Alternative Process for Developing Tier 2 SSROs

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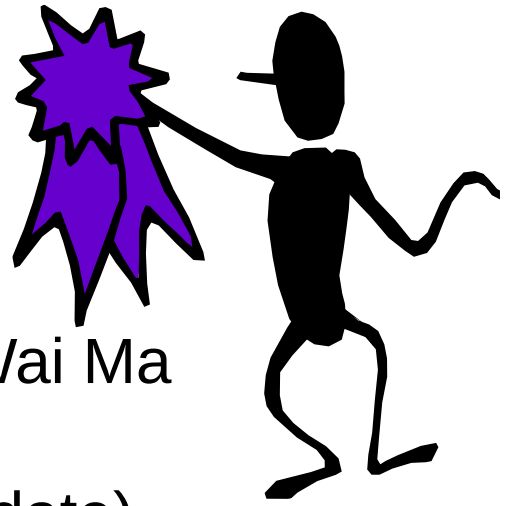
One Team. Infinite Solutions

Presentation Overview

- Provide background for research
- Overview of research program
  (technical details have been deliberately avoided; bigger picture perspective)
- Status update – Geomean Approach
  PLS Approach
  SEM Approach
  DRAMA Approach (B Zajdlik)
- Proposed next steps

Acknowledgements



Research Providers:

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Barry Zajdlik (Zajdlik & Associates, PhD Candidate)
Drs Eric Lamb, Steven Siciliano (University of
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Dr Melissa Whitfield-Aslund (IRDC, Intrinsik)

Research Partners:

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Chris Meloche (HuskyEnergy / PTAC)
Gladys Stephenson (Stantec R&D Fund)
AUPRF, CAPP, EPAC

Background

- Alberta Reg. have a provision for application of a Tier 2 Pass/Fail Approach to assess risk associated with remediated soils contaminated with PHC residuals that remain above Tier 1 standards - direct contact exposure pathway
- There is also a provision for deriving site-specific Tier 2 remedial objectives but, to date, there is no process for this derivation
- There is evidence that the risk associated with exposure of ecological receptors to soils with weathered and aged PHC residuals is less than that associated with soil contaminated with fresh product
- As a result, the risk for ecological receptors associated with exposure to petroleum hydrocarbons in soil is often over estimated

Background

- Cost of a Tier 2 ecotoxicity assessment can range from 24K to 212K, depending on the number of soils assessed and the size of the test battery (# species and # methods)
- When the soils pass (i.e., meet the criteria established for the land use) and site closure is supported by other lines of evidence, the cost savings can be high, and closure obtained
- When the soils fail, site closure is not supported and further remediation of the soils might be warranted or management measures imposed
- Other options include: removal & disposal; Tier 3 risk assessment; new remedial technologies; caveat on land title etc.

Develop a Tier 2 process that would allow the derivation of site-specific remedial objectives or clean-up values

The Challenges

- Share the vision and get buy in
- Establish a national database where ecotoxicological data (response variables) are linked with soil physico-chemical data (pedological variables) and concentration of contaminants of concern
- Develop models that could predict “effects” for soils with specified characteristics and specified contaminants of concern
- Use the distribution of predicted effects to guide management decisions

AUPRF Project 2012
Feasibility of Four Approaches

1. Distribution of the geometric means of the NOAECs and LOAECs – Robin Angell (Stantec Consulting Ltd.)
2. Enhancing the Signal-to-Noise Ratio to Estimate SSROs relying on statistical procedures for data reduction and model averaging (DRAMA) - Barry Zajdlik (Zajdlik & Associates)
3. Structural Equation Modeling (SEM) – Dr. Eric Lamb (UoS)
4. Partial Least-squares (PLS) Multivariate Regression – Dr. Melissa Whitfield-Aslund (NSERC IRDC, Intrinsik)

