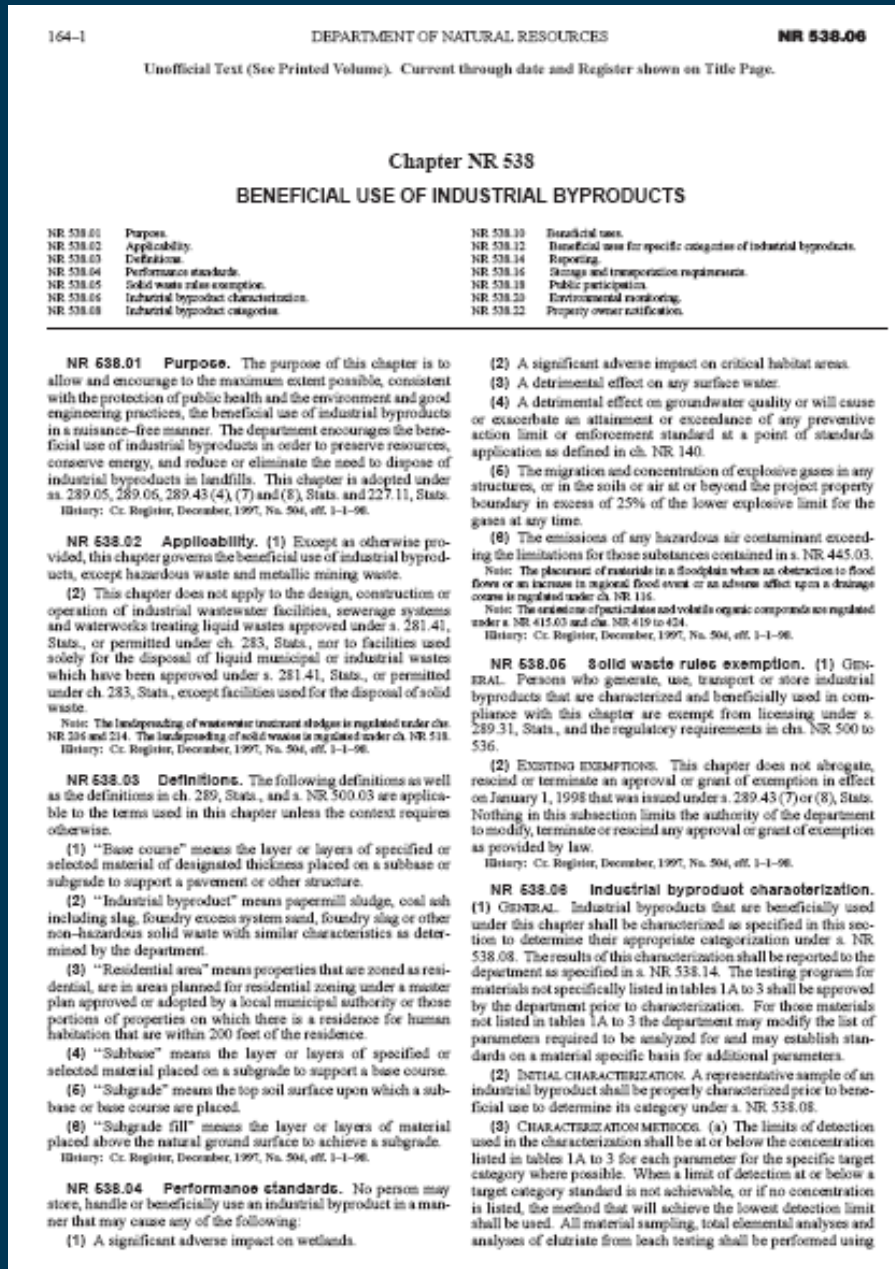
Environmental Assessment of Foundry Byproducts for Unbound Highway Applications

Craig H. Benson, PhD, PE
Recycled Materials Resource Center
University of Washington
chbenson@u.washington.edu
www.recycledmaterials.org

Issues to Consider

- Should we be concerned about environmental assessment of foundry byproducts (or other industrial resources)?
- Does a standard method exist to evaluate environmental impacts associated with foundry byproducts?
- Do leachates from foundry byproducts have more contaminants or greater concentrations than conventional construction materials?

Wisconsin NR 538 Code



164–1 DEPARTMENT OF NATURAL RESOURCES **NR 538.06**

Unofficial Text (See Printed Volume). Current through date and Register shown on Title Page.

Chapter NR 538

BENEFICIAL USE OF INDUSTRIAL BYPRODUCTS

NR 538.01 Purpose. The purpose of this chapter is to allow and encourage to the maximum extent possible, consistent with the protection of public health and the environment and good engineering practices, the beneficial use of industrial byproducts in a nuisance–free manner. The department encourages the beneficial use of industrial byproducts in order to preserve resources, conserve energy, and reduce or eliminate the need to dispose of industrial byproducts in landfills. This chapter is adopted under ss. 289.05, 289.06, 289.43 (4), (7) and (8), Stats. and 227.11, Stats.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.02 Applicability. (1) Except as otherwise provided, this chapter governs the beneficial use of industrial byproducts, except hazardous waste and metallic mining waste.

(2) This chapter does not apply to the design, construction or operation of industrial wastewater facilities, sewerage systems and waterworks treating liquid wastes approved under s. 281.41, Stats., or permitted under ch. 283, Stats., nor to facilities used solely for the disposal of liquid municipal or industrial wastes which have been approved under s. 281.41, Stats., or permitted under ch. 283, Stats., except facilities used for the disposal of solid waste.

Note: The landspreading of wastewater treatment sludges is regulated under chs. NR 206 and 214. The landspreading of solid wastes is regulated under ch. NR 518.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.03 Definitions. The following definitions as well as the definitions in ch. 289, Stats., and s. NR 500.03 are applicable to the terms used in this chapter unless the context requires otherwise.

(1) "Base course" means the layer or layers of specified or selected material of designated thickness placed on a subbase or subgrade to support a pavement or other structure.

(2) "Industrial byproduct" means papermill sludge, coal ash including slag, foundry excess system sand, foundry slag or other non–hazardous solid waste with similar characteristics as determined by the department.

(3) "Residential area" means properties that are zoned as residential, are in areas planned for residential zoning under a master plan approved or adopted by a local municipal authority or those portions of properties on which there is a residence for human habitation that are within 200 feet of the residence.

(4) "Subbase" means the layer or layers of specified or selected material placed on a subgrade to support a base course.

(5) "Subgrade" means the top soil surface upon which a subbase or base course are placed.

(6) "Subgrade fill" means the layer or layers of material placed above the natural ground surface to achieve a subgrade.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.04 Performance standards. No person may store, handle or beneficially use an industrial byproduct in a manner that may cause any of the following:

(1) A significant adverse impact on wetlands.

(2) A significant adverse impact on critical habitat areas.

(3) A detrimental effect on any surface water.

(4) A detrimental effect on groundwater quality or will cause or exacerbate an attainment or exceedance of any preventive action limit or enforcement standard at a point of standards application as defined in ch. NR 140.

(5) The migration and concentration of explosive gases in any structures, or in the soils or air at or beyond the project property boundary in excess of 25% of the lower explosive limit for the gases at any time.

(6) The emissions of any hazardous air contaminant exceeding the limitations for those substances contained in s. NR 445.03.

Note: The placement of materials in a floodplain where an obstruction to flood flows or an increase in regional flood event or an adverse affect upon a drainage course is regulated under ch. NR 116.

Note: The emissions of particulates and volatile organic compounds are regulated under s. NR 415.03 and chs. NR 419 to 424.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.06 Solid waste rules exemption. (1) GENERAL. Persons who generate, use, transport or store industrial byproducts that are characterized and beneficially used in compliance with this chapter are exempt from licensing under s. 289.31, Stats., and the regulatory requirements in chs. NR 500 to 536.

(2) EXISTING EXEMPTIONS. This chapter does not abrogate, rescind or terminate an approval or grant of exemption in effect on January 1, 1998 that was issued under s. 289.43 (7) or (8), Stats. Nothing in this subsection limits the authority of the department to modify, terminate or rescind any approval or grant of exemption as provided by law.

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

NR 538.08 Industrial byproduct characterization. (1) GENERAL. Industrial byproducts that are beneficially used under this chapter shall be characterized as specified in this section to determine their appropriate categorization under s. NR 538.08. The results of this characterization shall be reported to the department as specified in s. NR 538.14. The testing program for materials not specifically listed in tables 1A to 3 shall be approved by the department prior to characterization. For those materials not listed in tables 1A to 3 the department may modify the list of parameters required to be analyzed for and may establish standards on a material specific basis for additional parameters.

(2) INITIAL CHARACTERIZATION. A representative sample of an industrial byproduct shall be properly characterized prior to beneficial use to determine its category under s. NR 538.08.

(3) CHARACTERIZATION METHODS. (a) The limits of detection used in the characterization shall be at or below the concentration listed in tables 1A to 3 for each parameter for the specific target category where possible. When a limit of detection at or below a target category standard is not achievable, or if no concentration is listed, the method that will achieve the lowest detection limit shall be used. All material sampling, total elemental analyses and analyses of elutriate from leach testing shall be performed using

- Evaluate byproducts based on total elemental analysis and water leach tests.
- Define byproduct categories based on test data.
- Define suitable application based on category.

Applications Based on Category

Table 4

Beneficial Use Methods

	Industrial Byproduct Category				
	5	4	3	2	1
(1) Raw Material for Manufacturing a Product	X	X	X	X	X
(2) Waste Stabilization / Solidification	X	X	X	X	X
(3) Supplemental Fuel Source / Energy Recovery	X	X	X	X	X
(4) Landfill Daily Cover / Internal Structures	X	X	X	X	X
(5) Confined Geotechnical Fill (a) commercial, industrial or institutional building subbase (b) paved lot base, subbase & subgrade fill (c) paved roadway base, subbase & subgrade fill (d) utility trench backfill (e) bridge abutment backfill (f) tank, vault or tunnel abandonment (g) slabjacking material		X	X	X	X
(6) Encapsulated Transportation Facility Embankment		X	X	X	X
(7) Capped Transportation Facility Embankment			X	X	X
(8) Unconfined Geotechnical Fill			X	X	X
(9) Unbonded Surface Course				X	X
(10) Bonded Surface Course				X	X
(11) Decorative Stone				X	X
(12) Cold Weather Road Abrasive				X	X
Note: General beneficial use in accordance with s. NR 538.12 (3)					X

Note: Refer to s. NR 538.10 for description of each beneficial use

History: Cr. Register, December, 1997, No. 504, eff. 1–1–98.

