Screening-level Assessment of Uncapped Landfills in the Pinelands Area

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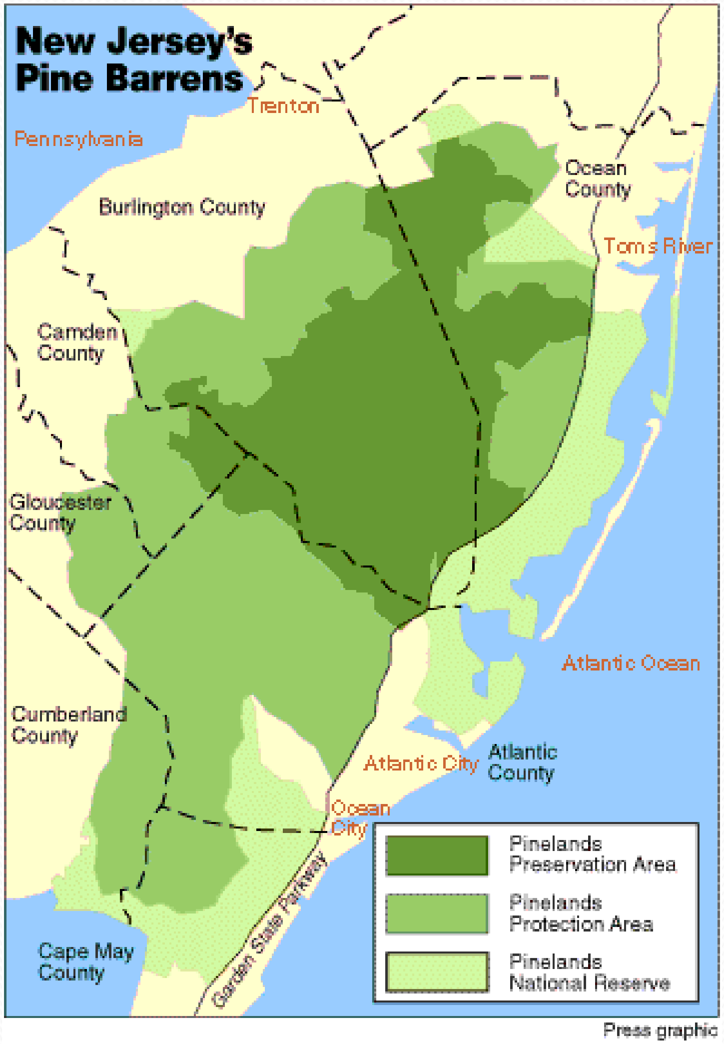
Project Background



- **Purpose:** There are at least 60 closed, uncapped landfills in the New Jersey Pinelands. The question posed by the Pinelands Commission was "Which of these pose environmental or health concerns, based on down-gradient water quality? Which need more monitoring or remediation before redevelopment?"
- **Study area:** The New Jersey Pinelands Reserve

Landfill Selection Criteria

- Within the New Jersey Pinelands Area
- Not solely vegetation or construction waste
- Permitted by NJDEP
- Ceased Operation after 9/23/1980 (if in Preservation Area after 1/14/81)
- No current Remediation effort underway
- 48 landfills meet these criteria
  - 30 of those had monitoring well data

Project objectives

- **Develop a screening tool for assigning *levels of concern* for closed, uncapped landfills**
  - Based on a simplified a solute-transport model
  - Uses monitoring-well data, hydraulic parameters, contaminant chemical properties, and distances from the landfill to receptors (water, wetlands, urban areas) to landfills
  - Level of concern is based on steady-state concentrations of contaminants at receptors relative to regulatory concentrations
- **Apply screening tool to landfills in the New Jersey Pinelands**
  - Assemble and quality-assure water-quality data
  - Assemble hydrologic, landfill, contaminant reactivity and other data
  - Predict contaminant concentrations reaching receptors

Sources of Information

- Well Permits, Well Records, Drillers' Logs
- Monitoring Well Lab Results
- Permit Applications and Site descriptions
- GIS data (NJDEP and USGS)
- State and Federal Water-Quality Standards
- Published chemical property data for contaminants
- Solute transport model developed by PA DEP (Quick Domenico)

QA of water-quality data

- Monitoring-well data were received as paper files from NJDEP
- Data were manually digitized by USGS
- 10%-100% of entries were checked for errors
  - Original data-entry errors by NJDEP
  - Transcription errors by USGS
  - Error rate was low, typically >>1%
- An Access database was populated with water-quality and all other relevant data
- Additional quality checking was conducted whenever data were accessed
- **Data acquisition, managing and QA was a major effort in this investigation**

Domenico approach to groundwater-transport model

- Based on widely used transport equations
- Supported by the USEPA.
  - USEPS Center for Subsurface Modeling Support
    - BIOSCREEN, BIOCHLOR, FOOTPRINT, and REMChlor
- Spreadsheet version developed by PA DEP
  - "Quick Domenico"
- Estimates contaminant concentration downgradient from a source

Generic solute transport equation and Dominico transport model

$$\frac{\partial C}{\partial t} + \frac{v}{R}\frac{\partial C}{\partial x} - \frac{D_x}{R}\frac{\partial^2 C}{\partial x^2} - \frac{D_y}{R}\frac{\partial^2 C}{\partial y^2} - \frac{D_z}{R}\frac{\partial^2 C}{\partial z^2} + \lambda C = 0$$

