Risks of Linuron Use to Federally Threatened California Red-legged Frog (*Rana aurora draytonii*)

Pesticide Effects Determination

Environmental Fate and Effects Division
Office of Pesticide Programs
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1. Executive Summary

The purpose of this assessment is to evaluate potential direct and indirect effects on the California red-legged frog *(Rana aurora draytonii*) (CRLF) arising from FIFRA regulatory actions regarding use of linuron on agricultural and non-agricultural sites. In addition, this assessment evaluates whether these actions can be expected to result in modification of the species' designated critical habitat. This assessment was completed in accordance with the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) *Endangered Species Consultation Handbook* (USFWS/NMFS, 1998) and procedures outlined in the Agency's Overview Document (U.S. EPA, 2004).

The CRLF was listed as a threatened species by USFWS in 1996. The species is endemic to California and Baja California (Mexico) and inhabits both coastal and interior mountain ranges. A total of 243 streams or drainages are believed to be currently occupied by the species, with the greatest numbers in Monterey, San Luis Obispo, and Santa Barbara counties (USFWS, 1996) in California.

Linuron [3-(3,4-dichlorophenyl)-1-methoxy-1-methylurea], first registered in 1966, is a substituted urea herbicide registered for use on asparagus, carrots, celery, corn (field and sweet), cotton, parsley, parsnips, sorghum, and soybeans, turnip, wheat (winter), kenaf for pulp and fiber production, bulb flowers (e.g., Calla lily, daffodil, tulip, iris), marigolds (grown for seed) and agricultural fallow/idle land. Linuron is also used in non-cropland environments, including: non-agricultural rights-of-way (e.g., fencerows and hedgerows), non-agricultural uncultivated areas, ornamental plants, and poplar trees. Label language either restricts or prohibits a number of these uses in California (e.g., use on poplar trees is only registered for the Midwest and cotton use is registered for east of the Rocky Mountains). This assessment evaluates only those registered uses which allow use in California. Linuron is registered for application preplant, preemergence, postemergence, or post-transplant using ground equipment. The registered modes of application are band treatment, directed spray, or broadcast spray. The end-use formulations of linuron include wettable powder (50% a.i.), flowable concentrate (40.6% a.i.), water dispersible granules (50% a.i.), and liquid suspensions. There are currently 23 end-use products and 5 technical products registered for linuron.

Linuron acts on target plants as a photosynthesis inhibitor by inhibiting the photosystem II reaction center. It has low acute toxicity to mammals and birds but has chronic toxicity to mammals, birds, fish, and aquatic invertebrates.

In non-target mammals it is a demonstrated endocrine disruptor. There is ample evidence from special studies submitted by the registrant as well as open literature studies which indicate that linuron is an endocrine disruptor. These findings include, in part: (1) competitive androgen receptor antagonist; but not an estrogen receptor antagonist; (2) competitive inhibition of the transcriptional activity of dihydrotestosterone (DHT)-human androgen receptor (hAR) in vitro, decreased anogenital distance and/or an increase in the retention of areolae/nipples in male offspring following in utero exposure to linuron; (3) inhibition of steroidogenic enzymes, and (4) decreased responsiveness of Leydig cells to luteinizing hormone in both immature (22 days) and mature (11 months) male rats treated with linuron, mature rats were less responsive than immature ones; (5) F0 and F1 males had significantly increased levels of estradiol and luteinizing hormone[1].

Linuron is an animal carcinogen. Oncogenicity studies in the rat and mouse did not show consistent tumor profiles between sexes and species. In the combined chronic toxicity/oncogenicity study in rats, common neoplasms, included pituitary adenomas of the pars anterior in both male and female rats and mammary fibroadenomas in female rats. Testicular adenomas were observed in 6%, 28% and 54%, respectively for control, 125 and 625 ppm dose groups. Decreased incidences of both these tumor types were noted in the high-dose female group. In the mouse oncogenicity study, treatment of up to 104 weeks with 1500 ppm resulted in a significant increase in the incidence of hepatocellular adenomas (control, 6%; 1500 ppm, 25%, $p < 0.05$) in females. Linuron was not mutagenic in bacteria or in cultured mammalian cells. There was also no indication of a clastogenic effect up to toxic doses in vivo. Based on the results of these studies, linuron was classified as an unquantifiable Group C carcinogen (a possible human carcinogen for which there is limited animal evidence) requiring no quantification of human cancer risk [1].

Linuron has a half-life of less than 60 days, and is only slightly mobile. Increased mobility may occur under specific environmental conditions such as in coarse textured soils and soils with low levels of organic matter. Linuron dissipates by abiotic and biotic processes such as microbial degradation. In surface soils with adequate organic matter, the combined processes of adsorption and microbial degradation would limit linuron's potential to migrate to ground water. Linuron could run off to surface water bodies. In that case, given half-life values ranging from 21 to 49 days, it would slowly degrade to three primary metabolites. However, information on the persistence and mobility of these degradates is not currently available.

Since CRLFs exist within aquatic and terrestrial habitats, exposure of the CRLF, its prey and its habitats to linuron are assessed separately for the two habitats. Tier-II aquatic exposure models are used to estimate high-end exposures of linuron in aquatic habitats resulting from runoff and spray drift from different uses. Peak model-estimated environmental concentrations resulting from different linuron uses range from 6.9 to 60.3 µg/L. These estimates are supplemented with analysis of available California surface water monitoring data from U. S. Geological Survey's National Water Quality Assessment (NAWQA) program and the California Department of Pesticide Regulation. The maximum concentration of linuron reported by NAWQA for California surface waters with agricultural watersheds is 0.71 µg/L. This value is approximately 85 times lower than the maximum model-estimated environmental concentration.

To estimate on-site linuron dietary exposures to the terrestrial-phase CRLF, and its potential prey resulting from uses involving linuron applications, the T-REX model is

[1] **HED Chapter for the Linuron Tolerance Reassessment Eligibility Decision**
PC Code: 035506. Case 0047. DP Barcode D271950 FROM: Carol Christensen, Risk Assessor Reregistration Branch II Health Effects Division (7509C)

used for spray treatment. AgDRIFT and AGDISP models are also used to estimate deposition of linuron on off-site terrestrial and aquatic habitats from spray drift. The TerrPlant model is used to estimate linuron exposures to terrestrial-phase CRLF habitat, including plants inhabiting semi-aquatic and dry areas, from site run-off and spray drift. The T-HERPS model is used to allow for further characterization of dietary exposures of terrestrial-phase CRLFs relative to birds.

The effects determination assessment endpoints for the CRLF include direct toxic effects on the survival, reproduction, and growth of the CRLF itself, as well as indirect effects, such as reduction of the prey base or modification of its habitat. Direct effects to the CRLF in the aquatic habitat are based on toxicity information for freshwater fish, which are generally used as a surrogate for aquatic-phase amphibians. In the terrestrial habitat, direct effects are based on toxicity information for birds, which are used as a surrogate for terrestrial-phase amphibians. Given that the CRLF's prey items and designated critical habitat requirements in the aquatic habitat are dependant on the availability of freshwater aquatic invertebrates and aquatic plants, toxicity information for these taxonomic groups is also discussed. In the terrestrial habitat, indirect effects due to depletion of prey are assessed by considering effects to terrestrial insects, small terrestrial mammals, and frogs. Indirect effects due to modification of the terrestrial habitat are characterized by available data for terrestrial monocots and dicots.

Risk quotients (RQs) are derived as estimates of potential risk. Acute and chronic RQs are compared to the Agency's levels of concern (LOCs) to identify instances where linuron use within the action area has the potential to adversely affect the CRLF and its designated critical habitat via direct toxicity or indirectly based on direct effects to its food supply (i.e., freshwater invertebrates, algae, fish, frogs, terrestrial invertebrates, and mammals) or habitat (i.e., aquatic plants and terrestrial upland and riparian vegetation). When RQs for each particular type of effect are below LOCs, the pesticide is determined to have "no effect" on the CRLF. Where RQs exceed LOCs, a potential to cause adverse effects is identified, leading to a conclusion of "may affect." If a determination is made that use of linuron within the action area "may affect" the CRLF and its designated critical habitat, additional information is considered to refine the potential for exposure and effects, and the best available information is used to distinguish those actions that "may affect, but are not likely to adversely affect" (NLAA) from those actions that are "likely to adversely affect" (LAA) the CRLF and its critical habitat.

For those linuron uses that are prohibited from use in California, the Agency makes a No Effect determination on the CRLF because exposure would not occur; these uses are: cotton, hybrid poplar, parsley, parsley grown for seed, potato, winter wheat, and post harvest and fallow ground.

The Agency has determined that there is a "May affect, likely to adversely affect" (LAA) for direct and indirect effects to the CRLF. Additionally, the Agency has determined that there is the potential for modification of CRLF designated critical habitat from the use of the chemical. Based on the best available information, the Agency makes a May Affect,

and Likely to Adversely Affect determination for linuron exposure to the CRLF based on direct and indirect effects to the aquatic- and terrestrial-phase CRLF.
A summary of the risk conclusions and effects determinations for the CRLF and its critical habitat is presented in Tables 1.1 and 1.2. Use-specific determinations for direct and indirect effects to the CRLF are provided in Tables 1.3 and 1.4. Further information on the results of the effects determination is included as part of the Risk Description in Section 5.2.

Table 1.1 Effects Determination Summary for Effects of Linuron on the CRLF

Assessment Endpoint	Effects Determination [1]	Basis for Determination
Survival, growth, and/or reproduction of CRLF individuals	LAA	Potential for Direct Effects
		Aquatic-phase (Eggs, Larvae, and Adults): There are no acute LOC exceedances for freshwater fish (as a surrogate to the aquatic-phase frog). Chronic LOC is exceeded for freshwater fish (as a surrogate to the aquatic-phase frog). Chronic LOCs are exceeded from uses on asparagus, carrot, parsnip, sorghum, soybean, kenaf, and right-of-way.
		Terrestrial-phase (Juveniles and Adults): The acute dose-based LOC is exceeded for birds (as a surrogate to the terrestrial-phase frog). The dietary-based acute LOC is exceeded. Chronic LOC is exceeded for birds (as a surrogate to the terrestrial-phase frog). Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for CRLF.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity: The LOC for non-vascular aquatic plants is exceeded for indirect effects to CRLF. The LOC for vascular aquatic plants is exceeded for indirect effects to CRLF. Acute LOC is exceeded for aquatic invertebrates as indirect effects to dietary food items to CRLF. Chronic LOC is exceeded for aquatic invertebrates as indirect effects to dietary food items to CRLF. Use of linuron on all use sites will exceed acute LOC for CRLF.
		Terrestrial prey items, riparian habitat: Acute LOC is marginally exceeded for terrestrial invertebrates as indirect effects to dietary food items to CRLF. The LOC for birds (as a surrogate to the terrestrial-phase frog) eating contaminated small insects at all use sites is exceeded. Chronic LOC is exceeded for small mammals used as food source for CRLF. Acute LOC is marginally exceeded for small mammals used as food source for CRLF at all but the 1 lb ai/A use sites. There are no terrestrial plant data available to assess risk to non-target plants used as food source and habitat for CRLF. Mode of action of chemical would indicate that non-target plants are potentially at risk from use of linuron. The analysis indicates that LOCs are exceeded for non-target terrestrial plants from runoff and spray drift at all sites.

1 No effect (NE); May affect, but not likely to adversely affect (NLAA); May affect, likely to adversely affect (LAA)

Table 1.2 Effects Determination Summary for the Critical Habitat Impact Analysis		
Assessment Endpoint	Effects Determination [1]	Basis for Determination
Modification of aquatic-phase PCE	Habitat Modification	Due to aquatic vascular and terrestrial plant communities being reduced from all use sites, there is potential for alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond. These plant communities provide for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs. In addition, there is potential for alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food. Aquatic non-vascular plants used as food source for CRLF may be potentially affected from linuron use on asparagus, sorghum, kenaf, and rights-of way sites. Reduction of aquatic based food sources (aquatic invertebrates) may occur from all use sites. These effects may indirectly affect aquatic–phase CRLF by reducing the food source. Linuron may directly cause chronic effects to aquatic-phase CRLF in water bodies.
Modification of terrestrial-phase PCE		The use of linuron at all use sites may create the following modification of PCE: elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs, Elimination and/or disturbance of dispersal habitat, reduction and/or modification of food sources for terrestrial phase juveniles and adults, and alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source. Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for direct effects to CRLF. Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for prey food items of small mammals, frogs, and invertebrates. Food source for CRLF is reduced and CRLF is indirectly affected.

[1] Habitat Modification or No effect (NE)

Table 1.3 Linuron Use-specific Direct Effects Determinations[1] for the CRLF				
Use(s)	Aquatic Habitat		Terrestrial Habitat	
	Acute	Chronic	Acute	Chronic
Asparagus	NE	LAA	LAA	LAA
Carrot	NE	LAA	LAA	LAA
Celery	NE	NE	LAA	LAA
Corn, Field	NE	NE	LAA	LAA
Parsnip	NE	NLAA	LAA	LAA
Sorghum	NE	LAA	LAA	LAA
Soybean	NE	LAA	LAA	LAA
Kenaf	NE	LAA	LAA	LAA
Non-Ag Right Of Way Fence/Hedge Rows	NE	LAA	LAA	LAA
Ornamental: Herbaceous Plants	NE	NE	LAA	LAA

[1] NE = No effect; NLAA = May affect, but not likely to adversely affect; LAA = Likely to adversely affect

Table 1.4 Linuron Use-specific Indirect Effects Determinations[1] Based on Effects to Prey										
Use(s)	Algae	Aquatic Invertebrates		Terrestrial Invertebrates (Acute)	Aquatic-phase frogs and fish		Terrestrial-phase frogs		Small Mammals	
		Acute	Chronic		Acute	Chronic	Acute	Chronic	Acute	Chronic
Asparagus	LAA	LAA	LAA	NLAA	NE	LAA	LAA	LAA	NLAA	LAA
Carrot	NE	LAA	LAA	NLAA	NE	LAA	LAA	NLAA	NLAA	LAA
Celery	NE	LAA	LAA	NLAA	NE	NE	LAA	NLAA	NLAA	LAA
Corn, Field	NE	LAA	LAA	NLAA	NE	NE	LAA	NLAA	NLAA	LAA
Parsnip	NE	LAA	LAA	NLAA	NE	NLAA	LAA	NLAA	NLAA	LAA
Sorghum	LAA	LAA	LAA	NLAA	NE	LAA	LAA	NLAA	NLAA	LAA
Soybean	NE	LAA	LAA	NLAA	NE	LAA	LAA	NLAA	NLAA	LAA
Kenaf	LAA	LAA	LAA	NLAA	NE	LAA	LAA	NLAA	NLAA	LAA
Non-Ag Right Of Way Fence/Hedge Rows	LAA	LAA	LAA	NLAA	NE	LAA	LAA	NLAA	NLAA	LAA
Ornamental: Herbaceous Plants	NE	LAA	LAA	NLAA	NE	NE	LAA	NLAA	NLAA	LAA

[1] NE = No effect; NLAA = May affect, not likely to adversely affect; LAA = Likely to adversely affect

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated. When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (i.e., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (i.e., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of CRLF life stages within specific recovery units and/or designated critical habitat within the action area. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the species.
- Quantitative information on prey base requirements for individual aquatic- and terrestrial-phase frogs. While existing information provides a preliminary picture of the types of food sources utilized by the frog, it

does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.

- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together with the information described above, a more complete prediction of effects to individual frogs and potential modification to critical habitat.

2. Problem Formulation

Problem formulation provides a strategic framework for the risk assessment. By identifying the important components of the problem, it focuses the assessment on the most relevant life history stages, habitat components, chemical properties, exposure routes, and endpoints. The structure of this risk assessment is based on guidance contained in U.S. EPA's *Guidance for Ecological Risk Assessment* (U.S. EPA 1998), the Services' *Endangered Species Consultation Handbook* (USFWS/NMFS 1998) and is consistent with procedures and methodology outlined in the Overview Document (U.S. EPA 2004) and reviewed by the U.S. Fish and Wildlife Service and National Marine Fisheries Service (USFWS/NMFS 2004).

2.1 Purpose

The purpose of this endangered species assessment is to evaluate potential direct and indirect effects on individuals of the federally threatened California red-legged frog *(Rana aurora draytonii*) (CRLF) arising from FIFRA regulatory actions regarding use of linuron on terrestrial food, feed, forestry, non-food, and outdoor residential sites. In addition, this assessment evaluates whether use on these crops is expected to result in modification of the species' designated critical habitat. This ecological risk assessment has been prepared consistent with a settlement agreement in the case *Center for Biological Diversity (CBD) vs. EPA et al*. (Case No. 02-1580-JSW(JL)) settlement entered in Federal District Court for the Northern District of California on October 20, 2006.

In this assessment, direct and indirect effects to the CRLF and potential modification to its designated critical habitat are evaluated in accordance with the methods described in the Agency's Overview Document (U.S. EPA 2004). Screening level methods include use of standard models such as PRZM-EXAMS, T-REX, TerrPlant, AgDRIFT, and AGDISP, all of which are described at length in the Overview Document. Additional refinements include use of the T-HERPS model. Use of such information is consistent with the methodology described in the Overview Document (U.S. EPA 2004), which specifies that "the assessment process may, on a case-by-case basis, incorporate additional methods, models, and lines of evidence that EPA finds technically appropriate for risk management objectives" (Section V, page 31 of U.S. EPA 2004).

In accordance with the Overview Document, provisions of the ESA, and the Services' *Endangered Species Consultation Handbook*, the assessment of effects associated with registrations of linuron is based on an action area. The action area is the area directly or indirectly affected by the federal action, as indicated by the exceedence of the Agency's Levels of Concern (LOCs). It is acknowledged that the action area for a national-level FIFRA regulatory decision associated with a use of linuron may potentially involve numerous areas throughout the United States and its Territories. However, for the purposes of this assessment, attention will be focused on relevant sections of the action area including those geographic areas associated with locations of the CRLF and its designated critical habitat within the state of California. As part of the "effects determination," one of the following three conclusions will be reached regarding the potential use of linuron in accordance with current labels:

- "No effect";
- "May affect, but not likely to adversely affect"; or
- "May affect and likely to adversely affect".

Designated critical habitat identifies specific areas that have the physical and biological features, (known as primary constituent elements or PCEs) essential to the conservation of the listed species. The PCEs for CRLFs are aquatic and upland areas where suitable breeding and non-breeding aquatic habitat is located, interspersed with upland foraging and dispersal habitat.

If the results of initial screening-level assessment methods show no direct or indirect effects (no LOC exceedances) upon individual CRLFs or upon the PCEs of the species' designated critical habitat, a "no effect" determination is made for use of linuron as it relates to this species and its designated critical habitat. If, however, potential direct or indirect effects to individual CRLFs are anticipated or effects may impact the PCEs of the CRLF's designated critical habitat, a preliminary "may affect" determination is made for the FIFRA regulatory action regarding linuron.

If a determination is made that use of linuron within the action area(s) associated with the CRLF "may affect" this species or its designated critical habitat, additional information is considered to refine the potential for exposure and for effects to the CRLF and other taxonomic groups upon which these species depend (e.g., aquatic and terrestrial vertebrates and invertebrates, aquatic plants, riparian vegetation, etc.). Additional information, including spatial analysis (to determine the geographical proximity of CRLF habitat and linuron use sites) and further evaluation of the potential impact of linuron on the PCEs is also used to determine whether modification of designated critical habitat may occur. Based on the refined information, the Agency uses the best available information to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that "may affect and are likely to adversely affect" the CRLF or the PCEs of its designated critical habitat. This information is presented as part of the Risk Characterization in Section 5 of this document.

The Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because linuron is expected to directly impact living organisms within the action area (defined in Section 2.7), critical habitat analysis for linuron is limited in a practical sense to those PCEs of critical habitat that are biological or that can be reasonably linked to biologically mediated processes (i.e., the biological resource requirements for the listed species associated with the critical habitat or important physical aspects of the habitat that may be reasonably influenced through biological processes). Activities that may modify critical habitat are those that alter the PCEs and appreciably diminish the value of the habitat. Evaluation of actions related to use of linuron that may alter the PCEs of the CRLF's critical habitat form the basis of the critical habitat impact analysis. Actions that may affect the CRLF's designated critical habitat have been identified by the Services and are discussed further in Section 2.6.

2.2 Scope

Linuron is registered in California for several agricultural and non-agricultural uses (see Table 2.1).

Table 2.1 Registered Uses of Linuron in California

Site	Use Group
Asparagus	Terrestrial: Food Crop
Carrot	Terrestrial: Food Crop
Celery	Terrestrial: Food Crop
Corn, Field	Terrestrial: Food Crop
Parsley	Terrestrial: Food Crop
Parsnip	Terrestrial: Food Crop + Feed Crop
Sorghum	Terrestrial: Food Crop + Feed Crop
Turnip	Terrestrial: Food Crop
Kenaf	Terrestrial: Non-Food Crop
Non-Ag Right Of Way Fence/Hedge Rows	Terrestrial: Non-Food Crop
Ornamental: Herbaceous Plants	Terrestrial: Non-Food Crop
Ornamental Bulbs	Terrestrial: Non-Food Crop

Source: LUIS 11.2 – General Chemical Report (07/23/2007) and current product labels.

The end result of the EPA pesticide registration process (*i.e.*, the FIFRA regulatory action) is an approved product label. The label is a legal document that stipulates how and where a given pesticide may be used. Product labels (also known as end-use labels) describe the formulation type (*e.g.*, liquid or granular), acceptable methods of application, approved use sites, and any restrictions on how applications may be conducted. Thus, the use or potential use of linuron in accordance with the approved product labels for California is "the action" relevant to this ecological risk assessment.

Although current registrations of linuron allow for use nationwide, this ecological risk assessment and effects determination addresses currently registered uses of linuron in portions of the action area that are reasonably assumed to be biologically relevant to the CRLF and its designated critical habitat. Further discussion of the action area for the CRLF and its critical habitat is provided in Section 2.7.

In soil, linuron degrades to 3,4-dichloroanaline. The soil microorganism *Bacillus sphaericus* degrades linuron to *N,O*-dimethylhydroxylamine and carbon dioxide; however, *Aspergillus niger* degraded linuron to phenylmethylurea, phenylmethoxy-urea, chloroaniline, ammonia, and carbon dioxide. Linuron's photo-degradation products include 3-(3-chloro-4-hydroxyphenyl)-1-methoxy-1-methylurea, 3,4-ichlorophenylurea, and 3-(3,4-dichlorophenyl)-1-methylurea formed at yields of 13, 10, and 2 percent, respectively. In a laboratory study, linuron photo-decomposed to a trichlorinated biphenyl with the accompanying loss of hydrogen chloride. In an alkaline solution, linuron's hydrolysis yielded an aromatic amine. With the exception of the anaerobic aquatic metabolism degradation pathway, all other pathways result in degradate formations that are less than 10% by weight of the parent compound and are therefore not included in this risk assessment. Further, it is unlikely that the California Red Legged Frog would frequent the anaerobic aquatic soil and therefore degradates formed in this environment are also not included in this assessment.

The Agency does not routinely include, in its risk assessments, an evaluation of mixtures of active ingredients, either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank. In the case of the product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively in accordance with the Agency's Overview Document and the Services' Evaluation Memorandum (U.S., EPA 2004; USFWS/NMFS 2004).

Linuron has registered products that contain multiple active ingredients. However, there are no available data on mixtures containing linuron in the open literature. There are no product LD50 values, with associated 95% Confidence Intervals (CIs) available for linuron among the data submitted to the Agency. The assessment will be based on the toxicity of a single active ingredient of linuron. Analysis of the available open literature and acute oral mammalian LD_{50} data for multiple active ingredient products relative to the single active ingredient is provided in Appendix A.

As discussed in USEPA (2000) a quantitative component-based evaluation of mixture toxicity requires data of appropriate quality for each component of a mixture. In this mixture evaluation, an LD50 with associated 95% CI is needed for the formulated product. The same quality of data is also required for each component of the mixture. Given that the formulated products for linuron do not have LD50 data available it is not possible to undertake a quantitative or qualitative analysis for potential interactive effects. However, because the active ingredients are not expected to have similar mechanisms of action, metabolites, or toxicokinetic behavior, it is reasonable to conclude that an assumption of dose-addition would be inappropriate. Consequently, an assessment based on the toxicity of linuron is the only reasonable approach that employs the available data to address the potential acute risks of the formulated products.

2.3 Previous Assessments

Linuron was registered in the United States in 1966 as a substituted urea herbicide for use on asparagus, barley, carrots, celery, corn (field and sweet), cottonseed, forage, grain, hay, oats, parsley, parsnips, potatoes, rye, sorghum, soybeans, straw, and wheat (winter). A Registration Standard for linuron was issued in June 1984 (NTIS #PB 85-149011) which required the submission of product chemistry, residue chemistry, toxicology, ecological effects and environmental fate studies.

In 1984, the Agency initiated a Special Review because linuron exceeded the oncogenicity risk criteria. The Agency was concerned about applicator exposure and dermal penetration. The Special Review was concluded in 1988 and in the Federal Register (dated 6/26/90), the Agency revised the toxicological classification of linuron from a quantifiable Group C carcinogen to an unquantifiable Group C carcinogen. As a result, in 1991 DuPont voluntarily cancelled uses on cotton. However, other registrants have not deleted this use from their end-use product registration labels. Uses on barley, oats, rye, forage, grain, hay, and straw were also voluntarily cancelled and do not appear on any labels.

Three Data Call-Ins (DCIs) were subsequently issued (May 1986, September 1990, and November 1993) requiring additional data on product chemistry, chronic toxicity, processing and cooking studies, ecological effects, phytotoxicity and cropfield trials replacement data for studies generated by Craven Laboratories.

A Reregistration Eligibility Decision was completed in 1995 and reflects a reassessment of all data which were submitted in response to the Registration Standard and the subsequent Data Call-Ins (DCIs). This assessment indicated the following:

- The environmental data base of only parent linuron is essentially complete. Linuron appears relatively immobile. Increased mobility of linuron may occur under specific environmental conditions such as coarse textured soils and soils with low organic matter levels. Additional data on leaching/adsorption and desorption may be helpful to assess the mobility of the primary degradates of linuron; as well as field dissipation to assess the rates of dissipation of parent linuron and its primary degradates.

- Levels of concern from linuron use have been exceeded for acute effects to birds, mammals, fish, aquatic invertebrates, aquatic plants and endangered species. Risk to terrestrial plants cannot be assessed due to the lack of adequate data. High risk to terrestrial plants is likely, based on the herbicidal properties of linuron. In addition, levels of concern for chronic effects have been exceeded for birds and mammals. Chronic effects to fish cannot be fully evaluated since a NOEL was not determined. Chronic effects to aquatic invertebrates cannot be evaluated due to inconsistencies between acute and chronic testing.

- Following discussions with the technical registrant, several risk mitigation measures were agreed upon. These measures include the following:
  - prohibiting the aerial uses of linuron
  - prohibiting the use on sand or loamy sand soils
  - prohibiting the use on soils of <1% organic matter
  - reducing the maximum use rate for soybeans (to 1.0 lb ai/A), field corn (to 0.75 lb ai/A), potatoes (to 1.5 lbs ai/A), asparagus (to 2.0 lbs ai/A)
  - limiting soybeans, field corn, potatoes to 1 application per year (pre-emergent use only) and limit asparagus to 3 applications per year

In February 2008, EFED completed a Section 3 drinking water assessment (DWA) of linuron on lentils. Risk conclusions indicate that the proposed use of linuron on lentils in Washington and Idaho has the potential to adversely affect non-target organisms, particularly non-target terrestrial plants, birds, and mammals. In addition, the DWA noted that there is a potential for direct adverse effects to listed aquatic and terrestrial plant species, avian and mammalian species and a potential for adverse indirect effects to other listed species.

In 2004, Office of Pesticide Programs (OPP) requested the initiation of ESA section 7(a)(2) consultation t regarding the potential impact of Linuron on seven listed Evolutionary Significant Units (ESU) of the Pacific salmon and steelhead. OPP determined that linuron may affect but is not likely to adversely affect these species.

2.4 Stressor Source and Distribution

2.4.1 Environmental Fate Properties

The parent linuron half-life is less than 60 days and is only slightly mobile. Linuron may be more mobile under specific environmental conditions such as on soils with less organic matter levels, or otherwise have low retention capacities.

Linuron is primarily adsorbed to soil organic matter with limited adsorption to the inorganic, mineral phase of soil. Linuron tends to be more mobile in surface soils with low organic matter levels or in permeable subsoils exposed on the land surface because of erosion. Decreased adsorption in low organic matter soil horizons may result in enhanced mobility and increased leaching potential of parent linuron. For surface soils with adequate organic matter levels, the combined processes of adsorption and microbial degradation would lower the potential for linuron to migrate to ground water.

Transport of linuron dissolved in surface runoff and/or in suspended sediment through runoff to surface water bodies (e.g., lakes, streams, etc.) could result. Linuron is stable under hydrolysis and has a moderate susceptibility to direct photolysis in water (half-life = 49 days). Its half-life in surface water could increase under conditions of low microbiological activity and long hydrological residence times. Its reported half-life in an anaerobic aquatic metabolism study was less than 21 days. Based upon its relatively low to intermediate soil and sediment to water partitioning, significant fractions of any linuron in water could exist both dissolved in the water column and adsorbed to suspended and bottom sediment. The reported BCFs for linuron (ranging from 40x to 240x) indicate that the bioconcentration potential for linuron is relatively low.

Table 2.2 lists the environmental fate properties of linuron, along with the major and minor degradates detected in the submitted environmental fate and transport studies.