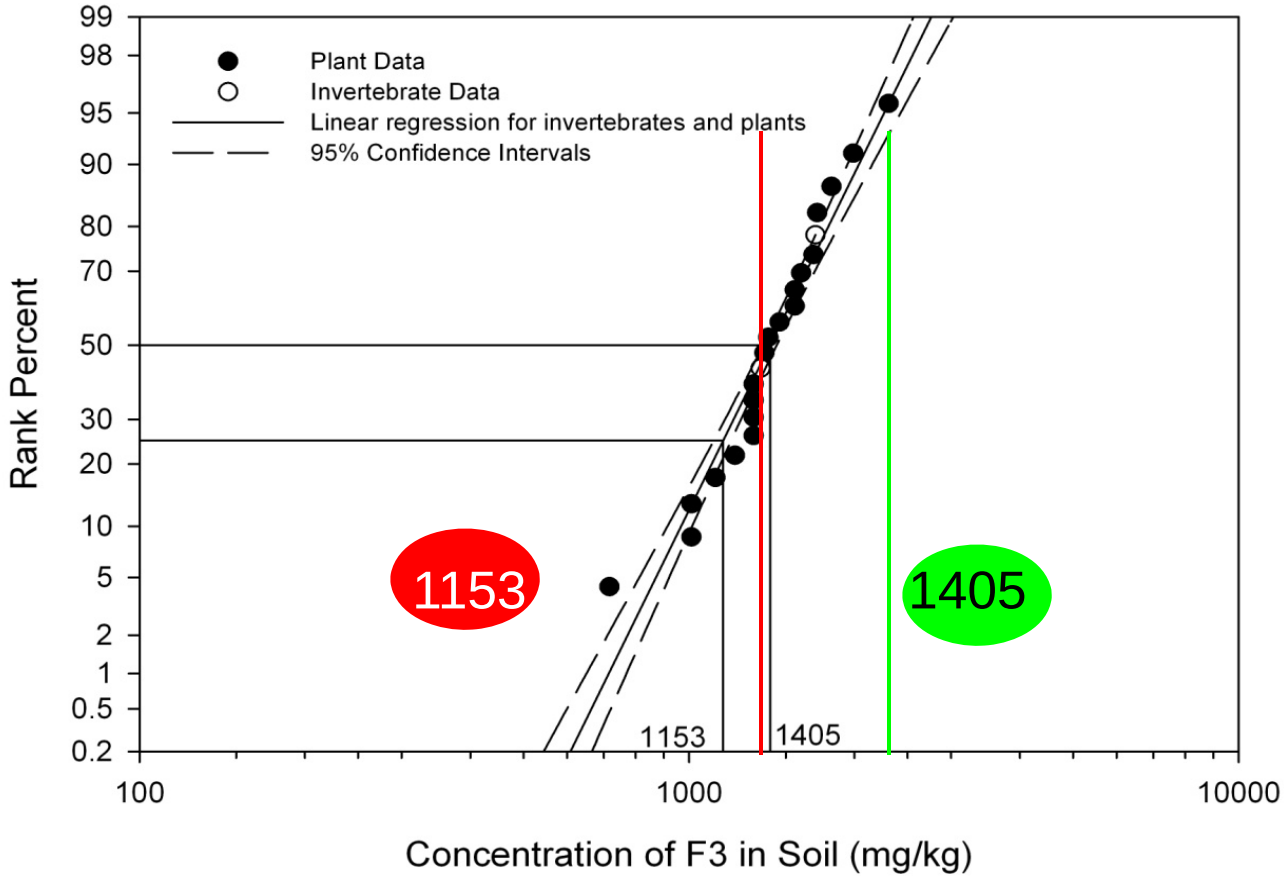
Draft report submitted Jan. 31. 2013

GeoMean Approach

Rationale

Data from the Tier 2 ecotoxicity assessment could be used to derive a SSRO by examining the distribution of the ranks of the geometric means of the no-observed-adverse-effects concentrations (NOAECs) and the lowest-observed-adverse effects concentrations (LOAECs)

GeoMean Approach - Result



Tier 2 Assessment: 4 plant and 2 invertebrate spp.
8 fine-textured site soil samples and 3 reference control soils
>25 toxicity endpoints