Generic model of three-dimensional (3D) non-steady-state
solute transport of a dissolved solute through porous media

$$C(x,y,z,t) = (\frac{C_o}{8})\exp\left\{ {x}/{2\alpha_x}\left[1-\left(1+{4\lambda\alpha_x}/{v}\right)^{\frac{1}{2}}\right]\right\} erfc\left\{\left[x - vt\left(\sqrt{1+4\lambda\alpha_x / v}\right)\right] / 2\sqrt{\alpha_x vt}\right\}$$

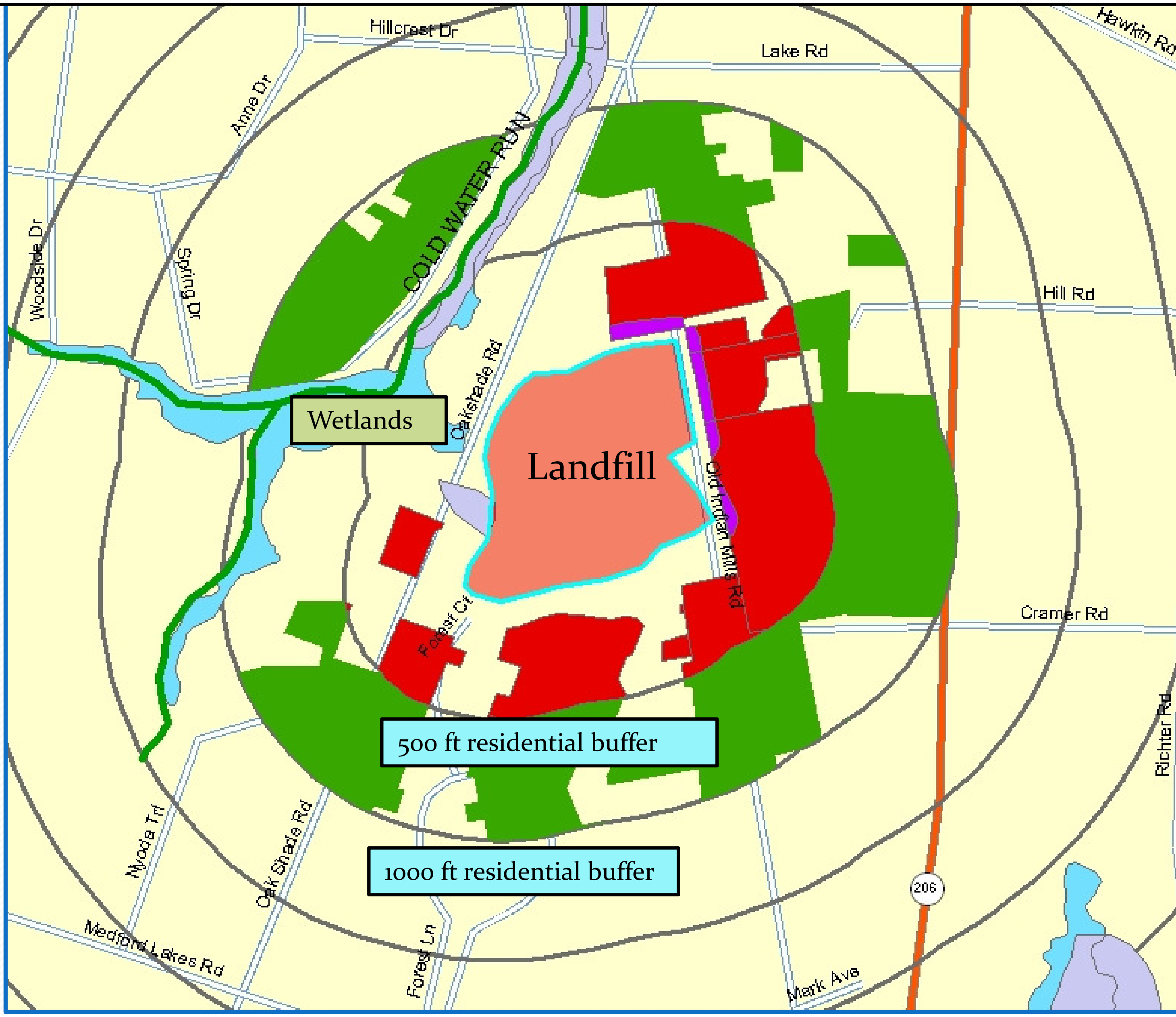
$$\left\{erf\left[\left(y+Y/2\right)/2\sqrt{\alpha_y x}\right] - erf\left[\left(y-Y/2\right)/2\sqrt{\alpha_y x}\right]\right\}\left\{erf\left[\left(z+Z/2\right)2\sqrt{\alpha_z x}\right] - erf\left[\left(z-Z/2\right)/2\sqrt{\alpha_z x}\right]\right\}$$

Domenico solute transport model. Important point: this equation can be
Solved algebraically, e.g. on a spreadsheet

Receptors were defined as:

- Nearest ***stream*** to landfill
- Nearest ***wetlands*** to landfill
- Nearest ***residential area*** to landfill

Geographical Information System (GIS) Map showing a Landfill in the Pinelands and Receptors



