high (known *Phytophthora* detections) or high contamination potential (Checklist 4-1A).
C. Soils with intermediate contamination potential (Checklist 4-1A) should only be considered for import if all modifying risk factors (Checklist 4-1B) are low.
D. If import soils have a distinct risk of *Phytophthora* contamination, use only in situations that have the lowest potential receptivity (Checklists 4-2A, B).

4.4.1. Handling import soils with a low but distinct risk of *Phytophthora* contamination

Low-risk import soils (item D in the list above), or similar materials need to be handled in a way that prevents their inadvertent spread into sensitive, receptive areas. Care should be taken to avoid spilling import soils in sensitive areas during transport. Follow all BMPs related to cleaning tools, equipment, and wearables that have been in contact with low-risk soil.

It is also necessary to avoid introducing additional contamination into low-risk import soil (item D in the list above). Because workers cannot readily distinguish between import soils with different contamination risk levels, follow basic sanitation practices such as using clean tools and equipment, etc., (see BMP SI1 below) when handling either clean or low-risk imported soil.

4.5. SOIL IMPORT RISK ANALYSIS SUMMARY

Figures 4-1 and 4-2 summarize the decision processes related to Checklists 4-1A,B and 4-2A,B. Figure 4-1 looks at the process starting with a soil source, either intact field soil or an existing soil stockpile (Checklists 4-1A,B). Figure 4-2 considers the site where the imported soil will be used and indicates the minimum standards that the soil should meet (Checklists 4-2A,B).

As shown in these diagrams and discussed above, soil considered for import needs to meet one of three standards denoted by green and yellow rounded boxes in Figures 4-1 and 4-2:

- Heat-treated to eliminate *Phytophthora* (dark green): cleanest possible soil, unrestricted use
- Minimum likelihood of *Phytophthora* contamination (light green): unrestricted use
- Low *Phytophthora* contamination risk (yellow): use is restricted to sites with low sensitivity / receptivity; not for use in sensitive sites.
- As noted above, soil with a high risk of contamination (red) is not suitable as import soil.

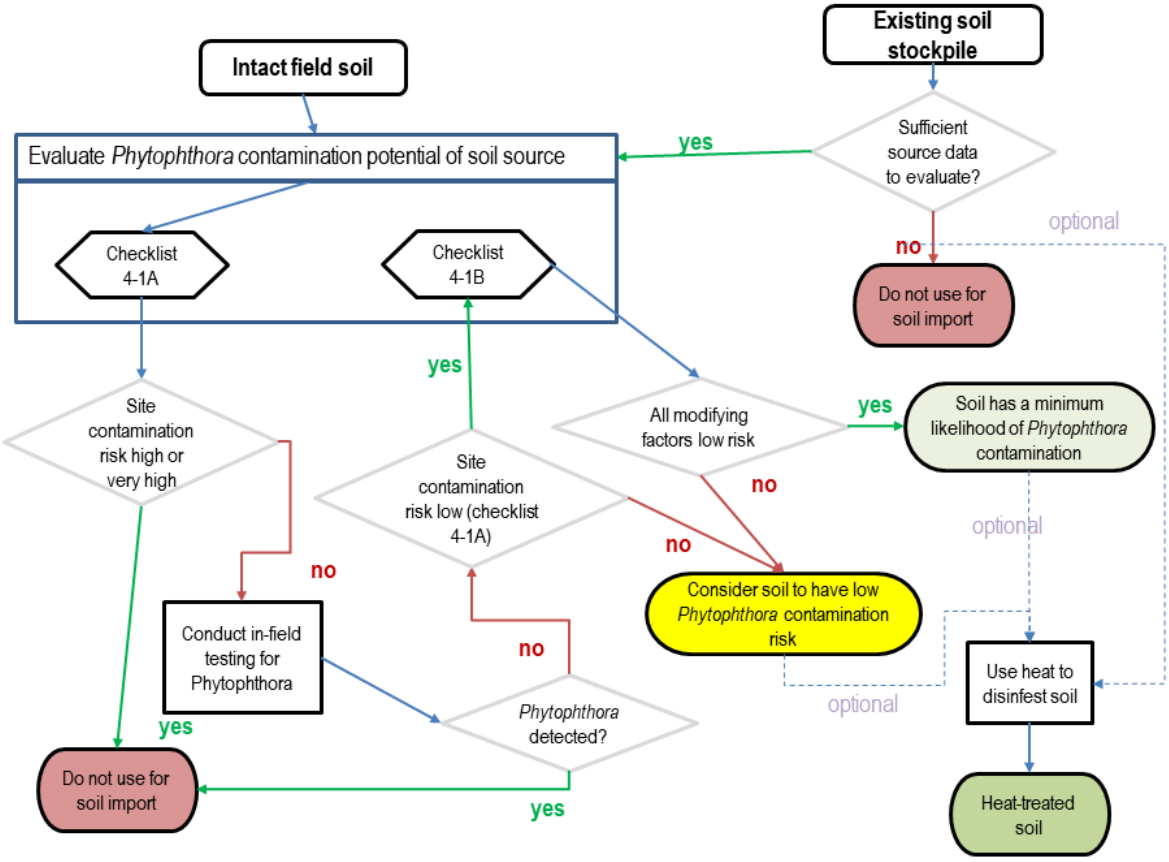


Figure 4-1. Decision tree outlining steps for deciding whether a soil source is suitable for import and the contamination risk classification of the resulting imported soil. The decision tree is based on Checklists 4-1A and 4-1B.