Lower category number provides more stringent limits on leaching characteristics.

Water Leach Test Criteria – NR 538

Category 4 ASTM Water Leach Test

Standard (mg/l)	Parameter	Ferrous Foundry Excess System Sand	Ferrous Foundry Slag	Coal Ash	Other[1]
0.03	Antimony (Sb)				X
0.25	Arsenic (As)				X
10	Barium (Ba)	X			X
0.02	Beryllium (Be)				X
0.025	Cadmium (Cd)	X	X	X	X
2500	Chloride (Cl)				X
0.5	Chromium, Total (Cr)			X	X
6.5	Copper (Cu)				X
1	Total Cyanide				X
20	Fluoride (F)				X
3	Iron (Fe)	X	X		X
0.075	Lead (Pb)	X	X		X
0.5	Manganese (Mn)				X
0.01	Mercury (Hg)	X	X		X
0.5	Nickel (Ni)				X
50	Nitrite & Nitrate (NO_2+NO_3–N)				X
30	Phenol				X
0.25	Selenium (Se)			X	X
0.25	Silver (Ag)			X	X
2500	Sulfate			X	X
0.01	Thallium (Tl)				X
50	Zinc (Zn)				X

1 As provided under s. NR 538.06 (1), the testing program for materials other than ferrous foundry system sand, ferrous foundry slag and coal ash must be approved by the department prior to characterization. For other materials the department may modify the list of parameters required to be analyzed for and may establish standards on a material specific basis for additional parameters.

Note: All testing is to be conducted on a representative sample of a single industrial byproduct prior to commingling with other materials, unless otherwise approved by the department.

- Contaminants of concern depend on byproduct being considered.
- Category 1 has the most test requirements.

Recap – Leaching Issues

- True or False: Foundry sands leach more contaminants than traditional construction materials.
- True or False: US EPA has developed nationwide regulations regarding how and when industrial byproducts can be used in construction applications.
- True or False: Wisconsin regulations for byproducts use can be applied in other states.

Methods to Assess Leaching

- Batch tests:

- solid and liquid in a vial

- tumbled to ensure local well-stirred

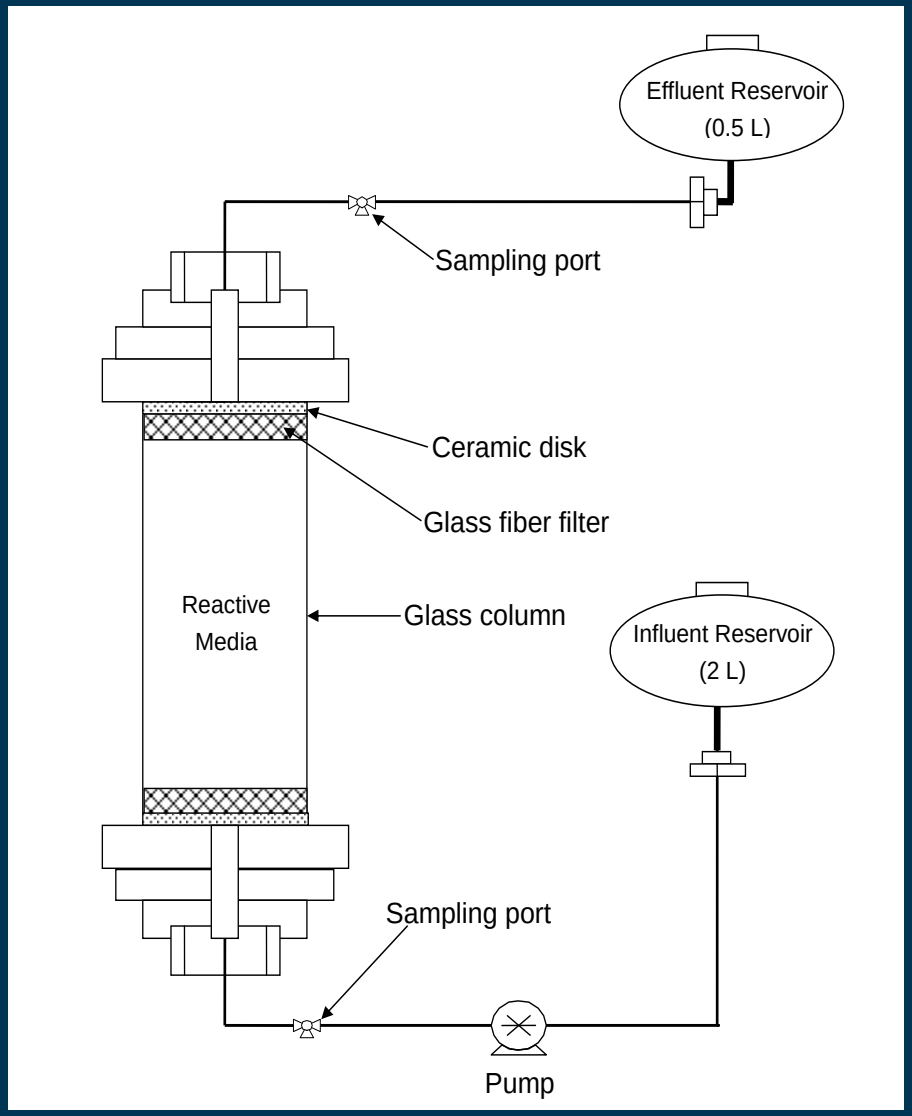
- supernatant analyzed for contaminants of concern

- Column tests:

- flow through experiment simulating field scenario

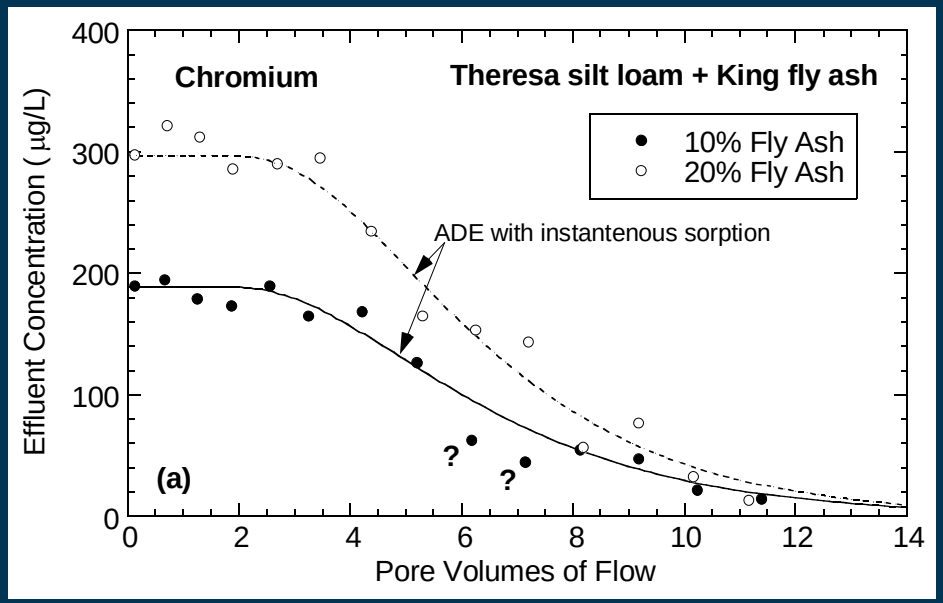
- effluent analyzed for contaminants of concern.

Column Test Schematic



Column test example

Effluent concentrations



Advantages/Disadvantages of Batch Test

Advantages:

- Fast and simple
- Relatively inexpensive

Disadvantages:

- Liquid-to-solid ratio > field
- Perfect mixing not realized in the field
- Can underestimate peak field concentrations

Advantages/Disadvantages of Column Test

Advantages:

- Simulates field condition more accurately
- Shows temporal evolution of concentration

Disadvantages:

- Complicated and time consuming
- More expensive
- Leaching pattern may not replicate field.

Standardized Batch Tests

- TCLP – toxicity characteristic leaching procedure (EPA Method 1311)

- acetic acid/NaOH solution with pH 4.9 or 2.9
- liquid-to-solid ratio = 20:1
- purpose: to determine if a waste is hazardous waste under RCRA (40 CFR Part 261)

What does “not hazardous” imply?

Standardized Batch Tests

- SPLP – synthetic precipitation leaching procedure (EPA Method 1312)

- sulfuric and nitric acid solution (60/40)
- East of Mississippi River, pH 4.2
- West of Mississippi River, pH 5.0
- liquid-to-solid ratio = 20:1
- purpose: to evaluate leaching of waste in response to precipitation

Standardized Batch Tests

- ASTM Water Leach Test (D 3987)

