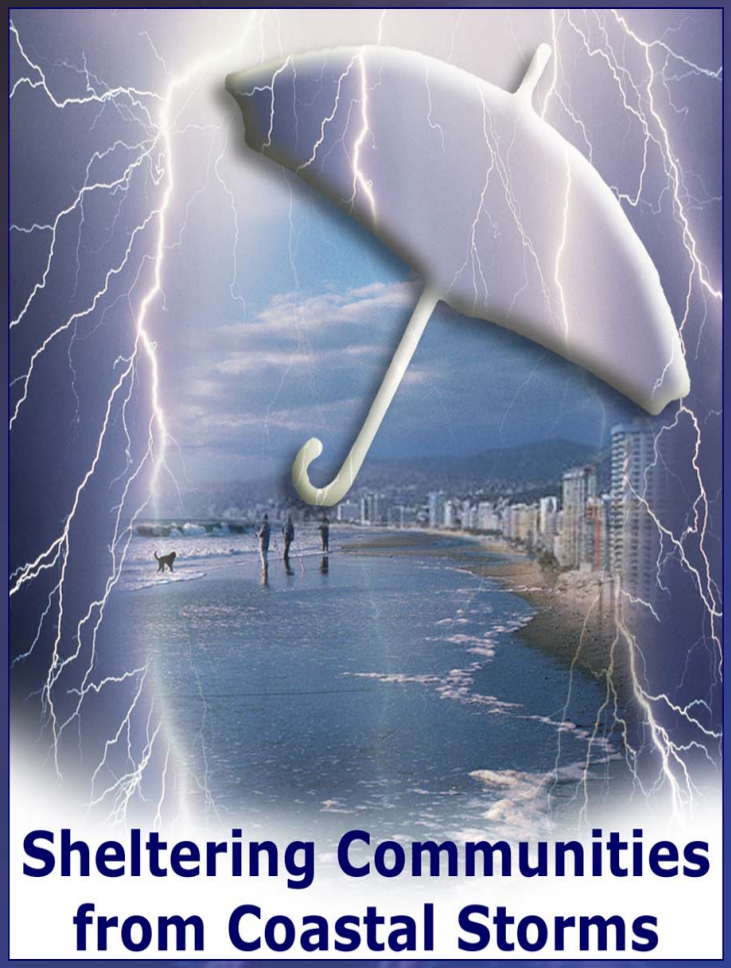
Comparison of Storm Intensity and Timing on Modeled Risks from Runoff Contaminants in Two U.S. Regions



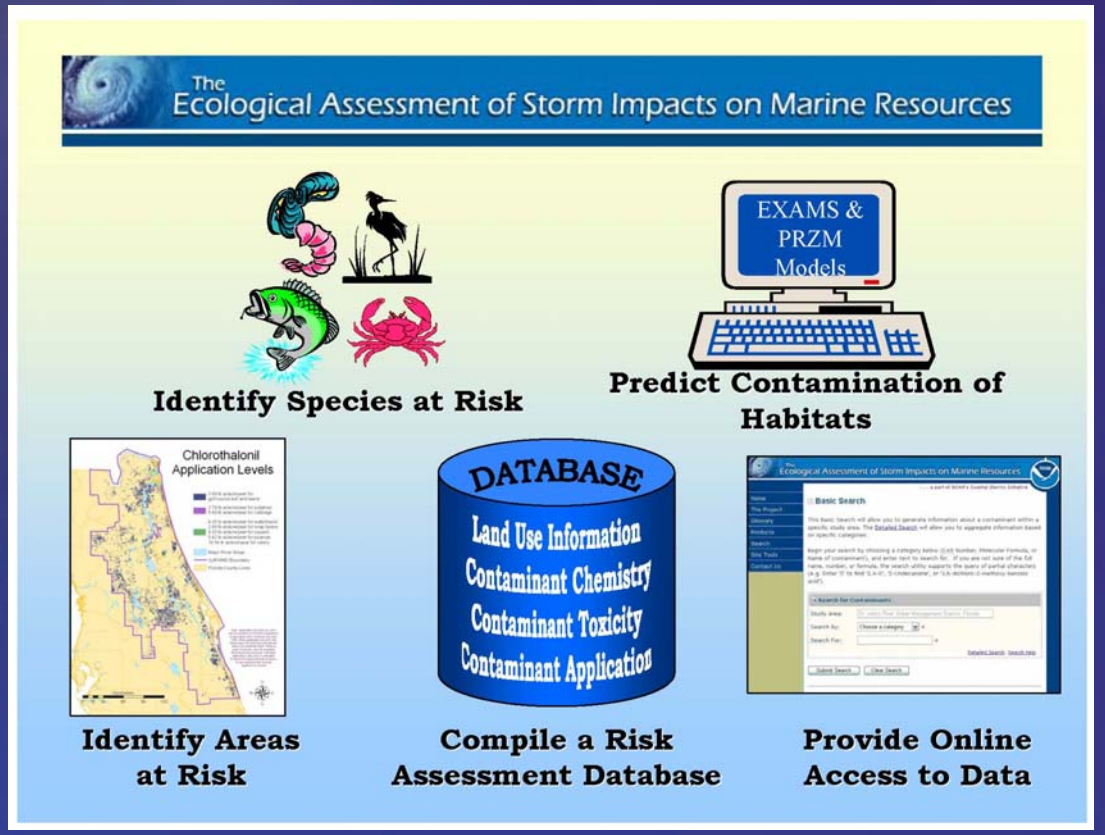
Erica Boyce

Thomas Siewicki

NOAA National Ocean Service
Center for Coastal
Environmental Health and
Biomolecular Research

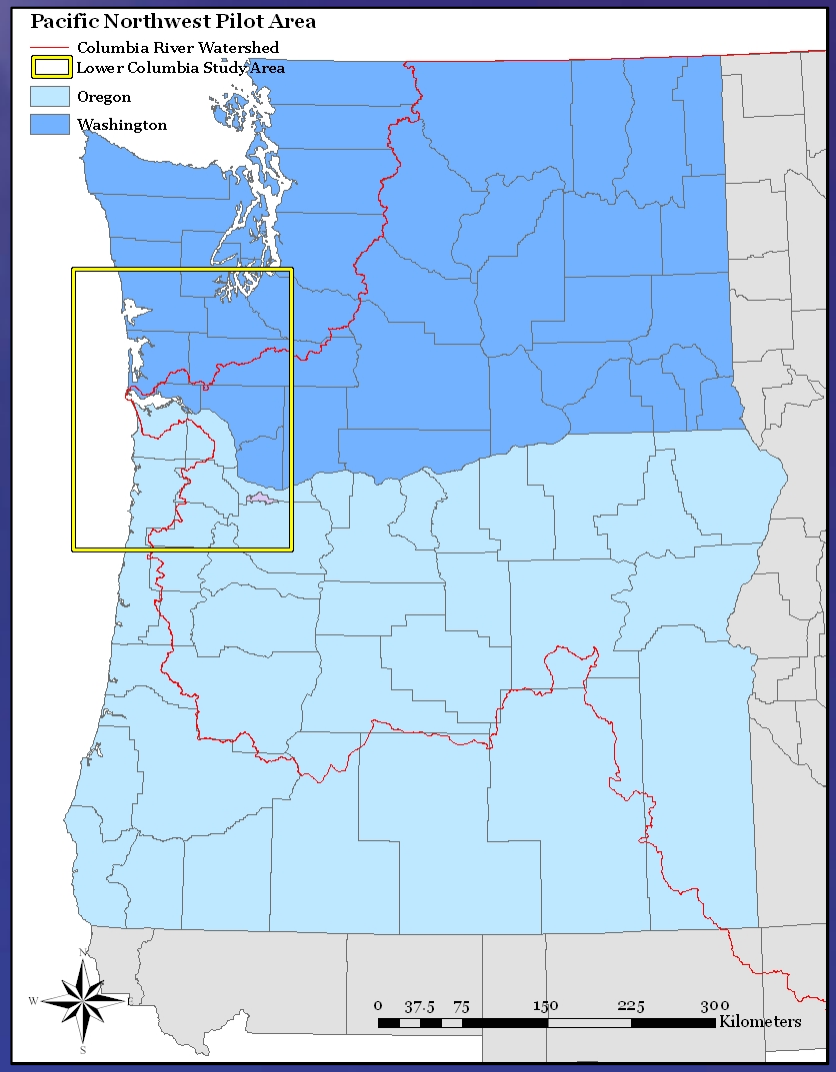
Coastal Storms Program – Ecological Assessment Components

