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Potato Cyst Nematode Eradication in Idaho

Amended Environmental Assessment, July 2007

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Agency Contact:
Osama El-Lissy
Director, Emergency Management
Emergency and Domestic Programs
Animal Plant Health Inspection Service
U.S. Department of Agriculture
4700 River Rd. Unit 134
Riverdale, MD 20737

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I. Purpose and Need

The U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), is proposing a treatment program to eradicate the potato cyst nematode (PCN), *Globodera pallida*. PCN is a devastating soil-borne pest to potato crops with the potential to impact related agricultural and nonagricultural plant species. Damage varies from small patches to complete crop failure. Infestations generally start out as isolated patches which become larger in subsequent years. If untreated, PCN can cause up to 80-percent yield loss in potato fields. The nematode is spread through the transport of soil via seed potatoes, nursery stock, flower bulbs, farm equipment, or soil-bearing surfaces. Although natural dispersion in soil is limited to a few millimeters, wind and water can aid in increasing the natural spread.

PCN was first detected in Idaho during a Cooperative Agricultural Pest Survey in mid-April 2006. In June and July of 2006, two fields were confirmed positive for PCN. On August 29, 2006, APHIS and the Idaho State Department of Agriculture announced the establishment of a regulatory area covering approximately 10,000 acres near Shelly, Idaho. Five new fields tested positive after additional testing within the regulatory area. Surveys of seed potatoes yielded no positive detections of PCN. No additional positive PCN detections were found in surveys conducted throughout the 33 potato-producing States during the National Survey Plan for 2006. A total of 916 acres are currently known to be infected by PCN in seven fields in Bonneville and Bingham Counties, Idaho. At this time, no other infestations are known to occur in the United States.

APHIS has the responsibility for taking actions to exclude, eradicate, and/or control plant pests under the Plant Protection Act (7 U.S.C. 7701 et seq.). It is important that APHIS take the steps necessary to eradicate PCN from areas in Idaho to prevent spread to potato crops in the United States. APHIS, in cooperation with the Idaho State Department of Agriculture, is proposing an eradication program of PCN from the infested areas in Idaho. The eradication program will continue for a period of 5 to 7 years to ensure elimination of the nematode.

An environmental assessment (EA) was prepared in May 2007 to address the potential action of eradicating the PCN where it had been detected near Shelly, ID (USDA APHIS 2007). The EA was prepared consistent with the National Environmental Policy Act of 1969 (NEPA) and APHIS' NEPA implementing procedures (7 CFR, part 372) for the purpose of evaluating how the proposed action, if implemented, may affect the quality of the human environment.

In the EA the treatment alternative consisted of using one, or a combination of fumigants. The fumigants proposed for use were methyl bromide, 1,3-dichloropropene (DCP), and dimethyl disulfide (DMDS). The May 2007 EA analyzed one application of DCP per growing season at an application rate of 177 lb active ingredient (ai) per acre (ac). Subsequently, experience in the field with methyl bromide applications indicated there was a need to have the option to be able to apply DCP, if needed, twice per year. In addition, higher application rates are desired to insure adequate efficacy during treatment. The current pesticide label for DCP, which is sold as Telone II®, does not allow for two applications at a rate above 177 lb ai/ac. However, a special local use need label under Section 24(c) of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is being considered for a new use pattern that allows for either one or two DCP applications per season at a rate of 177 to 354 lb ai/ac per application. This amended EA discusses how the proposed changes in DCP use may affect the quality of the human environment.

II. Background

A. Biology of Potato Cyst Nematode

PCN refers to two commonly known species, *Globodera rostochiensis* and *G. pallida*, which belong to an important group of plant parasitic nematodes that affect agricultural crops. The nematode identified in the proposed eradication program is *G. pallida*.

Typical of most nematode life cycles, *G. pallida* has four distinct juvenile stages and an adult stage. The second-stage juvenile hatches from the egg which is contained within a cyst formed from the cuticle of an adult female. Upon hatching, the second-stage juvenile is considered the active phase because it is the life stage that actively seeks host plants. Hatching occurs based on appropriate environmental factors and the presence of substances diffusing from the roots of host plants within the Solanaceae family, which includes the potato, tomato, and eggplant, as well as other nonagricultural hosts (appendix A). Extensive hatching will occur under optimal conditions; however, some juveniles will always remain dormant for several years, regardless of the conditions, to insure population viability (Turner and Evans, 1998). In cases where a host plant is not present, infestations can persist up to 30 years due to delayed hatching and the ability of the second-stage juvenile to become dormant within the cuticle cyst of the female (Turner, 1996; DEFRA, 1996).

Once the second-stage juvenile encounters a host it will enter the root near the growing point, or a lateral root, and use its mouth, or stylet, to pierce a cell wall. A feeding tube is then formed as a precursor to the formation of a synctium, or transfer cell, which is formed by the enlargement of root cells and breakdown of the cell walls. The synctium facilitates the passage of nutrients to the nematode. In cases where the nematodes are able to maintain the synctium, they will molt to the sedentary third and fourth stages and then molt to either male or female adults. In cases where the synctium cannot be maintained and there is a lack of available nutrients, more male nematodes will be produced. Emergent males do not feed and the fourth-stage male remains within the third-stage cuticle until the final molt to the adult. Likewise, in situations of high-nutrient availability, more females, which require high nutrient levels to facilitate egg production, will be produced.

Third-stage juvenile females develop a sac-like shape that will continue to expand through the fourth stage until the body lies outside the root cortex with only the head remaining in the root area. Once females breach the root zone, they release sex pheromones that attract males for fertilization. After fertilization, embryos will develop in the egg until the second-stage juvenile emerges. Prior to hatching of the second-stage juvenile, the female will die and the cuticle will form a protective cyst that will contain anywhere from 200 to 500 eggs (EPPO, 1990; Turner and Evans, 1998).

Cysts break off from infected plants and remain in the soil until a suitable host plant is present thus allowing the second-stage juvenile to hatch and repeat the life cycle. The number of generations is dependent on environmental factors and host plant suitability, but is typically one generation per year in cooler soils and can be twice per year under the appropriate environmental conditions (Turner and Evans, 1998).

In cases where PCN can establish itself successfully on a host plant, it will reduce the size of the root system and alter total mineral uptake by the plant, resulting in reduced growth and yields due to water stress, altered mineral ratios, and early senescence. The impact on yield is affected by *G. pallida* abundance where numbers can reach 10,000 individuals per gram of soil (DEFRA, 1996). However, nematode-related impacts to yield are also related to environmental factors and different plant cultivars (Phillips et al., 1998).

B. Affected Environment

The current area being considered for treatment consists of several potato fields in the vicinity of Shelley, Idaho, totaling approximately 1,000 acres. The fields are within close proximity of one another and are located in a rural area along with some residences. There are several drinking water wells within the treatment area. No schools or commercial establishments are within the vicinity of the treatment area. The Snake River is adjacent to the treatment area but is still ¼ of a mile away from the PCN-infested area.

III. Alternatives

This EA analyzes the potential environmental consequences of the proposed action to eradicate PCN from fields in Idaho where the nematode has been detected. Two alternatives are being considered: (1) no action by APHIS to eliminate PCN, and (2) the treatment alternative, which includes the application of chemical treatments to eradicate PCN from infested fields in Idaho over a period of 5 to 7 years.

A. No Action Alternative

Under the no action alternative, APHIS would not eradicate PCN from Idaho. A Federal domestic quarantine would remain in effect. Under the quarantine, the infested fields may not grow potatoes, tomatoes, eggplants, or other host crops of PCN. In addition, regulated articles including potatoes, nursery stock, soil, and so forth may not be moved outside the quarantine zone except under specified conditions that these articles are from sites that have been tested and found free of PCN. Farm equipment may not be removed from an infected field unless it has been pressure washed to ensure that all soil has been removed or it has been steam treated in accordance with schedule T406–d of the PPQ Treatment Manual (available online: www.aphis.usda.gov/import_export/plants/manuals/ports/treatment.shtml).

