Sustainable pesticide use practices for the protection of water resources

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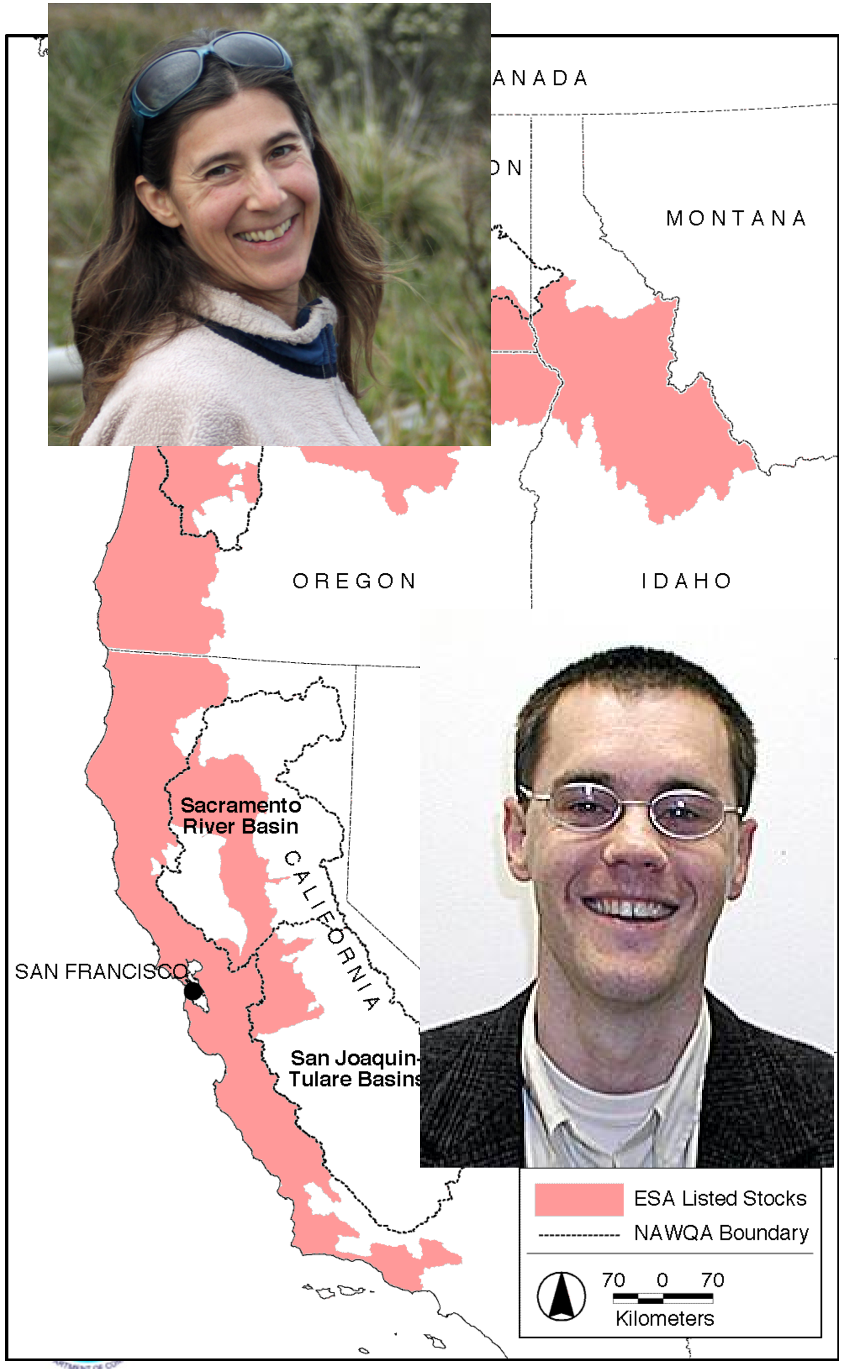
Oregon State University | Agricultural Experiment Station

OSU Extension Service

Impact of Agriculture and Forestry on Salmonids in the Pacific Northwest



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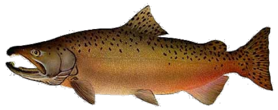
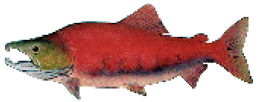
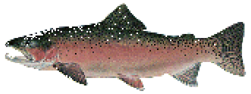
28 Evolutionarily Significant Units


Oncorhynchus kisutch


Oncorhynchus keta


Oncorhynchus nerka


Oncorhynchus mykiss

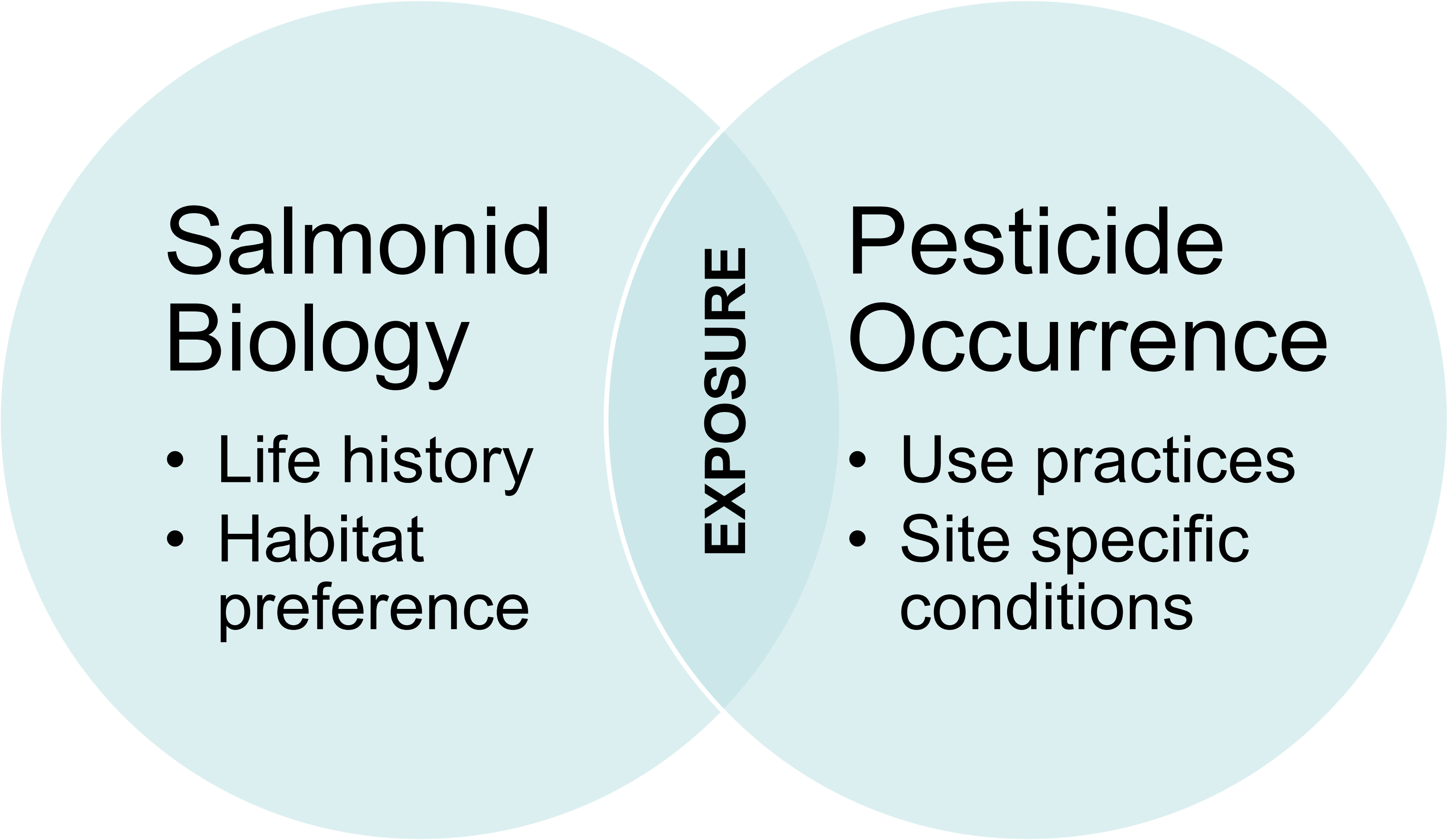

Oncorhynchus tshawytscha

PNW Stakeholders

- Pesticide users
  - Industry
  - Agriculture
  - Forestry
  - Rights of Way
  - Municipal
  - Residential

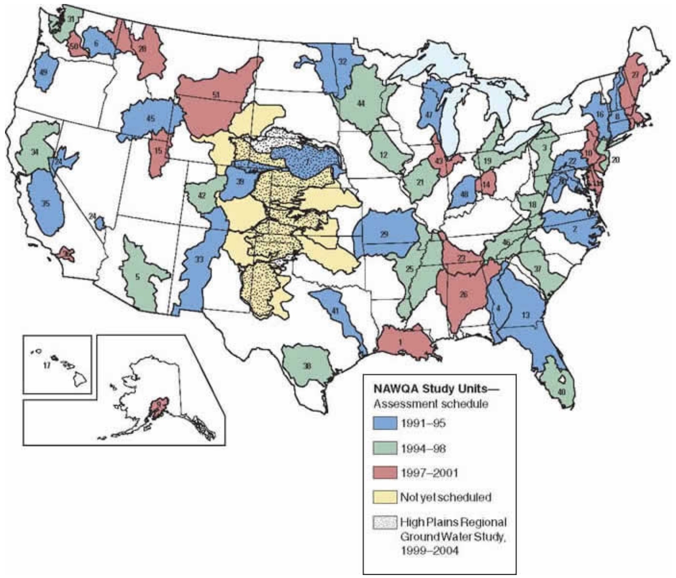
- Federal Government
- State Government/PSP/WQPMT
- Tribes
- Land Grant universities
- Watershed Councils
- Non-Governmental Organizations
- Soil and Water Conservation Districts
- Irrigation districts
- Public

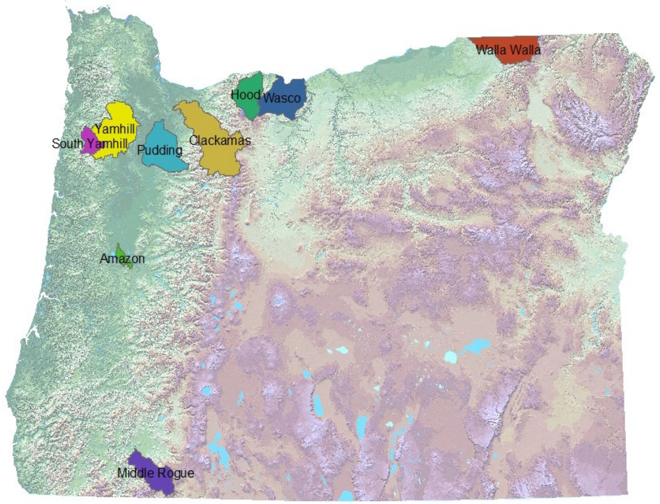
Pacific Salmonid Pesticide Opportunities for Exposure

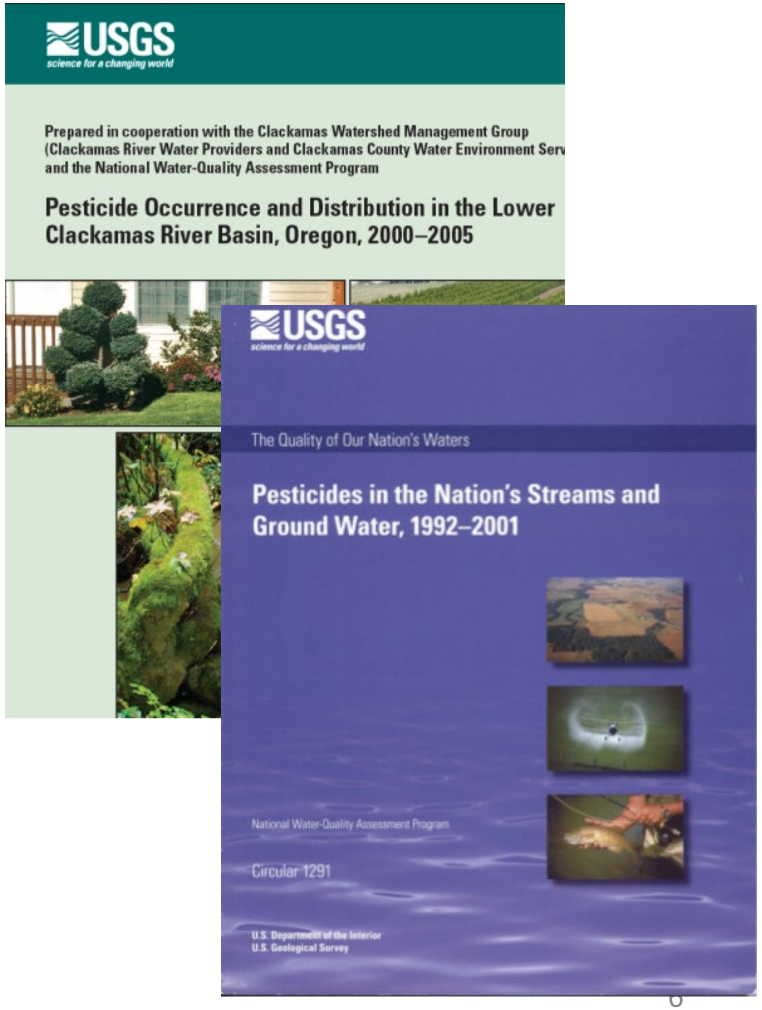


Pesticide Surface Water Monitoring in the U.S. and Oregon

- USGS Monitoring
  - National Water Quality Assessment Program (NAWQA)
  - Clackamas studies
- DEQ/ODA Monitoring
  - Pesticide Stewardship Partnership (PSP)
    - 9 Watersheds
    - 4 in Willamette Valley



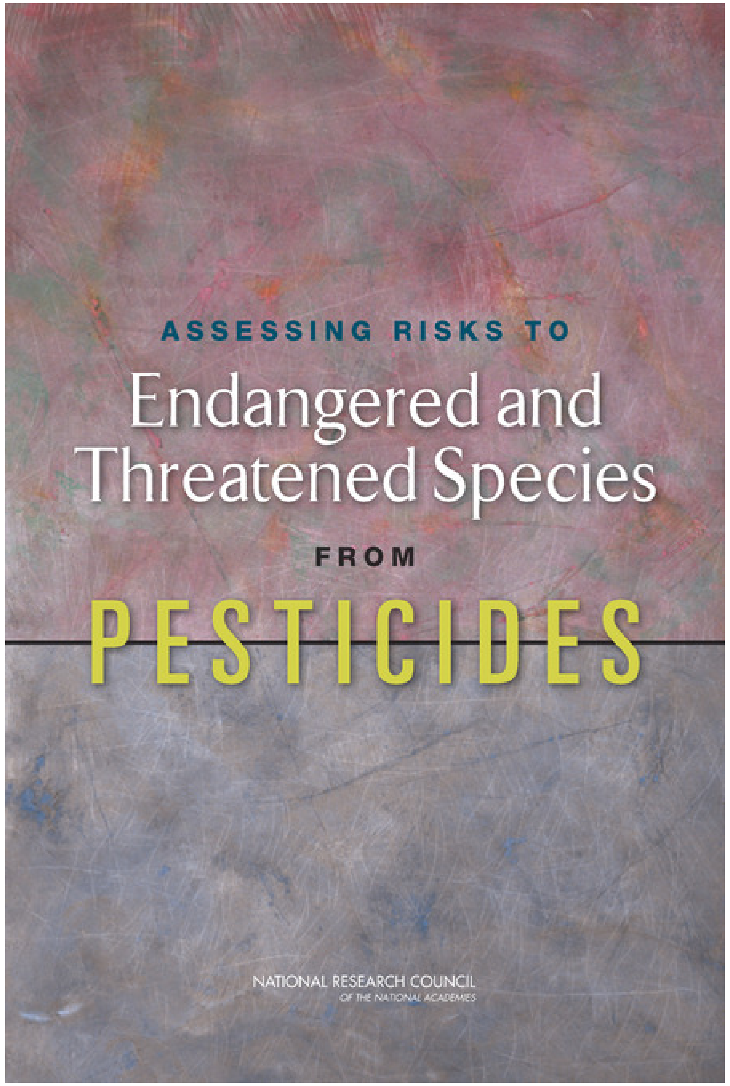




ESA/FIFRA - National Research Council Review (2013)

- Evaluate current pesticide risk assessment approaches relating to ESA listed species (biological opinions)

- Reach consensus on common risk assessment methods
  - Modelling/model assumptions
  - Geospatial information
  - Characterize effects direct, indirect, sublethal and cumulative; mixtures and inert ingredients
  - Characterize <u>uncertainty</u>