- **Risk Assessment**
  - Land uses
  - Toxicology
  - Database
    http://www.chbr.noaa.gov/easi
- **Modeling**
  - Transport and fate
  - Representative watershed
- **Toxicology**
  - Indigenous species
  - To fill information voids



Pilot Areas

Source: www.sjrwmd.org



Transport and Fate Modeling

- **Three Contaminants chosen by a preliminary risk assessment**
  - Florida – Atrazine, Fipronil, and Imidacloprid
  - PNW – Carbaryl, Diquat Dibromide, Fluoranthene
- **PRZM-3 (Pesticide Root Zone Model)**
  - Groundwater Hydrology and Chemical Transport
  - Effects of Rain, Application, Transpiration, etc.
- **EXAMS-II (Exposure Analysis Modeling System)**
  - Surface Water Effects of Sorption, Biodegradation, Photolysis, etc.
  - Uses Output of PRZM
  - Predicted Concentrations Compared to Aquatic Animal and Human Health Levels of Concern.

PRZM Methods

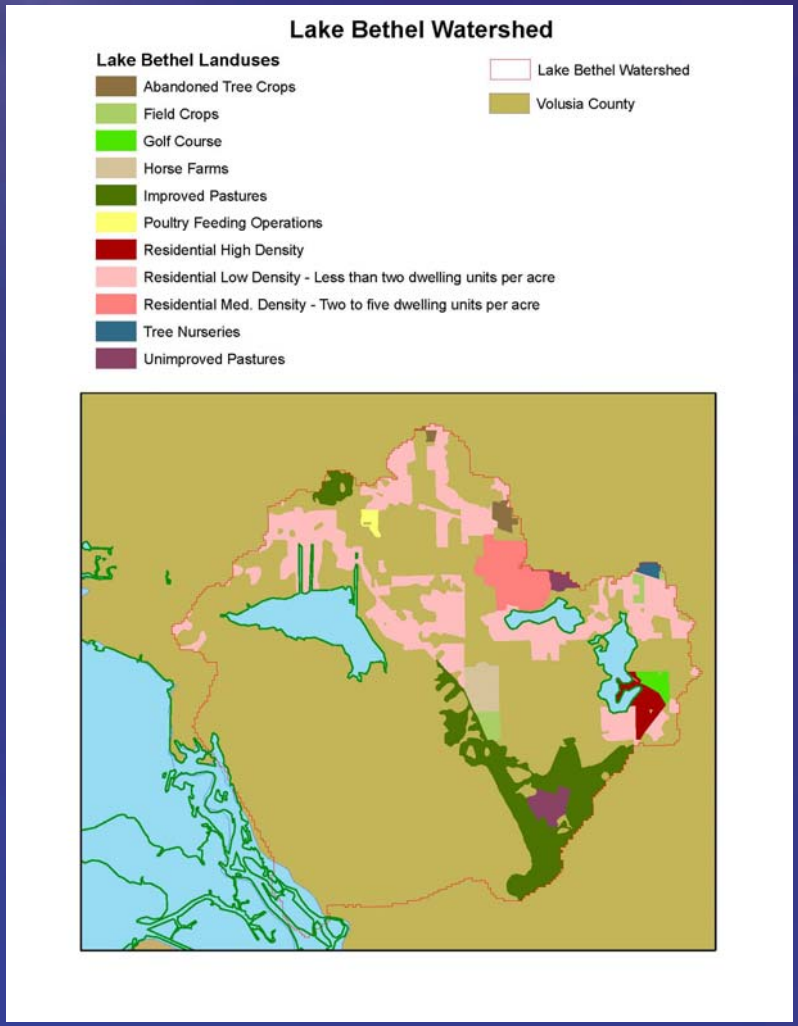
- Published chemical parameters
- Local meteorological data
  - 2-Yr, 25-Yr and 100-Yr storms
  - Rainfall on the 1st of the month

- Contaminants applied at maximum allowed rate
- Pesticides applied 1, 6 or 16 days before storms

EXAMS Methods

- Used PRZM loadings and other inputs
- Published chemical parameters
- Local meteorological data

Lake Bethel
Volusia County, Florida

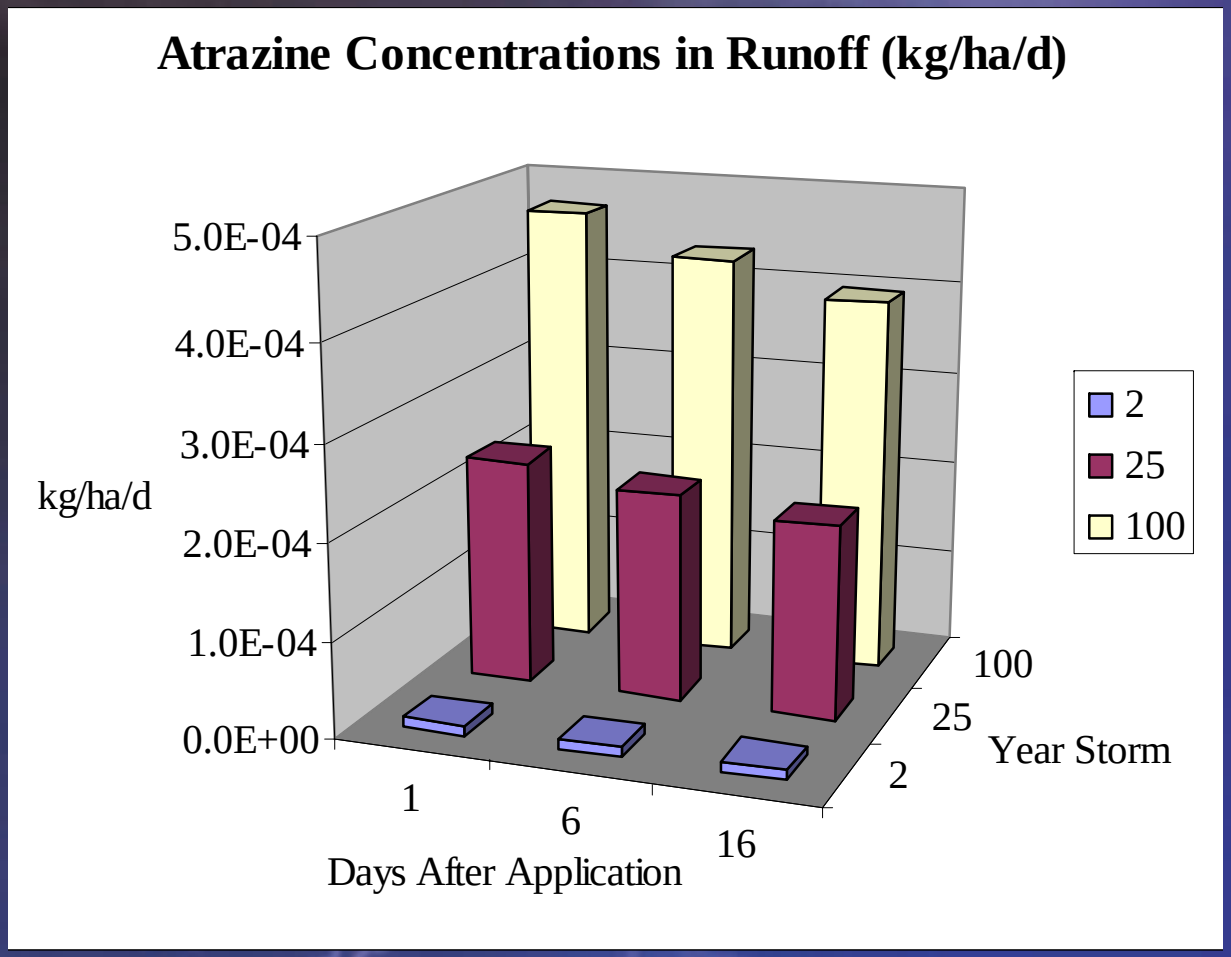


Source: www.sjrwmd.org

Florida PRZM Methods

- **Lake Bethel, Florida environment**
  - Estuarine headwaters are most susceptible
  - Typical of Southeastern US changing adjacent land uses
- **Pesticides applied at maximum allowed rate**
  - Atrazine 142 times Fipronil
  - Atrazine 4 times Imidacloprid
  - Imidacloprid 32 times Fipronil