Some control or management measures might be taken by other entities; however, these actions would not be under APHIS' control nor funded by APHIS. In addition, local business owners and area residents could attempt to control PCN. Due to the difficulty in controlling PCN and the several methods of dispersal from infested areas, the nematode would be expected to expand its range into other potato-growing areas, as well as infest areas containing other Solanaceae species. Other agricultural crops, such as tomato and eggplant, could be expected to be impacted, as well as nonagricultural Solanaceae, which could also serve as a source for reinfestation into previously treated fields.

B. Treatment Alternative

This alternative consists of maintaining a Federal quarantine, as well as treatment of currently infested fields, with a chemical treatment in the spring and fall. This twice per year treatment could continue for 5 to 7 years to ensure that PCN is eradicated. PCN population levels will be monitored on a regular basis to assess the progress of the eradication effort. A spring treatment would occur around the first part of May, depending on soil temperature, with the fall treatment occurring approximately August to mid-September. A nonharvested cover planting will be done after the spring treatment. Also a cover planting may be done after the fall treatment; however, this planting will be dependent on weather conditions and pesticide label directions. When appropriate, cover plantings may consist of biofumigants, which are plants that naturally produce secondary products that are toxic to some soil microorganisms, including nematodes. Management of fields during the eradication program, including use of a cover planting, will be established through cooperative grower agreements. In addition, phytosanitary requirements are in place for application equipment to ensure that PCN is not artificially spread from treated fields. Different chemical treatment options are available for spring and fall and are discussed below.

1. Methyl Bromide

A standard application of methyl bromide would be injected approximately 12 inches below the soil surface at a rate of 400 lbs of 98 percent methyl bromide plus 2 percent chloropicrin per acre. Methyl bromide is odorless and the chloropicrin serves as a warning agent. An impermeable tarp will cover the treated field for approximately 4 days to reduce offsite transport and promote degradation of the fumigant.

2. 1,3-Dichloropropene

Telone II®, which contains the active ingredient 1,3 dichloropropene (DCP), will be applied at a rate of 18-36 gallons per acre, or approximately 177-354 lbs active ingredient per acre depending on site conditions. Applications occur as an injection at least 12 inches below the soil surface. The point of injection is sealed by compacting the soil to minimize volatilization. With the proposed special local use label Telone II®can be applied once or twice a year; therefore, in the PCN eradication program, it can be used as a stand alone treatment, or in combination with methyl bromide or dimethyl disulfide (DMDS) in a growing season.

3. Dimethyl Disulfide

DMDS is a new treatment option which is currently under development. DMDS has shown efficacy against a variety of nematodes at rates comparable to methyl bromide. Once DMDS has been registered and labeled for the control of PCN, it will be evaluated as a possible methyl bromide replacement in the PCN eradication program.

IV. Environmental Impacts

A. No Action Alternative

The no action alternative in the PCN program would be the continuation of the domestic quarantine that is currently in place in Idaho. In addition to preventing farmers from growing potatoes and other host crops, the quarantine restricts interstate movement of regulated articles including—

- Potatoes;
- Nursery stock;
- Soil, compost, humus, muck, peat, and decomposed manure;
- Grass sod;
- Small grains and soybeans;
- Hay, straw, fodder, and plant litter;
- Ear corn, except shucked;
- Used farm equipment;
- Any other products, articles, or means of conveyance of any character, whatsoever, when it is determined by an inspector that they present a hazard of the spread of PCN.

The no action alternative would provide a means of slowing the spread of PCN outside of the State but, due to the difficulty in inspecting all the regulated articles listed above, it would be difficult to contain the infested acreage to the small area where it currently occurs. In addition, PCN may be spread by wind dispersal, water runoff from infested fields, and livestock movement from infested areas (Turner and Evans, 1998). PCN would be expected to expand its range beyond the currently infested fields and possibly infect other potato growing areas within the State of Idaho, as well as other potato-growing regions in the United States (figure 1.)

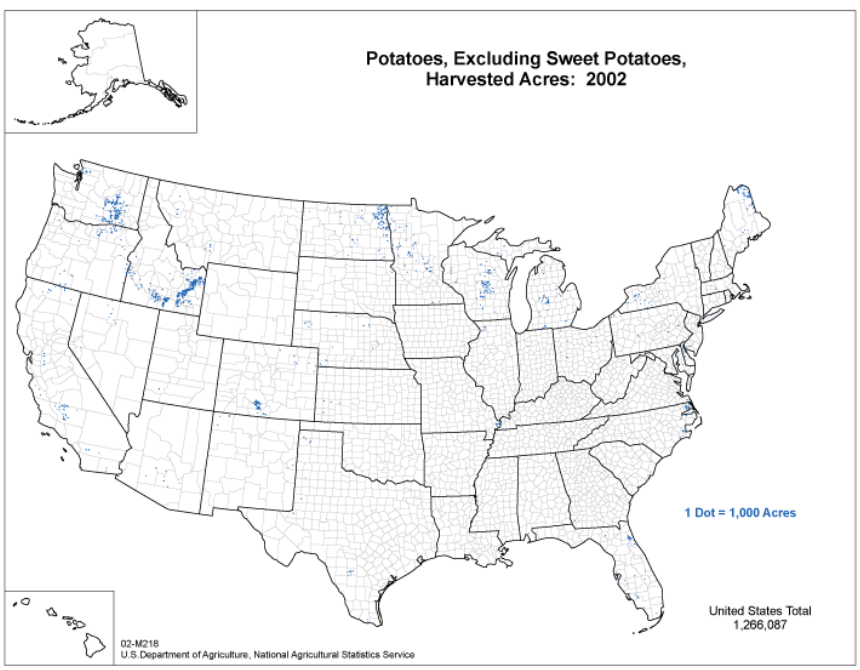


Figure 1. Harvested potato acreage for 2002 in the United States.

Movement of PCN to other potato-growing areas of the United States would eventually result in nematode levels reaching economic threshold levels that would justify additional pesticide applications. Applications to newly infested areas could result in pesticide applications occurring in proximity to sensitive areas that could be a human health and/or environmental concern. The current area of infestation does not occur in an environmentally sensitive area; therefore, risks to human health and the environment are considered minimal.

While the current infestation is localized and affects only potatoes, PCN is known to have additional host plants within the plant family Solanaceae (appendix A). These include other agricultural crops, such as tomatoes and eggplant, and also a wide variety of nonagricultural species. While the impacts of PCN to nonagricultural Solanaceae are unknown, it could impact those species in cases where nematode levels increase to damaging levels. In addition, these areas could serve as sources for PCN to be spread to other areas and be reintroduced into previously treated fields.

Controlling PCN in agricultural and nonagricultural areas would require increased pesticide use that would result in an increase in pesticide loading to the environment with fumigants, such as methyl bromide, as well as other nematicides. High-use rates are common with fumigants so any additional pesticide applications to control PCN could dramatically increase environmental loading while also increasing potential risk. Environmental concerns could result from the increased use of pesticides while also increasing production costs for any crops that would require additional pesticide applications. The eradication of PCN from the relatively small area that has been identified for the current program would mitigate the need for additional pesticide applications over larger geographic areas at a later time, after PCN has spread beyond its current range.

B. Treatment Alternative

This alternative consists of maintaining the quarantine to prevent any futher movement of PCN, and to eradicate PCN from currently infested fields using two pesticide applications per season. The quarantine and associated monitoring for PCN are not expected to have any environmental effects; therefore, the discussion on potential environmental impacts from the preferred alternative will focus on pesticide use.