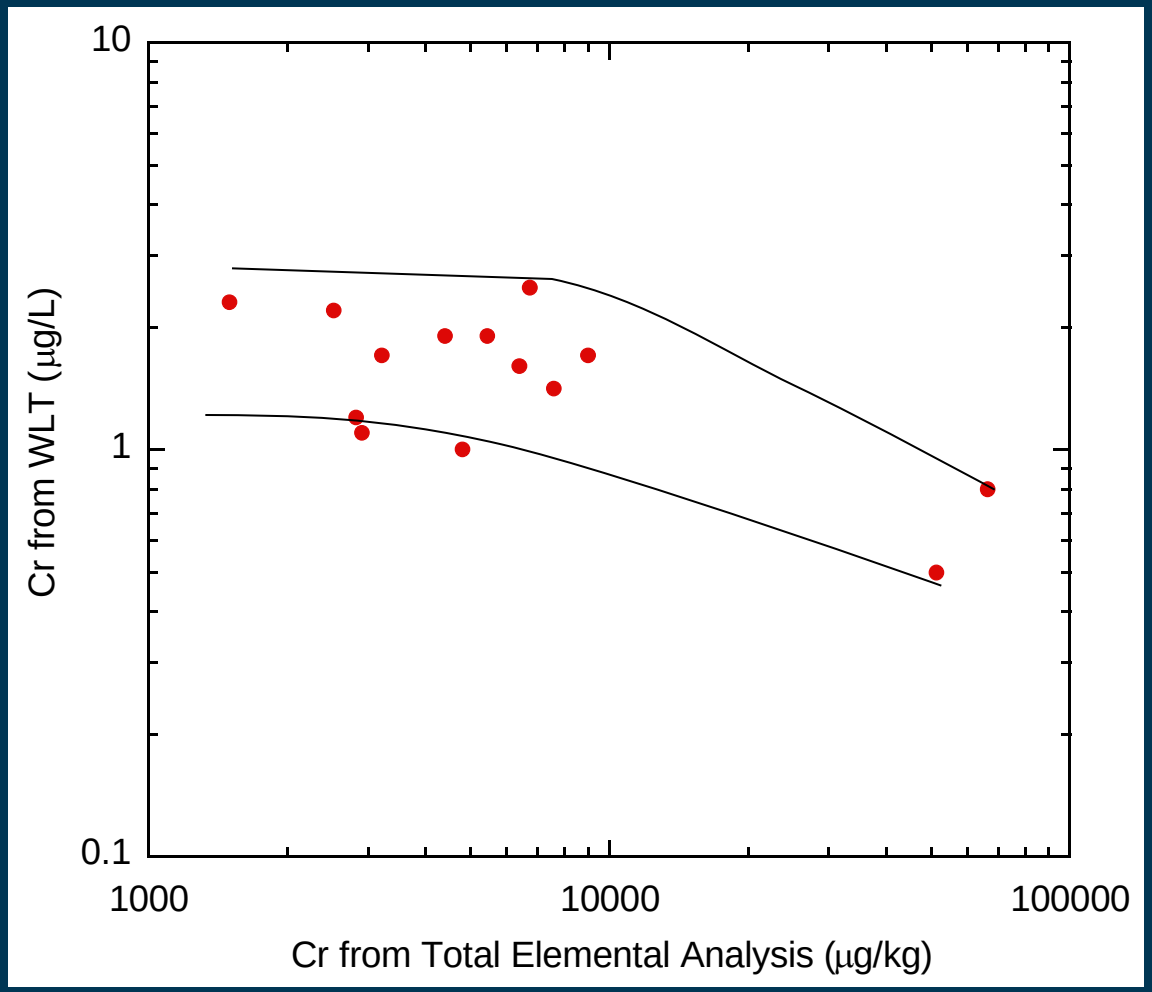
- Deionized water
- liquid-to-solid ratio = 20:1
- purpose: to evaluate leaching of waste

Which batch test mimics field condition?

Total vs. Leachable Concentrations

- Total concentrations determined by digesting (dissolving) the solid in a liquid. Includes leachable and non-leachable constituents.
- Presence of constituent in solid phase does not imply it will leach into water.
- Correlation does not exist between total concentrations and leachable concentrations. Do not assess byproducts based on total concentrations.

Example: Leachable (D 3987) vs. Total Concentrations from Green Sands & Soils



No direct correspondence between total and leachable concentrations, even though total concentrations vary more than one order of magnitude.

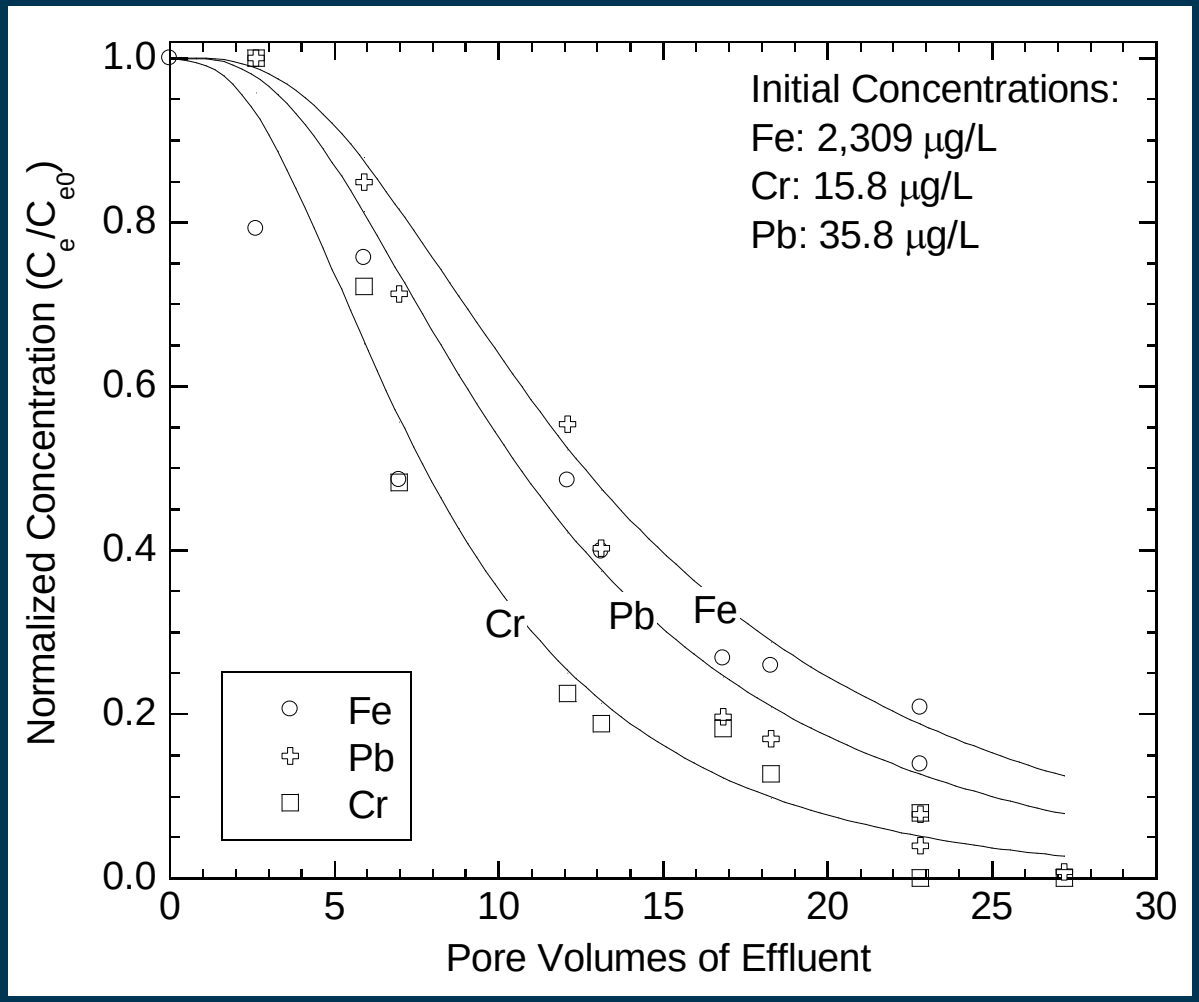
Water Leach Tests on Green Sands from Grey Iron Foundries

Material	Concentration (μg/L)								
	Be (0.4)	Al (1500)	Cr (10)	Mn (25)	Fe (150)	Ni (20)	Cu (130)	Zn (2500)	As (5)
Green Sand 1	0.1	250.4	1.1	4.4	91.6	1.8	12.4	2.3	3.5
Green Sand 2	0.1	**1876.0**	1.6	8.1	**658.6**	2.0	13.5	5.7	4.2
Green Sand 3	0.1	376.0	2.2	2.1	**163.8**	0.9	8.4	2.3	2.6
Green Sand 4	0.2	**3131.0**	2.5	17.4	**1483.4**	3.1	17.1	8.8	**7.3**
Green Sand 5	0.1	1257.6	1.9	8.0	**376.2**	3.0	15.4	5.9	4.2
Green Sand 6	<0.1	859.5	1.0	5.7	**234.0**	2.2	17.9	2.4	1.1
Green Sand 7	<0.1	183.6	0.5	12.4	**515.0**	1.9	3.2	1.7	1.7
Green Sand 8	**0.5**	**2060.6**	1.7	7.1	**486.8**	2.4	15.0	2.9	2.1
Green Sand 9	0.1	240.5	1.7	**46.2**	**415.5**	7.0	11.2	57.0	0.6
Green Sand 10	<0.1	851.1	1.9	9.6	**256.0**	2.0	20.6	4.4	4.3
Green Sand 11	0.1	1217.0	2.3	5.7	**342.5**	1.6	12.2	5.0	**7.5**
Green Sand 12	<0.1	89.4	0.8	2.7	128.2	1.6	13.3	1.1	0.3
Silty Sand	0.2	137.7	1.2	5.7	91.7	2.6	**208.4**	24.0	<0.2
Clean Sand	<0.1	141.84	1.41	3.2	7.72	1.29	3.58	<0.2	2.07

Water Leach Tests on Green Sands from Grey Iron Foundries & Soils

Material	Concentration (μg/L)								
	Se (10)	Mo (50)	Ag (10)	Cd (0.5)	Sb (1.2)	Ba (400)	Hg (0.2)	Tl (0.4)	Pb (1.5)
Green Sand 1	3.7	3.0	0.0	0.1	0.6	7.8	**1.0**	0.0	0.3
Green Sand 2	5.5	3.0	0.2	<0.03	0.2	12.3	**0.8**	0.0	0.9
Green Sand 3	<2.0	2.2	0.1	0.0	0.4	2.7	**1.1**	0.1	0.2
Green Sand 4	5.5	5.0	0.1	0.0	**1.6**	18.6	**1.0**	0.0	**1.7**
Green Sand 5	<2.0	3.3	<0.02	0.1	0.6	14.4	**0.7**	0.0	0.5
Green Sand 6	5.9	9.9	0.3	0.3	**2.2**	9.1	**1.3**	0.2	**5.1**
Green Sand 7	<2.0	1.2	0.4	<0.03	0.3	7.0	**0.5**	<0.02	1.4
Green Sand 8	<4	7.9	3.1	**0.6**	**3.4**	10.3	**0.5**	0.3	**12.2**
Green Sand 9	<2.0	2.4	0.3	0.4	0.3	11.1	**0.5**	0.1	**5.3**
Green Sand 10	<2.0	2.9	0.1	<0.03	0.5	10.1	**0.5**	0.0	0.3
Green Sand 11	<2.0	6.6	0.1	0.1	0.7	6.4	**0.6**	0.0	0.4
Green Sand 12	<2.0	6.0	<0.02	<0.03	0.2	4.5	**0.4**	<0.02	0.2
Silty Sand	<4	0.3	0.2	**1.1**	**1.6**	7.1	**1.0**	0.1	**32.1**
Clean Sand	<2	0.3	<0.02	<0.03	0.18	7.1	**1.1**	0.04	0.08