Quick Domenico model spreadsheet

ADVECTIVE TRANSPORT WITH THREE DIMENSIONAL DISPERSION,1ST ORDER DECAY and RETARDATION - WITH CALIBRATION TOOL

Project: Fate and Transport Training
Date: 8/20/2002 Prepared by: JPS
Contaminant: Benzene

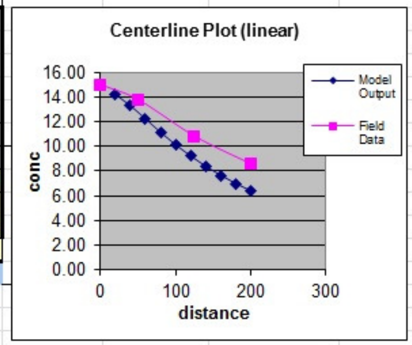
NEW QUICK_DOMENICO.XLS
SPREADSHEET APPLICATION OF "AN ANALYTICAL MODEL FOR MULTIDIMENSIONAL TRANSPORT OF A DECAYING CONTAMINANT SPECIES"
P.A. Domenico (1987)
Modified to Include Retardation

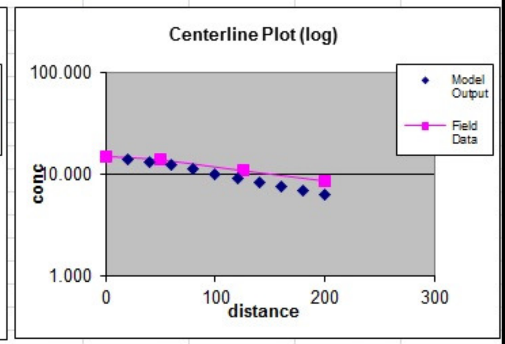
SOURCE CONC (MG/L)	Ax (ft)	Ay (ft)	Az (ft) >=.001	LAMBDA day-1	SOURCE WIDTH (ft)	SOURCE THICKNESS (ft)	Time (days) (days)
15	5.00E+01	5.00E+00	1.00E-04	0.002	100	10	1000

Hydraulic Cond (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dec. frac.)	Soil Bulk Density (g/cm^3)	KOC	Frac. Org. Carb.	Retard-ation (R)	V (=K*i/n*R) (ft/day)
3.00E+01	0.01	0.358	1.7	58	1.00E-03	1.275418994	0.657030223

Point Concentration

	x(ft)	y(ft)	z(ft)
	200	100	0
Conc. At	200	100	0
at	1000	days =	1.144 mg/l





AREAL CALCULATION MODEL DOMAIN
Length (ft) 200
Width (ft) 200

	20	40	60	80	100	120	140	160	180	200
200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
100	0.003	0.084	0.263	0.466	0.651	0.807	0.931	1.026	1.096	1.144
0	14.200	13.293	12.227	11.150	10.142	9.226	8.404	7.667	7.007	6.415
-100	0.003	0.084	0.263	0.466	0.651	0.807	0.931	1.026	1.096	1.144
-200	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003

Field Data:					
Centerline Concentration	15	13.81	10.85	8.61	
Distance from Source	0	50	125	200	

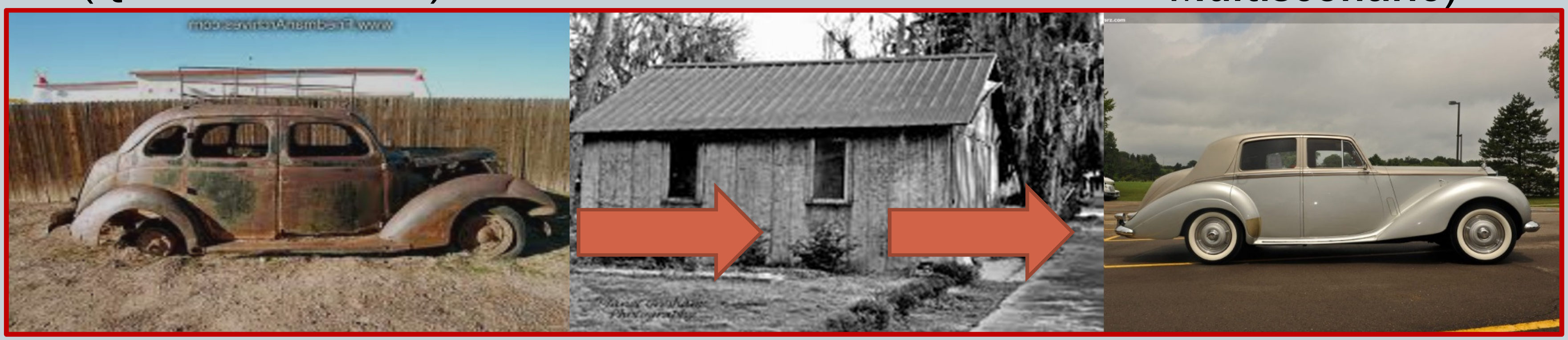
Limitations: Only one scenario per worksheet, no provision for archiving scenarios, several input parameters could be calculated automatically (dispersivities, time to steady-state), graphics of limited value

Quick Domenico is a classic,
But our new model is a Rolls Royce!