Pesticides being considered for use in the PCN eradication program are methyl bromide, DCP, and, possibly in the future as a methyl bromide replacement, DMDS. The use of DCP is also considered a methyl bromide replacement fumigant (UNEP, 2002). Based on the current label for methyl bromide and the updated label for DCP, the possible combination of pesticides used in a given season could be two applications of methyl bromide; one application of methyl bromide in the spring followed by a late summer/early fall application of DCP; a spring application of DCP followed by a methyl bromide application in the fall; or two applications of DCP. There could also be a combination of applications such that part of the treatment area is treated with one chemical and the remainder of the treatment area is treated with the other chemical. This would be most likely to occur where the area was treated with DCP and buffer areas around wells and occupied structures were treated with methyl bromide.

A cover planting will be made after the first application with the potential for a winter cover planting to be made after the fall application. The ability to make a winter cover planting will be dependent upon environmental conditions that would allow a cover planting to become established prior to the end of the growing season. A cover planting can be useful to prevent soil erosion due to the winds that are frequent in the treatment area. Cover plantings are ideal to help prevent the spread of PCN via the aid of wind and will be used whenever possible; however, winter cover plantings are not typically used in the area.

The chemical treatments, as applied in this preferred alternative, will result in minimal human health and nontarget effects. This is based on the notices to the public, the adherence to warning signs on the treatment areas, as well as to the adherance to the pesticide labels. There is concern of effects to global warming with the use of methyl bromide because it is a volatile compound and is a known ozone depleting chemical. However, the quantity and use of methyl bromide, under this alternative, will not produce significant effects, as described below.

1. Methyl Bromide/ Chloropicrin

The Environmental Protection Agency- (EPA) approved pesticide label for the proposed application of methyl bromide for the PCN eradication program contains two active ingredients. Methyl bromide is the primary active ingredient comprising 98 percent of the formulated product while chloropicrin makes up the remaining 2 percent of the product. The purpose of adding chloropicrin to the formulation is to act as a warning agent because methyl bromide is odorless, while chloropicrin has a strong odor. Risk profiles for both chemicals are discussed in the following sections.

2. Methyl Bromide

a. Toxicity

Methyl bromide is an odorless gas that has low to moderate toxicity via oral or inhalation exposure. Methyl bromide does have high toxicity through dermal and ocular routes of exposure (EPA, 2006). The median lethal oral dose (LD_{50}) in the rat was 104 milligrams per kilogram (mg/kg), while the median lethal inhalation concentration (LC_{50}) was 780 parts per million (ppm) (EPA, 2005). Neurotoxicity is the major hazard concern in acute and chronic toxicity exposure studies. Decreased activity, ataxia, and tremors are common signs of exposure in inhalation studies using methyl bromide. In developmental inhalation studies using the rabbit, the maternal no observed adverse effects level (NOAEL) was 40 ppm, while the developmental toxicity NOAEL was also 40 ppm. In longer term studies (5 to 7 weeks) using the dog, a systemic NOAEL of 26 ppm was established based on daily doses of methyl bromide. Chronic studies using the rat, over a 127-week period, resulted in a lowest observed adverse effects level of 3 ppm, based on respiratory irritation and a systemic toxicity NOAEL of 30 ppm. Methyl bromide has not been shown to be carcinogenic (EPA, 2006).

In nontarget organisms, such as birds, the clinical signs of toxicity are comparable to mammals. Decreased activity, ataxia, and tremors were noted clinical signs of toxicity for the bobwhite quail and the LD_{50} value was 73 mg/kg with a no observable effect concentration (NOEC) of 33 mg/kg.

Methyl bromide is moderately to highly toxic to aquatic organisms. The range of acute LC_{50} values in five different fish species ranges from 0.7 to 17 ppm. Chronic fish toxicity is lower with a reported NOEC of 0.1 ppm. Toxicity to the freshwater aquatic invertebrate, *Daphnia magna*, appears to be similar to fish with a reported 48-hour LC_{50} value of 2.6 ppm and a NOEC of 1.2 ppm. The breakdown product of methyl bromide, the bromide ion, has also been evaluated for aquatic toxicity and found to be much less toxic to aquatic fauna. For acute exposures to fish and invertebrates, the bromide ion was approximately four to five orders of magnitude less toxic for invertebrates and fish, respectively. Chronic fish toxicity values for the bromide ion were also less toxic than methyl bromide with a NOEC value that is an order of magnitude less than the parent.

b. Exposure and Risk

The primary mechanism of methyl bromide dissipation is through volatilization into the atmosphere. Methyl bromide that does not volatilize is susceptible to hydrolysis (half-life 8 to 30 days), as well as microbial activity, with reported aerobic soil half-lives ranging from 6 to 57 days, depending on soil type. Degradation of methyl bromide is dependent on soil organic matter with increased rates of degradation in soils with increasing levels of organic matter. Methyl bromide degradation in water is somewhat pH-dependent with hydrolysis half-life values ranging from 29 days at a pH of 3, to 9 days at a pH of 8 (EPA, 2005). The high pH of the soil in the areas to be treated will contribute to the rapid breakdown of methyl bromide.

Management techniques in the field can also have a large influence on methyl bromide volatilization and degradation. The use of a tarp after methyl bromide application has been shown to be an effective means of reducing volatilization and increasing degradation of methyl bromide (EPA, 2005). Soil injection has also been shown as an effective means of limiting methyl bromide volatilization (Yagi et al., 1995). Both management actions are to be implemented in the PCN eradication program as a means to limit off-site movement of methyl bromide. Language on the label regarding placards for the site, as well as the use of the warning agent chloropicrin, will further reduce potential human-related exposure. No food crops will be planted in the treated fields during the program which will eliminate risk of dietary exposure.

Exposure is expected to be minimal in both terrestrial and aquatic environments due to the location of the application sites in relation to sensitive areas and the safety language present on the label. While methyl bromide is highly soluble (15.2 g/L) and mobile in soil, the distance of the application area from surface and groundwater precludes any exposure that could impact human health or nontarget aquatic organisms. The closest surface water is approximately 0.25 miles from the application area, while soil type and water table depth mitigate groundwater exposure. Surface to groundwater distance ranges from 35 to 50 feet based on data collected in proximity to the proposed application area (USGS, 2000). The low rainfall in the area, coupled with the ability to manage irrigation water, provide additional confidence that movement of methyl bromide into ground and surface water is unlikely.

Soil invertebrates, as well as any other nontarget animals present during the fumigation and unable to escape, are expected to succumb to the fumigation. The fumigated areas are relatively small and are, thus, likely to be recolonized within a short time. No permanent impact, other than to PCN, is expected.

There is the potential for small nontarget terrestrial organisms to be exposed through inhalation or ingestion of contaminated soil. The proposed treatment areas are agricultural fields which are highly disturbed areas. The likelihood of small terrestrial organisms being exposed is expected to be minimal. The use of a tarp and the warning agent, chloropicrin, will act as a deterrent for small mammals that may try to forage in or near treated fields. Residues in forage from any cover plantings in treated fields would not contain methyl bromide due to the time period between the fumigation and planting. Any exposure to nontarget terrestrial organisms related to the ingestion of treated soil or inhalation should not be at levels sufficient to cause adverse effects. Small terrestrial nontarget organisms that could serve as prey would not be expected to accumulate sufficient residues to impact predators. Methyl bromide has been shown to be rapidly excreted primarily through urine or exhaled as carbon dioxide (EPA, 2006a). The environmental fate and limited exposure pathway, as well as the rapid metabolism of methyl bromide, would suggest that methyl bromide does not accumulate in the tissue of exposed animals.

Methyl bromide has been identified by EPA and the United Nations as a product that can cause ozone layer depletion. However, manmade sources of methyl bromide contribute a minor amount of ozone-depleting compounds to the atmosphere when compared to other chlorine and bromine gas sources (figure 2). Total chlorine gas sources are more than 100-fold above bromine sources.