Example: Column Leach Test on Green Sand No. 2

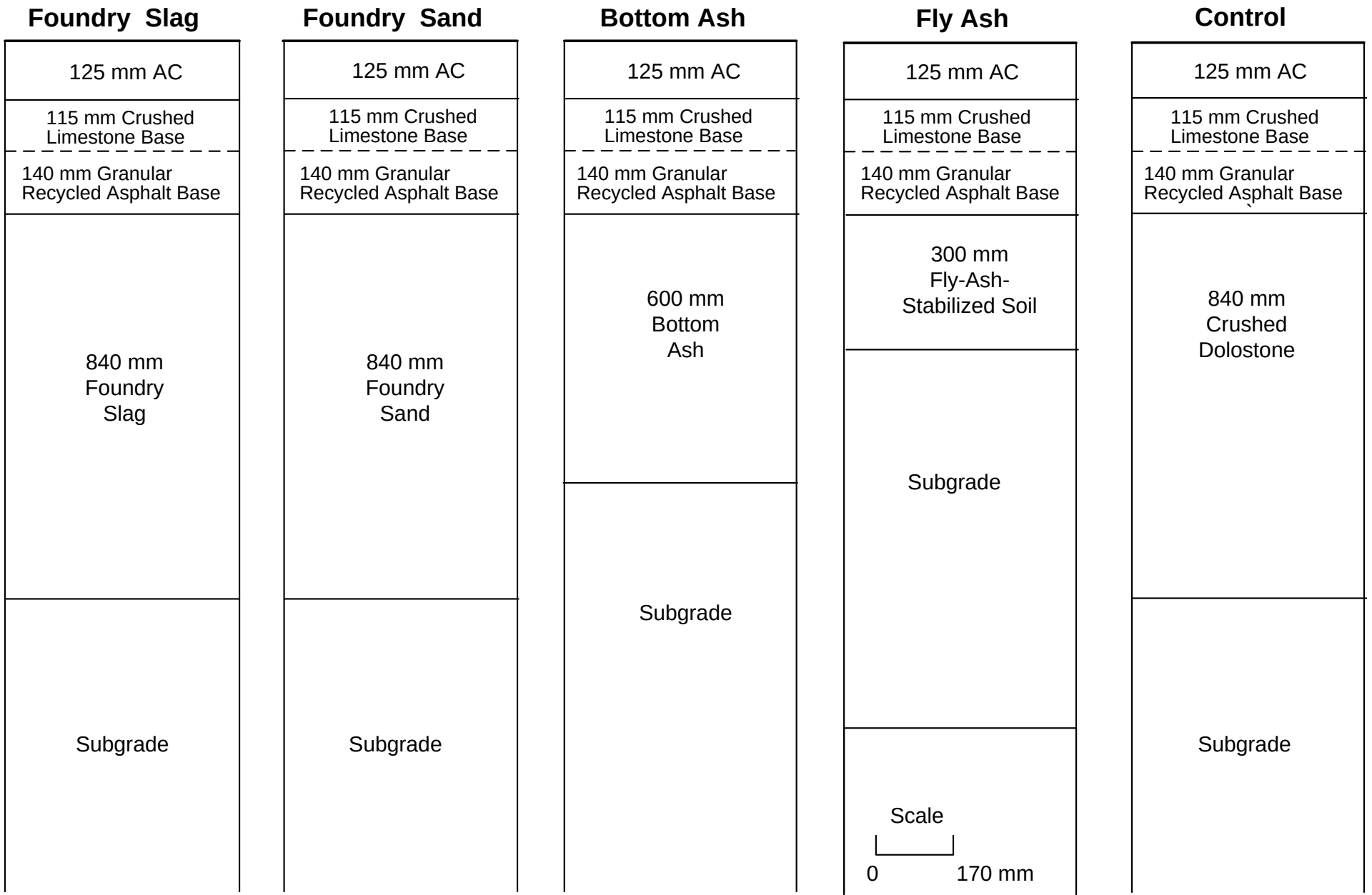


- MCL only exceeded for Pb.
- Concentrations diminish over time.
- WLT on Green Sand 2 is 0.9 ❍g/L. Initial eluted concentration higher from column test.

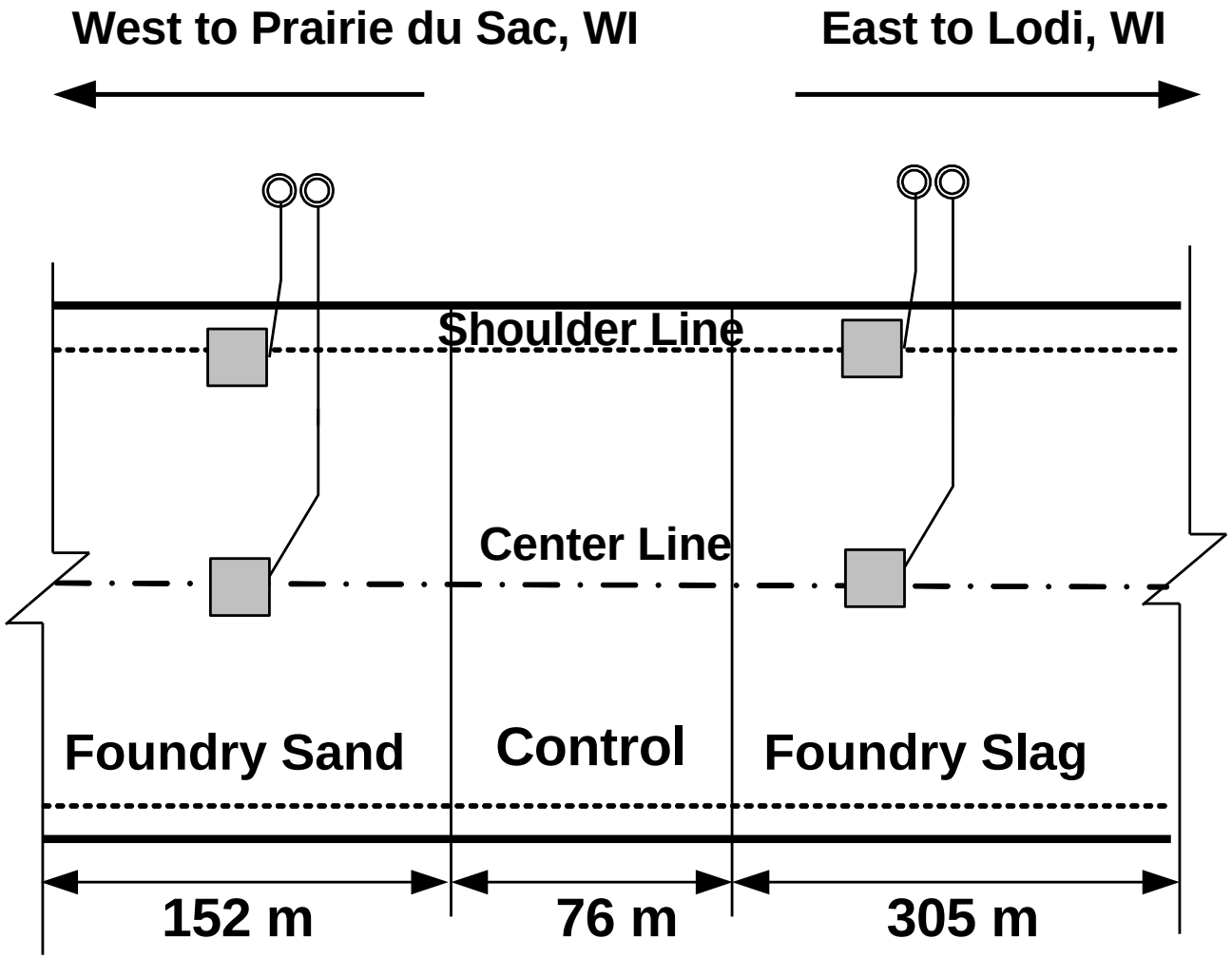
Recap – Leaching Test Methods

- True or False: A non-hazardous designation from a TCLP test indicates that a byproduct can be used in construction.
- True or False: The TCLP, SPLP, and ASTM WLT yield similar concentrations in leachate.
- True or False: Leachate concentrations are directly related to total concentrations.
- True or False: Flow through conditions in a column test better represent the field than well-stirred conditions in a batch test.

