Calculation of Risk-Based Cleanup Levels and Site-Specific Remedial Objectives for Bromacil in the Environment

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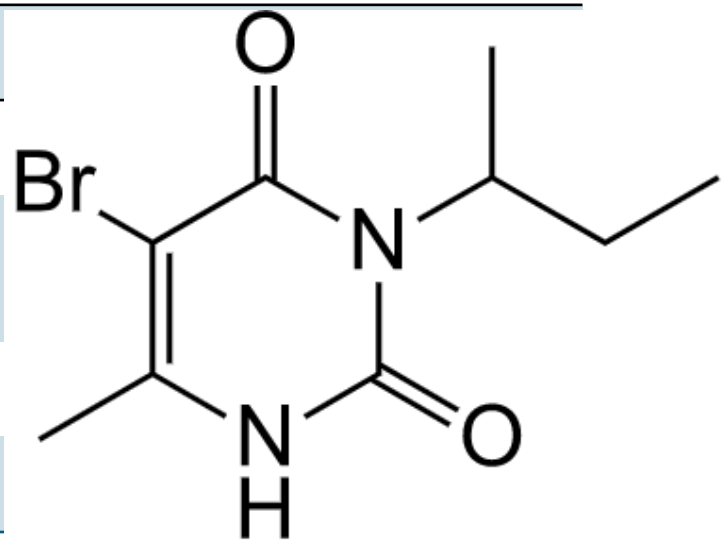
Agenda

- **Overview of Bromacil**
- **Bromacil in the Environment**
- **Existing Bromacil Guidelines**
- **Case Study – ATCO Former Kneehill Substation**
- **Conclusions and Ongoing Work**

Overview of Bromacil

Parameter	Value
IUPAC Name	5-bromo-3-butan-2-yl-6-methyl-1*H*-pyrimidine-2,4-dione
Pesticide Class	Substituted uracil herbicide
Chemical Formula	$C_9H_{13}BrN_2O_2$
Mode of Action (plants)	Inhibition of photosynthesis at electron transport chain

Parameter	Symbol	Units	Value
MW	MW	g/mol	261.12
Organic Carbon Partition Coefficient	Koc	kg/L	46 – 126
Solubility	S	mg/L	815
Half-Life	$k_{1/2}$	days	60 – 1494



Bromacil in the Environment

- Used for non-selective weed and brush control on non-agricultural lands
- Approved for broadcast and spot ground application
- Primarily used in AB, MB and ON

- Other sources include spray drift, accidental spills, equipment-washing operations, dumping of tank residues
- Relatively non-toxic to aquatic invertebrates and fish species
- Toxic through oral exposure to birds and mammals

Existing Bromacil Guidelines – Irrigation Water

- Effects on crops vary from beneficial, to tolerant, to harmful
- Toxic to a variety of nontarget crop species
- Mode of action is inhibition of photosynthesis at electron transport chain
- Interim Canadian water quality guidelines for bromacil developed in 1993

- 0.0006 mg/L for cereals, tame hays, and pastures based on the lowest MATC* for sorghum+ safety factor
- 0.0002 mg/L for other crops based on the lowest MATC* for cucumbers + safety factor

**MACT = maximum acceptable toxicant concentration*

Existing Bromacil Guidelines – Freshwater Aquatic Life

- Toxic to a variety of freshwater plants and algae through the same mode of action as terrestrial vegetation
- Relatively nontoxic to fish and freshwater invertebrates
- Interim Canadian water quality guidelines for bromacil developed in 1997
- 0.005 mg/L based on the lowest measured LC_{50} for green algae + safety factor