PLS Approach

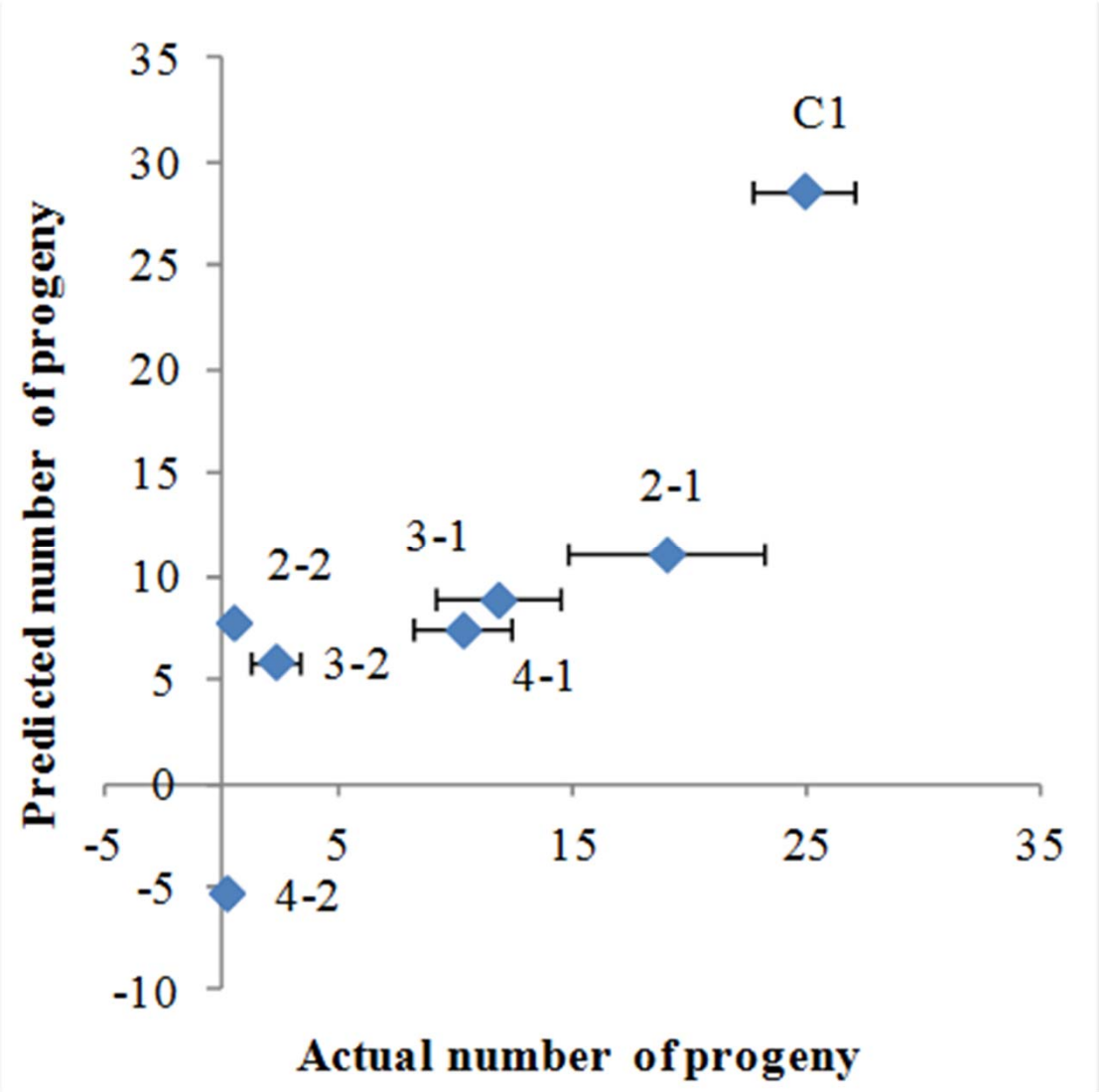
Rationale

PLS multivariate analyses can be used to describe the relationship between a multivariate predictor matrix (X – soil and contaminant variables) and a response matrix (Y – toxicity data).

It assesses the strength of the relationship between X and Y and can be used to predict future unknown ‘Y values’ based on known (measured) X data

Details provided in PTAC poster presentation by Whitfield-Aslund et al. and in the draft report submitted in January 2013

PLS Approach - Results



PLS models were derived using leave-one-class-out cross-validation (LOCOCV) procedures

Model fit was evaluated

Predictive ability was evaluated

PLS Approach - Results

Demonstrated the importance of non-contaminant variables in explaining the variability in the biological response data (earthworm progeny production) relative to the contaminant variables which are highlighted in yellow

Variable	VIP
Total_Carbon	1.52
Total_Nitrogen	1.49
Soil_Moisture	1.37
Total_Xylenes	1.33
Salt_Magnesium	1.32
Sodium_Adsorption_Ratio	1.30
Salt_Chloride	1.26
Total_PHC	1.24
Hydrometer_Silt	1.24
Salt_Calcium	1.23
CCME_Coarse	1.23
Ammonia	1.23
Total_Sulphur	1.23
F4G	1.19
Toluene	1.17
F4	1.17
Arsenic	1.13
Hydrometer_Clay	1.12
pH	1.09
Salt_Sodium	1.09

