Assessing Risks of Herbicidal Vegetation Management in a Sensitive Watershed

Erin Conlisk and Susan Kegley, Pesticide Research Institute

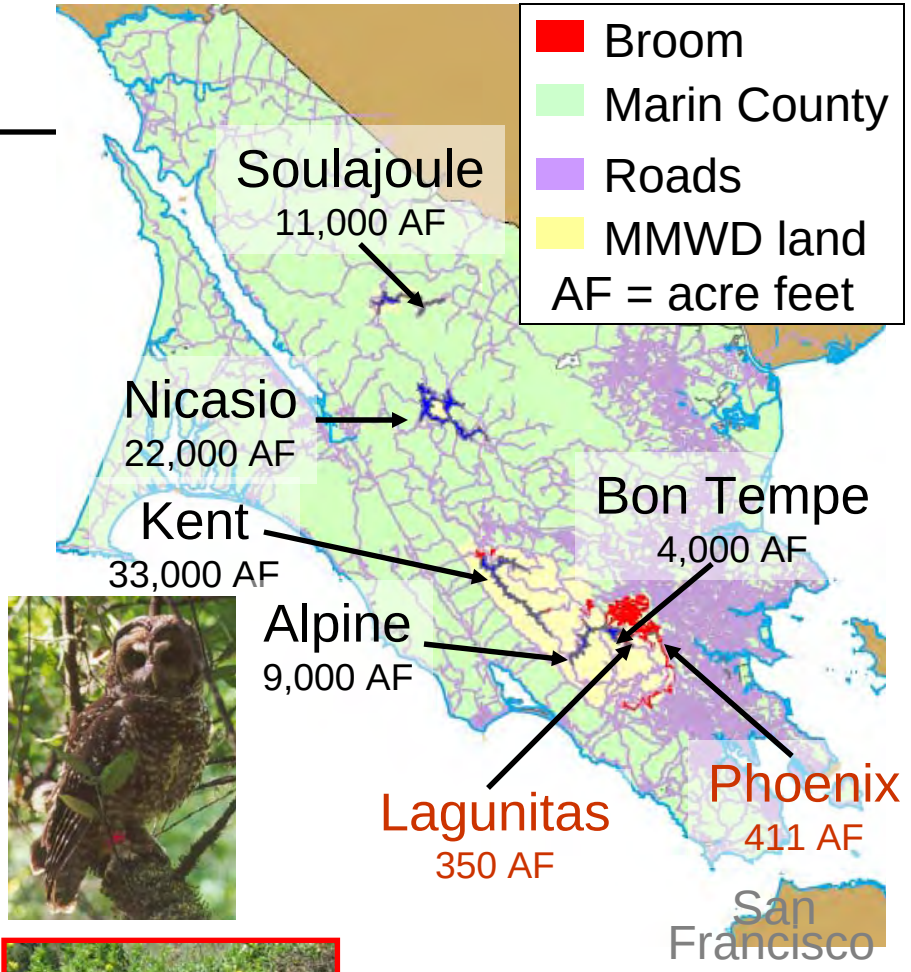
Pesticide Research Institute

Outline

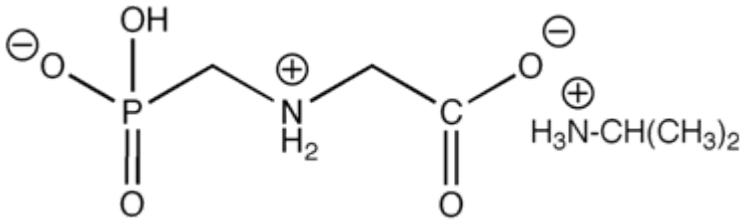
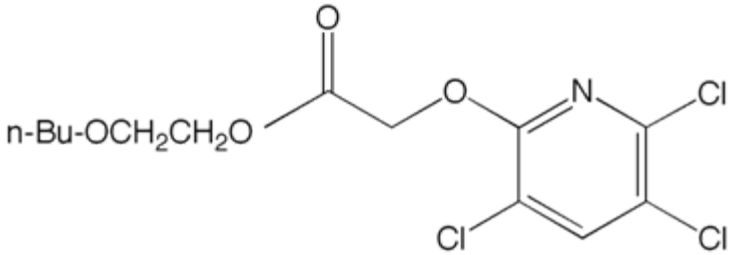
- **Background**: Marin Municipal Water District (MMWD's) Vegetation Management Plan
- **Step 1 of Risk Assessment**: Toxicity Reference Values, or doses that may cause adverse effects
- **Step 2 of Risk Assessment**: Estimated Exposure
- **Step 3 of Risk Assessment**: Hazard Quotients, or ratio of exposure to Toxicity Reference Value
- **Conclusions**

Background

- MMWD manages 7 reservoirs
- MMWD 34 manages square miles of land used as a public park
- MMWD responsible for maintaining:
  - Fuel breaks, fire roads
  - Native plants and wildlife
- *Genista monospessulana* French broom (800 acres), thistle, teasel
  - Treatment Methods
    - Non-chemical: Pulling, grazing, mowing, fire
    - Chemical herbicides



Herbicides Under Consideration

	AQUAMASTER (glyphosate IPA, no surfactant)	GARLON 4 ULTRA (triclopyr BEE, methylated seed oil solvent)
		
Application Rate	1-2 lbs/acre	1-2 lbs/acre
Application Method	foliar	foliar, basal bark, thin line
Soil Half-life	22-96	12-69
Water Half-life	35	165 (25° C)
Registration Date	1974	1979
US Annual Use	110 million lbs/yr	1-3 million lbs/yr
Degradation Products	AMPA	TMP, TCP
Mobility	low, adheres to soil	high
Dermal Permeability	0.00041 hr^{-1} (low)	0.041 hr^{-1} (high)
Product Formulation	glyphosate IPA	Triclopyr BEE

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Toxicity Reference Values

GOAL: Distill toxicology literature into a Toxicity Reference Value (TRV).

TOXICOLOGY LITERATURE:

- Humans and Wildlife:

  Peer-reviewed Journals

  EPA REDs: Registration Eligibility Decisions

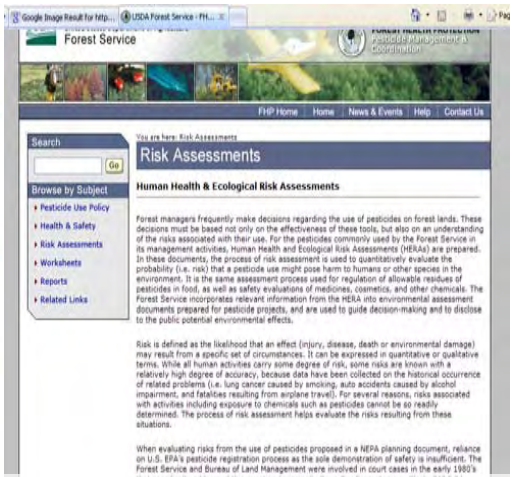
  USFS/SERA: general risk assessment

- Wildlife:

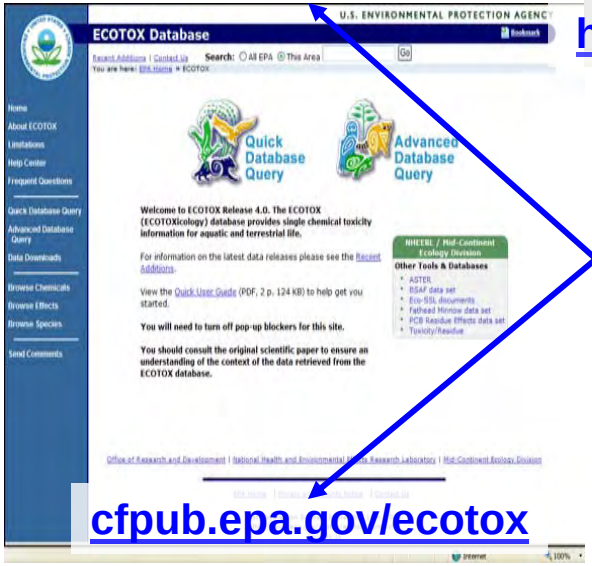
  EPA Ecotox

"Quick and dirty" summary of EPA data at pesticideinfo.org

www.epa.gov/pesticides/reregistration/status.htm



www.fs.fed.us/foresthealth/pesticide/risk.shtml



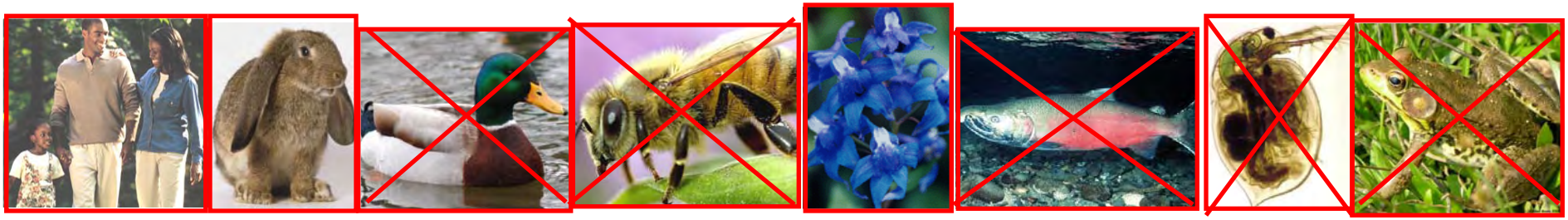
cfpub.epa.gov/ecotox

Toxicity Reference Values

ENDPOINTS: (expressed in mg/kg or mg/L)

- ***Preferred*: No Observed Effect Concentration/Level (NOEC/Ls)**
- Lowest Observed Effect Concentration/Level (LOEC/L)
- Lethal Concentration/Dose to 50% of population (LC/D_{50})

TAXA: Humans, mammals, birds, insects, microbes, non-target plants, fish, amphibians, aquatic invertebrates, and aquatic plants.



UNCERTAINTIES:

- Differences between species
- Differences between individuals of a species
- Chronic versus acute toxicity
- No NOEC/Ls are available
- Effects that are not studied; for example, endocrine disruption

Reference Dose (RfD):

$$RfD = \frac{NOEL}{100}$$

The risk assessment is only as good as the TRVs.

Toxicity Reference Values

Taxa and Exposure Type	Glyphosate IPA (mg/kg or mg/L)	Triclopyr BEE or TCP (mg/kg or mg/L)
Humans, acute RfD	**2**	**1.0 male, 0.05 female**
Humans, chronic RfD	**2**	**0.05 male, 0.012 female (TCP)**
Mammals, acute	**175**	**100**
Mammals, chronic	**175**	**5**
Birds, acute	**562**	**65**
Birds, chronic	**100**	**10**
Honeybees, chronic	**540**	**179**
Plants (tolerant)	**0.56**	**0.0039**
Fish (tolerant), acute	**25.7**	**0.013**
Fish (tolerant), chronic	**25.7**	**0.075 (TCP)**
Amphibians, acute	**6.5**	**6.7**
Amphibians, chronic	**1.8**	**1.2**
Aquatic invertebrates, acute	**130**	**0.1**
Aquatic invertebrates, chronic	**50**	**0.1**
Algae (tolerant)	**3**	**0.07**

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Exposure Estimates

GOAL: Determine exposures we might expect in the environment.