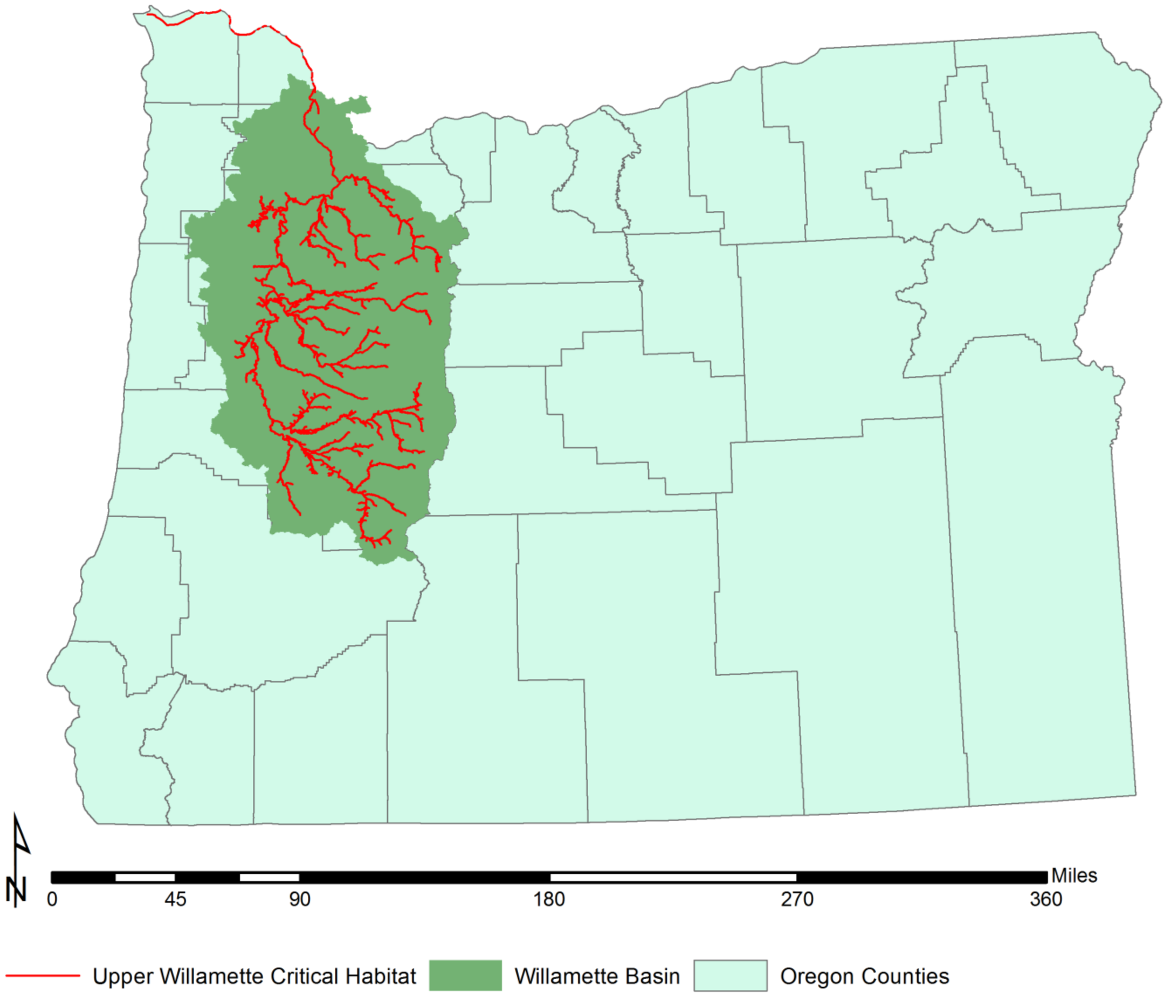
Willamette Basin Salmonid Critical Habitat

Willamette Basin (HUC 4)
- 12 HUC 8 subbasins
- 388 HUC12 watersheds

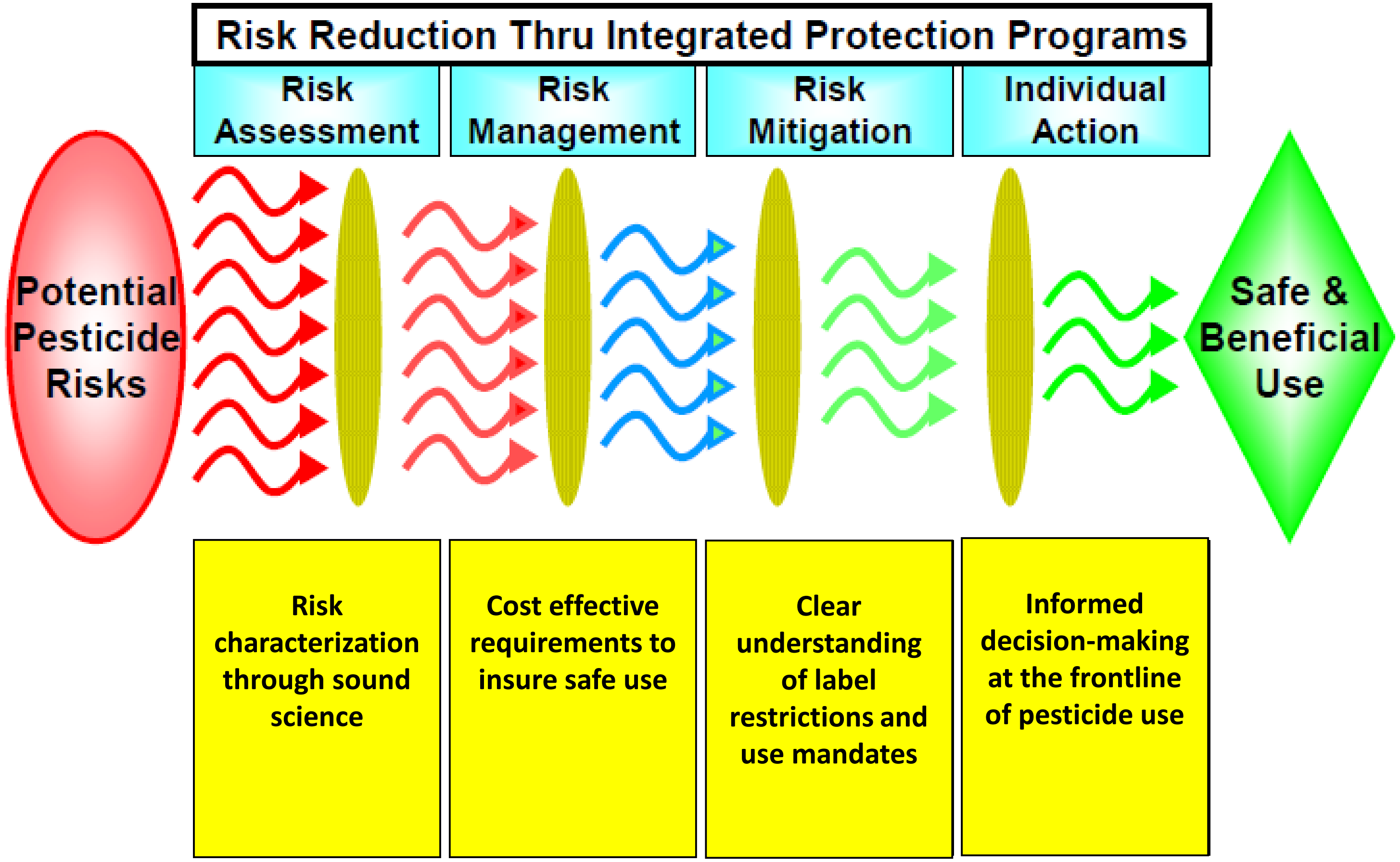
Diverse agriculture (170 crop varieties), forestry, urban pesticide use practices

More than 500 pesticide active ingredients registered in Oregon

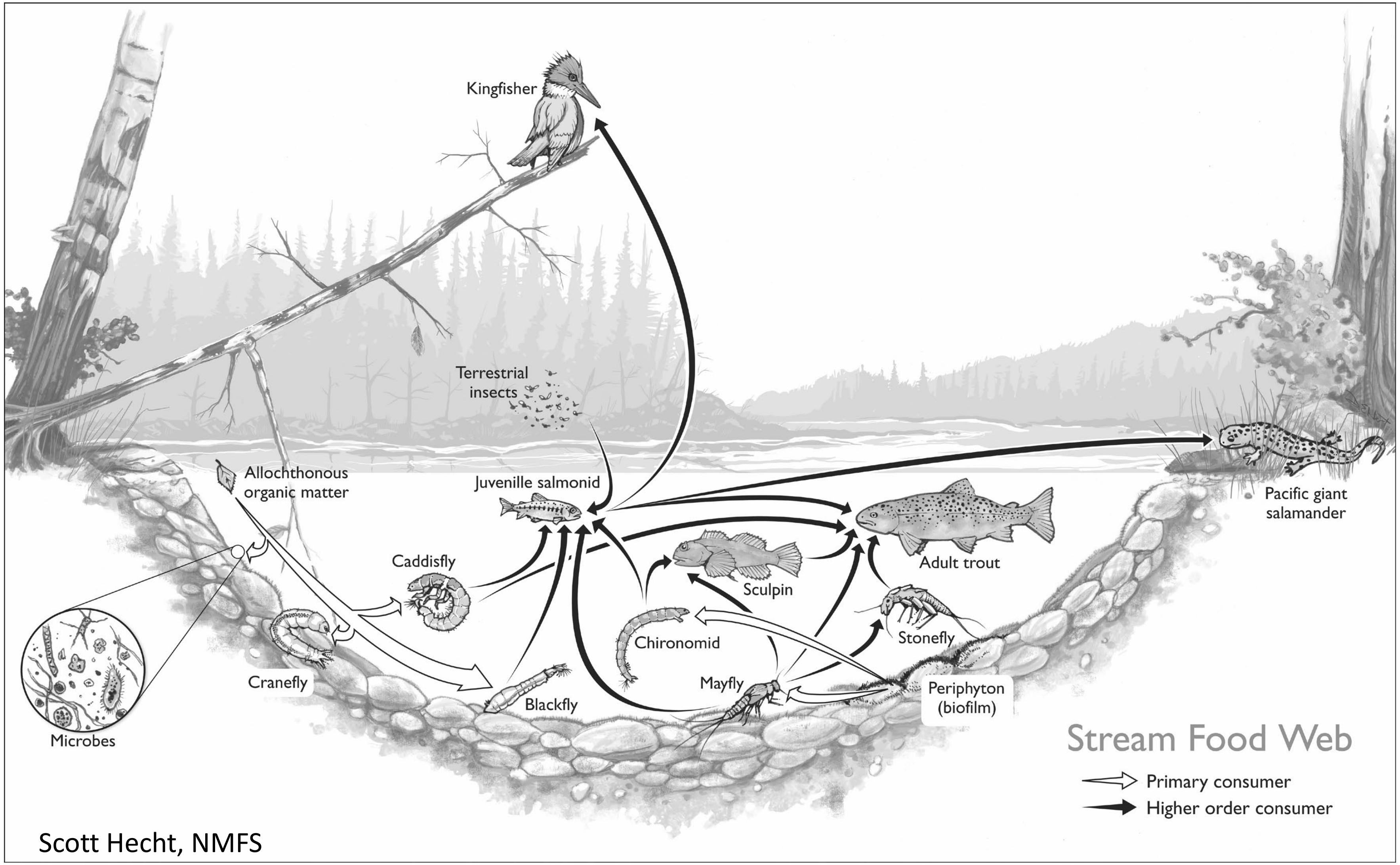
Pesticide co-occurrence with salmon/food web life histories?



FIFRA/FQPA Federal – State Partnerships designed to Achieve Safe and Beneficial Pesticide Use



Pacific Salmonid Biology, Food Web and Critical Habitat



Scott Hecht, NMFS

Fig. 1. Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modeling structure and tools.

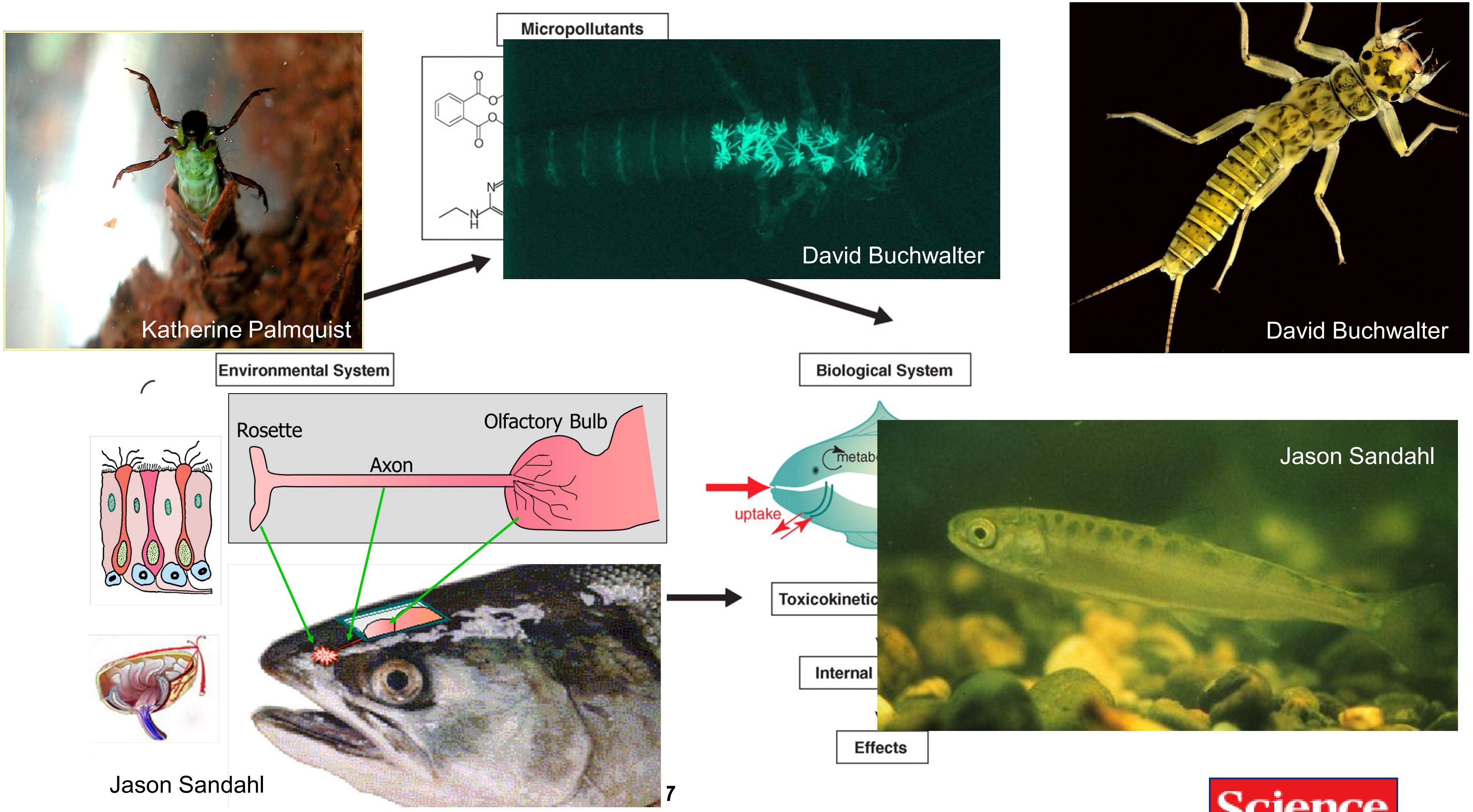
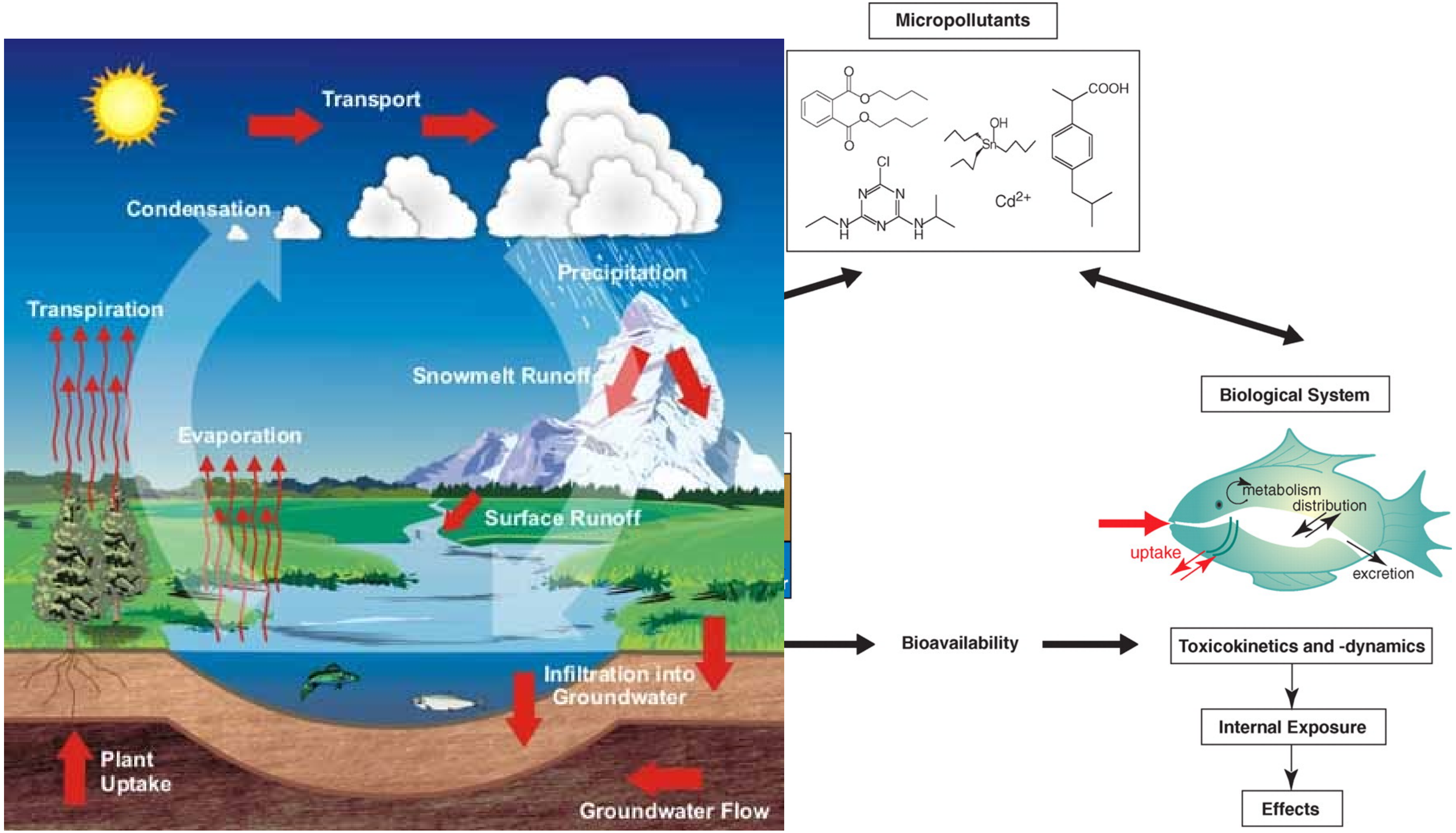