PLS Approach - Conclusion

- Possible to link multivariate soil properties to some ecotoxicity endpoints
- To date, predictive power of these models is likely inadequate for soils with soil properties that vary substantially from those used to derive the models
- The approach shows great promise on a site-specific basis and its utility will be improved when additional datasets are included in the model building process
- Results were corroborated by DRAMA findings

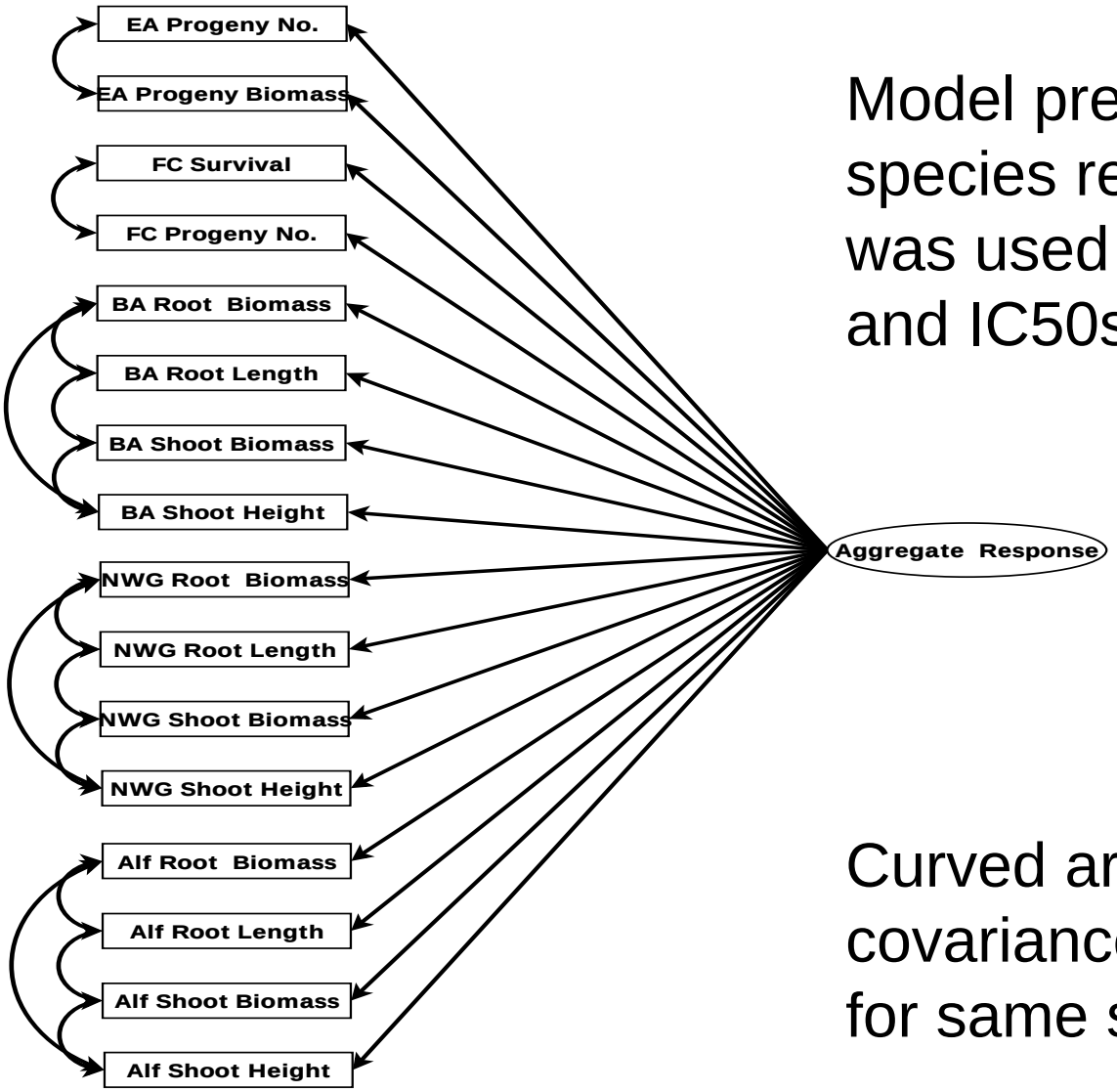
SEM Approach

- Structural equation modeling (SEM) was investigated as a potential process for deriving SSROs for PHCs

- Two components: measurement model (indicator or latent variables) and the structural model (paths between variables)