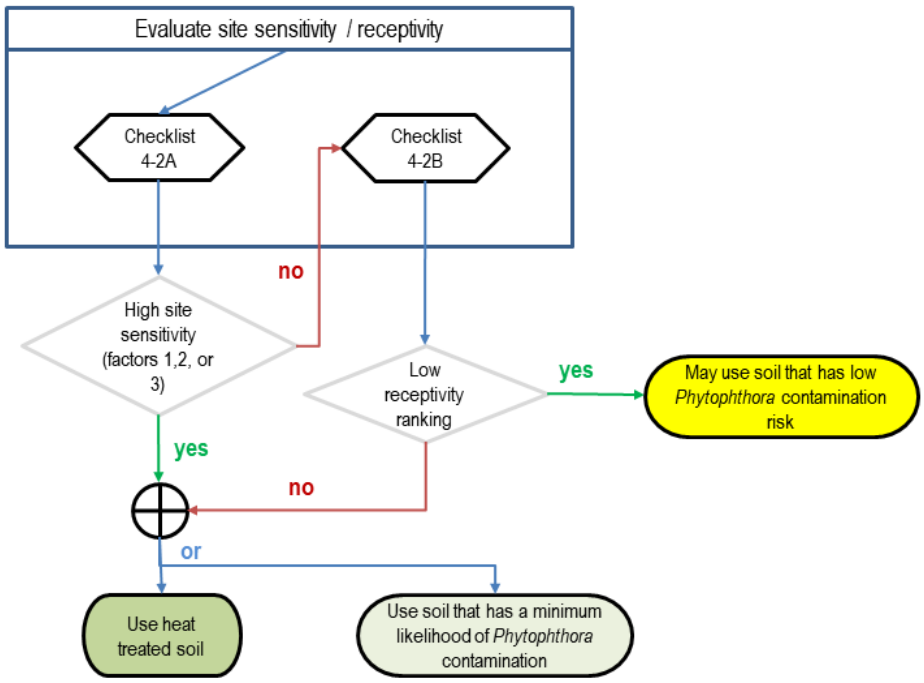


Figure 4-2. Decision tree for selecting import soil based on the sensitivity and receptivity of the receiver site. The decision tree indicates the appropriate minimum standard that import soil should meet based on site characteristics evaluated using Checklists 4-2A and 4-2B.

4.6. SOIL IMPORT AND HANDLING BMPS.

Note: If dealing with soil stockpiles, the extensive guidelines in the 2015 GGNRA Earth Materials Management (EMM) SOP document (GGNRA, NPS 2015a) should be consulted. Practices listed in this section are additions to those practices and intended to minimize the potential for *Phytophthora* contamination. The BMPs described here do not eliminate the need to follow applicable GGNRA EMM SOPs.

SI1. Clean handling and transport of imported soil

Imported soil may be either contaminated with *Phytophthora* or free of contamination (heat -treated or from very low risk source). Regardless of the contamination status, avoid introducing additional *Phytophthora* contamination during soil handling and transport. To avoid a variety of potential hazards and adverse consequences, imported soils should be fully contained during transport.

SI1.1. Worker footwear and clothing

To prevent contamination of imported soil and to prevent spread of contamination from soil, workers that come in in contact with the soil or surfaces where it is placed should have clean footwear and clothing.

BMPs	Notes
SI1.1.1. Workers should avoid unnecessary contact with imported soil and beds of vehicles used to transport it to minimize the need for decontamination.	
SI1.1.2. Soles and uppers of footwear must be free of debris and soil before making contact with imported soil or cleaned transport vehicle beds. Clean and sanitize footwear as described in Section S5.	
SI1.1.3. For workers that will be entering cleaned transport vehicle beds or handling import soil, worker clothing shall be free of all mud, soil, and detritus. If clothing is not freshly laundered, all debris and adhered soil should be removed by brushing with a stiff brush.	

SI1.2. Vehicles, equipment, and tools

Use of clean vehicles, equipment, and tools helps prevent unintentional contamination of imported soil from outside sources. The objective in cleaning and sanitation is to prevent the contamination of imported soil with potentially contaminated soil, roots, plant debris, or water, which would allow this contamination to be transferred to the job site. More thorough cleaning and sanitizing cleaned surfaces is required to minimize risks when moving from contaminated sites or into sensitive sites.

All cleaning activities in this section should be carried out away from the job site, preferably in a facility that allows for capture and proper disposal of debris and contaminated water, such as a commercial vehicle washing facility.