Field Evaluation: The STH 60 Project



Lysimeter Layout: STH 60



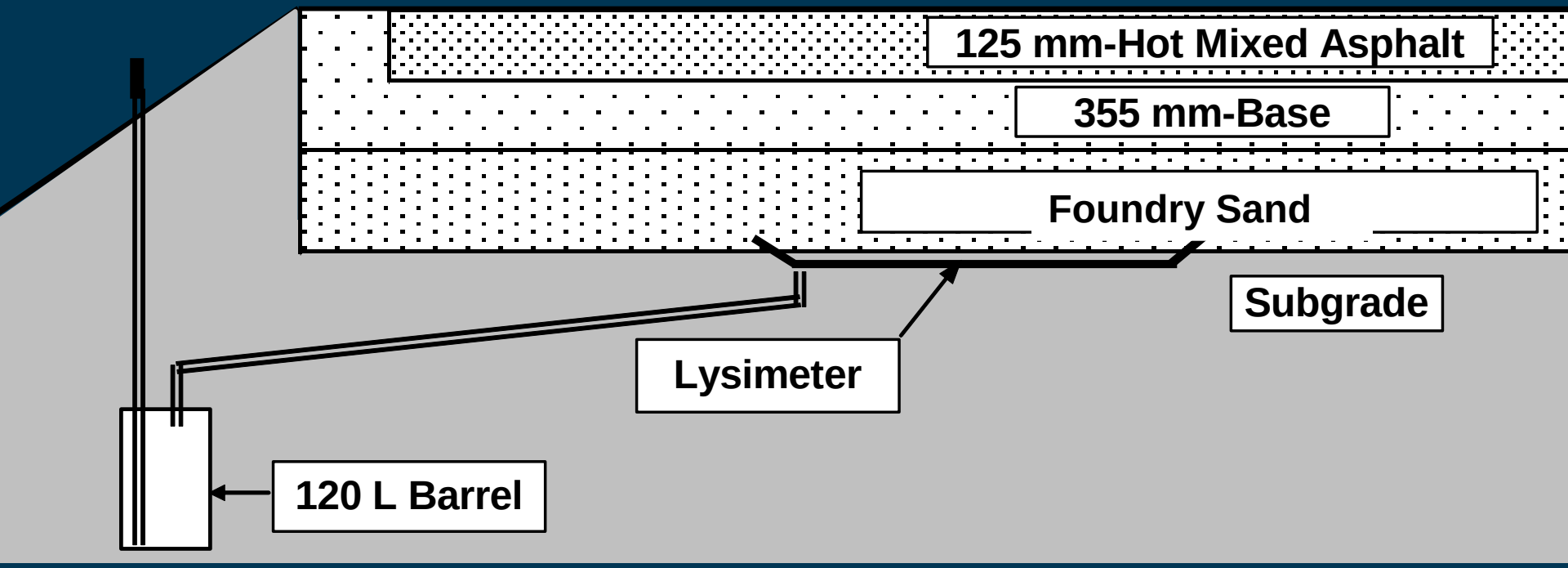
Legend

Lysimeter

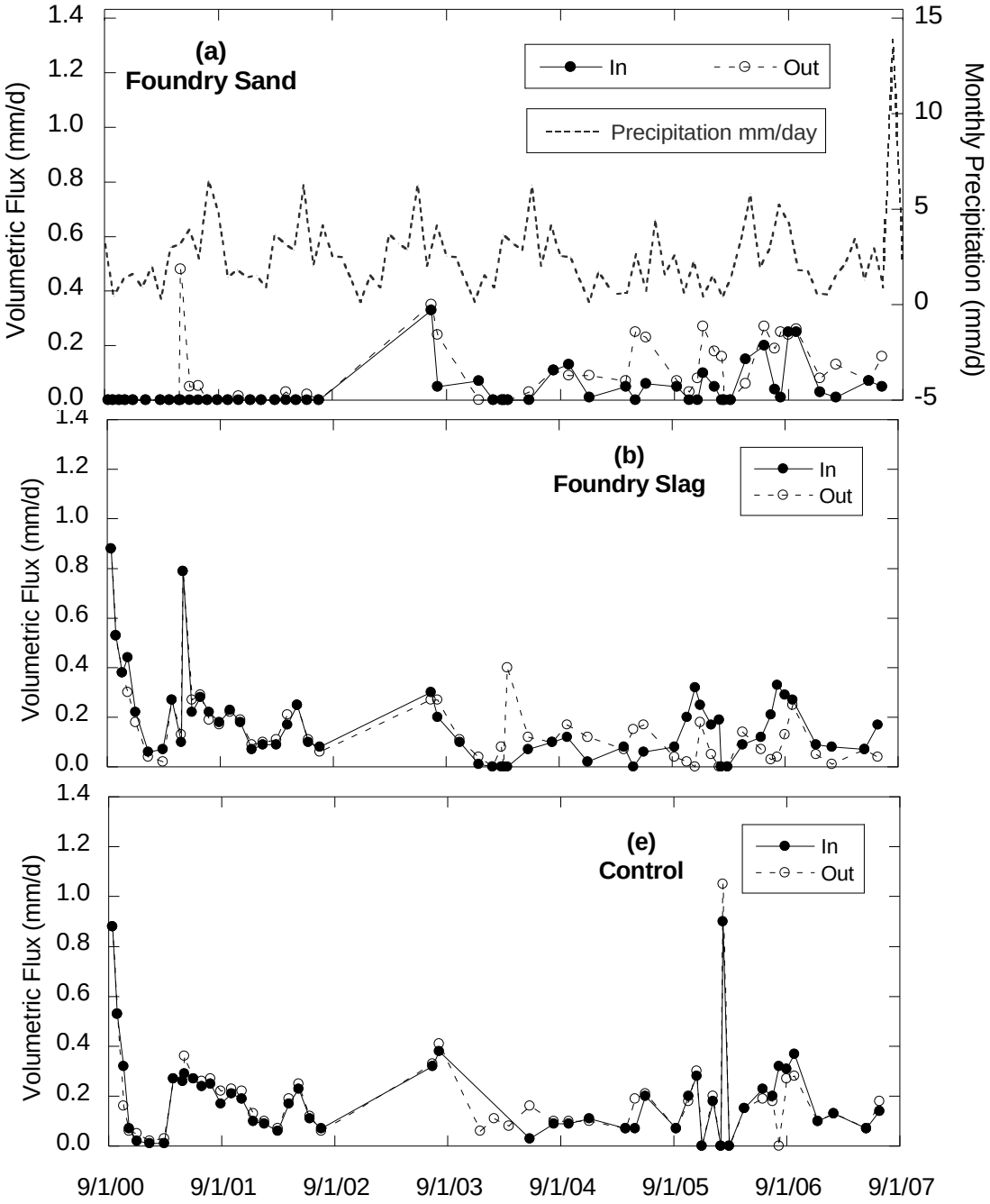
Collection Tank

(Not to scale)

Lysimeter Cross-Section: STH 60



Leachate analyzed for Ag, Cd, Cr, and Se per NR 538

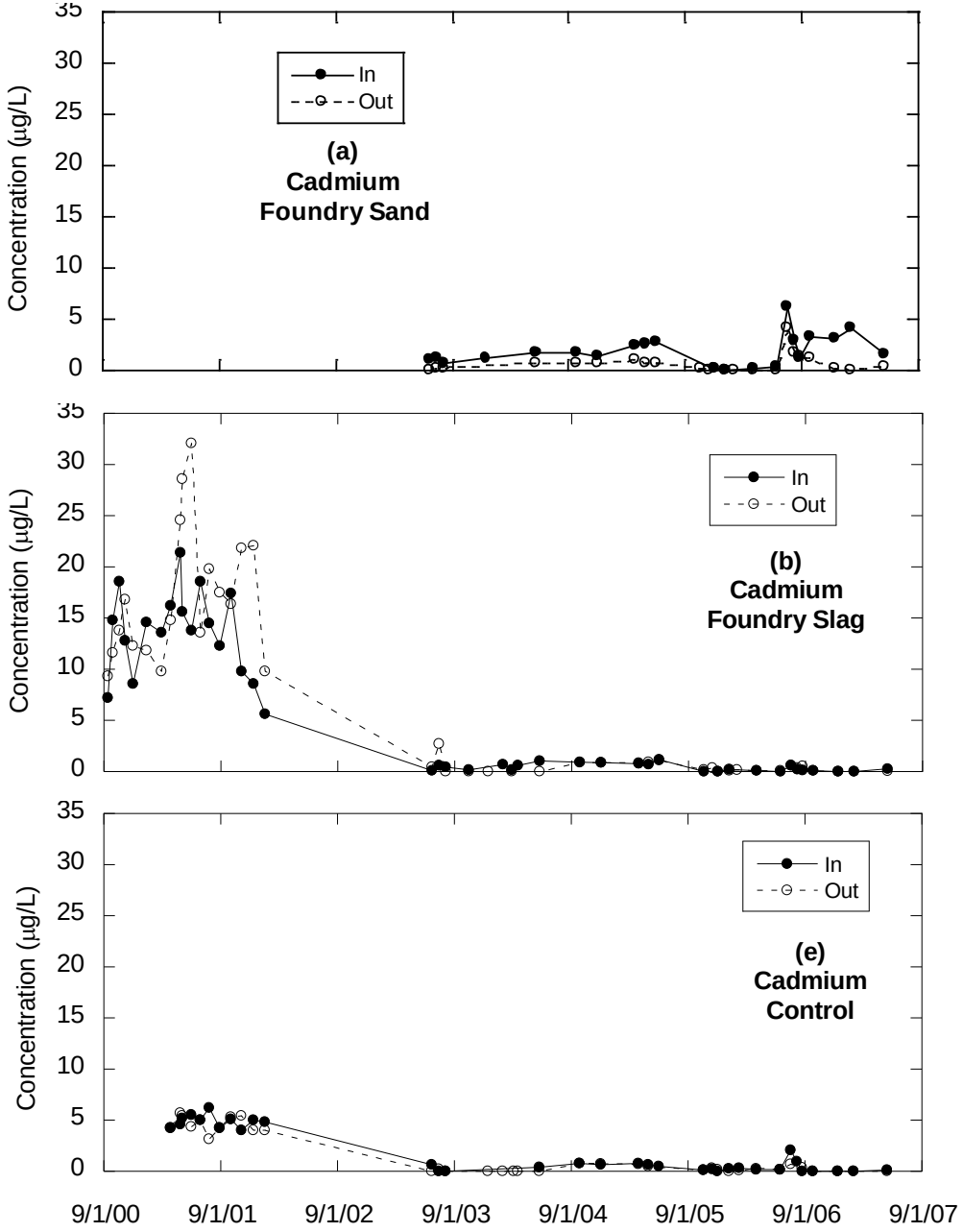


Fluxes

Flux from foundry sand section delayed because the sand had lower hydraulic conductivity than slag or control (BC = 12%).

Flux generally < 0.2 mm/d for foundry sand; < 0.4 mm/d for slag or control.

Seasonal variation.