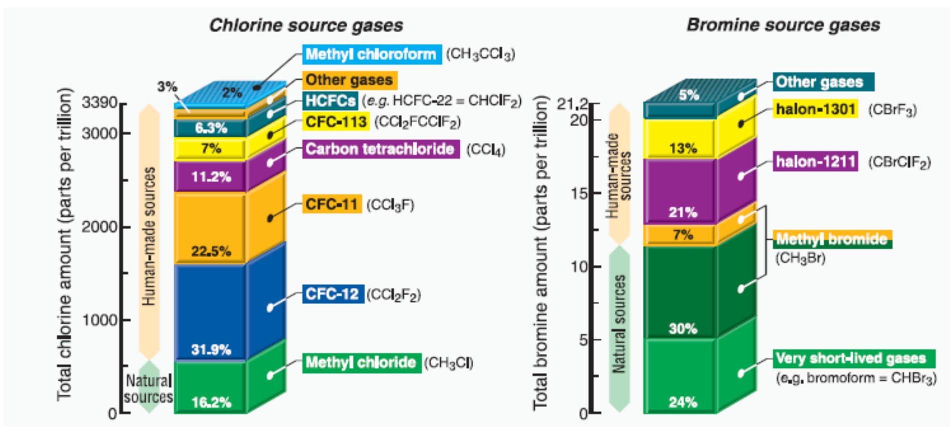


Figure 2. Primary source of chlorine and bromine gases for the stratosphere in 2004. (Source: UNEP, 2006. Twenty Questions and Answers about the Ozone Layer: 2006 Update.)

Atmospheric methyl bromide levels peaked in the mid- to late-1990's and have been decreasing at a rate of 4 to 6 percent per year in the northern hemisphere since 1996 (UNEP, 2007; Yokouchi et al., 2002). While many of the ozone-depleting substances have long half-lives in the atmosphere, the half-life for methyl bromide is comparatively shorter (0.7 years) and, therefore, any decline in methyl bromide use is reflected more quickly in atmospheric levels.

Based on the proposed application rate for the PCN program (400 lb product/acre), and the total global human use of methyl bromide in 2006 (143,000,000 lb), the percent contribution to global human methyl bromide use from the PCN eradication program would be 0.27 percent for one application per season, and 0.55 percent if two applications are made (EPA, 2006b). This is a minor contribution to the total manmade methyl bromide released and an even smaller contribution to all ozone-depleting substances. The additional methyl bromide loading will not occur indefinitely, however, in a worse case scenario would occur twice per season for up to 7 years. Nevertheless, without the proposed PCN eradication program, PCN distribution would be expected to expand into other potato-growing areas in the United States, potentially resulting in a substantial increase in the use of methyl bromide over a much larger area for a longer period of time.

c. Summary

Based on the method of application and the lack of residues from any crop or drinking water, the use of methyl bromide poses minimal risk to human health. The use of methyl bromide also poses minimal risk to nontarget organisms. Aquatic organisms will not be impacted because the application sites are far enough from any water source to minimize residues from drift or runoff. In addition, high soil pH will speed degradation and low rainfall will greatly limit any potential for runoff or leaching into ground and surface waters. Risk to terrestrial organisms (other than the soil invertebrates in the treated fields that are expected to perish) is also minimal due to the method of application and the environmental fate of methyl bromide. Risk to human health and the environment is further reduced by other management practices such as injection of methyl bromide in the soil, posting warning signs at the application site, and the use of a tarp to reduce volatilization and enhance degradation. Potential impact to the ozone layer is also minimal because methyl bromide is not a large source of manmade ozone depleting gases, and its use in this program relative to global methyl bromide use is negligible.

3. Chloropicrin

a. Toxicity

Chloropicrin is a product that is present in the methyl bromide formulation proposed for use in the PCN eradication program. While chloropicrin is a fumigant, when it is applied as 2 percent of the formulation or less, as in this case, it is considered a warning agent preventing accidental fumigant exposure because methyl bromide is odorless. Chloropicrin, when inhaled, causes eye and nasal irritability. It has chemical properties similar to other fumigants, such as high volatility (vapor pressure of 23.8 mm @ 25 ^{o}C) and a low affinity for binding to soil (Koc 36.05 ml/g).

Mammalian toxicity data for chloropicrin demonstrates high acute and chronic toxicity based on acute oral (LD_{50} = 37.5 mg/kg), acute inhalation (LC_{50} = 17 ppm), and chronic inhalation (NOEL = 0.4 ppm) studies. Chronic feeding studies using the rat and dog resulted in a NOAEL value of 0.1 mg/kg/day for both test species based on periportal hepatocyte vacuolation and thyroid C-cell hyperplasia in the rat, and gastrointestinal irritation and blood chemistry alterations in the dog (EPA, 2006c).

No acute or chronic data appear to be available that describe effects to avian species.

Chloropicrin is considered very highly toxic to aquatic organisms, with fish LC_{50} values ranging from 16.5 part per billion (ppb) for the rainbow trout to 105 ppb for the bluegill sunfish. Toxicity to aquatic invertebrates is similar to fish with a 48-hour median effective concentration (EC_{50}) value of 63 ppb for *Daphnia pulex*. No chronic aquatic toxicity values appear to be available for chloropicrin; this may be due to its extremely short half-life in water (EPA, 2006d).

b. Exposure and Risk

Based on the chemical properties of chloropicrin, the primary route of dissipation is through volatilization. Once the material volatilizes, it will photolyze rapidly with half-lives ranging from 3.4 to 8 hours in direct sunlight. Material left in the soil will break down with half-lives ranging from 4.5 to 10 days (EPA, 2006d). No exposure from drift is expected based on the method of application (soil injection approximately 12 inches below the soil surface). In addition, an impermeable tarp will be present on the fields after application further reducing exposure to any nontarget terrestrial organisms. Chloropicrin is highly soluble and mobile; however, due to the low rainfall in the area, the location of the treatment fields relative to aquatic resources and the application method, contamination from runoff or leaching is unlikely. Residues in water and aquatic organisms are not expected. No food crops will be harvested from the treated fields for the duration of the program.

Direct and indirect exposure to nontarget terrestrial organisms (other than soil invertebrates in the treated fields which are expected to succumb) is highly unlikely due to the method of application and the use of an impermeable tarp during treatment. There is a slight possibility that terrestrial prey could be contaminated if they ingest soil from the treated area after tarp removal. However, prey would have to occupy the treated fields immediately after tarp removal to be exposed. Because its use for this application is as a warning agent, any terrestrial prey would most likely not forage in treated areas due to the eye and nasal irritability of chloropicrin. In the event of chloropicrin exposure, residues would not accumulate in tissue based on the low octanol water partition coefficient (2.58) and rapid metabolism in mammals. Risks to human health and the environment are expected to be minimal.

c. Summary

Based on the method of application and the lack of residues from any crop or drinking water, the use of chloropicrin poses minimal risk to human health. The use of chloropicrin also poses minimal risk to nontarget organisms (other than to soil invertebrates in the treated sites which are expected to succumb). Aquatic organisms will not be impacted because of low rainfall in the area and the application sites are far enough from any of the fields to minimize residue from leaching, drift, or runoff. Risk to terrestrial organisms is also minimal due to the method of application and the environmental fate of chloropicrin. Risk to human health and the environment is further reduced by other management practices such as soil injection during application, posting warning signs at the application site, and the use of a tarp to reduce volatilization and enhance degradation. Based on the lack of exposure and available toxicity data, the use of chloropicrin and methyl bromide as a formulated mixture will not significantly increase environmental risk as compared to their associated risks when used individually.