BMPs	Notes
SI1.2.1. Equipment and vehicles used for transporting imported soil shall be free of soil and debris accumulations on tires, wheel wells, vehicle undercarriages, and other surfaces before traveling to soil loading and delivery sites. Use a high-pressure washer, compressed air, brushes, or other means to ensure that soil and debris are completely removed. All vehicles (heavy equipment, hauling vehicles and trailers) will be pressure-washed before their first entry into the Park or when being moved for use in a different jobsite within the park. .	GGNRA EMM SOPs (GGNRA, NPS 2015a) require removal of vegetation, EMs, and grease that may carry invasive species' seeds or vegetative parts or contaminated soil. Multiple successive entries of the same hauling vehicle into the Park would not require additional pressure washing unless the vehicle shows signs of EMs, plant materials, or as requested by Park staff. See also BMP C3.1 (Section 3) for further information minimizing contamination of transport vehicles at the delivery site and Section S5 for cleaning specifications.
SI1.2.2. Hand tools, shovels, loaders, and other equipment used to handle imported soil must be clean and free of soil and plant debris before initial use for loading or unloading. Use a high-pressure washer, compressed air, brushes, or other means to ensure that soil and debris are completely removed.	See section S5.2.1 for details on cleaning tools and small equipment.
SI1.2.3. No soil or plant debris from the interior of vehicles or equipment (cabs, etc.) shall be deposited at the work site. If drivers/operators will be entering or exiting vehicles at the job site, the cab must be free of mud, soil, plant parts, and organic debris before arriving at the job site. Interior floors, floor mats, and seats must be free of potentially contaminated material.	GGNRA EMM SOPs (GGNRA, NPS 2015a) require that vehicles transporting soil be thoroughly cleaned, inside and out, prior to entering the Park, and between working in different areas of the park.
SI1.2.4. Hauling vehicles that have previously transported material contaminated with *Phytophthora* or other invasive species will be pressure-washed before transporting different material.	GGNRA EMM SOPs (GGNRA, NPS 2015a) require that loose material cleaned from truck beds be bagged to prevent dispersal of contaminated material from truck during transit through park on way to wash station. Bagged material is disposed of as Class II Designated Landfill Waste.
SI1.2.5. Staff will inspect all vehicles and equipment prior to their entry into the Park for contamination with soil, plant debris, and invasive species. Staff will inspect vehicles before they move from one project area to another.	From GGNRA EMM SOPs (GGNRA, NPS 2015a).
Special conditions: sensitive sites	
SI1.2.6. For equipment, vehicles, or tools used to transport or handle imported soil (heat-treated or very low contamination risk) for use at a designated sensitive site, exterior cleaning shall include the use of a detergent solution or cleaning of contaminated parts should be followed with treatment by a sanitizing agent. Washed / sanitized equipment should be allowed to dry before loading or handling soil.	See Section S5.2. for cleaning/sanitizing specifications.

SI1.3. Offloading of imported soil at the delivery site

BMPs	Notes
SI1.3.1. Unload imported soils directly at the final point of use whenever possible. If redistribution from the delivery vehicle is needed, load new clean materials directly into clean, dry surfaces in loaders, vehicles, carts, trailers, etc. Do not place materials directly on the ground except at site of use, especially under wet conditions.	If stockpiling is necessary, follow guidelines in SI2 below. Park staff to determine whether sanitation is also required.
SI1.3.2. Minimize time between soil delivery at the job site and subsequent distribution to avoid need for stockpiling and potential contamination.	Applies to sites where soil contamination is likely or difficult to prevent. If stockpiling is necessary, follow guidelines in SI2 below.
SI1.3.3. Distribute imported soil directly from vehicles or loaders in amounts needed to target areas to the degree possible to minimize the need for redistribution by grading over extended areas.	Objective is to minimize movement of imported soil once it is mixed with potentially-contaminated site soil.
Special conditions: infested sites	
SI1.3.4. Do not move or redistribute imported soil that has been mixed with site soil beyond immediate area of soil contact (adds to SI 1.3.3)	Once imported soil is mixed with contaminated soil, further movement of the material can spread contamination. Same as Section 3 C6.1.6.

SI2. Creating and maintaining stockpiles of imported soil

As noted above in SI1.3, direct offloading from vehicles and equipment to the site of use is preferable because it avoids additional handling and storage steps in which contamination can be introduced. In the case where imported soil may be contaminated with *Phytophthora*, it is also necessary to avoid spread of this contaminated soil beyond the stockpile and final use areas.

BMPs	Notes
SI2.1. Locate the stockpile to minimize the potential for contamination. Stockpiles should be not situated where contamination with soil or runoff cannot be prevented.	
SI2.2. Where feasible, stockpile soil on clean, intact pavement or other smooth cleanable surfaces. Clean the surface by removing all soil and plant debris, wash with water, and allow to dry before depositing soil.	
SI2.3. If pavement or similar clean surfaces are not available use clean tarps or landscape fabric to create separation between the stockpile and underlying surfaces.	
SI2.4. Use stockpiled soil as soon as possible and avoid creation of stockpiles that will become inactive (i.e., not used within any 14-day period).	Inactive definition comes from GGNRA EMM SOPs (GGNRA, NPS 2015a).
SI2.5. The stockpile site should be situated and managed to prevent runoff or other surface water flows that may transport contamination from reaching the pile. Situate the stockpile in an elevated position and/or use berms or other barriers to prevent water flow from reaching the stockpile. Perimeter protections around stockpiles should prevent both inflow of water into the base of the pile and outflow of water from the pile.	*Phytophthora* contamination can be moved directly as spores in flowing water or indirectly with infested soil or plant debris transported in flowing water. Perimeter protections specified in the GGNRA EMM SOPs (GGNRA, NPS 2015a) do not account for water inflow as a source of contamination.