EXPOSURE SCENARIOS:

Water:
- General public/wildlife drinking contaminated water
- Aquatic Life

Ingestion:
- General public eating contaminated berries
- Wildlife eating contaminated vegetation (off and on-site)

Dermal:
- Accidental spray of workers
- Accidental spray of general public/wildlife (bees and small mammals)
- General public brushing against contaminated vegetation

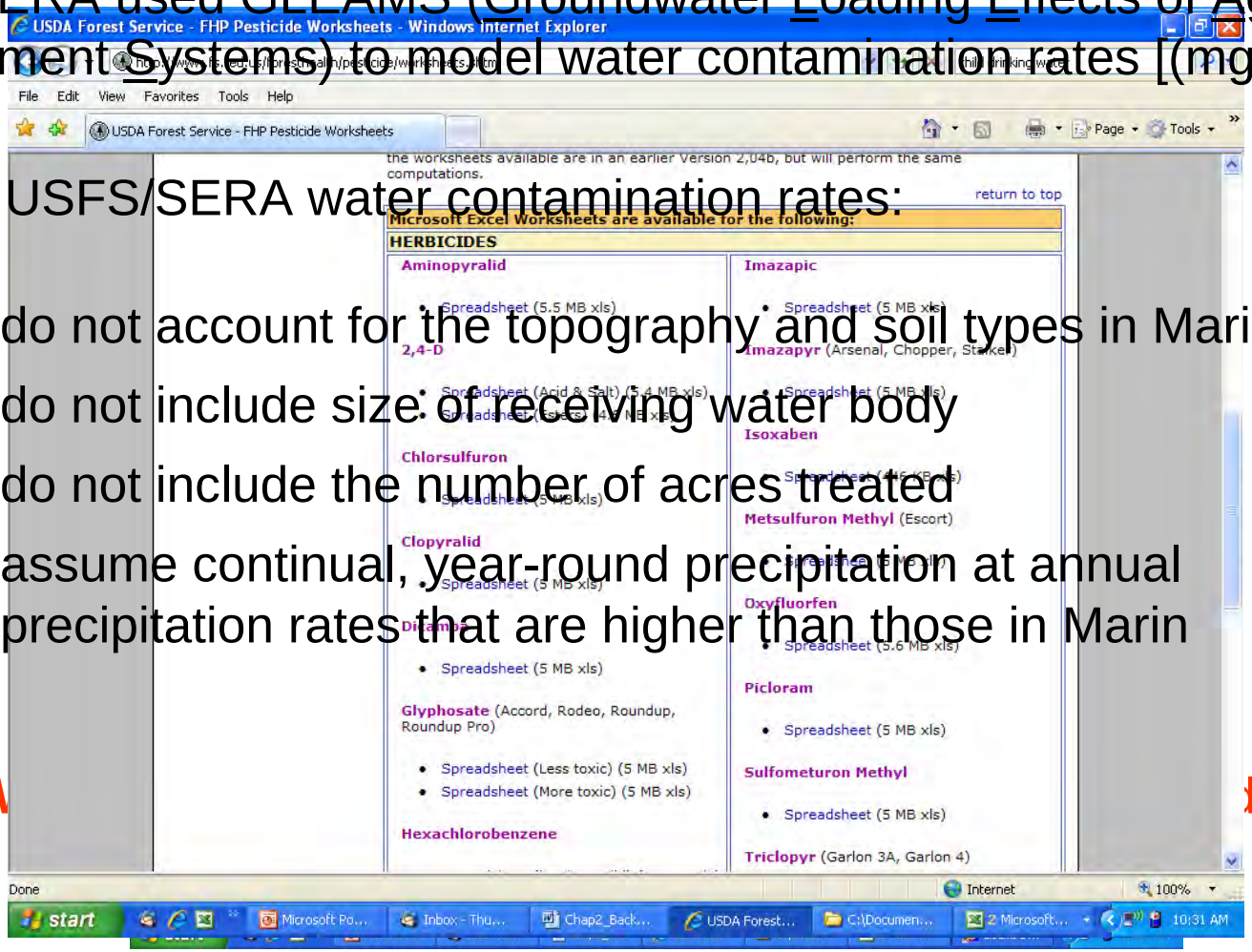
Inhalation

Exposure Estimates – Water Contamination

Started with USFS/SERA exposure worksheets:

www.fs.fed.us/foresthealth/pesticide/worksheets.shtml

USFS/SERA used GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) to model water contamination rates [(mg/L)/(lb/acre)]



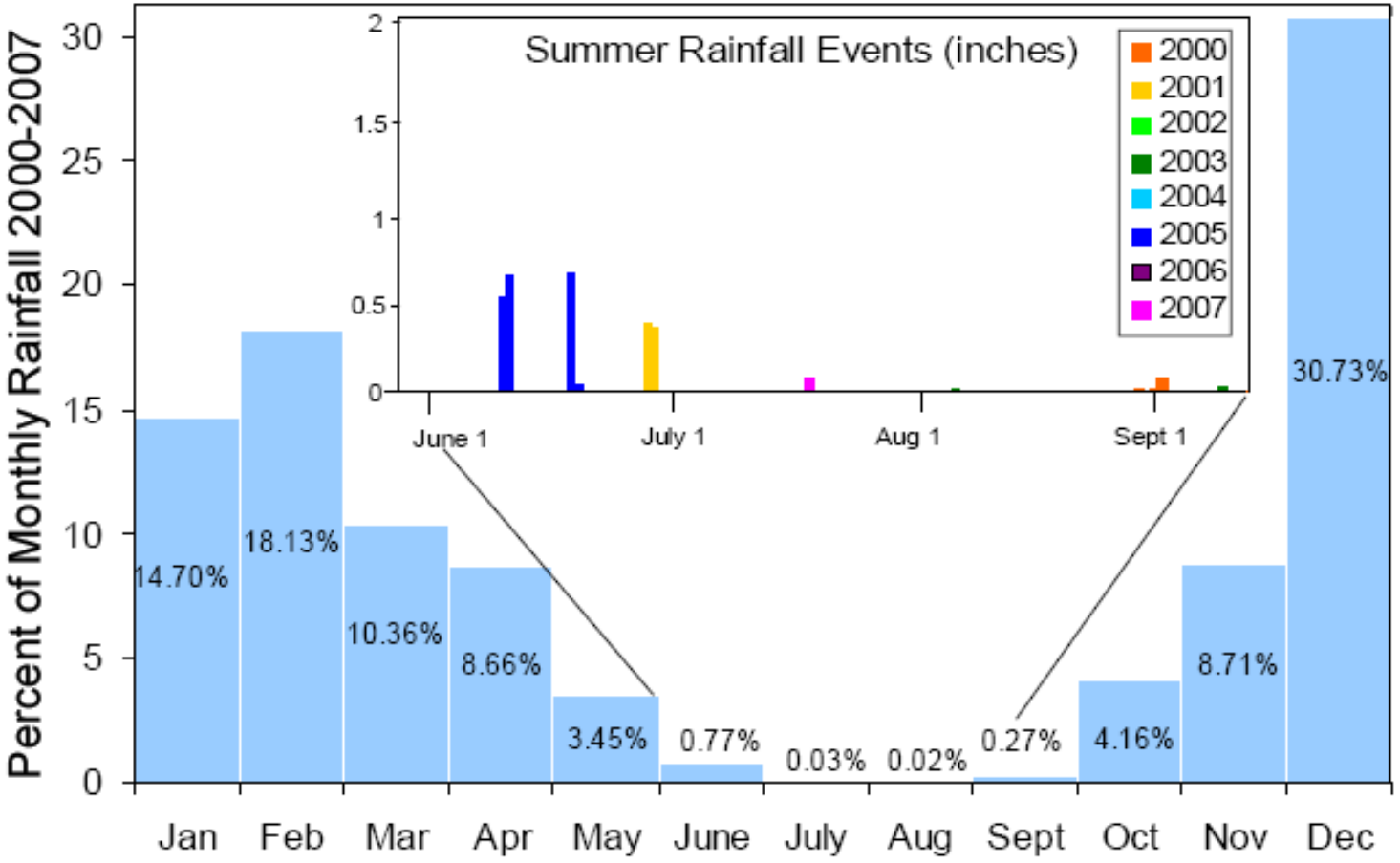
Generic USFS/SERA water contamination rates:

- do not account for the topography and soil types in Marin
- do not include size of receiving water body
- do not include the number of acres treated
- assume continual, year-round precipitation at annual precipitation rates that are higher than those in Marin

MMW… …d with

Exposure Estimates – Marin Precipitation

Marin-specific water contamination rates need to incorporate Mediterranean climate.

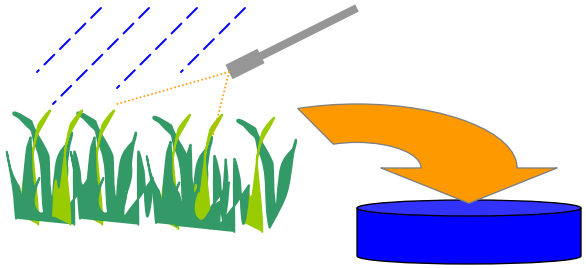


In 2007, USFS/SERA revised water contamination scenarios for the aminopyralid risk assessment.

Exposure Estimates – Water

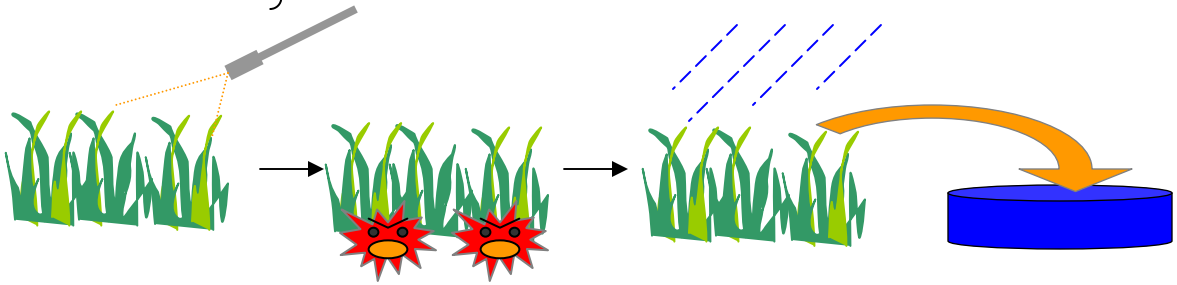
Calculate the **maximum herbicide volume** that can be applied in a watershed.