Table 2.2 Summary of Linuron Environmental Fate Properties

Study	Value (units)	Major Degradates *Minor Degradates*	MRID #
Hydrolysis	Stable at pH 5, 7, 9	*Aromatic amine in alkaline solution* *3,4 DCA (~1%), DCPMU (~1%), DML (~1%), DCPU (~1%)*	40916201
Direct Aqueous Photolysis	$T_{½}$ = 49	3-(3-chloro-4-hydroxyphenyl)-1-methoxy-1-methylurea, 3,4-ichlorophenylurea, and 3-(3,4-dichlorophenyl)-1-methylurea	40103601
Soil Photolysis	$T_{½}$ >> 15 days (79% of the parent remained after 15 days	*Norlinuron (<8.4%), desmethyl linuron (<8.4%), 3,4 DCA (<8.4%)*	40171711
Aerobic Soil Metabolism	$T_{½}$ = 49	Desmethoxy linuron (3%), desmethyl linuron (2.1%), norlinuron (1.9%)	41625401
Anaerobic Soil Metabolism	N/A	N/A	40142501
Anaerobic	$T_{½}$ = 21	desmethoxy linuron	40142501

Table 2.2 Summary of Linuron Environmental Fate Properties			
Study	Value (units)	Major Degradates *Minor Degradates*	MRID #
Aquatic Metabolism		(46.7%), desmethoxy monolinuron (78%), *desmethyl linuron (<5%), norlinuron (<5) , 3,4 DCA (<5%)*	
Aerobic Aquatic Metabolism	$T_{½}$ = 48	Desmethoxy linuron (<10%), desmethyl linuron (<10%), norlinuron (<10%), 3-4 DCA (<10%)	40142501
$K_{d\text{-}ads}$ / $K_{d\text{-}des}$ (mL/g) $K_{oc\text{-}ads}$ / $K_{oc\text{-}des}$ (mL/g)	 370		 RED, 1995
Terrestrial Field Dissipation	Unable to determine a pattern of formation and decline based on the submitted studies		41734201, 41734202

N/A – Data Not Available

2.4.2 Environmental Transport Mechanisms

Potential transport mechanisms include pesticide surface water runoff, spray drift, and secondary drift of volatilized or soil-bound residues leading to deposition onto nearby or more distant ecosystems. Surface water runoff and spray drift are expected to be the major routes of exposure for linuron. Based on the physico-chemical properties, linuron is not expect to volatize.

Linuron dissipates principally by biotic processes such as microbial degradation. Degradation of linuron by abiotic processes (i.e., hydrolysis, photolysis) do not appear to be significant routes of dissipation.

In general, deposition of drifting pesticides is expected to be greatest close to the site of application. Computer models of spray drift (AgDRIFT and/or AGDISP) are used to determine potential exposures to aquatic and terrestrial organisms via spray drift. The distance of potential impact away from the use sites (action area) is determined by the distance required to fall below the LOC for mammals.

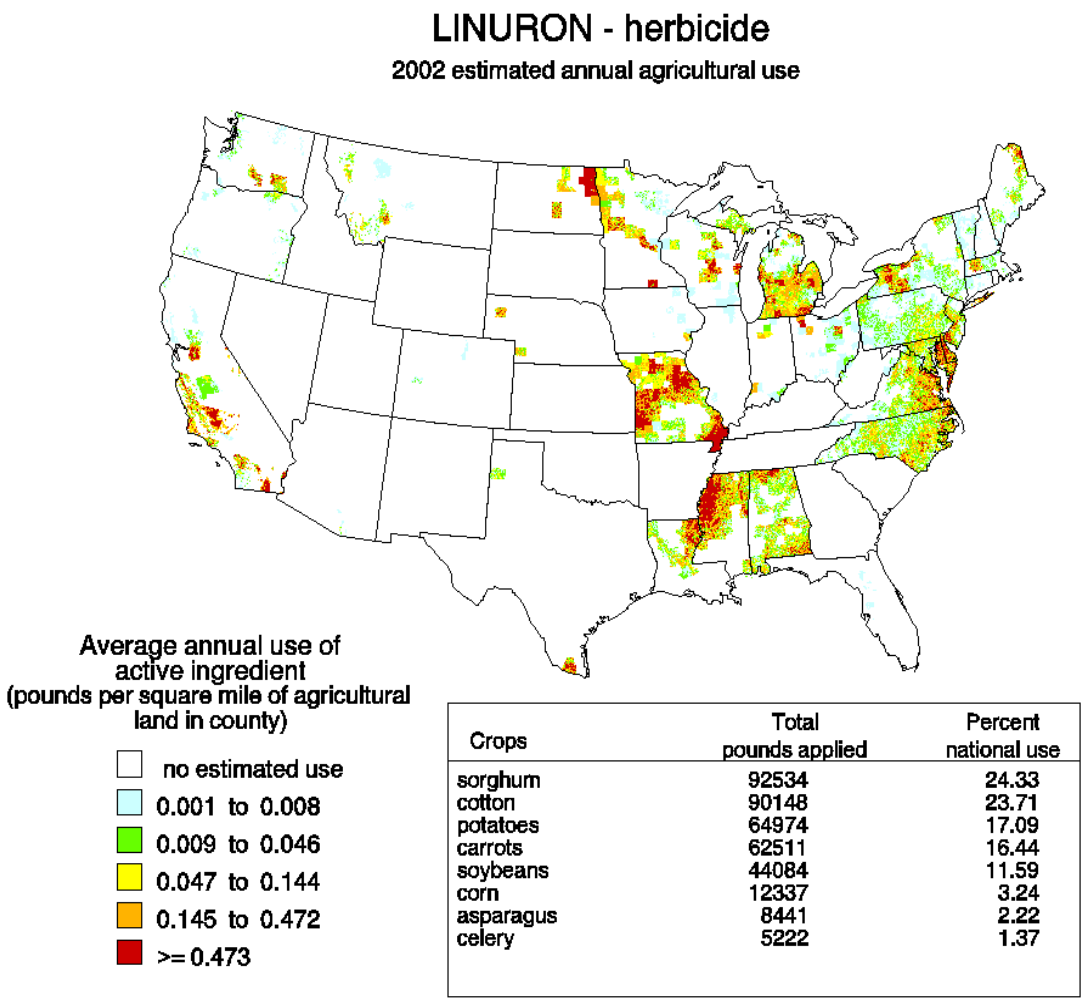
2.4.3 Mechanism of Action

Linuron acts on target plants as a photosynthesis inhibitor by inhibiting the photosystem II reaction center. Linuron is a systemic pesticide and is taken up by the plant either foliar or by the roots and is transported throughout the plant. The main use of linuron is to control germinating and newly emerging grasses and broad leaf weeds. Generally, it is applied to newly emerging crops as an over the top spray.

2.4.4 Use Characterization

This section summarizes the best estimates available for the pesticide uses of linuron. These estimates are derived from a variety of published and proprietary sources available to the Agency. The data, reported on an aggregate and site (crop) basis, reflect annual fluctuations in use patterns as well as the variability in using data from various information sources. Linuron is approved for a wide range of noxious weeds, but local conditions and weed resistance have limited its use to specific states and, often, specific portions of states. Based on the 1995 USEPA Reregistration Eligibility Decision (RED) document for linuron, the herbicide's primary use on the national level was for controlling weeds in soybean crops.

A national map showing the estimated poundage of linuron used in 2002 by county is presented in Figure 2.1. The map was downloaded from the U.S. Geological Survey (USGS), National Water Quality Assessment Program (NAWQA) website (url:http://water.usgs.gov/nawqa/pnsp/usage/maps/show_map.php?year=02&map=m1993).



Crops	Total pounds applied	Percent national use
sorghum	92534	24.33
cotton	90148	23.71
potatoes	64974	17.09
carrots	62511	16.44
soybeans	44084	11.59
corn	12337	3.24
asparagus	8441	2.22
celery	5222	1.37

Source: USGS, 2002

Figure 2.1 Linuron Use in Total Pounds per County

Analysis of labeled use information is the critical first step in evaluating the federal action. The current label for linuron represents the FIFRA regulatory action, therefore, labeled use and application rates specified on the label form the basis of this assessment. The assessment of use information is critical to the development of the action area and selection of appropriate modeling scenarios and inputs.

In California the principle uses for linuron was to control weeds in carrots and asparagus. Table 2.3 presents the uses and corresponding application rates and methods of application in California as specified by the product labels and therefore considered in this assessment. The application rates are for agricultural and non-agricultural uses of the pesticide.

Table 2.3 Linuron Uses Assessed for the CRLF[1]			
Use	Application Method	Max. Single Appl. Rate (lb ai/A)*	Max. Number of Application per Year
Asparagus	chemigation, spray, ground boom, or sprinkler irrigation.	4	1
Carrot	broadcast, chemigation, spray, ground boom, or sprinkler irrigation	1.5	1
Celery	broadcast, chemigation, spray, ground boom, or sprinkler irrigation	1.0	1
Corn (field)	directed spray	1.5	1
Parsley	broadcast, chemigation, spray, ground boom, or sprinkler irrigation	1.5	1
Parsnip	ground spray	1.5	1
Sorghum	chemigation, ground boom, sprinkler irrigation	1	1
Turnip	chemigation, ground boom, sprinkler irrigation	1	1
Kenaf	direct spray	1	1
Non-Ag Right of Way	ground boom	3	1
Ornamental Plants	ground boom, sprinkler irrigation, chemigation	1	1
Ornamental Bulbs	ground boom, sprinkler irrigation, chemigation	1	1

* EFED Label Data Report – 27 June 2007

The Agency's Biological and Economic Analysis Division (BEAD) provides an analysis of both national- and county-level usage information (Kaul and Jones, 2006) using state-level usage data obtained from USDA-NASS[2], Doane (www.doane.com; the full dataset is not provided due to its proprietary nature) and the California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database[3]. CDPR PUR is considered a more comprehensive source of usage data than USDA-NASS or proprietary databases,

[2] United States Depart of Agriculture (USDA), National Agricultural Statistics Service (NASS) Chemical Use Reports provide summary pesticide usage statistics for select agricultural use sites by chemical, crop and state. See http://www.usda.gov/nass/pubs/estindx1.htm#agchem.

[3] The California Department of Pesticide Regulation's Pesticide Use Reporting database provides a census of pesticide applications in the state. See http://www.cdpr.ca.gov/docs/pur/purmain.htm.

and thus the usage data reported for linuron by county in this California-specific assessment were generated using CDPR PUR data. Four years (2002-2005) of usage data were included in this analysis. Available data from CDPR PUR were obtained for every pesticide application made on every use site at the section level (approximately one square mile) of the public land survey system. BEAD summarized these data to the county level by site, pesticide, and unit treated. Calculating county-level usage involved summarizing across all applications made within a section and then across all sections within a county for each use site and for each pesticide. The county level usage data that were calculated include: average annual pounds applied, average annual area treated, and average and maximum application rate across all five years. The units of area treated are also provided where available.

A summary of linuron usage for all California use sites is provided below in Table 2.4.

Table 2.4 Summary of California Department of Pesticide Registration (CDPR) Pesticide Use Reporting (PUR) Data from 2002 to 2005 for Currently Registered Linuron Uses [1]

Site	County	Average Annual Pounds	Avg App Rate	Avg 95th% App Rate	Avg 99th% App Rate	Avg Max App Rate
Asparagus	Contra	1437	0.86	1.0	1.5	1.5
	Fresno	272.5	1.66	2.01	2.01	2.01
	Imperial	894.5	1.05	1.6	1.67	1.67
	Kern.	230.6	1.6	3.0	3.0	3.0
	Monterey	385.7	1.1	2.0	2.0	2.0
	Sacramento	165.5	1.0	1.0	1.0	1.0
	San Benito	210.2	1.24	2.0	2.2	2.2
	San Joaquin	2710.4	.78	1.5	1.5	2.73
	San Luis Obispo	4.0	1.0	1.0	1.0	1.0
	Santa Barbara	413.6	1.15	2.0	2.0	2.0
Carrot	Butte	0.02	0.7	0.94	0.94	.094
	Colusa	216.0	1.2	1.5	1.5	1.5
	Fresno	80.8	0.9	1.5	1.5	1.5
	Glenn	24.5	1.3	1.5	1.5	1.5
	Imperial	12517.6	0.73	1.08	1.5	2.0
	Kern	25549.6	0.76	1.25	1.5	5.54
	Kings	316.9	1.21	1.25	1.25	1.25
	Los Angeles	4773.0	0.66	1.25	1.5	2.84
	Madera	205.2	0.74	1.3	1.3	1.3
	Merced	12.4	1.0	1.5	1.5	1.5
	Monterey	2026.4	0.83	1.0	1.25	10.0
	Riverside	1105.4.	0.63	1.0	1.25	2.5
	San Benito	51.5	0.66	0.75	0.81	1.5
	San Diego	0.18	0.82	1.5	1.5	1.5
	San Diego (forage fodder)	74.6	0.46	0.94	0.94	0.94
	San Joaquin	168.7	0.82	1.06	1.5	1.5
	San Luis Obispo	2102.8	0.69	1.25	2.5	2.5

	Santa Barbara	3605.0	.0.73	1.25	1.25	1.25
	Stanislaus	0.43	1.25	1.25	1.25	1.25
	Sutter	34.1	1.13	1.5	1.5	1.5
	Ventura	287.9	.067	1.0	1.0	1.25
	Yolo	18.4	1.33	1.5	1.5	1.5
Celery	Imperial	64.0	0.88	1.0	1.0	1.0
	Monterey	675.4	0.62	1.0	1.0	1.0
	San Joaquin	24.3	0.75	0.75	0.75	0.75
	San Luis Obispo	322.8	0.47	0.75	1.0	2.4
	Santa Barbara	1498.0	0.65	1.0	1.0	2.5
	Santa Clara	1.06	0.25	0.25	0.25	0.25
	Santa Cruz	1.06	0.38	0.38	0.38	0.38
	Ventura	2284.6	0.39	1.0	1.0	6.43
Corn (field)	San Joaquin	2.25	0.5	0.5	0.5	0.5
Parsnip	Kern	8.0	0.52	0.52	0.52	0.52
	San Joaquin	0.14	1.1	1.1	1.1	1.1
	San Luis Obispo	10.1	1.25	1.25	1.25	1.25
Sorghum	Orange	0.06	0.5	0.5	0.5	0.5
Soybean	Monterey	1.19	0.5	0.5	0.5	0.5
Kenaf	N/S	N/S	N/S	N/S	N/S	N/S
Non-Ag RoW	Imperial	7.63	N/S	N/S	N/S	N/S
	Monterey	31.0	N/S	N/S	N/S	N/S
	San Luis Obispo	3.75	N/S	N/S	N/S	N/S
	Santa Barbara	35.2	N/S	N/S	N/S	N/S
	Santa Cruz	0.13	N/S	N/S	N/S	N/S
	Ventura	22.0				
Ornamental Plants	Humboldt	8.88	0.97	1.0	1.0	1.0
	Kern	20.25	0.76	1.27	1.27	1.27
	Merced	0.09	0.75	0.75	0.75	0.75
	Monterey	9.0	1.0	1.0	1.0	1.0
	Monterey	257.9	1.0	1.0	3.0	5.4
	Riverside	31.9	0.94	1.05	5.21	5.21
	San Benito	3.0	1.0	1.0	1.0	1.0
	San Joaquin	9.75	1.5	1.5	1.5	1.5
	San Luis Obispo	2.17	0.89	1.0	1.0	1.0
	San Luis Obispo	18.5	1.0	1.0	1.0	1.0
	San Mateo	17.44	2.39	5.0	6.0	6.0
	Santa Barbara	107.2	1.8	7.58	10.0	10.0
	Santa Barbara	11.65	0.8	1.5	1.5	1.5
	Santa Clara	4.0	1.08	1.3	1.3	1.3
	Santa Cruz	129.8	0.98	1.0	1.11	4.88
	Ventura	0.41	0.07	0.07	0.07	0.07

1 Some of these rates of application may reflect higher rates than is the maximum currently used on the label. This may be due to historical use rate prior to lowering of application rates due to mitigation process from previous RED and also may be due to some misuse of linuron that was not in accordance to legal labels.

Note: N/S – Not Specified

Source: BEAD Application Rate Data

2.5 Assessed Species

The CRLF was federally listed as a threatened species by USFWS effective June 24, 1996 (USFWS 1996). It is one of two subspecies of the red-legged frog and is the largest native frog in the western United States (USFWS 2002). A brief summary of information regarding CRLF distribution, reproduction, diet, and habitat requirements is provided in Sections 2.5.1 through 2.5.4, respectively. Further information on the status, distribution, and life history of and specific threats to the CRLF is provided in Attachment 1.
Final critical habitat for the CRLF was designated by USFWS on April 13, 2006 (USFWS 2006; 71 FR 19244-19346). Further information on designated critical habitat for the CRLF is provided in Section 2.6.

2.5.1 Distribution

The CRLF is endemic to California and Baja California (Mexico) and historically inhabited 46 counties in California including the Central Valley and both coastal and interior mountain ranges (USFWS 1996). Its range has been reduced by about 70%, and the species currently resides in 22 counties in California (USFWS 1996). The species has an elevational range of near sea level to 1,500 meters (5,200 feet) (Jennings and Hayes 1994); however, nearly all of the known CRLF populations have been documented below 1,050 meters (3,500 feet) (USFWS 2002).

Populations currently exist along the northern California coast, northern Transverse Ranges (USFWS 2002), foothills of the Sierra Nevada (5-6 populations), and in southern California south of Santa Barbara (two populations) (Fellers 2005a). Relatively larger numbers of CRLFs are located between Marin and Santa Barbara Counties (Jennings and Hayes 1994). A total of 243 streams or drainages are believed to be currently occupied by the species, with the greatest numbers in Monterey, San Luis Obispo, and Santa Barbara counties (USFWS 1996). Occupied drainages or watersheds include all bodies of water that support CRLFs (i.e., streams, creeks, tributaries, associated natural and artificial ponds, and adjacent drainages), and habitats through which CRLFs can move (i.e., riparian vegetation, uplands) (USFWS 2002).

The distribution of CRLFs within California is addressed in this assessment using four categories of location including recovery units, core areas, designated critical habitat, and known occurrences of the CRLF reported in the California Natural Diversity Database (CNDDB) that are not included within core areas and/or designated critical habitat (see Figure 2.2). Recovery units, core areas, and other known occurrences of the CRLF from the CNDDB are described in further detail in this section, and designated critical habitat is addressed in Section 2.6. Recovery units are large areas defined at the watershed level that have similar conservation needs and management strategies. The recovery unit is primarily an administrative designation, and land area within the recovery unit boundary is not exclusively CRLF habitat. Core areas are smaller areas within the recovery units that comprise portions of the species' historic and current range and have been determined by USFWS to be important in the preservation of the species. Designated critical habitat is generally contained within the core areas, although a number of critical habitat units are outside the boundaries of core areas, but within the boundaries of the recovery units. Additional information on CRLF occurrences from the CNDDB is used to cover the current range of the species not included in core areas and/or designated critical habitat, but within the recovery units.

Recovery Units

Eight recovery units have been established by USFWS for the CRLF. These areas are considered essential to the recovery of the species, and the status of the CRLF "may be considered within the smaller scale of the recovery units, as opposed to the statewide range" (USFWS 2002). Recovery units reflect areas with similar conservation needs and population statuses, and therefore, similar recovery goals. The eight units described for the CRLF are delineated by watershed boundaries defined by US Geological Survey hydrologic units and are limited to the elevational maximum for the species of 1,500 m above sea level. The eight recovery units for the CRLF are listed in Table 2.5 and shown in Figure 2.2.

Core Areas

USFWS has designated 35 core areas across the eight recovery units to focus their recovery efforts for the CRLF (see Figure 2.2). Table 2.4 summarizes the geographical relationship among recovery units, core areas, and designated critical habitat. The core areas, which are distributed throughout portions of the historic and current range of the species, represent areas that allow for long-term viability of existing populations and reestablishment of populations within historic range. These areas were selected because they: 1) contain existing viable populations; or 2) they contribute to the connectivity of other habitat areas (USFWS 2002). Core area protection and enhancement are vital for maintenance and expansion of the CRLF's distribution and population throughout its range.

For purposes of this assessment, designated critical habitat, currently occupied (post-1985) core areas, and additional known occurrences of the CRLF from the CNDDB are considered. Historically occupied sections of the core areas are not evaluated as part of this assessment because the USFWS Recovery Plan (USFWS 2002) indicates that CRLFs are extirpated from these areas. A summary of currently and historically occupied core areas is provided in Table 2.5 (currently occupied core areas are bolded). While core areas are considered essential for recovery of the CRLF, core areas are not federally-designated critical habitat, although designated critical habitat is generally contained within these core recovery areas. It should be noted, however, that several critical habitat units are located outside of the core areas, but within the recovery units. The focus of this assessment is currently occupied core areas, designated critical habitat, and other known CNDDB CRLF occurrences within the recovery units. Federally-designated critical habitat for the CRLF is further explained in Section 2.6.

Table 2.5 California Red-legged Frog Recovery Units with Overlapping Core Areas and Designated Critical Habitat				
Recovery Unit [1] (Figure 2.a)	Core Areas [2,7] (Figure 2.a)	Critical Habitat Units [3]	Currently Occupied (post-1985) [4]	Historically Occupied [4]
Sierra Nevada Foothills and Central Valley (1) (eastern boundary is the 1,500m elevation line)	Cottonwood Creek (partial) (8)	--	✓	
	Feather River (1)	BUT-1A-B	✓	
	Yuba River-S. Fork Feather River (2)	YUB-1	✓	
	--	NEV-1[6]		
	Traverse Creek/Middle Fork American River/Rubicon (3)	--	✓	
	Consumnes River (4)	ELD-1	✓	
	S. Fork Calaveras River (5)	--		✓
	Tuolumne River (6)	--		✓
	Piney Creek (7)	--		✓
	East San Francisco Bay (partial)(16)	--	✓	
North Coast Range Foothills and Western Sacramento River Valley (2)	Cottonwood Creek (8)	--	✓	
	Putah Creek-Cache Creek (9)	--		✓
	Jameson Canyon – Lower Napa Valley (partial) (15)	--	✓	
	Belvedere Lagoon (partial) (14)	--	✓	
	Pt. Reyes Peninsula (partial) (13)	--	✓	
North Coast and North San Francisco Bay (3)	Putah Creek-Cache Creek (partial) (9)	--		✓
	Lake Berryessa Tributaries (10)	NAP-1	✓	
	Upper Sonoma Creek (11)	--	✓	
	Petaluma Creek-Sonoma Creek (12)	--	✓	
	Pt. Reyes Peninsula (13)	MRN-1, MRN-2	✓	
	Belvedere Lagoon (14)	--	✓	
	Jameson Canyon-Lower Napa River (15)	SOL-1	✓	
South and East San Francisco Bay (4)	--	CCS-1A[6]		
	East San Francisco Bay (partial) (16)	ALA-1A, ALA-1B, STC-1B	✓	
	--	STC-1A[6]		
	South San Francisco Bay (partial) (18)	SNM-1A	✓	
Central Coast (5)	South San Francisco Bay (partial) (18)	SNM-1A, SNM-2C, SCZ-1	✓	
	Watsonville Slough- Elkhorn Slough (partial) (19)	SCZ-2 [5]	✓	
	Carmel River-Santa Lucia (20)	MNT-2	✓	
	Estero Bay (22)	--	✓	
	--	SLO-8[6]		
	Arroyo Grande Creek (23)	--	✓	

	Santa Maria River-Santa Ynez River (24)	--	✓	
Diablo Range and Salinas Valley (6)	East San Francisco Bay (partial) (16)	MER-1A-B, STC-1B	✓	
	--	SNB-1[6], SNB-2[6]		
	Santa Clara Valley (17)	--	✓	
	Watsonville Slough- Elkhorn Slough (partial)(19)	MNT-1	✓	
	Carmel River-Santa Lucia (partial)(20)	--	✓	
	Gablan Range (21)	SNB-3	✓	
	Estrella River (28)	SLO-1A-B	✓	
Northern Transverse Ranges and Tehachapi Mountains (7)	--	SLO-8[6]		
	Santa Maria River-Santa Ynez River (24)	STB-4, STB-5, STB-7	✓	
	Sisquoc River (25)	STB-1, STB-3	✓	
	Ventura River-Santa Clara River (26)	VEN-1, VEN-2, VEN-3	✓	
	--	LOS-1[6]		
Southern Transverse and Peninsular Ranges (8)	Santa Monica Bay-Ventura Coastal Streams (27)	--	✓	
	San Gabriel Mountain (29)	--		✓
	Forks of the Mojave (30)	--		✓
	Santa Ana Mountain (31)	--		✓
	Santa Rosa Plateau (32)	--	✓	
	San Luis Rey (33)	--		✓
	Sweetwater (34)	--		✓
	Laguna Mountain (35)	--		✓

[1] Recovery units designated by the USFWS (USFWS 2000, pg 49).
[2] Core areas designated by the USFWS (USFWS 2000, pg 51).
[3] Critical habitat units designated by the USFWS on April 13, 2006 (USFWS 2006, 71 FR 19244-19346).
[4] Currently occupied (post-1985) and historically occupied core areas as designated by the USFWS (USFWS 2002, pg 54).
[5] Critical habitat unit where identified threats specifically included pesticides or agricultural runoff (USFWS 2002).
[6] Critical habitat units that are outside of core areas, but within recovery units.
[7] Currently occupied core areas that are included in this effects determination are bolded.

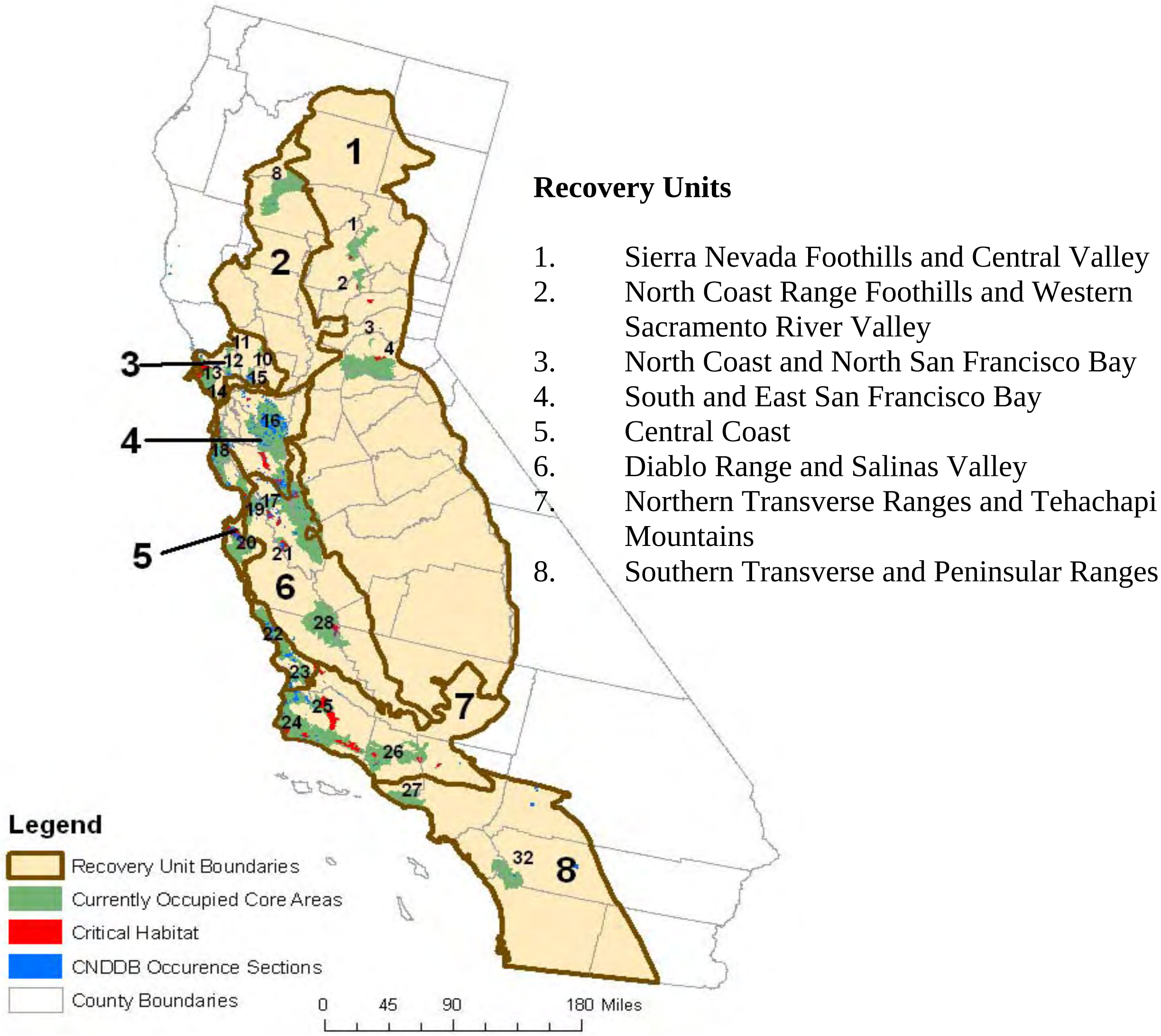


Figure 2.2 Recovery Unit, Core Area, Critical Habitat, and Occurrence Designations for CRLF

Core Areas

1. Feather River
2. Yuba River- S. Fork Feather River
3. Traverse Creek/ Middle Fork/ American R. Rubicon
4. Cosumnes River
5. South Fork Calaveras River*
6. Tuolumne River*
7. Piney Creek*
8. Cottonwood Creek
9. Putah Creek – Cache Creek*
10. Lake Berryessa Tributaries
11. Upper Sonoma Creek
12. Petaluma Creek – Sonoma Creek
13. Pt. Reyes Peninsula
14. Belvedere Lagoon
15. Jameson Canyon – Lower Napa River
16. East San Francisco Bay
17. Santa Clara Valley
18. South San Francisco Bay
19. Watsonville Slough-Elkhorn Slough
20. Carmel River – Santa Lucia
21. Gablan Range
22. Estero Bay
23. Arroyo Grange River
24. Santa Maria River – Santa Ynez River
25. Sisquoc River
26. Ventura River – Santa Clara River
27. Santa Monica Bay – Venura Coastal Streams
28. Estrella River
29. San Gabriel Mountain*
30. Forks of the Mojave*
31. Santa Ana Mountain*
32. Santa Rosa Plateau
33. San Luis Ray*
34. Sweetwater*
35. Laguna Mountain*

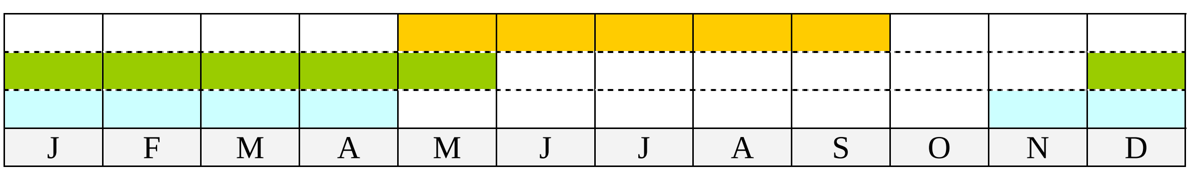
* Core areas that were historically occupied by the California red-legged frog are not included in the map

Other Known Occurrences from the CNDBB

The CNDDB provides location and natural history information on species found in California. The CNDDB serves as a repository for historical and current species location sightings. Information regarding known occurrences of CRLFs outside of the currently occupied core areas and designated critical habitat is considered in defining the current range of the CRLF. See: http://www.dfg.ca.gov/bdb/html/cnddb_info.html for additional information on the CNDDB.