SI2.6. Stockpiles should be kept covered with impervious material if they are: • inactive (not used within any 14-day period). • subject to soil loss or deposition by wind or water • located where they are subject to traffic by pedestrians or large animals that could carry contamination into the pile Plastic must be at least 10mil thick and held in place with clean sandbags or other methods. If conditions warrant (sensitive sites, high likelihood of unauthorized traffic, severe weather) keep piles covered whenever they not in active use or being directly monitored.	Requirements for covering and inactive definition are from the GGNRA EMM SOPs (GGNRA, NPS 2015a).
SI2.7 Sand in sand bags and fill materials in wattles or other perimeter protection devices must be from clean sources or heat-treated to avoid contamination of the stockpile.]	Sand from river quarries or extracted with water may be contaminated with *Phytophthora*. *Phytophthora erythroseptica* is a known pathogen of rice in California, and rice wattles, unless heat-treated, may carry this pathogen. See Section 5.3 for heat treatment specifications. Standards for raw wood, S5.3.3., may be used for wattles.
SI2.8. The integrity of the stockpile coverings and perimeters shall be checked regularly and repaired if damage that could affect the function of these protections is observed.	
SI 2.9. Do not combine soils of different contamination risk profiles in the same stockpile. Completely use stockpiled import soil from a given source for a compatible use and clean the site before creating a new stockpile at the same location.	The contamination risk of any mixed stockpile becomes that of the most contaminated material added.
SI2.10. Tarps, landscape fabric, etc. used on a stockpile must be cleaned and sanitized before use on a new source of soil or at another location. Safely dispose of materials that cannot be sanitized.	
SI2.11. Stockpiled import soil that is transported or spilled beyond the pile onto soil, etc., is considered contaminated and should not be returned to the pile. Spillage and other excess soil may be collected for disposal, or, if approved, it may be left in place or used for low sensitivity / receptivity uses (e.g., under pavement).	Initially clean materials are considered contaminated once mixed with potentially-contaminated soil, plant debris, or runoff. Material flow from a stockpile is one-way, from the pile to the use location, with no returns, including excess in carts, wheelbarrows, etc.

SECTION 5. DEFINITIONS AND SPECIFICATIONS

CONTENTS

5.1. DEFINITIONS

Cast soil — excess soil generated by trail work that is placed beyond the trail edge.

Cast vegetation — removed vegetation that is placed beyond the trail edge.

Clean —1. *As used in reference to tools, equipment, and wearables*: free of soil, mud, and organic debris. Cleaning should emphasize parts of equipment tools or vehicles that may shed debris or soil particles when used.
2. *As used in reference to materials (earth materials, mulches, timbers, etc.)* — sanitized, heat-treated, or free of contamination due to manufacturing conditions or sourcing, and maintained in a way to prevent subsequent contamination.

Contaminated (or potentially contaminated) — 1. *As used in Trail, Construction and Earth Materials BMPs*: any surface or material containing soil, roots, plant debris, water, or other material that contains (or could contain) viable spores or other propagules of *Phytophthora* (see also infested).
2. *As used in nursery BMPs* — any surface or material that is not sanitized, heat-treated, or otherwise clean. The ground and anything that has been in contact with it should be considered as potentially contaminated.

Decontaminate — To remove potentially contaminated soil and debris by cleaning or cleaning followed by sanitizing.

Infected — a plant that has a pathogen that has grown into its tissues. Infections normally involve internal colonization of plant tissues and are not eliminated via surface treatments such as disinfectant dips. Only plants or plant parts are referred to as infected (see also infested).

Infested — containing or superficially contaminated with propagules of a pathogen. Soil, tools, and surfaces may be infested with spores of pathogens (see also infected). As used in this document, infested and contaminated are similar in meaning. When referring to soil, *infested* indicates that the pathogen is established and distributed in the soil and associated host roots, whereas *contaminated* generally refers to a more limited and often more recent introduction.

Job site — areas where specified work is being performed; may include associated areas used for staging, parking, stockpiles, and access roads within and leading to these areas. The boundary of the job site will be determined by GGNPC for each project site.

Phytosanitary — free of plant pathogens; as an adjective, used to describe techniques or practices that prevent materials from being infected or infested with plant pathogens (e.g., phytosanitary measures).

Propagule — living portions of a plant, fungus, oomycete, etc. that can serve to reproduce that organism. For plants, propagules include seeds, cuttings, divisions, bulbs, corms, tubers, etc. For fungi or oomycetes (including *Phytophthora*), these include both vegetative filaments (mycelium) as well as various spores and resistant structures.

Sanitize — Clean and treat with a sanitizing agent or via a lethal heat exposure to kill plant pathogens present as external contamination

Sanitized — cleaned to remove debris and soil particles and subsequently treated with a disinfecting agent such as sodium hypochlorite (chlorine bleach), quaternary ammonium compounds, alcohol, or heat in a manner that destroys any residual plant pathogen propagules.

Sanitizing agent — Materials such as bleach (sodium hypochlorite solutions), alcohol, quaternary ammonium compounds, and peroxides that can directly kill exposed propagules of *Phytophthora* or other plant pathogens when used properly. Most sanitizing agents can also kill a wide variety of bacteria and deactivate many viruses. Note that most materials referred to as fungicides are applied to plants to suppress disease but may not kill the pathogens and are not sanitizing agents.

Surface water — water from creeks, rivers, ponds, or runoff from rainfall or urban or agricultural irrigation.