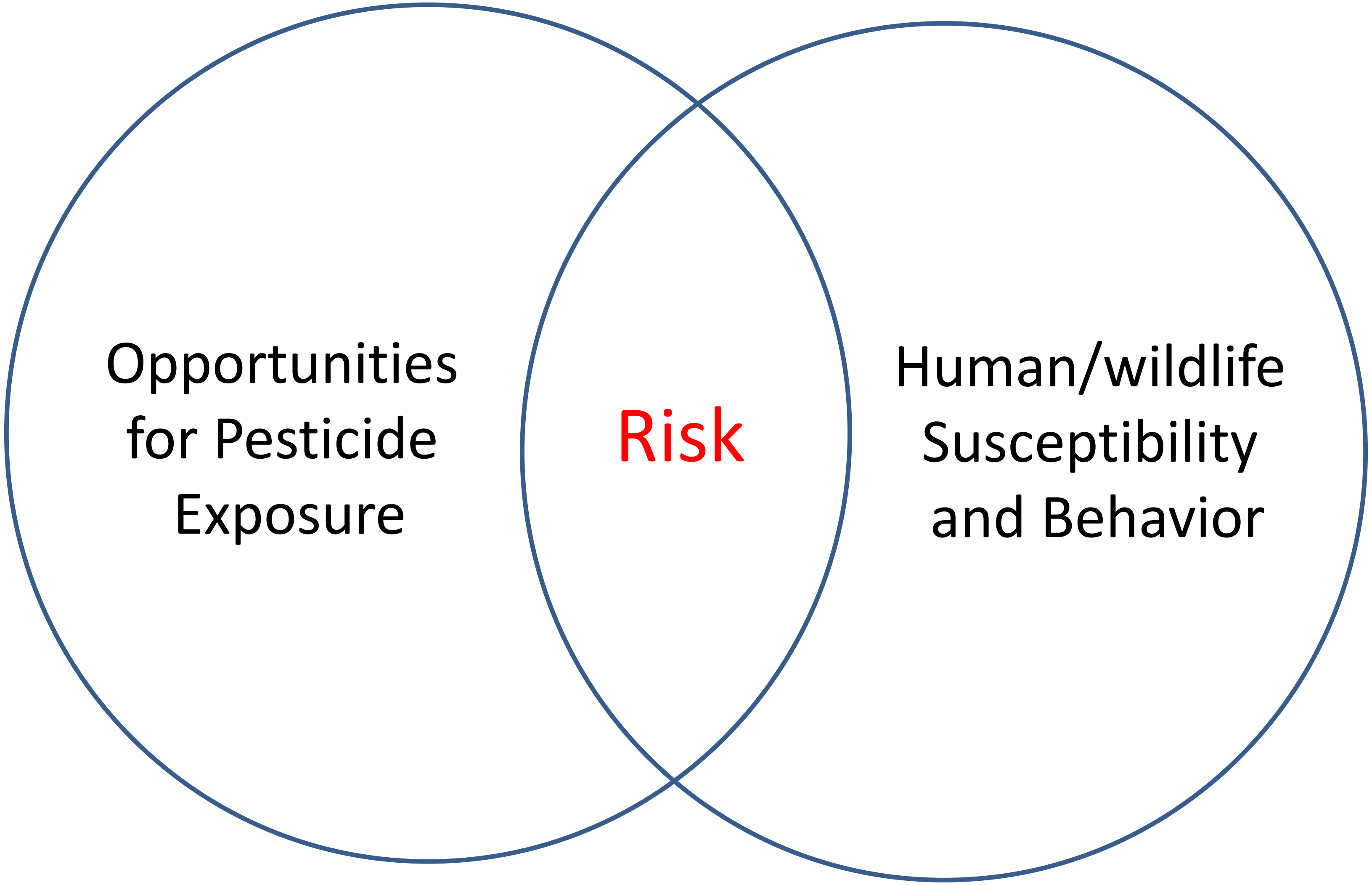
Fig. 1. Consistent exposure and effect assessment is possible if processes in the environmental system and in the organisms (biological system) are treated with the same modeling structure and tools.



René P. Schwarzenbach et al. Science 2006;313:1072-1077

Science AAAS

Risk: Conceptual Framework



Sustainable Agriculture and Forestry

- The core concept of sustainability[1] is that lasting success requires an integrated approach to:
  - producing food, fiber, and other products
  - farm and forest profitability
  - quality of life for farmers, foresters, and communities
  - stewardship of natural resources

- Sustainability requires recognizing and acting upon productivity, economic, social, and environmental goals as <u>a simultaneous set of system attributes.</u>

[1]Brundtland, G. H. (1987). Our Common Future. Annex to U.N. General Assembly document A/42/427.

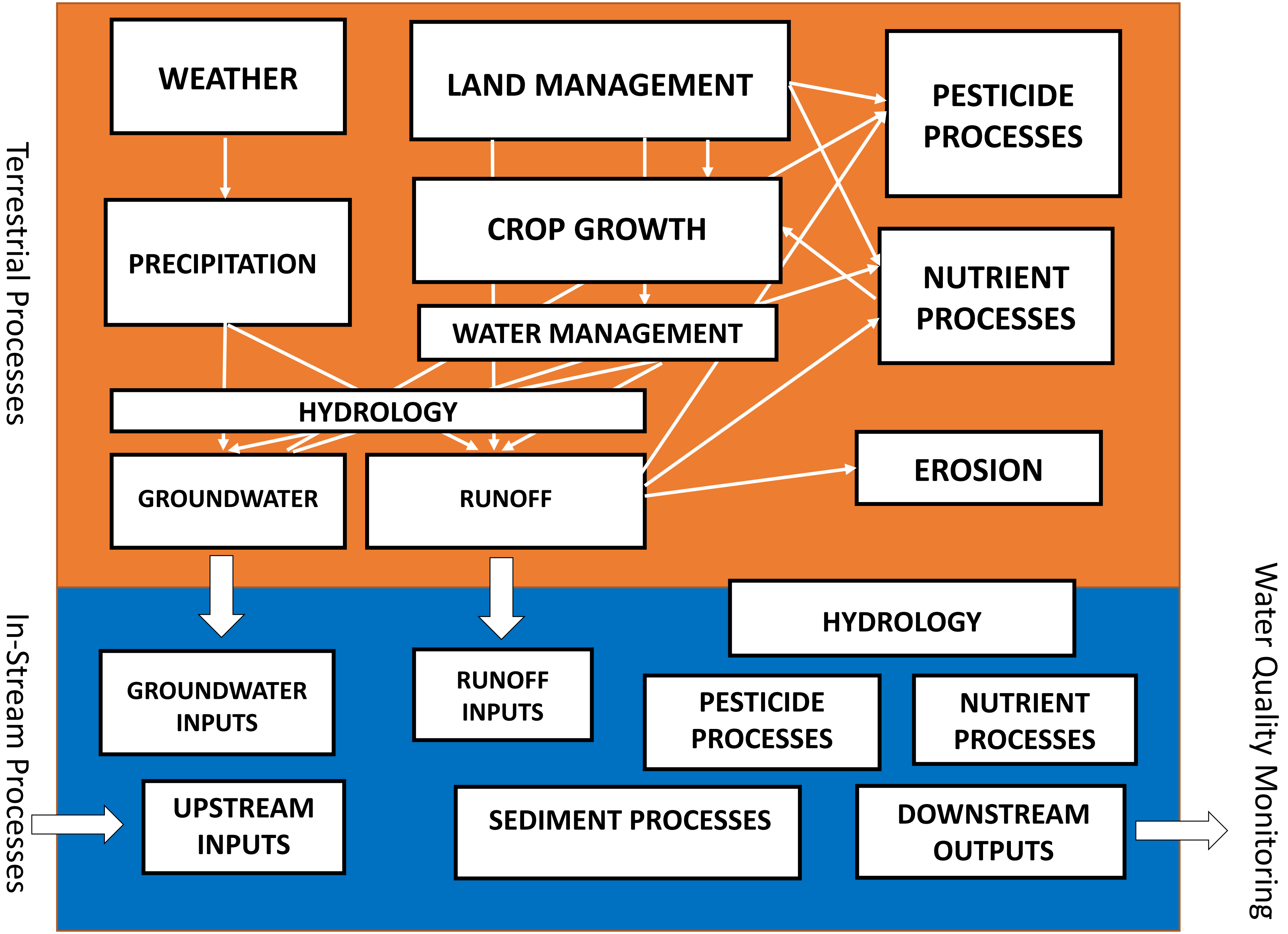
Technology to Enable Sustainable Production

- Farm/forest operations management
- Agronomy/horticulture/animal science/forest science
- Pest management/IVM
- Nutrient management
- Water Management
- Natural resource stewardship
- Supply chain management
- Information management

Farm/Forest Production System

Digital Agriculture and Forestry

Water quality stewardship - conceptual model

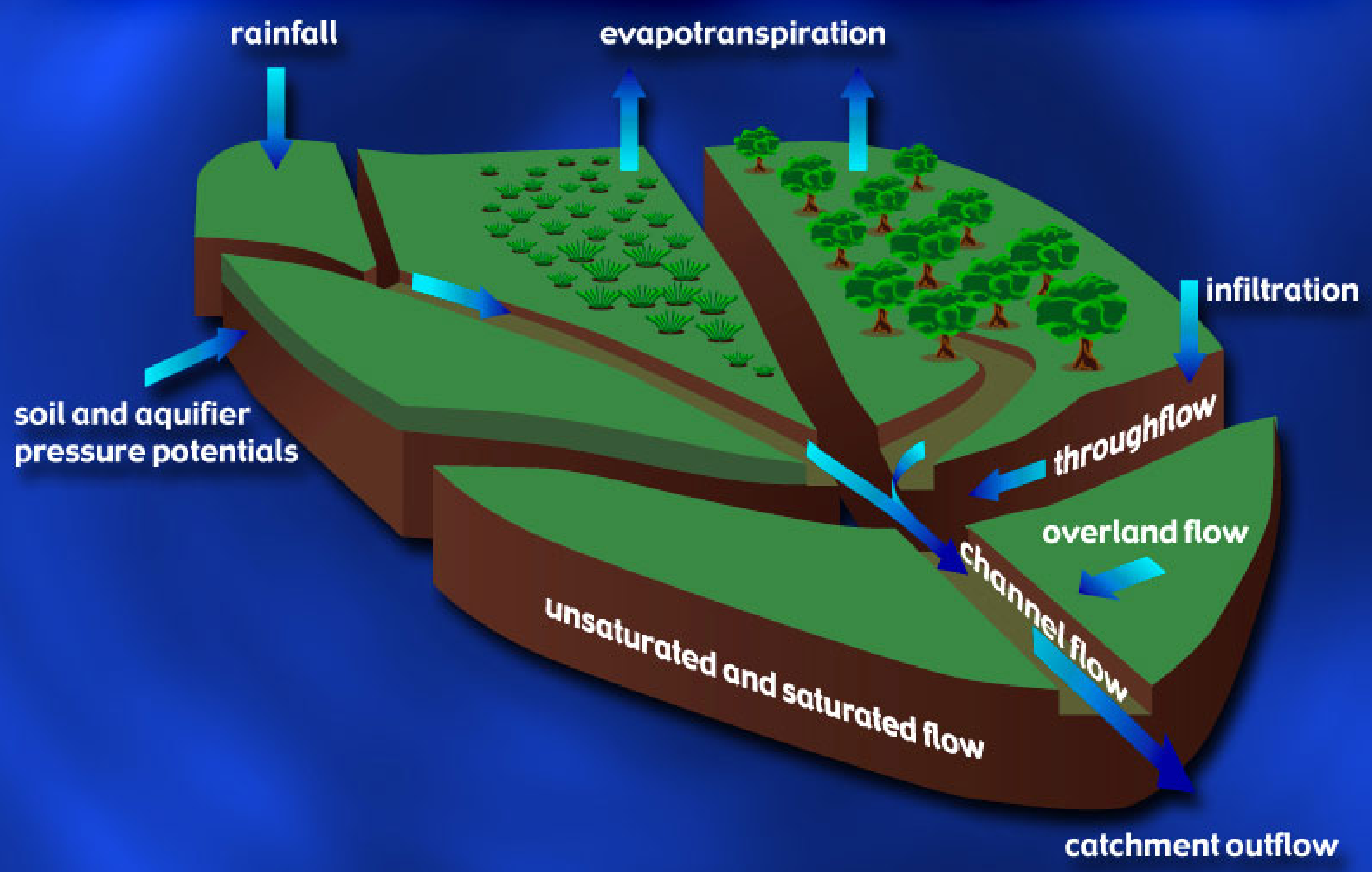


Herbicides Commonly Used in the Pacific Northwest

Trade name	Common name	½ life (days)	Koc	water sol mg/L	vapor pressure (mm Hg)
Sencor	metribuzin	40	60	1220	1.0x10-5
Banvel	Dicamba (acid)	14	2	400000	3.4x10-5
Milestone	aminopyralid	35	11	2480	7.1x10-11
Garlon	trichlopyr	30	210	260	3.0x10-8
Dual	metolachlor	90	200	530	3.1x10-5
Roundup	glyphosate	47	24000	530000	0
2,4-D	2, 4 D acid	10	20	89	1.1x10-7
2,4-D ester	2,4-D butoxyethyl ester	7	500	100	1.0X10-7
Chopper	imazapyr	90	100	1100	1.3x10-11
Velpar	hexazinone	90	54	3300	8.2x10-11
Kerb	pronamide	60	800	15	8.5x10-5
Oust	Sulfometuron methyl	28	78	70	1.7x10-16
Goal	oxyfluorfen	35	100000	0.1	2.0x10-7
Prowl	pendimethalin	90	500	0.3	9.4x10-6
Buctril	bromoxynil	7	10000	0.8	4.8x10-6
Dachthal	DCPA	100	5000	0.5	2.5x10-6

OSU Extension Pesticide Properties Database EM 8709

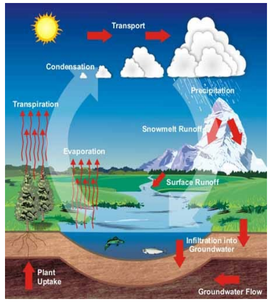
Pesticide Loss at the Watershed Scale



Soil and Water Assessment Tool (SWAT)

Conceptual model
↓
Process model (computer)
↓
ArcSWAT (GIS),
use of spatial data (maps)
↓
Describe daily changes
in watershed
↓
Pesticides in surface water