2.5.2 Reproduction

CRLFs breed primarily in ponds; however, they may also breed in quiescent streams, marshes, and lagoons (Fellers 2005a). According to the Recovery Plan (USFWS 2002), CRLFs breed from November through late April. Peaks in spawning activity vary geographically; Fellers (2005b) reports peak spawning as early as January in parts of coastal central California. Eggs are fertilized as they are being laid. Egg masses are typically attached to emergent vegetation, such as bulrushes (*Scirpus* spp.) and cattails (*Typha* spp.) or roots and twigs, and float on or near the surface of the water (Hayes and Miyamoto 1984). Egg masses contain approximately 2000 to 6000 eggs ranging in size between 2 and 2.8 mm (Jennings and Hayes 1994). Embryos hatch 10 to 14 days after fertilization (Fellers 2005a) depending on water temperature. Egg predation is reported to be infrequent and most mortality is associated with the larval stage (particularly through predation by fish); however, predation on eggs by newts has also been reported (Rathburn 1998). Tadpoles require 11 to 28 weeks to metamorphose into juveniles (terrestrial-phase), typically between May and September (Jennings and Hayes 1994, USFWS 2002); tadpoles have been observed to over-winter (delay metamorphosis until the following year) (Fellers 2005b, USFWS 2002). Males reach sexual maturity at 2 years, and females reach sexual maturity at 3 years of age; adults have been reported to live 8 to 10 years (USFWS 2002). Figure 2.3 depicts CRLF annual reproductive timing.



Light Blue = Breeding/Egg Masses
Green = Tadpoles (except those that over-winter)
Orange = Young Juveniles
Adults and juveniles can be present all year

Figure 2.3 – CRLF Reproductive Events by Month

2.5.3 Diet

Although the diet of CRLF aquatic-phase larvae (tadpoles) has not been studied specifically, it is assumed that their diet is similar to that of other frog species, with the aquatic phase feeding exclusively in water and consuming diatoms, algae, and detritus (USFWS 2002). Tadpoles filter and entrap suspended algae (Seale and Beckvar, 1980) via mouthparts designed for effective grazing of periphyton (Wassersug, 1984, Kupferberg *et al.*; 1994; Kupferberg, 1997; Altig and McDiarmid, 1999).

Juvenile and adult CRLFs forage in aquatic and terrestrial habitats, and their diet differs greatly from that of larvae. The main food source for juvenile aquatic- and terrestrial-phase CRLFs is thought to be aquatic and terrestrial invertebrates found along the shoreline and on the water surface. Hayes and Tennant (1985) report, based on a study examining the gut content of 35 juvenile and adult CRLFs, that the species feeds on as many as 42 different invertebrate taxa, including Arachnida, Amphipoda, Isopoda, Insecta, and Mollusca. The most commonly observed prey species were larval alderflies (*Sialis* cf. *californica*), pillbugs (*Armadilliadrium vulgare*), and water striders (*Gerris* sp). The preferred prey species, however, was the sowbug (Hayes and Tennant, 1985). This study suggests that CRLFs forage primarily above water, although the authors note other data reporting that adults also feed under water, are cannibalistic, and consume fish. For larger CRLFs, over 50% of the prey mass may consists of vertebrates such as mice, frogs, and fish, although aquatic and terrestrial invertebrates were the most numerous food items (Hayes and Tennant 1985). For adults, feeding activity takes place primarily at night; for juveniles feeding occurs during the day and at night (Hayes and Tennant 1985).

2.5.4 Habitat

CRLFs require aquatic habitat for breeding, but also use other habitat types including riparian and upland areas throughout their life cycle. CRLF use of their environment varies; they may complete their entire life cycle in a particular habitat or they may utilize multiple habitat types. Overall, populations are most likely to exist where multiple breeding areas are embedded within varying habitats used for dispersal (USFWS 2002). Generally, CRLFs utilize habitat with perennial or near-perennial water (Jennings et al. 1997). Dense vegetation close to water, shading, and water of moderate depth are habitat features that appear especially important for CRLF (Hayes and Jennings 1988). Breeding sites include streams, deep pools, backwaters within streams and creeks, ponds, marshes, sag ponds (land depressions between fault zones that have filled with water), dune ponds, and lagoons. Breeding adults have been found near deep (0.7 m) still or slow moving water surrounded by dense vegetation (USFWS 2002); however, the largest number of tadpoles have been found in shallower pools (0.26 – 0.5 m) (Reis, 1999). Data indicate that CRLFs do not frequently inhabit vernal pools, as conditions in these habitats generally are not suitable (Hayes and Jennings 1988).

CRLFs also frequently breed in artificial impoundments such as stock ponds, although additional research is needed to identify habitat requirements within artificial ponds (USFWS 2002). Adult CRLFs use dense, shrubby, or emergent vegetation closely associated with deep-water pools bordered with cattails and dense stands of overhanging vegetation (http://www.fws.gov/endangered/features/rl_frog/rlfrog.html#where).

In general, dispersal and habitat use depends on climatic conditions, habitat suitability, and life stage. Adults rely on riparian vegetation for resting, feeding, and dispersal. The foraging quality of the riparian habitat depends on moisture, composition of the plant community, and presence of pools and backwater aquatic areas for breeding. CRLFs can be found living within streams at distances up to 3 km (2 miles) from their breeding site and have been found up to 30 m (100 feet) from water in dense riparian vegetation for up to 77 days (USFWS 2002).

During dry periods, the CRLF is rarely found far from water, although it will sometimes disperse from its breeding habitat to forage and seek other suitable habitat under downed trees or logs, industrial debris, and agricultural features (UWFWS 2002). According to Jennings and Hayes (1994), CRLFs also use small mammal burrows and moist leaf litter as habitat. In addition, CRLFs may also use large cracks in the bottom of dried ponds as refugia; these cracks may provide moisture for individuals avoiding predation and solar exposure (Alvarez 2000).

2.6 Designated Critical Habitat

In a final rule published on April 13, 2006, 34 separate units of critical habitat were designated for the CRLF by USFWS (USFWS 2006; FR 51 19244-19346). A summary of the 34 critical habitat units relative to USFWS-designated recovery units and core areas (previously discussed in Section 2.5.1) is provided in Table 2.4.

'Critical habitat' is defined in the ESA as the geographic area occupied by the species at the time of the listing where the physical and biological features necessary for the conservation of the species exist, and there is a need for special management to protect the listed species. It may also include areas outside the occupied area at the time of listing if such areas are 'essential to the conservation of the species.' All designated critical habitat for the CRLF was occupied at the time of listing. Critical habitat receives protection under Section 7 of the ESA through prohibition against destruction or adverse modification with regard to actions carried out, funded, or authorized by a federal Agency. Section 7 requires consultation on federal actions that are likely to result in the destruction or adverse modification of critical habitat.

To be included in a critical habitat designation, the habitat must be 'essential to the conservation of the species.' Critical habitat designations identify, to the extent known using the best scientific and commercial data available, habitat areas that provide essential life cycle needs of the species or areas that contain certain primary constituent elements (PCEs) (as defined in 50 CFR 414.12(b)). PCEs include, but are not limited to, space for individual and population growth and for normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, rearing (or development) of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species. The designated critical habitat areas for the CRLF are considered to have the following PCEs that justify critical habitat designation:

- Breeding aquatic habitat;
- Non-breeding aquatic habitat;
- Upland habitat; and
- Dispersal habitat.

Further description of these habitat types is provided in Attachment 1.

Occupied habitat may be included in the critical habitat only if essential features within the habitat may require special management or protection. Therefore, USFWS does not include areas where existing management is sufficient to conserve the species. Critical habitat is designated outside the geographic area presently occupied by the species only when a designation limited to its present range would be inadequate to ensure the conservation of the species. For the CRLF, all designated critical habitat units contain all four of the PCEs, and were occupied by the CRLF at the time of FR listing notice in April 2006. The FR notice designating critical habitat for the CRLF includes a special rule exempting routine ranching activities associated with livestock ranching from incidental take prohibitions. The purpose of this exemption is to promote the conservation of rangelands, which could be beneficial to the CRLF, and to reduce the rate of conversion to other land uses that are incompatible with CRLF conservation. Please see Attachment 1 for a full explanation on this special rule.

USFWS has established adverse modification standards for designated critical habitat (USFWS 2006). Activities that may destroy or adversely modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the species. Evaluation of actions related to use of linuron that may alter the PCEs of the CRLF's critical habitat form the basis of the critical habitat impact analysis. According to USFWS (2006), activities that may affect critical habitat and therefore result in adverse effects to the CRLF include, but are not limited to the following:

(1) Significant alteration of water chemistry or temperature to levels beyond the tolerances of the CRLF that result in direct or cumulative adverse effects to individuals and their life-cycles.
(2) Significant increase in sediment deposition within the stream channel or pond or disturbance of upland foraging and dispersal habitat that could result in elimination or reduction of habitat necessary for the growth and reproduction of the CRLF by increasing the sediment deposition to levels that would adversely affect their ability to complete their life cycles.
(3) Significant alteration of channel/pond morphology or geometry that may lead to changes to the hydrologic functioning of the stream or pond and alter the timing, duration, water flows, and levels that would degrade or eliminate the CRLF and/or its habitat. Such an effect could also lead to increased sedimentation and degradation in water quality to levels that are beyond the CRLF's tolerances.
(4) Elimination of upland foraging and/or aestivating habitat or dispersal habitat.
(5) Introduction, spread, or augmentation of non-native aquatic species in stream segments or ponds used by the CRLF.

(6) Alteration or elimination of the CRLF's food sources or prey base (also evaluated as indirect effects to the CRLF).

As previously noted in Section 2.1, the Agency believes that the analysis of direct and indirect effects to listed species provides the basis for an analysis of potential effects on the designated critical habitat. Because linuron is expected to directly impact living organisms within the action area, critical habitat analysis for linuron is limited in a practical sense to those PCEs of critical habitat that are biological or that can be reasonably linked to biologically mediated processes.

2.7 Action Area

For listed species assessment purposes, the action area is considered to be the area affected directly or indirectly by the federal action and not merely the immediate area involved in the action (50 CFR 402.02). It is recognized that the overall action area for the national registration of linuron is likely to encompass considerable portions of the United States based on the large array of agricultural uses. However, the scope of this assessment limits consideration of the overall action area to those portions that may be applicable to the protection of the CRLF and its designated critical habitat within the state of California. The Agency's approach to defining the action area under the provisions of the Overview Document (USEPA 2004) considers the results of the risk assessment process to establish boundaries for that action area with the understanding that exposures below the Agency's defined Levels of Concern (LOCs) constitute a no-effect threshold. For the purposes of this assessment, attention will be focused on the footprint of the action (i.e., the area where pesticide application occurs), plus all areas where offsite transport (i.e., spray drift, downstream dilution, etc.) may result in potential exposure within the state of California that exceeds the Agency's LOCs.

Deriving the geographical extent of this portion of the action area is based on consideration of the types of effects that linuron may be expected to have on the environment, the exposure levels to linuron that are associated with those effects, and the best available information concerning the use of linuron and its fate and transport within the state of California. Specific measures of ecological effect for the CRLF that define the action area include any direct and indirect toxic effect to the CRLF and any potential modification of its critical habitat, including reduction in survival, growth, and fecundity as well as the full suite of sublethal effects available in the effects literature. Therefore, the action area extends to a point where environmental exposures are below any measured lethal or sublethal effect threshold for any biological entity at the whole organism, organ, tissue, and cellular level of organization. In situations where it is not possible to determine the threshold for an observed effect, the action area is not spatially limited and is assumed to be the entire state of California.

The definition of action area requires a stepwise approach that begins with an understanding of the federal action. The federal action is defined by the currently labeled uses for linuron. An analysis of labeled uses and review of available product labels was completed. Several of the currently labeled uses are special local needs (SLN) uses or are restricted to specific states and are excluded from this assessment. In addition, a distinction has been made between food use crops and those that are non-food/non-agricultural uses. For those uses relevant to the CRLF, the analysis indicates that, for linuron, the following agricultural uses are considered as part of the federal action evaluated in this assessment:

- Asparagus
- Carrot
- Celery
- Corn (field)
- Parsley
- Parsnip
- Sorghum
- Turnip
- Kenaf

In addition, the following non-food and non-agricultural uses are considered:

- Non-agricultural Right of Way and Fence/Hedge Rows
- Ornamental Plants (marigold for seed)
- Ornamental Bulbs

Following a determination of the assessed uses, an evaluation of the potential “footprint” of linuron use patterns (i.e., the area where pesticide application occurs) is determined. This “footprint” represents the initial area of concern, based on an analysis of available land cover data for the state of California. The initial area of concern is defined as all land cover types and the stream reaches within the land cover areas that represent the labeled uses described above. A map representing all the land cover types that make up the initial area of concern for linuron is presented in Figure 2.4.

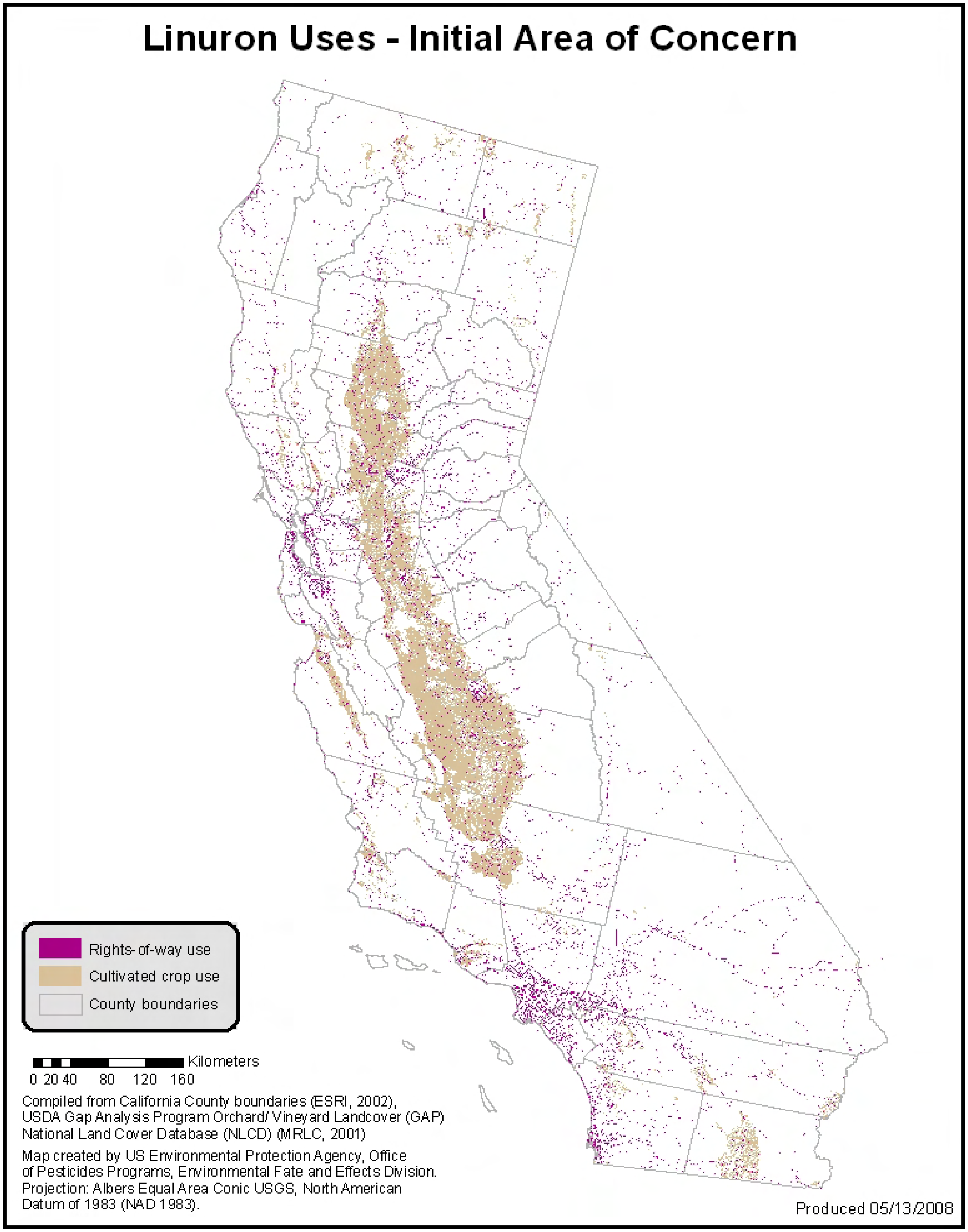


Figure 2.4 Initial area of concern, or "footprint" of potential use, for linuron

Once the initial area of concern is defined, the next step is to define the potential boundaries of the action area by determining the extent of offsite transport via spray drift and runoff where exposure of one or more taxonomic groups to the pesticide exceeds the listed species LOCs.

As previously discussed, the action area is defined by the most sensitive measure of direct and indirect ecological toxic effects including reduction in survival, growth, reproduction, and the entire suite of sublethal effects from valid, peer-reviewed studies.

Due to a positive result in a carcinogenicity test ((MRIDs 0029680, 00029679 (1980); 00167411 (1986) 0124195 (1981)), the spatial extent of the action area (i.e., the boundary where exposures and potential effects are less than the Agency's LOC) for Linuron cannot be determined. Therefore, it is assumed that the action area encompasses the entire state of California, regardless of the spatial extent (i.e., initial area of concern or footprint) of the pesticide use(s).

Linuron may exhibit increased mobility under certain environmental conditions, it has the potential to reach aquatic and off site terrestrial environments via runoff and spray drift. Linuron dissipates principally by biotic processes such as microbial degradation. Linuron's aerobic soil metabolism half-life ranges from 57 to 100 days. In surface soils with adequate organic matter, the combined processes of adsorption and microbial degradation would limit linuron's potential to migrate to ground water. Linuron could runoff to surface water bodies, and can be applied by ground spray, where it could contaminate surface waters through spray drift. In surface waters, particularly those with low microbiological activity and long hydrological residence times, linuron's aerobic aquatic half-live may increase. However, the half-life may decrease under anaerobic conditions. Its bioconcentration potential is relatively low.

The AgDRIFT model (Version 2.01) is used to define how far from the initial area of concern an effect to a given species may be expected via spray drift. The spray drift analysis for linuron using the most sensitive endpoint (mammal reproductive NOEL) suggests that a maximum spray drift distance of 2,972.4 feet was derived. Further detail on the spray drift analysis is provided in Section 3.2.5.

In addition to the buffered area from the spray drift analysis, the final action area also considers the downstream extent of linuron that exceeds the LOC (discussed in Section 3.2.6).

An evaluation of usage information was conducted to determine the area where use of linuron may impact the CRLF. This analysis is used to characterize where predicted exposures are most likely to occur, but does not preclude use in other portions of the action area. A more detailed review of the county-level use information was also completed. These data suggest that linuron has historically been used on a wide variety of agricultural and non-agricultural uses.

2.8 Assessment Endpoints and Measures of Ecological Effect

Assessment endpoints are defined as "explicit expressions of the actual environmental value that is to be protected."[4] Selection of the assessment endpoints is based on valued entities (*e.g.,* CRLF, organisms important in the life cycle of the CRLF, and the PCEs of its designated critical habitat), the ecosystems potentially at risk (*e.g.,* waterbodies, riparian vegetation, and upland and dispersal habitats), the migration pathways of linuron (*e.g.,* runoff, spray drift, etc.), and the routes by which ecological receptors are exposed to linuron *(e.g.,* direct contact, *etc.).*

2.8.1. Assessment Endpoints for the CRLF

Assessment endpoints for the CRLF include direct toxic effects on the survival, reproduction, and growth of the CRLF, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating potential effects to PCEs, which are components of the habitat areas that provide essential life cycle needs of the CRLF. Each assessment endpoint requires one or more "measures of ecological effect," defined as changes in the attributes of an assessment endpoint or changes in a surrogate entity or attribute in response to exposure to a pesticide. Specific measures of ecological effect are generally evaluated based on acute and chronic toxicity information from registrant-submitted guideline tests that are performed on a limited number of organisms. Additional ecological effects data from the open literature are also considered. It should be noted that assessment endpoints are limited to direct and indirect effects associated with survival, growth, and fecundity, and do not include the full suite of sublethal effects used to define the action area. According the Overview Document (USEPA 2004), the Agency relies on acute and chronic effects endpoints that are either direct measures of impairment of survival, growth, or fecundity or endpoints for which there is a scientifically robust, peer reviewed relationship that can quantify the impact of the measured effect endpoint on the assessment endpoints of survival, growth, and fecundity.

A complete discussion of all the toxicity data available for this risk assessment, including resulting measures of ecological effect selected for each taxonomic group of concern, is included in Section 4 of this document. A summary of the assessment endpoints and measures of ecological effect selected to characterize potential assessed direct and indirect CRLF risks associated with exposure to linuron is provided in Table 2.6.

[4] From U.S. EPA (1992). *Framework for Ecological Risk Assessment.* EPA/630/R-92/001.

Table 2.6 Assessment Endpoints and Measures of Ecological Effects	
Assessment Endpoint	Measures of Ecological Effects[5]
Aquatic-Phase CRLF (Eggs, larvae, juveniles, and adults)[a]	
Direct Effects	
1. Survival, growth, and reproduction of CRLF	1a. Amphibian acute LC_{50} (ECOTOX) or most sensitive fish acute LC_{50} (guideline or ECOTOX) if no suitable amphibian data are available 1b. Amphibian chronic NOAEC (ECOTOX) or most sensitive fish chronic NOAEC (guideline or ECOTOX) 1c. Amphibian early-life stage data (ECOTOX) or most sensitive fish early-life stage NOAEC (guideline or ECOTOX)
Indirect Effects and Critical Habitat Effects	
2. Survival, growth, and reproduction of CRLF individuals via indirect effects on aquatic prey food supply (*i.e.*, fish, freshwater invertebrates, non-vascular plants)	2a. Most sensitive fish, aquatic invertebrate, and aquatic plant EC_{50} or LC_{50} (guideline or ECOTOX) 2b. Most sensitive aquatic invertebrate and fish chronic NOAEC (guideline or ECOTOX)
3. Survival, growth, and reproduction of CRLF individuals via indirect effects on habitat, cover, food supply, and/or primary productivity (*i.e.*, aquatic plant community)	3a. Vascular plant acute EC_{50} (duckweed guideline test or ECOTOX vascular plant) 3b. Non-vascular plant acute EC_{50} (freshwater algae or diatom, or ECOTOX non-vascular)
4. Survival, growth, and reproduction of CRLF individuals via effects to riparian vegetation	4a. Distribution of EC_{25} values for monocots (seedling emergence, vegetative vigor, or ECOTOX) 4b. Distribution of EC_{25} values for dicots (seedling emergence, vegetative vigor, or ECOTOX)
Terrestrial-Phase CRLF (Juveniles and adults)	
Direct Effects	
5. Survival, growth, and reproduction of CRLF individuals via direct effects on terrestrial phase adults and juveniles	5a. Most sensitive bird[b] or terrestrial-phase amphibian acute LC_{50} or LD_{50} (guideline or ECOTOX) 5b. Most sensitive bird[b] or terrestrial-phase amphibian chronic NOAEC (guideline or ECOTOX)
Indirect Effects and Critical Habitat Effects	
6. Survival, growth, and reproduction of CRLF individuals via effects on terrestrial prey (*i.e.*,terrestrial invertebrates, small mammals , and frogs)	6a. Most sensitive terrestrial invertebrate and vertebrate acute EC_{50} or LC_{50} (guideline or ECOTOX)[c] 6b. Most sensitive terrestrial invertebrate and vertebrate chronic NOAEC (guideline or ECOTOX)
7. Survival, growth, and reproduction of CRLF individuals via indirect effects on habitat (*i.e.*, riparian and upland vegetation)	7a. Distribution of EC_{25} for monocots (seedling emergence, vegetative vigor, or ECOTOX 7b. Distribution of EC_{25} for dicots (seedling emergence, vegetative vigor, or ECOTOX)

[a] Adult frogs are no longer in the "aquatic phase" of the amphibian life cycle; however, submerged adult frogs are considered "aquatic" for the purposes of this assessment because exposure pathways in the water are considerably different that exposure pathways on land.
[b] Birds are used as surrogates for terrestrial phase amphibians.

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[5] All registrant-submitted and open literature toxicity data reviewed for this assessment are included in Appendix A.

2.8.2 Assessment Endpoints for Designated Critical Habitat

As previously discussed, designated critical habitat is assessed to evaluate actions related to the use of linuron that may alter the PCEs of the CRLF's critical habitat. PCEs for the CRLF were previously described in Section 2.6. Actions that may modify critical habitat are those that alter the PCEs and jeopardize the continued existence of the CRLF. Therefore, these actions are identified as assessment endpoints. It should be noted that evaluation of PCEs as assessment endpoints is limited to those of a biological nature (i.e., the biological resource requirements for the listed species associated with the critical habitat) and those for which linuron effects data are available.

Adverse modification to the critical habitat of the CRLF includes, but is not limited to, the following, as specified by USFWS (2006):

1. Alteration of water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs.
2. Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs.
3. Significant increase in sediment deposition within the stream channel or pond or disturbance of upland foraging and dispersal habitat.
4. Significant alteration of channel/pond morphology or geometry.
5. Elimination of upland foraging and/or aestivating habitat, as well as dispersal habitat.
6. Introduction, spread, or augmentation of non-native aquatic species in stream segments or ponds used by the CRLF.
7. Alteration or elimination of the CRLF's food sources or prey base.

Measures of such possible effects by labeled use of linuron on critical habitat of the CRLF are described in Table 2.7. Some components of these PCEs are associated with physical abiotic features (e.g., presence and/or depth of a water body, or distance between two sites), which are not expected to be measurably altered by use of pesticides. Assessment endpoints used for the analysis of designated critical habitat are based on the adverse modification standard established by USFWS (2006).

Table 2.7 Summary of Assessment Endpoints and Measures of Ecological Effect for Primary Constituent Elements of Designated Critical Habitat[a]	
Assessment Endpoint	Measures of Ecological Effect
Aquatic-Phase CRLF PCEs *(Aquatic Breeding Habitat and Aquatic Non-Breeding Habitat)*	
Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.	a. Most sensitive aquatic plant EC_{50} (guideline or ECOTOX) b. Distribution of EC_{25} values for terrestrial monocots (seedling emergence, vegetative vigor, or ECOTOX) c. Distribution of EC_{25} values for terrestrial dicots (seedling emergence, vegetative vigor, or ECOTOX)
Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	a. Most sensitive EC_{50} values for aquatic plants (guideline or ECOTOX) b. Distribution of EC_{25} values for terrestrial monocots (seedling emergence or vegetative vigor, or ECOTOX) c. Distribution of EC_{25} values for terrestrial dicots (seedling emergence, vegetative vigor, or ECOTOX)
Alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source.	a. Most sensitive EC_{50} or LC_{50} values for fish or aquatic-phase amphibians and aquatic invertebrates (guideline or ECOTOX) b. Most sensitive NOAEC values for fish or aquatic-phase amphibians and aquatic invertebrates (guideline or ECOTOX)
Reduction and/or modification of aquatic-based food sources for pre-metamorphs (*e.g.*, algae)	a. Most sensitive aquatic plant EC_{50} (guideline or ECOTOX)
Terrestrial-Phase CRLF PCEs *(Upland Habitat and Dispersal Habitat)*	
Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or dripline surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance	a. Distribution of EC_{25} values for monocots (seedling emergence, vegetative vigor, or ECOTOX) b. Distribution of EC_{25} values for dicots (seedling emergence, vegetative vigor, or ECOTOX) c. Most sensitive food source acute EC_{50}/LC_{50} and NOAEC values for terrestrial vertebrates (mammals) and invertebrates, birds or terrestrial-phase amphibians, and freshwater fish.
Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal	
Reduction and/or modification of food sources for terrestrial phase juveniles and adults	
Alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	

[a] Physico-chemical water quality parameters such as salinity, pH, and hardness are not evaluated because these processes are not biologically mediated and, therefore, are not relevant to the endpoints included in this assessment.

2.9 Conceptual Model

2.9.1 Risk Hypotheses

Risk hypotheses are specific assumptions about potential adverse effects (*i.e.,*changes in assessment endpoints) and may be based on theory and logic, empirical data, mathematical models, or probability models (U.S. EPA, 1998). For this assessment, the risk is stressor-linked, where the stressor is the release of linuron to the environment. The following risk hypotheses are presumed for this endangered species assessment:

The labeled use of linuron within the action area may:

- directly affect the CRLF by causing mortality or by adversely affecting growth or fecundity;
- indirectly affect the CRLF by reducing or changing the composition of food supply;
- indirectly affect the CRLF or modify designated critical habitat by reducing or changing the composition of the aquatic plant community in the ponds and streams comprising the species' current range and designated critical habitat, thus affecting primary productivity and/or cover;
- indirectly affect the CRLF or modify designated critical habitat by reducing or changing the composition of the terrestrial plant community (i.e., riparian habitat) required to maintain acceptable water quality and habitat in the ponds and streams comprising the species' current range and designated critical habitat;
- modify the designated critical habitat of the CRLF by reducing or changing breeding and non-breeding aquatic habitat (via modification of water quality parameters, habitat morphology, and/or sedimentation);
- modify the designated critical habitat of the CRLF by reducing the food supply required for normal growth and viability of juvenile and adult CRLFs;
- modify the designated critical habitat of the CRLF by reducing or changing upland habitat within 200 ft of the edge of the riparian vegetation necessary for shelter, foraging, and predator avoidance.
- modify the designated critical habitat of the CRLF by reducing or changing dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal.
- modify the designated critical habitat of the CRLF by altering chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs.

2.9.2 Diagram

The conceptual model is a graphic representation of the structure of the risk assessment. It specifies the linuron release mechanisms, biological receptor types, and effects endpoints of potential concern. The conceptual models for aquatic and terrestrial phases of the CRLF are shown in Figures 2.5 and 2.6, respectively, and the conceptual models for the aquatic and terrestrial PCE components of critical habitat are shown in Figures 2.7

and 2.8, respectively. Exposure routes shown in dashed lines are not quantitatively considered because the contribution of those potential exposure routes to potential risks to the CRLF and modification to designated critical habitat is expected to be negligible.