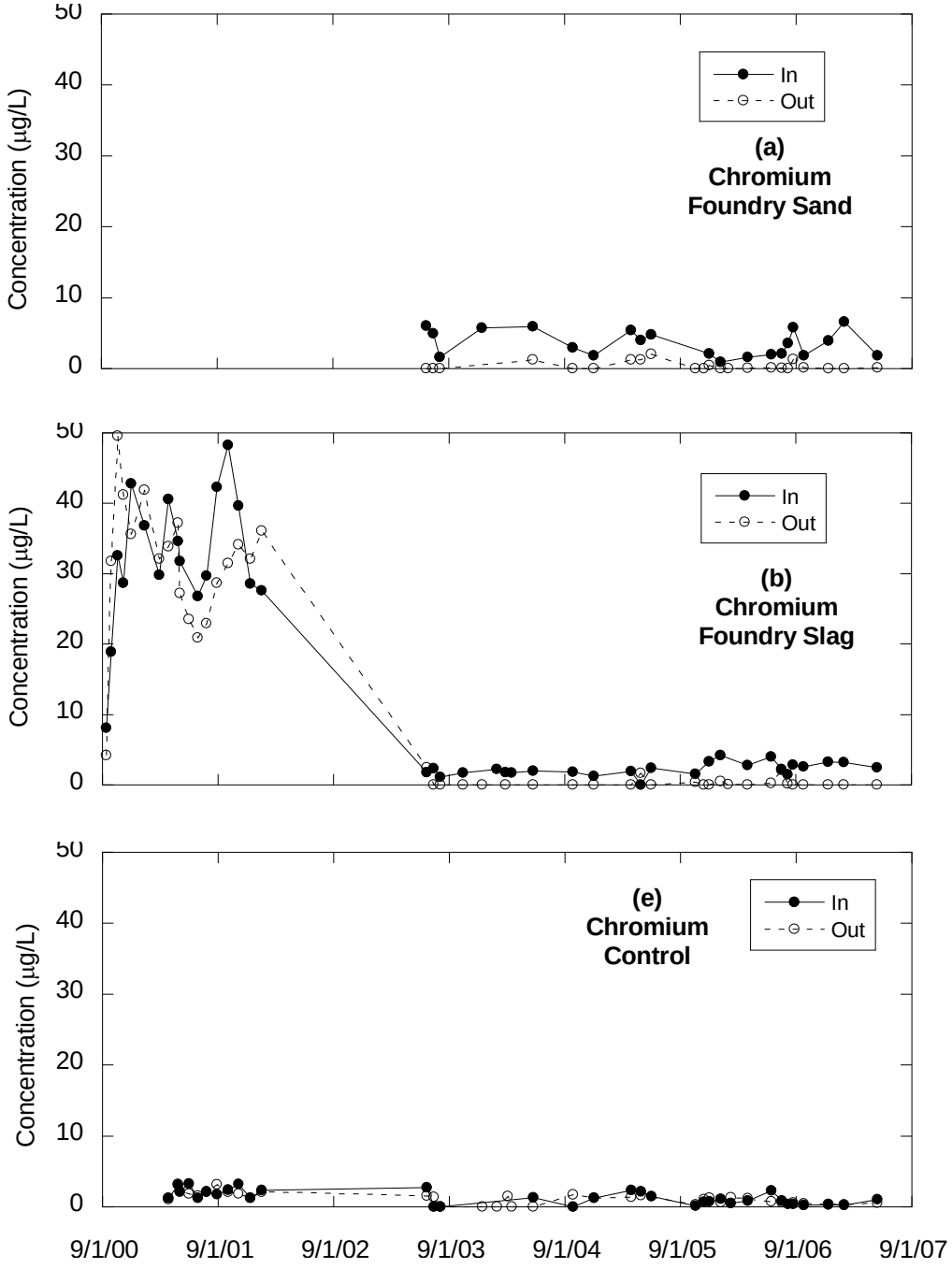
Cadmium

MCL = 5 µg/L.

Note that control elutes Cd > MCL early in study.

All sections drop below MCL within two years (except outlier in July 2006).

DL: Cd = 0.7 µg/L



Chromium

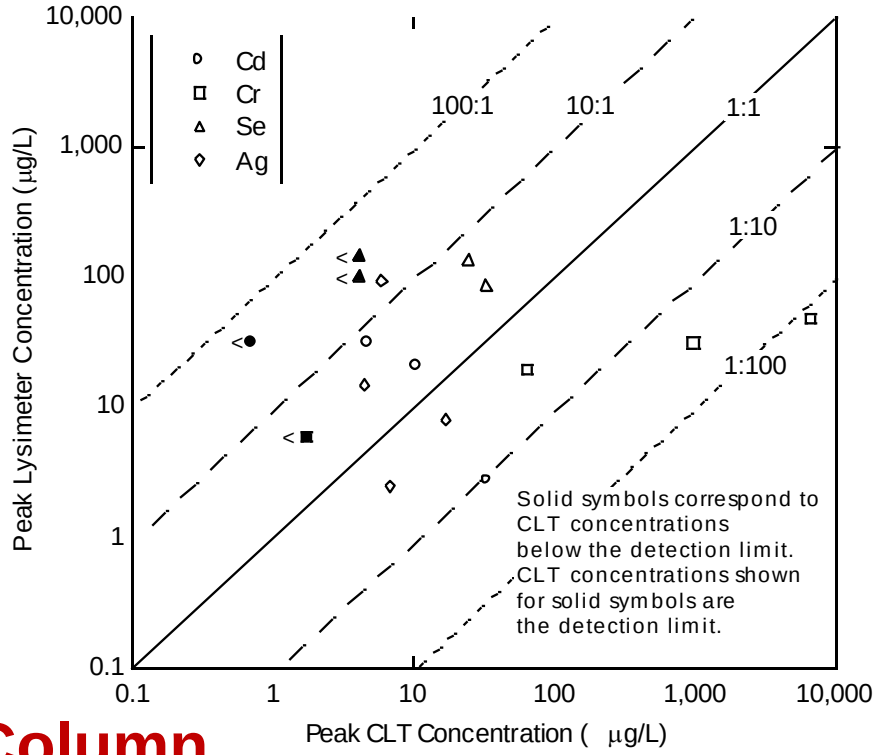
MCL = 100 ❍g/L.

None of test sections elute Cr > MCL.

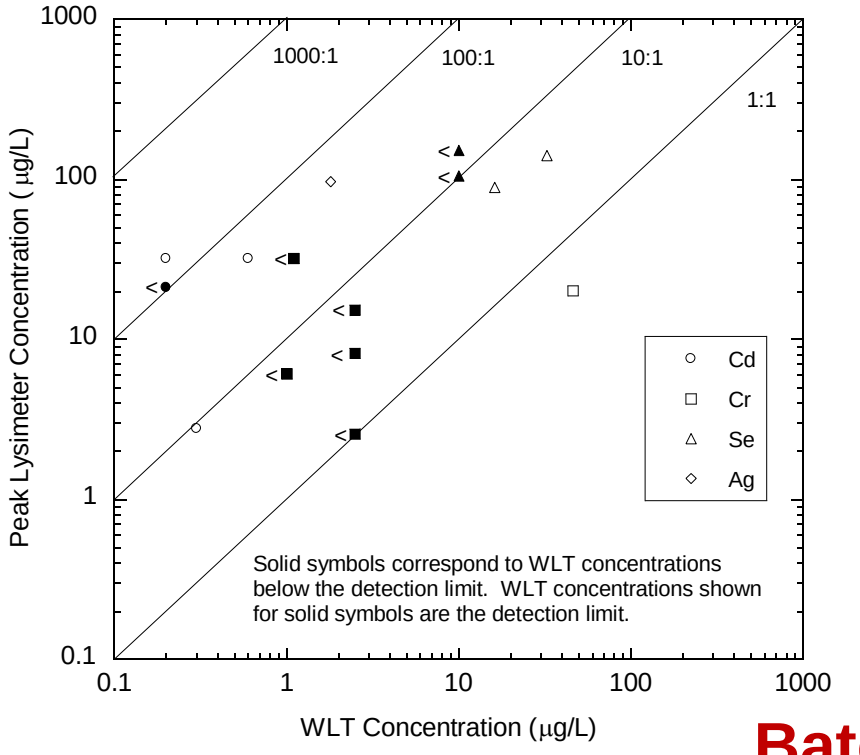
Foundry sand and control are essentially same; slag is similar to sand & control after one year.

DL: Cr = 1.7 ❍g/L

Column or batch: which is more realistic?



Column



Batch

From foundry sand, foundry slag, coal fly ash, & coal bottom ash

CLT has better agreement with field than WLT; neither is perfect.

Recap – Field Leaching Data

- True or False: Long-term field leaching data are available for most industrial byproducts used in construction.
- True or False: Control tests should be avoided to prevent confusion when interpreting leachate data.
- True or False: HMA pavement surfaces are essentially impermeable.
- Concentrations from column tests (a) or batch (b) water leach tests are more similar to concentrations measured in the field.

Models to Evaluate Groundwater Impacts

- WiscLEACH
  (https://mywebspace.wisc.edu/chbenson/Software/)

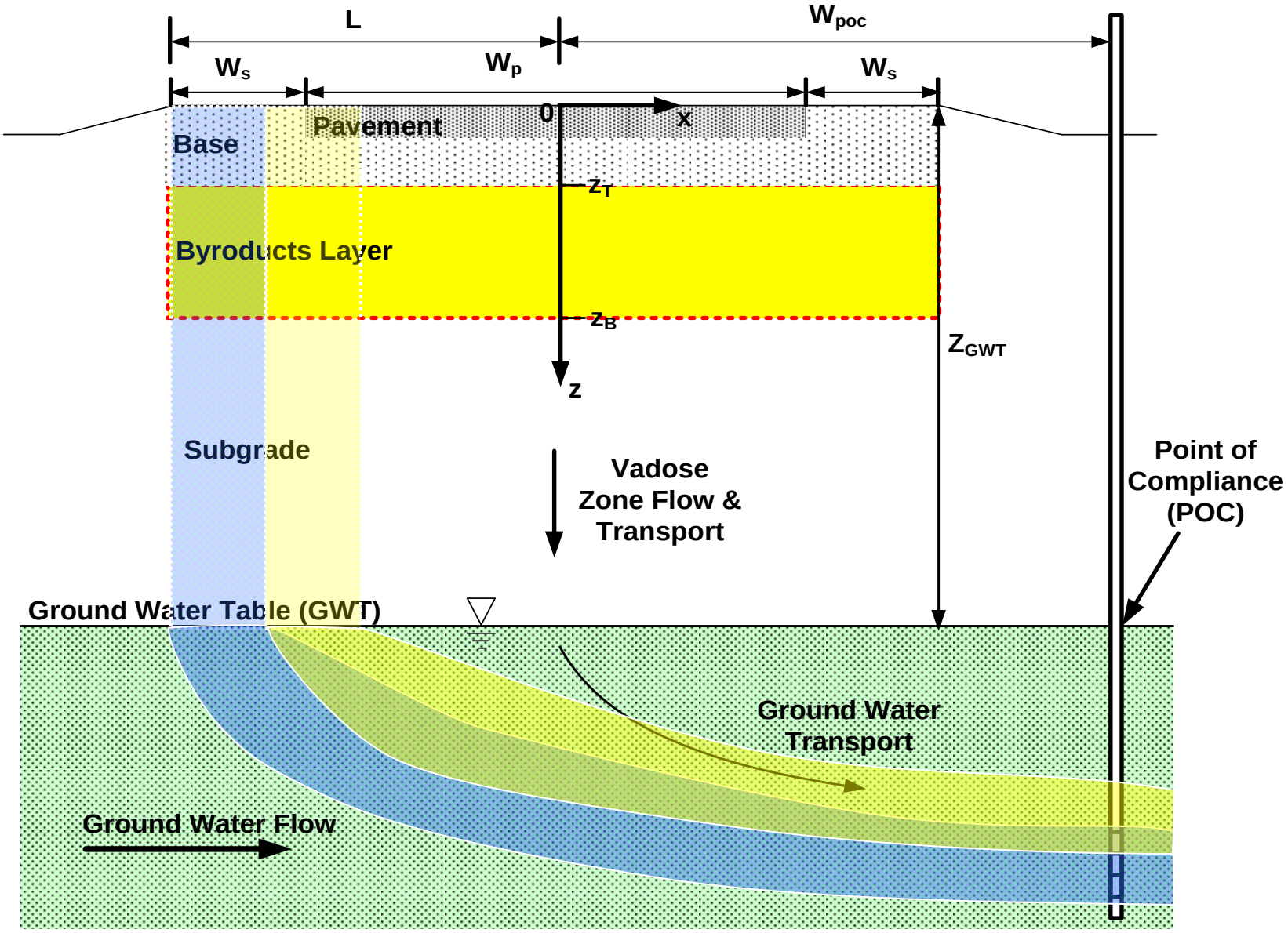
- IWEM
  (http://www.epa.gov/epaoswer/non-hw/industd/tools/iwem/index.htm)