Details provided in the PTAC poster presentation by Lamb et al. and in the draft report submitted in January 2013

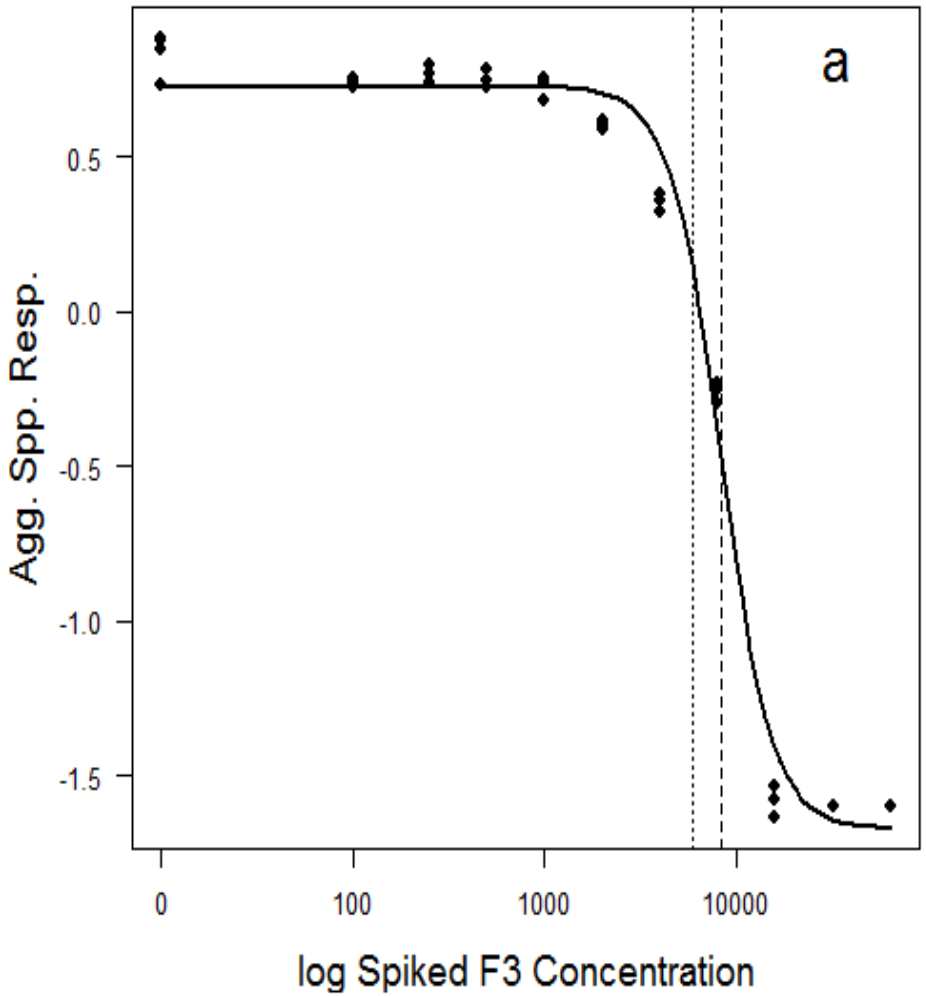
SEM – Measurement Model



Model predicted an aggregate species response variable that was used to estimate IC20s and IC50s