Runoff of Atrazine

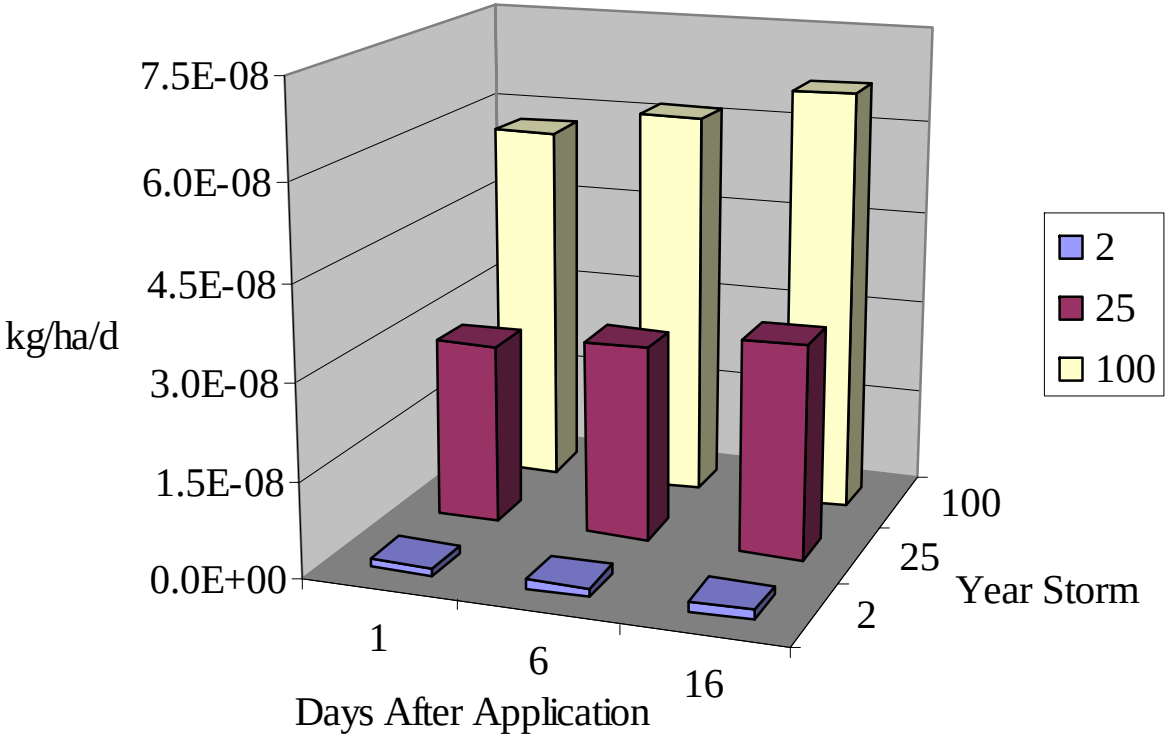


- **Highest concentration of the 3 pesticides**
- **Storms:**

  100-Yr > 25-Yr > 2-Yr
- **Application:**

  1-D > 6-D > 16-D

Runoff of Fipronil

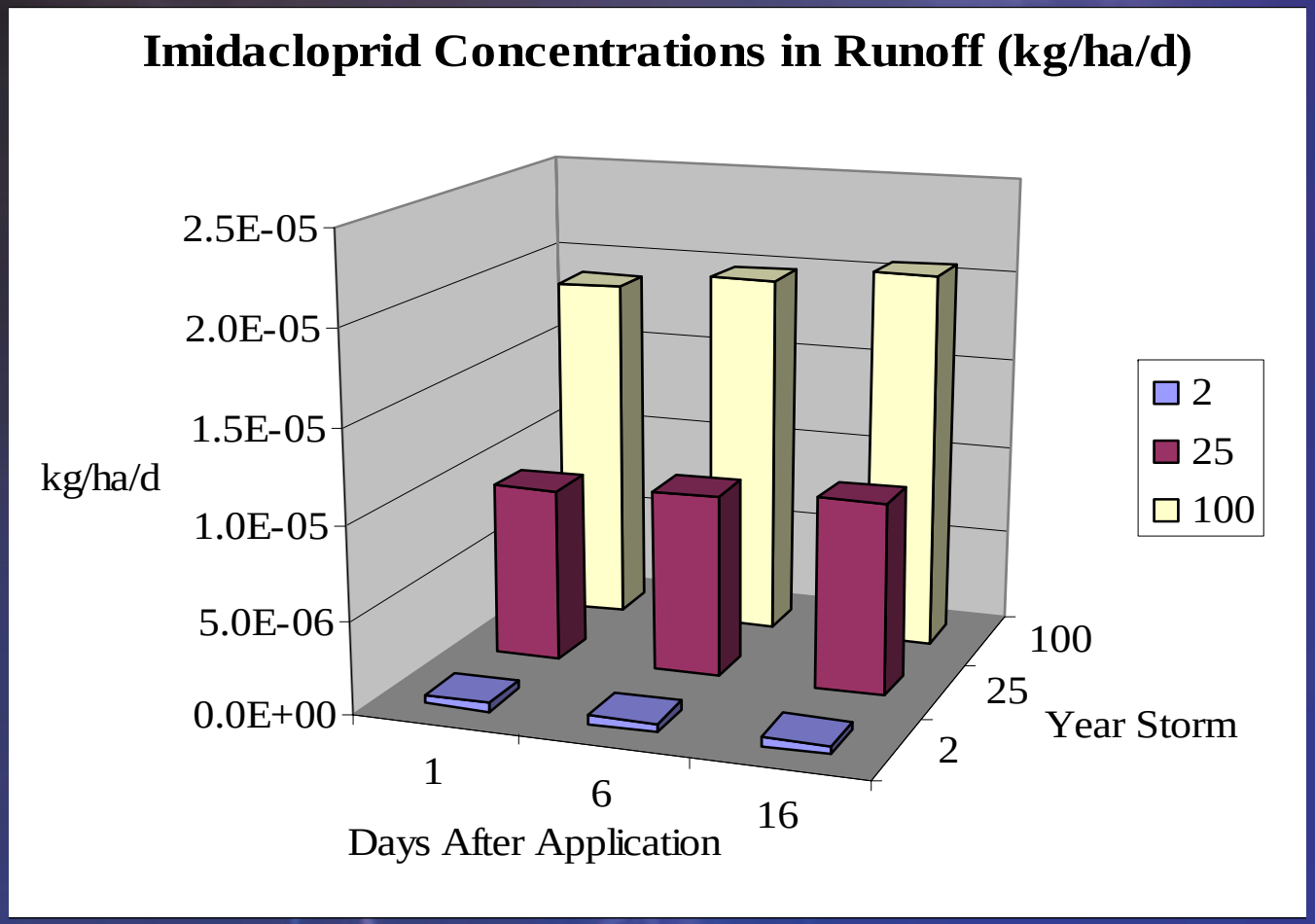


- **Lowest concentration of the 3 pesticides**
- **Storms:**

  100-Yr > 25-Yr > 2-Yr
- **Application:**

  16-D > 6-D > 1-D

Runoff of Imidacloprid



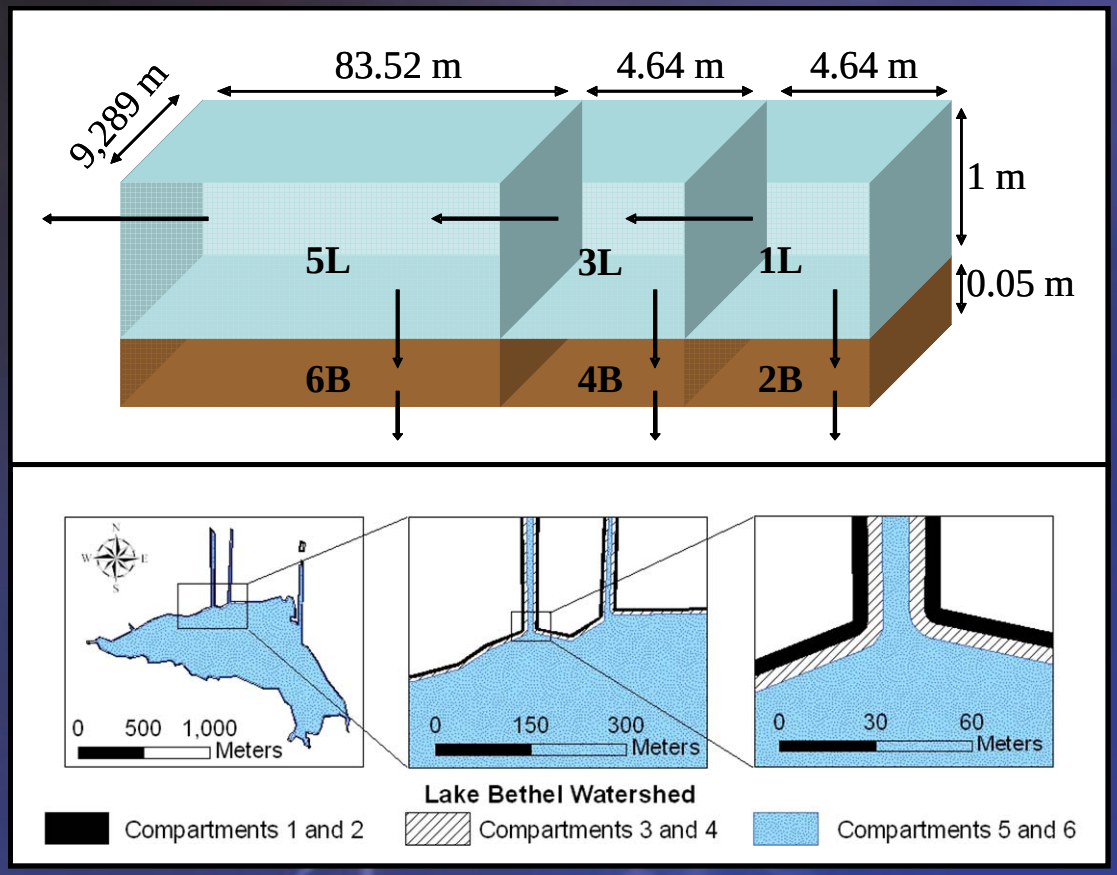
- **Storms:**

  100-Yr > 25-Yr > 2-Yr

- **Application:**

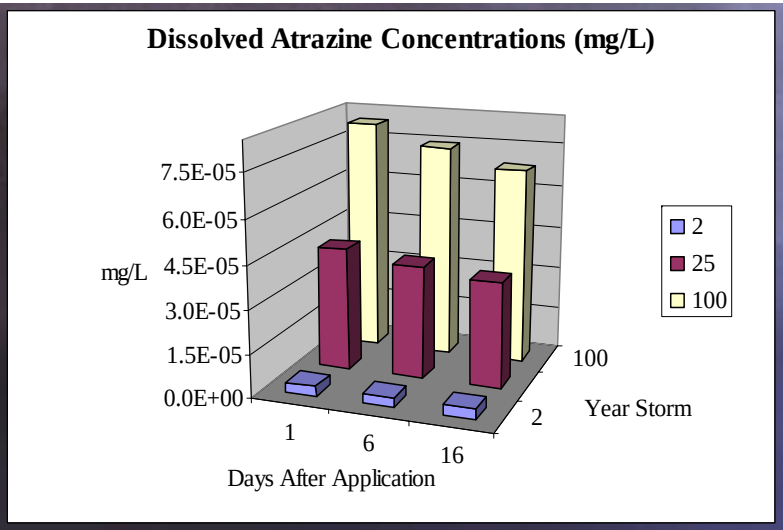
  16-D > 6-D > 1-D

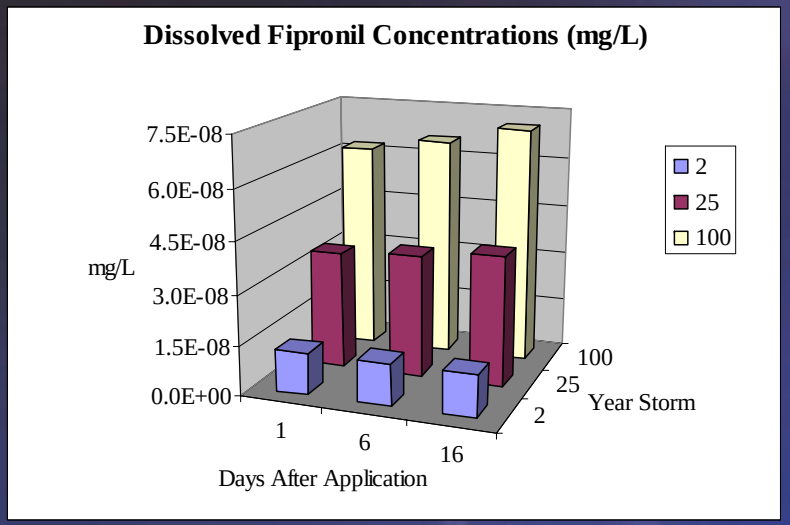
Lake Bethel EXAMS Compartments *(Conceptual)*

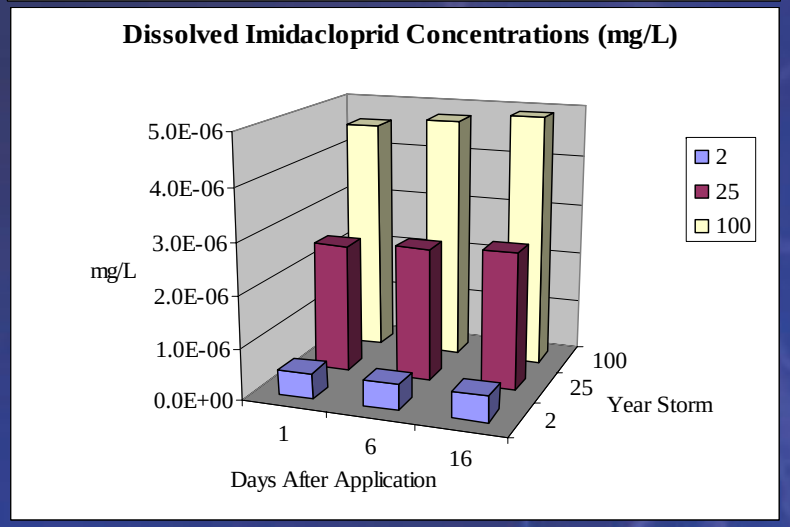


- Odd numbers are littoral
- Even numbers are benthic
- 1 and 2 are closest to shoreline
- 3 and 4 are next
- 5 and 6 are main lake body

Dissolved Chemical Concentrations in Littoral Compartment Nearest Shore