Conceptual model



Process model - computer

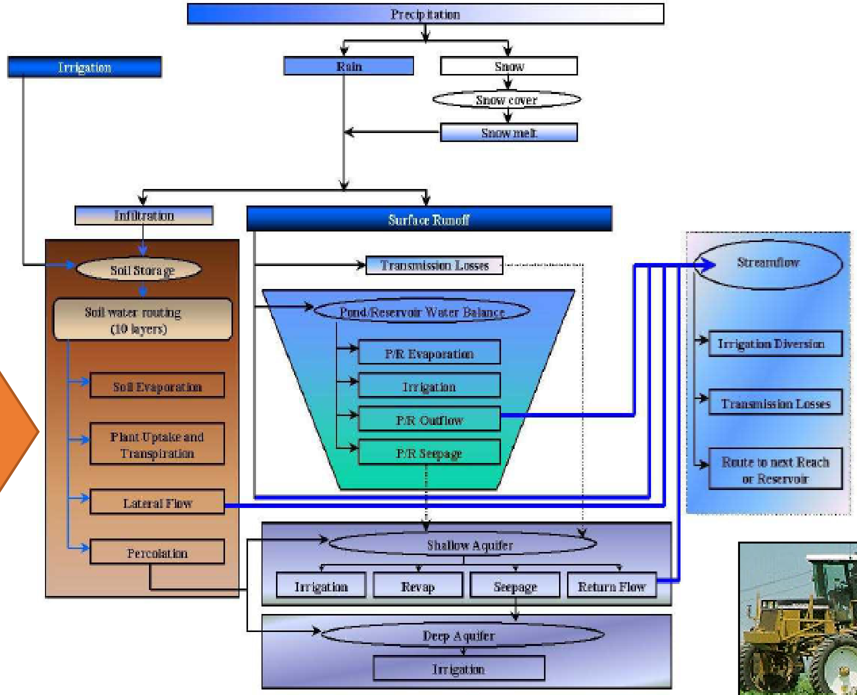
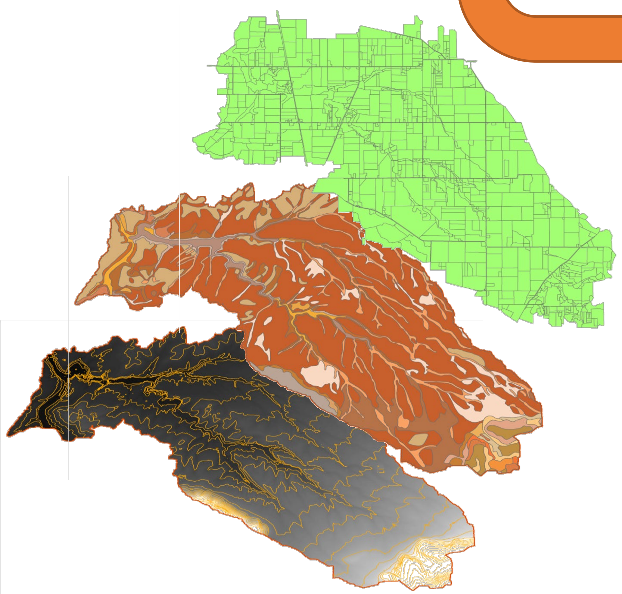
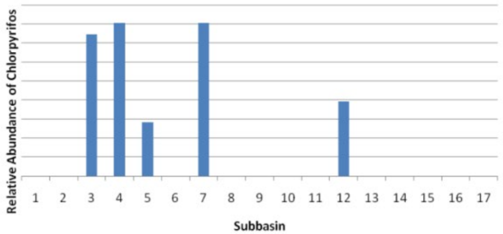


Figure 1.5: Schematic of pathways available for water movement in SWAT



Daily Pesticide Load
Following Early Season Application



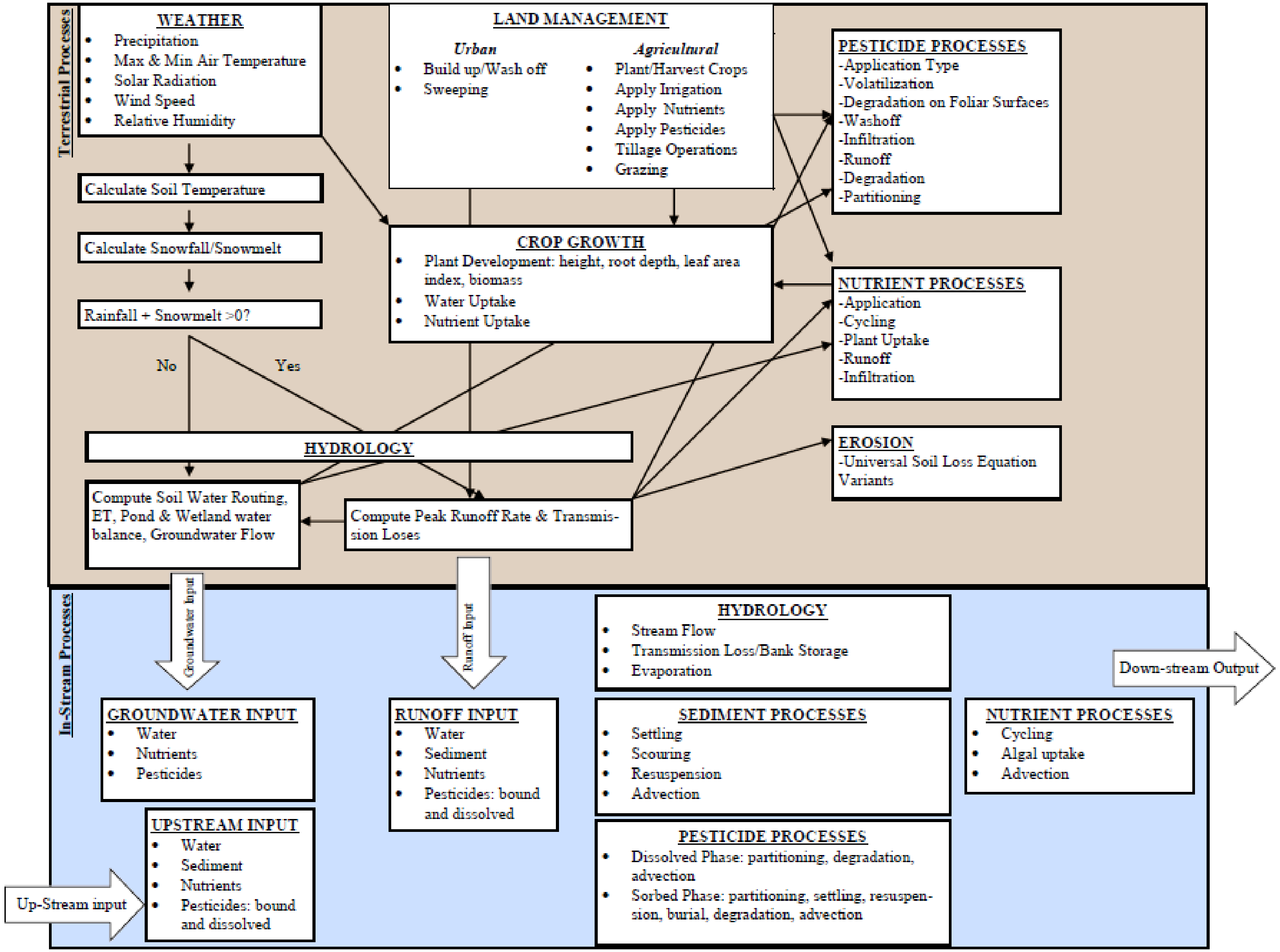
Soil and Water Assessment Tool (SWAT)

- Watershed scale model[1]
  - Developed by USDA Agricultural Research Service
  - Based on over 40 years of expertise

- Developed to evaluate the impact of land management practices on:
  - Hydrology
  - Erosion/Sediment transport
  - Nutrient fate
  - Pesticide fate

- Physically based process model that operates on a daily time step

- GIS interface, ArcSWAT, used for spatially explicit parameterization using readily available data



Watershed scale modeling of pesticide fate

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Modeling spray drift and runoff-related inputs of pesticides to receiving water☆

Xuyang Zhang*, Yuzhou Luo, Kean S. Goh

California Department of Pesticide Regulation, Sacramento, CA, 95814, United States

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Health & Ecological Risk Assessment

Soil and Water Assessment Tool Model Predictions of Annual Maximum Pesticide Concentrations in High Vulnerability Watersheds

Michael F Winchell,† Natalia Peranginangin,‡ Raghavan Srinivasan,§ and Wenlin Chen‡*

†Stone Environmental, Montpelier, Vermont, USA

‡Syngenta Crop Protection, Greensboro, North Carolina, USA

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Journal of Environmental Quality TECHNICAL REPORTS

ENVIRONMENTAL MODELS, MODULES, AND DATASETS

Evaluation of Watershed-Scale Simulations of In-Stream Pesticide Concentrations from Off-Target Spray Drift

Michael F. Winchell,* Naresh Pai, Benjamin H. Brayden, Chris Stone, Paul Whatling, John P. Hanzas, and Jody J. Stryker

We selected two watersheds near The Dalles (Supplemental Fig. S1) to evaluate a watershed-scale drift simulation approach using SWAT. We chose these watersheds based on the high cherry orchard area and the high malathion use intensity occurring during the dry season (May–August) (Supplemental

Journal of Environmental Quality TECHNICAL REPORTS

ENVIRONMENTAL MODELS, MODULES, AND DATASETS

A Systems Approach to Modeling Watershed Ecohydrology and Pesticide Transport

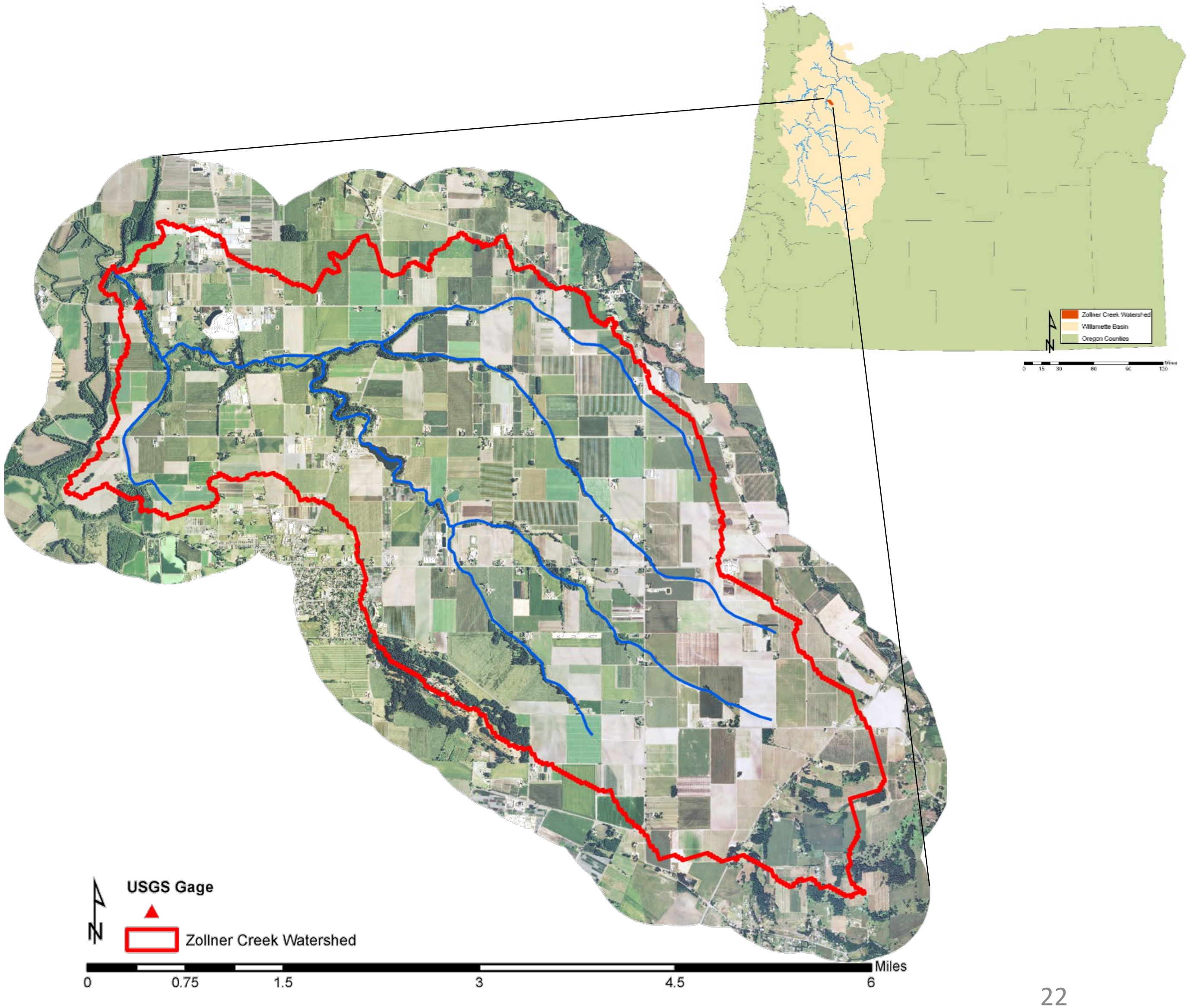
Philip Janney* and Jeffrey Jenkins

Core Ideas

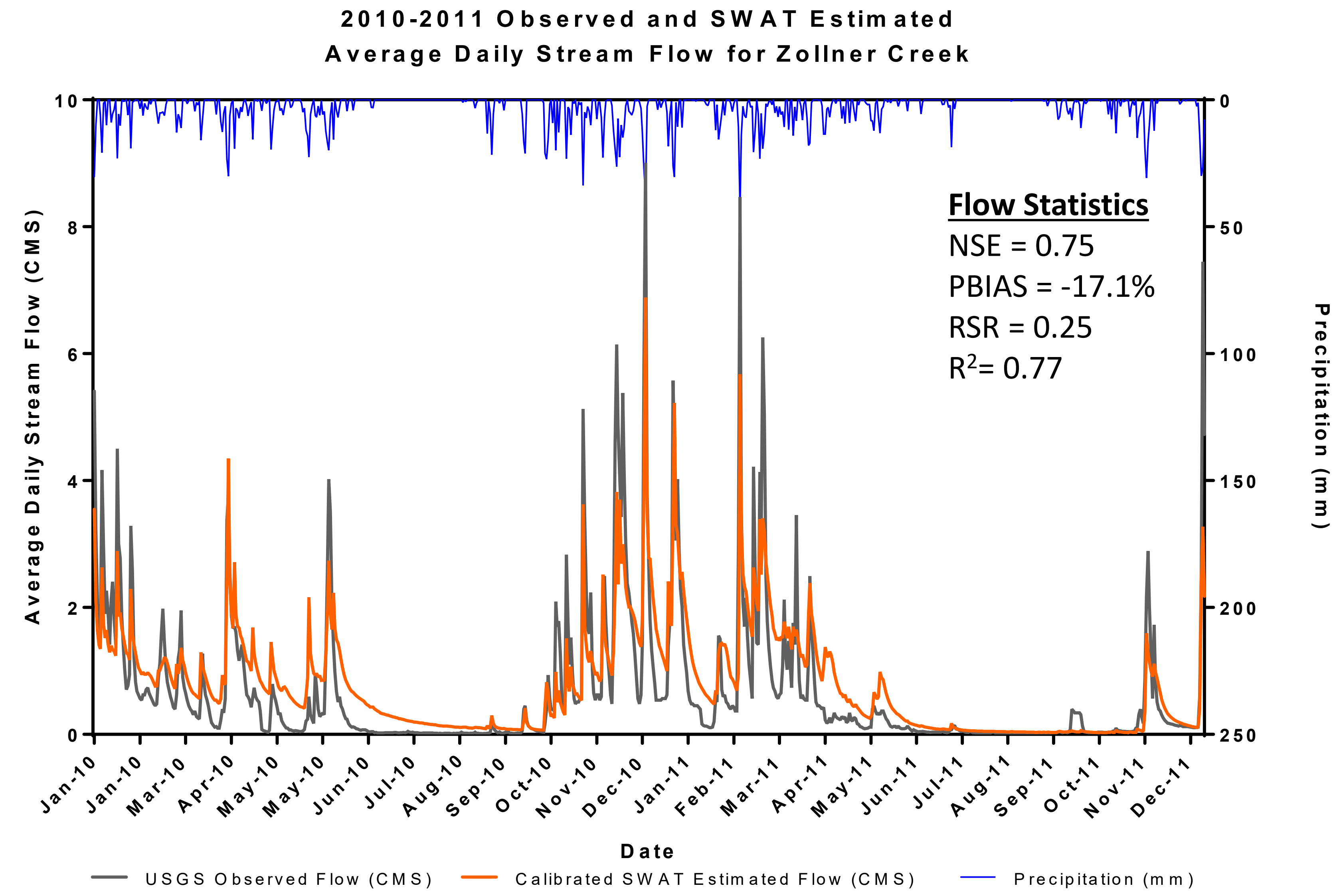
- Sequential model optimization incorporating local knowledge improved ecohydrologic estimates.
- Probabilistic pesticide application provided more realistic model estimates of solute transport.
- This modeling application allows a systems approach to sustainable agricultural practices.