5.2. CLEANING AND SANITATION SPECIFICATIONS

5.2.1. Cleaning tools, surfaces, and footwear

Surfaces and tools must be clean before use. Tools and working surfaces should be smooth and nonporous to the degree possible to facilitate cleaning. Wood handles on tools should be sealed with a waterproof coating to make them easier to clean.

Remove all soil and organic material (roots, sap, etc.) from the surface. If necessary, use a detergent solution and brush to scrub surface contaminants at a utility sink. Screwdrivers or similar implements may be needed to clean soil out of crevices or shoe treads. Brushes and other implements used to help remove soil must be cleaned and sanitized after use.

Items should be dry before use. Allow to air dry or use clean towels or compressed air to dry more quickly. Transport cleaned items in clean vehicles, bins, bags, etc., to prevent recontamination.

5.2.2. Sanitizing tools, surfaces, and footwear

Sanitizing of cleaned equipment may be required if equipment has been used in a high risk contaminated area or is to be used in a highly sensitive site (high receptivity). After surface soil and contamination are

removed, allow equipment surfaces to dry if possible so that water on the surface does not dilute sanitizing agents. If surfaces are still wet, apply enough sanitizer to completely displace the water film. Treat the cleaned surface with one of the following sanitizing agents, allowing the appropriate contact time before use or rinsing. Sanitizing agents may be applied by using spray bottles or other sprayers. Use coarse droplets to minimize mist and drift and apply to thoroughly wet the surface. Observe all appropriate safety precautions and follow product labels carefully to prevent inhaling aerosols or contact with eyes or skin when using these agents.

- 70-90% ethyl or isopropyl alcohol - spray to thoroughly wet the surface and allow to air dry before use
- freshly diluted bleach solution (0.525% sodium hypochlorite, Table 1) for a minimum of 1 minute. Bleach solutions degrade quickly. Bleach solutions dispensed by spray bottles need to be made fresh daily. Due to corrosivity, bleach solutions are not advised for steel or other materials damaged by bleach.
- quaternary ammonium disinfectant - use according to manufacturer recommendations, making sure that the label indicates that the product is suitable for your use situation and has activity against *Phytophthora* when used as directed. Solution should be freshly made or tested to ensure target concentration.

It may be impractical to use the above sanitizing agents on very large equipment, such as earth moving equipment. In cases where such equipment is to be used in sensitive sites, material should be cleaned thoroughly with pressure washing equipment until all visible soil is removed. The surfaces can then be sanitized by either:

- follow-up high-pressure washing using a strong detergent solution before final rinsing
- use of thorough high-temperature (180-200 F minimum) pressure washing

For either method, washing should be done to maximize the exposure of potentially contaminated areas to detergent or heat.

Table 5-1. Dilutions of commonly available bleach products needed to obtain approximately 0.525% sodium hypochlorite (NaOCl) concentrations (about 5000 ppm available chlorine).

Percent sodium hypochlorite in bleach	Parts bleach	Parts water	Diluted bleach percent sodium hypochlorite
5.25%	1	9	0.525%
6.0%	1	10.4	0.526%
8.25%	1	14.6	0.529%
8.3%	1	14.8	0.525%

For example, adding 100 ml of 5.25% bleach to 900 ml of water will make 1000 ml of 0.525% NaOCl solution. If using 8.3% bleach, add 100 ml of bleach to 1480 ml of water to make 1580 ml of 0.525% NaOCl.

5.2.3. Procedures for cleaning vehicles and large equipment

Always preclean equipment that is heavily contaminated to remove large accumulations of soil or plant debris. Collect this material for disposal or conduct precleaning where the material originated. Precleaning using brushes, scrapers, compressed air, etc. reduces the amount of wash water required and the amount of contaminated water and wet waste soil that needs to be processed when it is collected in a portable wash station.

Use pressure washing with adequate pressure and appropriate nozzles capable of removing all soil and debris. External areas that should be free of soil and debris after cleaning include:

- Crevices in upper surface and panels
- Tires, rims, and fender wells
- Spare tire mounting area
- Bumpers
- Front and rear quarter panels
- Around and behind grills
- Bottom of radiator vent openings
- Brake mechanisms
- Transmission
- Stabilizer bar
- Shock absorbers
- Front and rear axles
- Truck and trailer beds
- Suspension units
- Exhaust systems
- Light casings and mirrors
- Exposed engine compartments

For tracked vehicles:

- Tracks
- Axles and tensioners
- Rollers
- Sprockets and idlers

For soil-moving implements:

- Blades
- Buckets
- Rippers and tines
- Rollers
- Compactors

After all visible soil and debris have been washed away, follow by rinsing from bottom to top of vehicle. Equipment should be inspected after cleaning before leaving the washdown area to ensure that areas of concern have not been missed.

Note: Always check equipment manufacturer's specifications to determine whether the equipment or portions of it are not compatible with pressure washing, including with hot water. Use alternative compatible cleaning methods for equipment or portions of equipment that cannot be pressure washed.

Vehicle interiors should be cleaned to prevent contaminated material from being deposited at the job site when opening doors or exiting the vehicle. Dry materials can be removed by vacuuming. Mud and other deposits may require cleaning with liquid cleaners. Areas that should be free of soil and plant materials include:

- Upholstery and beneath seats
- Floor mats and floors beneath then
- Beneath foot pedals
- Inside folds of gear shift cover
- Bottom of door jamb

Initial cleaning before Park entry
In general, equipment and vehicles should be cleaned at permanent commercial vehicle wash facilities or other off-site wash-down facilities before initial entry to a job site or before subsequent re-entry if the vehicle has been driven off pavement when away from the job site.