No chemical degradation:



$$\text{Max Volume (NO degradation)} = \frac{\left(\text{RfD (mg/kg)}\right) \times \left(\text{10\% RfD}\right) \times \left(\text{child weight (13.3 kg)}\right)}{\left(\text{child drinking rate (1.4 L)}\right)} \times \left(\text{gal per pound}\right) \times \left(\text{2.2x10}^{-6}\text{ lbs/mg}\right) \times \left(\text{5x10}^{8}\text{ L Phoenix Lake}\right)$$

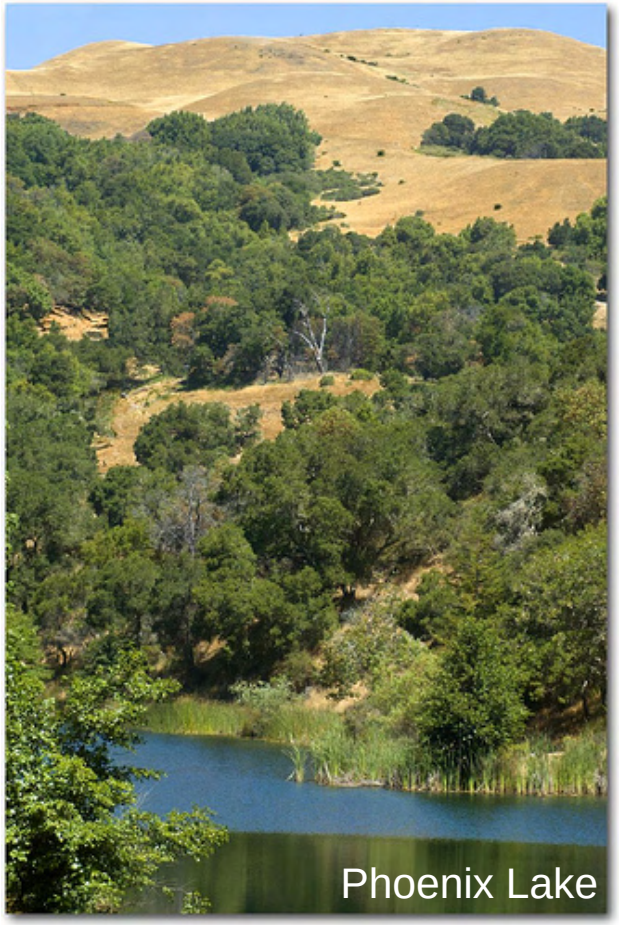
Chemical degradation over 60 days:



$$\text{Max Volume (WITH degradation)} = \left(\text{Max Volume (NO degradation)}\right) \times \frac{1}{\left(\text{Gallons remaining} = exp\left(-\frac{\ln(0.5)}{\text{halflife}} \times t\ (60\text{ days})\right)\right)}$$

Maximum Application Results

Scenario: 10% of Reference Dose, 100% runoff to Phoenix Lake	**Maximum Volume of Chemical (gal)**	**Maximum Treatable Area (acres)**
Aquamaster (glyphosate, applied at 2 lbs/acre)		
No degradation	530	1,060
60-day degradation	1,308	2,616
Garlon 4 Ultra (triclopyr, applied at 2 lbs/acre)		
No degradation	13	26
60-day degradation	40	80



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Wildlife Hazard Quotients

HAZARD QUOTIENTS ratio of estimated exposures to TRVs.

WILDLIFE:

$$HQ = \frac{\text{exposure estimate}}{TRV}$$


Common Egret

HQ > 1 organisms will likely be affected

1 > HQ > 0.1 organisms may be affected

HQ < 0.1 organisms not likely to be affected

Risk assessments are only as good as the TRVs.
When data are sparse, more caution is warranted.

Human Hazard Quotients

HAZARD QUOTIENTS ratio of estimated exposures to the RfDs. *Main difference from wildlife TRVs is the uncertainty factors (NOELs divided by 100).*

HUMAN:

$$HQ = \frac{\text{exposure estimate}}{\text{RfD}}$$

HQ > 1 adverse effects may occur

1 > HQ > 0.1 adverse effects possible in vulnerable groups

HQ < 0.1 adverse effects unlikely for toxicity types studied

Risk assessments are only as good as the RfDs.
When data are sparse, more caution is warranted.

Human Hazard Quotients

	Scenario Probability	Glyphosate HQ	Triclopyr HQ
Herbicide Applicators, Concentrated Product			
Contaminated gloves worn for 1 hr	**Improbable**	**0.0043**	**11.8**
Spill on hands, unwashed for 1 hr	**Improbable**	**0.0094**	**0.46**
General exposure, backpack spraying	**Highly Probable**	**0.0066**	**0.53**
General exposure, ground spraying	**Highly Probable**	**0.022**	**0.90**
General Public, Women and Children			
Vegetation contact after spray	**Improbable**	**0.0011**	**2.80**
Contaminated fruit consumption	**Improbable**	**0.012**	**0.48**
Drinking water after 20-gallon spill (concentrated) into Bon Tempe	**Highly Improbable**	**0.00028**	**0.0012**
Drinking water long-term runoff	**Probable**	**6.2×10^{-5}**	**0.052**

HQ > 1 Estimated dose exceeds Reference Dose

Wildlife Hazard Quotients

	Scenario Probability	Glyphosate HQ	Triclopyr HQ
Terrestrial Wildlife			
Direct spray of small mammal, 50% of body	**Possible**	**0.0027**	**0.30**
Small mammal eating contaminated fruit	**Possible**	**0.014**	**0.025**
Large mammal eating contaminated grass	**Possible**	**0.19**	**0.34**
Small mammal eating contaminated insects	**Probable**	**0.26**	**0.46**
Small bird eating contaminated insects	**Probable**	**0.13**	**1.2**
Carnivorous small mammal	**Possible**	**0.024**	**0.042**
Carnivorous bird	**Possible**	**0.012**	**0.099**
Aquatic Wildlife			
Fish, long-term runoff	**Probable**	**8.5×10^{-6}**	**0.48**
Tadpoles, long-term runoff	**Probable**	**0.00045**	**0.017**
Aquatic invertebrates, long-term runoff	**Probable**	**0.000016**	**0.20**

HQ > 1 Estimated dose exceeds Toxicity Reference Value

Conclusions

Triclopyr has considerably higher Hazard Quotients. Why?

Triclopyr:

- is inherently more toxic than glyphosate
- has toxic degradation products
- is mobile (high water contamination rates)
- has higher dermal permeability
- is particularly toxic to aquatic life

Results also apply to triclopyr TEA (in Garlon 3A)

Vegetation managers may want to limit triclopyr use

Handout discusses precautionary rules for triclopyr use

Thank You

Janet Klein with MMWD
Leonard Charles with LCA (Leonard Charles Associates),
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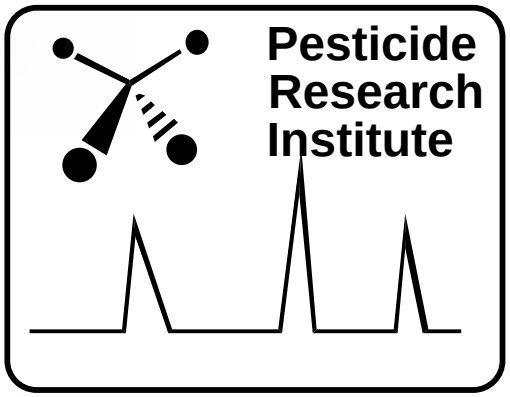
Marion Moses with Pesticide Education Center,
Bob Castle with MMWD,
David Bakke with USFS,
Mike Sweeney with MMWD,
Joel Trumbo with CA Department of Fish and Game,
Patrick Durkin with SERA,
Lynn Milliman with LCA**.**

Minimum Risk Pesticides - Washington Toxics Coalition
List of Study Chemicals (PDF)
Chemical Control Tools Presentation(PDF)
Herbicide Risk Assessment(PDF)

•Sept. 4 **Weed Control Tools: Chemical Focus (Continued)**

Sir Francis Drake High School
1327 Sir Francis Drake Blvd., San Anselmo
6:30 - 9:30 PM

Herbicide Risk Assessment Ch. 1(PDF)
Herbicide Risk Assessment Ch. 2(PDF)
Herbicide Risk Assessment Ch. 3(PDF)
Herbicide Risk Assessment Ch. 4(PDF)
Herbicide Risk Assessment Ch. 5(PDF)
Herbicide Risk Assessment Ch. 6(PDF)
Herbicide Risk Assessment Ch. 7(PDF)
Herbicide Risk Assessment Ch. 8(PDF)
Herbicide Risk Assessment Ch. 9(PDF)
Herbicide Risk Assessment Appendices(PDF)



• Nov. 12 **Alternatives**

2007 Vegetation Management Workshops

• April 26 **Watershed Vegetation Management Update: Scope of Work**

Slide Show Presentation (3.9 MB PDF)

http://www.marinwater.org/controller?action=menuclick&id=433

Toxicity Reference Values

ADJUSTMENT FACTORS:

Human Reference Dose (RfD) typically derived from mammal NOEL.

- ÷ 10 for differences in chemical sensitivity between mammals and humans
- ÷ 10 for differences in sensitive individuals

Wildlife TRVs have numerous data gaps

- ÷ 20 to make an LC/D50 a NOEC/L for sensitive populations (*e.g.* endangered species)
- ÷ 6 to make an LC/D_{50} a NOEC/L
- ÷ 3 to make an LOEC/L a NOEC/L
- Distinction between “tolerant” and “sensitive” species is made
- Other gaps (for example, chronic versus acute) are not adjusted

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Human Risk Assessment Results

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Tadpoles, long-term runoff	**Probable**	**0.00045**	**0.017**	**0.017**
Aquatic invertebrates, long-term runoff	**Probable**	**0.000016**	**0.20**	**0.029**

Net Acreage	Common Name	Cal-IPC Status[1]	CDFA Ranking[2]	Life Form	MMWD Priority	Gross Acreage[4]	Net Acreage[5]
Genista monspessulana	French broom	High	C	Shrub	1	798.5[6]	334.0
Cytisus scoparius	Scotch broom	High	C	Shrub	2		
Spartium junceum	Spanish broom	High	Not ranked	Shrub	3		
Centaurea solstitialis	yellow starthistle	High	C	Annual herb	4	85	19.0
Carthamus lanatus	distaff thistle	Moderate	B	Annual herb	5	0	0
Centaurea calcitrapa	purple starthistle	Moderate	B	Annual herb	6	100	1.0
Aegilops triuncialis	barbed goatgrass	High	B	Annual grass	7	65	6.5
Taeniatherum caput-medusae	Medusahead	High	C	Annual grass	8	Not yet mapped	Not yet mapped
Ehrharta erecta	panic veldtgrass	Moderate	Not ranked	Perennial grass	9	2	0.02
Dipsacus species	teasel	Moderate	Not ranked	Biennial herbs	10	1	0.2
Festuca arundinacea	tall fescue	Moderate	Not ranked	Perennial bunchgrass	11	20	18.0
Phalaris aquatica	Harding grass	High	Not ranked	Perennial bunchgrass	12	Not yet mapped	Not yet mapped
Other Species:							
Acacia species: *A.dealbata* *B.melanoxylon* others not rated	wattle	Moderate Limited	Not ranked	Tree		1.0	0.01
**Ageratina adenophora*	eupatorium	Moderate	Not ranked	Perennial herb		0	0
Cortaderia jubata	pampas grass	High	Not ranked	Perennial bunchgrass	13	40	8.8
Crataegus monogyna	European hawthorn	Limited	Not ranked	Tree	13	1	0.05
Crocosmia crocosmaeflora	montbretia	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped

Scientific Name	Common Name	Cal-IPC Status[1]	CDFA Ranking[2]	Life Form	MMWD Priority[3]	Gross Acreage[4]	Net Acreage[5]
Crocosmia crocosmaeflora	montbretia	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Delairea odorata	cape ivy	High	Not ranked	Vine	13	2	0.1
Dittrichia graveolens	stinkweed	Moderate	Not ranked	Annual herb	13	Not yet mapped	Not yet mapped
Echium species: *E. candicans* *others not rated*	pride of Madeira	Limited	Not ranked	Shrub	13	2	0.05
Eucalyptus globulus	Tasmanian bluegum	Moderate	Not ranked	Tree	13	0.1	0.01
Foeniculum vulgare	fennel	High	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
**Helichrysum petiolare*	licorice plant	Limited	Not ranked	Subshrub	13	0	0
Mentha pulegium	pennyroyal	Moderate	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Myosotis latifolia	broadleaf forget-me-not	Limited	Not ranked	Perennial herb	13	Not yet mapped	Not yet mapped
Pinus species	non-native pines	Not rated	Not ranked	Trees	13	Not yet mapped	Not yet mapped
Vinca major	big periwinkle	Moderate	Not ranked	Perennial herb	13	<5	<5

Notes:

1 - California Invasive Plant Council ratings: High – species that have severe ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal and establishment. Most are widely distributed ecologically. Moderate – species that have substantial and apparent – but generally not severe – ecological impacts on physical processes, plant and animal communities, and vegetation structure. Their reproductive biology and other attributes are conducive to moderate to high rates of dispersal, though establishment is generally dependent upon ecological disturbance. Ecological amplitude and distribution may range from limited to widespread. Limited – species that are invasive but their ecological impacts are minor on a statewide level, or there was not enough information to justify a higher score. Their reproductive biology and other attributes result in low to moderate rates of invasiveness. Ecological amplitude and distribution are generally limited, although these species may be locally persistent and problematic.

2 –California Department of Food and Agriculture noxious weed ratings: A noxious weed is a plant that has been defined as a pest by law or regulation. “A” rated weeds are plants of known economic importance subject to state (or agricultural commissioner when acting as a state agent) enforced action involving: eradication, quarantine, containment, rejection or other holding action; “B” rated weeds are plants of known economic importance subject to: eradication, containment, control or other holding action at the discretion of the individual county agricultural commissioner or a plant of known economic importance subject to state endorsed holding action and eradication only when found in a nursery; “C” rated weeds are plants subject to no state enforced action outside of nurseries except to retard spread, at the discretion of the commissioner, or plants subject to no state enforced action except to provide for pest cleanliness in nurseries.

3 - All species that are not prioritized are of equal concern but less concern than the 12 prioritized species.

4 - The acreage of a given vegetation management unit assessed by a mapper and determined to have some degree of weed infestation.

5 - A subset of the Gross Acreage, the net acreage is only that area which directly has that weed (without interstitial spaces). The Net Acreage is a measurement of the Gross Acreage x % Cover of that weed at that location.

6 – Mapping of broom is incomplete and ongoing. The broom species are not always differentiated by mappers as they often co-occur.

***** Present on adjacent lands but not detected as of 2007 on MMWD lands.

Table
Use of Herbicides, 1999-2005

Year	Pathfinder II	Roundup	Transline
1999	8 gal.		
2000	5 gal.	0.13 gal.	0.23 gal
2001		0.15 gal	
2002		1.28 gal.	
2003		2.9 gal.	
2004		76 gal.	
2005		20.25 gal.	

Table 12
Summary of Average Labor Demands and Costs for Broom Treatment Techniques

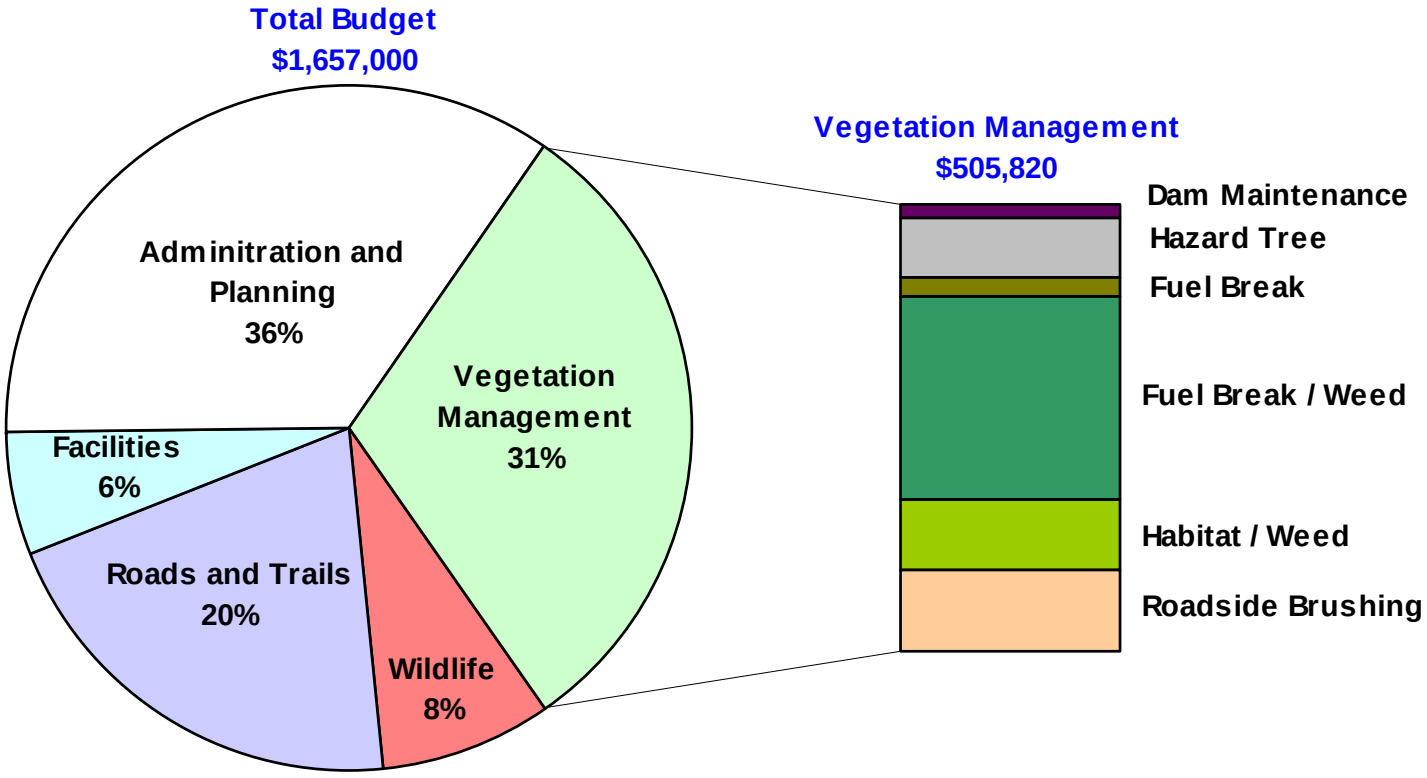
Crew	Activity Description	Person Hours an Acre	Labor Cost Per Acre	Equipment cost per acre	Total Cost Per Acre
MMWD only	Grazing (goats)	8	$264	$933	$1,197
Contract	hand-pulling, follow up	60	$1,496	N/A	$1,496
MMWD / Americorps	hand-pulling, follow up	147	$392	$267	$659
MMWD and AOWP crew	hand-pulling, follow up	125	$663	$260	$923
MMWD / Americorps	hand-pulling, initial clearing	567	$1,511	$1,031	$2,542
MMWD and AOWP crew	hand-pulling, initial clearing	385	$2,042	$802	$2,844
MMWD staff	Hot Foam	111	$2,748	$916	$3,664
Contract	Mowing with hand tools, follow up	20	$495	N/A	$495
MMWD only	Mowing with hand tools, follow up	24	$538	$130	$668
Contract	Mowing with hand tools, initial clearing	150	$3,727	N/A	$3,727
MMWD only	Mowing with heavy equipment (excavator), follow up	9	$270	$364	$634
MMWD and AOWP crew	Mulching	40	$212	$83	$295
MMWD	Prescribed burning				$1,500
Contract	propane flaming	50	$1,246	N/A	$1,246
MMWD Americorps	propane flaming	80	$879	$700	$1,579
MMWD staff	propane flaming	65	$1,609	$569	$2,178
MMWD staff	chemical	??	$75-$100	$25	$100