Old Model (Quick Domenico)

USGS Model Renovation Service (Ron Baker's office)

New Model (Quick Domenico Multiscenario)



<u>Under the hood</u>:

-Up to 50 simulations on a single spreadsheet

-Automatic calculation of appropriate run time and dispersivity

-Regulatory values of contaminants for comparison to model outputs

Quick Domenico Multi-scenario (QDM)

Quick Domenico Multi-scenario (QDM) Spreadsheet

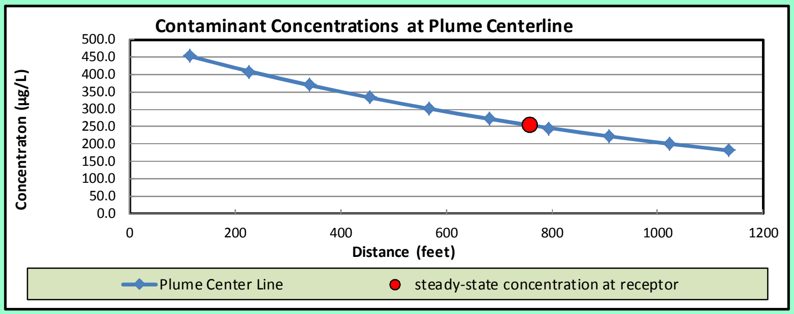
Project:	South Toms River	Password:		Date:	5/23/2014	Prepared by:	RJB

Simulation Number:	7	Contaminant:	›gen, Nitrate, Disso	Receptor:	Stream

Steady-State Concentraton (ug/L)	254.13
Regulatory Value (ug/L)	320.00
Percent of Regulatory Value	79.42

Source	Dispersivity						Time to reach	Receptor Distance from Source		
Concentrat	Ax	Ay	Az	Lambda	Width	Thickness	Steady State			
(µg/L)	(ft)	(ft)	(ft) >=.001	day-1	(ft)	(ft)	(days)	x(ft)	y(ft)	z(ft)
500.000	15.44	1.54	0.001	0.001266	868	10	1319	757	0	0

Hydraulic	Hydraulic		Soil Bulk		Fraction			Model Domain		
Conductivi	Gradient	Porosity	Density	KOC	Organic	Retardation	Velocity			Peclet
(ft/day)	(ft/ft)	(dec. frac.)	(g/cm^3)	(dec. frac.)	Carbon	(dec. frac.)	(ft/day)	Length (ft)	Width (ft)	Number
50	0.01	0.358	1.7	0.0	0.001	1.00	1.40	1136	868	68



Lateral Distance (f	Simulated Concentrations Downgradient from Source									
	Distance from source									
	113.55	*227.1*	*340.65*	*454.2*	*567.75*	*681.3*	*794.85*	*908.4*	*1021.95*	*1135.5*
	Concentration of Contaminant									
868	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
434	225.868	204.065	184.37	166.57	150.49	135.96	122.84	110.98	100.26	90.52
0	451.735	408.129	368.73	333.14	300.98	271.93	245.68	221.96	200.51	181.04
-434	225.868	204.065	184.37	166.57	150.49	135.96	122.84	110.98	100.26	90.52
-868	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Optional Field Data for model calibration: enter centerline concentrations from well sample data and distances from source to receptor										
Concentra	0	0	0	0	0	0	0	0	0	0
Distance (f	0	0	0	0	0	0	0	0	0	0

A simulation (from numbers 1-50 is selected, and all parameters and results for that simulation are shown in the spreadsheet. Results as a percent of a regulatory value also are shown.

QDM: User-input parameters

Simulation Number	Receptor	Contaminant	Source Concentration (ug/L)	Decay constant Lambda ($days^{-1}$)	Source Width (ft)	Source Thickness (ft)	Hydraulic Conductivity (ft/day)	Hydraulic Gradient (ft/ft)	Porosity (dimensionless)	Soil Bulk Density (g/cm3)	KOC	Fraction Organic Carbon	←-Distance to Receptor-→ x(ft)	y(ft)	z(ft)	Regulatory Value (ug/L)
1	Stream	Chloride	40666.7	0	868	10	50	0.010	0.358	1.70	0.0	0.001	757	0	0	230000.00
2	Wetlands and Hydric So	Chloride	40666.7	0	868	10	50	0.010	0.358	1.70	0.0	0.001	7	0	0	230000.00
3	Residential	Chloride	40666.7	0	868	10	50	0.010	0.358	1.70	0.0	0.001	250	0	0	250000.00
4	Stream	Nitrogen, Amm	17100.0	0.1	868	10	50	0.010	0.358	1.70	3.1	0.001	757	0	0	200.00
5	Wetlands and Hydric So	Nitrogen, Amm	17100.0	0.1	868	10	50	0.010	0.358	1.70	3.1	0.001	7	0	0	200.00
6	Residential	Nitrogen, Amm	17100.0	0.1	868	10	50	0.010	0.358	1.70	3.1	0.001	250	0	0	3000.00
7	Stream	Nitrogen, Nitrat	500.0	0.001265753	868	10	50	0.010	0.358	1.70	0.0	0.001	757	0	0	320.00
8	Wetlands and Hydric So	Nitrogen, Nitrat	500.0	0.001265753	868	10	50	0.010	0.358	1.70	0.0	0.001	7	0	0	320.00
9	Residential	Nitrogen, Nitrat	500.0	0.001265753	868	10	50	0.010	0.358	1.70	0.0	0.001	250	0	0	10000.00
10																
11																
12																
13																
14																
15																
16																
17																
18																
19																
20																