The following specifications are from the GGNRA EMM SOPs (GGNRA NPS 2015a).

> 1. Vehicles must be thoroughly cleaned, inside and out, prior to entering the Park, and between working in different areas of the park. Removal of vegetation, EMs, and grease that may carry invasive species' seeds or vegetative parts, or contaminated soil is required. All vehicles (heavy equipment, hauling vehicles and trailers) will be pressure-washed before their first entry into the Park. Hauling vehicles that have previously transported invasive species-contaminated material will be pressure-washed before transporting clean material. Subsequent entries of hauling vehicles into the Park would not require pressure washing unless the vehicle shows signs of EMs, plant materials, or as requested by Park staff.
>
> 2. Staff will inspect all vehicles and equipment prior to their entry into the Park for EMs and invasive species. Staff will inspect vehicles before they move from one project area to another.

Cleaning before re-entry or upon exit from contaminated areas
When working in a contaminated site, vehicles and heavy equipment should be cleaned before leaving the job site and driving through the park.

If vehicles travel exclusively on pavement or dry soil, and vehicles or equipment are not contaminated with mud or moist soil, dry surface soil and debris may be removed by the use of brushes and compressed air. If soil and debris deposits are not fully removed, follow up with pressure washing.

During wet soil conditions, all vehicles should be cleaned by use of pressure washers. Remove large loose aggregations of soil and mud by brushing or compressed air while vehicles and equipment are in the area where the soil originated to minimize shedding of contaminated soil along the exit route.

5.2.4. Relocatable washdown pads and racks for cleaning equipment and vehicles

In construction and similar activities, equipment and vehicle must be decontaminated before entering sensitive areas or leaving contaminated areas. In these situations, the use of relocatable washdown pads and racks is preferable to washing equipment out onto the ground, where water and soil containing *Phytophthora* propagules may be deposited in noninfested areas or may be tracked elsewhere. Wash-down racks or pads allow for collection and proper disposal or treatment of contaminated water, soil, and debris.

Staging area for cleaning operations.
Where possible, stage cleaning operation on paved areas. If this is not possible, use gravel and geotextile to develop entry and exit routes that minimize tracking of soil in and out of the cleaning area. Do not situate washdown sites close to:

- *Phytophthora*-sensitive species
- waterbodies and watercourses, or drains that discharge directly into these
- other sensitive resources
- clean tools and equipment, materials, stockpiles, etc., that could be contaminated with splashed water, mud, and/or runoff.

For decontamination of vehicles leaving contaminated areas, the washdown staging area should be sited as close to the outer edge of a contaminated area as feasible, to minimize tracking of contaminated soil from the area.

For decontamination of vehicles entering sensitive areas, the washdown staging area should be sited as far as possible from the sensitive resource area, along a route where vehicles will not become contaminated between the washdown area and the sensitive area.

Especially if large amounts of wash water and contaminated soil will be generated, use a raised platform or wash rack with an integrated catchment system to simplify collection and processing of waste water and solids. If this is not possible, use a bermed relocatable mat system that allows for capture and processing of water and solids. The wash pad should have means for elevating vehicles or otherwise allow for complete washing and inspection of the undersides of vehicles and equipment. Side containment barriers should be used to prevent splashing of soil and contaminated water during washing operations.

Both contaminated water and solids from the washdown pad should be contained. Solid wastes (typically a slurry of saturated soil) may be transferred to dewatering bags, and then overbagged in impermeable bags for landfill disposal. Alternatively, the slurry may be pumped out and disposed of in a suitable waste facility. Waste water is typically pumped into holding tanks to allow for settling of suspended solids, and then filtered to remove buoyant particulate matter. Unless water is filtered to exclude particles of greater than about 7 micrometers, the filtered water must still be treated via chlorination, heating, or other effective means to eliminate *Phytophthora* inoculum before reuse or discharge into the environment. Wash water may also become contaminated with hydrocarbons or other substances from vehicles and equipment. Parks staff will determine whether levels of these chemical contaminants permit onsite disposal of treated water or require offsite disposal at a suitable facility.

Clean, drain, and dry all equipment used for washing operations after the final use of the day. Thoroughly clean and disinfest brushes, scrapers, and other cleaning implements after use and before storing.

5.2.5. Water chlorination for elimination of *Phytophthora* propagules

Water to be treated by chlorination should first be filtered to remove organic debris. For water used in dust and fire suppression, add an approved chlorine product to obtain about 50 ppm available chlorine (Table 5-2). Prepare the mixture at least 5 minutes before water is used. Note that water pH should be between 6.0 and 7.5 for optimum activity of chlorine.

Specifications and precautions for treatment of water with Clorox® bleach to prevent spread of Port Orford cedar root disease, caused by *Phytophthora lateralis,* are provided below for reference. The information has been edited to allow for calculation of dilutions for bleach products with differing levels of sodium hypochlorite. The Ultra Clorox ® brand regular bleach referred to in the cited label (EPA Reg. No. 5813-50) is 6.0% sodium hypochlorite (yields 5.7% available chlorine).