- STUWMPP
  (http://www.dot.state.mn.us/stateaid/res_flyash.html)

-IMPACT
(http://www.trb.org/TRBNet/ProjectDisplay.asp?ProjectID=739)

All are freeware

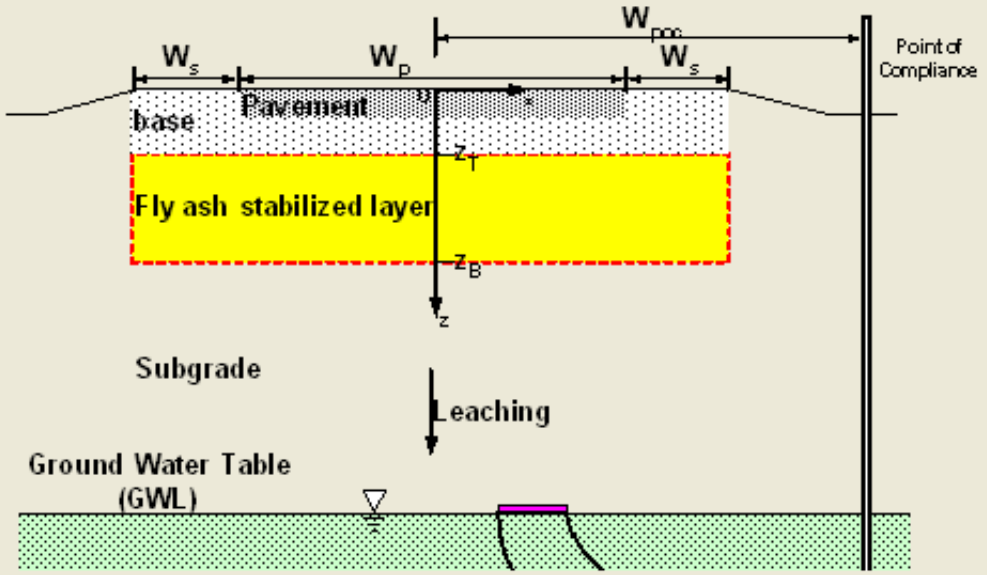
WiscLEACH Conceptual Model



Site Parameters

Enter site parameters

	Value	Unit
Point of compliance (Wpoc):	20	m
Pavement width (Wp) :	10	m
Shoulder width (Ws):	1.5	m
Depth to ground water table (GWL) :	6	m
Depth to top of stablized layer (Dt) :	.38	m
Depth to bottom of stablized layer (Db) :	.68	m
Annual precipitation (Prcpt) :	.365	m/year
Maximum simulation time (Tmax) :	60	year



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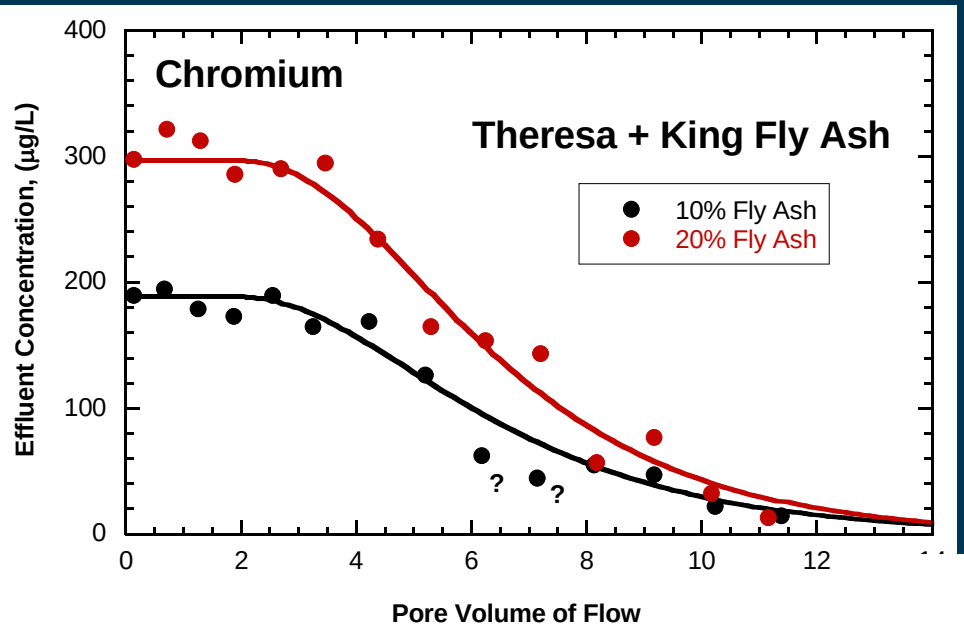
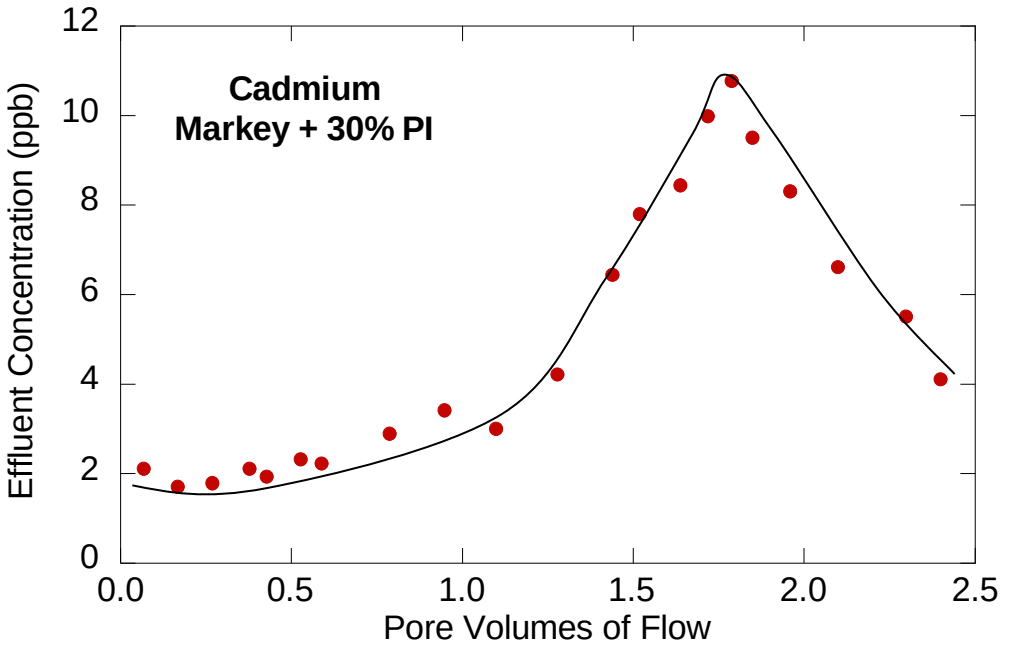
Input is in Windows format with graphical interface.