Existing Bromacil Guidelines

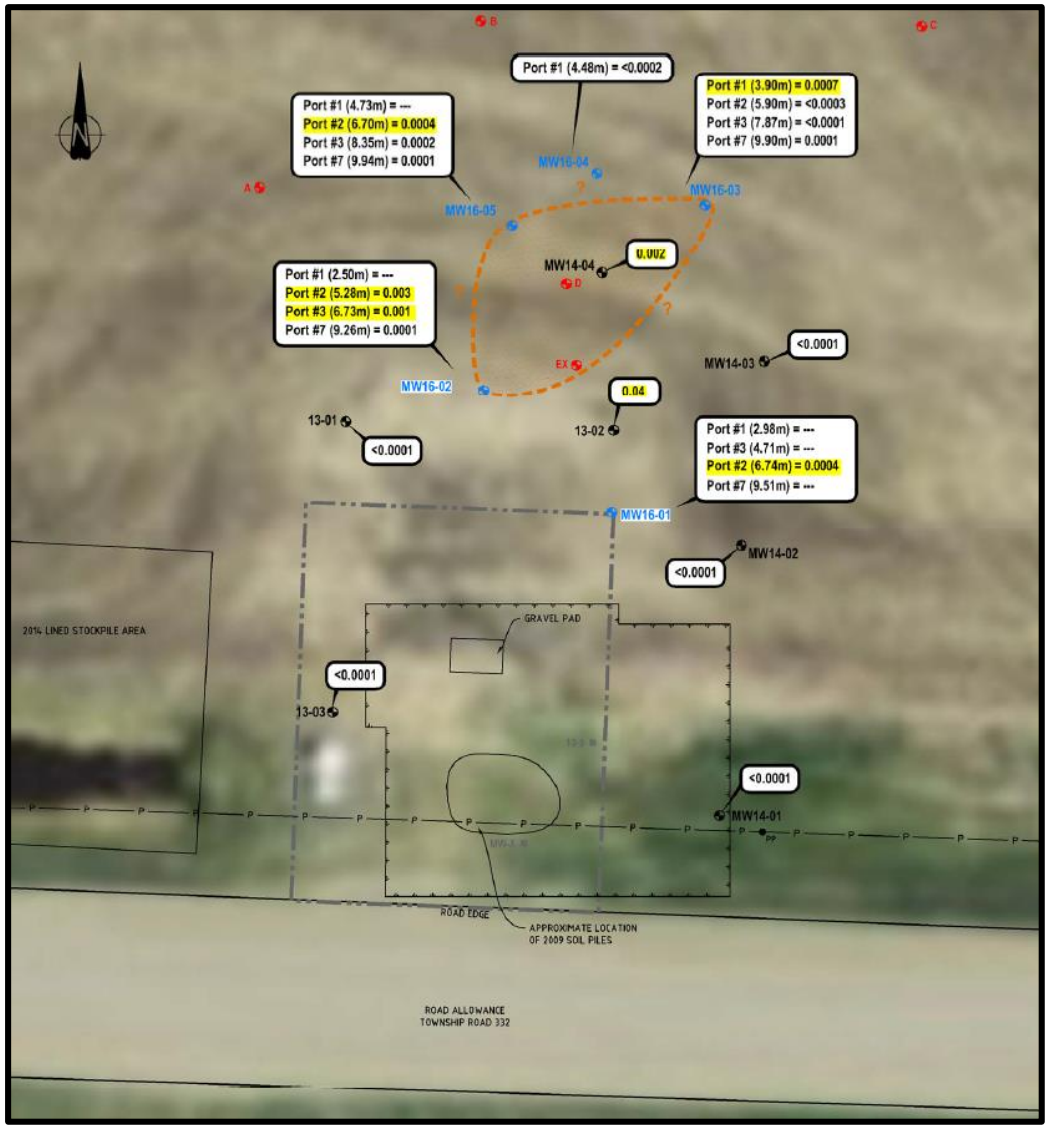
- **Soil**
  - Direct contact: 2,000 mg/kg
  - Protection of DUA (fine / coarse): 7 mg/kg / 10 mg/kg
  - Direct Soil Contact (fine / coarse): 0.2 mg/kg / 0.12 mg/kg
  - Protection of FWAL: 0.009 mg/kg
  - Protection of livestock water: 2 mg/kg
  - Irrigation water: < DL

- **Groundwater**
  - Potable water: 0.95 mg/L
  - Ecosoil Contact (fine / coarse): 0.44 mg/L / 0.3 mg/L
  - Livestock watering – 1.1 mg/L

Case Study – ATCO Former Kneehill Substation

- Former substation located on approximately 300 m^2 site at 02-14-033-26 W4M
- Bromacil historically used for weed control
- Phase II ESA identified bromacil was COC in soil and groundwater
- Fine-grained soils
- Relatively flat topography
- Surrounding land use and assumed end land use agricultural

Case Study – ATCO Former Kneehill Substation



- Bromacil-impacted soils excavated in 2014
- Dissolved bromacil concentrations remained above Tier 1 Guidelines after post remedial monitoring
- Dugout located approximately 300 metres southeast of the Site
- Potential receptors include:
  - crops through use of irrigation water
  - aquatic receptors (vegetation / invertebrates) in dugout

Case Study – ATCO Former Kneehill Substation

- **Approach**
  - Recalculate irrigation water guideline using an SSD following CCME guidelines
  - Use fate and transport modelling to assess FWAL for receiving environment
    - Insufficient data were available to recalculate freshwater aquatic life guideline using an SSD
  - Evaluate residual concentrations in groundwater against recalculated guidelines to estimate potential risks
  - Submit to AEP for regulatory approval