- Up to 50 scenarios are entered and archived per landfill
- Regulatory values are input

QDM: Automatically-calculated input parameters

Simulation Number	←--Dispersivity--→ Ax (ft)	Ay (ft)	Az (ft)	←Simulation Time→ Time (days)	Time (years)	Model Length (ft)	Model Width (ft)	Conc. At Steady State	Velocity (V)	% of Regulatory Value
1	15.44	1.5	0.001	1355	3.7	1136	868		1.40	
2	0.00	0.0	0.001	13	0.0	11	868		1.40	
3	8.13	0.8	0.001	448	1.2	375	868		1.40	
4	15.44	1.5	0.001	587	1.6	1136	868		1.38	
5	0.00	0.0	0.001	13	0.0	11	868		1.38	
6	8.13	0.8	0.001	248	0.7	375	868		1.38	
7	15.44	1.5	0.001	1319	3.6	1136	868	254.13	1.40	79.4
8	0.00	0.0	0.001	13	0.0	11	868		1.40	
9	8.13	0.8	0.001	441	1.2	375	868		1.40	
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										

- Dispersivities, time to steady-state and model dimensions are calcualted
- Contaminant concentration and % of regulatory value are calcualted for the selected simulation number (in this case 7).

Applying QDM to Pinelands landfills

- Identify distance from landfill to nearest receptors:
  - Stream
  - Wetlands
  - Residential
- Simulate concentration of Cl^- at each receptor:
  - Most conservative, "worst case" scenario
- Select other contaminants to be simulated
  - Based on concentration and detection frequency

Criteria for Selecting contaminants to simulate

- Frequently detected
- High concentration relative to regulatory standards
- Informed judgment

Concentrations of contaminants used in models

- Highest average daily concentration among all monitoring wells samples
- Contaminants analyzed for but not detected are assigned the detection limit
  - e. g. if benzene is not detected in a well-water sample, but the detection limit is 0.1 ppb, benzene concentration for that well is assigned as 0.1 ppb.

Assessing Vulnerability of Groundwater to Contaminants of Concern (COCs) from Landfills

- **Level of Concern = Unknown**
  - Data are insufficient to characterize the presence of COCs.
- **Level of Concern = Low**
  - COCs do not reach receptors at concentrations greater than the Practical Quantitation Limit (PQL).
- **Level of Concern = Moderate**
  - COCs reach receptors at concentrations greater than the PQL but less than 50% of any relevant regulatory standard.
- **Level of Concern = High**
  - COCs reach receptors, which may be coincident with the landfill, at concentrations greater than or equal to 50% of one or more relevant regulatory standards.

Vulnerability assessment

Level of Concern for Specific Analytes and Receptors									
Organics and Inorganics Excluding Nutrients							Nutrients		
	Chloride						Ammonia as N	Nitrate as N	Total P
Stream	High (A), but not a COC						Low	High (A)	Low
Wetland or Hydric Soil	High (A), but not a COC						High (A)	High (A)	Low
Residential	High (A), but not a COC						Low	Moderate	Low

Summary of Domenico Results: Level of Concern (Excluding Nutrients)		
Level of Concern	**Criteria**	**Meets criteria?**
Unknown	Data are insufficient to characterize the presence of COCs.	No
Low	**COCs do not reach receptors at concentrations greater than the practical quantitation limit (PQ).**	**Yes (non-nutrients)**
Moderate	COCs reach receptors at concentrations greater than the PQL but less than 50% of any relevant regulatory standard.	No
High (A)	COCs reach receptors at concentrations greater than or equal to 50% of one or more relevant regulatory standards.	**Yes (nutrients)**
High (B)	Receptor coincides with landfill location, where COC concentration is greater than or equal to 50% of one or more relevant regulatory standards	No

Domenico simulation indicates that the level of concern for this landfill is of low for non-nutrients and high for nutrients.

Summary of Model Results: Number of Landfills for Each Level of Concern

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Total landfills studied:	48
Unknown level of concern (insufficient data):	18
Low level of concern:	12
Moderate level of concern:	0
High level of concern:	18

Summary of Model Results (continued)

- **Contaminants responsible for high level of concern**
  - Arsenic (2 landfills)
  - Barium (3 landfills)
  - Benzene (1 landfills)
  - Cyanide (1 landfill)
  - Lead (8 landfills)
  - Mercury (2 landfills)
  - Selenium (1 landfill)

Results of This Study

- Groundwater quality under 30 landfills
  - Based on historical water-quality data
- Modeling tool to assess down-gradient threat levels
  - Screening-level Microsoft Excel application
- Results of modeling for 30 landfills
  - Water quality at down-gradient receptors
- Levels of concern at 30 landfills
  - Based on regulatory contaminant concentration and modeling results

