Seminario tecnico

ORGANO-CLORURATI ED IDROGEOLOGIA DELLE AREE URBANE: INQUINAMENTO PUNTUALE O DIFFUSO ?

Bologna, 11 Giugno 2015

Idrogeologia dei solventi clorurati: chiavi di lettura alternative rispetto agli approcci classici

Maria Filippini, Alessandro Gargini

Alma Mater Studiorum – Università di Bologna
Dipartimento di Scienze Biologiche, Geologiche ed Ambientali

maria.filippini3@unibo.it
alessandro.gargini@unibo.it

IDROGEOLOGIA DEI DNAPL

Dalla sorgente al piezometro

- **Una elevata complessità multifase**
- **Contaminant hydrogeology-La ricerca**
- **Fattori geologici di controllo**

  (eterogeneità, acquitardi, torbe)
- **Sfide**

  caratterizzazione

  individuazione del responsabile

  assimilation capacity

DNAPL

Dense Non - Aqueous Phase Liquid

DNAPL = affonda (trielina)

LNAPL = galleggia (idrocarburi)

«AFFONDARE» IN UN BICCHIER D'ACQUA

DENSITÀ ACQUA = 1

DENSITÀ OLIO D'OLIVA = 0,92

GALLEGGIA!!!!!

DENSITÀ PETROLIO = 0,73

GALLEGGIA!!!!!!!!

DENSITÀ TRICLOROETILENE = 1,46

TCE

AFFONDA!!!!!!!

DENSITÀ TETRACLOROETILENE = 1,63

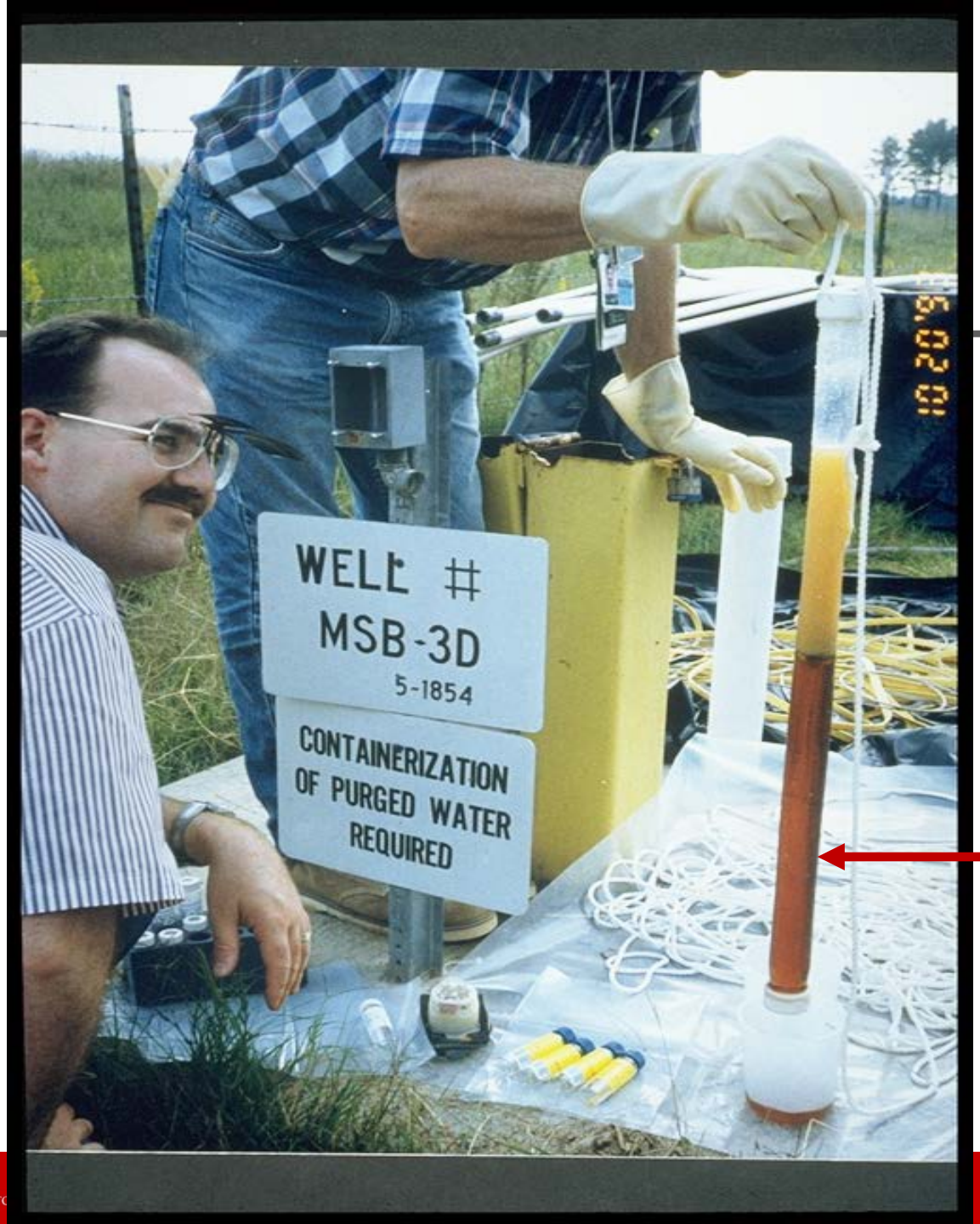
PCE

AFFONDA!!!!