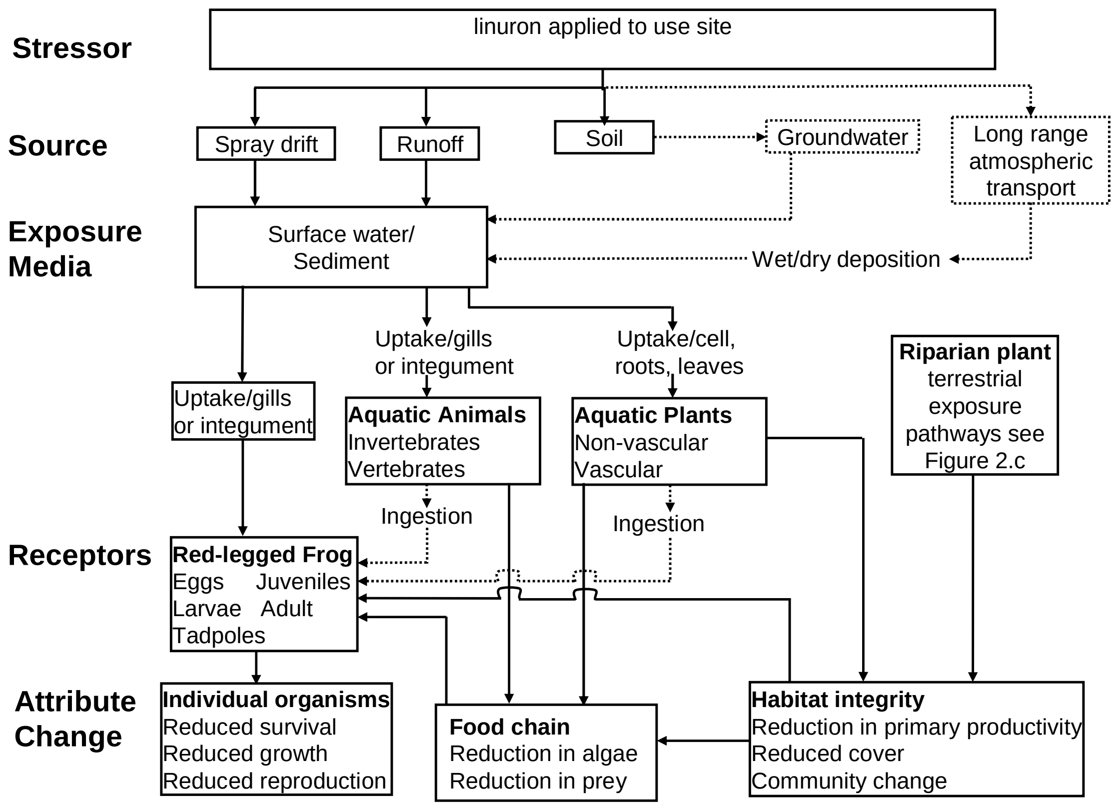

Figure 2.5 Conceptual Model for Aquatic-Phase of the CRLF

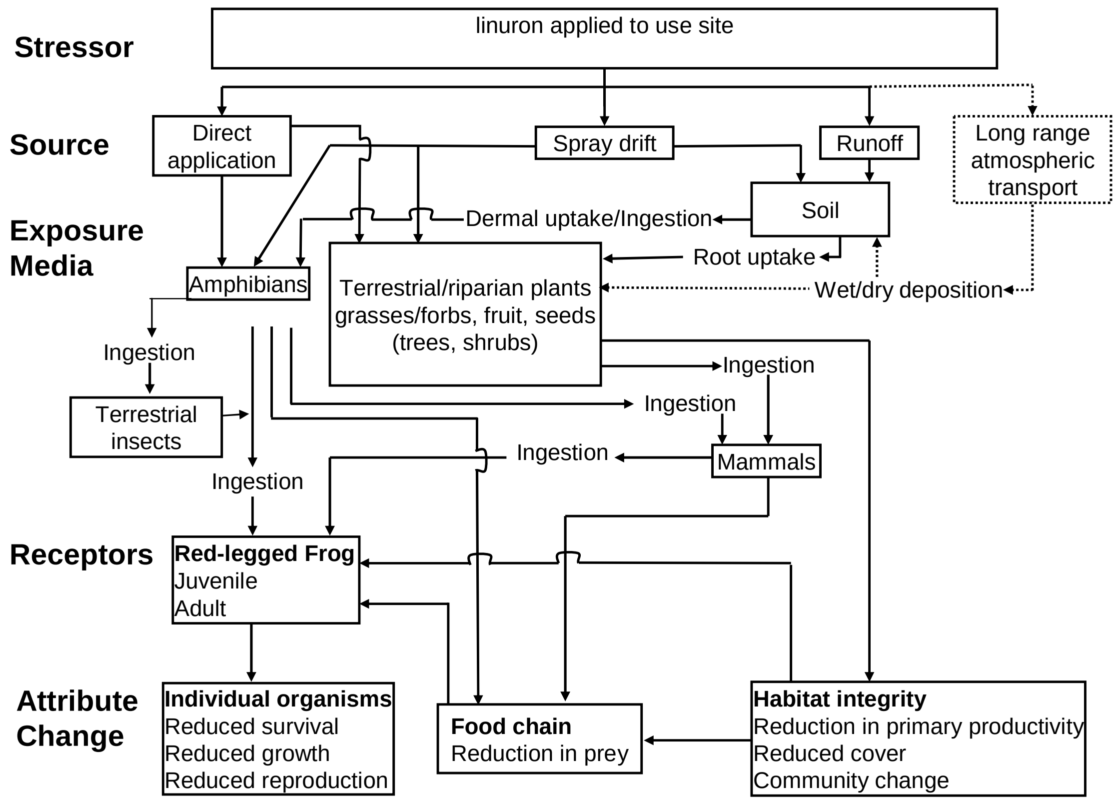

Figure 2.6 Conceptual Model for Terrestrial-Phase of the CRLF

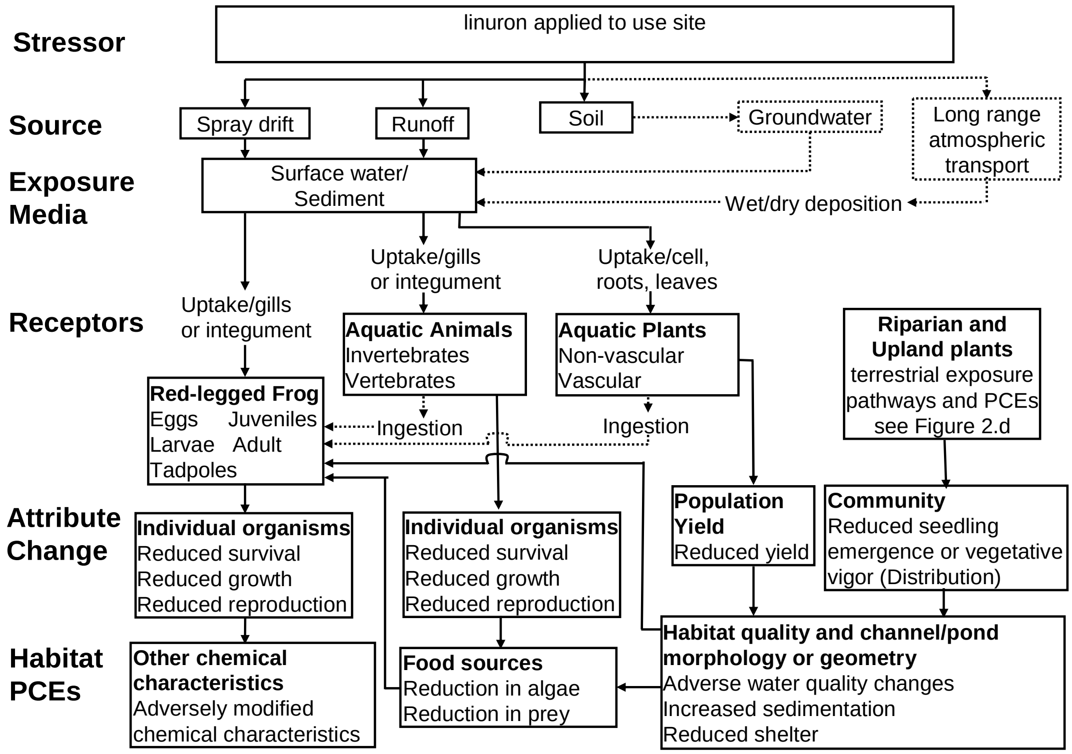

Figure 2.7 Conceptual Model for Pesticide Effects on Aquatic Component of CRLF Critical Habitat

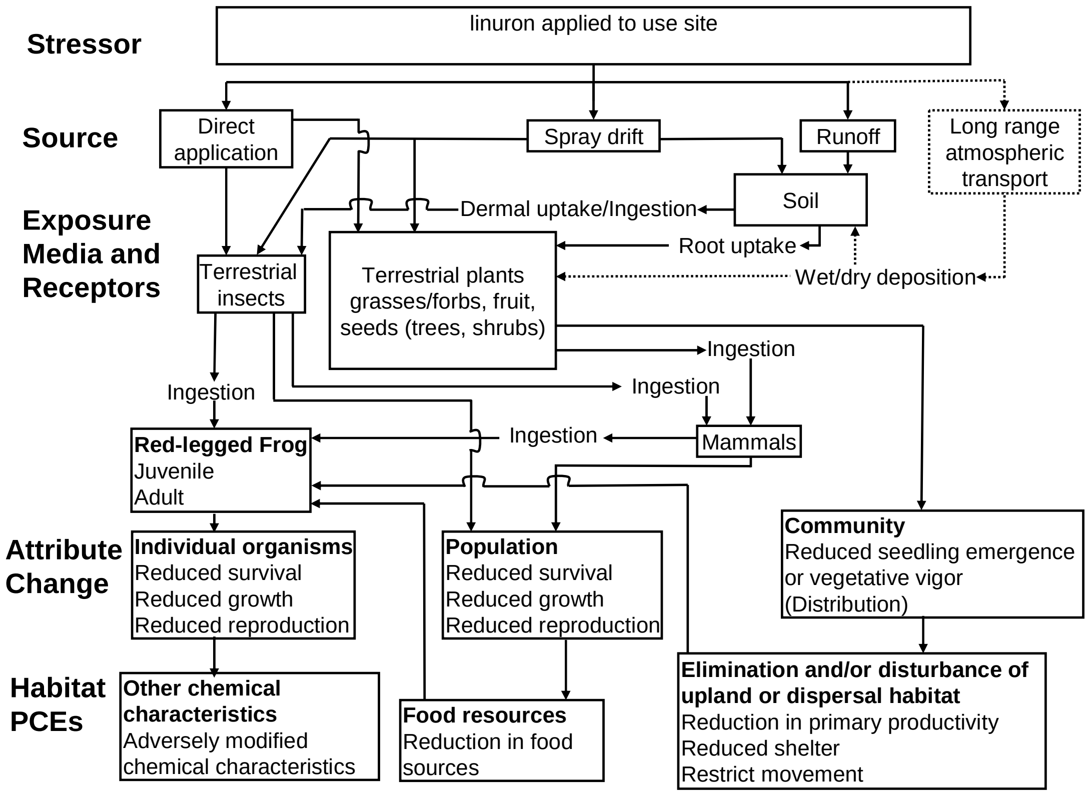

Figure 2.8 Conceptual Model for Pesticide Effects on Terrestrial Component of CRLF Critical Habitat

2.10 Analysis Plan

In order to address the risk hypothesis, the potential for direct and indirect effects to the CRLF, its prey, and its habitat is estimated. In the following sections, the use, environmental fate, and ecological effects of linuron are characterized and integrated to assess the risks. This is accomplished using a risk quotient (ratio of exposure concentration to effects concentration) approach. Although risk is often defined as the likelihood and magnitude of adverse ecological effects, the risk quotient-based approach does not provide a quantitative estimate of likelihood and/or magnitude of an adverse effect. However, as outlined in the Overview Document (U.S. EPA, 2004), the likelihood of effects to individual organisms from particular uses of linuron is estimated using the probit dose-response slope and either the level of concern (discussed below) or actual calculated risk quotient value.

2.10.1 Measures to Evaluate the Risk Hypothesis and Conceptual Model

2.10.1.1 Measures of Exposure

The environmental fate properties of linuron along with available monitoring data indicate that runoff and spray drift are the principle potential transport mechanisms of linuron to the aquatic and terrestrial habitats of the CRLF. In this assessment, transport of linuron through runoff and spray drift is considered in deriving quantitative estimates of linuron exposure to CRLF, its prey and its habitats. The reported vapor pressure of linuron is 1.5 x 10^{-5} mm Hg at 24°C; therefore, volatilization is not considered a probable route of dissipation.

Measures of exposure are based on aquatic and terrestrial models that predict estimated environmental concentrations (EECs) of linuron using maximum labeled application rates and methods of application. The models used to predict aquatic EECs are the Pesticide Root Zone Model coupled with the Exposure Analysis Model System (PRZM/EXAMS). T-REX is used to predict terrestrial EECs on food items. TerrPlant is used to derive EECs relevant to terrestrial and wetland plants. These models are parameterized using relevant reviewed registrant-submitted environmental fate data.

PRZM (v3.12.2, May 2005) and EXAMS (v2.98.4.6, April 2005) are screening simulation models coupled with the input shell pe5.pl (Aug 2007) to generate daily exposures and 1-in-10 year EECs of linuron that may occur in surface water bodies adjacent to application sites receiving linuron through runoff and spray drift. PRZM simulates pesticide application, movement and transformation on an agricultural field and the resultant pesticide loadings to a receiving water body via runoff, erosion and spray drift. EXAMS simulates the fate of the pesticide and resulting concentrations in the water body. The standard scenario used for ecological pesticide assessments assumes application to a 10-hectare agricultural field that drains into an adjacent 1-hectare water body, 2-meters deep (20,000 m^3 volume) with no outlet. PRZM/EXAMS was used to estimate screening-level exposure of aquatic organisms to linuron. The measure of exposure for aquatic species is the 1-in-10 year return peak or rolling mean concentration. The 1-in-10 year peak is used for estimating acute exposures of direct effects to the CRLF, as well as indirect effects to the CRLF through effects to potential prey items, including: algae, aquatic invertebrates, fish and frogs. The 1-in-10-year 60-day mean is used for assessing chronic exposure to the CRLF and fish and frogs serving as prey items; the 1-in-10-year 21-day mean is used for assessing chronic exposure for aquatic invertebrates, which are also potential prey items.

Exposure estimates for the terrestrial-phase CRLF and terrestrial invertebrates and mammals (serving as potential prey) assumed to be in the target area or in an area exposed to spray drift are derived using the T-REX model (version 1.3.1, 12/07/2006). This model incorporates the Kenega nomograph, as modified by Fletcher *et al.* (1994), which is based on a large set of actual field residue data. The upper limit values from the nomograph represented the 95th percentile of residue values from actual field measurements (Hoerger and Kenega, 1972). For modeling purposes, direct exposures of the CRLF to linuron through contaminated food are estimated using the EECs for the small bird (20 g) which consumes small insects. Dietary-based and dose-based exposures of potential prey (small mammals) are assessed using the small mammal (15 g) which consumes short grass. The small bird (20g) consuming small insects and the small mammal (15g) consuming short grass are used because these categories represent the largest RQs of the size and dietary categories in T-REX that are appropriate surrogates for the CRLF and one of its prey items. Estimated exposures of terrestrial insects to linuron are bound by using the dietary based EECs for small insects and large insects.

Birds are currently used as surrogates for terrestrial-phase CRLF. However, amphibians are poikilotherms (body temperature varies with environmental temperature) while birds are homeotherms (temperature is regulated, constant, and largely independent of environmental temperatures). Therefore, amphibians tend to have much lower metabolic rates and lower caloric intake requirements than birds or mammals. As a consequence, birds are likely to consume more food than amphibians on a daily dietary intake basis, assuming similar caloric content of the food items. Therefore, the use of avian food intake allometric equation as a surrogate to amphibians is likely to result in an over-estimation of exposure and risk for reptiles and terrestrial-phase amphibians. Therefore, T-REX (version 1.3.1) has been refined to the T-HERPS model (v. 1.0), which allows for an estimation of food intake for poikilotherms using the same basic procedure as T-REX to estimate avian food intake.

EECs for terrestrial plants inhabiting dry and wetland areas are derived using TerrPlant (version 1.2.2, 12/26/2006). This model uses estimates of pesticides in runoff and in spray drift to calculate EECs. EECs are based upon solubility, application rate and minimum incorporation depth.

Spray drift models, AGDISP and/or AgDRIFT are used to assess exposures of terrestrial phase CRLF and its prey to linuron deposited on terrestrial habitats by spray drift. AGDISP (version 8.13; dated 12/14/2004) (Teske and Curbishley, 2003) is used to simulate aerial and ground applications using the Gaussian farfield extension. In addition to the buffered area from the spray drift analysis, the downstream extent of linuron that exceeds the LOC for the effects determination is also considered.

2.10.1.2 Measures of Effect

Data identified in Section 2.8 are used as measures of effect for direct and indirect effects to the CRLF. Data were obtained from registrant submitted studies or from literature studies identified by ECOTOX. The ECOTOXicology database (ECOTOX) was searched in order to provide more ecological effects data and in an attempt to bridge existing data gaps. ECOTOX is a source for locating single chemical toxicity data for aquatic life, terrestrial plants, and wildlife. ECOTOX was created and is maintained by the USEPA, Office of Research and Development, and the National Health and Environmental Effects Research Laboratory's Mid-Continent Ecology Division.

The assessment of risk for direct effects to the terrestrial-phase CRLF makes the assumption that toxicity of linuron to birds is similar to or less than the toxicity to the terrestrial-phase CRLF. The same assumption is made for fish and aquatic-phase CRLF. Algae, aquatic invertebrates, fish, and amphibians represent potential prey of the CRLF in the aquatic habitat. Terrestrial invertebrates, small mammals, and terrestrial-phase amphibians represent potential prey of the CRLF in the terrestrial habitat. Aquatic, semi-aquatic, and terrestrial plants represent habitat of CRLF.

The acute measures of effect used for animals in this screening level assessment are the LD_{50}, LC_{50} and EC_{50}. LD stands for "Lethal Dose", and LD_{50} is the amount of a material, given all at once, that is estimated to cause the death of 50% of the test organisms. LC stands for “Lethal Concentration” and LC_{50} is the concentration of a chemical that is estimated to kill 50% of the test organisms. EC stands for “Effective Concentration” and the EC_{50} is the concentration of a chemical that is estimated to produce a specific effect in 50% of the test organisms. Endpoints for chronic measures of exposure for listed and non-listed animals are the NOAEL/NOAEC and NOEC. NOAEL stands for “No Observed-Adverse-Effect-Level” and refers to the highest tested dose of a substance that has been reported to have no harmful (adverse) effects on test organisms. The NOAEC (*i.e.*, “No-Observed-Adverse-Effect-Concentration”) is the highest test concentration at which none of the observed effects were statistically different from the control. The NOEC is the No-Observed-Effects-Concentration. For non-listed plants, only acute exposures are assessed (*i.e.*, EC_{25} for terrestrial plants and EC_{50} for aquatic plants).

It is important to note that the measures of effect for direct and indirect effects to the CRLF and its designated critical habitat are associated with impacts to survival, growth, and fecundity, and do not include the full suite of sublethal effects used to define the action area. According the Overview Document (USEPA 2004), the Agency relies on effects endpoints that are either direct measures of impairment of survival, growth, or fecundity or endpoints for which there is a scientifically robust, peer reviewed relationship that can quantify the impact of the measured effect endpoint on the assessment endpoints of survival, growth, and fecundity.

2.10.1.3 Integration of Exposure and Effects

Risk characterization is the integration of exposure and ecological effects characterization to determine the potential ecological risk from agricultural and non-agricultural uses of linuron, and the likelihood of direct and indirect effects to CRLF in aquatic and terrestrial habitats. The exposure and toxicity effects data are integrated in order to evaluate the risks of adverse ecological effects on non-target species. For the assessment of linuron risks, the risk quotient (RQ) method is used to compare exposure and measured toxicity values. EECs are divided by acute and chronic toxicity values. The resulting RQs are then compared to the Agency’s levels of concern (LOCs) (USEPA, 2004) (see Appendix C).

For this endangered species assessment, listed species LOCs are used for comparing RQ values for acute and chronic exposures of linuron directly to the CRLF. If estimated exposures directly to the CRLF of linuron resulting from a particular use are sufficient to exceed the listed species LOC, then the effects determination for that use is “may affect”. When considering indirect effects to the CRLF due to effects to animal prey (aquatic and terrestrial invertebrates, fish, frogs, and mice), the listed species LOCs are also used. If estimated exposures to CRLF prey of linuron resulting from a particular use are sufficient to exceed the listed species LOC, then the effects determination for that use is a “may affect." If the RQ being considered also exceeds the non-listed species acute risk LOC, then the effects determination is a LAA. If the acute RQ is between the listed species LOC and the non-listed acute risk species LOC, then further lines of evidence (*i.e*. probability of individual effects, species sensitivity distributions) are considered in distinguishing between a determination of NLAA and a LAA. When considering indirect effects to the CRLF due to effects to algae as dietary items or plants as habitat, the non-listed species LOC for plants is used because the CRLF does not have an obligate relationship with any particular aquatic and/or terrestrial plant. If the RQ being considered for a particular use exceeds the non-listed species LOC for plants, the effects determination is "may affect". Further information on LOCs is provided in Appendix C.

2.10.2 Data Gaps

The key environmental fate data gaps include the following:

- There is a lack of adequate adsorption/desorption data for the parent and degradates; resulting in uncertainty in the extent of mobility and fate in the water column.
- There is a lack of more than one data point for aerobic aquatic metabolism; resulting in uncertainties in linuron's half-life in the water column.

The key effects data gaps include the following:

- There is a lack of adequate terrestrial non-target plant data. Due to this data gap, data from other herbicides that have similar herbicidal modes of action have been compiled to provide the most sensitive phytotoxic endpoint to represent linuron phytoxicity.
- There is a lack of adequate freshwater invertebrate chronic data.
- There is a lack of adequate freshwater fish chronic data;

3. Exposure Assessment

Linuron is formulated as water dispersible granules, and wettable powder. Application equipment includes boom sprayer, sprinkler irrigation, chemigation/directed spray, and soil broadcast treatment. Exposures from these application methods are considered in this assessment because they are expected to result in the upper bound off-target levels of linuron due to run off and spray drift levels.

3.1 Label Application Rates and Intervals

Linuron labels may be categorized into two types: labels for manufacturing uses (including technical grade linuron and its formulated products) and end-use products. While technical products, which contain linuron of high purity, are not used directly in the environment, they are used to make formulated products, which can be applied in specific areas to control weeds. The formulated product labels legally limit linuron's potential use to only those sites that are specified on the labels.

Currently registered agricultural and non-agricultural uses of linuron within California include agricultural and non-agricultural crops. The uses being assessed were summarized in Tables 2.2 and 2.3

3.2 Aquatic Exposure Assessment

3.2.1 Modeling Approach

Aquatic exposures are quantitatively estimated for all of the assessed uses with scenarios that represent high exposure sites for linuron use. Each of these sites represents a 10 hectare field that drains into a 1-hectare pond that is 2 meters deep and has no outlet. Exposure estimates generated using the standard pond are intended to represent a wide variety of vulnerable water bodies that occur at the top of watersheds including prairie pot holes, playa lakes, wetlands, vernal pools, man-made and natural ponds, and intermittent and first-order streams. As a group, there are factors that make these water bodies more or less vulnerable than the standard surrogate pond. Static water bodies that have larger ratios of drainage area to water body volume would be expected to have higher peak EECs than the standard pond. These water bodies will be either shallower or have large drainage areas (or both). Shallow water bodies tend to have limited additional storage capacity, and thus, tend to overflow and carry pesticide in the discharge whereas the standard pond has no discharge. As watershed size increases beyond 10 hectares, at some point, it becomes unlikely that the entire watershed is planted to a single crop, which is all treated with the pesticide. Headwater streams can also have peak concentrations higher than the standard pond, but they tend to persist for only short periods of time and are then carried downstream.

Crop-specific management practices for all of the assessed uses of linuron were used for modeling, including application rates, number of applications per year, application intervals, buffer widths and resulting spray drift values modeled from AgDRIFT and AgDISP, and the first application date for each crop. The date of first application was developed based on several sources of information including data provided by BEAD, a summary of individual applications from the CDPR PUR data, and Crop Profiles maintained by the USDA.

3.2.2 Model Inputs

The input parameters for PRZM and EXAMS are presented in Table 3.1.

Table 3.1 Summary of PRZM/EXAMS Environmental Fate Data Used for Aquatic Exposure Inputs for Linuron Endangered Species Assessment for the CRLF		
Fate Property	Value (unit)	MRID (or source)

Table 3.1 Summary of PRZM/EXAMS Environmental Fate Data Used for Aquatic Exposure Inputs for Linuron Endangered Species Assessment for the CRLF		
Fate Property	Value (unit)	MRID (or source)
Molecular Weight	249.1 g/mol	http://sitem.herts.ac.uk/aeru/footprint/en/
Henry's constant	2.6E-6 atm-m^{-3}/mol	http://sitem.herts.ac.uk/aeru/footprint/en/
Vapor Pressure	1.5E-5 torr	RED, 1995
Solubility in Water	810 mg/l	Solubility X10; per Input Parameter Guidance
Photolysis in Water	49 days	MRID 40103601
Aerobic Soil Metabolism Half-lives	147 days (49 x 3)	RED, 1995 Value reflects input parameter guidance (multiply by 3) to account for potential uncertainty from a single value.
Hydrolysis	Stable at pH7	MRID 40916201
Aerobic Aquatic Metabolism (water column)	144 days (48 x 3)	MRID 40142501 Value reflects input parameter guidance (multiply by 3) to account for potential uncertainty from a single value.
Anaerobic Aquatic Metabolism (benthic)	63 days (21 x 3)	MRID 40142501 Value reflects input parameter guidance (multiply by 3) to account for potential uncertainty from a single value.
Koc	370 mg/l	RED, 1995
Application rate and frequency	Various (see table 3.2)	Per Label Instructions
Application intervals	Once per year	N/S
Chemical Application Method (CAM)	1 – Ground boom	Label; Input Guidance for Eco Assessments
Application Efficiency	0.99	Per Input Guidance for Eco Assessments
Spray Drift Fraction[1]	0.01	Per Input Guidance for Eco Assessments

1 – Spray drift not included in final EEC due to edge-of-field estimation approach
2 – Inputs determined in accordance with EFED "*Guidance for Chemistry and Management Practice Input Parameters for Use in Modeling the Environmental Fate and Transport of Pesticides*" dated February 28, 2002

3.2.3 Results

The aquatic EECs for the various scenarios and application practices are listed in Table 3.2. Peak EECs ranged from 2.6 to 336.8 ppb for use on turnips and non-agricultural rights of way (impervious surfaces), respectively.

Table 3.2 Aquatic EECs (µg/L) for Linuron Uses in California							
Crop	Scenario	Application Rate (lbs/A)	Application Date (day-month)	Peak EEC	96 Hour EEC	21 Day EEC	60 Day EEC
Asparagus	CA Row Crop RLF	4	01-01	27.5	26.9	23.7	18.3
Carrot	CA Row Crop RLF	1.5	01-01	10.3	10.1	8.9	6.8
Celery	CA Row Crop RLF	1	01-01	6.9	6.7	5.9	4.6
Corn (field)	CA Corn OP	1.5	01-04	8.4	8.1	7.1	5.5
Kenaf	CA Corn OP	1	01-01	25.8	25.1	19.2	16.7
Ornamental Plants	CA Nursery	1	01-01	12.9	12.3	10.7	8.4
Ornamental Bulbs	CA Nursery	1	01-01	12.9	12.3	10.7	8.4
Parsley	CA Lettuce STD	1.5	01-01	40.9	39.9	37.0	30.5
Parsnip	CA Sugar Beet OP	1.5	01-01	8.9	8.7	6.7	6.1
Non-Ag Right of Way	CA Right of Way RLF	3	02-11	60.3	58.3	51.3	39.2
Non-Ag Right of Way	Impervious Surfaces	3	02-11	336.8	328.2	284.5	211.0
Sorghum - silage	CA Wheat RLF	1	01-01	12.7	12.4	11.2	9.3
Turnip	CA Potato RLF	1	01-01	2.6	2.5	2.3	1.8

3.2.4 Existing Monitoring Data

3.2.4.1 USGS NAWQA Surface Water Data

A critical step in the process of characterizing EECs is comparing the modeled estimates with available surface water monitoring data. The USGS has collected 5196 surface water samples from 40 agricultural streams (nation-wide). Linuron was detected in 2.7% of the samples at a detection limit of 0.01 ppb. The maximum concentration observed nationally was 1.4 ppb. In an earlier study, researchers sampled eight tributaries of Lake Erie between April 1983 and August 1985.[6] The time weighted mean concentration ranged from below the 0.001 ppb to 0.86 ppb with a mean concentration of 0.21 ppb.

3.2.4.2 USGS NAWQA Groundwater Data

No data were available.

3.2.4.3 California Department of Pesticide Regulation Data

[6] Baker, DB, TJ Logan, JM Davidson, JL Baker and MR Overcash. Effects of Conservation Tillage on Groundwater Quality: Nitrates and Pesticides. XIX+292P. Lewis Purblishers, Inc.: Chelsea, Michigan. Illus.Maps. ISBN 0-87371-080-0.; 0 (0). 1987. 65-92.

The California Department of Pesticide Regulation (CDPR) has been collecting surface water data on linuron since 1993. These data indicate that linuron concentrations range from non-detect to 0.71 ppb. Only in one instance (0.198 ppb detected at the Mud Slough, a tributary to the San Joaquin River in May '01) has linuron been detected above its detection limit since 1994.

3.2.4.4 Atmospheric Monitoring Data

The California Air Review Board conducted application and ambient air monitoring of linuron in Kern County[7]. Application monitoring was conducted around the use of linuron as a herbicide on 100 acres of carrots from September 15 to September 19, 1997 and ambient monitoring was conducted to coincide with the use of linuron on carrots from August 19 to September 26, 1997.

The analytical limit of detection (LOD) and limit of quantization (LOQ) for linuron were 0.020 and 0.066 ug/sample respectively. The air concentration, expressed in units of ug/m3 (or pptv), associated with the LOQ is dependent on the volume of air sampled which varies from sample to sample. For a 24-hour sampling period at 3 L/m the air concentration would be 0.0 15 ug/m3 (1.5 pptv) as associated with the LOQ.

Two of the four application background samples had results slightly above the LOQ for linuron and the other two were <LOD. Of the twenty-eight application samples collected (spikes, blanks, collocated and background samples excluded) nineteen were found to be above the LOQ. The highest linuron concentration, 0.42 ug/m3 (42 pptv), was observed at the south sampling site during the 6th sampling period.