4. DCP

a. Toxicity

DCP is a pre-plant fumigant that has high acute and dermal toxicity while having comparably lower inhalation toxicity. Acute toxicity values for DCP range from an oral rat LD_{50} value of 224 and 300 mg/kg in females and males, respectively. The dermal LD_{50} in rabbits is reported as 333 mg/kg while the inhalation LC_{50} in rats was 3.88 to 4.69 mg/L, depending on sex. In 13-week subchronic feeding studies, the rat and mouse NOEL values were 5 and 15 mg/kg based on basal cell hyperplasia in the stomachs of the rat, and decreased weight gain in the mouse. Subchronic inhalation studies in mice and rats resulted in NOEL values that range from 30 to 90 ppm, based on decreased weight gain, or they were the highest concentration tested.

DCP is considered a carcinogen by EPA based on a 2-year chronic feeding study using rats. The NOEL was determined to be 2.5 mg/kg/day based on an increase in the incidence of basal cell hyperplasia of the nonglandular mucosa of the stomach. The study also revealed hepatocellular adenoma formation at the highest dose tested in the study, 25 mg/kg/day (EPA, 1998).

Developmental studies testing DCP revealed a NOEL of less than 20 ppm in the rat, and a maternal NOEL of 20 ppm in the rabbit. Both values were based on reduced body weight when compared to the controls. In a two-generation inhalation rat study, the parental NOEL was 30 ppm while the reproductive toxicity NOEL was greater than the highest test concentration (90 ppm).

Acute effects to birds demonstrate that DCP is moderately toxic with a reported LD_{50} value of 152 mg/kg for the bobwhite quail. Dietary LC_{50} values for the bobwhite quail and mallard duck are greater than 10,000 ppm; however, these values should be interpreted with caution because the product is highly volatile and was most likely lost during the duration of the study. No chronic avian studies are available due to the short dissipation half-life of DCP.

DCP is considered to be moderately toxic to fish and very highly toxic to aquatic invertebrates based on standard toxicity tests. Several fish LC_{50} values exist for DCP with the most sensitive species being the walleye (LC_{50} = 1.08 ppm) and most tolerant being the bluegill sunfish (LC_{50} = 7.1 ppm). Toxicity to freshwater invertebrates appears to be limited to *Daphnia magna* with a reported 48-hour EC_{50} value of 0.09 mg/L. No chronic aquatic vertebrate or invertebrate data is available due to the short half-life of DCP in aquatic systems.

b. Exposure and Risk

DCP is similar to methyl bromide in that it is highly volatile, water soluble (> 2000 mg/L), and mobile in soil (Kd range 0.23 to 1.09). The dissipation of DCP after application occurs primarily through volatilization, leaching, and anaerobic soil metabolism. Field volatility studies with DCP have shown that 25 percent of the material volatilizes from the field within 14 days, while field dissipation half-lives range from 1 to 7 days. Laboratory metabolism half-life values in soil range from 12 to 54 days under aerobic conditions, but are much shorter under anaerobic soil conditions with a half-life of 2.4 to 9.1 days. Increased microbial degradation of DCP occurs with increasing temperature in most cases (Dungan and Yates, 2003). In aquatic systems, DCP volatilizes from water or can be degraded through hydrolysis. Hydrolysis half-lives are temperature dependent with reported half-lives of approximately 100 days at 2^{o}C, 13 days at 15^{o}C, and 2 days at 29^{o}C. Hydrolysis half-lives do not appear to be pH dependent with a reported half life of 13.5 days for pH values of 5, 7, and 9 at a constant temperature of 20^{o}C (EPA, 1998). DCP that dissipates into the atmosphere is not susceptible to photolysis.

DCP is mobile and has high solubility; however, due to the low rainfall in the area, the distance of the treated fields from surface water (approximately 0.25 miles), and the method of application, no residues are expected to occur via drift or runoff to aquatic water bodies. Site-soil characteristics and the location of the water table (35 to 50 ft) reduce the potential for DCP, or its metabolites, to contaminate groundwater through leaching. Data collected by U. S. Geological Survey (USGS) in soil types similar to those in the area where the eradication program is being proposed demonstrated that DCP residues were at, or below, detection limits at 3 ft below the surface in a majority of the soils tested. One sampling site did have concentrations above the detection limit at 3 ft below the soil surface but levels were low (<3.0 ppb) (USGS, 2000). The label for DCP requires 100-ft buffers adjacent to water wells and occupied structures, further reducing human health risks. Human health risks from dietary exposure through crop residues will not occur because any potential cover plantings will not be harvested from treated fields for the duration of the program.

DCP exposure to terrestrial nontarget organisms can occur through direct or indirect exposure. The likelihood of direct exposure (other than to soil invertebrates in the treated fields) is low because DCP will not drift due to the method of application which involves injecting the material into the soil at a minimum depth of 12 inches. In compliance with the label, the soil will then be sealed by compaction after injection of DCP which serves to reduce volatilization (Wang et al., 2001). Plant residues from a cover planting that could serve as forage for nontarget organisms are not expected due to the lack of residues that have been determined in multiple crop residue studies (EPA, 1998).

Field dissipation and degradation of DCP could result in soil residues that could be ingested by mammals and birds that serve as prey for predators and scavengers. The residues would be low due to the short dissipation half-life and method of application of DCP. Additionally, residues should not be significant based on metabolism studies with DCP. Dosing studies with rats and mice show rapid excretion of DCP through the urine, indicating predators and scavengers would not accumulate significant DCP residues (EPA, 1998); therefore, indirect exposure via contaminated prey is not expected to occur based on the metabolism and environmental fate of DCP.

c. Summary

Based on the method of application and the lack of residues from any crop or in drinking water, the use of DCP poses minimal risk to human health and the environment when applied once or twice per year according to label directions at rates up to 354 pounds of active ingredient per acre. The application site will also be posted to insure no incidental human exposure occurs by accessing treated fields. The use of DCP also poses minimal risk to nontarget organisms. Aquatic organisms will not be impacted because rainfall in the area is low and the application sites are far enough from any water source to minimize residues from drift, runoff, or leaching. Risk to nontarget terrestrial organisms (other than soil invertebrates which are expected to succumb) is also minimal due to the method of application and environmental fate of DCP. Risk to human health and the environment is further reduced by other management practices such as soil injection during application, sealing the injection site to reduce offsite transport, and a 100-ft buffer around water wells and occupied structures.

5. DMDS

a. Toxicity

DMDS is a potential new fumigant that could serve as a methyl bromide replacement in the future in the PCN eradication program. Similar to the other fumigants that are part of the PCN program, DMDS is highly soluble (2700 mg/L), volatile (vapor pressure = 38.8 hPa), and has a low binding affinity for soil (Koc range 15 to 47).

DMDS has low dermal and inhalation toxicity when compared to oral toxicity values. Acute mammalian toxicity data show that the DMDS oral LD_{50} value in rats ranges from 290 to 500 mg/kg, with a dermal toxicity of greater than 2,000 mg/kg, and an inhalation LC_{50} of 805 ppm based on a 4-hour exposure. In longer term studies, DMDS does not appear to cause developmental effects to rats based on inhalation exposure. Repeated exposure to mammals results in eye, skin, and respiratory tract irritation, along with reduced lymphocyte counts, and inflammation of the lymph nodes.

DMDS is moderately toxic to birds with a reported acute oral LD_{50} value for the bobwhite quail of 342 mg/kg and a NOEL of 172 mg/kg. The inhalation LC_{50} for the bobwhite quail is 478 ppm. No chronic avian toxicity data is currently available.