Zollner Creek Watershed, Willamette Basin, Oregon

- HUC12 - 15mi^2 watershed
- Watershed area 90% agriculture:
  > 600 fields, >30 crops
- Pesticide surface water monitoring since 1993 (USGS and Oregon DEQ)
- Contains critical habitat for Upper Willamette chinook and steelhead ESUs
- Weather characterized by dry summers and wet winters
- USGS stream flow gage (Station ID: 14201300)



SWAT Hydrologic Characterization[1]



[1]Janney, P., and J. Jenkins. 2019. A Systems Approach to Modeling Watershed Ecohydrology and Pesticide Transport. J. Environ. Qual. 48:1047-1056.

Characterizing Pesticide Use Patterns

- All authorized uses (federal/state labeled uses)
- Actual use records
  - Proprietary
  - Logistically difficult
  - Retrospective
- Probabilistic methods based on local knowledge
  - Realistic boundary conditions (pest management along crop timelines)
  - Characterize complex decision making process (producers, CCAs, Extension)
  - Both retrospective and prospective – evaluate future outcomes

Labels for Oregon – PICOL database

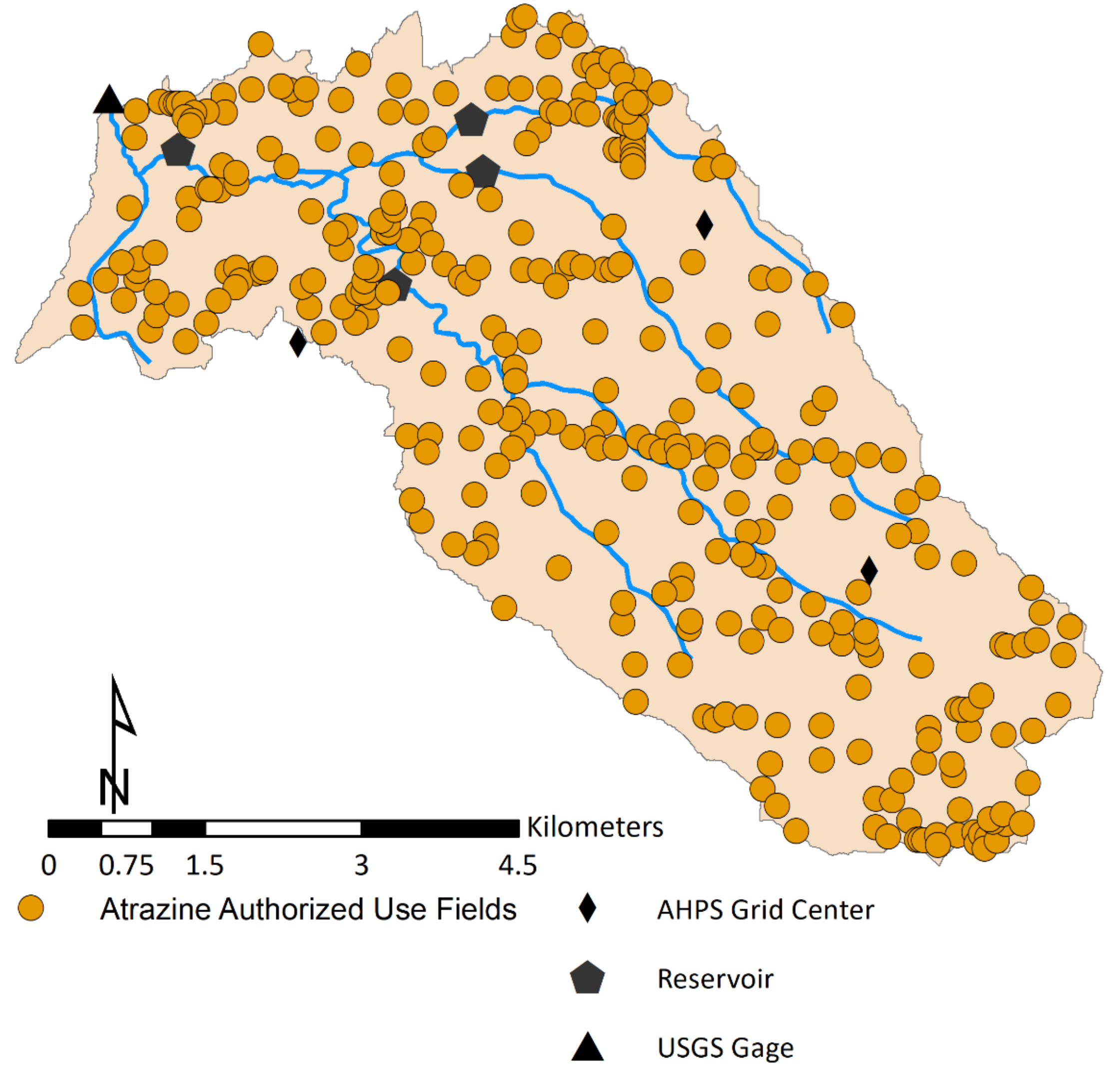
↓

Collaborate with CCAs and growers to refine use estimates

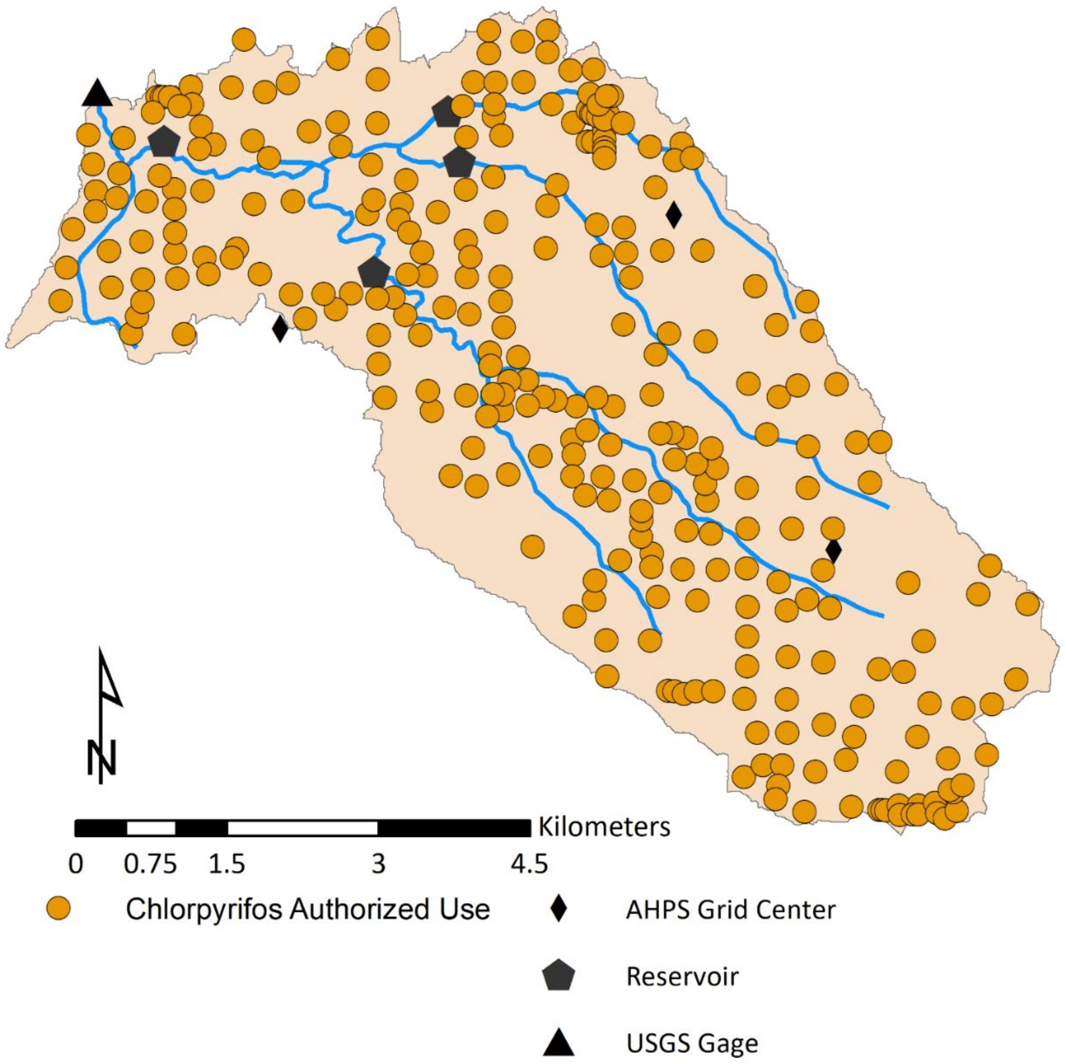
↓

Create boundary conditions for probabilistic analysis of application practices

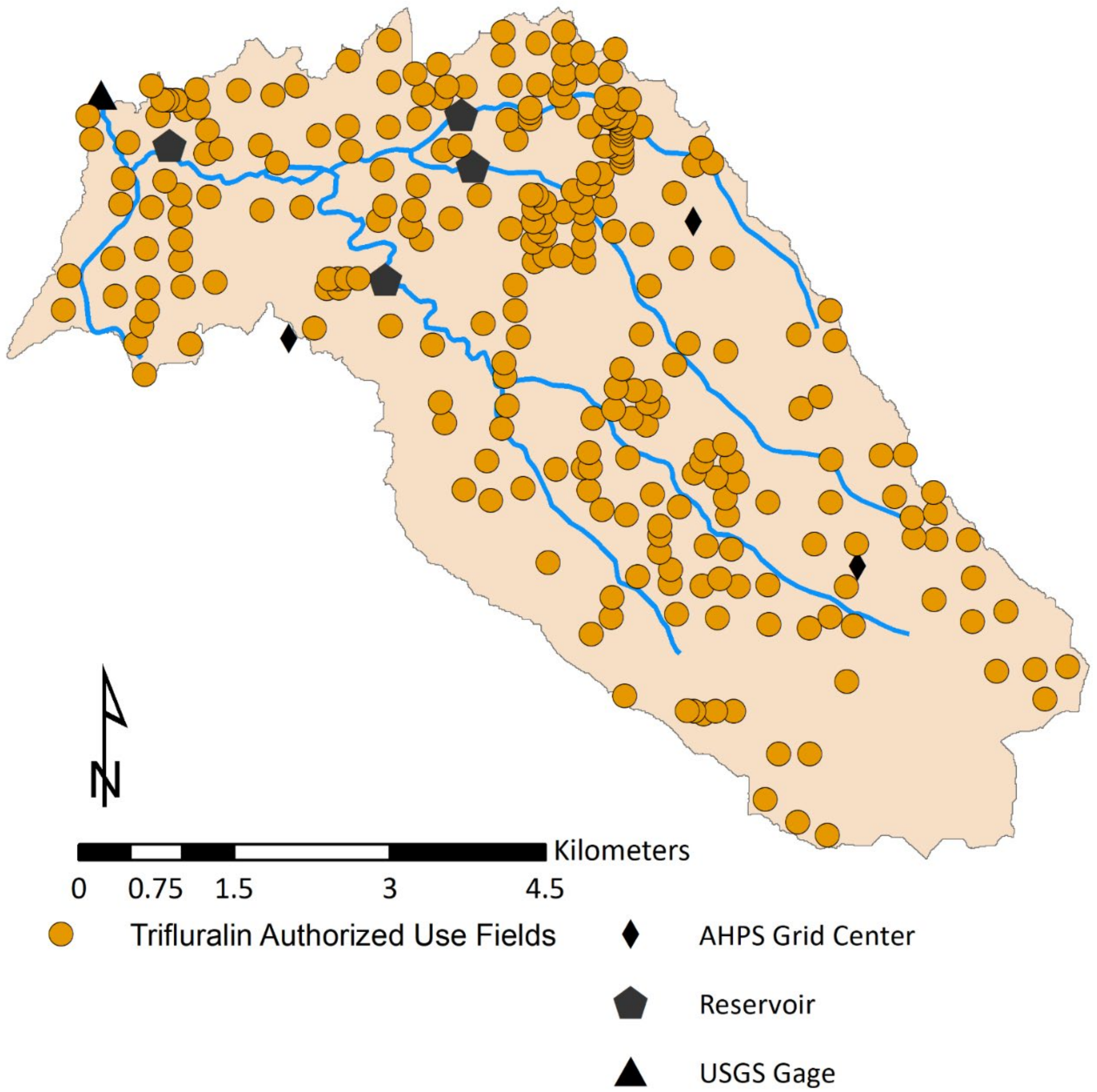
Atrazine Authorized Use in the Zollner Creek Watershed



Chlorpyrifos Authorized Use in the Zollner Creek Watershed

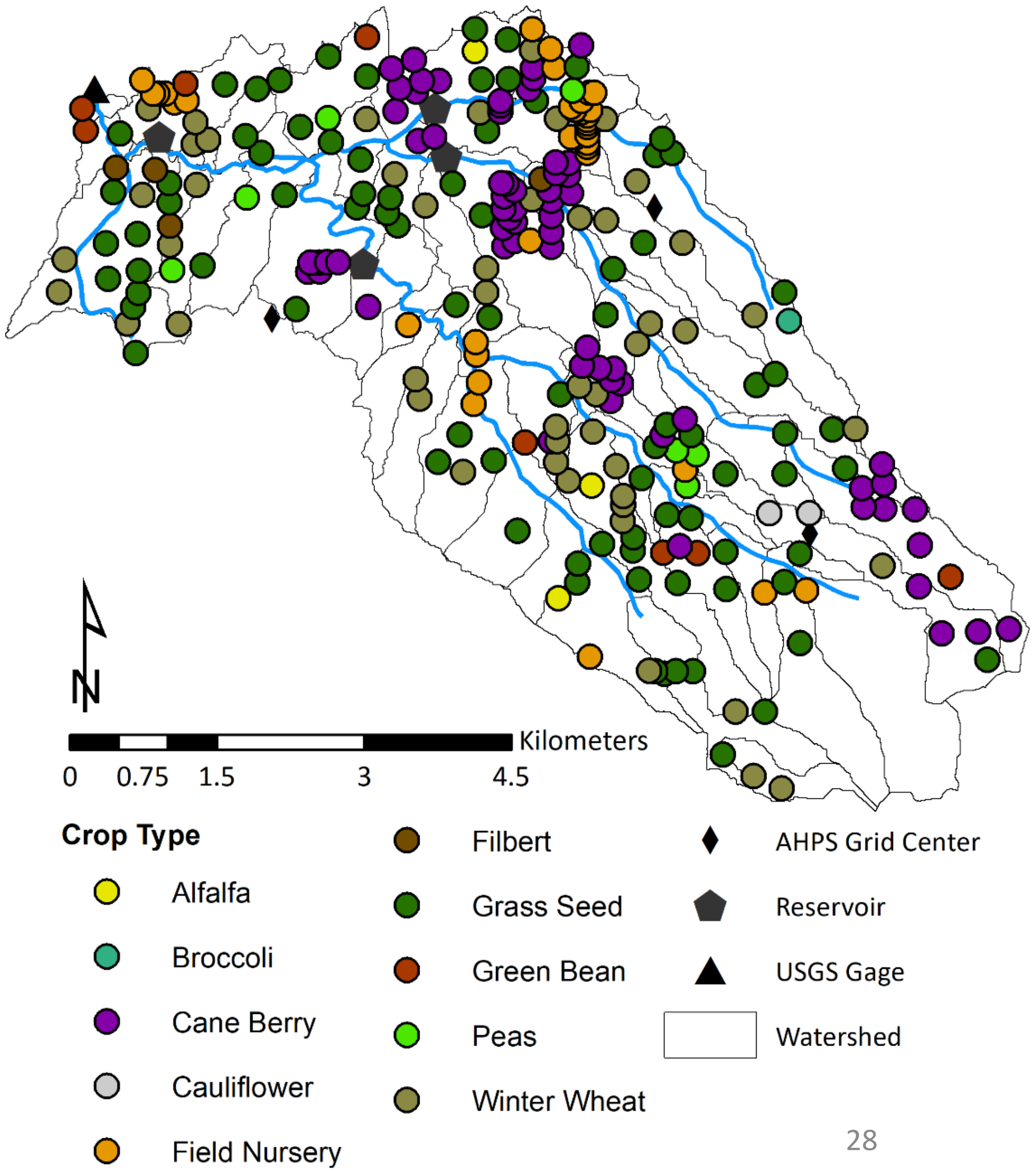


Trifluralin Authorized Use in the Zollner Creek Watershed



Trifluralin Use - PNW Herbicide Handbook

- Pre-plant soil incorporated:
  - Broccoli: May-July; 0.5-1 lb AI/A; 3-4” incorporation
  - Cauliflower: May-July; 0.5-1 lb AI/A; 3-4” incorporation
  - Green beans: May-July; 0.5-0.75 lb AI/A; 2-3” incorporation
  - Peas: May-July; 0.5-0.75 lb AI/A; 1-2” incorporation
- Spring pre-emergent:
  - Caneberries (nonbearing): March-April; 2.5-5lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  - Field grown nursery: March-April; 2-5lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  - Filberts: March-April; 0.5-1lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
- Fall pre-emergent:
  - Alfalfa: September-October; 2lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  - Grass seed: September-October; 2lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate
  - Winter wheat: October-November; 0.5-1lb AI/A; activate with single rain event or 0.5” irrigation or mechanically incorporate