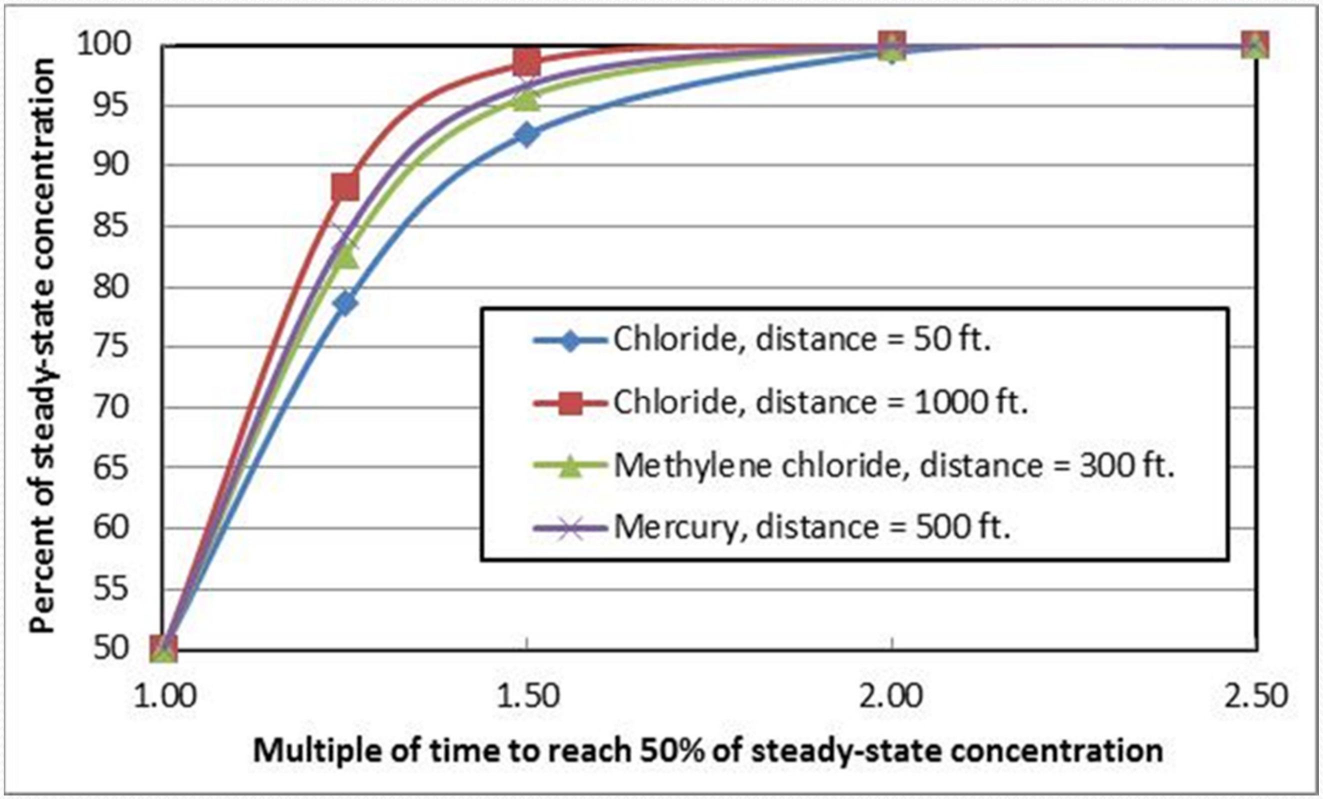
Next steps

- Journal article (Waste Management Journal)
  - Draft received supervisory review
  - Comments addressed, preparing for submission to journal
- Pinelands Commission application of results
  - Will assist in deciding what additional monitoring or remediation is needed before a landfill site can be redeveloped
- Proposal to NJDEP to apply method widely to landfills in New Jersey