DMDS has moderate to high acute toxicity to aquatic organisms. Aquatic toxicity values for DMDS range from a 96-hour LC_{50} value of 0.97 ppm for the rainbow trout, to a value of 5.01 ppm for the zebrafish. The NOEC values in both LC_{50} studies were 0.54 ppm and 3.30 ppm for the rainbow trout and zebrafish, respectively. Acute freshwater invertebrate sensitivity is represented by *D. magna* with a 48-hour EC_{50} value of 1.82 ppm (NOEC = 0.62 ppm).

b. Exposure and Risk

Similar to most fumigants, volatilization is a major dissipation pathway for DMDS. This chemical is hydrolytically stable at relevant pH values but has a half-life of 8.7 days (summer) and 64.6 days (winter), based on photolytic half-life values. DMDS is susceptible to microbial breakdown with aerobic soil metabolism half-life values ranging from 2.69 to 3.04 days. Under anaerobic soil conditions, DMDS has a reported half-life of 14.3 days. In aquatic environments, DMDS dissipation half-lives range from 3.5 to 45 hours, suggesting a short period of exposure in aquatic environments.

Based on the application method of injecting DMDS into the soil, low area rainfall, and the distance of the application areas to aquatic areas (a minimum of 0.25 miles), no off-site movement from drift, runoff, or leaching to aquatic systems is expected. Human health-related exposure is not expected at the time of exposure due to the application method and other precautionary statements that would be part of the proposed label. No food crops will be harvested from treated areas for the duration of the program which will preclude risk from dietary exposure to human health.

Risk to nontarget organisms (other than soil invertebrates which are expected to succumb) is also expected to be minimal. Off-site movement from drift, runoff, or leaching are not expected based on the distance of the fields from aquatic resources. In cases where DMDS could reach aquatic areas, its half-life in water is extremely short, further reducing risk to aquatic nontarget organisms. Exposure and risk to terrestrial nontarget organisms is also minimal due to the method of application, the toxicity of DMDS, and its environmental fate. There is the possibility that small mammals could be exposed to treated soil immediately after application. Potentially exposed organisms are not expected to accumulate DMDS because it does not appear to be a compound that would accumulate in tissue due to its volatility and low octanol/water partition coefficient (1.77). In addition, aerobic soil metabolism half-life data suggests that the material would only be available for a short period of time.

c. Summary

Based on the method of application and the lack of residues from any crop or drinking water, the use of DMDS poses minimal risk to human health. The use of DMDS also poses minimal risk to nontarget organisms. Risks to aquatic organisms will be minimal because rainfall is low in the area and the application sites are far enough from any water bodies to minimize residue from drift or runoff. Risk to terrestrial organisms, other than soil invertebrates, is also minimal due to the low inhalation toxicity, method of application, and the environmental fate of DMDS.

C. Cumulative Effects

Cumulative effects from the preferred alternative relate to the management actions in the proposed treatment area. The fields are currently potato fields which will be taken out of production for the duration of the eradication program. A cover planting will be made after the first application to reduce the potential for soil erosion; therefore, no cumulative impacts related to soil erosion are expected. A cover planting may be used in the winter; however, it will be dependent on whether environmental conditions allow the planting to establish prior to the end of the growing season. Historically, winter cover plantings are not used in this area; therefore, any soil erosion related to the preferred alternative is not expected to be any greater than would occur under typical agricultural practices in the area.

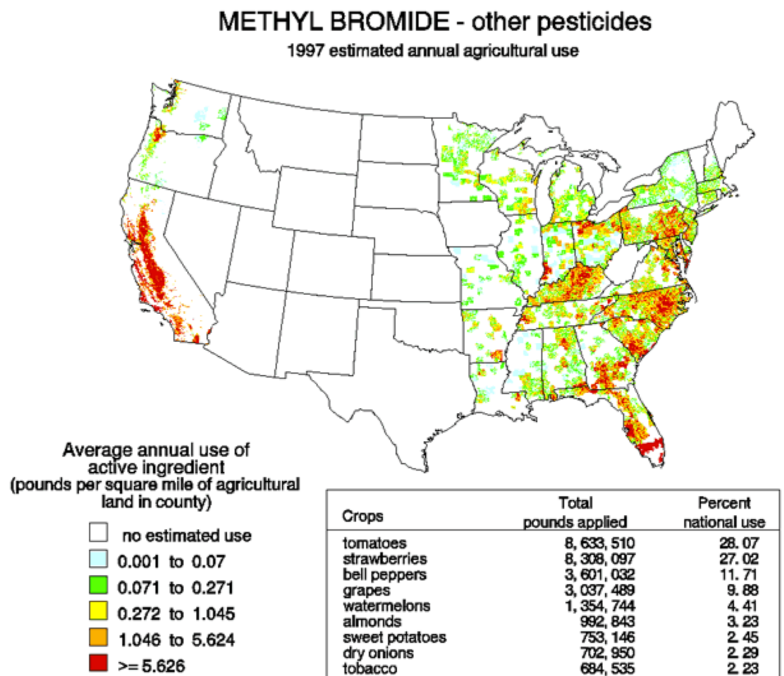
Based on the preferred alternative of two pesticide applications per season, the potential cumulative effects of each pesticide that could be used for a given application will be discussed individually.

1. Methyl Bromide

Cumulative effects on aquatic resources from methyl bromide applications are not expected due to the distance from the application area to aquatic resources and the method of application which would mitigate potential risk to surface and groundwater resources. Applications for the PCN eradication program would not have any cumulative effects on surface or groundwater quality. The approximately 1,000-acre treatment area is composed of potato fields that will not be planted with crops that could provide residues for human health exposure; therefore, there would be no cumulative effects from additional methyl bromide crop residues. As previously discussed, methyl bromide is a highly volatile fumigant that can impact air quality and has been identified as an ozone depleting compound. The impact of methyl bromide on air quality, as it relates to other methyl bromide use on a local level, is expected to be minimal. Based on use-data from 1997, no agricultural methyl bromide use takes place in the area where applications are being proposed (figure 3).

Cumulative impacts on overall air quality are expected to be minimal based on the environmental fate of methyl bromide and the current air quality in the area where applications are expected to occur. The Idaho Department of Environmental Quality (DEQ) monitors air quality in different areas of the State to determine attainment based on six priority pollutants. The priority pollutants are particulate matter, carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, and lead. Non-attainment has previously occurred in four different areas of the State; however, none of the areas are within the proposed area for treatment. Based on data from the Idaho DEQ, the air quality in proximity to the proposed treatment area meets all Federal and State standards (Idaho DEQ, 2005, 2006). Methyl bromide is not one of the priority pollutants considered by the Idaho DEQ, and its use in the PCN eradication program should not affect currently monitored priority pollutants, or the ability of the area to maintain attainment.

On a global scale, the use of methyl bromide in the PCN eradication program will contribute to the overall release of manmade ozone-depleting substances. However, relative to the global use of methyl bromide, two applications per year of methyl bromide in the PCN eradication project equates to approximately 0.55 percent of the total annual manmade methyl



Crops	Total pounds applied	Percent national use
tomatoes	8, 633, 510	28. 07
strawberries	8, 308, 097	27. 02
bell peppers	3, 601, 032	11. 71
grapes	3, 037, 489	9. 88
watermelons	1, 354, 744	4. 41
almonds	992, 843	3. 23
sweet potatoes	753, 146	2. 45
dry onions	702, 950	2. 29
tobacco	684, 535	2. 23
cucumbers	555, 569	1. 81

Figure 3. Estimated methyl bromide use in the United States.
(Source: USGS, 2000. Method for Estimating Pesticide Use for County Areas in the Conterminous United States.)

bromide use. When compared to all sources of chlorinated and brominated ozone-depleting substances, the proposed use represents an even smaller fraction of the total amount of ozone depleting compounds (figure 2). The current estimate assumes both applications will be made using methyl bromide which is not likely to occur throughout the duration of the 5- to 7-year eradication program. In some cases, DCP will be the product applied in the spring and/or fall, reducing methyl bromide use in half or nearly completely for those years. In addition, DMDS could be registered for PCN control in the future and serve as a replacement for methyl bromide, thus, reducing it use even further.