- **Storms:**

  100-Yr > 25-Yr > 2-Yr

- **Compartments:**

  1 >> 3 > 5

- **Pesticides (concentration not toxicity):**

  Atrazine > Imidacloprid > Fipronil

- **Application Date:**

  Atrazine: 1 > 6 > 16

  Fipronil and Imidacloprid: 16 > 6 > 1

- **Note different Scales**

Florida Modeling Results
Atrazine

http://instruct1.cit.cornell.edu

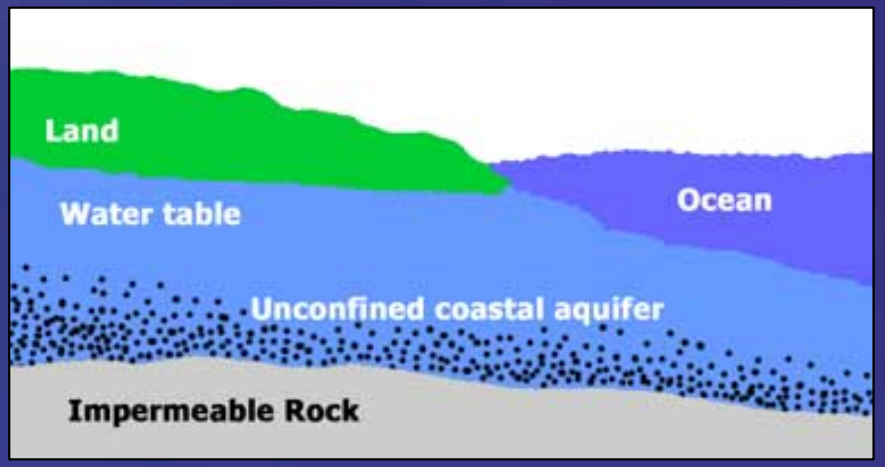
- **Max runoff and erosion**
  - application one day before the rain
- **Peak short term runoff**
  - 13 ug/l
  - approximate chromic toxicity threshold for a copepod
  - near acute toxicity threshold for algae
  - lower than acute toxicity levels for most crustaceans and finfish (Bejarno and Chandler, 2003; Bringman and Kehn, 1976)
- **Storage within core depth**
  - higher than fipronil and imidacloprid
- **Risk**
  - relatively short lived
  - poses lower risk if storms occur a few weeks after application