Probabilistic Assessment of Application Patterns

- Management operations randomized by field
  - Applications limited to workable days
  - Application rates were both probabilistic and deterministic
  - Pesticides Properties DataBase[1] representative values

- Monte Carlo methods utilized to create spatial and temporal distribution of application patterns
  - 500 SWAT scenarios generated and run

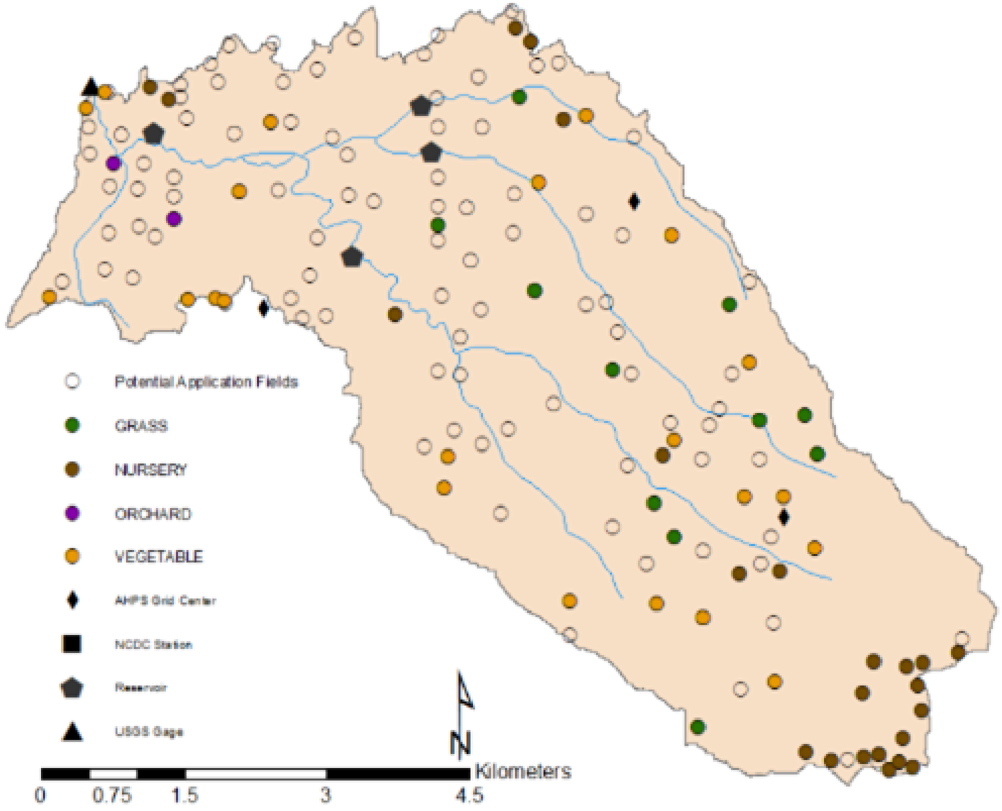
- Generate a distribution of spatial and temporal patterns of pesticide use practices
  - Estimate likely pesticide use patterns

[1] PPDB: Pesticide Properties DataBase, University of Hertfordshire.

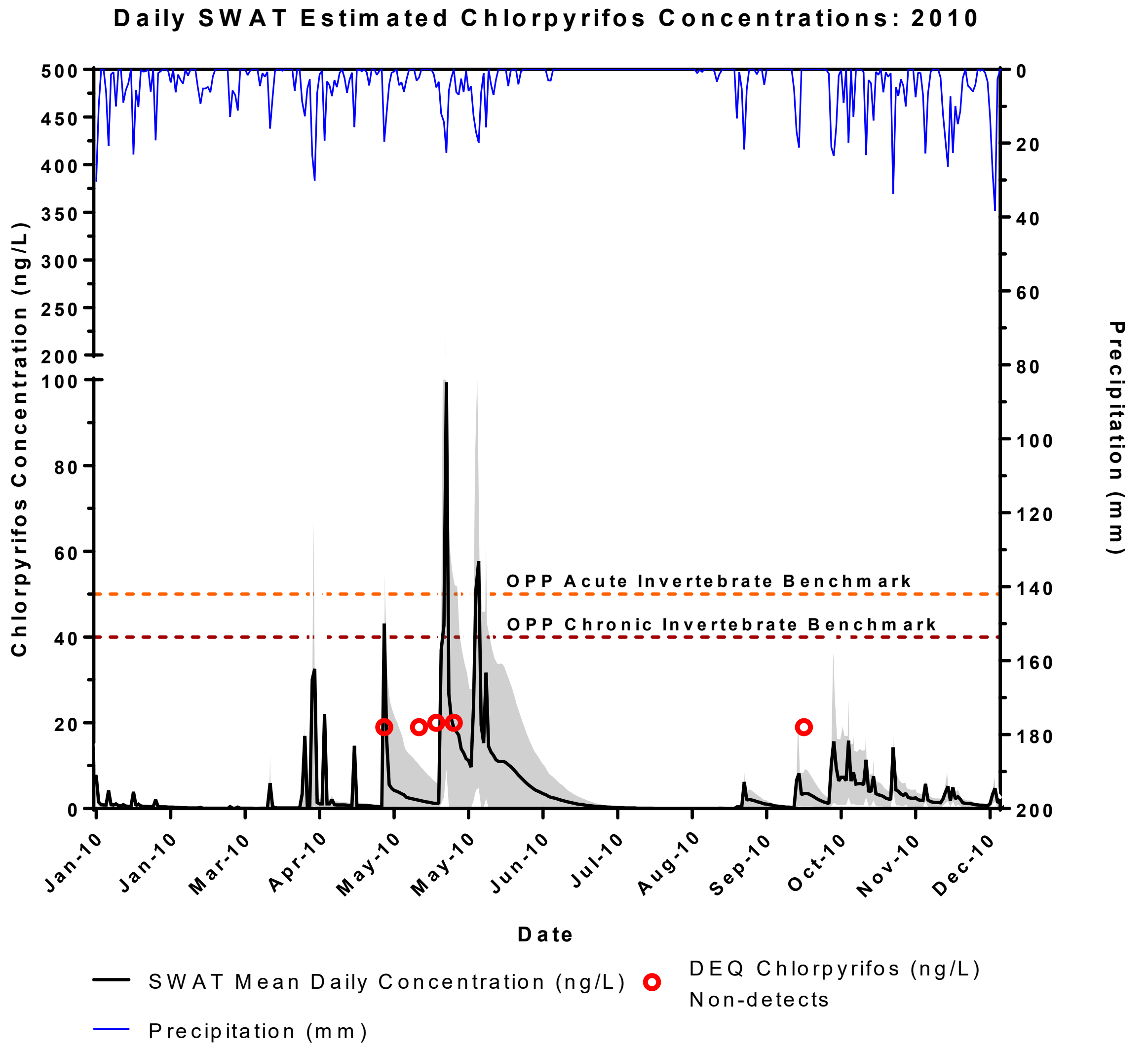
Generalized (not actual) Distribution of Chlorpyrifos Applications - 2011

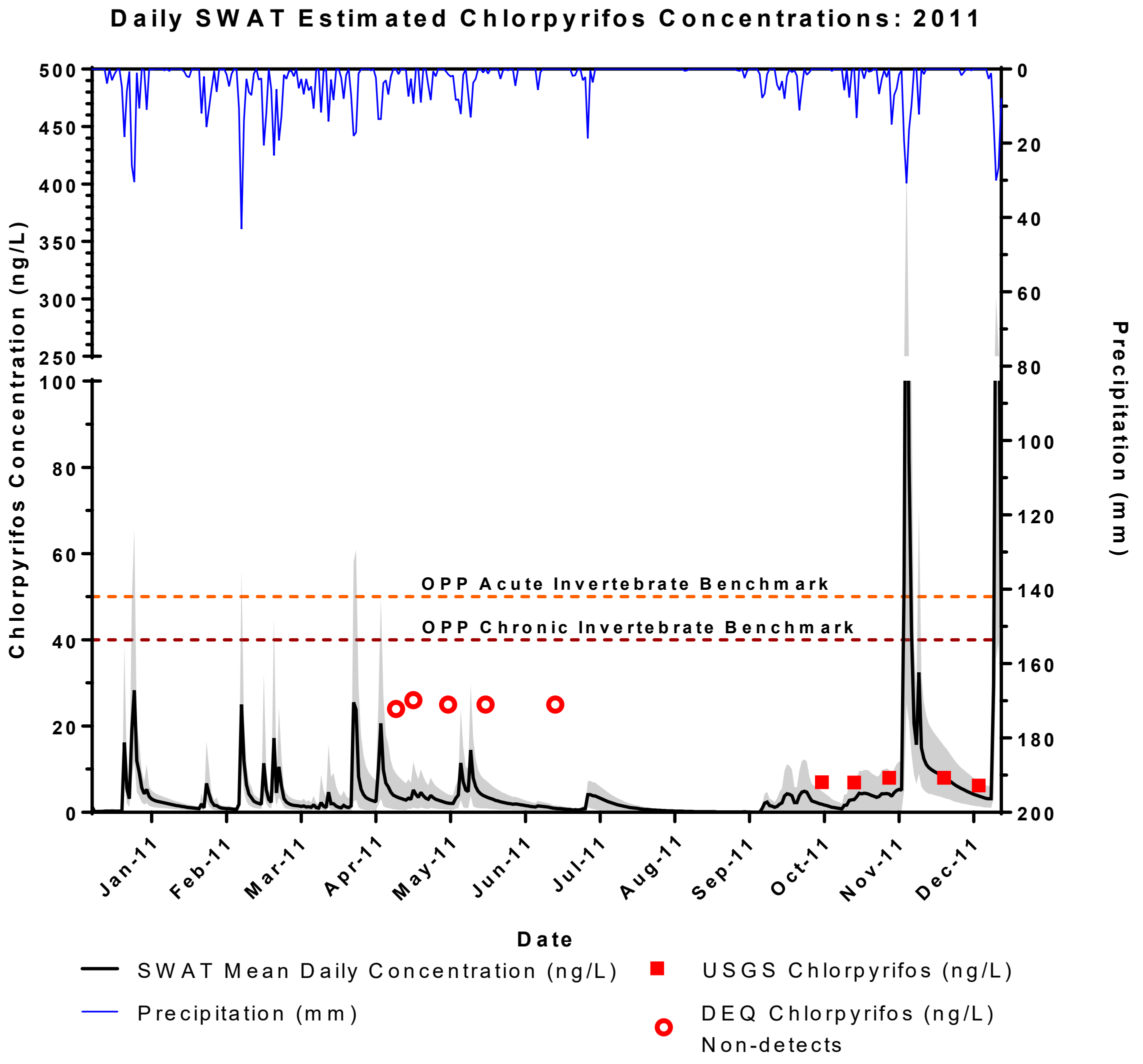
CROP TYPE	# POTENTIAL APPLICATION SITES	APPLICATION PERIOD	PROBABILITY OF APPLICATION	# WORKABLE DAYS
Seed/Sod Grass	82	Sept-Oct	0.1	15
Nursery	35	Apr-July	0.4	36
Orchard	3	Mar-Apr	0.75	12
	3	May-Aug	0.1	54
Vegetable	2	Apr-May	1	14
	10	Apr-June	1	16
	7	May-July	1	33
	1	June-July	1	23
	1	Aug-Sept	1	30

1 of 500 daily simulations

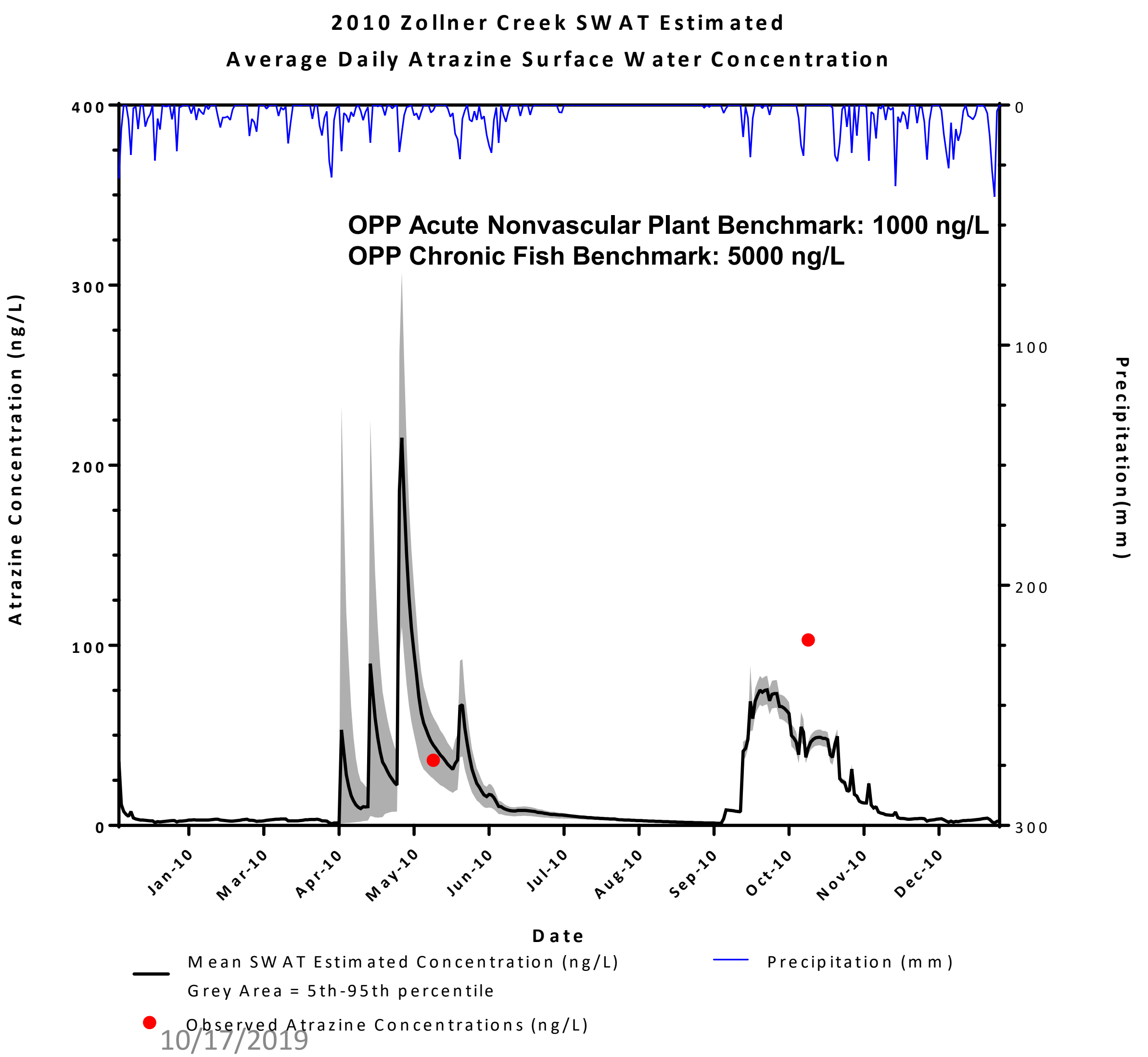


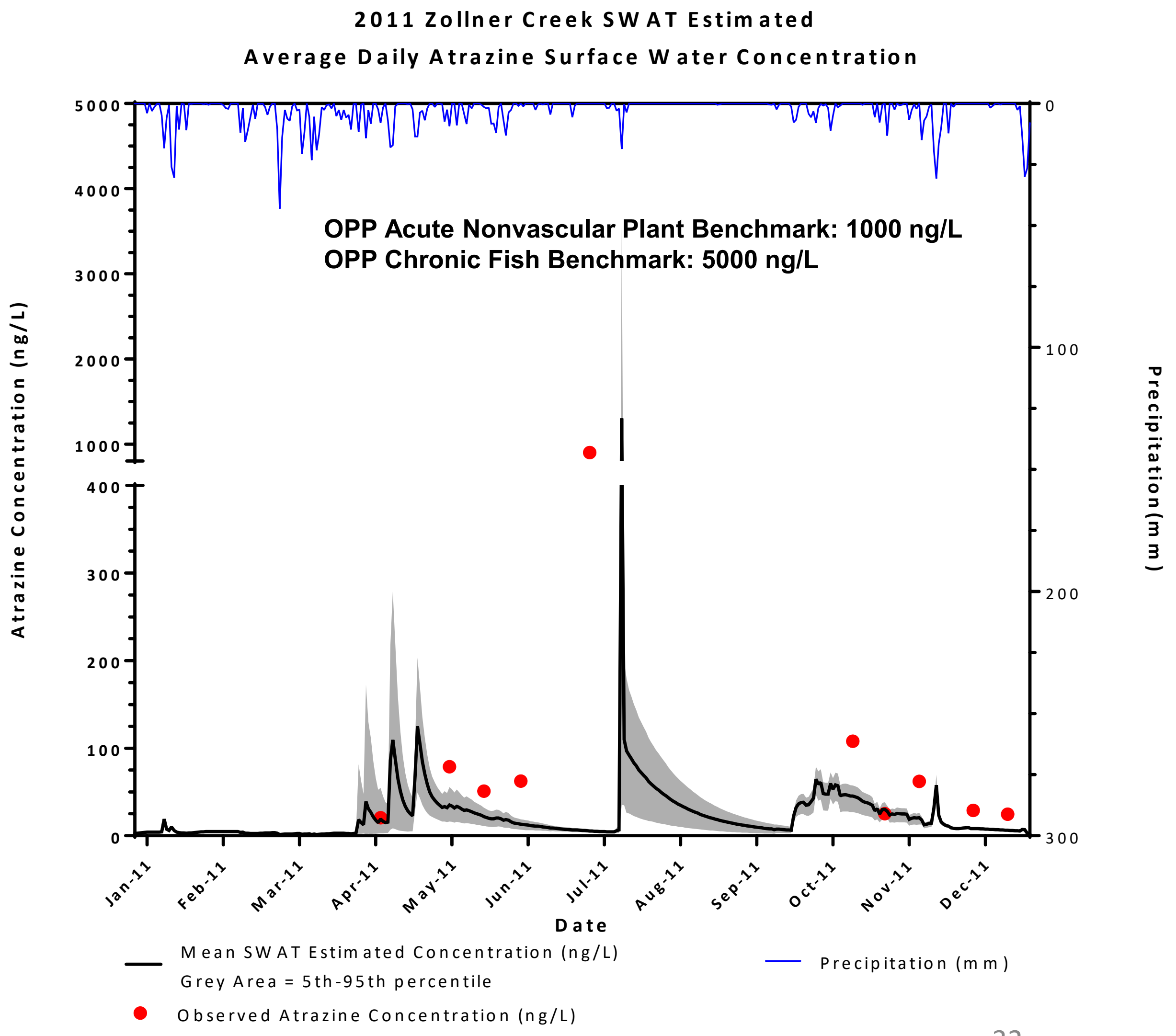
SWAT Estimates of Daily Chlorpyrifos Concentration