Source: MMWD

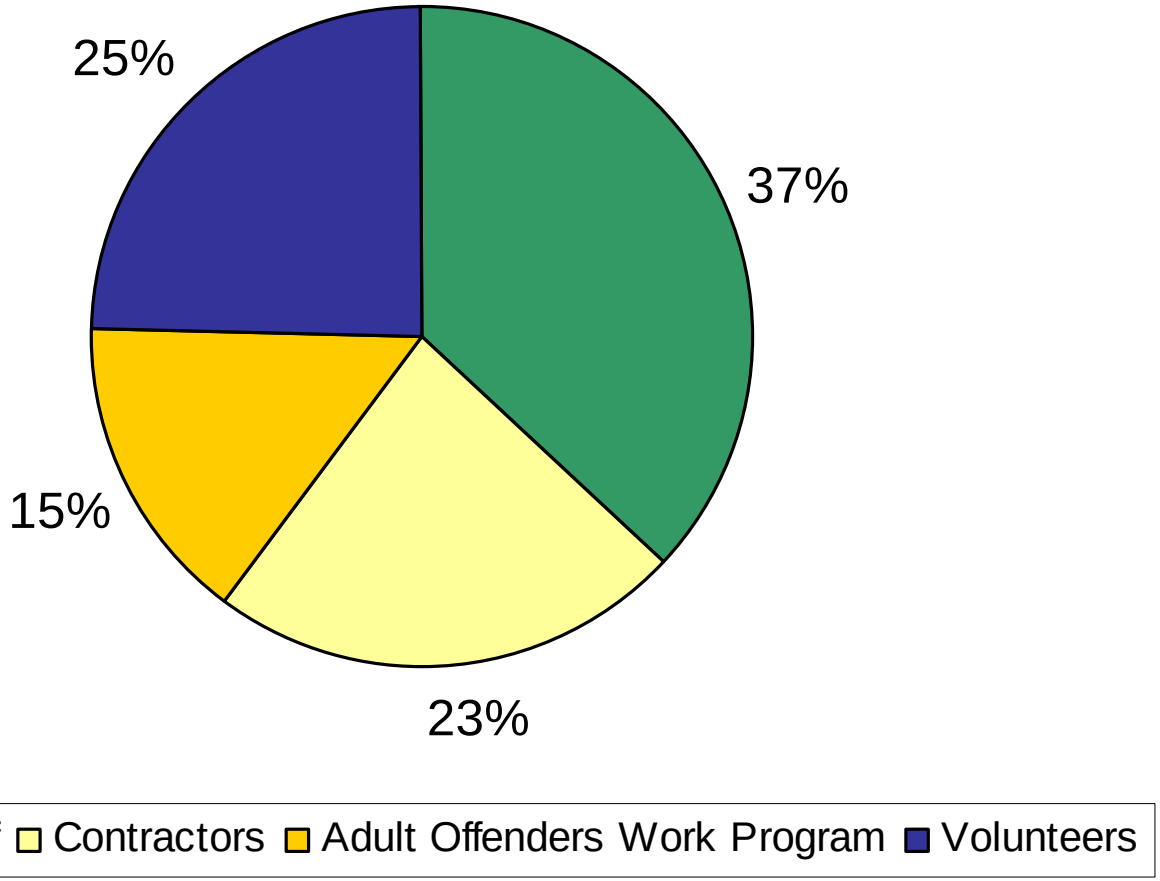
	Scenario Probability	Glyphosate		Triclopyr		Clopyralid		Clove Oil		Pelargonic Acid	
		RfD	HQ	RfD	HQ	RfD	HQ	RfD	HQ	RfD	HQ
Herbicide Applicators											
Accidental exposure to dilluted product											
Contaminated gloves worn for 1 min	Probable	2	$2.1x10^{-6}$	1	0.016	0.75	$8x10^{-7}$	2.5	0.0083	20	0.0075
Contaminated gloves worn for 1 h	Improbable	2	0.00013	1	0.94	0.75	$5x10^{-5}$	2.5	0.50	20	0.44
Spill on hands, unwashed for 1 h	Improbable	2	0.00028	1	0.037	0.75	.00013	2.5	0.0068	20	0.0017
Spill on lower legs, unwashed for 1 h	Improbable	2	0.00068	1	0.091	0.75	.00034	2.5	0.017	20	0.0042
Accidental exposure to concentrated product											
Contaminated gloves worn for 1 min	Probable	2	$7.2x10^{-5}$	1	0.20	0.75	.00016	2.5	0.28	20	0.26
Contaminated gloves worn for 1 h	Improbable	2	0.0043	1	**11.8**	0.75	0.0098	2.5	**17**	20	16
Spill on hands, unwashed for 1 h	Improbable	2	0.0094	1	0.46	0.75	0.029	2.5	0.23	20	0.061
Spill on lower legs, unwashed for 1 h	Improbable	2	0.023	1	**1.14**	0.75	0.072	2.5	0.57	20	0.15
Backpack spraying (diluted product, foliar applications)	Highly Probable	2	0.013	0.05	0.53	0.15	0.012	2.5	0.042	20	0.0055
Backpack spraying (concentrated product, cut-stump and basal bark applications)	Highly Probable	2	0.0066	0.05	0.53	[c]	[c]	[c]	[c]	20	0.009
Ground spraying (diluted product, foliar applications)	Highly Probable	2	0.022	0.05	0.90	0.15	0.021	2.5	0.0014	20	0.00033
General Public											
Vegetation contact after spray, shorts & T-shirt, woman	Improbable	2	0.0011	0.05	**2.80**	0.75	0.00025	2.5	0.064	20	0.0065
Contaminated fruit consumption after spray, acute	Improbable	2	0.012	0.05	0.48	0.75	0.0022	2.5	0.025	20	0.0013
Woman (triclopyr) or child (other herbicides) drinking water after a 20-gallon spill of concentrated product into Bon Tempe	Highly Improbable	2	0.00028	0.05	.0012	0.75	0.00055	2.5	**11**	20	.000029
Woman (triclopyr) or child (other herbicides) drinking water after a 20-gallon spill of diluted product into Bon Tempe	Highly Improbable	2	$8.2x10^{-6}$	0.05	$9x10^{-5}$	0.75	$2.6x10^{-6}$	2.5	**3.2**	20	$8.1x10^{-7}$
Woman (triclopyr) or child (other herbicides) drinking water after long-term runoff into Bon Tempe	Probable	2	$6.2x10^{-5}$	.012	0.052	0.15	0.00038	2.5	[d]	20	[d]

	Scenario Probability	Glyphosate		Triclopyr		Clopyralid		Clove Oil		Pelargonic Acid	
		TRV	HQ	TRV	HQ	TRV	HQ	TRV	HQ	TRV	HQ
Terrestrial Wildlife		mg/kg		mg/kg		mg/kg		mg/kg		mg/kg	
Direct spray of small mammal, 50% of body, first-order absorption	Possible	175	0.0027	100	0.30	75	0.00068	250	0.20	1,000	0.089
Direct spray of small mammal, 50% of body, 100% absorption	Improbable	175	0.27	100	0.48	75	0.045	250	0.78	1,000	0.19
Direct spray 50% of honeybee body, 100% absorption	Improbable	540	0.59	179	**1.79**	1,075	0.022	5,000	0.26	45	**28**
Consumption of contaminated fruit by small mammal	Possible	175	0.014	100	0.025	75	0.0023	250	0.010	1,000	0.002
Consumption of contaminated grass by large mammal	Possible	175	0.19	100	0.34	75	0.032	250	0.55	1,000	0.14
Consumption of contaminated grass by large bird	Possible	562	0.096	65	0.83	77	0.049	250	0.86	333	0.65
Consumption of contaminated insects by small mammal	Probable	175	0.26	100	0.46	75	0.043	250	0.74	1,000	0.19
Consumption of contaminated insects by small bird	Probable	562	0.13	65	**1.2**	77	0.068	250	**1.2**	333	0.90
Consumption of contaminated prey, carnivorous small mammal	Possible	175	0.024	100	0.042	75	0.0039	250	0.068	1,000	0.017
Consumption of contaminated prey, carnivorous bird	Possible	562	0.012	65	0.099	77	0.0058	250	0.10	333	0.078
Aquatic Wildlife		mg/L		mg/L		mg/L		mg/L		mg/L	
Sensitive fish, long-term runoff into Bon Tempe Reservoir	Probable	2.57	0.00032	0.042	0.48	5	0.00015	0.45	d	0.46	d
Tolerant fish, long-term runoff into Bon Tempe Reservoir	Probable	25.7	$8.5x10^{-6}$	b	b	23.1	.000032	b	d	b	d
Tadpoles, long-term runoff into Bon Tempe Reservoir	Probable	1.8	0.00045	6.7	0.017	c	c	d	d	2.2	d
Aquatic invertebrates, long-term runoff into Bon Tempe Reservoir	Probable	50	0.000016	0.1	0.20	23.1	.000032	22	d	3.3	d
Aquatic plants, long-term runoff into Bon Tempe Reservoir	Probable	3	0.00027	0.07	0.29	6.9	0.00011	NA	d	30	d

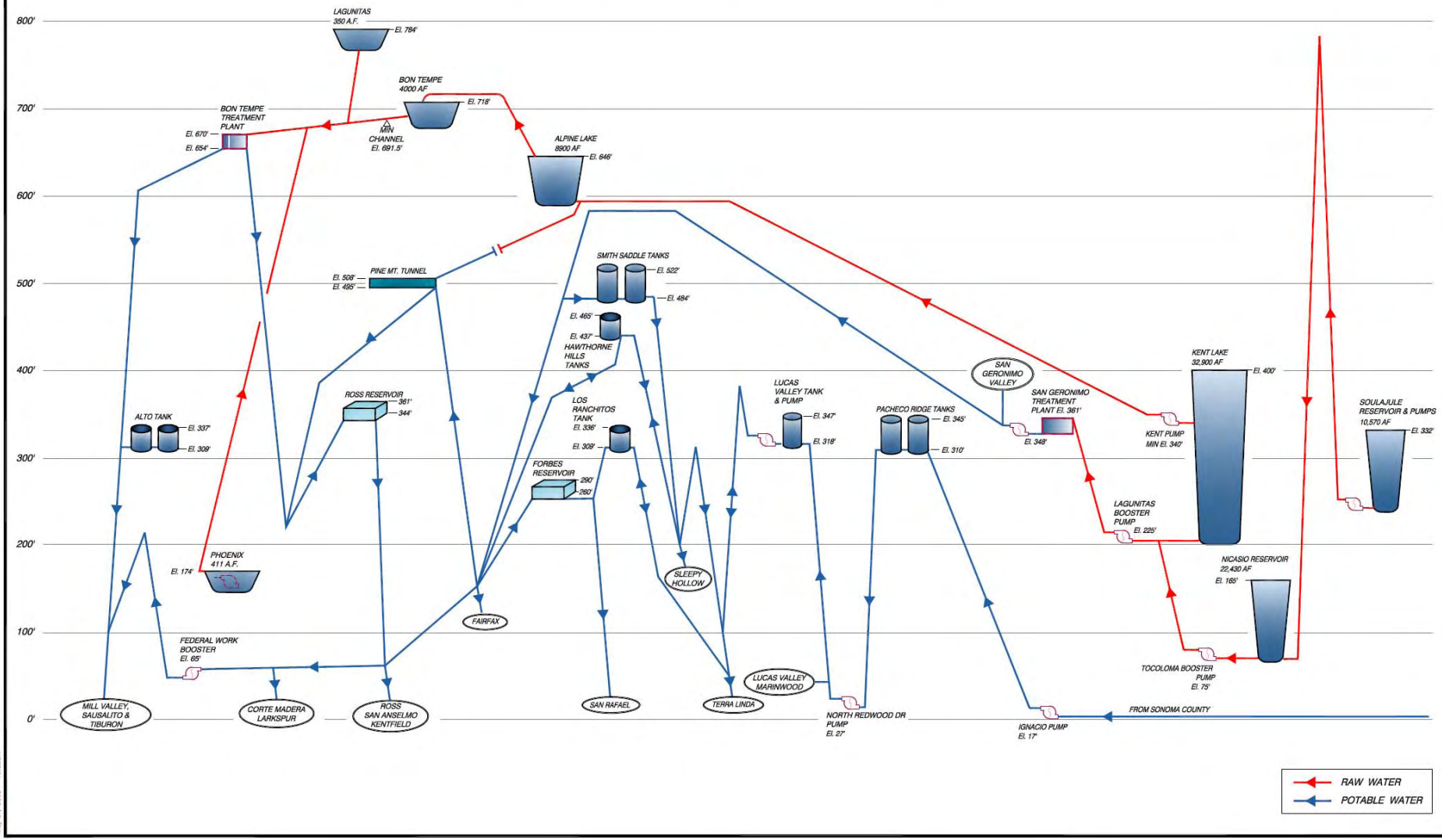
Watershed Resource Program Budget
Fiscal Year 2007 / 2008