2. DCP

The potential cumulative impacts of DCP to aquatic resources are similar to those stated for methyl bromide. The distance of aquatic resources from the application area is approximately 0.25 miles, and, due to the method of application that has been described previously, no runoff or drift is expected to reach surface water. The label for DCP does contain a groundwater advisory; however, the soil conditions and depth to the water table reduce the likelihood of DCP, used at the maximum label rates allowed under the proposed special local use label, moving into groundwater. DCP is regularly used in the eradication area; however, groundwater monitoring for DCP and its metabolites have shown no historical detections (USGS, 2000).

Based on the chemical properties of DCP, it will volatilize into the atmosphere. Additional DCP use does occur in Idaho primarily on potatoes, sugar beets and onions. Cumulative impacts related to air quality could occur in those areas where other potato fields are being treated, or, if sugar beets, and onions are grown in proximity to fields that are part of the eradication program. Currently, neither sugar beets nor onions are grown near the PCN-infested fields. The potential cumulative impacts to air quality would be minimal due to temporal differences in the PCN-related DCP applications. For a majority of uses, DCP is used as a pre-plant fumigant which would mean applications would occur just prior to the growing season in early spring. The projected applications for DCP in the PCN eradication program will typically occur late summer or early fall, at a time when any volatilized DCP from earlier applications would have dissipated and been dispersed by wind. If PCN eradication efforts resulted in spring applications of DCP at the 36 gallons per acre maximum rate (a distinct possibility), even when combined with other spring DCP applications that may occur in the area, cumulative effects to air quality would be expected to be minimal due to efforts to minimize volatilization by soil injection and sealing the soil where injections occur.

In cases where both applications during a growing season are made using DCP, a reduction in the use of methyl bromide would occur since the DCP application would largely replace the methyl bromide application. Methyl bromide would only continue to be used in the buffer areas around wells and occupied structures. This would almost eliminate the negligible cumulative effects related to ozone depletion from the use of methyl bromide that were identified in this EA.

3. DMDS

Uncertainty exists regarding the potential cumulative effects of DMDS use in the PCN eradication program. The product is still in the development and research phase, and the number of crops intended for use is currently unknown. If the product gains registration approval, DMDS could replace some methyl bromide applications. Because there currently is little to no methyl bromide use in the general area where the eradication program is proposed, its cumulative effects would be expected to be minimal on air quality even if it replaced all methyl bromide uses. No cumulative effect on aquatic resources and crop residues would be expected because of the environmental fate properties of DMDS in addition to the reasons previously discussed for methyl bromide and DCP. Upon registration, to the extent that it serves as a replacement product for methyl bromide, it would reduce the quantity of ozone depleting compounds released into the atmosphere.

D. Threatened and Endangered Species

Section 7 of the Endangered Species Act (ESA) and its implementing regulations require Federal agencies to ensure that their actions are not likely to jeopardize the continued existence of endangered or threatened species or result in the destruction or adverse modification of critical habitat. APHIS prepared a biological assessment that considered the impact of the PCN eradication program on threatened and endangered species in or near the program area. Upon concluding the assessment, APHIS determined that the proposed eradication program will have no effect on the Utah valvata snail (*Valvata utahensis*) and may affect, but is not likely to adversely affect the bald eagle (*Haliaeetus leucocephalus)*. The proposed changes in treatment options will not change the effects determination for the species.

In accordance with the Section 7 consultation process, the biological assessment was submitted to the U.S. Fish and Wildlife Service (FWS), Eastern Idaho Field Office in Chubbuck, Idaho. FWS has concurred that the proposed eradication program will have no effect on the Utah valvata snail and is not likely to adversely affect the bald eagle. Since the preparation of the biological assessment and the FWS concurrence, the bald eagle has been delisted and effective August 8, 2007 is no longer subject to the Endangered Species Act.

V. Other Considerations

Executive Order (EO) 13175, "Consultation and Coordination with Indian Tribal Governments," was issued to ensure that there would be "meaningful consultation and collaboration with tribal officials in the development of Federal policies that have tribal implications…." There are no tribal lands in the vicinity of the proposed eradication project. Thus, the initiation of this project will have no direct impact to Native Americans. However, if PCN were to spread from the currently infested fields, there is a potential to impact all potato growers, including those who are Native Americans. Federal and State agriculture officials have consulted and collaborated with Indian tribal officials to ensure that they are well-informed and represented in policy and program decisions that may impact their agricultural interests. Collaboration with the Native American officials will continue, as appropriate, until the proposed eradication of PCN is achieved.

EO 12898, "Federal Actions to Address Environmental Justice in Minority Populations and Low-income Populations," focuses Federal attention on the environmental and human health conditions of minority and low-income communities and promotes community access to public information and public participation in matters relating to human health or the environment. This EO requires Federal agencies to conduct their programs, policies, and activities that substantially affect human health or the environment in a manner so as not to exclude persons and populations from participation in or benefiting from such programs. It also enforces existing statutes to prevent minority and low-income communities from being subjected to disproportionately high or adverse human health or environmental effects. APHIS has determined that the environmental and human health effects from the proposed changes in treatment options available for eradication of PCN in Idaho are minimal and are not expected to have disproportionate adverse effects to any minority or low-income populations.

EO 13045, "Protection of Children from Environmental Health Risks and Safety Risks," acknowledges that children, as compared to adults, may suffer disproportionately from environmental health and safety risks because of developmental stage, greater metabolic activity levels, and behavior patterns. This EO (to the extent permitted by law and consistent with the agency's mission) requires each Federal agency to identify, assess, and address environmental health risks and safety risks that may disproportionately affect children. Applications will not occur in proximity to schools, parks, or day care facilities where children may be present. In addition, the method of application and management of the fields will minimize residues from drift, volatilization, and dietary exposure. Based on the distance of the application area from surface and groundwater resources, no residues from any of the proposed fumigants would be expected in drinking water. A cover planting will be planted between applications and possibly after the fall application; however, none of the planting will be harvested for human or livestock consumption. None of the alternatives and proposed amendments being considered are expected to have disproportionately high or adverse human health or environmental effects to children.

VI. Listing of Agencies and Persons Consulted

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
State Plant Health Director
9134 W. Blackeagle Drive
Boise, ID 83709

Idaho Program Director
U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Idaho Falls, ID 83042

Regional Program Manager
U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Western Regional Office
2150 Centre Avenue, Bldg B
Ft. Collins, CO 80526

Assistant Regional Director
U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Western Regional Office
2150 Centre Avenue, Bldg B
Ft. Collins, CO 80526

Bureau Chief
Plant Industries Division
Idaho State Department of Agriculture
P.O. Box 790
Boise, ID 83701

Vice President, Legal & Government Affairs
Idaho Potato Commission
661 South Rivershore Lane, Suite 230
Eagle, ID 83616–5397

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
Emergency Management
4700 River Road, Unit 134
Riverdale, MD 20737–1236

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Policy and Program Development
Environmental Services
4700 River Road, Unit 149
Riverdale, MD 20737–1238

U.S. Department of Agriculture
Animal and Plant Health Inspection Service
Plant Protection and Quarantine
Environmental Compliance
4700 River Road, Unit 150
Riverdale, MD 20737–1229

U.S. Fish and Wildlife Service
Eastern Idaho Field Office
4425 Burley Drive, Suite A
Chubbuck, ID 83202

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Appendix A: Potential Host Plants for *Globodera pallida*

Bold= confirmed in the literature
Non Bold = listed in either CABI Compendium or GPDD

Note: Most papers were prepared before *Globodera pallida* was distinguished from *G. rostochiensis*. Many older papers refer to the potato cysts nematodes as a strain of *Heterodera schachtii*.