CCME Protocol for the Derivation of Water Quality Guidelines

Irrigation Water Requirements

- **Minimum Dataset Requirements**
  - Full Guideline / Interim Guideline
    - 3+ / 2+ grass / grain species – cereals, tame hays, and pastures.
    - 5+ / 2+ other species –lettuce, sunflower, cabbage, onion, tomato, etc.
  - Chronic irrigation studies required
  - Sensitive and biologically relevant endpoints (e.g., yield at harvest, growth rate, etc.)
  - SSD of retained studies with 5% effects / 95% protection

Case Study – ATCO Former Kneehill Substation

Irrigation Water Guideline Derivation

- USEPA ECOTOX Knowledgebase and OPP Pesticide Ecotoxicity Database

- 377 plant identified from database search:
  - Only data for pure bromacil were retained
  - Excluded tropical species / species not grown in or native to Canada
  - Only EC_{25} endpoints for chronic studies were retained

- Retained 20 studies for 8 representative species including bread wheat, rapeseed, turnip, soybean, tomato, and sorghum

Case Study – ATCO Former Kneehill Substation

Irrigation Water Requirements

- Application rate of bromacil was converted to an approximate irrigation water concentration based on growing season water use and rainfall

- For growing season irrigation water use:

- $\mathbf{Water\ Use\ (\frac{m^3}{acre}) = (Water\ Use\ (m)\ - Rainfall\ (m) - Soil\ Moisture\ (m))\ x\ Conversion\ Factor(\frac{m^2}{acre})}$

Growing Season Irrigation Water Use									
Water Use (m)	-	Rainfall (m)	-	Soil Moisture (m)	x	Conversion Factor (m^2/acre)	=	Irrigation Water Use per Acre (m^3/acre)	Irrigation Water Use per Acre (L/acre)
0.452	-	0.3	-	0.1	x	4048.58	=	210.53	2.11×10^5

Case Study – ATCO Former Kneehill Substation

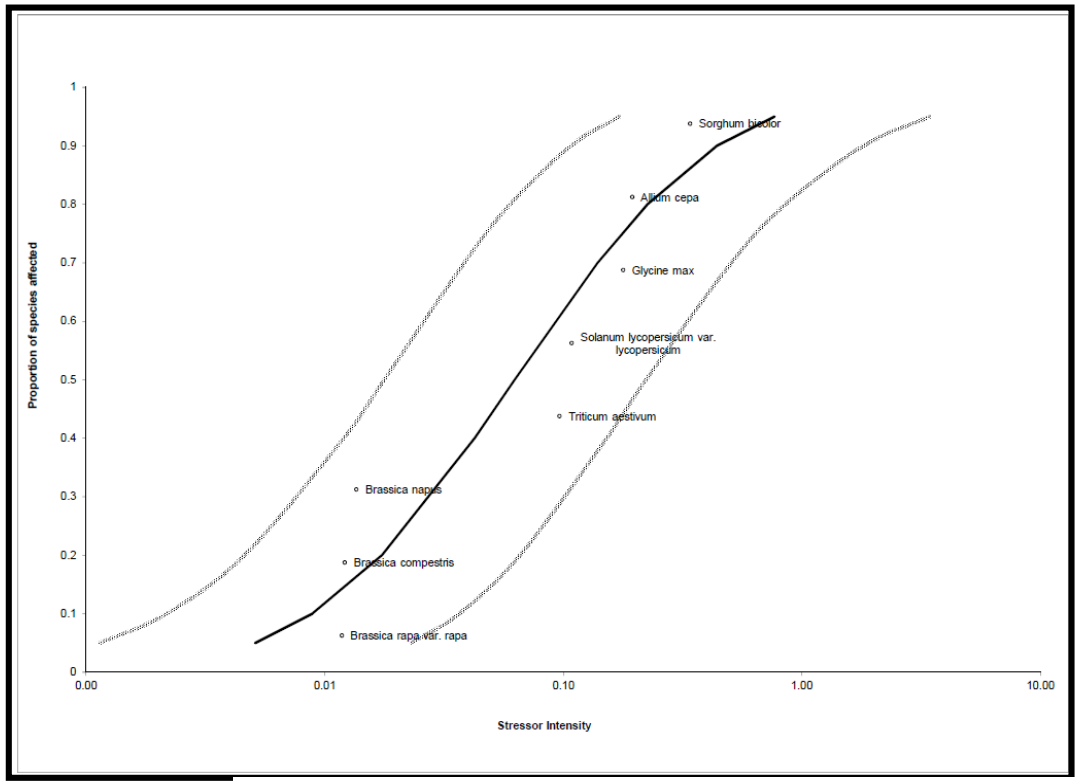
Toxicity Endpoint Conversion

- Toxicity endpoints based on mass per acre were converted to a concentration using calculated growing season irrigation water use