Vegetation Management Fiscal 2006 / 2007
Person Hours by Labor Source



TRANSMISSION SCHEMATIC



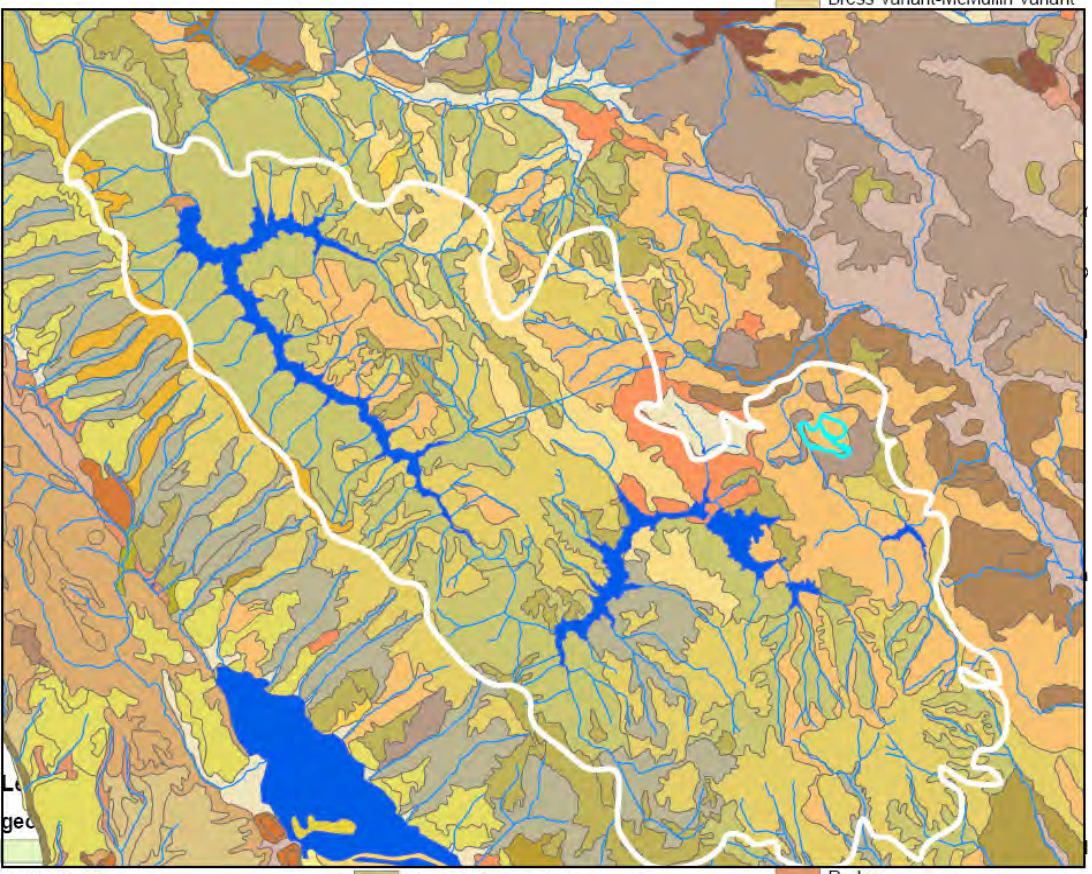
Scenario	Qualitative Probability of Occurrence	Comments
Water Contamination Scenarios		
Accidental spill 20 gallons	Highly Improbable	Only a vehicle accident could cause a spill of such a large volume. **Mitigations:** Prohibit vehicles carrying herbicides on reservoir dams; use spill-proof containers.
1 gallon	Improbable	A spill of this volume could result from mixing chemicals near water or a spill of a backpack sprayer. **Mitigations:** Mix chemicals away from waterways; designate dry stream crossings for workers; use spill-proof containers; use stream and reservoir buffers.
Peak rainfall runoff immediately after application	Highly Improbable	Peak rainfall runoff immediately after an application would result from an application conducted during the rainy season. **Mitigations:** Apply herbicides only between June 1 and Sept. 15 to provide at least 30–60 days between the application and a large rain event; use stream and reservoir buffers.
Long-term rainfall runoff over several months after an application	Probable	Rain 30-60 days after a late summer application is likely to occur, and some of the herbicide and its breakdown products could run off into water bodies. **Mitigations:** Minimize herbicide use where possible; use stream and reservoir buffers; Treat areas closed to reservoir buffers early in dry season to maximize degradation period prior to onset of rains.

Scenario		Qualitative Probability of Occurrence	Comments
Accidental			
Wearing contaminated gloves for 1 minute		Probable	Chemical residues are likely to get into workers' gloves during herbicide applications. **Mitigations:** Train workers to wash hands and change gloves regularly; require use of on-site wash stations; have extra clean gloves available at the work site.
Wearing contaminated gloves, 1 hour		Improbable	Chemical residues can contaminate gloves, but it is unlikely that workers will continue working with contaminated gloves for one hour. **Mitigations:** Train workers to wash hands regularly; require on-site wash stations to be available; have extra clean gloves available at the work site.
Spill on hands, unwashed for 1 hour		Improbable	Spills to bare skin are unlikely if proper PPE is used.
Spill on lower legs, unwashed for 1 hour		Improbable	**Mitigations:** Require PPE and worker training for applicators; require additional PPE (aprons, rubber boots) for workers mixing pesticides; require on-site wash stations to be available.
General			
General Worker exposure	Backpack spray general	Highly Probable	Biomonitoring studies indicate that chemical exposure is unavoidable when applying herbicides.
exposure	Ground spray general	Highly Probable	**Mitigation:** Require PPE and worker training to minimize exposures.

Scenario	Qualitative Probability of Occurrence	Comments
Acute		
Direct spray of entire child's body	Highly Improbable	This event is only used to calculate exposures for a worst-case scenario and is not in the realm of possibility.
Direct spray of woman's lower legs	Highly Improbable	A direct spray to a person would only occur if the applicator were not paying attention to what she/he was spraying and if a person accidentally walked into the application site during an application. **Mitigations:** Train workers to stop an application immediately when another person approaches the site; post the area prior to the application and leave signs up for two weeks after the application; do not apply on weekends.
Brushing against contaminated vegetation	Improbable	Brushing against contaminated vegetation could occur if treated vegetation is close to trail edges or in an area people might "bushwhack" through as a short cut, but is unlikely with mitigations. **Mitigations:** Post the area prior to the application and leave signs up for two weeks after the application; do not apply on weekends; don't spray vegetation immediately adjacent to trails; mow tall vegetation prior to application.
Eating contaminated fruit	Improbable	A hiker could eat contaminated fruit from berry bushes that have received direct spray or spray drift. The likelihood of this exposure can be reduced through mitigations. **Mitigations:** Post the area prior to the application and leave signs up for two weeks after the application; do not apply on weekends; don't spray vegetation immediately adjacent to trails; mow tall vegetation prior to application.
Drinking contaminated water after accidental spill	Highly Improbable	Spills and peak runoff are highly improbable, as is drinking directly from a reservoir.
Drinking contaminated water after peak runoff	Highly Improbable	See mitigations for spills and peak runoff in Table 2-8 above.
Eating contaminated fish after a spill/peak runoff	Highly Improbable	Spills and peak runoff are highly improbable, and fish are unlikely to become contaminated from these events. See mitigations for spills and peak runoff in Table 2-8 above.
Chronic		
Eating contaminated fruit	Improbable	Same as acute scenario for eating contaminated fruit. See above.
Drinking water after long-term runoff	Probable	Rain 30-60 days after a late summer application is likely to occur, and some of the non-degraded herbicide could run off into water bodies. **Mitigations:** Minimize herbicide use where possible. Use stream and reservoir buffers.
Eating contaminated fish after long-term runoff	Possible	Although long-term runoff is Probable (see above), none of the herbicides being considered for use bioaccumulate to any significant extent. See mitigations for long-term runoff above.

Scenario		Qualitative Probability of Occurrence	Comments
Terrestrial Wildlife, Acute Exposures			
Direct spray	First-order absorption, small mammal	Possible	Hidden wildlife could be sprayed. **Mitigations:** Mow or trim tall vegetation prior to application.
	100% absorption, 50% surface area, small mammal	Improbable	Hidden wildlife or bees could be sprayed, but it is unlikely for the organism
	100% absorption, 50% surface area, honeybee	Improbable	to ingest/absorb all residues. See mitigations for first-order absorption above.
Eating vegetation/fruit	Fruit, small mammal, on-site[a]	Possible	Small mammals can reasonably be expected to eat contaminated berries that
	Grass, large mammal, on-site [a]	Probable (clopyralid) Possible (all others)	have fallen on the ground, and large mammals eat grass or other plants that may have received direct spray or spray drift.
	Grass, large bird, on-site [a]	Probable (clopyralid) Possible (all others)	**Mitigations:** Mow or trim tall vegetation prior to application; avoid spraying palatable plants or berries.
Drinking water	Small mammal, after accidental spill	Highly Improbable	Spills and peak runoff are Highly Improbable.
	Large mammal, after accidental spill	Highly Improbable	See mitigations for spills and peak runoff in Table 2-8 above.
	Small bird, after accidental spill	Highly Improbable	
	Large bird, after accidental spill	Highly Improbable	
	Small mammal, after peak runoff	Highly Improbable	
	Large mammal, after peak runoff	Highly Improbable	
	Small bird, after peak runoff	Highly Improbable	
	Large bird, after peak runoff	Highly Improbable	
Eating insects	Small mammal	Probable	Insects are present on most plants and are difficult to avoid spraying. Insectivores are likely to eat contaminated insects near the site.
	Small bird	Probable	**Mitigations:** Mow or trim vegetation prior to application; avoid spraying blooming plants where pollinators might be.
Eating fish	Bird, after accidental spill	Highly Improbable	Spills are highly improbable. See notes and mitigations for spills and peak runoff in Table 2-8 above.
Eating prey	Small mammal	Possible	If small mammals are hidden, it is possible that they will be sprayed.
	Medium mammal	Possible	Carnivores may eat contaminated prey. See mitigations above for direct sprays.
	Large mammal	Possible	
	Bird	Possible	