Florida Modeling Results
Fipronil

- **Maximum runoff and erosion**
  - application 16 days before rain
- **Peak short term runoff**
  - $5.7e^{-3}$ ug/l
  - 50 times lower than the acute toxicity threshold for grass shrimp (Key et al, 2003)
- **Risk**
  - highly toxic
  - little chance that levels toxic to important prey would be reached even after a heavy rainfall

Florida Modeling Results Imidacloprid

- **Maximum runoff and erosion**
  - application 16 days before the rain
- **Peak short term runoff**
  - 0.63 ug/l
- **Risk**
  - levels suggest little risk
  - has the highest leaching rate
  - the only one to leach below the core depth
  - potential threat to deeper aquifers transport through groundwater.



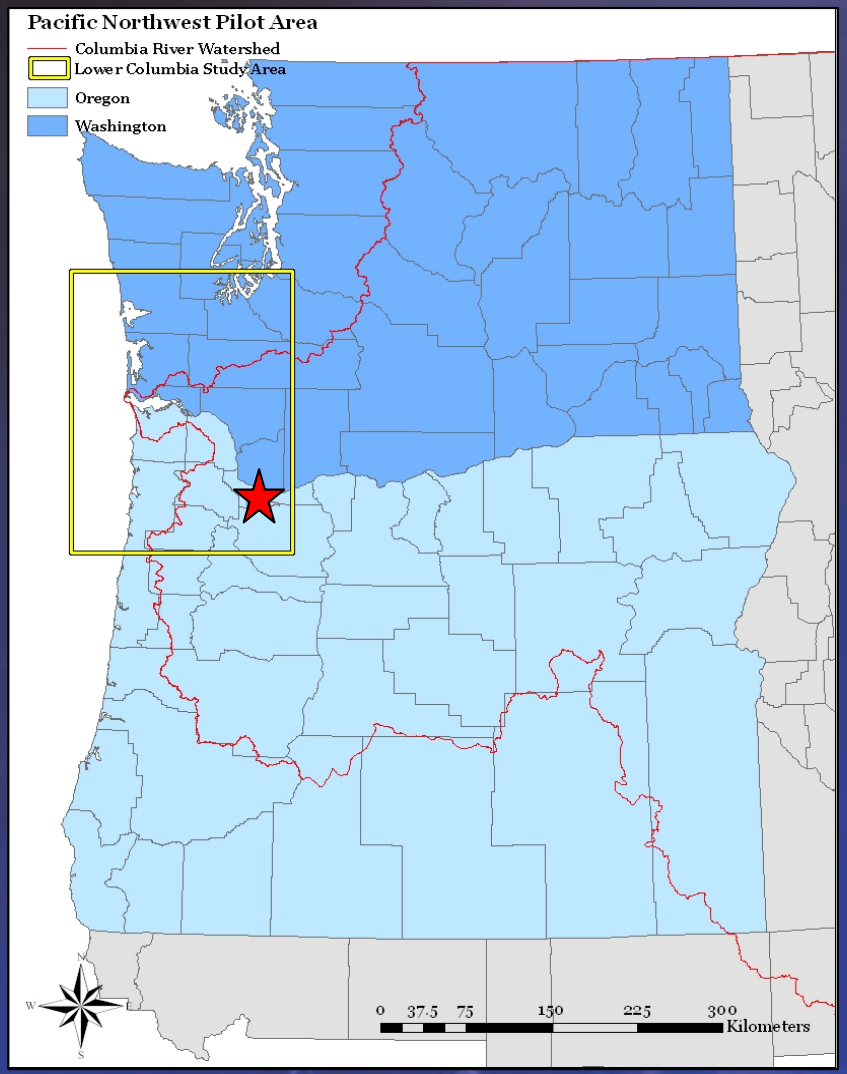
http://iml.jou.ufl.edu/projects/Spring04/Paquet/aquifer.html

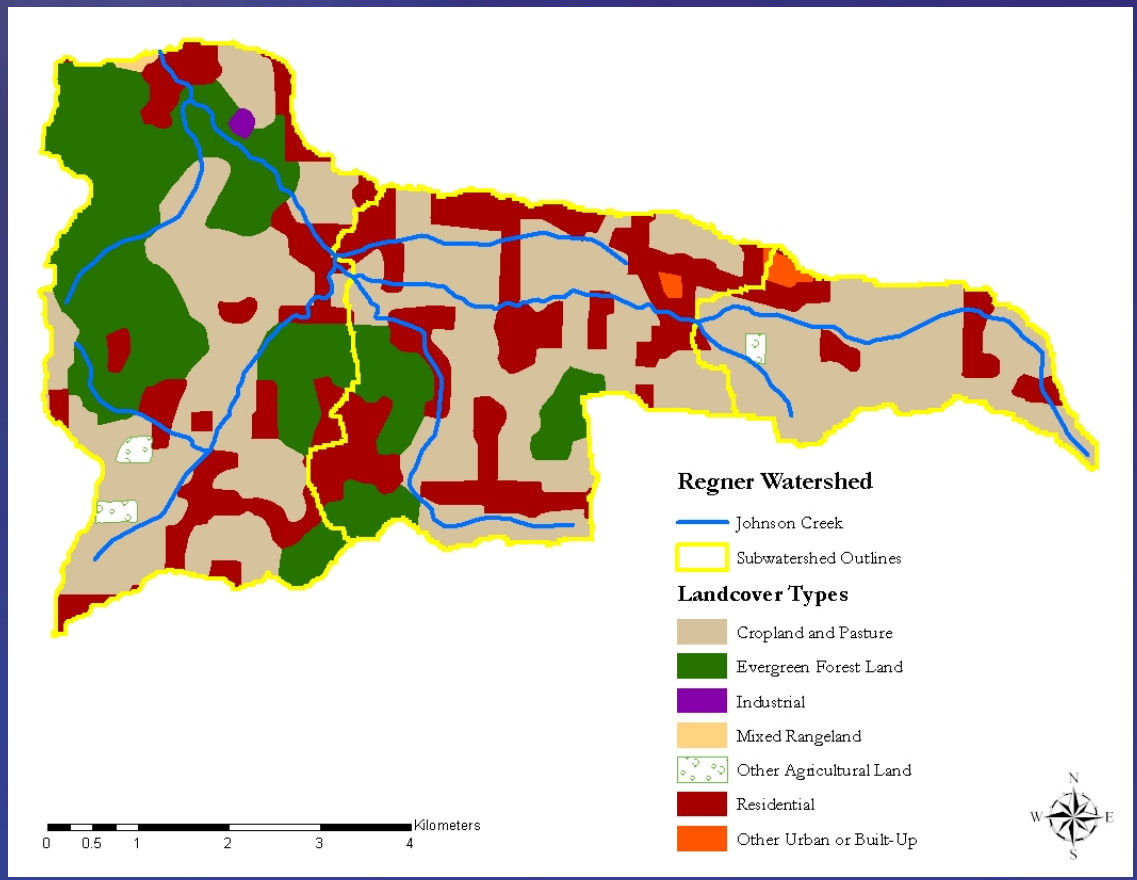
Florida Modeling Results Overall

- Each pesticide was storm and application date dependant
- Fipronil
  - Highest toxicty
  - Poses the least risk due to low transport over and through shallow soils
- Atrazine
  - Lowest toxicity
  - Highest threat due to high mobility and high application levels
- In combination
  - All three pesticides can occur in the modeled conditions
  - Key et al. (2006) identified the magnification coefficient of 1.21 to grass shrimp when atrazine, fipronil, and imidacloprid were present together