Leaching Patterns

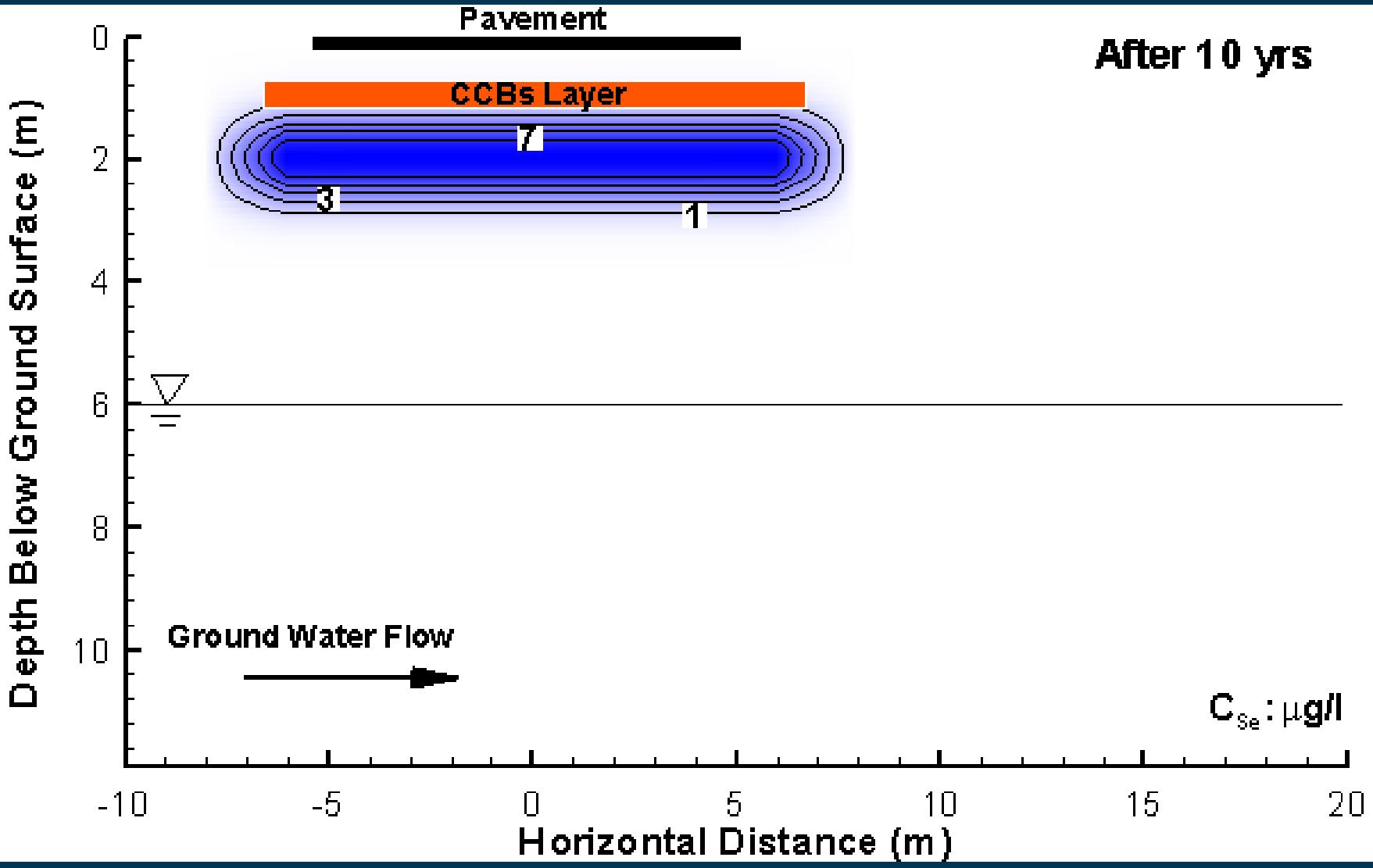


First flush following ADRE

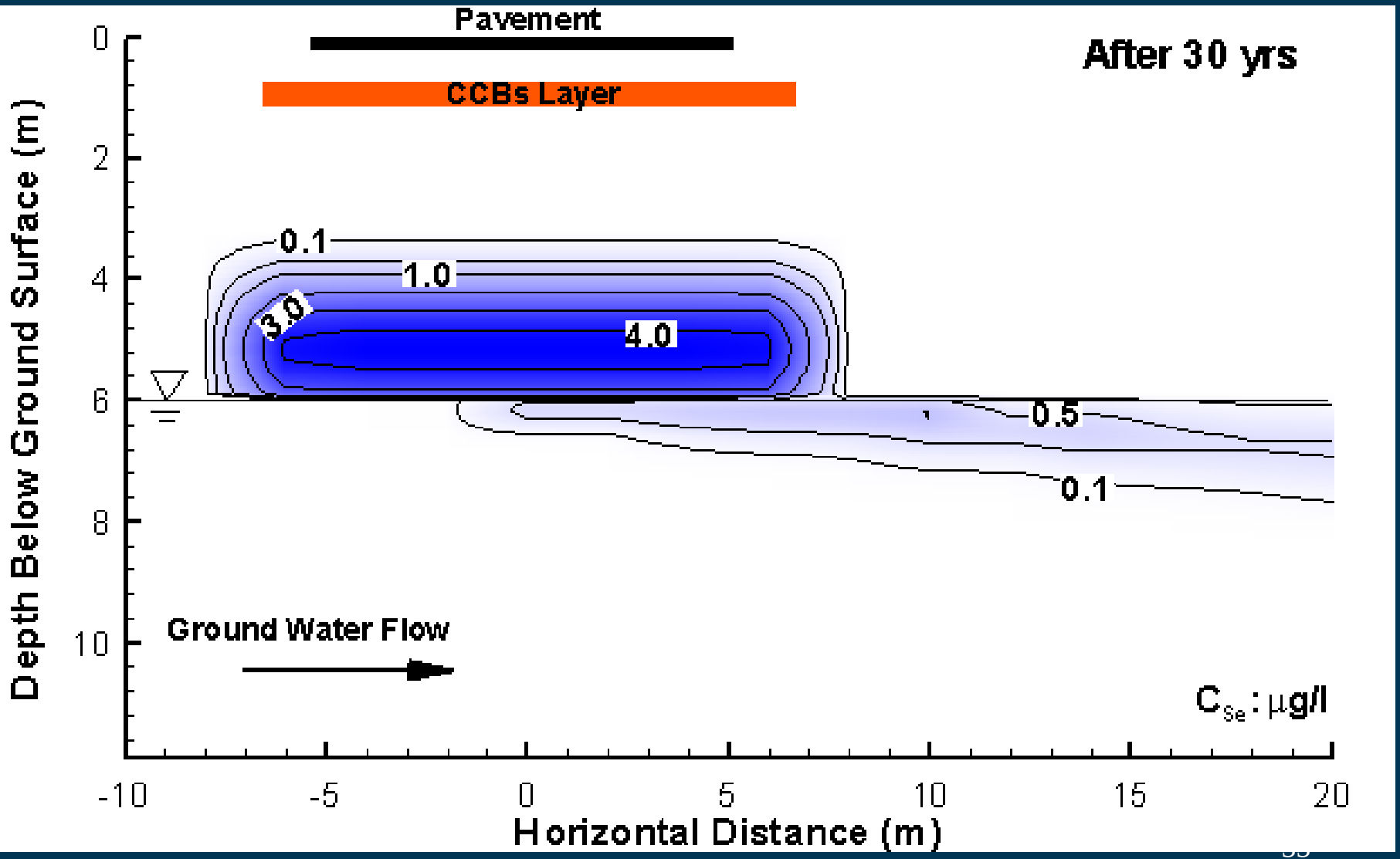
Delay response (user defined)



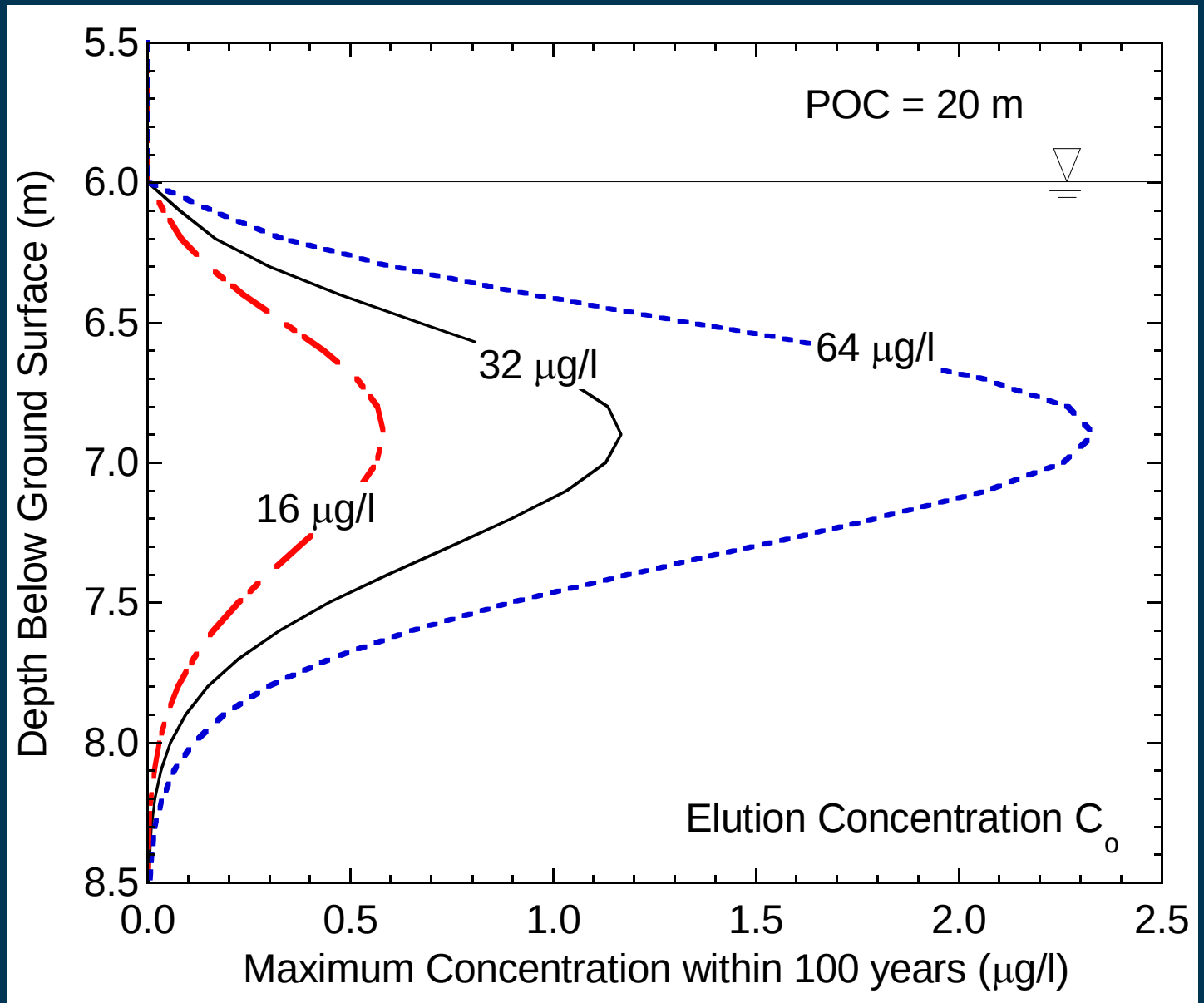
Typical Output: Se Concentration - 10 yr



Typical Output: Se Concentration - 30 yr



Example: Maximum Concentrations at Point of Compliance



Concluding Comments

- Look for regulations in your state. If none exist, propose using Wisconsin's NR 538.
- Column tests provide a more realistic depiction of leaching, but batch tests are more common.
- Peak concentrations in effluent from column tests and from the field typically are larger than those measured in batch tests.
- Conduct tests with eluent that resembles field condition if possible. Do not use acidic eluents unless justified by site conditions.

Concluding Comments

- Do not use TCLP for assessing suitability of foundry byproducts (or other industrial resources) for use in construction applications. ASTM D 3987 preferred.
- Determination of “non-hazardous” by TCLP does not mean OK. Only inference is that solid would not need to be disposed in a hazardous waste landfill.
- Compare leaching from byproducts against leaching from conventional materials. Leaching is expected from nearly all materials used for unbound applications in highway construction.

Concluding Comments

- Models exist to evaluate groundwater impacts from reuse applications when a code providing predefined reuse options (e.g., Wisc. NR 538) does not exist. Comparison should be made considering byproducts as well as conventional materials.