Source: USDA Forest Service Pacific Southwest Region, Forest Health Protection, Natural Resources Management. (no date). Managing for healthy Port-Orford-cedar in the Pacific Southwest Region. https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5332563.pdf

ULTRA CLOROX ® BRAND REGULAR BLEACH (EPA Reg. No. 5813-50) FOR PORT ORFORD CEDAR ROOT DISEASE (*Phytophthora lateralis*)

TREATMENT USE

When used as directed, this product is effective in controlling the spread of the fatal fungus *Phytophthora lateralis* [Port Orford Cedar Root Disease] in areas of California and Oregon where Port Orford Cedar (*Chamaecyparis lawsoniana*) grows. Water is commonly drafted from streams and fire ponds within forested areas to use in dust abatement on forest

roads, equipment cleaning, and for fire suppression. The water source can spread the root disease fungus to uninfested areas.

Treating water prior to use helps control the spread of the fungus.

Directions for Use: Add beach to drafted water as noted in the table below to obtain about 50 parts per million available chlorine in the resulting mixture. Prepare the mixture at least 5 minutes prior to application for dust abatement; fire suppression; and cleaning trucks, and logging, road building, and maintenance equipment. To reduce the likelihood of getting Clorox in streams, add Clorox to fire trucks and road watering equipment only after they have left the stream area where they were filled.

Table 5-2. Dilution table to obtain approximately 50 ppm available chlorine.

Percent sodium hypochlorite in bleach	Parts bleach	Parts water	Percent sodium hypochlorite in resulting water solution
5.25%	1	900	0.00583%
6.00%	1	1000	0.00599%
8.25%	1	1400	0.00589%
8.30%	1	1430	0.00580%

PRECAUTIONARY STATEMENTS
HAZARDS TO HUMANS AND DOMESTIC ANIMALS DANGER: CORROSIVE
May cause severe irritation or damage to eyes and skin. Harmful if swallowed. Protect eyes when handling. For prolonged use, wear gloves. Wash after contact with product. Avoid breathing vapors and use only in a well-ventilated area.

FIRST AID IF IN EYES:
Rinse with plenty of water for 15 minutes. Get prompt medical attention.

IF SWALLOWED:
Drink large amounts of water. DO NOT induce vomiting. Call a physician or poison control center immediately.

IF IN CONTACT WITH SKIN:
Wash skin thoroughly with water.

PHYSICAL OR CHEMICAL HAZARDS:
Product contains a strong oxidizer. Always flush drains before and after use. Do not use or mix with other household chemicals, such as toilet bowl cleaners, rust removers, acids, or products containing ammonia. To do so will release hazardous irritating gases. Prolonged contact with metal may cause pitting or discoloration.

For Institutional use only:
ENVIRONMENTAL HAZARDS:
Do not discharge effluent containing this product into lakes, ponds, estuaries, oceans or other waters unless in accordance with the requirements of a National Pollutant Discharge System (NPDES) permit and the permitting authority has been notified in writing prior to discharge.

STORAGE AND DISPOSAL:
Store this product upright in a cool, dry area, away from direct sunlight and heat to avoid deterioration. In case of spill, flood areas with large quantities of water. Small quantities of spilled or unusable product should be diluted with water before disposal in a sanitary sewer. Do not reuse empty container, but rinse and place in trash or recycle where facilities accept colored HDPE bottles.

Do not contaminate water, food, or feed by storage, disposal or use of this product. Store away from children. Reclose cap tightly after each use. Offer empty container for recycling. If recycling is not available, discard container in trash. DO NOT allow product [and/or rinsate] to enter storm drains, lakes, streams, or other bodies of water.

CLOROX CUSTOMER ASSISTANCE (800) 292-2200

5.3. HEAT TREATMENT FOR SANITATION

Phytophthora species and other plant pathogens can be killed by exposure to high temperatures for a sufficient length of time. *Phytophthora* species and other water molds are relatively sensitive to heat. Temperatures of 122°F (50°C) for 30 minutes will kill propagules of many *Phytophthora* species, though more heat tolerant *Phytophthora* species can survive up to about 72 minutes at this temperature (Funahashi and Parke 2016).

The most common methods for applying heat for sanitation are via:

- steam or aerated steam (steam/air mixtures)
- hot water
- dry heat (e.g., in non-insulated or insulated containers heated by electricity, natural gas, or propane)
- solarization (solar heating via the greenhouse effect under clear plastic or glass)

Effective treatment times decrease as temperatures increase. For instance, metal tools can be sterilized by exposure to flame for a short period. Standard treatments for killing plant pathogens in water include 203°F (95°C) for 30 seconds and 185°F (85°C) for 3 minutes (Runia and Amsing 2001). However, longer treatment times at lower temperatures are more practical for treating large volumes and bulky materials. Based on multiple studies, **heating of moist materials to 140°F (60°C) or higher for at least 30 minutes will kill propagules of *Phytophthora*** and other water molds, as well as most plant pathogenic fungi.

Materials to be heat-treated should be moist before treatment because target organisms are killed more readily and at lower temperatures if they are hydrated. For 30-minute heat treatments, temperatures had to be increased by up to 36°F (20°C) to kill dry propagules of some plant pathogenic fungi compared to temperatures required for propagules premoistened for 16 hours (van Loenen et al 2003). If materials to be treated have not been moist for at least 12 hours, treatment temperature and/or time should be increased well above minimum standards to ensure efficacy.