http://www.ipmworks.ca/background.html

Johnson Creek Headwaters – Multnomah and Clackamas Counties, Oregon

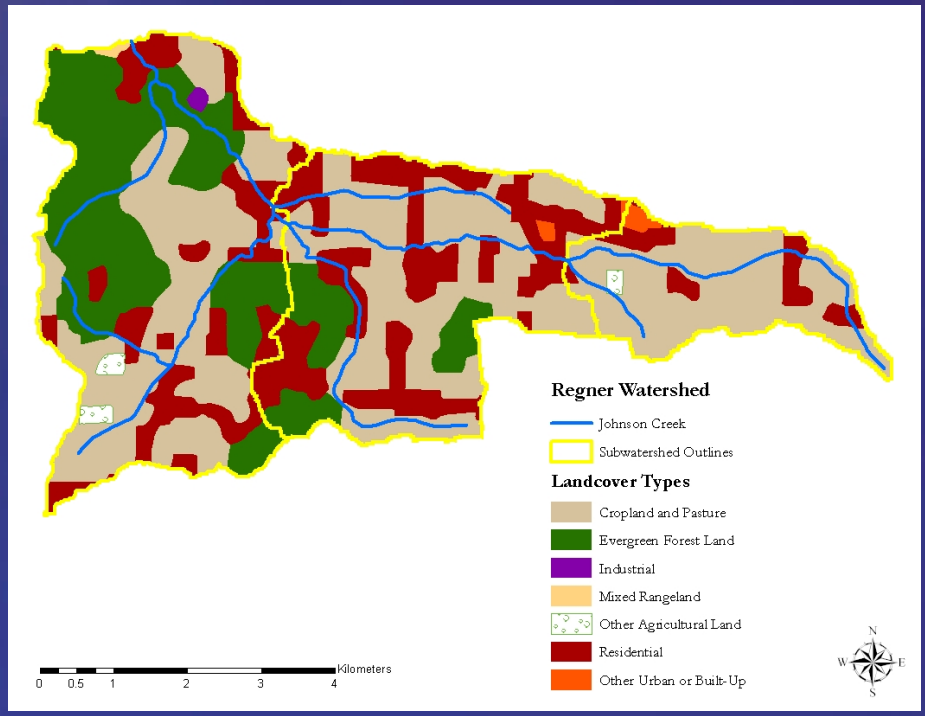




Coastal Storms Initiative

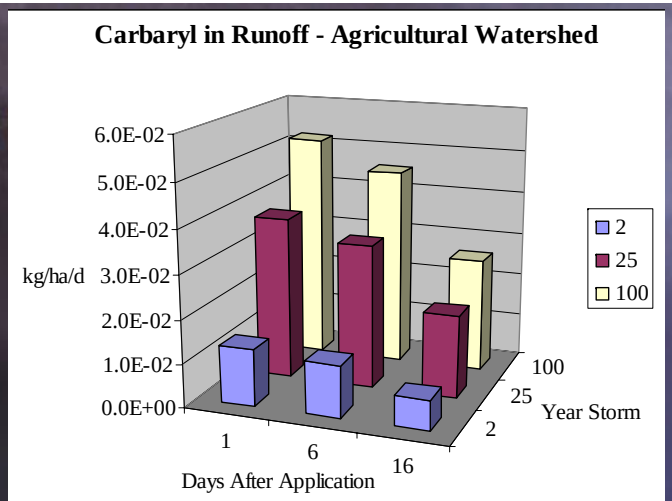
Johnson Creek PRZM Methods

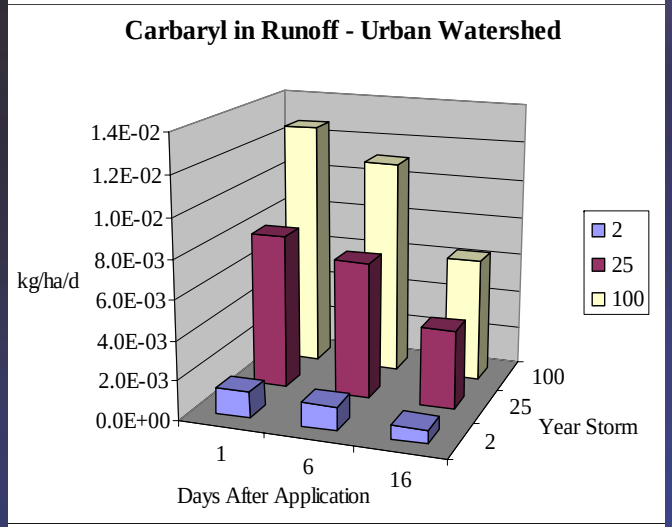
- Johnson Creek headwaters environment
  - Urbanized freshwater stream, spawning salmon habitat
  - Typical of Northwestern US adjacent land uses
- Segmented the watershed according to predominant land use
  - Agricultural
  - Urban
  - Forested

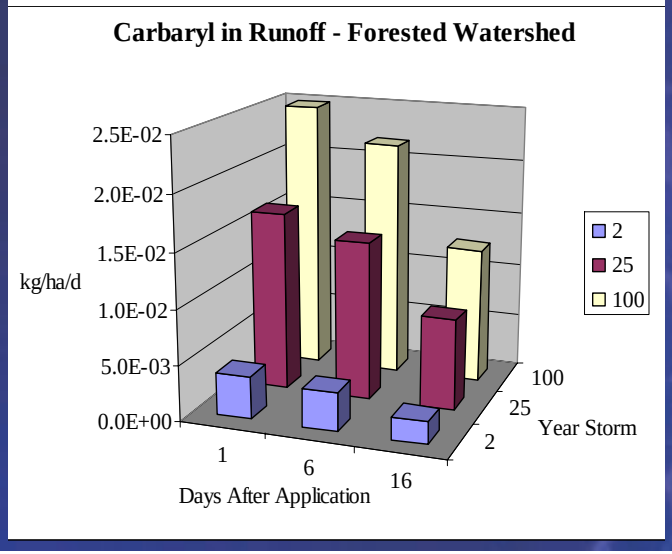


Johnson Creek PRZM Methods

- Carbaryl and Diquat Dibromide were applied at maximum allowed rate
- Pesticides applied 1, 6 or 16 days before storms
- Fluoranthene not included in PRZM model runs







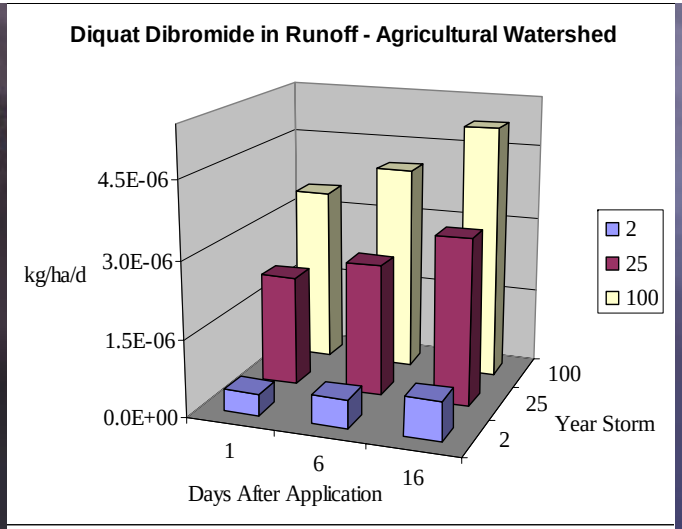
Runoff of Carbaryl

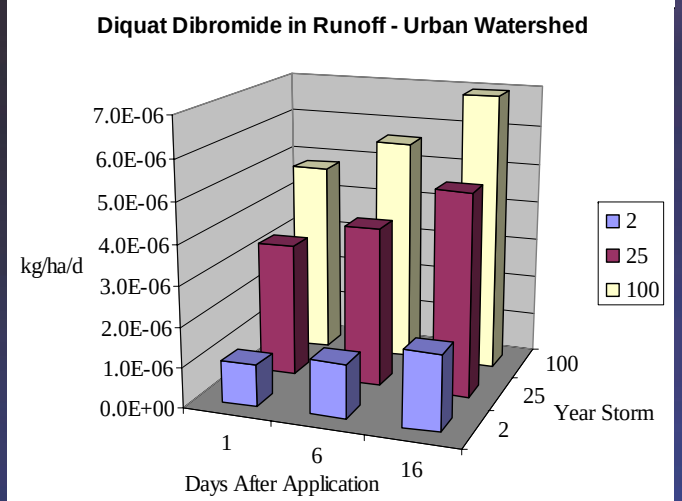
- **Highest concentration of the 2 pesticides**
- **Storms:**