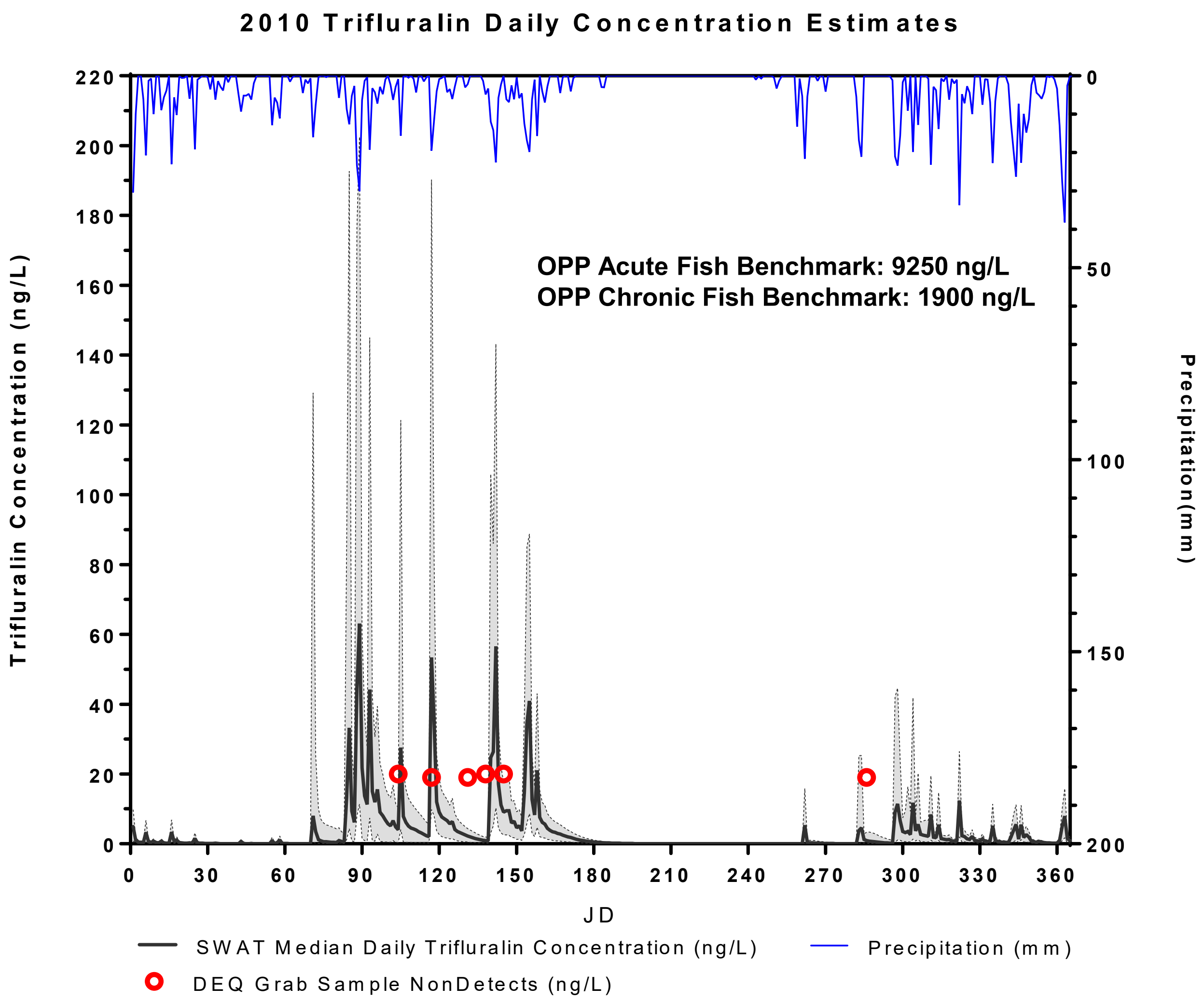


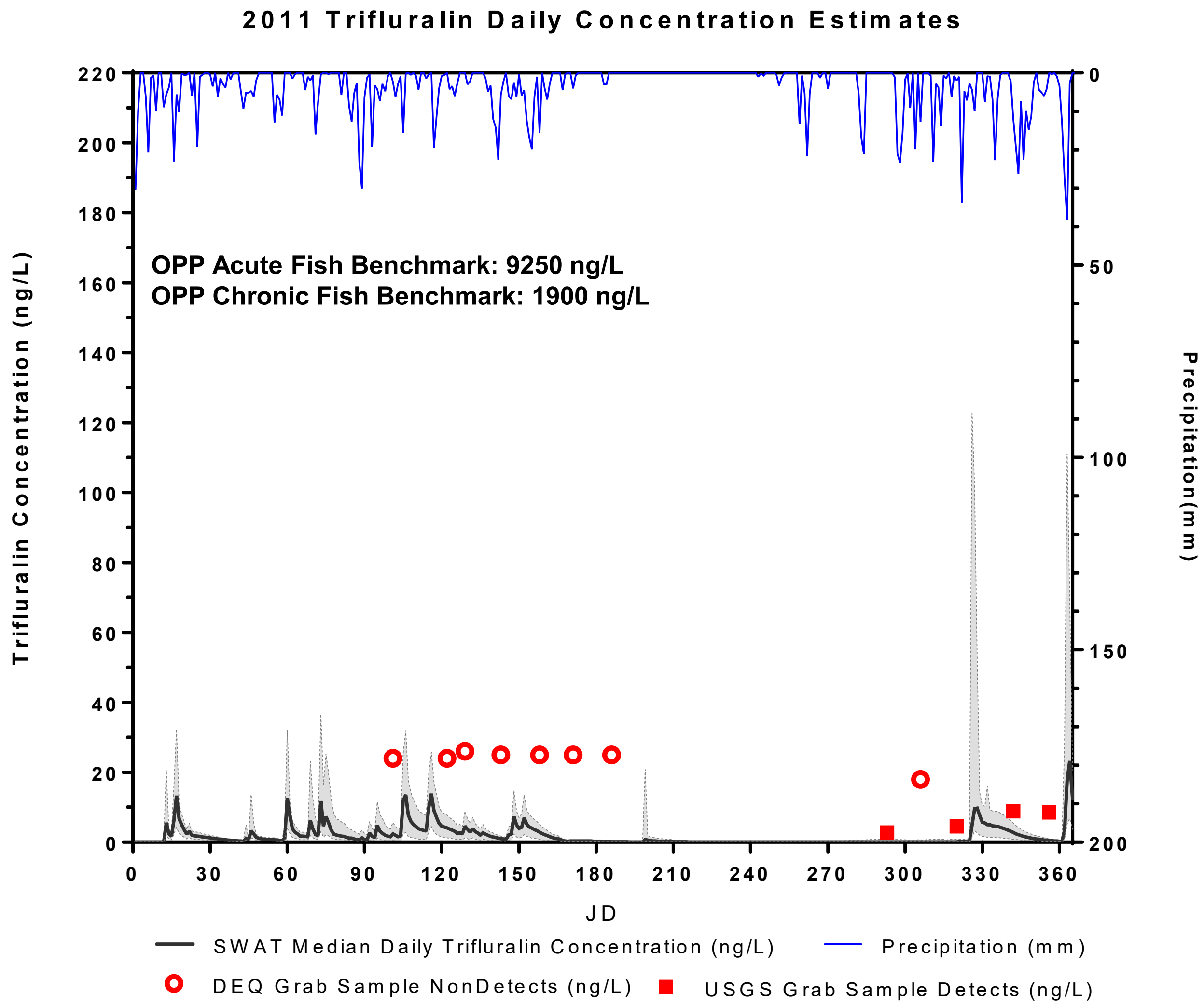
SWAT Estimates of Daily Atrazine Concentration



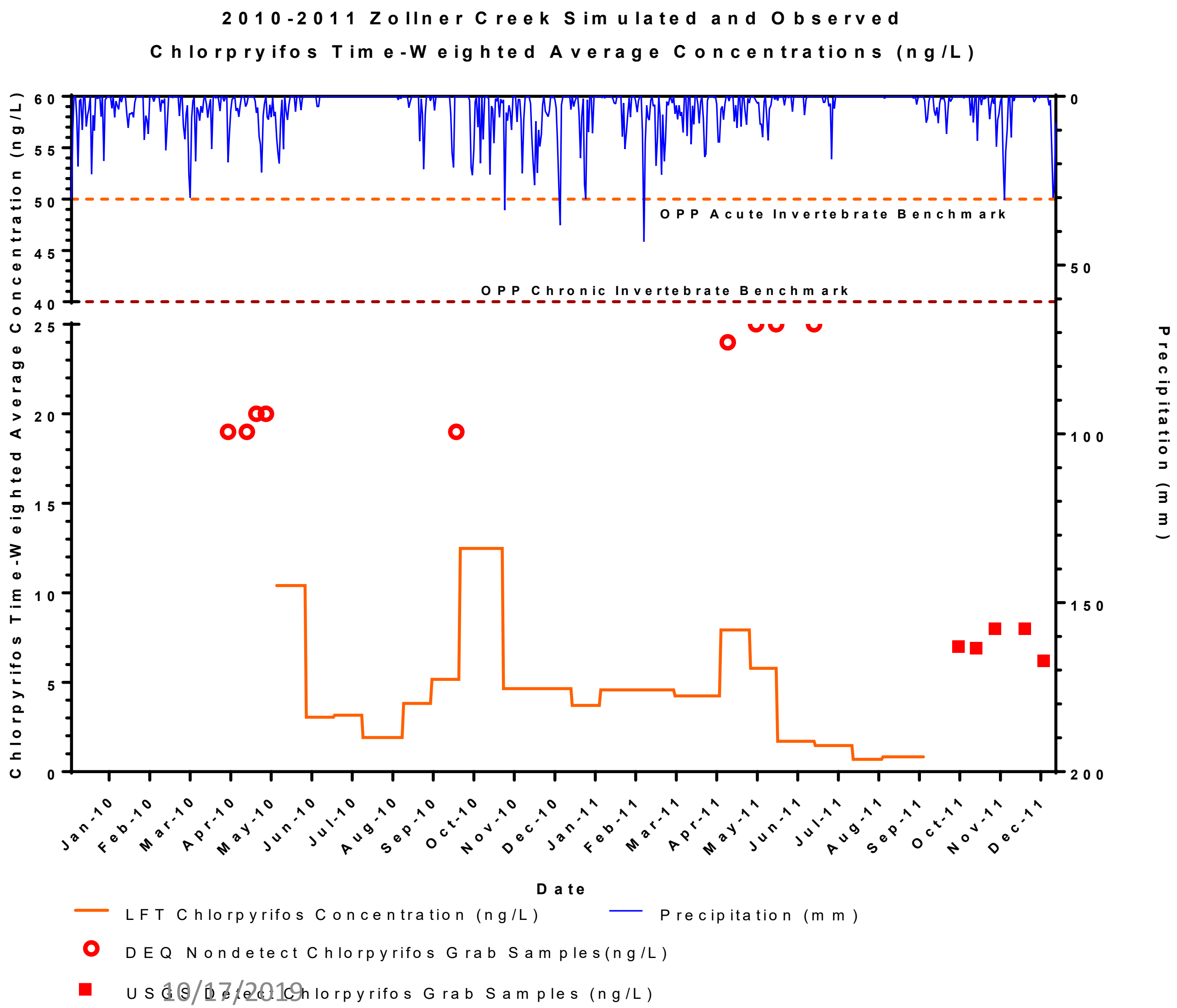


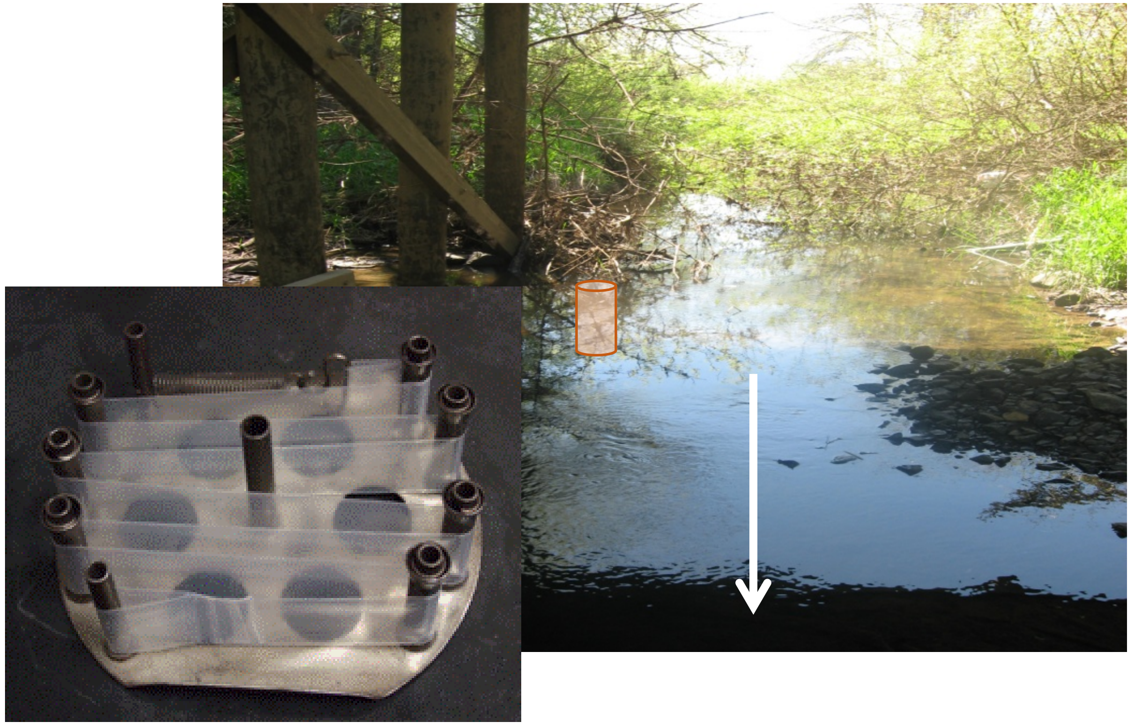
SWAT Estimates of Daily Trifluralin Concentration