Of the 112 ambient samples collected (spikes, blanks and collocated samples excluded), none were found to be above the LOQ. Linuron was "detected" in eight samples

3.2.5 Spray Drift Buffer Analysis

In order to determine terrestrial and aquatic habitats of concern due to linuron exposures through spray drift, it is necessary to estimate the distance that spray applications can drift from the treated area and still be present at concentrations that exceed levels of concern. An analysis of spray drift distances was completed using AgDISP, and the Gaussian extension to AgDISP.

The AgDISP model with the Gaussian extension (for longer range transport because the extent of the regular AgDISP model was exceeded) was used to evaluate potential distances beyond which exposures would be expected to be below LOC.

The AgDISP model was run in ground mode with the following settings beyond the standard default settings.

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[7] Report for the Application and Ambient Air Monitoring of Linuron in Kern County, Air Resources Board, California Environmental Protection Agency, Project No. C97-043 (Application), January 13, 1999.

- 15 gal/acre spray volume rate (label specific)
- 4 ft release height (label specific)
- 10 mph limitation (label specific)
- Very fine to fine spectrum (default value)
- No canopy
- Nonvolatile fraction of 0.03 (for 4 lb ai/A).
- Volatile fraction of 0.016 (for 4 lb ai/A).

For the terrestrial phase, an analysis was conducted using the most sensitive terrestrial endpoint, the rat reproductive NOAEC of 0.74 mg/kg-bw/day which is also equivalent to 12.5 mg/kg dietary. This distance identifies those locations where terrestrial landscapes can be impacted by spray drift deposition alone (no runoff considered) at concentrations above the listed species LOC for chronic effects to small mammals. The LOC was compared to the highest RQ for ground applications to asparagus at 4.0 lbs ai/acre. In this analysis, the most sensitive endpoint was the NOAEC of 12.5 ppm, which yielded a terrestrial spray drift distance of 2,972.4 feet. This is the distance at which the chronic LOC for small mammals is not exceeded. Lower application rates would yield a lower buffer distance. This distance represents the maximum extent where effects are possible using the most sensitive data and the endangered species LOC for small mammals. Appendix I contains the model output from the AgDISP terrestrial analysis.

Similar to the analysis described above, the buffer distance needed to get below the most sensitive aquatic LOC was determined. This distance identifies those locations where water bodies can be impacted by spray drift deposition alone (no runoff considered) resulting in concentrations above the LOC. The most sensitive aquatic endpoint is for *Daphnia magna* with NOAEC and EC_{50} values of 0.09 and 51.3 ppb, respectively. The analysis yields a lower buffer distance than the terrestrial buffer with a distance of 2,706.7 feet. The results of the analysis are presented in Table 3.3. Appendix I contains the model output from the AgDISP aquatic analysis

In order to characterize the portion of the action area that is relevant to the CRLF and specific to the area where the effects determination (i.e. NLAA versus LAA) will be made, a similar analysis was conducted using the most sensitive small mammal chronic NOAEC of 12.5 ppm. However, with linuron, the chronic mammalian LOC is the most sensitive terrestrial endpoint. Chronic LOC is the same for endangered and non-endangered animals. The maximum distance for the ground use of linuron on asparagus at 4.0 lbs ai/acre is 2972.4 feet with reductions in distance for lower application rates. A summary of the AgDISP modeled distance for the maximum application rate as discussed previously is presented in Table 3.3.

Table 3.3 Summary of AgDISP Predicted Spray Drift Buffer		
Application Rate (lb/A)(method)	Uses Represented	Distance Where LOC is No Longer Exceeded (ft)
4.0 (ground)	Asparagus	2,972.4 for terrestrial organisms
3.0 (ground)	Non-Ag Right of Way	2,706.7 for aquatic organisms

3.2.6 Downstream Dilution Analysis

To complete this assessment, the greatest ratio of aquatic RQ to LOC was estimated. Using an assumption of uniform runoff across the landscape, it is assumed that streams flowing through treated areas (i.e. the initial area of concern) are represented by the modeled EECs; as those waters move downstream, it is assumed that the influx of non-impacted water will dilute the concentrations of linuron present.

Using a NOAEC for *Daphnia magna* (the most sensitive species) of 0.09 ug/L and a maximum peak EEC for applications to non-agricultural rights-of-way of 51.3 ug/L yields an RQ/LOC ratio of 570 (570/1). Using the downstream dilution approach (described in more detail in Appendix D) yields a target percent crop area (PCA). This value has been input into the downstream dilution approach and a total of 23.9 kilometers of stream downstream from the initial area of concern (footprint of use). Similar to the spray drift buffer described above, the LAA/NLAA determination is based on the area defined by the point where concentrations exceed the NOEC value, in this case 0.09 ug/L (*Daphnia magna*).

3.3 Terrestrial Animal Exposure Assessment

T-REX (Version 1.3.1) is used to calculate dietary and dose-based EECs of linuron for the CRLF and its potential prey (*e.g.* small mammals and terrestrial insects) inhabiting terrestrial areas. EECs used to represent the CRLF are also used to represent exposure values for frogs serving as potential prey of CRLF adults. T-REX simulates a 1-year time period. For this assessment, ground spray applications of linuron are considered, as discussed in below.

Terrestrial EECs for ground spray applications of linuron were derived for the uses registered in California. Given that no data on interception and subsequent dissipation from foliar surfaces is available for linuron, a default foliar dissipation half-life of 35 days is used based on the work of Willis and McDowell (1987). Use specific input values, including number of applications, and application rate are shown in Table 3.4. An example output from T-REX is available in Appendix E.

Table 3.4. T-REX Model Input Parameters

Input	Value
Percentage a.i.	100
Application Rate per Crop Scenario (lbs/A)	
Asparagus	4
Carrot	1.5
Celery	1.0
Corn (field)	1.5
Parsnip	1.5
Sorghum (silage)	1

Soybean	1.5
Kenaf	1
Non-Ag Right of Way	3
Ornamental Plants	1
Half-life (days)	35
Number of Applications	1
Avian LD50 (mg/kg-bw)	940 (bobwhite quail)
Avian LD50 (mg/kg-diet)	1700 (mallard duck)
Avian Reproduction NOAEC (mg/kg-diet)	100
Mineau et al. Scaling Factor	1.15
Rat LD50 (mg/kg-bw)	2600
Reported Rat Chronic Endpoint (mg/kg-bw)	0.74
Reported Rat Chronic Diet Concentration (mg/kg)	12.5 ppm

T-REX is also used to calculate EECs for terrestrial insects exposed to linuron. Dietary-based EECs calculated by T-REX for small and large insects (units of a.i./g) are used to bound an estimate of exposure to bees. Available acute contact toxicity data for bees exposed to linuron (in units of µg a.i./bee), are converted to µg a.i./g (of bee) by multiplying by 1 bee/0.128 g. The EECs are later compared to the adjusted acute contact toxicity data for bees in order to derive RQs.

For modeling purposes, exposures of the CRLF to linuron through contaminated food are estimated using the EECs for the small bird (20 g) which consumes small insects. Dietary-based and dose-based exposures of potential prey are assessed using the small mammal (15 g) which consumes short grass. Upper-bound Kenega nomogram values reported by T-REX for these two organism types are used for derivation of EECs for the CRLF and its potential prey (Table 3.5). Dietary-based EECs for small and large insects reported by T-REX as well as the resulting adjusted EECs are available in Table 3.6. An example output from T-REX v. 1.3.1 is available in Appendix E.

Table 3.5 Upper-bound Kenega Nomogram EECs for Dietary- and Dose-based Exposures of the CRLF and its Prey to Linuron

Use	EECs for CRLF		EECs for Prey (small mammals)	
	Dietary-based EEC (ppm)	Dose-based EEC (mg/kg-bw)	Dietary-based EEC (ppm)	Dose-based EEC (mg/kg-bw)
Asparagus	540.0	615.0	960.0	915.3
Carrot	202.5	230.6	360.0	343.2
Celery	135.0	153.7	240.0	228.8
Corn (field)	202.5	230.63	360.0	343.2
Parsnip	202.5	230.6	360.0	343.3
Sorghum	135.0	153.7	240.0	228.8
Soybean	202.5	230.6	360.0	343.2
Kenaf	135.0	153.7	240.0	228.8
Non-Agricultural Right of Way	405.0	461.2	405.0	686.5
Ornamental Plants	135.0	153.7	240.0	228.8

Table 3.6 EECs (ppm) for Indirect Effects to the Terrestrial-Phase CRLF via Effects to Terrestrial Invertebrate Prey Items		
Use	Small Insect	Large Insect
Asparagus	540.0	60.0
Carrot	135.0	15.0
Celery	135.0	15.0
Corn (field)	135.0	15.0
Parsnip	202.5	22.5
Sorghum	135.0	15.0
Soybean	202.5	22.5
Kenaf	135.0	15.0
Non-Agricultural Right of Way	405.0	45.0
Ornamental Plants	135.0	15.0

3.4 Terrestrial Plant Exposure Assessment

TerrPlant (Version 1.1.2) is used to calculate EECs for non-target plant species inhabiting dry and semi-aquatic areas. Parameter values for application rate, drift assumption and incorporation depth are based upon the use and related application method (**Table 3.10**). A runoff value of 0.02 is utilized based on Linuron's solubility, which is classified by TerrPlant as 810 mg/L. For ground application methods, drift is assumed to be 1%. EECs relevant to terrestrial plants consider pesticide concentrations in drift and in runoff. These EECs are listed by use in Table 3.7. An example output from TerrPlant v.1.2.2 is available in Appendix F**.**

Table 3.7 TerrPlant Inputs and Resulting EECs for Plants Inhabiting Dry and Semi-aquatic Areas Exposed to Linuron via Runoff and Drift						
Use	**Application rate (lbs a.i./A)**	**Application method**	**Drift Value (%)**	**Spray drift EEC (lbs a.i./A)**	**Dry area EEC (lbs a.i./A)**	**Semi-aquatic area EEC (lbs a.i./A)**
Aparagus	4.0	Foliar - ground	1	0.04	0.12	0.84
Rights-of-Way	3.0	Foliar - ground	1	0.03	0.09	0.63
Carrot, Corn, Parsnip, Soybean	1.5	Foliar - ground	1	0.015	0.045	0.315
Celery, Sorghum, Kenaf, Ornamentals	1.0	Foliar - ground	1	0.01	0.03	0.21

4. Effects Assessment

This assessment evaluates the potential for linuron to directly or indirectly affect the CRLF or modify its designated critical habitat. As previously discussed in Section 2.7, assessment endpoints for the CRLF effects determination include direct toxic effects on the survival, reproduction, and growth of CRLF, as well as indirect effects, such as reduction of the prey base or modification of its habitat. In addition, potential modification of critical habitat is assessed by evaluating effects to the PCEs, which are components of the critical habitat areas that provide essential life cycle needs of the CRLF. Direct effects to the aquatic-phase of the CRLF are based on toxicity information for freshwater fish, while terrestrial-phase effects are based on avian toxicity data, given that birds are generally used as a surrogate for terrestrial-phase amphibians. Because the frog's prey items and habitat requirements are dependent on the availability of freshwater fish and invertebrates, small mammals, terrestrial invertebrates, and aquatic and terrestrial plants, toxicity information for these taxa are also discussed. Acute (short-term) and chronic (long-term) toxicity information is characterized based on registrant-submitted studies and a comprehensive review of the open literature on linuron.

As described in the Agency's Overview Document (U.S. EPA, 2004), the most sensitive endpoint for each taxon is used for risk estimation. For this assessment, evaluated taxa include aquatic-phase amphibians, freshwater fish, freshwater invertebrates, aquatic plants, birds (surrogate for terrestrial-phase amphibians), mammals, terrestrial invertebrates, and terrestrial plants.

Toxicity endpoints are established based on data generated from guideline studies submitted by the registrant, and from open literature studies that meet the criteria for inclusion into the ECOTOX database maintained by EPA/Office of Research and Development (ORD) (U.S. EPA, 2004). Open literature data presented in this assessment were obtained from as well as ECOTOX information obtained on [11/30/2007]. In order to be included in the ECOTOX database, papers must meet the following minimum criteria:

(1) the toxic effects are related to single chemical exposure;
(2) the toxic effects are on an aquatic or terrestrial plant or animal species;
(3) there is a biological effect on live, whole organisms;
(4) a concurrent environmental chemical concentration/dose or application rate is reported; and
(5) there is an explicit duration of exposure.

Data that pass the ECOTOX screen are evaluated along with the registrant-submitted data, and may be incorporated qualitatively or quantitatively into this endangered species assessment. In general, effects data in the open literature that are more conservative than the registrant-submitted data are considered. The degree to which open literature data are quantitatively or qualitatively characterized for the effects determination is dependent on whether the information is relevant to the assessment endpoints (*i.e.*, maintenance of CRLF survival, reproduction, and growth) identified in Section 2.8. For example, endpoints such as behavior modifications are likely to be qualitatively evaluated, unless quantitative relationships between modifications and reduction in species survival, reproduction, and/or growth are available. Although the effects determination relies on endpoints that are relevant to the assessment endpoints of survival, growth, or reproduction, it is important to note that the full suite of sublethal endpoints potentially available in the effects literature (regardless of their significance to the assessment endpoints) are considered to define the action area for linuron.

Citations of all open literature not considered as part of this assessment because they were either rejected by the ECOTOX screen or accepted by ECOTOX but not used (e.g., the endpoint is less sensitive) are included in Appendix G. Appendix G also includes a rationale for rejection of those studies that did not pass the ECOTOX screen and those that were not evaluated as part of this endangered species risk assessment.

A detailed spreadsheet of the available ECOTOX open literature data, including the full suite of lethal and sublethal endpoints is presented in Appendix P. Appendix J also includes a summary of the human health effects data for linuron.

In addition to registrant-submitted and open literature toxicity information, other sources of information, including use of the acute probit dose response relationship to establish the probability of an individual effect and reviews of the Ecological Incident Information System (EIIS), are conducted to further refine the characterization of potential ecological effects associated with exposure to linuron. A summary of the available aquatic and terrestrial ecotoxicity information, use of the probit dose response relationship, and the incident information for linuron are provided in Sections 4.1 through 4.4, respectively.

The terminal residues of concern in plants and animals are linuron (parent) and metabolites convertible to 3,4-DCA including desmethoxy-linuron, norlinuron, desmethyl linuron, and hydroxy-norlinuron. The Agency determined that 3,4-DCA was not of regulatory concern in connection with the registered use of linuron due to the very low levels at which the chemical is detected in plants and animals (<0.01ppm). The Agency concluded that with the possible exception of 3,4-DCA itself, metabolites convertible to 3,4-DCA are not likely to be more toxic than the parent compound. This risk assessment will consider the total residues of linuron as parent linuron for purposes of risk assessment

A detailed summary of the available ecotoxicity information for all linuron degradates and formulated products are presented in Appendix A.

The Agency does not routinely include, in its risk assessments, an evaluation of mixtures of active ingredients, either those mixtures of multiple active ingredients in product formulations or those in the applicator's tank. In the case of the product formulations of active ingredients (that is, a registered product containing more than one active ingredient), each active ingredient is subject to an individual risk assessment for regulatory decision regarding the active ingredient on a particular use site. If effects data are available for a formulated product containing more than one active ingredient, they may be used qualitatively or quantitatively[8] [9].

[8] Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, Environmental Protection Agency (January 2004) (Overview Document).

[9] Memorandum to Office of Prevention, Pesticides and Toxic Substance, US EPA conveying an evaluation by the U.S. Fish and Wildlife Service and National Marine Fisheries Service of an approach to assessing the ecological risks of pesticide products (January 2004).

There are no product LD50 values, with associated 95% Confidence Intervals (CIs) available for linuron.

As discussed in USEPA (2000) a quantitative component-based evaluation of mixture toxicity requires data of appropriate quality for each component of a mixture. In this mixture evaluation, an LD50 with associated 95% CI is needed for the formulated product. The same quality of data is also required for each component of the mixture. Given that the formulated products for linuron do not have LD50 data available it is not possible to undertake a quantitative or qualitative analysis for potential interactive effects. However, because the active ingredients are not expected to have similar mechanisms of action, metabolites, or toxicokinetic behavior, it is reasonable to conclude that an assumption of dose-addition would be inappropriate.

4.1 Toxicity of Linuron to Aquatic Organisms

Table 4.1 summarizes the most sensitive aquatic toxicity endpoints for the CRLF, based on an evaluation of both the submitted studies and the open literature, as previously discussed. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the CRLF is presented below. Additional information is provided in Appendix A.

Table 4.1 Freshwater Aquatic Toxicity Profile for Linuron

Assessment Endpoint	Species	Toxicity Value Used in Risk Assessment	Citation MRID # or ECOTOX #	Comment
Acute Direct Toxicity to Aquatic-Phase CRLF	Rainbow trout	LC_{50} = 3 ppm ai	MRID 40445501	acceptable
Chronic Direct Toxicity to Aquatic-Phase CRLF	Rainbow trout	NOEC = 5.58 ppb ai	ACR calculation	Section 4.1.1.2
Indirect Toxicity to Aquatic-Phase CRLF via Acute Toxicity to Freshwater Invertebrates (i.e. prey items)	*Daphnia magna*	EC_{50} = 0.12 ppm ai	MRID 00142932	acceptable
Indirect Toxicity to Aquatic-Phase CRLF via Chronic Toxicity to Freshwater Invertebrates (i.e. prey items)	*Daphnia magna*	NOEC = 0.00009 ppm (NOEC = 0.09 ppb)	ACR calculation	Section 4.1.2.2
Indirect Toxicity to Aquatic-Phase CRLF via Acute Toxicity to Non-vascular Aquatic Plants	freshwater diatom (*Navicula pelliculosa)*	EC_{50} = 0.0137 ppm	MRID 43992302	acceptable
Indirect Toxicity to Aquatic-Phase CRLF via Acute Toxicity to Vascular Aquatic Plants	*Elodea nuttalli*	EC_{50} = 0.0025 ppm	ECOTOX 18629	Supplemental [1]

1 This study is considered to be supplemental due to lack of raw data and replicates.

Toxicity to aquatic fish and invertebrates is categorized using the system shown in Table 4.2 (U.S. EPA, 2004). Toxicity categories for aquatic plants have not been defined.

Table 4.2 Categories of Acute Toxicity for Aquatic Organisms	
LC_{50} (ppm)	Toxicity Category
< 0.1	Very highly toxic
> 0.1 - 1	Highly toxic
> 1 - 10	Moderately toxic
> 10 - 100	Slightly toxic
> 100	Practically nontoxic

4.1.1 Toxicity to Freshwater Fish

Given that no linuron toxicity data are available for aquatic-phase amphibians, freshwater fish data were used as a surrogate to estimate direct acute and chronic risks to the CRLF. Freshwater fish toxicity data were also used to assess potential indirect effects of linuron to the CRLF. Effects to freshwater fish resulting from exposure to linuron may indirectly affect the CRLF via reduction in available food. As discussed in Section 2.5.3, over 50% of the prey mass of the CRLF may consist of vertebrates such as mice, frogs, and fish (Hayes and Tennant, 1985). Fish toxicity studies for two freshwater species using the technical grade active ingredient (TGAI) are required to establish the acute toxicity of linuron to fish. The preferred test species are rainbow trout (a coldwater fish) and bluegill sunfish (a warm water fish).

A summary of acute and chronic freshwater fish data, including data from the open literature, is provided below in Sections 4.1.1.1 through 4.1.1.3.

4.1.1.1 Freshwater Fish: Acute Exposure (Mortality) Studies

Two acceptable freshwater fish (rainbow trout and bluegill sunfish) studies using the technical active ingredient of linuron were submitted to the Agency. The LC_{50} values are 3 ppm and 9.6 ppm for the trout and the sunfish, respectively. There is sufficient information to characterize technical linuron as “moderately toxic” to both coldwater and warmwater fish.

Three acceptable freshwater fish (one rainbow trout and two bluegill sunfish) studies using the formulated products of linuron were submitted to the Agency. These products consist of two Lorox 50 WP (50% ai) and one Lorox 50 DF (54% ai). The LC_{50} ranged from 9.2 ppm to 16.4 ppm for the sunfish and trout, respectively. There is sufficient information to characterize the formulated linuron as “moderately toxic” to both coldwater and warmwater fish.

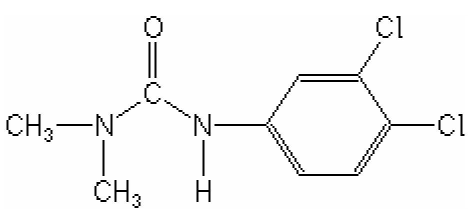
4.1.1.2 Freshwater Fish: Chronic Exposure (Growth/Reproduction) Studies

There is one fish Early Life Stage submitted to the Agency using rainbow trout (MRID 42061804). This study is not acceptable for risk assessment since effects were observed at the lowest concentration tested (0.042 ppm). Therefore the study failed to determine a NOEC level.

Since there are no chronic toxicity values for freshwater fish, an Acute to Chronic Ratio (ACR) has been calculated from a group of phenylurea herbicides that the Agency has data for.

Phenylurea herbicides with both an acute 96-hr LC_{50} value and fish early life stage NOEC for the same freshwater fish species are tabulated in Table 4.3. Additionally, freshwater fish data for tebuthiuron, a substituted diazolyluron urea herbicide, were included as one of a limited number of substituted ureas with both acute and chronic toxicity data. Acute-to-chronic ratio (ACR) values ranged from 5.5 to 538 for freshwater fish. The studies were all submitted studies done under comparable conditions.

The more toxic of the substituted urea herbicides were linuron and diuron, which each have only a single ring structure on a nitrogen rather than two ring structures like tebuthiuron and thidiazuron, and have two chlorines on the phenyl ring (Appendix O). Siduron like tebuthiuron and thidiazuron, have two ring structures attached to nitrogens and no chlorine on the phenyl ring. A large ACR is not unusual where the mode of action for chronic effects differ from the acute, especially if metabolic activation is involved. Based on this toxicity pattern and several of the ACR values being non-definitve but large, the diuron ACR (538) for the Fathead minnow was used as a conservative ACR factor for extrapolating a linuron early life stage NOEC (NOEC = 96-h LC_{50}/ACR = 3000/538 = 5.58 ppb a.i.) from the most acutely sensitive linuron rainbow trout result.



Diuron CAS 330-54-1; PC 035505

Figure 4.1 Diuron structure

Table 4.3 Phenylurea Herbicide 96-h Acute LC50, Freshwater Fish Early Life Stage NOEC Values, and ACR

Phenylurea Herbicide	Test Species	Acute Test Results			Early Life Stage Test Results				ACR
		Acute 96-h LC_{50} (ppm)	Study Conditions and Classification [a]	Acute Value Source (MRID)	Study Conditions and Classification [b]	Study Duration (days)	NOEC [LOEC] (ppm)	Chronic Value Source (MRID)	
diuron	Fathead minnow, *P. promelas*	14.2	age N.R., S, 98.6% a.i., Supplemental	00141636	S, 98.6%, Acceptable	60	0.0264 [0.0618]	00141636	538
linuron	Rainbow trout, *O. mykiss*	3.0	0.77 g, S, 96.2% a.i., Acceptable	404455-01	F, 98.4%, Supplemental	80	<0.042 [NA]	42061804	>71
Tebuthiuron	Fathead minnow, *P. promelas*	>180.0	Juv, S, 98% a.i., Supplemental	00041685	F, 98% a.i., Acceptable	28	9.3 [18.0]	00090084	>19
Tebuthiuron	Rainbow trout, *O. mykiss*	143.0	age N.R., S, 98% a.i., Acceptable	00020661	F, 98% a.i., Acceptable	45	26,000 [52.0]	00090083	5.5
Thidiazuron	Fathead minnow, *P. promelas*	--	--	--	F, 99.3% a.i., Acceptable	35	5.7 [>5.7]	42270301	--

[a] age or size – N.R = not reported, Juv = juvenile; test type – S = static; purity; study classification
[b] test type – S = static, F = flow-through; study classification

4.1.1.3 Freshwater Fish: Sublethal Effects and Additional Open Literature Information

A review of the literature using the ECOTOX database found that linuron affects the baseline olfactory sensory neuron (OSN) responses of sockeye salmon (*Oncorhynchus nerka*) above 1 µg/L (NOEC = 1 µg/L). The sense of smell for anadromous salmon is crucial for the survival of salmon in predator evasion and conspecific recognition (ECOTOX 90046; Tierney, 2007). Frogs do not use the sense of smell to migrate in estuarine and freshwater bodies. Therefore, the data point was considered irreverent and not used.

4.1.2 Toxicity to Freshwater Invertebrates

Freshwater aquatic invertebrate toxicity data were used to assess potential indirect effects of linuron to the CRLF. Effects to freshwater invertebrates resulting from exposure to linuron could indirectly affect the CRLF via reduction in available food items. As discussed in Section 2.5.3, the main food source for juvenile aquatic- and terrestrial-phase CRLFs is thought to be aquatic invertebrates found along the shoreline and on the water surface, including aquatic sowbugs, larval alderflies and water striders.

A summary of acute and chronic freshwater invertebrate data, including data published in the open literature, is provided below in Sections 4.1.2.1 through 4.1.2.3.

4.1.2.1 Freshwater Invertebrates: Acute Exposure Studies

One acceptable acute aquatic invertebrate study with the technical active ingredient using *Daphnia magna* (MRID 00142935) was submitted to the Agency. The EC_{50} was found to be 0.12 ppm. There is sufficient information to characterize technical linuron as "highly toxic" to aquatic invertebrates.

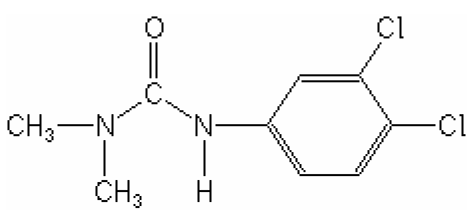
One acceptable acute study using the formulated product of linuron using *Daphnia magna* (MRID 00018199) was submitted to the Agency. This product consists of Lorox 50 DF (54% ai). The EC_{50} was found to be 1.1 ppm product or 0.594 ppm ai.

4.1.2.2 Freshwater Invertebrates: Chronic Exposure Studies

One aquatic invertebrate life cycle study using *Daphnis magna* was submitted to the Agency (MRID 42153401). The NOEC level was defined to be 0.13 ppm which is similar to the *Daphnis magna* acute EC_{50} of 0.12 ppm. NOEC values should at least be a dose concentration lower in aquatic toxicity studies. Since NOEC value is inconsistent with the acute value, the Agency has determined that the study would not be acceptable for use in risk assessment.

Since there are no chronic toxicity values for freshwater invertebrates, an Acute to Chronic Ratio (ACR) was calculated from a group of phenylurea herbicides that the Agency has data for. The studies were all submitted studies done under comparable conditions.

Because there was no reproduction NOEC for the freshwater invertebrate, D. magna, a value was extrapolated using other phenylurea herbicide toxicity data. Phenylurea herbicides with acute *D. magna* 48-hr EC_{50} immobilization values and/or chronic reproduction NOEC are tabulated in Table 4.4. Excluding the ACR of 0.9 which is not appropriate (i.e., level which effects 50% survival should not be lower than the reproduction NOEC), the ACR values ranged from 2.1 to 1,400 for *D. magna.* A large ACR is not unusual where the mode of action for chronic effects differ from the acute, especially if metabolic activation is involved. Based on this toxicity pattern and several of the ACR values being non-definitve but large, the diuron ACR (1400) for the *D. magna* was used as a conservative ACR factor for extrapolating a linuron reproductive NOEC (NOEC = 96-h EC_{50}/ACR = 120/1400 = 0.09 ppb a.i.) from the most acutely sensitive linuron *D. magna* result. *D. magna* reproduction value of 0.09 ppb was used for linuron as a conservative estimate of its reproductive effect level.



Diuron CAS 330-54-1; PC 035505

Figure 4.2 Diuron Structure

Table 4.4 Phenylurea herbicide *D. magna* Acute 48-h EC_{50}, Reproduction NOEC, and ACR Values									
		Acute Toxicity Results			Reproduction Study Results				
Phenyl-urea Herbicide	Test Species	Acute 48-h EC_{50} (ppm)	Study Conditions and Classification (a)	Acute Value Source (MRID and Acc)	Study Conditions and Classification (b)	Study Duration (days)	NOAEC [LOAEC] (ppm)	Chronic Value Source (MRID and Acc)	ACR
diuron	Water flea, *D. magna*	8.4	age N.R., S, 80% a.i., Acceptable	42046003	S, 98.2% a.i., Supplemental	21 d	0.006 [0.2]	TN 2418	1400
diuron	Water flea, *D. magna*	1.4	1st inst, S, 95% a.i., Acceptable	40094602	S, 98.2% a.i., Supplemental	21 d	0.006 [2]	TN 2418	233
linuron	Water flea, *D. magna*	0.270	1st instar, S, 95.1% a.i., Acceptable	40098001	S, 98.4% a.i., Acceptable	21 d	0.130 [0.240]	42153401	2.1
Linuron	Water flea, *D. magna*	0.120	1st-inst, S, 94.4% a.i., Acceptable	00258300, 00142932	S, 98.4% a.i., Acceptable	21 d	0.130 [0.240]	42153401	0.9
linuron	Water flea, *D. magna*	1.91	<24 h, S, 98.4% a.i., Acceptable	43996501	S, 98.4% a.i., Acceptable	21 d	0.130 [0.240]	42153401	15
metobenzuron	Water flea, *D. magna*	--	--	--	F, 98.3% a.i.	21 d	0.023 [0.054]	41965020	--
tebuthiuron	Water flea, *D. magna*	297.0	<10-h; S, 99.2% a.i., Acceptable	00041694	SR, 97.4% a.i., Acceptable	21 d	21.8 [44.2]	00138700	14
thidiazuron	Water flea, *D. magna*	10.0	<24-h; S; 98.4%; Acceptable	ACC09981	F, 99.3% a.i., Acceptable	21 d	<0.1	43075201	>100
thidiazuron	Water flea, *D. magna*	5.7	<24 h, S, 99.5% a.i., Acceptable	46203503	F, 99.3% a.i., Supplemental	21 d	<0.1	42132002	>57

(a) age or size – N.R = not reported; test type – S = static; purity; study classification
(b) test type – S = static, F = flow-through; study classification

4.1.2.3 Freshwater Invertebrates: Open Literature Data

The most sensitive aquatic invertebrate found in the open literature through ECOTOX is *Rotifera* sp. (ECOTOX 96385, Van den Brink, 1999). The literature indicated that abundance of the filter-feeding *Rotifera* (*Synchaeta pectinata*, *Polyarthra remata*) was significantly decreased from exposure to linuron at 50 ppb with NOEC established as 5 ppb. The microcosm ecosystem went from rotifer dominated to be dominated by the Cladocera grazers (*Daphnia* sp.). Post-treatment observations indicate that the rotifers did not recover their population abundance.