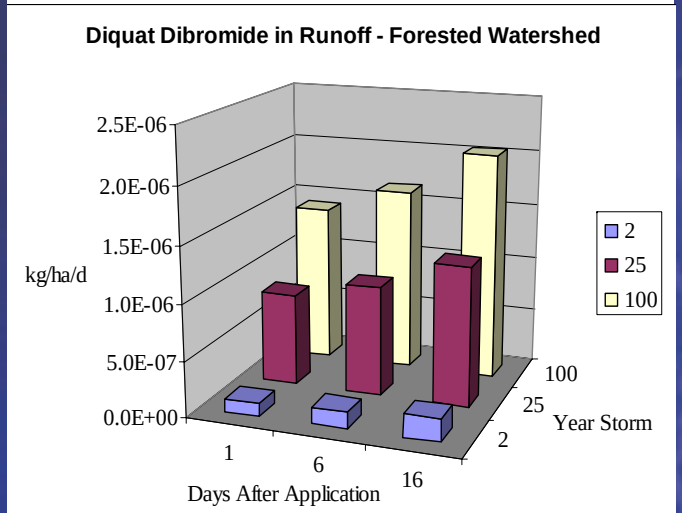
  100-Yr > 25-Yr > 2-Yr
- **Application:**

  1-D > 6-D > 16-D
- **Landuse:**

  Ag > Urban > Forested







Runoff of Diquat Dibromide

- **Lowest concentration of the 2 pesticides**
- **Storms:**

  100-Yr > 25-Yr > 2-Yr
- **Application:**

  16-D > 6-D > 1-D
- **Landuse:**

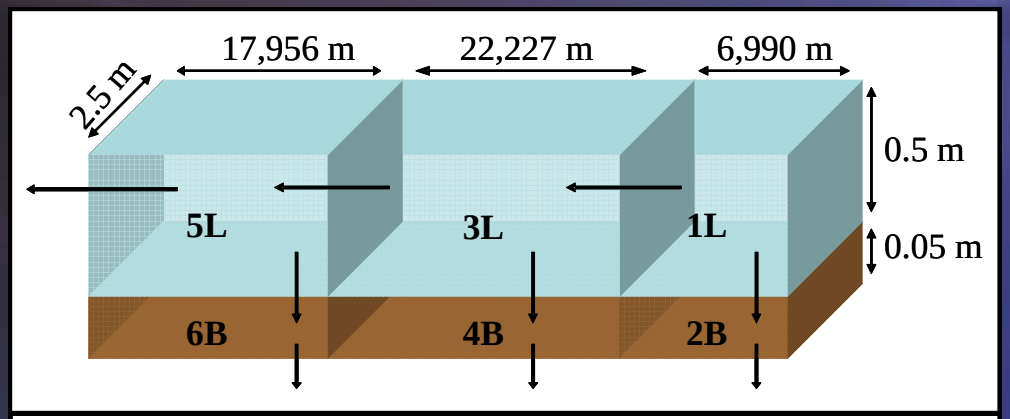
  Urban > Ag > Forested

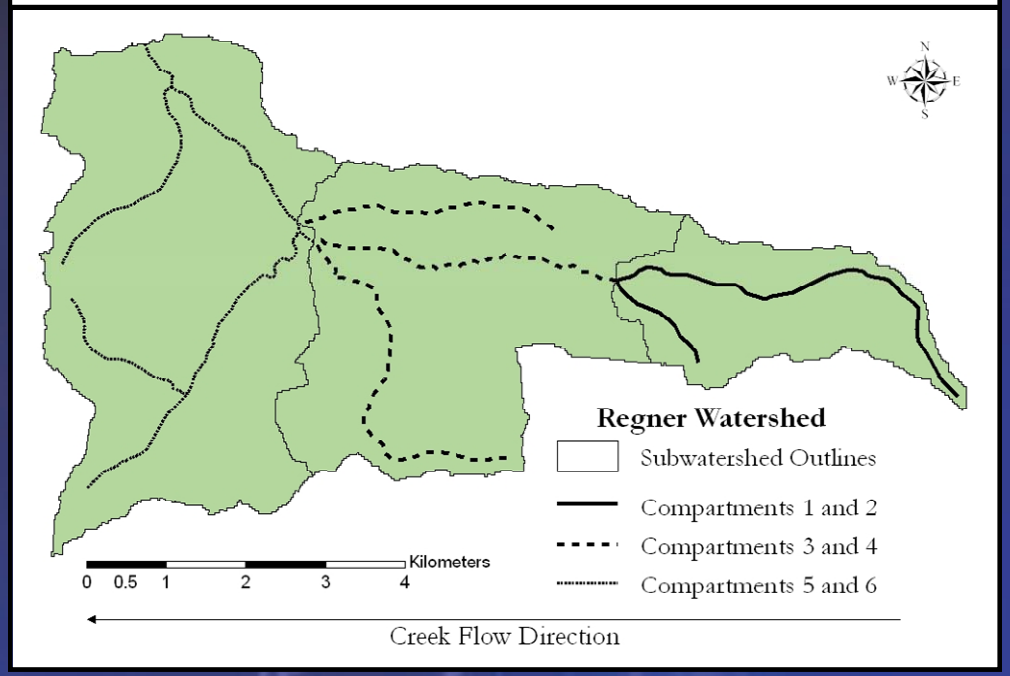
EXAMS Methods

- Used PRZM loadings and other inputs
- Fluoranthene loading was estimated from reported roadway runoff concentrations (Hewitt and Rashed, 1992) – entered the modeled system on days of rain
- Published chemical parameters
- Local meteorological data

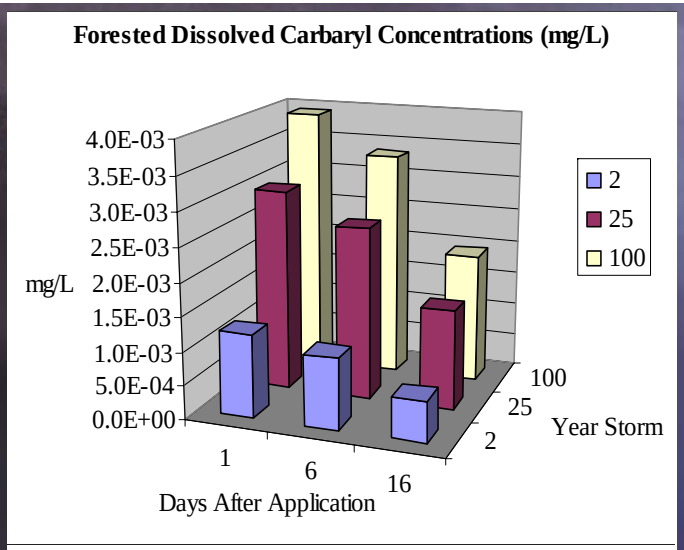
http://web.pdx.edu/

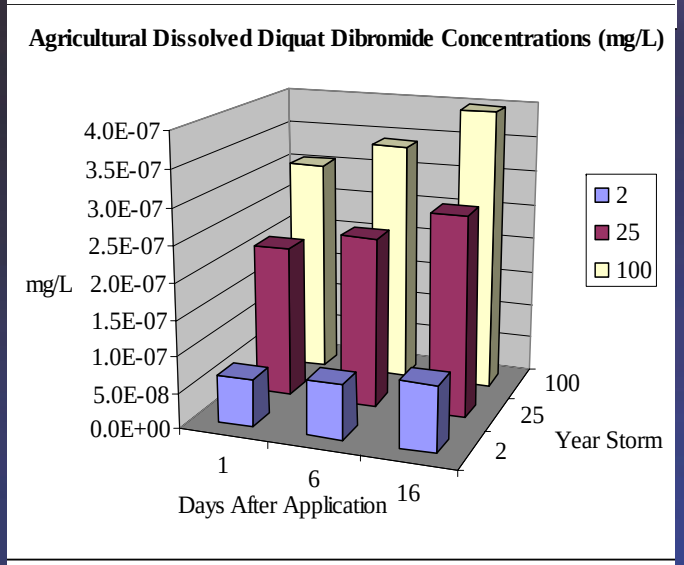
Johnson Creek EXAMS Compartments *(Conceptual)*