In all heat treatment procedures, the timing of the heat exposure period starts when the coolest portion of the heated material reaches the target temperature (use a temperature probe). Total heating time can be reduced by ensuring that the treated materials are as warm as possible before treatment. Preheating via solarization or simply warming materials in the sun will help reduce energy needs. Total heating time will also be minimized if the heated material can be agitated and heat is uniformly distributed. In all heat treatments, some margin for error should be allowed to account for non-uniform heating. Use treatment times substantially longer than the minimum (at least double) if it is difficult to determine what portion of material will be the slowest to reach the target temperature when placing the temperature probe..

5.3.1. Heat treatment of soil with moist or dry heat sources

Soil can be heated by steam, aerated steam, or dry heat. If using a dry heat source, such as forced hot air, soil should be moistened to near field capacity and soil should be agitated to provide for efficient heating. Heat soil until the temperature of the coolest portion of the treated soil has maintained a temperature of **at least 140 F (60 C) for at least 30 minutes**. This heat treatment regime is lethal to most plant pathogenic fungi and oomycetes such as *Phytophthora* but does not do not kill all soil microorganisms and will not result in “sterile” soil.

Excessive soil heating at high temperatures (generally above 180-212° F [82-100°C]) can increase the potential for phytotoxicity. Soils, especially those containing readily-decomposed organic matter, can develop levels of ammonium, manganese, or other compounds that are phytotoxic to some plants. Phytotoxicity is usually temporary and is reduced over time or with leaching.

5.3.2. Heat treating lumber or other materials contaminated with soil prior to reuse

Lumber, fence posts, and other soil contaminated materials can be treated by solarization or moist or dry heat as described above. The surface of materials to be treated should be moistened prior to beginning treatment, and a temperature probe should be placed in the coolest place in the pile to check that the proper temperature is reached for the necessary time period. If moistening is not feasible, materials treated with dry heat should be treated at higher temperatures and/or longer periods. For 30-minute heat treatments, temperatures had to be increased by up to 36°F (20°C) to kill dry propagules of some plant pathogenic fungi compared to temperatures required for propagules premoistened for 16 hours

5.3.3. Heat treating raw wood to be used in restoration projects

Raw wood imported into a project area should be heat treated prior to importation. Raw wood materials include rootwads or logs used for coarse woody debris. The International Plant Protection Convention (IPPC), a part of the United Nation's Food and Agriculture Organization, has developed an international standard for heat treatment of woody material. The International Standard for Phytosanitary Measures (ISPM) Pub. No.15, "Guidelines for Regulating Wood Packaging Material in International Trade," requires heating wood to a minimum core temperature of 133 °F (56 °C) for a minimum of 30 min. These guidelines are for all forms of wood packaging material that may serve as a pathway for insects posing a threat mainly to living trees. This temperature–time regime was chosen in consideration of the wide range of pests for which this combination is documented to be lethal and a commercially feasible treatment. This standard can be used for treating raw wood imported into projects to eliminate *Phytophthora* and other pests. However, heating to a core temperature of 140 °F (60 °C) for at least 30 minutes provides a higher level of safety.

5.3.4. Soil solarization

For materials heated via solarization, temperatures fluctuate based on sun exposure. The required treatment duration is related to the total amount of time above target temperatures of about 110-125°F (43-52°C). Typical treatment duration for soil solarization is 4 to 6 weeks at the hottest time of the year, but may be shorter if the coolest portions of the treated material routinely reach 125°F (52°C) or more. Efficient solarization requires relatively long daily periods of full solar exposure. It is difficult to reach effective temperatures for a sufficient duration in chronically cloudy or partially shaded sites.

In a static solarization system, soil should be piled no more than 6-10 inches (15-25 cm) deep to facilitate heating to the bottom of the pile. Soil should be moistened to near field capacity before solarization. Solarization should continue until the coolest portion of the soil has been heated to a temperature of 113°F (45°C) for at least 15 hours or a temperature of at least 122°F (50°C) for at least 2 hours. Temperature should be measured by placing temperature probes at several places in the heated material. There are several types of relatively inexpensive temperature probes that will record temperatures over time and are suitable for use.

It may take from several days to more than a week to attain these time/temperature thresholds depending on the weather and your solarization setup. To achieve maximum efficiency, plastic sheeting should be 6 mil (0.15 mm) clear thermal anti-condensate greenhouse film . This material has efficient thermal qualities and a long service life. In cooler areas, using a double layer of plastic film separated by an air gap reduces heat loss.

Alternatively, small amounts of soil can be heated more quickly and efficiently in an insulated solar oven. Heating will be more efficient and uniform if hot air can circulate beneath and around soil container(s) within the solar oven. Solar ovens differ from standard solarization mainly in that the soil is contained in an insulated vessel. Solar ovens can therefore heat faster and achieve higher temperatures than solarized soil, which loses heat to the underlying surface. Using a layer of insulation (e.g., foam insulation) beneath the soil in a standard solarization setup will also reduce heat loss and increase heating efficiency.

Care must be taken to avoid contamination of soil after heat treatment. Heat-treated material should only be transferred into sanitized equipment (bins, trailers, etc.) using sanitized tools by workers with clean gloves following phytosanitary working practices.

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