4.1.3 Toxicity to Aquatic Plants

Aquatic plant toxicity studies were used as one of the measures of effect to evaluate whether linuron may affect primary production and the availability of aquatic plants as food for CRLF tadpoles. Primary productivity is essential for indirectly supporting the growth and abundance of the CRLF.

Two types of studies were used to evaluate the potential of linuron to affect aquatic plants. Laboratory and field studies were used to determine whether linuron may cause direct effects to aquatic plants. A summary of the laboratory data and freshwater field studies for aquatic plants is provided in Sections 4.1.3.1 and 4.1.4.

4.1.3.1 Aquatic Plants: Laboratory Data

The most sensitive non-vascular plant acute EC_{50} is the freshwater diatom *Navicula pelliculosa* with an EC_{50} of 0.0137 ppm. The only vascular plant tested is the duckweed, *Lemna gibba* which has an EC_{50} of 0.0273 ppm ai. The NOEC for the duckweed is 0.0010 ppm ai. Below is a Table 4.5 showing the ranges of all the aquatic plants that were submitted by the registrant for testing.

Table 4.5 Comparison of Aquatic Plant Toxicity

Species	Plant type	EC_{50}	Reference (MRID)
Navicula pelliculosa	Freshwater diatom	0.0137 ppm ai	43992302
Selenastrum capricornutum	Green algae	0.067 ppm ai	42086801
Lemna gibba	Vascular floating plant (Duckweed)	0.0273 ppm ai	43992301
Anabaena flos-aquae	Blue-green algae or cyanobacteria	0.0388 ppm ai	43992302
Skeletonema costatum	Marine diatom	0.0359 ppm ai	43992302

4.1.3.1 Aquatic Plants: Open Literature Data

Most sensitive vascular plant acute EC_{50} found in the ECOTOX database is *Elodea nuttalli* (ECOTOX 18629, 96385, Van den Brink, 1999). The EC_{50} is 0.075 and 0.0025 ppm for biomass and inhibition of relative growth, respectively. There is no other information attributed to the green algae EC_{50}. The Van den Brink study was based on a series of microcosms which are dosed at 5 different concentrations. This study is considered to be supplemental due to lack of raw data and replicates.

4.2 Toxicity of Linuron to Terrestrial Organisms

Table 4.6 summarizes the most sensitive terrestrial toxicity endpoints for the CRLF, based on an evaluation of both the submitted studies and the open literature. A brief summary of submitted and open literature data considered relevant to this ecological risk assessment for the CRLF is presented below.

Table 4.6 Terrestrial Toxicity Profile for Linuron

Endpoint	Species	Toxicity Value Used in Risk Assessment	Citation MRID#	Comment
Acute Direct Toxicity to Terrestrial-Phase CRLF (LD_{50})	Bobwhite quail	LD_{50} = 940 mg/kg-bw	MRID 00150170	acceptable
Acute Direct Toxicity to Terrestrial-Phase CRLF (LC_{50})	northern bobwhite quail	LC_{50} = 1700 ppm ai	MRID 00034769	acceptable
Chronic Direct Toxicity to Terrestrial-Phase CRLF	northern bobwhite quail and mallard duck	NOEC = 100 ppm	MRID 42541801, 42541802	Acceptable Effects observed on egg production, adult body weight, feed consumption, hatchability, and offspring survivability at 300 ppm.
Indirect Toxicity to Terrestrial-Phase CRLF (via acute toxicity to mammalian prey items)	rat	LD_{50} = 2600 mg/kg-bw	MRID 00027625	acceptable
Indirect Toxicity to Terrestrial-Phase CRLF (via chronic toxicity to mammalian prey items)	rat	NOEL = 0.74 mg/kg-bw or 12.5 ppm	MRID 41463401, 41864701	Acceptable Effects observed include decreased pup survivability and lower pup weight.
Indirect Toxicity to Terrestrial-Phase CRLF (via acute toxicity to terrestrial invertebrate prey items)	Honey bee	LD_{50} >120.86 µg/bee	MRID 00018842	Acceptable
Indirect Toxicity to Terrestrial- and Aquatic-Phase CRLF (via toxicity to terrestrial plants)	Seedling Emergence	EC_{25} = 0.004 lb ai/A NOEC = 0.002 lb ai/A	MRID 41223003	Section 4.2.4 (cucumber) most sensitive seedling emergence (atrazine)
	Vegetative Vigor	EC_{25} = 0.0017 lb ai/A NOEC = 0.0010 lb ai/A	MRID 44113401	Section 4.2.4 (tomato) most sensitive vegetative vigor (diuron)

Acute toxicity to terrestrial animals is categorized using the classification system shown in Table 4.7 (U.S. EPA, 2004). Toxicity categories for terrestrial plants have not been defined.

Table 4.7 Categories of Acute Toxicity for Avian and Mammalian Studies		
Toxicity Category	Oral LD_{50}	Dietary LC_{50}
Very highly toxic	< 10 mg/kg	< 50 ppm
Highly toxic	10 - 50 mg/kg	50 - 500 ppm
Moderately toxic	51 - 500 mg/kg	501 - 1000 ppm
Slightly toxic	501 - 2000 mg/kg	1001 - 5000 ppm
Practically non-toxic	> 2000 mg/kg	> 5000 ppm

4.2.1 Toxicity to Birds

As specified in the Overview Document, the Agency uses birds as a surrogate for terrestrial-phase amphibians when amphibian toxicity data are not available (U.S. EPA, 2004). No terrestrial-phase amphibian data are available for linuron; therefore, acute and chronic avian toxicity data are used to assess the potential direct effects of linuron to terrestrial-phase CRLFs.

4.2.1.1 Birds: Acute Exposure (Mortality) Studies

Oral acute toxicity LD_{50} for bobwhite quail is 940 mg/kg-bw (712 – 1273). The probit slope is 4.0. This was tested using 92.4% technical grade linuron (MRID 00150170). This would categorize linuron to be slightly toxic to birds on acute oral basis.

The most sensitive dietary subacute LC_{50} is for bobwhite quail with 1700 ppm ai (1350-2150) and a probit slope of 7.1 (MRID 43987501). This was tested with technical grade linuron. Another technical subacute dietary study with mallard duck was submitted. The LC_{50} was found to be 4880 ppm ai (970 - infinity). Linuron is considered to be slightly toxic on a subacute dietary basis.

The most sensitive formulated linuron product dietary subacute LC_{50} tested is 3083 ppm ai (2419-3990) with mallard duck. This study (MRID 00022923) was tested with 50% formulation by USFWS in 1995. A total of three studies with formulated product testing were submitted. The other studies were tested with ring-necked pheasant and Japanese quail with the LC50 being 3438 ppm ai and >5000 ppm ai, respectively. Linuron is considered to be from slightly toxic to practically non-toxic on a subacute dietary basis for formulated product

4.2.1.2 Birds: Chronic Exposure (Growth, Reproduction) Studies

The avian reproductive studies (MRID 42541801, 42541802) using mallard duck and bobwhite quail found reproductive effects at 300 ppm ai with an NOEL being established at 100 ppm. The endpoints affected for mallard duck reproduction are egg production, adult body weight, feed consumption, viable embryos of eggs set, number of viable embryos, and number of live embryos. For the bobwhite quail the endpoints affected are hatchability and offspring survivability.

4.2.2 Toxicity to Mammals

Mammalian toxicity data are used to assess potential indirect effects of linuron to the terrestrial-phase CRLF. Effects to small mammals resulting from exposure to linuron may also indirectly affect the CRLF via reduction in available food. As discussed in Section 2.5.3, over 50% of the prey mass of the CRLF may consist of vertebrates such as mice, frogs, and fish (Hayes and Tennant, 1985).

4.2.2.1 Mammals: Acute Exposure (Mortality) Studies

Acute oral LD_{50} for rat was found to be 2600 mg/kg-bw. This value was calculated by the Health Effects Division as part of their assessment to support the linuron tolerance reassessment eligibility decision. The reference for the rat acute oral endpoint is MRID 00027625.

4.2.2.2 Mammals: Chronic Exposure (Growth, Reproduction) Studies

The HED Chapter for the Linuron Tolerance Reassessment Eligibility Decision of April 16, 2002 document also provides The NOEL for the rat 2-generation reproductive study is 0.74 mg/kg/day (MRIDs 41463401 (1990), 41864701 (1991)). This value was calculated by the Health Evaluation Division as part of their assessment to support the linuron tolerance reassessment eligibility decision. Reproductive effects were observed at 5.8 mg/kg/day, based on decreased pup survival and lower pup body weights of F_{1a}, F_{1b}, F_{2a}, and F_{2b} litters. The systemic NOEL from the study is also 0.74 mg/kg/day. Systemic effects were observed at 5.8 mg/kg/day, based on decreased body weight gains in males and females in both generations. The study also shows that the 0.74 mg/kg-bw/day is equivalent to 12.5 mg/kg dietary.

4.2.3 Toxicity to Terrestrial Invertebrates

Terrestrial invertebrate toxicity data are used to assess potential indirect effects of linuron to the terrestrial-phase CRLF. Effects to terrestrial invertebrates resulting from exposure to linuron could also indirectly affect the CRLF via reduction in available food.

The acute LD_{50} for honey bee is greater than 120.86 µg/bee. At the highest dose tested (120.86 µg/bee), only 6.1% of the population died. Linuron is classified as practically non-toxic to honey bee.

4.2.4 Toxicity to Terrestrial Plants

Terrestrial plant toxicity data are used to evaluate the potential for linuron to affect riparian zone and upland vegetation within the action area for the CRLF. Impacts to riparian and upland (i.e., grassland, woodland) vegetation could result in indirect effects to both aquatic- and terrestrial-phase CRLFs, as well as modification to designated critical habitat PCEs via increased sedimentation, alteration in water quality, and reduction in of upland and riparian habitat that provides shelter, foraging, predator avoidance and dispersal for juvenile and adult CRLFs.

Plant toxicity data from both registrant-submitted studies and studies in the scientific literature were reviewed for this assessment. Registrant-submitted studies are conducted under conditions and with species defined in EPA toxicity test guidelines. Sub-lethal endpoints such as plant growth, dry weight, and biomass are evaluated for both monocots and dicots, and effects are evaluated at both seedling emergence and vegetative life stages. Guideline studies generally evaluate toxicity to ten crop species. A drawback to these tests is that they are conducted on herbaceous crop species only, and extrapolation of effects to other species, such as the woody shrubs and trees and wild herbaceous species, contributes uncertainty to risk conclusions.

Commercial crop species have been selectively bred, and may be more or less resistant to particular stressors than wild herbs and forbs. The direction of this uncertainty for specific plants and stressors, including linuron, is largely unknown. Homogenous test plant seed lots also lack the genetic variation that occurs in natural populations, so the range of effects seen from tests is likely to be smaller than would be expected from wild populations.

Due to the lack of available plant data, alternative sources of data were used. The most sensitive phytotoxicity data from other herbicides that have similar modes of action as linuron will be used in lieu of linuron phytotoxicity data. The mode of action for linuron is inhibition of photosynthesis by inhibition of photosystem II. There are 14 herbicides on which phytotoxicity data are available that also inhibit the photosystem II in plants. Table 4.8 and 4.9 lists the herbicides and their respective EC_{25} and NOEC values. The most sensitive vegetative vigor EC_{25} value is from diuron with an EC_{25} of 0.0017 lb ai/a and NOEC of 0.0010 lb ai/A (Table 4.8). The most sensitive seedling emergence EC_{25} value is from atrazine with an EC_{25} of 0.004 lb ai/a and NOEC of 0.002 lb ai/A (Table 4.9).

Table 4.8 Photosystem II Inhibitors Vegetative Vigor

Herbicide	Species	EC25 (lb ai/A)	NOEC	MRID Reference
Ametryn	lettuce	0.027	0.013	40995808
Atrazine	carrot	0.003	0.0025	42041403
Bentazon sodium	cabbage	0.046	0.025	42129606
Bromacil	rape	0.0055	0.0030	44488307
Bromoxynil heptanoate	cabbage	0.011	0.0058	43059603
Bromoxynil octanoate	tomato	0.017	0.015	43633701
Diuron	tomato	0.0017	0.0010	44113401
Hexazinone	rape	0.011	0.0071	43162501
Prometon	lettuce	0.008	0.005	41725303
Pyrazon	soybean	0.036	0.009	41681502
Simazine	oat	0.025	0.016	42634604
Terbacil	cucumber	0.0022	0.00022	42336701

Table 4.9 Photosystem II Inhibitors Seedling Emergence

Herbicide	Species	EC25 (lb ai/A)	NOEC	MRID Reference
Ametryn	lettuce	0.006	<0.006	40995809
Atrazine	cucumber	0.004	0.002	41223003
Bentazon sodium	lettuce	0.13	0.12	42129606
Bromacil	rape	0.0047	<0.0047	44488307
Bromoxynil heptanoate	tomato	0.010	0.0039	43059603
Bromoxynil octanoate	lettuce	0.068	0.048	41606006
Diuron	tomato	0.075	0.047	44113401
Hexazinone	Sugar beet	0.010	0.0069	43162501
Prometon	lettuce	0.01	0.009	41725303
Propanil	lettuce	0.53	0.11	43069901
Pyrazon	soybean	0.124	0.099	41681501
Simazine	lettuce	0.011	0.002	42634603
Terbacil	rape	0.013	0.007	42336701

4.3 Use of Probit Slope Response Relationship to Provide Information on the Endangered Species Levels of Concern

The Agency uses the probit dose response relationship as a tool for providing additional information on the potential for acute direct effects to individual listed species and aquatic animals that may indirectly affect the listed species of concern (U.S. EPA, 2004). As part of the risk characterization, an interpretation of acute RQ for listed species is discussed. This interpretation is presented in terms of the chance of an individual event (i.e., mortality or immobilization) should exposure at the EEC actually occur for a species with sensitivity to linuron on par with the acute toxicity endpoint selected for RQ calculation. To accomplish this interpretation, the Agency uses the slope of the dose response relationship available from the toxicity study used to establish the acute toxicity measures of effect for each taxonomic group that is relevant to this assessment. The individual effects probability associated with the acute RQ is based on the mean estimate of the slope and an assumption of a probit dose response relationship. In addition to a single effects probability estimate based on the mean, upper and lower estimates of the effects probability are also provided to account for variance in the slope, if available.

Individual effect probabilities are calculated based on an Excel spreadsheet tool IECV1.1 (Individual Effect Chance Model Version 1.1) developed by the U.S. EPA, OPP, Environmental Fate and Effects Division (June 22, 2004). The model allows for such calculations by entering the mean slope estimate (and the 95% confidence bounds of that estimate) as the slope parameter for the spreadsheet. In addition, the acute RQ is entered as the desired threshold.

4.4 Incident Database Review

A review of the EIIS database for ecological incidents involving linuron was completed on 5/27/08. The results of this review for terrestrial, plant, and aquatic incidents are discussed below in Sections 4.4.1 through 4.4.3, respectively. A complete list of the incidents involving linuron including associated uncertainties is included as Appendix H.

4.4.1 Terrestrial Incidents

No terrestrial incidents were reported to the Agency.

4.4.2 Plant Incidents

Six non-target plant incidents involving the use of linuron were reported to the Agency. They are as follows:

1986 (incident number B000624-001) – In Michigan, soybeans sprayed with clomazone and linuron. Spray drift damage occurred to native trees and ornamental plants up to 0.5 mile in one direction and 0.25 mile in another direction. Damage appears to be similar to clomazone damage. The use was in accordance with registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as possible.
1993 (incident number I000358-001) – In Indiana, linuron, glyposate, and alachlor were spray onto nearby agricultural fields. About 80 acres of melons were damaged from the spray drift. The use was in accordance with registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as possible.
1997 (incident number I005880-016) - In Wisconsin, clomazone and linuron were applied to nearby agricultural fields. Spray drift damages apple trees. Damage appears to be similar to clomazone damage. The use is considered to be a misuse (accidental) of registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as probable.
1997 (incident number I005880-048) - In Wisconsin, clomazone and linuron were applied to nearby agricultural fields. Spray drift damaged nearby raspberry fields and Linden trees. The use is considered to be a misuse (accidental) of registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as probable.
2005 (incident number I016537-001) – In Maine, Linuron was applied to nearby potato field. Spray drift damages strawberry and Christmas tree field. The use was in accordance with registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as possible.
2006 (incident number I017606-001) – In Michigan, Linuron applied on pumpkin field and all the pumpkins died. This chemical is not registered for pumpkin. The use is considered to be a misuse (intentional) of registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as probable.

4.4.3 Aquatic Incidents

Only one aquatic incident was reported to the Agency involving the use of linuron.

1995 (incident number I004374-002) – In Missouri, fish kills occurred in three ponds downgrade from a shed that was being cleaned out. Pesticides were left outside of the shed. A rain storm came and washed pesticide residues into three ponds. About 150 bluegills, several largemouth bass, and grass carp were killed. Residues of linuron, pentachlorphenol, and 2,4-D were found in the water and soil nearby. The use is considered to be a misuse (accidental) of registered use for linuron. The certainty of injury being attributed to the non-target plants is categorized as possible.

5. Risk Characterization

Risk characterization is the integration of the exposure and effects characterizations. Risk characterization is used to determine the potential for direct and/or indirect effects to the CRLF or for modification to its designated critical habitat from the use of linuron in CA. The risk characterization provides an estimation (Section 5.1) and a description (Section 5.2) of the likelihood of adverse effects; articulates risk assessment assumptions, limitations, and uncertainties; and synthesizes an overall conclusion regarding the likelihood of adverse effects to the CRLF or its designated critical habitat (i.e., "no effect," "likely to adversely affect," or "may affect, but not likely to adversely affect").

5.1 Risk Estimation

Risk is estimated by calculating the ratio of exposure to toxicity. This ratio is the risk quotient (RQ), which is then compared to pre-established acute and chronic levels of concern (LOCs) for each category evaluated (Appendix C). For acute exposures to the CRLF and its animal prey in aquatic habitats, as well as terrestrial invertebrates, the LOC is 0.05. For acute exposures to the CRLF and mammals, the LOC is 0.1. The LOC for chronic exposures to CRLF and its prey, as well as acute exposures to plants is 1.0.

Risk to the aquatic-phase CRLF is estimated by calculating the ratio of exposure to toxicity using 1-in-10 year EECs based on the label-recommended linuron usage scenarios summarized in Table 3.2 and the appropriate aquatic toxicity endpoint from Table 4.1. Risks to the terrestrial-phase CRLF and its prey (*e.g*. terrestrial insects, small mammals and terrestrial-phase frogs) are estimated based on exposures resulting from applications of linuron (Tables 3.5 through 3.6) and the appropriate toxicity endpoint from Table 4.6. Exposures are also derived for terrestrial plants, as discussed in Section 3.3 and summarized in Table 3.7, based on the highest application rates of linuron use within the action area.

5.1.1 Exposures in the Aquatic Habitat

5.1.1.1 Direct Effects to Aquatic-Phase CRLF

Direct effects to the aquatic-phase CRLF are based on peak EECs in the standard pond and the lowest acute toxicity value for freshwater fish. In order to assess direct chronic risks to the CRLF, 60-day EECs and the lowest chronic toxicity value for freshwater fish are used. See Table 5.1. Based on the *chronic* LOC for exceedances for freshwater fish (as a surrogate to the aquatic-phase frog) linuron is likely to directly affect the aquatic-phase of the CRLF. The chronic RQs range from 7.0 (right-of-way) to 1.0 (parsnip). Chronic LOC are exceeded from uses on asparagus, carrot, parsnip, sorghum, soybean, kenaf, and right-of-way. Based on the chronic exceedances, a Likely to Adversely Affect (LAA) determination is made. There are no acute LOC exceedances for freshwater fish (as a surrogate to the aquatic-phase frog) and therefore is Not Likely to Adversely Affect (NLAA) from acute affects.

Table 5.1 Summary of Direct Effect RQs for the Aquatic-phase CRLF							
Use	Direct Effects to CRLF[a]	Surrogate Species	Toxicity Value (µg/L)	EEC (µg/L)	RQ	Probability of Individual Effect	LOC Exceedance and Risk Interpretation
Asparagus	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 27.5	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 18.3*	*3.3*	*Not calculated for chronic endpoints*	*Yes*
Carrot	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 10.3	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 6.8*	*1.2*	*Not calculated for chronic endpoints*	*Yes[d]*
Celery	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 6.9	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 4.6*	*<1.0*	*Not calculated for chronic endpoints*	*No[d]*
Corn (field)	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 8.4	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 5.5*	*<1.0*	*Not calculated for chronic endpoints*	*No[d]*
Parsnip	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 10.3	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 5.8*	*1.0*	*Not calculated for chronic endpoints*	*Yes*
Sorghum (silage)	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 18.1	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 13.5*	*2.4*	*Not calculated for chronic endpoints*	*Yes*
Soybean	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 10.3	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 6.8*	*1.2*	*Not calculated for chronic endpoints*	*Yes*
Kenaf	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 18.1	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 13.5*	*2.4*	*Not calculated for chronic endpoints*	*Yes*
Non-Ag Right of Way	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 60.3	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 39.2*	*7.0*	*Not calculated for chronic endpoints*	*Yes*
Ornamental Plants	Acute Direct Toxicity	Rainbow Trout	LC_{50} = 3,000	Peak: 6.9	<0.05	1 in 4.18E+08 (1 in 216 to 1 in 1.75 E+31)[b]	No[c]
	Chronic Direct Toxicity		*NOAEC = 5.58*	*60-day: 4.6*	*<1.0*	*Not calculated for chronic endpoints*	*No*

[a] RQs associated with acute and chronic direct toxicity to the CRLF are also used to assess potential indirect effects to the CRLF based on a reduction in freshwater fish and frogs as food items.

[b] A probit slope value for the acute rainbow trout toxicity test is not available; therefore, the effect probability was calculated based on a default slope assumption of 4.5 with upper and lower 95% confidence intervals of 2 and 9 (Urban and Cook, 1986).

[c] RQ < acute endangered species LOC of 0.05.

[d] RQ < chronic LOC of 1.0.

5.1.1.2 Indirect Effects to Aquatic-Phase CRLF via Reduction in Prey (non-vascular aquatic plants, aquatic invertebrates, fish, and frogs)

Non-vascular Aquatic Plants

Indirect effects of linuron to the aquatic-phase CRLF (tadpoles) via reduction in non-vascular aquatic plants in its diet are based on peak EECs from the standard pond and the lowest acute toxicity value for aquatic non-vascular plants. See Table 5.2. Based on LOC exceedances for non-aquatic vascular plants from linuron use on asparagus, sorghum, kenaf, and rights-of-way sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in non-vascular plants.

Table 5.2 Summary of Acute RQs Used to Estimate Indirect Effects to the CRLF via Effects to Non-Vascular Aquatic Plants (diet of CRLF in tadpole life stage and habitat of aquatic-phase CRLF)

Uses	Application rate (lb ai/A)*	Peak EEC (µg/L)	Indirect effects RQ** (food and habitat)
Asparagus	4.0	27.5	2.00
Carrot	1.5	10.3	0.75
Celery	1.0	6.9	0.50
Corn (field)	1.5	8.4	0.61
Parsnip	1.5	10.3	0.75
Sorghum (silage)	1.0	18.1	1.32
Soybean	1.5	10.3	0.75
Kenaf	1.0	18.1	1.32
Non-Ag Right of Way	3.0	60.3	4.40
Ornamental Plants	1.0	6.9	0.50

* EFED Label Data Report – 27 June 2007
** LOC exceedances (RQ $\geq$ 1) are bolded and shaded. RQ = use-specific peak EEC/ [*Navicula pelliculosa* EC_{50} = 13.7 ppb].

Aquatic Invertebrates

Indirect acute effects to the aquatic-phase CRLF via effects to prey (invertebrates) in aquatic habitats are based on peak EECs in the standard pond and the lowest acute toxicity value for freshwater invertebrates. For chronic risks, 21-day EECs and the lowest chronic toxicity value for invertebrates are used to derive RQs. A summary of the acute and chronic RQ values for exposure to aquatic invertebrates (as prey items of aquatic-phase CRLFs) is provided in Table 5.3. Based on LOC exceedances for chronic and acute aquatic invertebrates from all use sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in freshwater invertebrates prey items.

Table 5.3 Summary of Acute and Chronic RQs Used to Estimate Indirect Effects to the CRLF via Direct Effects on Aquatic Invertebrates as Dietary Food Items (prey of CRLF juveniles and adults in aquatic habitats)					
Uses	Application rate (lb ai/A)*	Peak EEC (µg/L)	21-day EEC (µg/L)	Indirect Effects Acute RQ**	Indirect Effects Chronic RQ**
Asparagus	4.0	27.5	23.7	0.23	263.3
Carrot	1.5	10.3	8.9	0.08	98.9
Celery	1.0	6.9	5.9	0.06	65.5
Corn (field)	1.5	8.4	7.1	0.07	78.9
Parsnip	1.5	10.3	8.9	0.08	98.9
Sorghum (silage)	1.0	18.1	16.3	0.15	181.1
Soybean	1.5	10.3	8.9	0.08	98.9
Kenaf	1.0	18.1	16.3	0.15	181.1
Non-Ag Right of Way	3.0	60.3	51.3	0.50	570.0
Ornamental Plants	1.0	6.9	5.9	0.06	65.5

* EFED Label Data Report – 27 June 2007
** = LOC exceedances (acute RQ $\geq$ 0.05; chronic RQ $\geq$ 1.0) are bolded and shaded. Acute RQ = use-specific peak EEC / [Daphnia magna EC_{50} = 120 ppb]. Chronic RQ = use-specific 21-day EEC / [Daphnia magna NOEC = 0.09 ppb].

Fish and Frogs

Fish and frogs also represent potential prey items of adult aquatic-phase CRLFs. RQs associated with acute and chronic direct toxicity to the CRLF (Table 5.1) are used to assess potential indirect effects to the CRLF based on a reduction in freshwater fish and frogs as food items. Based on chronic LOC exceedances at all use sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in freshwater fish and frogs as food items.

5.1.1.3 Indirect Effects to CRLF via Reduction in Habitat and/or Primary Productivity (Freshwater Aquatic Plants)

Indirect effects to the CRLF via direct toxicity to aquatic plants are estimated using the most sensitive non-vascular and vascular plant toxicity endpoints. Because there are no obligate relationships between the CRLF and any aquatic plant species, the most sensitive EC_{50} values, rather than NOAEC values, were used to derive RQs. Based on LOC exceedances at all use sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction via reduction in vascular plants. A summary of acute RQs used to estimate indirect effects to the CRLF via effects to vascular aquatic plants is presented in Table 5.4.

Table 5.4 Summary of Acute RQs Used to Estimate Indirect Effects to the CRLF via Effects to Vascular Aquatic Plants (habitat of aquatic-phase CRLF)[a]			
Uses	Application rate (lb ai/A)	Peak EEC (µg/L)	Indirect effects RQ* (food and habitat)
Asparagus	4.0	27.5	11.0
Carrot	1.5	10.3	4.1
Celery	1.0	6.9	2.8
Corn (field)	1.5	8.4	3.4
Parsnip	1.5	10.3	4.1
Sorghum (silage)	1.0	18.1	7.2
Soybean	1.5	10.3	4.1
Kenaf	1.0	18.1	7.2
Non-Ag Right of Way	3.0	60.3	24.1
Ornamental Plants	1.0	6.9	2.8

[a] RQs used to estimate indirect effects to the CRLF via toxicity to non-vascular aquatic plants are summarized in Table 5.2.
* = LOC exceedances (RQ $\geq$ 1) are bolded and shaded. RQ = use-specific peak EEC / [*Elodea nuttalli* EC_{50} = 2.5 ppb].

5.1.2 Exposures in the Terrestrial Habitat

5.1.2.1 Direct Effects to Terrestrial-phase CRLF

As previously discussed in Section 3.3, potential direct effects to terrestrial-phase CRLFs are based on foliar applications of linuron.

Potential direct acute effects to the terrestrial-phase CRLF are derived by considering dose- and dietary-based EECs modeled in T-REX for a small bird (20 g) consuming small invertebrates (Table 3.5) and acute oral and subacute dietary toxicity endpoints for avian species.

Potential direct chronic effects of linuron to the terrestrial-phase CRLF are derived by considering dietary-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates. Chronic effects are estimated using the lowest available toxicity data for birds. EECs are divided by toxicity values to estimate chronic dietary-based RQs. Based on acute and chronic LOC exceedances for the surrogate bird at all use sites, linuron is Likely to Adversely Affect (LAA) the terrestrial-phase of the CRLF directly. Tables 5.5 a&b present summaries of acute and chronic RQs used to estimate direct effects to CRLF.

Table 5.5a Summary of Acute RQs Used to Estimate Direct Effects to the Terrestrial-phase CRLF		
Use (Application Rate)	Dietary-based Acute RQ[1]	Dose-based Acute RQ[1]
Asparagus	0.32	0.91
Carrot	0.12	0.34
Celery	<0.1	0.23
Corn (field)	0.12	0.34
Parsnip	0.12	0.34
Sorghum (silage)	<0.1	0.23
Soybean	0.12	0.34
Kenaf	<0.1	0.23
Non-Ag Right of Way	0.24	0.68
Ornamental Plants	<0.1	0.23
* = LOC exceedances (acute RQ $\geq$ 0.1) are bolded and shaded. [1] Based on [bobwhite quail LD50 = 940 mg/kg-bw, LC50 =1700 ppm].		

Table 5.5b Summary of Chronic RQs Used to Estimate Direct Effects to the Terrestrial-phase CRLF	
Use (Application Rate)	Dietary-based Chronic RQ[1]
Asparagus	5.4
Carrot	2.03
Celery	1.35
Corn (field)	2.03
Parsnip	2.03
Sorghum (silage)	1.35
Soybean	2.03
Kenaf	1.35
Non-Ag Right of Way	4.05
Ornamental Plants	1.35
* = LOC exceedances (chronic RQ $\geq$ 1) are bolded and shaded. [1] Based on [bobwhite NOEC = 100 ppm].	