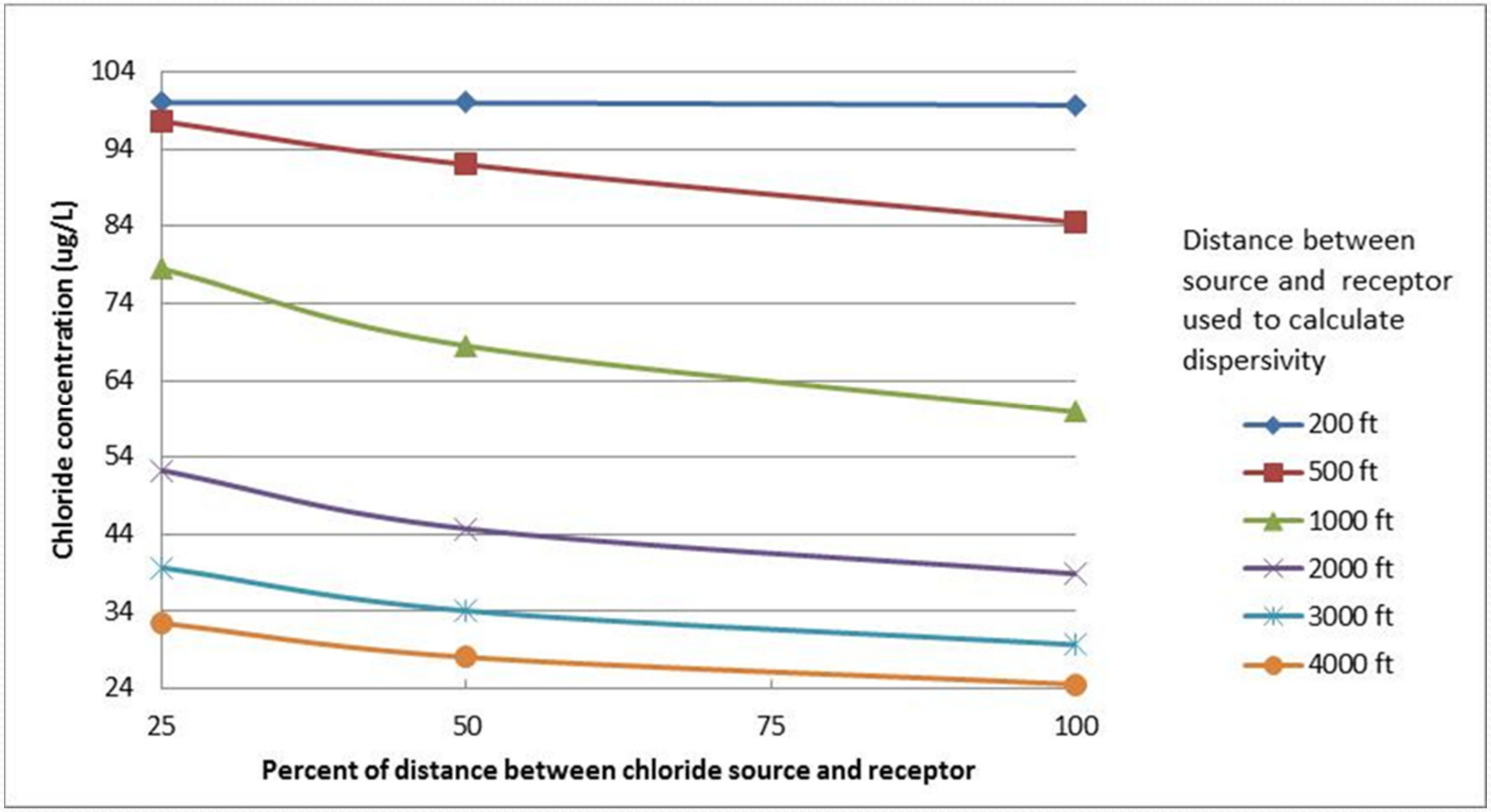
Determining time required to reach steady state conditions

- Domenico model can be solved for time required to achieve 50% of the steady-state concentration at a specified distance from the source:
  - $t_{1/2} = Rx/(V_s(1+4\alpha_x\lambda R/V_s)^{0.5})$
- A simulation for time = $t_{1/2}$ gives ½ x $C_{(steady\ state)}$
- Determine the factor F which, when multiplied by $t_{1/2}$, is the simulation time needed to achieve $C_{(steady\ state)}$
- **F x $t_{1/2}$ = time to reach steady-state conditions**