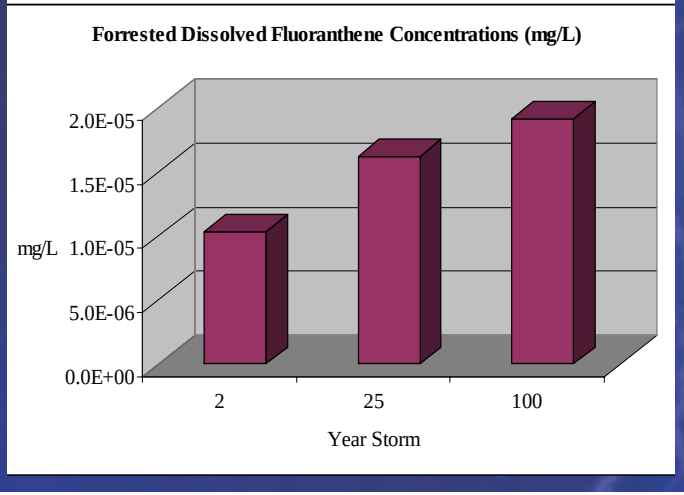




- Odd numbers are littoral
- Even numbers are benthic
- 1 and 2 are in the agricultural segment
- 3 and 4 are in the urban segment
- 5 and 6 are in the forested segment







Dissolved Chemical Concentrations in Littoral Compartments

- **Storms:** 100-Yr > 25-Yr > 2-Yr
- **Watersheds:**
  - Carbaryl highest in Forested Segment
  - Diquat highest in Agricultural Segment
  - Fluoranthene highest in Forested Segment
- **Pesticides (concentration not toxicity):**
  - Carbaryl > Fluoranthene > Diquat Dibromide
- **Application Date:**
  - Carbaryl: 1 > 6 > 16
  - Diquat Dibromide: 16 > 6 > 1

• **Note different Scales**

Johnson Creek Modeling Results Carbaryl

- **Maximum runoff and erosion**
  - application one or six days before the rain
- **Peak short term runoff**
  - 413 ug/l
  - two orders of magnitude higher than acute toxicity for daphnia
  - near salmonid toxic thresholds
  - exceeds acute toxicity to several crustacean (Verschueren, 1996; Macek and McAllister, 1970; Buchanan et al., 1969; Sanders and Cope, 1966)
- **Risk**
  - high storage
  - short lived

http://www.4j.lane.edu/partners/eweb/ve/salmon/salmon.jpeg

Johnson Creek Modeling Results Diquat Dibromide

- **Maximum runoff and erosion**
  - application 16 days before the rain
- **Peak short term runoff**
  - $5.6e^{-2}$ ug/l
  - five orders of magnitude less than acute toxicity for rainbow trout and the chinook salmon (Pimentel, 1971; Bond et al., 1960)
- **Risk**
  - very toxic
  - little chance that toxic levels will occur after heavy rainfall

http://techalive.mtu.edu/meec/module07/exotics_2.htm

Johnson Creek Modeling Results Fluoranthene

- **Peak short term runoff**
  - 2.0 ug/l
  - approximate acute toxicity thresholds for mysid shrimp and sea urchins (Montizaan, 1989; USEPA, 1991)
  - similar to salmonid acute toxicity levels when UV activated but much lower without UV activation (USEPA, 1991, 1991; Home and Oblad, 1983)
- **Risk**
  - Toxicity from roadway runoff possible under isolated conditions of intense runoff and little mixing

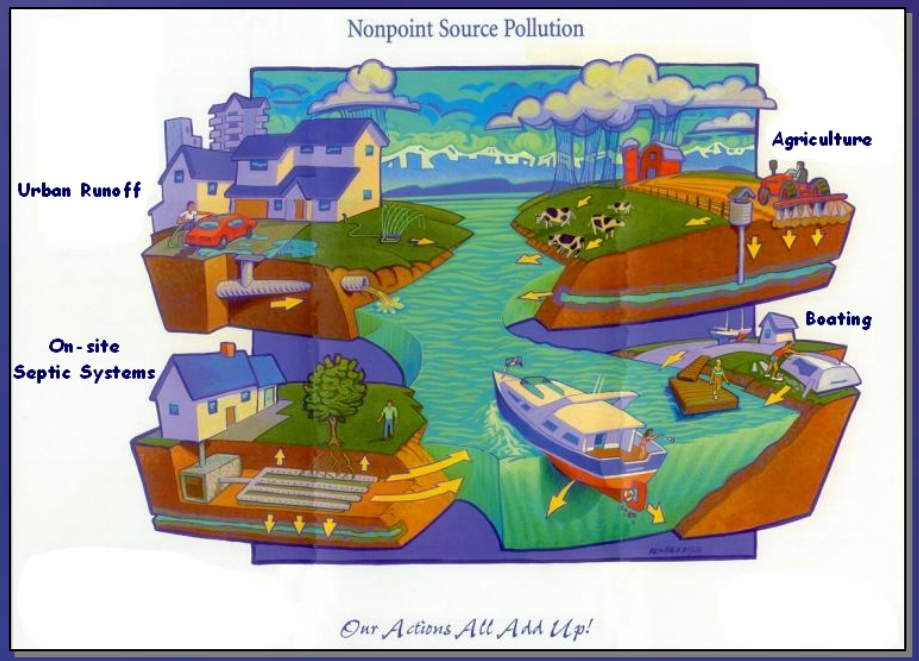
Johnson Creek Modeling Results Overall

- Both pesticides were storm and application date dependant
- The PAH, fluoranthene, was storm dependant
- Carbaryl
  - 5x more toxic than diquat dibromide to important salmonid species and transported at concentrations 7000 times higher
  - carbaryl poses greater risk to crustaceans followed by fluoranthene
- Fluoranthene
  - poses the greatest risk to spawning salmonids followed by carbaryl

http://www.oregonzoo.org

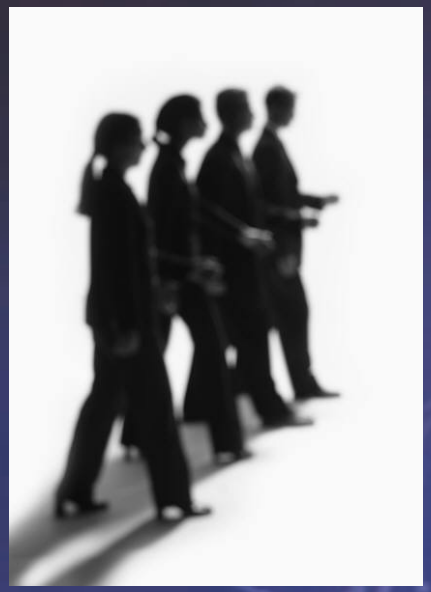
Overall Summary

- **PRZM Model**
  - Estimates shallow groundwater and runoff contamination
  - Identifies effects on runoff
  - Provides NPS inputs to exposure model
- **EXAMS Model**
  - Estimates surface water and sediment concentrations
  - Used to identify sensitive areas/habitats
  - Effects of storms types, application date
  - Compares pesticides, other contaminants



Acknowledgements

The authors wish to thank the following for their invaluable contributions to this research



Florida DEP

Dr. Ashok Shahane (FDACS)

SJRWMD

Karl Lee (USGS, Portland Oregon)

Johnson Creek Inter-Jurisdictional Committee

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