5.1.2.2 Indirect Effects to Terrestrial-Phase CRLF via Reduction in Prey (terrestrial invertebrates, mammals, and frogs)

5.1.2.2.1 Terrestrial Invertebrates

In order to assess the risks of linuron to terrestrial invertebrates, which are considered prey of CRLF in terrestrial habitats, the honey bee is used as a surrogate for terrestrial invertebrates. The toxicity value for terrestrial invertebrates is calculated by multiplying the lowest available acute contact LD_{50} of 120.86 µg a.i./bee by 1 bee/0.128g, which is based on the weight of an adult honey bee. The toxicity value for terrestrial invertebrates is calculated to be 944.22 ppm. The ECC calculated by T-REX for small and large insects are divided by the calculated toxicity value for terrestrial invertebrates, which is 944.22 µg a.i./g of bee. Based on LOC exceedances at all use sites for small insects as prey item, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in terrestrial invertebrate prey items. A summary of RQs used to estimate indirect effects to CRLF from direct effects on terrestrial invertebrates is presented in Table 5.6.

Table 5.6 Summary of RQs Used to Estimate Indirect Effects to the Terrestrial-phase CRLF via Direct Effects on Terrestrial Invertebrates as Dietary Food Items		
Use	Small Insect RQ*	Large Insect RQ*
Asparagus	0.57	0.06
Carrot	0.21	<0.05
Celery	0.14	<0.05
Corn (field)	0.21	<0.05
Parsnip	0.21	<0.05
Sorghum (silage)	0.14	<0.05
Soybean	0.21	<0.05
Kenaf	0.14	<0.05
Non-Ag Right of Way	0.43	<0.05
Ornamental Plants	0.14	<0.05
* = LOC exceedances (RQ $\geq$ 0.05) are bolded and shaded. Because a definitive endpoint was not established for terrestrial invertebrates (i.e., the value is greater than the highest test concentration), the RQ represents an upper bound value.		

5.1.2.2.2 Mammals

Risks associated with ingestion of small mammals by large terrestrial-phase CRLFs are derived for dietary-based and dose-based exposures modeled in T-REX for a small mammal (15g) consuming short grass. Acute and chronic effects are estimated using the most sensitive mammalian toxicity data. EECs are divided by the toxicity value to estimate acute and chronic dose-based RQs as well as chronic dietary-based RQs. Based on acute and chronic LOC exceedances on the prey item of small mammals at all use sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in small mammal prey items.

Table 5.7 Summary of Acute and Chronic RQs* Used to Estimate Indirect Effects to the Terrestrial-phase CRLF via Direct Effects on Small Mammals as Dietary Food Items (non-granular application)			
Use (Application Rate)	Chronic RQ		Acute RQ
	Dose-based Chronic RQ[1]	Dietary-based Chronic RQ[2]	Dose-based Acute RQ[3]
Asparagus	562.8	76.8	0.16
Carrot	211.0	28.8	0.06

Celery	140.7	19.2	<0.05
Corn (field)	211.0	28.8	0.06
Parsnip	211.0	28.8	0.06
Sorghum (silage)	140.7	19.2	<0.05
Soybean	211.0	28.8	0.06
Kenaf	140.7	19.2	<0.05
Non-Ag Right of Way	422.1	57.6	0.12
Ornamental Plants	140.7	19.2	<0.05

* = LOC exceedances (acute RQ ≥ 0.1 and chronic RQ ≥ 1) are bolded and shaded.
[1] Based on dose-based EEC and linuron rat NOAEL = 0.74 mg/kg-bw.
[2] Based on dietary-based EEC and linuron rat NOAEC = 12.5 mg/kg-diet.
[3] Based on dose-based EEC and linuron rat acute oral LD_{50} = 2600 mg/kg-bw.

5.1.2.2.3 Frogs

An additional prey item of the adult terrestrial-phase CRLF is other species of frogs. In order to assess risks to these organisms, dietary-based and dose-based exposures modeled in T-REX for a small bird (20g) consuming small invertebrates are used. See Section 5.1.2.1 and associated table (Table 5.5) for results. Estimates of potential direct effects on the terrestrial-phase CRLF were further refined using the T-HERPS spreadsheet. Based on this refinement acute (dietary-based) RQ (RQ range 0.2 – 0.1) exceeds the acute risk to listed species LOC for direct effects on terrestrial-phase CRLF foraging on small insects for all uses except Sorghum (silage), kenaf, and ornamental plants. In addition, the chronic risk LOC is exceeded (RQ range 5.4 – 1.4) for all uses. Based on acute and chronic LOC exceedances on the prey item of small frogs, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in small frog prey items.

5.1.2.3 Indirect Effects to CRLF via Reduction in Terrestrial Plant Community (Riparian and Upland Habitat)

Potential indirect effects to the CRLF resulting from direct effects on riparian and upland vegetation are assessed using RQs from terrestrial plant seedling emergence and vegetative vigor EC_{25} data as a screen. Since there are no available non-target terrestrial plant data, there will be no RQs to calculate.

Potential indirect effects to the CRLF resulting from direct effects on riparian and upland vegetation are assessed using RQs from terrestrial plant seedling emergence and vegetative vigor EC_{25} data as a screen. Due to the lack of available plant data, the most sensitive available data using EC_{25} and NOEC endpoints from herbicides that have similar mode of action to linuron. The mode of action for linuron is inhibition of photosynthesis by inhibition of photosystem II. See section 4.2.4 for additional information. Table 5.8 shows the RQ to non-target plants that are exposed to linuron from spray drift and runoff.

The RQs for non-target terrestrial plants range from 494 to 5.9. The LOC exceedance for non-target terrestrial plants is 1.0 or greater. Based on the TERRPLANT model, linuron is likely to indirectly affect the CRLF via reduction in terrestrial plant community. Based on LOC exceedances on the non-target terrestrial plants at all use sites, linuron is Likely to Adversely Affect (LAA) the CRLF indirectly via reduction in habitat.

Table 5.8 RQs* for Non-Target Plants Inhabiting Dry and Semi-Aquatic Areas Exposed to Linuron via Runoff and Drift

Use	Application rate (lbs a.i./A)	Application method	Drift Value (%)	Spray drift RQ	Dry area RQ	Semi-aquatic area RQ
Asparagus	4.0	Foliar – ground	1	23.5	70.6	494.1
Non-Ag Right of Way	3.0	Foliar – ground	1	17.6	52.9	370.6
Carrot, Corn (field), Parsnip, Soybean	1.5	Foliar – ground	1	8.8	26.5	185.3
Sorghum (silage), kenaf, ornamental plants	1.0	Foliar – ground	1	5.9	17.7	123.5
* = LOC exceedances (RQ $\geq$ 1) are bolded.						

5.1.3 Primary Constituent Elements of Designated Critical Habitat

5.1.3.1 Aquatic-Phase (Aquatic Breeding Habitat and Aquatic Non-Breeding Habitat)

Three of the four assessment endpoints for the aquatic-phase primary constituent elements (PCEs) of designated critical habitat for the CRLF are related to potential effects to aquatic and/or terrestrial plants:

- Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.
- Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.
- Reduction and/or modification of aquatic-based food sources for pre-metamorphs (*e.g.*, algae).

Based on the risk estimation for potential effects to aquatic and/or terrestrial plants provided in Sections 5.1.1.2, 5.1.1.3, and 5.1.2.3, linuron is likely to affect aquatic-phase PCEs of designated habitat related to effects on aquatic and/or terrestrial plants.

- Aquatic non-vascular plants used as food source for CRLF may be potentially affected from linuron use on asparagus, sorghum, kenaf, and rights-of way sites.
- Reduction of aquatic based food sources (aquatic invertebrates) may occur from all use sites.
- Due to aquatic vascular and terrestrial plant communities being reduced from all use sites, there is potential for alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond. These

plant communities provide for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.

- Due to aquatic vascular and terrestrial plant communities being reduced from all use sites, there is potential for alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food.

The remaining aquatic-phase PCE is "alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source." To assess the impact of linuron on this PCE, acute and chronic freshwater fish and invertebrate toxicity endpoints, as well endpoints for aquatic non-vascular plants are used as measures of effects. RQs for these endpoints were calculated in Sections 5.1.1.1 and 5.1.1.2. Based on chronic endpoints for freshwater fish and acute and chronic endpoints for aquatic invertebrates, linuron is likely to affect aquatic-phase PCEs of designated habitat related to effects of alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source.

5.1.3.2 Terrestrial-Phase (Upland Habitat and Dispersal Habitat)

Two of the four assessment endpoints for the terrestrial-phase PCEs of designated critical habitat for the CRLF are related to potential effects to terrestrial plants:

- Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or dripline surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance
- Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal

The risk estimation for terrestrial-phase PCEs of designated habitat related to potential effects on terrestrial plants is provided in Section 5.1.2.3. These results will inform the effects determination for modification of designated critical habitat for the CRLF.

The third terrestrial-phase PCE is "reduction and/or modification of food sources for terrestrial phase juveniles and adults." To assess the impact of linuron on this PCE, acute and chronic toxicity endpoints for birds, mammals, and terrestrial invertebrates are used as measures of effects. RQs for these endpoints were calculated in Section 5.1.2.2. Based on acute and chronic LOC exceedances at all use sites for CRLF prey items of small mammals and other frogs (bird as a surrogate), linuron is likely to affect the third terrestrial - phase PCEs.

The fourth terrestrial-phase PC is based on alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source. Direct acute and chronic RQs for terrestrial-phase CRLFs are presented in

Section 5.2.1.2. Due to acute and chronic LOC exceedances at all use sites to terrestrial-phase CRLFs, linuron is likely to affect the fourth terrestrial - phase PCEs.

5.2 Risk Description

The risk description synthesizes an overall conclusion regarding the likelihood of adverse impacts leading to an effects determination (*i.e.*, "no effect," "may affect, but not likely to adversely affect," or "likely to adversely affect") for the CRLF and its designated critical habitat.

If the RQs presented in the Risk Estimation (Section 5.1) show no direct or indirect effects for the CRLF, and no modification to PCEs of the CRLF's designated critical habitat, a "no effect" determination is made, based on linuron's use within the action area. However, if direct or indirect effect LOCs are exceeded or effects may modify the PCEs of the CRLF's critical habitat, the Agency concludes a preliminary "may affect" determination for the FIFRA regulatory action regarding linuron. Based on direct and indirect LOC exceedances for CRLF, the Agency concludes a preliminary may affect determination for the CRLF and critical habitat. A summary of the results of the risk estimation is provided in Table 5.9 for direct and indirect effects to the CRLF and in Table 5.10 for the PCEs of designated critical habitat for the CRLF.

Table 5.9 Risk Estimation Summary for Linuron - Direct and Indirect Effects to CRLF

Assessment Endpoint	Preliminary Effects Determination	Description of Results of Risk Estimation
Aquatic Phase (eggs, larvae, tadpoles, juveniles, and adults)		
Direct Effects Survival, growth, and reproduction of CRLF individuals via direct effects on aquatic phases	May affect	No acute LOC exceedances, however chronic LOC exceedances occur at all use sites except for ornamentals, celery and corn. RQsthat exceed chronic LOC range from 7.0 for rights-of-way to 1.0 for parsnip. **LAA is determined**.
Indirect Effects Survival, growth, and reproduction of CRLF individuals via effects to food supply (*i.e.,* freshwater invertebrates, non-vascular plants)	May affect	LOC for non-vascular plants are exceeded only for asparagus, sorghum, kenaf, and non-agricultural rights-of-way. These RQs that exceed LOC range from 4.4 to 1.32. Aquatic invertebrates acute and chronic LOC are exceeded. The acute RQs range from 0.50 to 0.06. The chronic RQs range from 570.0 to 263.3. **LAA is determined.**
Indirect Effects Survival, growth, and reproduction of CRLF individuals via effects on habitat, cover, and/or primary productivity (*i.e.,* aquatic plant community)	May affect	The LOC for aquatic vascular plants are exceeded for all use sites. The RQs range from 24.1 to 2.8. **LAA is determined**.
Indirect Effects Survival, growth, and reproduction of CRLF individuals via effects to riparian vegetation, required to maintain acceptable water quality and habitat in ponds and streams	May affect	The terrestrial non-target plant LOC is exceeded for all use sites. The RQs range from 494.1 (asparagus) to 123.5 (Sorghum (silage), kenaf, ornamental plants) for runoff to low-lying semi-aquatic areas and from 23.9 to 5.9 for spray drift to non-target plants. **LAA is determined.**

comprising the species' current range.		
Terrestrial Phase (Juveniles and adults)		
Direct Effects Survival, growth, and reproduction of CRLF individuals via direct effects on terrestrial phase adults and juveniles	May affect	For dietary-based direct effects – Direct acute LOC to CRLF is exceeded from the use of linuron on asparagus, rights-of-way, carrot, corn, parsnip, and soybean with RQs ranging from 0.32 to 0.12. No acute LOC exceedances for celery, sorghum, kenaf and ornamental crops. Chronic LOC exceedances occur at all use sites with RQs ranging from 5.4 to 1.35. **LAA is determined**. For dose-based direct effects - Acute LOC exceedances occur at all use sites with RQs ranging from 0.91 to 0.23. **LAA is determined.**
Indirect Effects Survival, growth, and reproduction of CRLF individuals via effects on prey (*i.e.*, terrestrial invertebrates, small terrestrial mammals and terrestrial phase amphibians)	May affect	For terrestrial invertebrates- Acute LOC exceedances occur at all use sites with RQs ranging from 0.57 to 0.14 for small insects. For large insects, LOC is exceeded only for asparagus use with RQ of 0.06. NLAA is determined. For small terrestrial mammals (dietary-based)- Chronic LOC exceedances occur at all use sites with RQs ranging from 76.8 to 19.2. **LAA is determined**. For small terrestrial mammals (dose-based) - acute LOC to CRLF is exceeded from the use of linuron on asparagus and rights-of-way with RQ of 0.16 and 0.12, respectively. LOC for carrot, corn, parsnip, and soybean have RQs of 0.06. No acute LOC exceedances for celery, sorghum, kenaf and ornamental crops. Chronic LOCs are exceeded at all use sites with RQs ranging from 562.8 to 140.7. NLAA is determined.
Indirect Effects Survival, growth, and reproduction of CRLF individuals via effects on habitat (*i.e.*, riparian vegetation)	May affect	The terrestrial non-target plant LOC is exceeded for all use sites. The RQs range from 494.1 (asparagus) to 123.5 (Sorghum (silage), kenaf, ornamental plants) for runoff to low-lying semi-aquatic areas and from 23.9 to 5.9 for spray drift to non-target plants. **LAA is determined**.

Table 5.10 Risk Estimation Summary for Linuron – PCEs of Designated Critical Habitat for the CRLF		
Assessment Endpoint	Preliminary Effects Determination	Description of Results of Risk Estimation
Aquatic Phase PCEs (Aquatic Breeding Habitat and Aquatic Non-Breeding Habitat)		
Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.	Habitat modification	LOCs are exceeded for terrestrial riparian plants and for aquatic vascular plants from exposure to linuron from runoff or spray drift.
Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	Habitat modification	LOCs are exceeded for terrestrial riparian plants and for aquatic vascular plants from exposure to linuron from runoff or spray drift. Alteration of riparian and vascular plants may result in alteration of temperature, turbidity, and oxygen content.
Alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source.	Habitat modification	LOC is exceeded for indirect effects on terrestrial and aquatic-phase CRLF from linuron application (survival, growth, and reproduction of CRLF individuals via effects on prey (*i.e.*, terrestrial invertebrates, small terrestrial mammals and terrestrial phase amphibians))
Reduction and/or modification of aquatic-based food sources for pre-metamorphs (e.g., algae)	Habitat modification	LOC for non-vascular plants are exceeded only for asparagus, sorghum, kenaf, and non-agricultural rights-of-way.
Terrestrial Phase PCEs (Upland Habitat and Dispersal Habitat)		
Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or dripline surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance	Habitat modification	At 200 feet, the deposition from 4 lb ai/A ground application will deposit 0.0204 lb ai/A on non-target terrestrial plants. This would result in RQ of 12, thereby exceeding the LOC for non-listed species of non-target plants.
Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal	Habitat modification	Effects are expected to non-target terresatrial plants over one mile from use site from ground application.
Reduction and/or modification of food sources for terrestrial phase juveniles and adults	Habitat modification	LOC is exceeded for indirect effects on terrestrial and aquatic-phase CRLF from linuron application (survival, growth, and reproduction of CRLF individuals via effects on prey (*i.e.*, terrestrial invertebrates, small terrestrial mammals and terrestrial phase amphibians))
Alteration of chemical characteristics	Habitat	LOC is exceeded for direct effects on terrestrial and

Table 5.10 Risk Estimation Summary for Linuron – PCEs of Designated Critical Habitat for the CRLF		
Assessment Endpoint	Preliminary Effects Determination	Description of Results of Risk Estimation
necessary for normal growth and viability of juvenile and adult CRLFs and their food source.	modification	aquatic-phase CRLF from linuron application

Following a preliminary "may affect" or "habitat modification" determination, additional information is considered to refine the potential for exposure at the predicted levels based on the life history characteristics (*i.e.*, habitat range, feeding preferences, etc.) of the CRLF. Based on the best available information, the Agency uses the refined evaluation to distinguish those actions that "may affect, but are not likely to adversely affect" from those actions that are "likely to adversely affect" the CRLF and its designated critical habitat.

The criteria used to make determinations that the effects of an action are "not likely to adversely affect" the CRLF and its designated critical habitat include the following:

- Significance of Effect: Insignificant effects are those that cannot be meaningfully measured, detected, or evaluated in the context of a level of effect where "take" occurs for even a single individual. "Take" in this context means to harass or harm, defined as the following:
  - Harm includes significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering.
  - Harass is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering.
- Likelihood of the Effect Occurring: Discountable effects are those that are extremely unlikely to occur.
- Adverse Nature of Effect: Effects that are wholly beneficial without any adverse effects are not considered adverse.

A description of the risk and effects determination for each of the established assessment endpoints for the CRLF and its designated critical habitat is provided in Sections 5.2.1 through 5.2.3.

5.2.1 Direct Effects

5.2.1.1 Aquatic-Phase CRLF

The aquatic-phase considers life stages of the frog that are obligatory aquatic organisms, including eggs and larvae. It also considers submerged terrestrial-phase juveniles and adults, which spend a portion of their time in water bodies that may receive runoff and spray drift containing linuron.

The acute toxicity data submitted to the Agency indicate that linuron is moderately toxic to freshwater fish.

There are no acute LOC exceedances for direct acute effect to the CRLF. However, chronic LOC exceedances occur at all use sites except for ornamentals, celery and corn.

The probability of an individual effect to the aquatic-phase CRLF is based on the slope of the dose response curve for the acute endpoint used to derive the RQ. The probability is calculated to be one in 4.18E+08 with 95% confidence interval of 1 in 216 to 1 in 1.75 E+31.

The monitoring data available are below the PRZM-EXAMS predictions by an order of magnitude. The monitoring data indicated that the time weighted mean concentration ranged from below the 0.001 ppb to 0.86 ppb with a mean concentration of 0.21 ppb. PRZM-EXAMS prediction (not including the scenarios for impervious surfaces) estimated linuron to be in the surface waters at peak concentrations from 27.5 ppb to 2.6 ppb and 60 day EEC from 18.3 ppb to 1.8. This would indicate that the modeled aquatic scenarios for linuron use sites may be over estimating the EEC.

There is one incident that was reported to the Agency concerning fish kills with linuron involvement. This incident occurred in 1995 in Missouri with fish kills occurring in three ponds downgrade from a shed that was being cleaned out. Pesticides were left outside of the shed. A rain storm came and washed pesticide residues into three ponds. About 150 bluegills, several largemouth bass, and grass carp were killed. Residues of linuron, pentachlorphenol, and 2,4-D were found in the water and soil nearby. This incident would be considered a misuse and not a labeled use of linuron.

No adequate chronic data were available for freshwater fish. Therefore, an acute to chronic ratio (ACR) was used to calculate what the chronic endpoint may be. Phenylurea herbicides with both an acute 96-hr LC_{50} value and fish early life stage NOEC for the same freshwater fish species are tabulated in Table 4.3. Additionally, freshwater fish data for tebuthiuron, a substituted diazolyluron urea herbicide, were included as one of a limited number of substituted ureas with both acute and chronic toxicity data. Acute-to-chronic ratio (ACR) values ranged from 5.5 to 538 for freshwater fish. The studies were all submitted studies done under comparable conditions. A large ACR is not unusual where the mode of action for chronic effects differ from the acute, especially if metabolic activation is involved. Diuron was used to calculate the ACR and thus provide a chronic toxicity endpoint to be used. The use of the most sensitive of the phenylurea herbicides may over estimate the toxicity of linuron but would provide conservative endpoint.

Based on the weight-of-evidence and lack of chronic data, the Agency concludes that there is a potential for direct effects to the aquatic-phase of the CRLF based on this chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.1.2 Terrestrial-Phase CRLF

The terrestrial-phase considers life stages of the frog that are terrestrial organisms, including eggs and larvae.

The acute toxicity data submitted to the Agency indicate that linuron is slightly toxic to birds on acute oral and subacute dietary basis.

The RQs were calculated from T-REX model. For dietary-based direct effects – acute LOC to CRLF is exceeded from the use of linuron on asparagus, rights-of-way, carrot, corn, parsnip, and soybean with RQs ranging from 0.32 to 0.12. No acute LOC exceedances for celery, sorghum, kenaf and ornamental crops. Chronic LOC exceedances occur at all use sites with RQs ranging from 5.4 to 1.35.

For dose-based direct effects the acute LOC exceedances occur at all use sites with RQs ranging from 0.91 to 0.23. The LOC for listed species is 0.1.

T-REX calculated acute dose-based RQs, acute dietary-based RQs and chronic dietary-based RQs exceed their respective LOCs, resulting in a "may affect" determination for all uses. In order to explore influences of amphibian-specific food intake equations on potential dose-based and dietary-based exposures of the terrestrial phase CRLF to linuron, T-HERPS is used. Modeling with T-HERPS incorporates the same application rates, intervals and number of applications for each use as defined for modeling using T-REX (Table 3.4). Since applications of linuron for all uses result in exposures sufficient to exceed the LOC for direct effects to the CRLF, the T-HERPS model was used to estimate EECs and subsequent risks to the CRLF based on amphibian-specific equations. These refined EECs and RQs were used to distinguish "NLAA" and "LAA" determinations. An example output from T-HERPS is available in Appendix N.

The T-HERPS model calculated the RQs to exceed the acute LOC for the frog (dose-based) that consumes a small mammal. On a dietary based RQ, the model calculates that acute LOC is exceeded for a frog that consumes small insects and a small mammal. These calculations are for all use sites. The chronic LOC calculates that the LOC is exceeded for frogs that consume small insects and small mammals at all use sites.

The probability of an individual effect to the terrestrial-phase CRLF is based on the slope of the dose response curve for the acute endpoint used to derive the RQ. The probability is calculated to be one in 2.94E+05 with 95% confidence interval of 1 in 4.4 to 1 in 7.81E+11.

Based on the weight-of-evidence, the Agency concludes that there is a potential direct impact to the terrestrial-phase of the CRLF based on acute and chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.2 Indirect Effects (via Reductions in Prey Base)

5.2.2.1 Algae (non-vascular plants)

As discussed in Section 2.5.3, the diet of CRLF tadpoles is composed primarily of unicellular aquatic plants (i.e., algae and diatoms) and detritus.

LOC for non-vascular plants are exceeded only for asparagus, sorghum, kenaf, and non-agricultural rights-of-way. These RQs that exceed LOC range from 4.4 to 1.32.

The fate characteristics indicate that linuron is expected to be persistent in aquatic environments with EECs after 60 days being above the Agency's LOC for non-vascular aquatic plants, a primary food source for aquatic-phase CRLF. The application of linuron is in California is anticipated to be in late winter and early spring. The timing of the application would coincide with reproduction of CRLF in aquatic environments as well as for the tadpoles to feed on non-vascular aquatic plants.

Based on the weight-of-evidence, the Agency concludes that there is a potential indirect impact to the aquatic-phase of the CRLF from reduction of food items (algae) and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.2.2 Aquatic Invertebrates

As discussed in Section 2.5.3, the diet of CRLF also includes aquatic invertebrates.

The potential for linuron to elicit indirect effects to the CRLF via effects on freshwater invertebrate food items is dependent on several factors including: (1) the potential magnitude of effect on freshwater invertebrate individuals and populations; and (2) the number of prey species potentially affected relative to the expected number of species needed to maintain the dietary needs of the CRLF. Together, these data provide a basis to evaluate whether the number of individuals within a prey species is likely to be reduced such that it may indirectly affect the CRLF.

No adequate chronic data were available for aquatic invertebrates. Therefore, an acute to chronic ratio (ACR) was used to calculate from a group of phenylurea herbicides that the Agency has data for to determine what the chronic endpoint may be. The ACR values ranged from 2.1 to 1,400 for *D. magna*. A large ACR is not unusual where the mode of action for chronic effects differ from the acute, especially if metabolic activation is involved. Based on this toxicity pattern and several of the ACR values being non-definitve but large, the diuron ACR (1400) for the *D. magna* was used as a conservative ACR factor for extrapolating a linuron reproductive NOEC (NOEC = 96-h EC_{50}/ACR = 120/1400 = 0.09 ppb a.i.) from the most acutely sensitive linuron *D. magna* result. *D. magna* reproduction value of 0.09 ppb was used for linuron as a conservative estimate of its reproductive effect level. The toxicity value categorizes linuron as being very highly toxic to aquatic invertebrates.

Using the endpoints, the acute and chronic LOC are exceeded for the aquatic invertebrates. The acute RQs range from 0.50 to 0.06. The chronic RQs range from 570.0 to 263.3.

Although the indirect affects to aquatic-phase CRLF may be borderline of significance from direct affects to aquatic invertebrates, it is anticipated that aquatic invertebrates availability as a food item to CRLF may be significantly reduced from chronic effects from exposure to linuron. The fate characteristics of linuron indicate that linuron is expected to be persistent in aquatic environments with EECs after 60 days being well above the Agency's chronic LOC for aquatic invertebrates.

The main food source for juvenile aquatic- and terrestrial-phase CRLFs is thought to be aquatic and terrestrial invertebrates found along the shoreline and on the water surface. The application of linuron is in California is anticipated to be in late winter and early spring. The timing of the application would coincide with juvenile aquatic- and terrestrial-phase CRLFs that would be feeding on aquatic and terrestrial invertebrates.

Based on the weight-of-evidence and lack of chronic data, the Agency concludes that there is a potential indirect impact to the aquatic invertebrates that the CRLF consumes based on acute and chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.2.3 Fish and Aquatic-phase Frogs

As discussed in Section 2.5.3, the diet of CRLF also includes small fish and other aquatic-phase frogs.

The acute toxicity data submitted to the Agency indicate that linuron is moderately toxic to freshwater fish. In lieu of actual frog toxicity data, fish toxicity data will serve as a surrogate for aquatic-phase frog toxicity data.

There are no acute LOC exceedances for direct acute effect to the CRLF. However, chronic LOC exceedances occur at all use sites except for ornamentals, celery and corn.

The probability of an individual effect to the aquatic-phase CRLF is based on the slope of the dose response curve for the acute endpoint used to derive the RQ. The probability is calculated to be one in 4.18E+08 with 95% confidence interval of 1 in 216 to 1 in 1.75 E+31.

No adequate chronic data were available for freshwater fish. Therefore, an acute to chronic ratio (ACR) was used to calculate what the chronic endpoint may be. Phenylurea herbicides with both an acute 96-hr LC_{50} value and fish early life stage NOEC for the same freshwater fish species are tabulated in Table 4.3. Additionally, freshwater fish data for tebuthiuron, a substituted diazolyluron urea herbicide, were included as one of a limited number of substituted ureas with both acute and chronic toxicity data. Acute-to-chronic ratio (ACR) values ranged from 5.5 to 538 for freshwater fish. The studies were all submitted studies done under comparable conditions. A large ACR is not unusual where the mode of action for chronic effects differ from the acute, especially if metabolic activation is involved. Diuron was used to calculate the ACR and thus provide a chronic toxicity endpoint to be used. The use of the most sensitive of the phenylurea herbicides may over estimate the toxicity of linuron but would provide conservative endpoint.

Although there are no indirect affects to aquatic-phase CRLF from direct affects to food items such as small fish, small frogs or tadpoles, it is anticipated that these food items for CRLF may be significantly reduced from chronic effects from exposure to linuron. The fate characteristics of linuron indicate that linuron is expected to be persistent in aquatic environments with EECs after 60 days being well above the Agency's chronic LOC for small fish, small frogs or tadpoles.

The application of linuron is in California is anticipated to be in late winter and early spring. The timing of the application would coincide with juvenile aquatic- and terrestrial-phase CRLFs that would be feeding on small fish, small frogs or tadpoles.

Based on the weight-of-evidence and lack of chronic data, the Agency concludes that there is a potential impact to the prey items of aquatic-phase CRLF based on this chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.2.4 Terrestrial Invertebrates

When the terrestrial-phase CRLF reaches juvenile and adult stages, its diet is mainly composed of terrestrial invertebrates.

Terrestrial invertebrate toxicity data are used to assess potential indirect effects of linuron to the terrestrial-phase CRLF. Effects to terrestrial invertebrates resulting from exposure to linuron may also indirectly affect the CRLF via reduction in available food.

The acute LD_{50} for honey bee is greater than 120.86 µg/bee. At the highest dose tested (120.86 µg/bee), only 6.1% of the population died. Linuron is classified as practically non-toxic to honey bee.

For terrestrial invertebrates- Acute LOC exceedances occur at all use sites with RQs ranging from 0.57 to 0.14 for small insects. For large insects, LOC is exceeded only for asparagus use with RQ of 0.06. Based on LOC exceedances at all use sites for small insects as prey item, linuron is likely to indirectly affect the CRLF via reduction in terrestrial invertebrate prey items.

Since there was no slope for the honey bee due to no LD50 value, the probability of an individual effect to terrestrial invertebrates can not be calculated.

It is uncertain if there was any mortalities on the honey bee at the highest dose concentration tested since the study did not indicate such data. There is much uncertainty about the RQs for terrestrial invertebrates since the honey bee LD_{50} value is greater than the highest dose tested and that linuron is considered to be practically non-toxic to the honey bee, the RQ value appears to be overestimated.

From the LOC exceedances the Agency concludes that there is a potential indirect impact to terrestrial-phase CRLF from reduction to terrestrial invertebrate prey items. Due to uncertainty about the toxicity of the terrestrial invertebrates, the low RQ and LOC exceedances being minimal; Linuron appears to Not Likely to Adversely Affect the CRLF indirectly from reduction of terrestrial invertebrate prey items.

5.2.2.5 Mammals

Life history data for terrestrial-phase CRLFs indicate that large adult frogs consume terrestrial vertebrates, including mice. Small mammals can take ou to 50% of the CRLF food intake.