Scenario		Qualitative Probability of Occurrence	Comments
Terrestrial Wildlife, Chronic Exposures			
Eating vegetation/fruit	Small mammal, on-site[b]	Possible	Small or large mammals or birds eat grass or other plants that may receive direct spray; however, most of these invasive species are not used as a food supply by
	Large mammal, on-site[b]	Possible	native mammals and it is unlikely that the entire diet will be from the application site.
	Large bird, on-site[b]	Possible	**Mitigations:** Mow tall vegetation; avoid spraying palatable plants.
Eating vegetation/fruit	Small mammal, off-site[b]	Probable	Because few acres will be treated and palatable vegetation is more abundant
	Large mammal, off-site[b]	Probable (clopyralid) Possible (all others)	off-site, most vegetation will be eaten off-site. Less-mobile herbivores such as small mammals in sites exposed to spray drift sites are more likely to be exposed than large
	Large bird, off-site[b]	Probable (clopyralid) Possible (all others)	mammals with a greater range. See mitigations for on-site chronic exposures above.
Drinking water runoff	Small mammal, after long-term	Possible	Rain 30-60 days after a late summer application will occur, and some of the
runoff	Large mammal, after long-term	Possible	non-degraded herbicide could run off into water bodies.
	Small bird, after long-term runoff	Possible	See mitigations and notes for long-term runoff in Table 2-8 above.
	Large bird, after long-term runoff	Possible	
Eating fish	Bird, after long-term runoff	Possible	Although long-term runoff is Probable, not all fish eaten by a bird will come from the contaminated reservoir. See mitigations for long-term runoff in Table 2-8 above.
Aquatic Organisms			
Acute, accidental spill		Highly Improbable	Spills and peak runoff are highly improbable.
Acute, peak runoff		Highly Improbable	See notes and mitigations for spills and peak runoff in Table 2-8 above.
Chronic, long-term runoff		Probable	Rain 30-60 days after a late summer application is likely to occur, and some of the non-degraded herbicide could run off into water bodies. See notes and mitigations for long-term runoff in Table 2-8 above.



SOIL_TYPE

- Ballard
- Ballard-Urban
- Barnabe
- Beaches
- Blucher-Cole
- Bonnydoon
- Bonnydoon Variant-gilroy-gilroy Var
- Bress Variant-McMullin Variant
- Centissima-Barnabe complex
- Centissima-Barnaby complex
- Clear Lake
- Cortina
- Cronkhite-Barnabe complex
- Dipsea-Barnabe
- Dipsea-Urban land-Barnabe complex
- Dune land
- Felton Variant-Soulajule complex
- Fluvents, channeled
- Gilroy-Gilroy Variant-Bonnydoon Var
- Henneke
- Humaquepts, seeped
- Hydraquents, saline
- Inverness
- Kehoe
- Kehoe Variant
- Los Oso-Bonnydoon complex
- Los Oso-Urban land-Bonnydoon comple
- Maymen-Maymen Variant
- Montara
- Novato
- Olompali
- Pablo-Bayview complex
- Palomarin-Wittenberg complex
- Pits, quarries
- Reyes
- Rock outcrop-Xerorthents complex
- Rodeo
- Saurin-Bonnydoon complex
- Saurin-Urban land-Bonnydoon c
- Sheridan Variant
- Sirdrak
- Sirdrak Variant
- Sobega
- Tamalpais-Barnabe Variant
- Tocaloma-McMullin Urban land c
- Tocaloma-McMullin complex
- Tocaloma-Saurin association, st
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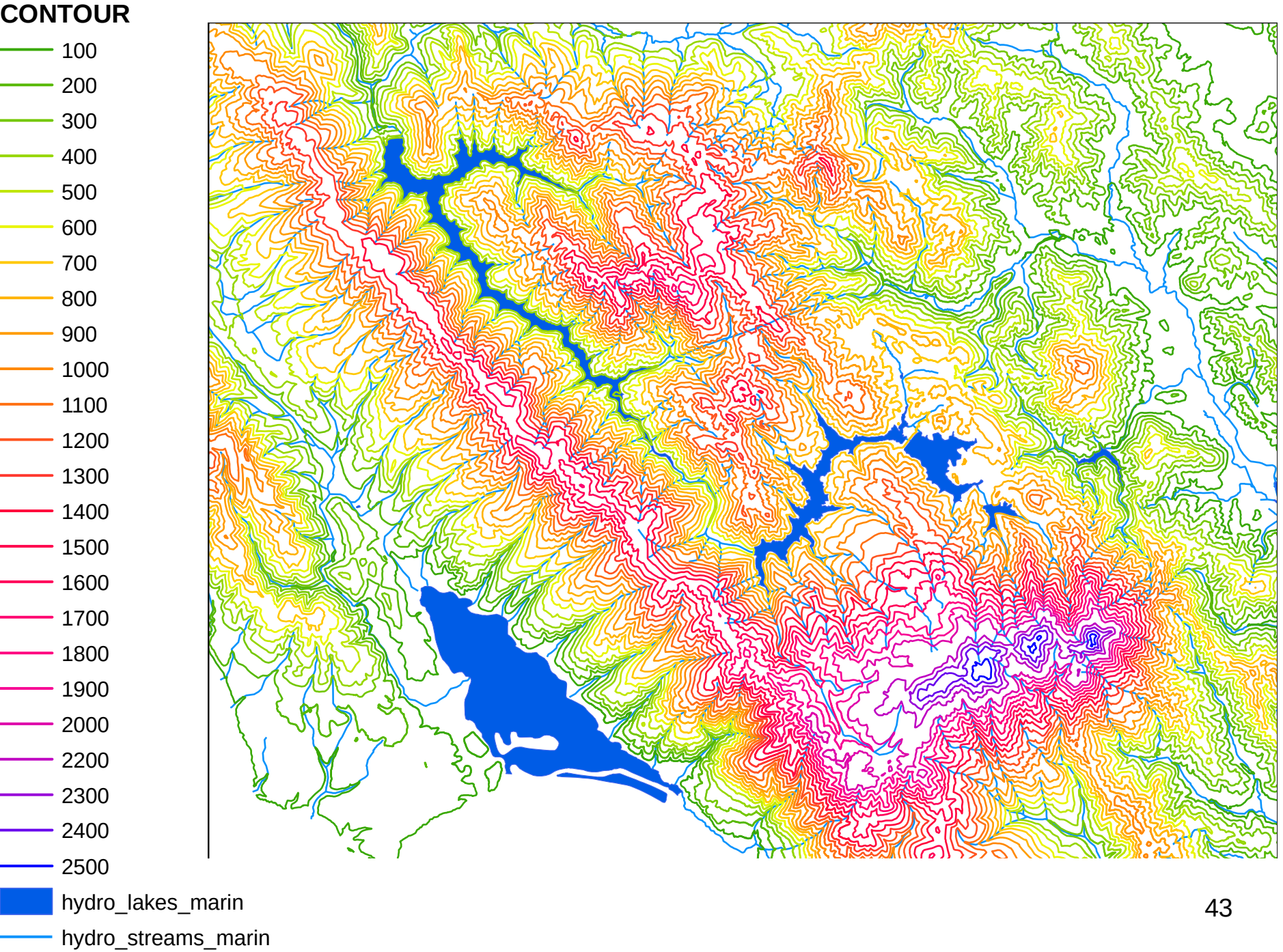
- Tocaloma-Surin association, extr
- Tomales
- Tomales-Sobega
- Tomales-Sobega complex
- Tomales-Steinbeck
- Urban land-Ballard complex
- Urban land-Xerothents complex


CONTOUR
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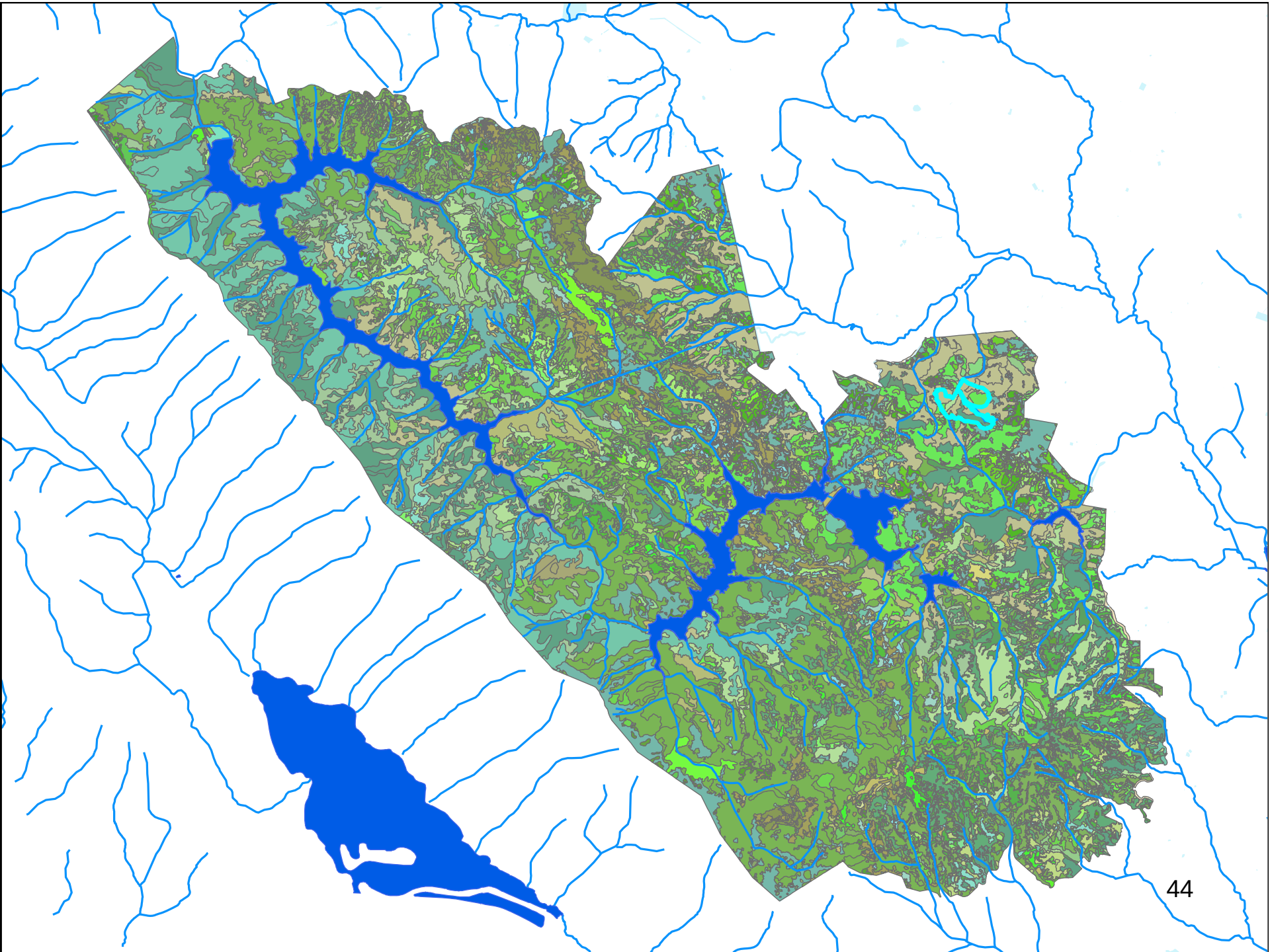
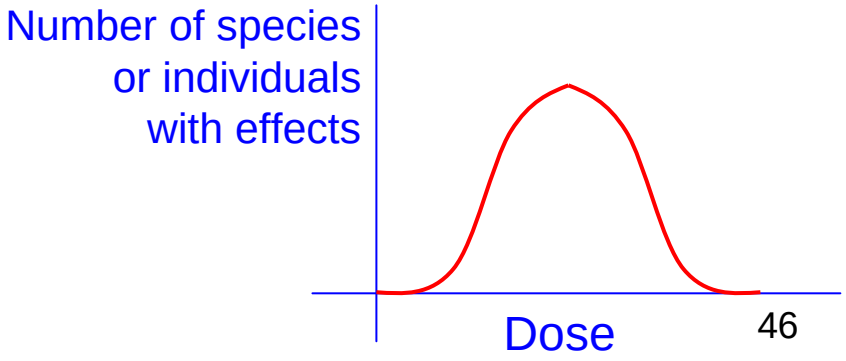