Primary Hosts:
Lycopersicon esculentum (tomato)
Solanum melongena (eggplant, aubergine)
Solanum tuberosum (potato)

Minor Hosts:
Datura stramonium (Devil's trumpet, Jamestown-weed)
Lycopersicon pimpinellifolium (currant tomato) (syn. **Lycopersicon racemigerum)**
Oxalis tuberosa (oca)
Solanum aviculare (kangaroo apple)
Solanum gilo (syn. Solanum integrifolium) (scarlet or tomato eggplant)
Solanum indicum (Indian nightshade)
Solanum marginatum (white-edged (margined) nightshade)
Solanum mauritianum (tree tobacco, earleaf nightshade)
Solanum nigrum (black nightshade) (Winslow (1954) found as a non-host, appears there are multiple varieties that vary in susceptibility/resistance (Scholte (2000)).
Solanum quitoense (Naranjillo)
Solanum sarrachoides (hairy nightshade)

Other hosts:
Atropa belladonna? (deadly nightshade) - Reported as a host by Franklin (1940), Found to be negative by Winslow (1954)
Datura tatula (jimsonweed)
Hyoscyamus niger (black henbane)
Lycopersicon esculentum aureum
Lycopersicon glandulosum (Peruvian nightshade)
Lycopersicon hirsutum (hairy tomato)
Lycopersicon mexicanum
Lycopersicon peruvianum (wild tomato)
Lycopersicon pyriforme (garden tomato)
Physalis philadephica (Mexican groundcherry)
Physochlainia orientalis (purple trumpet flowers)

Salpiglossis spp. (painted tongue)
Saracha jaltomata

Other *Solanum spp.*
Solanum acaule (Wild Andean potato)
Solanum aethiopicum (Ethiopian nightshade, African eggplant)
Solanum ajanhuiri (Ajanhuiri)
Solanum alandiae
Solanum alatum (red fruited nightshade)
Solanum americanum (American black nightshade)
Solanum anomalocalyx
Solanum antipoviczii *(now* ***S. stoloniferum*****)**
Solanum armatum (forest nightshade)
Solanum ascasabii
Solanum asperum
Solanum berthaultii (wild potato)
Solanum blodgettii (mullein nightshade)
Solanum boergeri
Solanum brevimucronatum
Solanum brevidens (wild potato-diploid)
Solanum bulbocastanum **–** (ornamental nightshade) - also listed as *S. bulbocastana*
Solanum calcense
Solanum calcense x Solanum cardenasii
Solanum caldasii
Solanum canasense
Solanum capsibaccatum
Solanum capsicoides (cockroach berry)
Solanum cardiophyllum (heartleaf horsenettle)
Solanum carolinense (Carolina horsenettle)
Solanum chacoense **–** (Chaco potato) also reported as *S. chacoense* v. *subtilis*
Solanum chaucha
Solanum chenopodioides
Solanum chloropetalum
Solanum citrullifolium (watermelon nightshade) **–** also listed as *S. citrillifolium*
Solanum coeruleifolium (chaucha)
Solanum commersonii (Commerson's nightshade)
Solanum curtilobum (rucki)
Solanum curtipes
Solanum demissum (nightshade)
Solanum demissum x Solanum tuberosum
Solanum dulcamara (bittersweet)
Solanum durum
Solanum elaeagnifolium (silverleaf nightshade)

Solanum famatinae
Solanum fraxinifolium
Solanum fructo-tecto
Solanum garciae
Solanum gibberulosum
Solanum giganteum (African holly)
Solanum gigantophyllum
Solanum glaucophyllum (waxyleaf nightshade)
Solanum goniocalyx (yellow potato)
Solanum gracile (whitetip nightshade)
Solanum heterodoxum (melonleaf nightshade)
Solanum heterophyllum (unarmed nightshade)
Solanum hirtum (huevo de gato)
Solanum hispidum (devil's fig)
Solanum intrusum (garden huckleberry)
Solanum jamesii (wild potato)
Solanum jujuyense
Solanum juzepczukii (ckaisalla)
Solanum kesselbrenneri (phureja)
Solanum kurtzianum
Solanum lanciforme (heartleaf nightshade)
Solanum lapazense
Solanum lechnoviczii
Solanum leptostygma (potato)
Solanum longipedicellatum *(now S. stoloniferum)*
Solanum luteum (red-fruited nightshade)
Solanum macolae
Solanum macrocarpon (African eggplant)
Solanum maglia
Solanum mamilliferum (chauca)
Solanum miniatum (red-fruited nightshade)
Solanum multidissectum
Solanum muricatum (pepino melon)
Solanum nitidibaccatum (Argentinian nightshade)
*Solanum ochroleucum (*syn. *S. nigrum)*
Solanum ottonis (divine nightshade)
Solanum pampasense
Solanum parodii
Solanum penelli
Solanum phureja (chauca)
Solanum photeinocarpum (terimini inuhoozuki)
Solanum pinnatisectum (tansyleaf nightshade)
Solanum platypterum
Solanum platense
Solanum polyacanthos
Solanum polyadenium (potato)

Solanum prinophyllum (forest nightshade)
Solanum radicans (cusmayllo)
Solanum raphanifolium (wild potato)
Solanum rostratum (buffalobur nightshade)
Solanum rybinii (phureja)
Solanum salamanii
Solanum saltense
Solanum sambucinum
Solanum sanctae-rosae
Solanum scabrum
Solanum schenkii
Solanum schickii
Solanum semidemissum
Solanum simplicifolium
Solanum sinaicum (nightshade)
Solanum sisymbrifolium? (sticky nightshade) (According to Scholte (2000)). *S. sisymbriifolium* combines a high hatching effect with complete resistance to *Globodera rostochiensis* and *G. pallida*).
Solanum sodomaeum (apple of Sodom)
Solanum soukupii
Solanum sparsipilum
Solanum stenotomum (pitiquina)
Solanum stoloniferum
Solanum suaveolens
Solanum subandigenum (Andigena)
Solanum sucrense
Solanum tarijense
Solanum tenuifilamentum (chauca)
Solanum tomentosum
Solanum toralopanum (apharuma)
Solanum triflorum (cutleaf nightshade)
Solanum tuberosum ssp. andigena (potato)
Solanum tuberosum ssp. tuberosum (Irish potato)
Solanum tuberosum 'Aquila',
Solanum tuberosum ' Xenia N'
Solanum utile- South American genus-strongly attacked
Solanum vallis-mexicae
Solanum vernei (purple potato)
Solanum verrucosum
Solanum villosum (red-fruited nightshade)
Solanum violaceimarmoratum
Solanum wittmackii
Solanum wittonense
Solanum xanti (chaparral nightshade)
Solanum yabari (pitiquina)
Solanum zuccagnianum (gilo)

Web Resources:

CABI Crop Compendium. www.cabicompendium.org
Extensive list of hosts. List *Salpiglossis spp.* that are actually *Solanum spp.*

Global pest and disease database. https://www.gpdd.info.
Extensive list of hosts.

HYPP Zoology. *Globodera rostochiensis* (Wollenweber, {Globodera pallida (Stone)}
http://www.inra.fr/Internet/Produits/HYPPZ/RAVAGEUR/6gloros.htm

This species exclusively parasitizes the Solanaceae, especially potato, tomato, egg plant and a few volunteer plants such as bittersweet (*Solanum dulcamara*) and henbane (*Hyoscyamus niger*).

Society of Nematologists. *Globodera pallida*.
http://nematode.unl.edu/pest5.htm

Potato (*Solanum tuberosum*) is the major host. Other hosts include many *Solanum* species, oca (*Oxalis tuberosa*), jamestown-weed (*Datura stramonium*), tomato (*Lycopersicon* spp.), and *Salpiglossis* spp.

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