- $Toxicity\ Endpoint\ Concentration\ \left(\frac{mg}{L}\right) = \frac{Toxicity\ Endpoint\ Concentration\ (\frac{mg}{acre})}{Irrigation\ Water\ Use\ per\ Acre\ (\frac{L}{acre})}$

	Toxicity Endpoint Conversion				
	Toxicity Endpoint Concentration (mg/acre)	÷	Irrigation Water Use per Acre (L/acre)	=	Toxicity Endpoint Concentration (mg/L)
Turnip	909	÷	2.11×10^{5}	=	4.32×10^{-3}

Case Study – ATCO Former Kneehill Substation



Irrigation Water SSRO

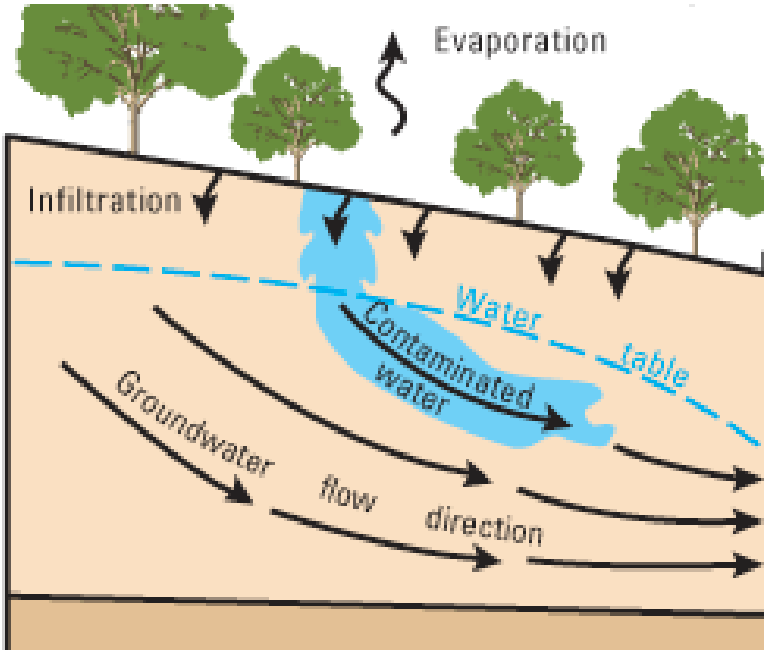
- Species Sensitivity Distribution
- ECOTOX and OPP
- Met minimum data requirements for derivation of an interim guideline
- Eight species including:
  - Bread wheat
  - Rapeseed
  - Turnip
  - Soybean
  - Tomato
  - Sorghum species
  - Onion

Proportion	Probit	Log Central Tendency	SSQ	Log Upper PI	Log Lower PI	Central Tendency	Upper PI	Lower PI
0.05	3.355	-2.291	0.112	-1.639	-2.942	0.0051	0.023	0.001
0.1	3.718	-2.051	0.099	-1.438	-2.663	0.0089	0.037	0.002
0.2	4.158	-1.760	0.088	-1.183	-2.337	0.0174	0.066	0.005
0.25	4.326	-1.649	0.085	-1.082	-2.216	0.0224	0.083	0.006
0.5	5.000	-1.203	0.080	-0.655	-1.751	0.0627	0.221	0.018
0.7	5.524	-0.856	0.083	-0.297	-1.416	0.1393	0.505	0.038
0.8	5.842	-0.646	0.088	-0.069	-1.223	0.2258	0.852	0.060
0.9	6.282	-0.355	0.099	0.258	-0.968	0.4412	1.809	0.108
0.95	6.645	-0.115	0.112	0.536	-0.766	0.7673	3.438	0.171

Case Study – ATCO Former Kneehill Substation

Freshwater Aquatic Life SSROs

- Insufficient toxicity data to recalculate the guideline using an SSD
- Fate and transport modeling applied for the dugout 300 metres southeast from the Site
- Used CCME FWAL guideline (0.005 mg/L) and the Domenico and Robbins Groundwater Transport Model to back-calculate the SSRO
- Estimated SSRO for groundwater was above the solubility so was set to the water solubility of bromacil (815 mg/L)
- Estimated SSRO for soils was 1,270 mg/kg