Determining time required to reach steady state conditions

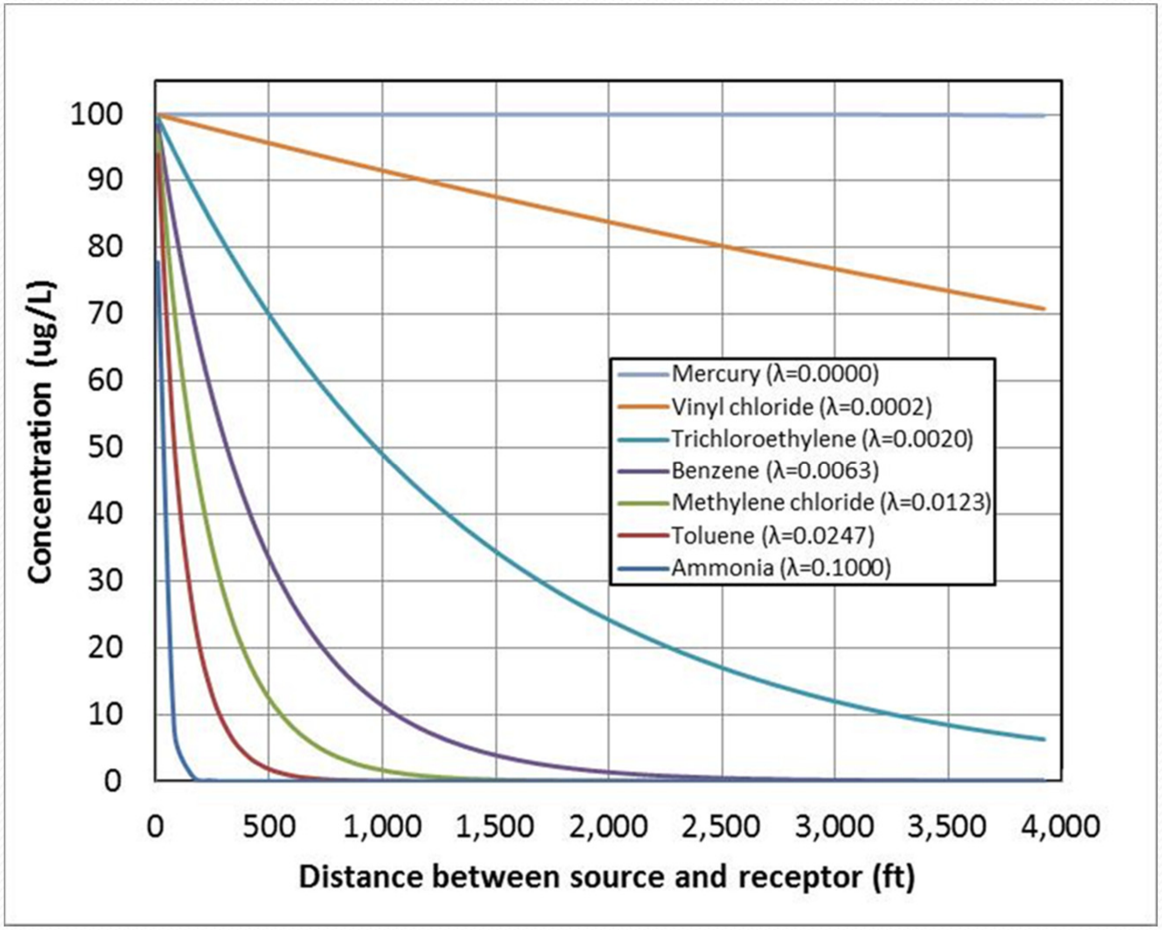


Model sensitivity to longitudinal dispersivity



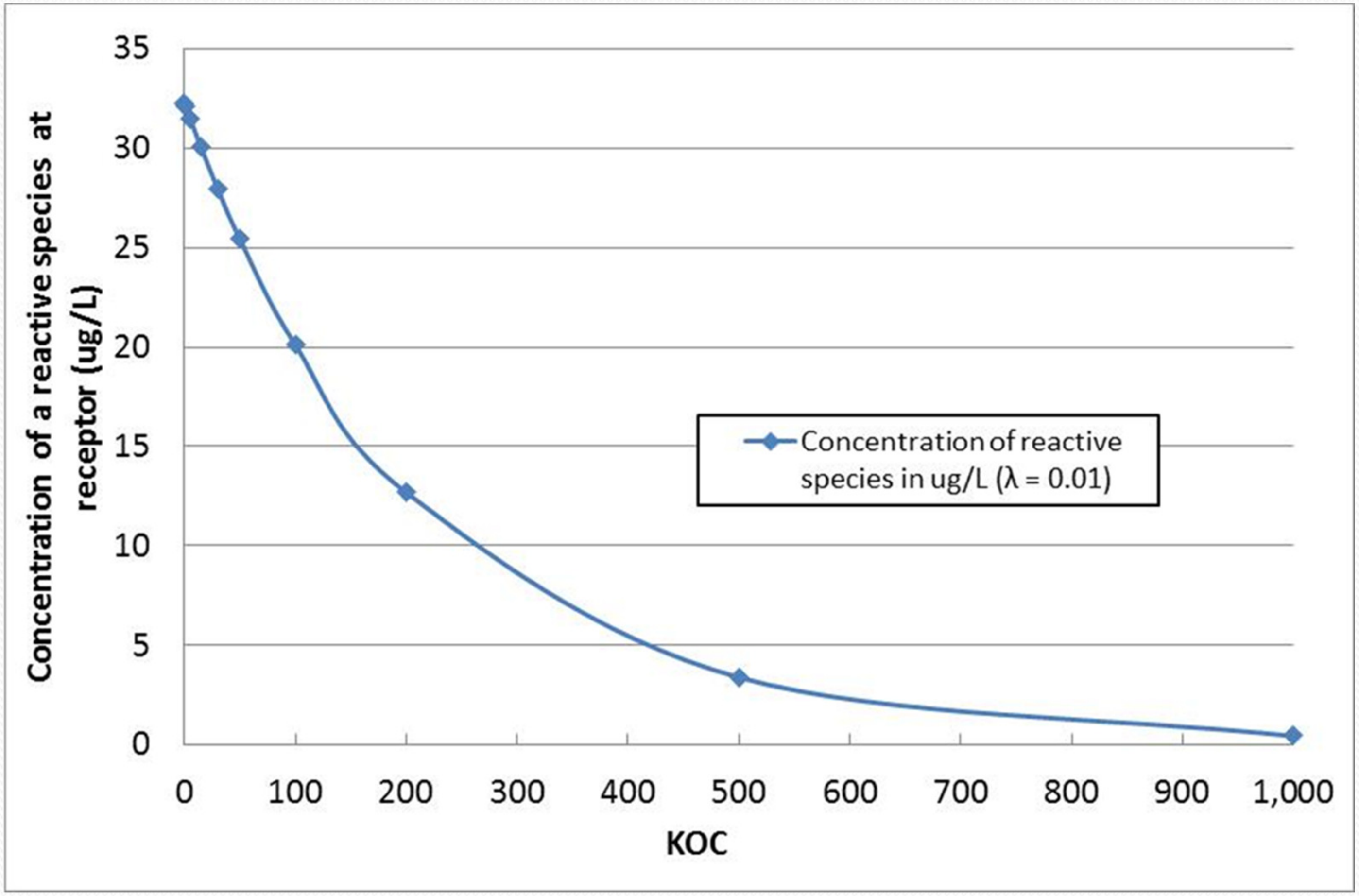
Model (contaminant concentration) is relatively insensitive to longitudinal dispersivity for conservative contaminants at distances of 200-4000 ft from source

Model sensitivity to contaminant first-order reaction rate constant (λ)



Model (contaminant concentration) is highly sensitive to contaminant reaction rate (λ), which varies widely among environments and is an important source of uncertainty in this and other reactive transport models.

Model sensitivity to KOC



Simulated concentration is highly sensitive to KOC when the contaminant is not conservative (λ>0)