AIS_VEG_TY
(French) Broom Alliance
Big-Leaf Maple -California Bay Mapping Unit
Bishop Pine / Eastwood Manzanita
Bishop Pine Alliance
Bishop Pine Pure Stands
Black Oak Alliance
Blue Blossom Alliance
Bulrush Alliance
California Annual Grasslands Alliance (Native
California Bay -Alder -Bigleaf Maple -Mixed W
California Bay -Buckeye
California Bay -Canyon Oak
California Bay -Coast Live Oak
California Bay -Interior Oak
California Bay -Tanoak
California Bay Alliance
California Bay Pure Stands
California Buckeye Alliance
California Sagebrush -Sticky Monkey Flower
California Sagebrush Alliance
California or Idaho Fescue Grasses
Canyon Oak -Interior Oak
Canyon Oak Alliance
Cattail Alliance
Chamise (pure)
Chamise - Serpentine Chaparral
Chamise -Eastwood Manzanita
Chamise -mixed chaparral
Chamise Alliance
Cliffs -Rock Outcrops
Coast Live Oak - Madrone Lower elevation M
Coast Live Oak -Douglas-fir
Coast Live Oak -Riparian
Coast Live Oak / (Grass-Poison Oak)
Coast Live Oak Alliance
Coyote Brush -California Sagebrush -Sticky M
Coyote Brush -Mixed Shrub / Grass
Coyote Brush / Annual or Perennial Grasslan
Coyote Brush Alliance
Douglas-fir -California Bay / Interior Oak
Douglas-fir -California Bay Mapping Unit
Douglas-fir -Mixed Hardwoods in Drier Woodl
Douglas-fir -Mixed Hardwoods in Upland Fore
Douglas-fir -Riparian
Douglas-fir -Tanoak
Douglas-fir Alliance
Douglas-fir -Mixed Hardwoods in Uplan
Douglas-fir -Riparian
Douglas-fir -Tanoak
Douglas-fir Alliance
Douglas-fir Pure Stands
Eastwood Manzanita Alliance
Field Questions
Giant Chinquapin Alliance
Grasslands on poorly developed soils
Grasslands on well-developed soils
Grasslands with a fern or sub-shrub (gc
Harding Grass Alliance
Interior Live Oak Alliance
Interior Live Oak- Eastwood Manzanita
Jepson?s Ceanothus (stand noted at N
LAND USE / UNVEGETATED
Landslides
Leather Oak -Chamise -Mt. Tamalpais M
Madrone -California Bay -Tanoak Fores
Madrone Alliance
Mixed Willow Mapping Unit
Mt. Tamalpais Manzanita - / sparse em
Mt. Tamalpais Manzanita - Chamise - (
Mt. Tamalpais Manzanita Alliance
Native Temperate Perennial Grasslands
Oregon Oak Alliance
Planted Stands of Pine
Poison Oak Alliance
Purple Needlegrass
Quarry
Redwood -Douglas-fir
Redwood -Pure Stands
Redwood -Riparian
Redwood -Upland Mixed Hardwoods
Redwood / Chinquapin
Redwood / Tanoak
Redwood /California Bay
Redwood Alliance
Reservoirs
Sargent Cypress / Mt. Tamalpais Manza
Sargent Cypress Alliance
Sargent Cypress Pure Stands
Sedge -Rush -Wet Graminoids Meadov
Sensitive Manzanita Alliance
Serpentine Balds
Silver Leaf Manzanita Alliance
Small Asian Elephant Ponds
Tall Temperate Annual Graminoids
Tall Temperate Perennial Herbaceous
Tanoak -California Bay -Canyon Oak Higher elevation Mixed Forest
Tanoak Alliance
Temperate Broadleaf Sclerophyll Evergreen Shrublands
Temporarily flooded or saturated Meadow Edge
Undifferentiated Marsh (cattail, bulrush, other scirpus spp.)
Upland Serpentine Grassland
Urban Developed -Built Up
Valley Oak Riparian Mapping Unit
WATER
Wetland Serpentine Grassland
White Alder -California Bay
adm_mmwd_v_parcel_marinmap
allmappedbroom_finished
Serpentine

LIST OF ABREVATIONS

MMWD – Marin Municipal Water District
TRV – Toxicity Reference Value
RfD – Human specific TRV with uncertainty adjustment factors
NOEL – No Observed Effect Level
LOEL – Lowest Observed Effect Level
LD_{50} – Lethal Dose to 50% of organisms
HQ – Hazard Quotient



Exposure Scenario Calculations:

General exposure from backpack spraying:

$$\text{Dose (mg/kg)} = \frac{(\text{daily hours worked}) \times (\text{hectares treated/hr}) \times (\text{application rate (kg/ha)}) \times (\text{handling contamination rate (mg/kg)/(kg handled/day)})}{(\text{organism bodyweight (kg)})}$$

Exposure from brushing against contaminated vegetation:

$$\text{Dose (mg/kg)} = \frac{(\text{surface area (cm}^2\text{)}) \times (\text{transfer rate (mg/hr cm}^2\text{)}) \times (\text{contact time (hr)}) \times (\text{fraction that drifts}) \times (\text{fraction skin absorbed})}{(\text{organism bodyweight (kg)})}$$

Water intake from child:

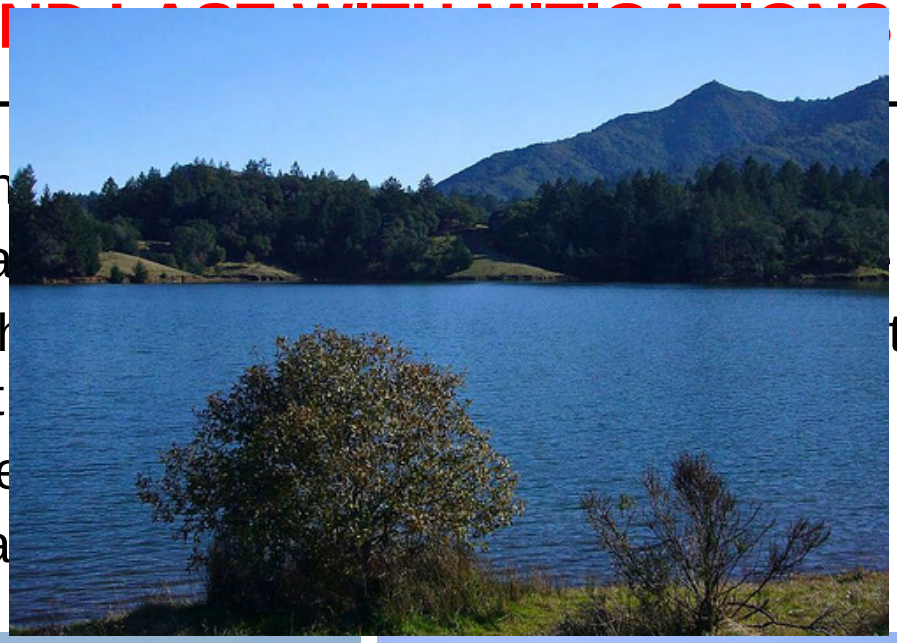
$$\text{Dose (mg/kg)} = \frac{(\text{water intake}) \times (\text{application rate (kg/ha)}) \times (\text{water contamination rate(mg/L)/(kg/ha)}) \times (\text{chemical decay: exp(-ln(2)t/halflife)})}{(\text{child bodyweight (kg)})}$$

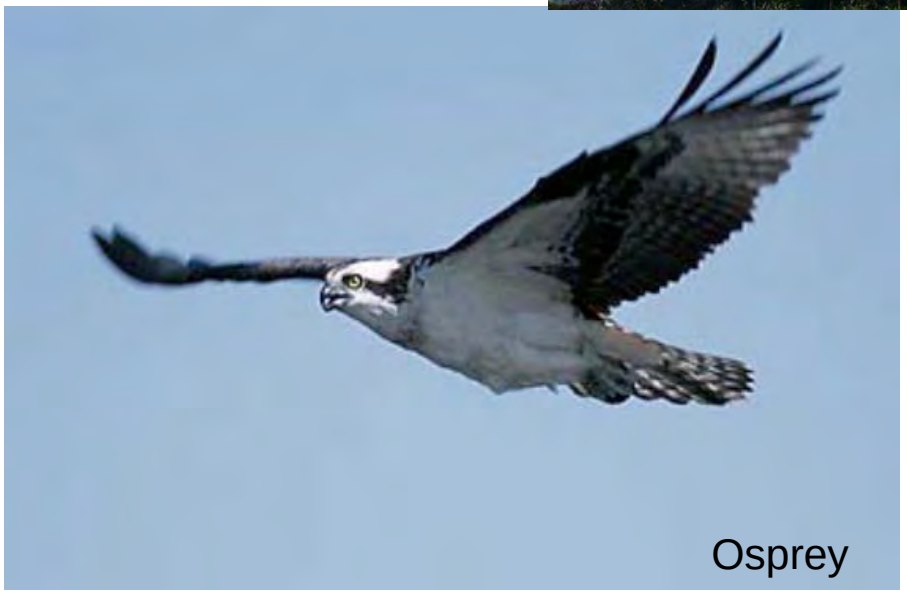
Large mammal herbivore or insectivorous small mammal:

$$\text{Dose (mg/kg)} = \frac{(\text{food needs (kcal)}) \times (\text{application rate (kg/ha)}) \times (\text{residue rate (mg/kg food) /(kg/ha)}) \times (\text{fraction that drifts}) \times (\text{fraction diet contaminated})}{(\text{adult male bodyweight (kg)})}$$

COMBINE THIS AI ALSO

- Triclopyr is more in
- Hazard quotients a
  - Given that high ther chemical is likely to affect
  - Wildlife will like
  - Vegetation ma





Osprey

Bon Tempe Lake