Case Study – ATCO Former Kneehill Substation

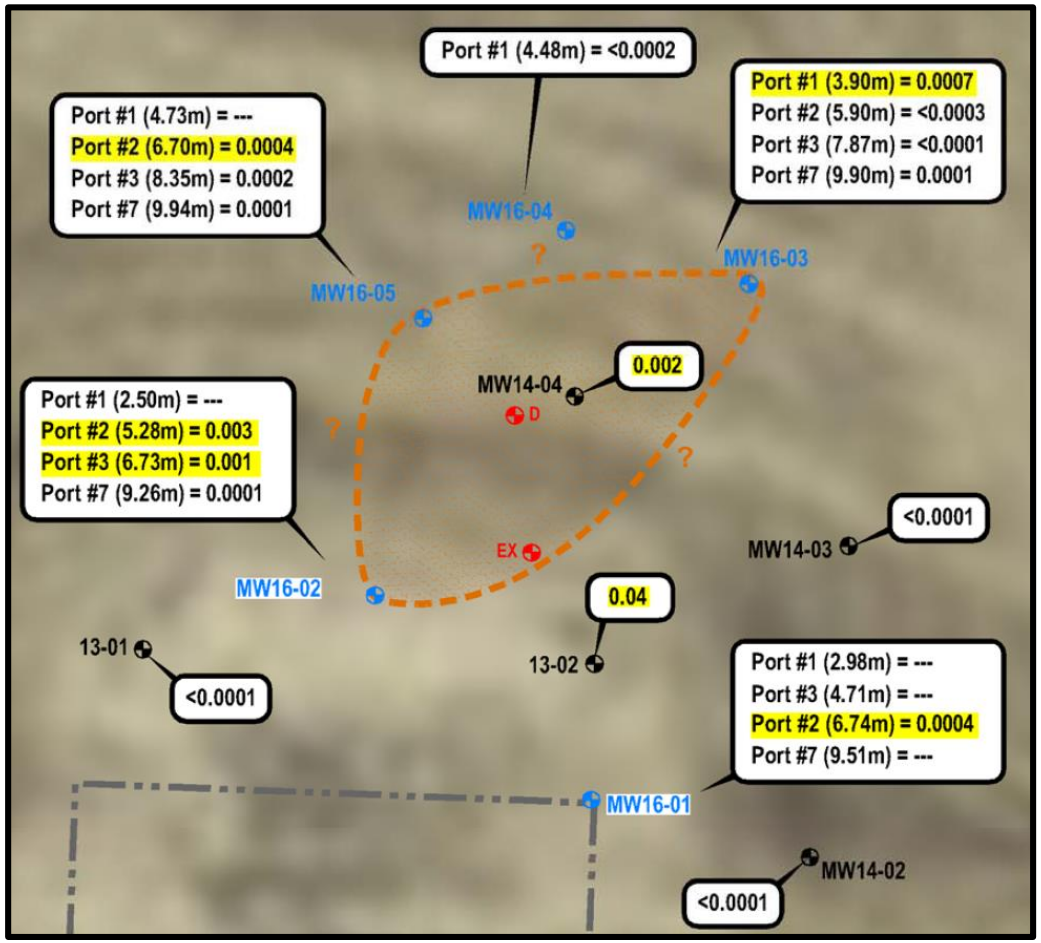
- SSROs were compared to concentrations in groundwater and indicated concentrations were acceptable.

- Ongoing monitoring required to verify concentrations of bromacil remain stable or are decreasing

- Acceptance and approval of the proposed SSROs from AEP
  - Acceptance of risk-based guidelines
  - Exposure control for dugout due to reliance on distance

Media and Pathway for SSRO	Value	Units
Groundwater for the Protection of IW	0.005	mg/L
Groundwater for the Protection of the FWAL	Solubility (815)	mg/L
Soils for the Protection of the FWAL	1,270	mg/kg

Notes: SSRO = Site-specific Remediation Objective. IW = Irrigation Water. FWAL = Fresh Water Aquatic Life. mg/L = milligrams per litre. mg/kg = milligrams per kilogram.



Conclusions and Ongoing Work

- Bromacil is widespread within the environment
- Bromacil guidelines are generally based on the toxicity of the most sensitive receptors with safety factors
- Toxicity data was used to estimate a SSRO protective of an agricultural crop population native to Alberta
- A guideline adjustment was used to back-calculate a SSRO protective of FWAL populations near the Site
- SSROs were accepted by AEP and used to screen out bromacil as a COC for the Site for irrigation water and implement exposure control for the dugout
- Cost savings of more than $500k

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