For small terrestrial mammals (dietary-based)- the chronic LOC is exceeded at all use sites with RQs ranging from 76.8 to 19.2. For small terrestrial mammals (dose-based) – the acute LOC to CRLF is exceeded from the use of linuron on asparagus and rights-of-way with RQ of 0.16 and 0.12, respectively. LOC for carrot, corn, parsnip, and soybean have RQs of 0.06. No acute LOC exceedances for celery, sorghum, kenaf and ornamental crops. Chronic LOCs are exceeded at all use sites with RQs ranging from 562.8 to 140.7.

The chronic effects are based on rat reproductive effects that were based on decreased pup survival and lower pup body weights of F_{1a} , F_{1b} , F_{2a} , and F_{2b} litters. The systemic effects were based on decreased body weight gains in males and females in both generations.

The probability of an individual effect to the mammal prey item is based on the slope of the dose response curve for the acute endpoint used to derive the RQ. The probability is calculated to be one in 2.94E+05 with 95% confidence interval of 1 in 4.4 to 1 in 7.81E+11.

Although there is LOC exceedances for direct effect (dietary-based) to a prey item of small mammals, the LOC exceedances of dose-based is very marginal. The dose-based RQs are from the T-HERPS model that is more refined and includes the weight of the frog, metabolism and amount of the prey items that the frog ingests. This would tend to be more accurate than the dietary-based RQs.

The chronic LOC is exceeded for small mammals significantly. The effects observed in the rat reproduction study were survival issues for the pups which can translate into survival issues for the progeny of the CRLF. Based on fate studies of linuron, residues of linuron are expected to persist in the terrestrial environment at concentrations that that will exceed the Agency's chronic LOC for small mammals.

Based on the weight-of-evidence, the Agency concludes that there is a potential indirect impact to the mammal prey item based on the chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.2.6 Terrestrial-phase Amphibians

Terrestrial-phase adult CRLFs also consume frogs. RQ values representing direct exposures of linuron to terrestrial-phase CRLFs are used to represent exposures of linuron to frogs in terrestrial habitats.

The acute toxicity data submitted to the Agency indicate that linuron is slightly toxic to birds on acute oral and subacute dietary basis.

The RQs were calculated from T-REX model. For dietary-based direct effects – acute LOC to CRLF is exceeded from the use of linuron on asparagus, rights-of-way, carrot, corn, parsnip, and soybean with RQs ranging from 0.32 to 0.12. No acute LOC exceedances for celery, sorghum, kenaf and ornamental crops. Chronic LOC exceedances occur at all use sites with RQs ranging from 5.4 to 1.35.

For dose-based direct effects the acute LOC exceedances occur at all use sites with RQs ranging from 0.91 to 0.23. The LOC for listed species is 0.1 RQ.

T-REX calculated acute dose-based RQs, acute dietary-based RQs and chronic dietary-based RQs exceed their respective LOCs, resulting in a “may affect” determination for all uses. In order to explore influences of amphibian-specific food intake equations on potential dose-based and dietary-based exposures of the terrestrial phase CRLF to linuron, T-HERPS is used. Modeling with T-HERPS incorporates the same application rates, intervals and number of applications for each use as defined for modeling using T-REX (Table 3.4). Since applications of linuron for all uses result in exposures sufficient to exceed the LOC for direct effects to the CRLF, the T-HERPS model was used to estimate EECs and subsequent risks to the CRLF based on amphibian-specific equations. These refined EECs and RQs were used to distinguish “NLAA” and “LAA” determinations. An example output from T-HERPS is available in Appendix N.

Since there were exceedances from the T-REX model, more refinement of the RQs was done with the T-HERPS model. The T-HERPS model calculated the RQs to exceed the acute LOC for the frog (dose-based) that consumes a small mammal. On a dietary based RQ, the model calculates that acute LOC is exceeded for a frog that consumes small insects and a small mammal. These calculations are for all use sites. The chronic LOC calculates that the LOC is exceeded for frogs that consume small insects and small mammals at all use sites.

The probability of an individual effect to the terrestrial-phase CRLF is based on the slope of the dose response curve for the acute endpoint used to derive the RQ. The probability is calculated to be one in 2.94E+05 with 95% confidence interval of 1 in 4.4 to 1 in 7.81E+11.

Based on the weight-of-evidence, the Agency concludes that there is a potential indirect impact to terrestrial-phase amphibians based on acute and chronic endpoint and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.3 Indirect Effects (via Habitat Effects)

5.2.3.1 Aquatic Plants (Vascular and Non-vascular)

Aquatic plants serve several important functions in aquatic ecosystems. Non-vascular aquatic plants are primary producers and provide the autochthonous energy base for aquatic ecosystems. Vascular plants provide structure, rather than energy, to the system, as attachment sites for many aquatic invertebrates, and refugia for juvenile organisms, such as fish and frogs. Emergent plants help reduce sediment loading and provide stability to nearshore areas and lower streambanks. In addition, vascular aquatic plants are important as attachment sites for egg masses of CRLFs.

Potential indirect effects to the CRLF based on impacts to habitat and/or primary production were assessed using RQs from freshwater aquatic vascular and non-vascular plant data.

LOCs are exceeded for aquatic vascular plants and algae from exposure to linuron from runoff or spray drift. LOC for non-vascular plants are exceeded only for asparagus, sorghum, kenaf, and non-agricultural rights-of-way. These RQs that exceed LOC range from 4.4 to 1.32. The LOC for aquatic vascular plants are exceeded for all use sites. The RQs range from 24.1 to 2.8.

The endpoint for aquatic vascular endpoint comes from the open literature rather than submitted studies. The species used is *Elodea nuttalli* in which the endpoint used is for biomass reduction. The information from the literature indicates that the study is supplemental due to lack of raw data and replicates from valid statistical analysis.

Based on the weight-of-evidence, the Agency concludes that there is a potential indirect impact to terrestrial-phase amphibians by aquatic habitat degradation from linuron exposure and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.3.2 Terrestrial Plants

Terrestrial plants serve several important habitat-related functions for the CRLF. In addition to providing habitat and cover for invertebrate and vertebrate prey items of the CRLF, terrestrial vegetation also provides shelter for the CRLF and cover from predators while foraging. Upland vegetation including grassland and woodlands provides cover during dispersal. Riparian vegetation helps to maintain the integrity of aquatic systems by providing bank and thermal stability, serving as a buffer to filter out sediment, nutrients, and contaminants before they reach the watershed, and serving as an energy source.

The terrestrial non-target plant LOC is exceeded for all use sites. The RQs range from 494.1 (asparagus) to 123.5 (Sorghum (silage), kenaf, ornamental plants) for runoff to low-lying semi-aquatic areas and from 23.9 to 5.9 for spray drift to non-target plants.

Differences of response between the dicots and monocots are minimal. The mode of action of linuron is inhibition of photosynthesis by inhibition of photosystem II. All plants rely on their energy requirements for production with the photosystem II system.

Although there is uncertainty in the use of another chemical's data as a surrogate to phytotoxicity data, there is more certainty in the fact that the mode of action of linuron will adversely affect non-target terrestrial plants. However, it is uncertain as to what the magnitude of the effects would be without phytotoxicity data on linuron. Therefore there is some confidence in ascertaining that there may be some habitat modification however unknown is the magnitude of the effect.

Based on the weight-of-evidence, the Agency concludes that there is a potential indirect impact to CRLF by terrestrial habitat degradation from linuron exposure and therefore linuron is Likely to Adversely Affect (LAA) the CRLF.

5.2.4 Modification to Designated Critical Habitat

Risk conclusions for the designated critical habitat are the same as those for indirect effects. Agency concludes that there is a potential indirect impact to CRLF by terrestrial habitat degradation from linuron exposure.

5.2.4.1 Aquatic-Phase PCEs

Three of the four assessment endpoints for the aquatic-phase primary constituent elements (PCEs) of designated critical habitat for the CRLF are related to potential effects to aquatic and/or terrestrial plants:

- Alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond: aquatic habitat (including riparian vegetation) provides for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs.
- Alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food source.
- Reduction and/or modification of aquatic-based food sources for pre-metamorphs (*e.g.*, algae).

Conclusions for potential indirect effects to the CRLF via direct effects to aquatic and terrestrial plants are used to determine whether modification to critical habitat may occur. There is a potential for habitat modification via impacts to aquatic plants (Sections 5.2.2.1 and 5.2.3.1) and terrestrial plants (5.2.3.2)

The remaining aquatic-phase PCE is "alteration of other chemical characteristics necessary for normal growth and viability of CRLFs and their food source." Other than impacts to algae as food items for tadpoles (discussed above), this PCE is assessed by considering direct and indirect effects to the aquatic-phase CRLF via acute and chronic freshwater fish and invertebrate toxicity endpoints as measures of effects. There is a potential for habitat modification via impacts to aquatic-phase CRLFs (Sections 5.2.1.1) and effects to freshwater invertebrates and fish as food items (Sections 5.2.2.2 and 5.2.2.3).

5.2.4.2 Terrestrial-Phase PCEs

Two of the four assessment endpoints for the terrestrial-phase PCEs of designated critical habitat for the CRLF are related to potential effects to terrestrial plants:

- Elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs: Upland areas within 200 ft of the edge of the riparian vegetation or drip line surrounding aquatic and riparian habitat that are comprised of grasslands, woodlands, and/or wetland/riparian plant species that provides the CRLF shelter, forage, and predator avoidance.

- Elimination and/or disturbance of dispersal habitat: Upland or riparian dispersal habitat within designated units and between occupied locations within 0.7 mi of each other that allow for movement between sites including both natural and altered sites which do not contain barriers to dispersal.

There is a potential for habitat modification via impacts to terrestrial plants (5.2.3.2).

The third terrestrial-phase PCE is "reduction and/or modification of food sources for terrestrial phase juveniles and adults." To assess the impact of linuron on this PCE, acute and chronic toxicity endpoints for terrestrial invertebrates, mammals, and terrestrial-phase frogs are used as measures of effects. There is a potential for habitat modification via indirect effects to terrestrial-phase CRLFs via reduction in prey base (Section 5.2.2.4 for terrestrial invertebrates, Section 5.2.2.5 for mammals, and 5.2.2.6 for frogs).

The fourth terrestrial-phase PCE is based on alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source. There is a potential for habitat modification via direct (Section 5.2.1.2) and indirect effects (Sections 5.2.2.4, 5.2.2.5, and 5.2.2.6) to terrestrial-phase CRLFs.

5.2.5.1 Downstream Dilution

In order to determine the extent of potential effects to lotic (flowing) aquatic habitats, the agricultural uses resulting in the greatest ratios of the RQ to the LOC for any endpoint for aquatic organisms is used to determine the distance downstream for concentrations to be diluted below levels that would be of concern (*i.e*. result in RQs above the LOC). This analysis is in Table 5.13 below. For this assessment, the greatest ratio was 570 (the highest aquatic invertebrate chronic RQ = 570; LOC = 1; 570 / 1= 5700; see Table 5.13) for indirect effects to the CRLF through reproductive effects to aquatic invertebrates exposed to linuron (non-ag rights-of-way use).

Table 5.13. RQ/LOC Ratio for Various Landcover Classes for Aquatic Organisms[a]

Direct/Indirect Effects to CRLF	Exposure	Highest RQ[a]	RQ/LOC Ratio
Indirect-Aquatic Invertebrates	Chronic	570	570

a RQ Calculations are presented in Section 5.1.

6. Uncertainties

6.1 Exposure Assessment Uncertainties

6.1.1 Maximum Use Scenario

The screening-level risk assessment focuses on characterizing potential ecological risks resulting from a maximum use scenario, which is determined from labeled statements of maximum application rate and number of applications with the shortest time interval between applications. The frequency at which actual uses approach this maximum use scenario may be dependant on pest resistance, timing of applications, cultural practices, and market forces.

6.1.2 Aquatic Exposure Modeling of Linuron

The standard ecological water body scenario (EXAMS pond) used to calculate potential aquatic exposure to pesticides is intended to represent conservative estimates, and to avoid underestimations of the actual exposure. The standard scenario consists of application to a 10-hectare field bordering a 1-hectare, 2-meter deep (20,000 m^3) pond with no outlet. Exposure estimates generated using the EXAMS pond are intended to represent a wide variety of vulnerable water bodies that occur at the top of watersheds including prairie pot holes, playa lakes, wetlands, vernal pools, man-made and natural ponds, and intermittent and lower order streams. As a group, there are factors that make these water bodies more or less vulnerable than the EXAMS pond. Static water bodies that have larger ratios of pesticide-treated drainage area to water body volume would be expected to have higher peak EECs than the EXAMS pond. These water bodies will be either smaller in size or have larger drainage areas. Smaller water bodies have limited storage capacity and thus may overflow and carry pesticide in the discharge, whereas the EXAMS pond has no discharge. As watershed size increases beyond 10-hectares, it becomes increasingly unlikely that the entire watershed is planted with a single crop that is all treated simultaneously with the pesticide. Headwater streams can also have peak concentrations higher than the EXAMS pond, but they likely persist for only short periods of time and are then carried and dissipated downstream.

The Agency acknowledges that there are some unique aquatic habitats that are not accurately captured by this modeling scenario and modeling results may, therefore, under- or over-estimate exposure, depending on a number of variables. For example, aquatic-phase CRLFs may inhabit water bodies of different size and depth and/or are located adjacent to larger or smaller drainage areas than the EXAMS pond. The Agency does not currently have sufficient information regarding the hydrology of these aquatic habitats to develop a specific alternate scenario for the CRLF. CRLFs prefer habitat with perennial (present year-round) or near-perennial water and do not frequently inhabit vernal (temporary) pools because conditions in these habitats are generally not suitable (Hayes and Jennings 1988). Therefore, the EXAMS pond is assumed to be representative of exposure to aquatic-phase CRLFs. In addition, the Services agree that the existing EXAMS pond represents the best currently available approach for estimating aquatic exposure to pesticides (USFWS/NMFS 2004).

In general, the linked PRZM/EXAMS model produces estimated aquatic concentrations that are expected to be exceeded once within a ten-year period. The Pesticide Root Zone Model is a process or "simulation" model that calculates what happens to a pesticide in an agricultural field on a day-to-day basis. It considers factors such as rainfall and plant transpiration of water, as well as how and when the pesticide is applied. It has two major components: hydrology and chemical transport. Water movement is simulated by the use of generalized soil parameters, including field capacity, wilting point, and saturation water content. The chemical transport component can simulate pesticide application on the soil or on the plant foliage. Dissolved, adsorbed, and vapor-phase concentrations in the soil are estimated by simultaneously considering the processes of pesticide uptake by plants, surface runoff, erosion, decay, volatilization, foliar wash-off, advection, dispersion, and retardation.

Uncertainties associated with each of these individual components add to the overall uncertainty of the modeled concentrations. Additionally, model inputs from the environmental fate degradation studies are chosen to represent the upper confidence bound on the mean values that are not expected to be exceeded in the environment approximately 90 percent of the time. Mobility input values are chosen to be representative of conditions in the environment. The natural variation in soils adds to the uncertainty of modeled values. Factors such as application date, crop emergence date, and canopy cover can also affect estimated concentrations, adding to the uncertainty of modeled values. Factors within the ambient environment such as soil temperatures, sunlight intensity, antecedent soil moisture, and surface water temperatures can cause actual aquatic concentrations to differ for the modeled values.

Unlike spray drift, tools are currently not available to evaluate the effectiveness of a vegetative setback on runoff and loadings. The effectiveness of vegetative setbacks is highly dependent on the condition of the vegetative strip. For example, a well-established, healthy vegetative setback can be a very effective means of reducing runoff and erosion from agricultural fields. Alternatively, a setback of poor vegetative quality or a setback that is channelized can be ineffective at reducing loadings. Until such time as a quantitative method to estimate the effect of vegetative setbacks on various conditions on pesticide loadings becomes available, the aquatic exposure predictions are likely to overestimate exposure where healthy vegetative setbacks exist and underestimate exposure where poorly developed, channelized, or bare setbacks exist.

In order to account for uncertainties associated with modeling, available monitoring data were compared to PRZM/EXAMS estimates of peak EECs for the different uses. As discussed above, several data values were available from NAWQA for linuron concentrations measured in surface waters receiving runoff from agricultural areas. The specific use patterns (e.g. application rates and timing, crops) associated with the agricultural areas are unknown, however, they are assumed to be representative of potential linuron use areas.

The monitoring data available are below the PZM-EXAMS predictions by an order of magnitude. The monitoring data indicated that the time weighted mean concentration ranged from below the 0.001 ppb to 0.86 ppb with a mean concentration of 0.21 ppb. PRZM-EXAMS prediction (not including the scenarios for impervious surfaces) estimated linuron to be in the surface waters at peak concentrations from 27.5 ppb to 2.6 ppb and 60 day EEC from 18.3 ppb to 1.8.

6.1.3 Action Area Uncertainties

The action area is considered to be the whole State of California since linuron is considered to be an animal carcinogen and can not be spatially defined.

6.1.4 Usage Uncertainties

County-level usage data were obtained from California's Department of Pesticide Regulation Pesticide Use Reporting (CDPR PUR) database. Four years of data (2002 – 2005) were included in this analysis because statistical methodology for identifying outliers, in terms of area treated and pounds applied, was provided by CDPR for these years only. No methodology for removing outliers was provided by CDPR for 2001 and earlier pesticide data; therefore, this information was not included in the analysis because it may misrepresent actual usage patterns. CDPR PUR documentation indicates that errors in the data may include the following: a misplaced decimal; incorrect measures, area treated, or units; and reports of diluted pesticide concentrations. In addition, it is possible that the data may contain reports for pesticide uses that have been cancelled. The CPDR PUR data does not include home owner applied pesticides; therefore, residential uses are not likely to be reported. As with all pesticide usage data, there may be instances of misuse and misreporting. The Agency made use of the most current, verifiable information; in cases where there were discrepancies, the most conservative information was used.

6.1.5 Terrestrial Exposure Modeling of Linuron

The Agency relies on the work of Fletcher et al. (1994) for setting the assumed pesticide residues in wildlife dietary items. These residue assumptions are believed to reflect a realistic upper-bound residue estimate, although the degree to which this assumption reflects a specific percentile estimate is difficult to quantify. It is important to note that the field measurement efforts used to develop the Fletcher estimates of exposure involve highly varied sampling techniques. It is entirely possible that much of these data reflect residues averaged over entire above ground plants in the case of grass and forage sampling.

It was assumed that ingestion of food items in the field occurs at rates commensurate with those in the laboratory. Although the screening assessment process adjusts dry-weight estimates of food intake to reflect the increased mass in fresh-weight wildlife food intake estimates, it does not allow for gross energy differences. Direct comparison of a laboratory dietary concentration- based effects threshold to a fresh-weight pesticide residue estimate would result in an underestimation of field exposure by food consumption by a factor of 1.25 – 2.5 for most food items.

Differences in assimilative efficiency between laboratory and wild diets suggest that current screening assessment methods do not account for a potentially important aspect of food requirements. Depending upon species and dietary matrix, bird assimilation of wild diet energy ranges from 23 – 80%, and mammal's assimilation ranges from 41 – 85% (U.S. Environmental Protection Agency, 1993). If it is assumed that laboratory chow is formulated to maximize assimilative efficiency (e.g., a value of 85%), a potential for underestimation of exposure may exist by assuming that consumption of food in the wild is comparable with consumption during laboratory testing. In the screening process, exposure may be underestimated because metabolic rates are not related to food consumption.

For the terrestrial exposure analysis of this risk assessment, a generic bird or mammal was assumed to occupy either the treated field or adjacent areas receiving a treatment rate on the field. Actual habitat requirements of any particular terrestrial species were not considered, and it was assumed that species occupy, exclusively and permanently, the modeled treatment area. Spray drift model predictions suggest that this assumption leads to an overestimation of exposure to species that do not occupy the treated field exclusively and permanently.

6.1.6 Spray Drift Modeling

It is unlikely that the same organism would be exposed to the maximum amount of spray drift from every application made. In order for an organism to receive the maximum concentration of linuron from multiple applications, each application of linuron would have to occur under identical atmospheric conditions (e.g., same wind speed and same wind direction) and (if it is an animal) the animal being exposed would have to be located in the same location (which receives the maximum amount of spray drift) after each application. Additionally, other factors, including variations in topography, cover, and meteorological conditions over the transport distance are not accounted for by the AgDRIFT/AGDISP model (*i.e*., it models spray drift from aerial and ground applications in a flat area with little to no ground cover and a steady, constant wind speed and direction). Therefore, in most cases, the drift estimates from AgDRIFT/AGDISP mayl overestimate exposure, especially as the distance increases from the site of application, since the model does not account for potential obstructions (*e.g.*, large hills, berms, buildings, trees, *etc*.). Furthermore, conservative assumptions (revise as appropriate) are made regarding the droplet size distributions being modeled ('ASAE Very Fine to Fine' for orchard uses and 'ASAE Very Fine' for agricultural uses), the application method (*i.e.*, aerial), release heights and wind speeds. Alterations in any of these inputs would decrease the area of potential effect.

6.2 Effects Assessment Uncertainties

6.2.1 Age Class and Sensitivity of Effects Thresholds

It is generally recognized that test organism age may have a significant impact on the observed sensitivity to a toxicant. The acute toxicity data for fish are collected on juvenile fish between 0.1 and 5 grams. Aquatic invertebrate acute testing is performed on recommended immature age classes (e.g., first instar for daphnids, second instar for amphipods, stoneflies, mayflies, and third instar for midges).

Testing of juveniles may overestimate toxicity at older age classes for pesticide active ingredients that act directly without metabolic transformation because younger age classes may not have the enzymatic systems associated with detoxifying xenobiotics. In so far as the available toxicity data may provide ranges of sensitivity information with respect to age class, this assessment uses the most sensitive life-stage information as measures of effect for surrogate aquatic animals, and is therefore, considered as protective of the CRLF.

6.2.2 Use of Surrogate Species Effects Data

Guideline toxicity tests and open literature data on linuron are not available for frogs or any other aquatic-phase amphibian; therefore, freshwater fish are used as surrogate species for aquatic-phase amphibians. Although no data are available for linuron, the available open literature information on toxicity to aquatic-phase amphibians shows that acute and chronic ecotoxicity endpoints for aquatic-phase amphibians are generally less sensitive than freshwater fish. Therefore, endpoints based on freshwater fish ecotoxicity data are assumed to be protective of potential direct effects to aquatic-phase amphibians including the CRLF, and extrapolation of the risk conclusions from the most sensitive tested species to the aquatic-phase CRLF is likely to overestimate the potential risks to those species. Efforts are made to select the organisms most likely to be affected by the type of compound and usage pattern; however, there is an inherent uncertainty in extrapolating across phyla. In addition, the Agency's LOCs are intentionally set very low, and conservative estimates are made in the screening level risk assessment to account for these uncertainties.

6.2.3 Sublethal Effects

When assessing acute risk, the screening risk assessment relies on the acute mortality endpoint as well as a suite of sublethal responses to the pesticide, as determined by the testing of species response to chronic exposure conditions and subsequent chronic risk assessment. Consideration of additional sublethal data in the effects determination t is exercised on a case-by-case basis and only after careful consideration of the nature of the sublethal effect measured and the extent and quality of available data to support establishing a plausible relationship between the measure of effect (sublethal endpoint) and the assessment endpoints. However, the full suite of sublethal effects from valid open literature studies is considered for the purposes of defining the action area.

A review of the literature using the ECOTOX database found that linuron affects the baseline olfactory sensory neuron (OSN) responses of sockeye salmon (*Oncorhynchus nerka*) above 1 µg/L (NOEC = 1 µg/L). The sense of smell for anadromous salmon is crucial for the survival of salmon in predator evasion and conspecific recognition (ECOTOX 90046; Tierney, 2007). Frogs do not use the sense of smell to migrate in estuarine and freshwater bodies. Therefore, the data point was considered irreverent and not used.

No additional sublethal effects information were found in the ECOTOX data base.

6.2.4 Location of Wildlife Species

For the terrestrial exposure analysis of this risk assessment, a generic bird or mammal was assumed to occupy either the treated field or adjacent areas receiving a treatment rate on the field. Actual habitat requirements of any particular terrestrial species were not considered, and it was assumed that species occupy, exclusively and permanently, the modeled treatment area. Spray drift model predictions suggest that this assumption leads to an overestimation of exposure to species that do not occupy the treated field exclusively and permanently.

7. Risk Conclusions

In fulfilling its obligations under Section 7(a)(2) of the Endangered Species Act, the information presented in this endangered species risk assessment represents the best data currently available to assess the potential risks of linuron to the CRLF and its designated critical habitat.

Based on the best available information, the Agency makes a Likely to Adversely Affect determination for the CRLF from the use of linuron. Additionally, the Agency has determined that there is the potential for modification of CRLF designated critical habitat from the use of the chemical.

A summary of the risk conclusions and effects determinations for the CRLF and its critical habitat, given the uncertainties discussed in Section 6, is presented in Tables 7.1 and 7.2.

Table 7.1 Effects Determination Summary for Effects of Linuron on the CRLF		
Assessment Endpoint	Effects Determination [1]	Basis for Determination
Survival, growth, and/or reproduction of CRLF individuals	LAA	Potential for Direct Effects
		Aquatic-phase (Eggs, Larvae, and Adults): There are no acute LOC exceedances for freshwater fish (as a surrogate to the aquatic-phase frog). Chronic LOC is exceeded for freshwater fish (as a surrogate to the aquatic-phase frog). Chronic LOCs are exceeded from uses on asparagus, carrot, parsnip, sorghum, soybean, kenaf, and right-of-way.
		Terrestrial-phase (Juveniles and Adults): The acute dose-based LOC is exceeded for birds (as a surrogate to the terrestrial-phase frog). The dietary-based acute LOC is exceeded. Chronic LOC is exceeded for birds (as a surrogate to the terrestrial-phase frog). Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for CRLF.
		Potential for Indirect Effects
		Aquatic prey items, aquatic habitat, cover and/or primary productivity: The LOC for non-vascular aquatic plants is for indirect effects to CRLF. The LOC for vascular aquatic plants is exceeded for indirect effects to CRLF. Acute LOC is exceeded for aquatic invertebrates as indirect effects to dietary food items to CRLF. Chronic LOC is exceeded for aquatic invertebrates as indirect effects to dietary food items to CRLF. Use of linuron on all use sites will exceed acute LOC for CRLF.
		Terrestrial prey items, riparian habitat: The LOC for birds (as a surrogate to the terrestrial-phase frog) eating contaminated small insects at all use sites. Chronic LOC is exceeded for small mammals used as food source for CRLF. Acute LOC is marginally exceeded for small mammals used as food source for CRLF at all but the 1 lb ai/A use sites. Acute LOC is marginally exceeded for terrestrial invertebrates as indirect effects to dietary food items to CRLF. There are no terrestrial plant data available to assess risk to non-target plants used as food source and habitat for CRLF. Mode of action of chemical would indicate that non-target plants are potentially at risk from use of linuron. The analysis indicates that LOCs are exceeded for non-target terrestrial plants from runoff and spray drift at all sites.

[1] No effect (NE); May affect, but not likely to adversely affect (NLAA); May affect, likely to adversely affect (LAA)

Table 7.2 Effects Determination Summary for the Critical Habitat Impact Analysis		
Assessment Endpoint	Effects Determination [1]	Basis for Determination
Modification of aquatic-phase PCE	HM	Due to aquatic vascular and terrestrial plant communities being reduced from all use sites, there is potential for alteration of channel/pond morphology or geometry and/or increase in sediment deposition within the stream channel or pond. These plant communities provide for shelter, foraging, predator avoidance, and aquatic dispersal for juvenile and adult CRLFs. In addition, there

		is potential for alteration in water chemistry/quality including temperature, turbidity, and oxygen content necessary for normal growth and viability of juvenile and adult CRLFs and their food. Aquatic non-vascular plants used as food source for CRLF may be potentially affected from linuron use on asparagus, sorghum, kenaf, and rights-of way sites. Reduction of aquatic based food sources (aquatic invertebrates) may occur from all use sites. These effects may indirectly affect aquatic–phase CRLF by reducing the food source. Linuron may directly cause chronic effects to aquatic-phase CRLF in water bodies.
Modification of terrestrial-phase PCE		The use of linuron at all use sites may create the following modification of PCE: elimination and/or disturbance of upland habitat; ability of habitat to support food source of CRLFs, Elimination and/or disturbance of dispersal habitat, reduction and/or modification of food sources for terrestrial phase juveniles and adults, and alteration of chemical characteristics necessary for normal growth and viability of juvenile and adult CRLFs and their food source. Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for direct effects to CRLF. Use of linuron on all use sites will exceed acute dietary- and dose-based LOC and chronic LOC for prey food items of small mammals, frogs, and invertebrates. Food source for CRLF is reduced and CRLF is indirectly affected.

[1] Habitat Modification (HM) or No effect (NE)

Based on the conclusions of this assessment, a formal consultation with the U. S. Fish and Wildlife Service under Section 7 of the Endangered Species Act should be initiated.

When evaluating the significance of this risk assessment's direct/indirect and adverse habitat modification effects determinations, it is important to note that pesticide exposures and predicted risks to the species and its resources (i.e., food and habitat) are not expected to be uniform across the action area. In fact, given the assumptions of drift and downstream transport (i.e., attenuation with distance), pesticide exposure and associated risks to the species and its resources are expected to decrease with increasing distance away from the treated field or site of application. Evaluation of the implication of this non-uniform distribution of risk to the species would require information and assessment techniques that are not currently available. Examples of such information and methodology required for this type of analysis would include the following:

- Enhanced information on the density and distribution of CRLF life stages within specific recovery units and/or designated critical habitat within the action area. This information would allow for quantitative extrapolation of the present risk assessment's predictions of individual effects to the proportion of the population extant within geographical areas where those effects are predicted. Furthermore, such population information would allow for a more comprehensive evaluation of the significance of potential resource impairment to individuals of the species.
- Quantitative information on prey base requirements for individual aquatic- and terrestrial-phase frogs. While existing information provides a preliminary picture of the types of food sources utilized by the frog, it

does not establish minimal requirements to sustain healthy individuals at varying life stages. Such information could be used to establish biologically relevant thresholds of effects on the prey base, and ultimately establish geographical limits to those effects. This information could be used together with the density data discussed above to characterize the likelihood of adverse effects to individuals.

- Information on population responses of prey base organisms to the pesticide. Currently, methodologies are limited to predicting exposures and likely levels of direct mortality, growth or reproductive impairment immediately following exposure to the pesticide. The degree to which repeated exposure events and the inherent demographic characteristics of the prey population play into the extent to which prey resources may recover is not predictable. An enhanced understanding of long-term prey responses to pesticide exposure would allow for a more refined determination of the magnitude and duration of resource impairment, and together with the information described above, a more complete prediction of effects to individual frogs and potential modification to critical habitat.

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