Curved arrows = expected covariance among endpoints for same species

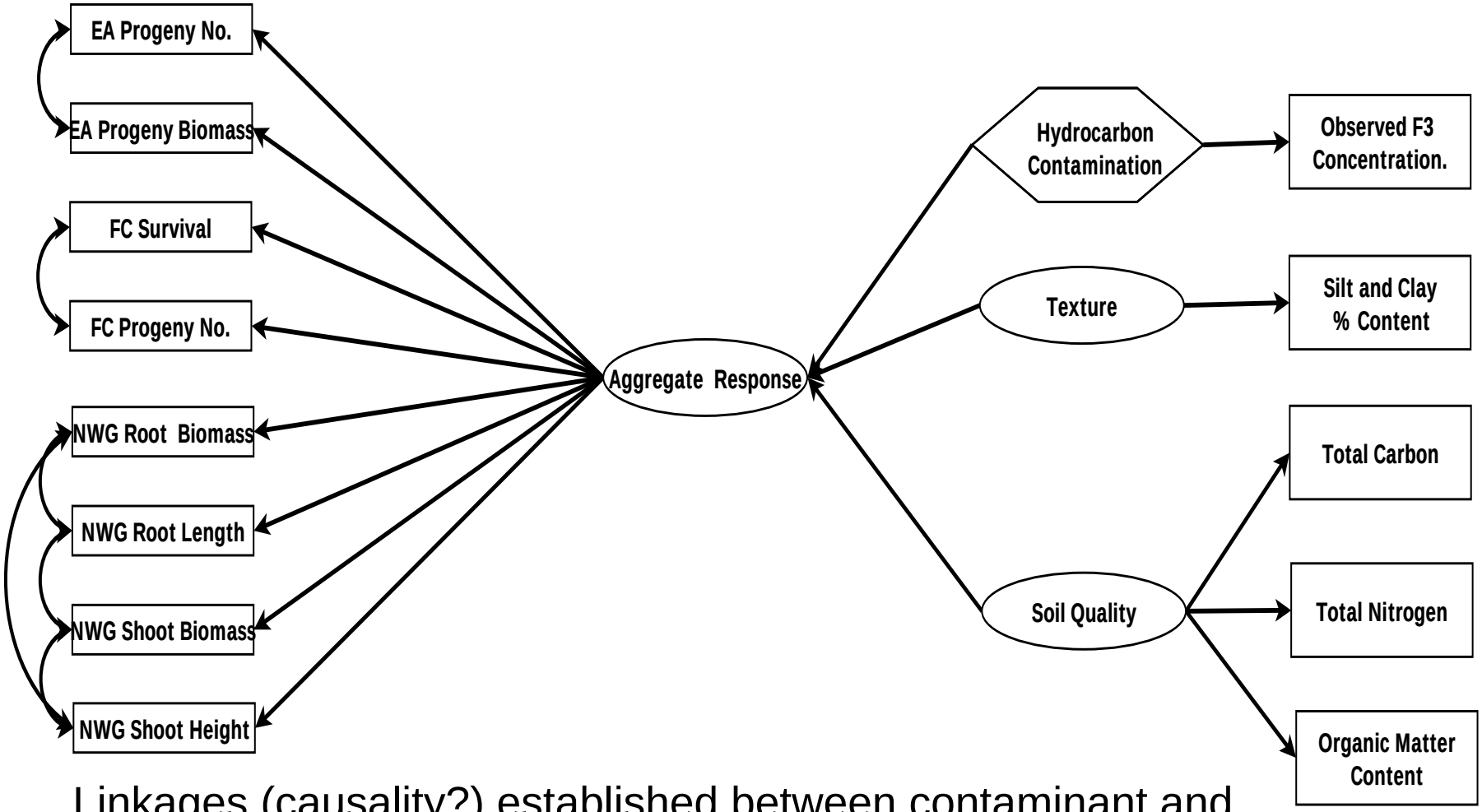
SEM – Measurement Model



IC50 Aggregate Response – – – –

IC25 Aggregate Response ·····

SEM – Structural Model



Linkages (causality?) established between contaminant and non-contaminant variables and the latent aggregate response variable

SEM – Conclusions

- Confirmatory factor analyses to aggregate multiple endpoints into a single latent variable that can then be incorporated into standard non-linear modeling to estimate any ICp value has the advantage of reconciling divergent endpoint data

- SEM also showed promise in that cross-site models successfully explained the aggregate species responses ($R^2 = 0.7$) **BUT**

- Those same models failed tests for model adequacy

- Additional datasets are required to further explore this approach

Summary

- Tier 2 Pass/Fail Approach is of limited value when site soils fail (currently)
- Failure to meet the Tier 2 criteria is not necessarily a failure due to toxicity when a substantial portion of the observed toxicity is attributable to non-contaminant variables (e.g. soil texture, organic matter, sulphur, pH etc.)
- Statistical approaches were used to quantify the relative importance of the PHC contaminants versus other non-contaminant variables with respect to toxicity
- The probability of making a correct decision is greatly increased when applying the appropriate statistical tools

Next Steps

- Apply PLS, DRAMA, and SEM analyses to a larger data set
- Finalize predictive models from each approach
- Apply models to site data independent of the model building dataset to predict distribution of effects (toxicity) on the site
- Collect samples of soil from a site and conduct single-species toxicity tests to generate toxicological data that can be used to test predictions of the models (verification/validation)
- Model refinement and recommendations

Questions?

"The marriage between statistics and ecotoxicology is more of one of convenience than of fidelity. The offspring of such a union are not necessarily (sic) handicapped at birth."

"Statistics are useful tools, not simply crutches to rely upon when all else fails"