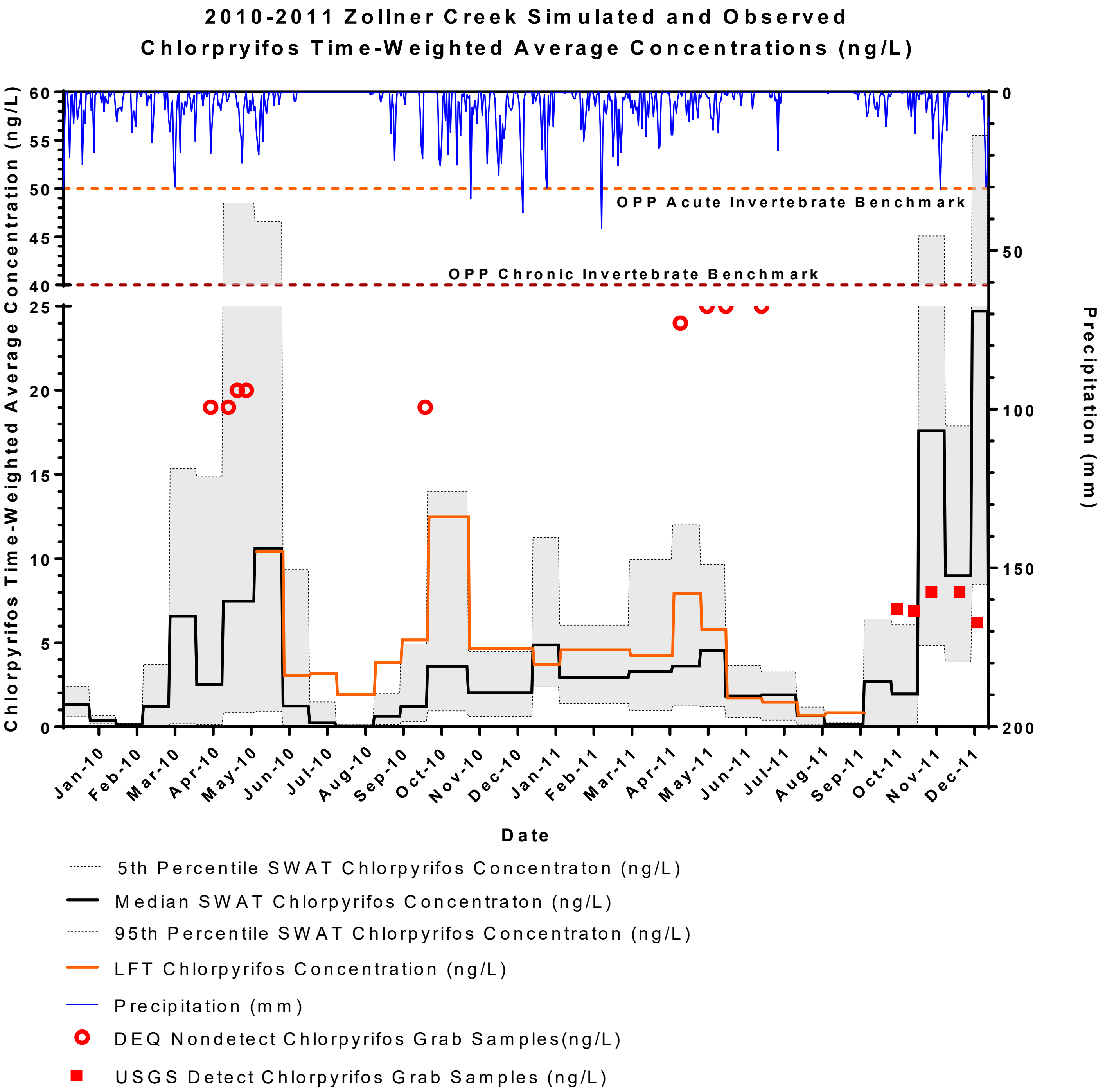


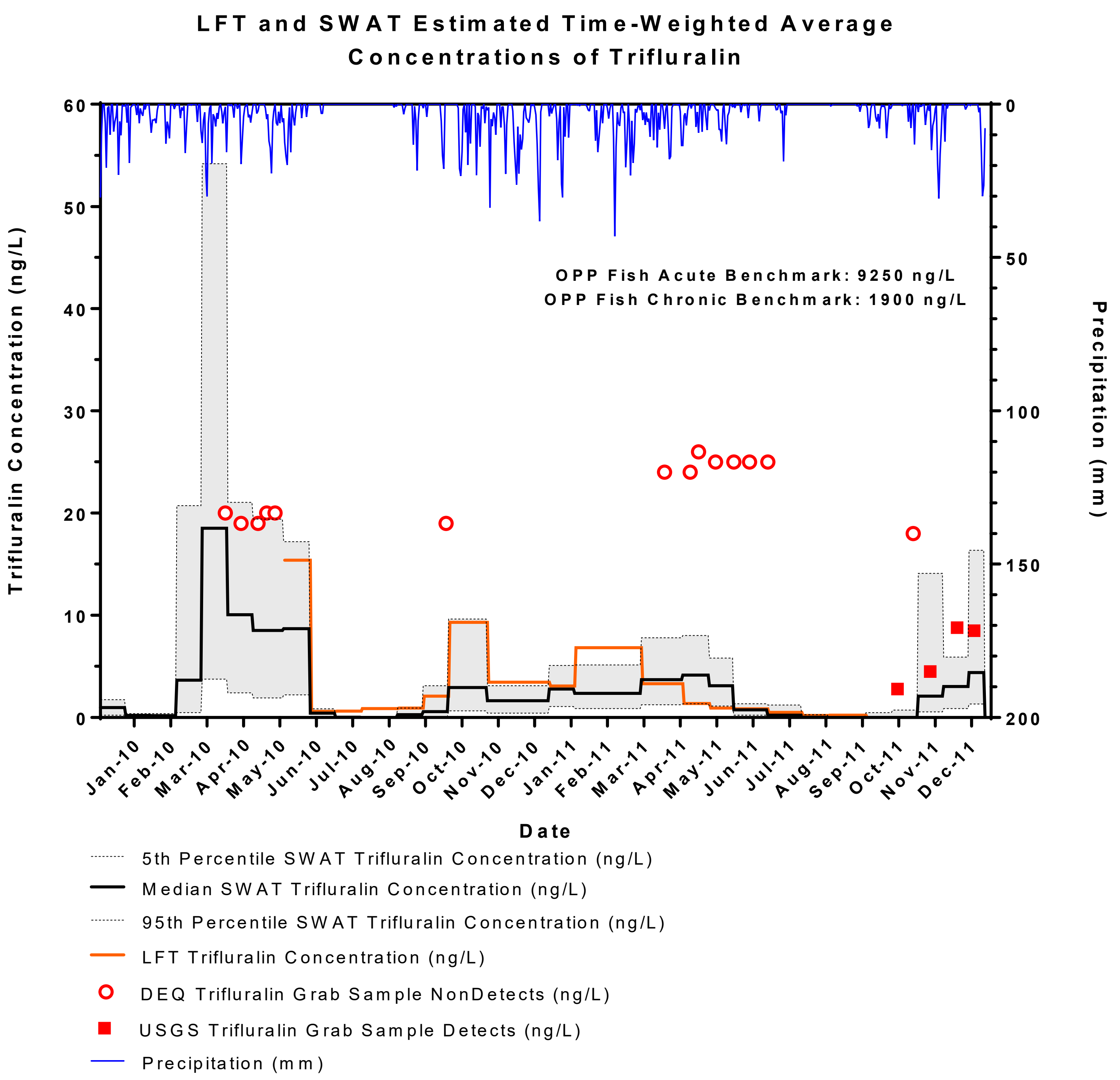
Passive Sampling Device 21 day Time Weighted Average Pesticide Concentrations in Surface Water





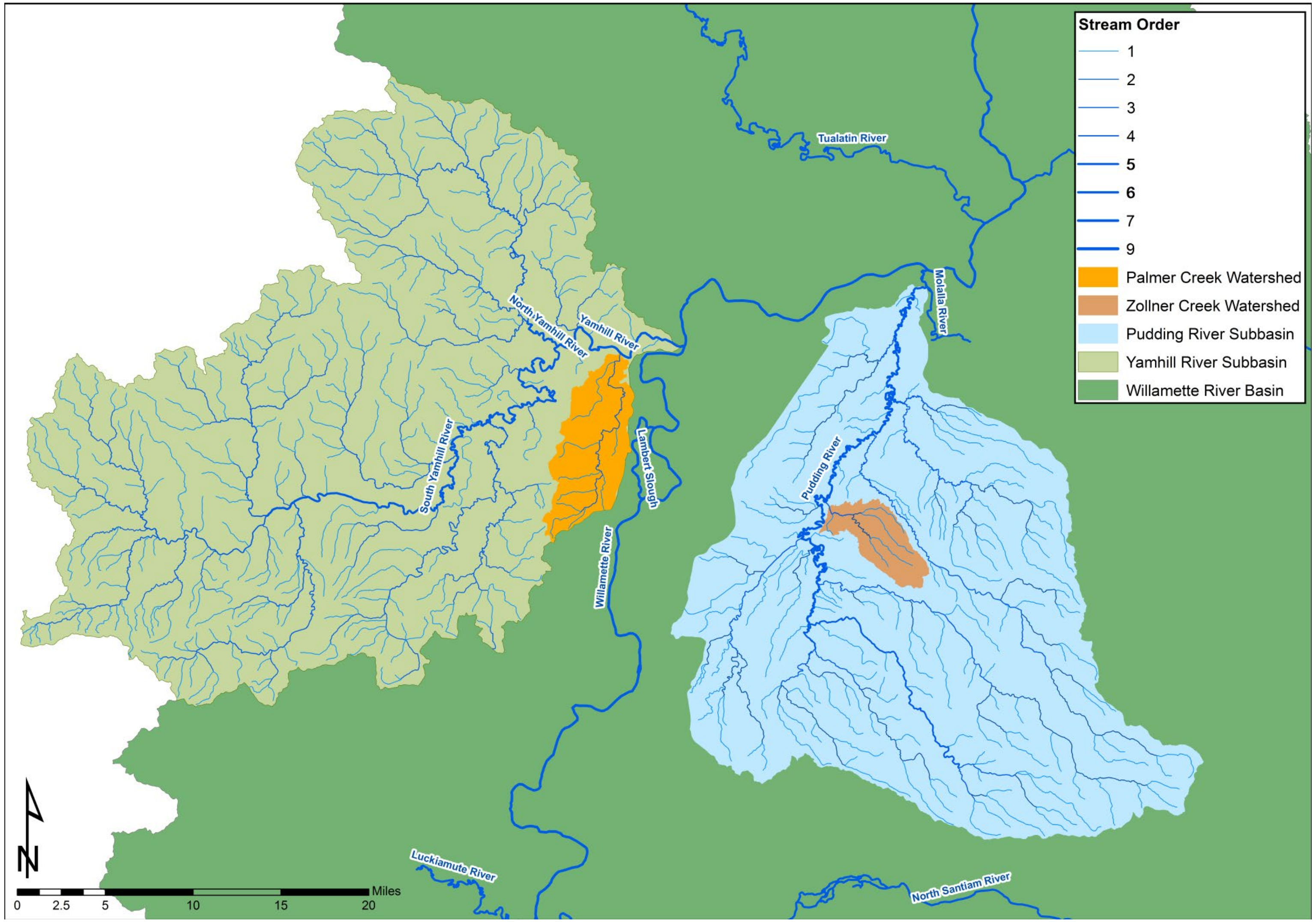
Lay Flat Tubing (LFT) passive samplers deployed continuously every ~21 days


2010-2011 Zollner Creek Simulated and Observed
Chlorpryifos Time-Weighted Average Concentrations (ng/L)
Chlorpyrifos Time-Weighted Average Concentration (ng/L)
Precipitation (mm)
OPP Acute Invertebrate Benchmark
OPP Chronic Invertebrate Benchmark
60
55
50
45
40
25
20
15
10
5
0
0
50
100
150
200
Jan-10
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Date
5th Percentile SWAT Chlorpyrifos Concentraton (ng/L)
Median SWAT Chlorpyrifos Concentraton (ng/L)
95th Percentile SWAT Chlorpyrifos Concentraton (ng/L)
LFT Chlorpyrifos Concentration (ng/L)
Precipitation (mm)
DEQ Nondetect Chlorpyrifos Grab Samples(ng/L)
USGS Detect Chlorpyrifos Grab Samples (ng/L)



LFT and SWAT Estimated Time-Weighted Average
Concentrations of Trifluralin
Trifluralin Concentration (ng/L)
Precipitation (mm)
60
50
40
30
20
10
0
0
50
100
150
200
OPP Fish Acute Benchmark: 9250 ng/L
OPP Fish Chronic Benchmark: 1900 ng/L
Jan-10
Feb-10
Mar-10
Apr-10
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10
Nov-10
Dec-10
Jan-11
Feb-11
Mar-11
Apr-11
May-11
Jun-11
Jul-11
Aug-11
Sep-11
Oct-11
Nov-11
Dec-11
Date
5th Percentile SWAT Trifluralin Concentration (ng/L)
Median SWAT Trifluralin Concentration (ng/L)
95th Percentile SWAT Trifluralin Concentration (ng/L)
LFT Trifluralin Concentration (ng/L)
DEQ Trifluralin Grab Sample NonDetects (ng/L)
USGS Trifluralin Grab Sample Detects (ng/L)
Precipitation (mm)

Transferability of Watershed Assessment Framework



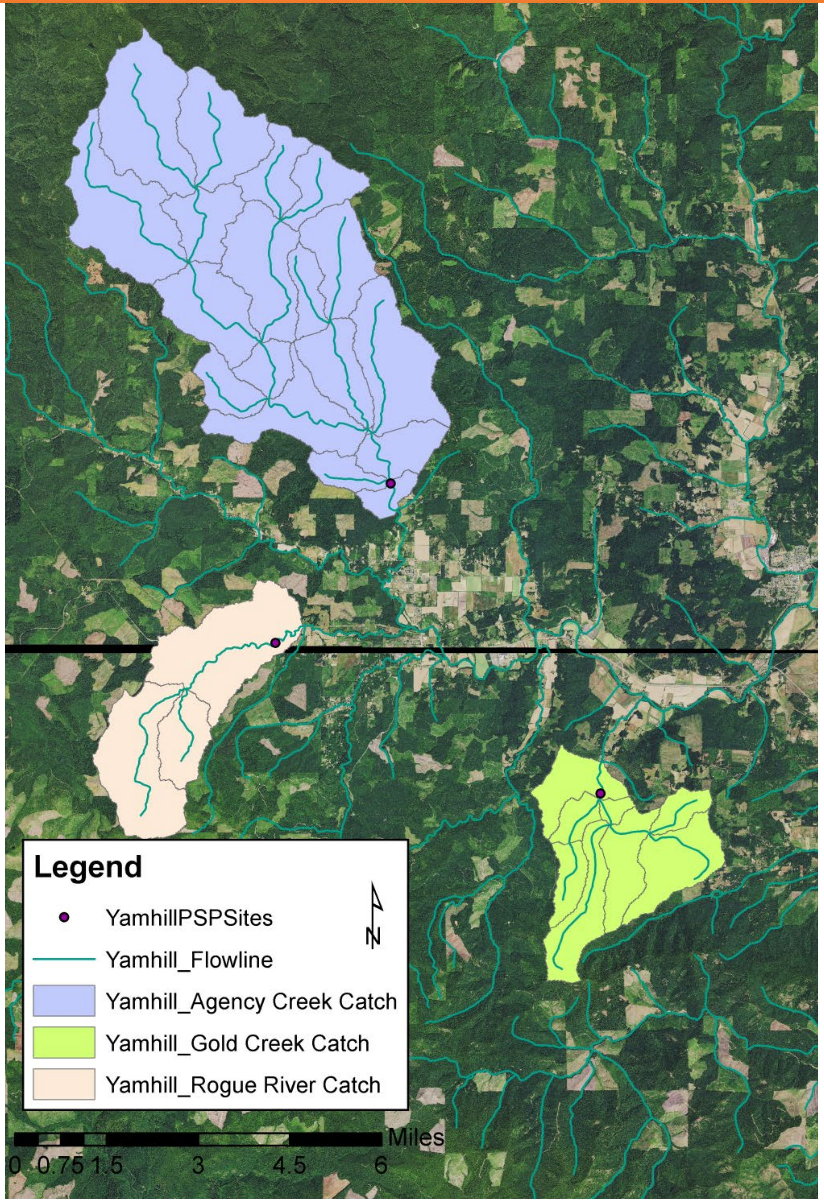
South Yamhill Forest Watersheds

Evaluation of **South Yamhill Pesticide Stewardship Partnership Area**

OSU application of SWAT:

Integrate Institutional knowledge/local expertise
Evaluate forestry IVM/herbicides in surface water
Estimate daily loading – benchmark exceedances
Inform best management practices/success stories

HERBICIDE	NUMBER OF SAMPLES	NUMBER OF DETECTIONS	DETECTION FREQUENCY %	AQUATIC LIFE BENCHMARK µg/L	NUMBER OF BENCHMARK EXCEEDENCES
atrazine	183	6	3.3	1	0
AMPA	63	1	1.6	249500	0
DEET	168	3	1.8	37500	0
desethylatrazine	153	8	5.2	N/A	N/A
fluridone	168	1	.6	480	0
hexazinone	168	3	1.8	7	0
imazapyr	157	1	.6	24	0
metsulfuron-methyl	57	2	3.5	.36	0
sulfometuron methyl	153	4	2.6	.45	0



Fostering sustainable practices through participative modeling