Raro esempio di "cattura" di fase pura in piezometro

Produzione armamenti nucleari -
Savannah River site (North Carolina)

Jackson & Mariner, 1995 (Groundwater)



DNAPL entro un bailer

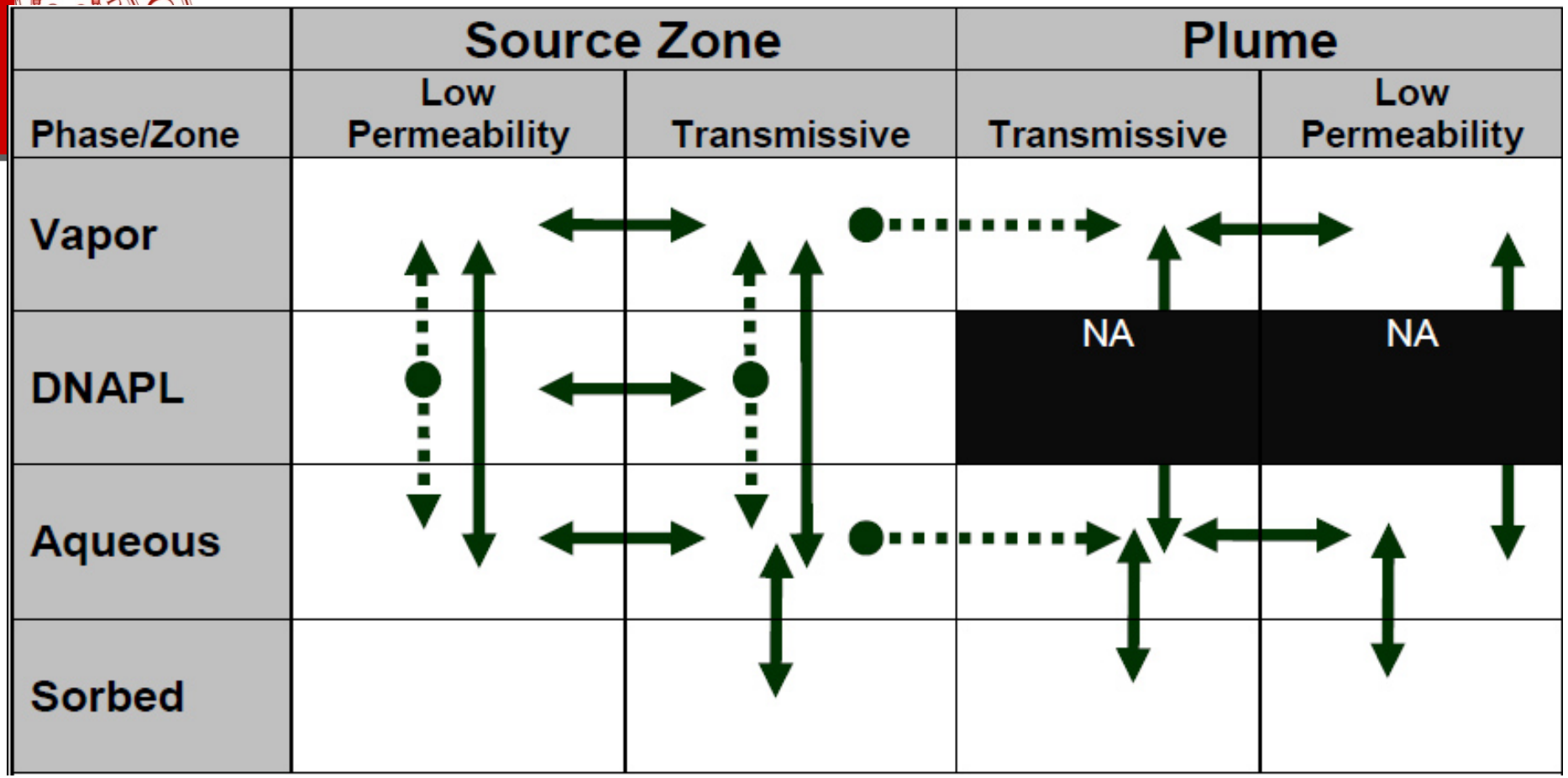
PRINCIPALI DNAPLs

- Solventi, sgrassanti e detergenti
- Creosoto/catrame di carbone
- Miscugli di rifiuti industriali (es.peci clorurate)
- Oli Policlorobifenili
- Alcuni pesticidi in stato non diluito in acqua

Fenomeno idrogeologico "recente" ed incremento delle conoscenze "assai recente"

- Produzione industriale dei solventi cresce enormemente dopo Seconda Guerra Mondiale
- Fino alla fine anni'70 plume non riconosciuti come un pericolo
- Fase DNAPL non riconosciuta come la causa dei plume fino alla seconda metà anni '80

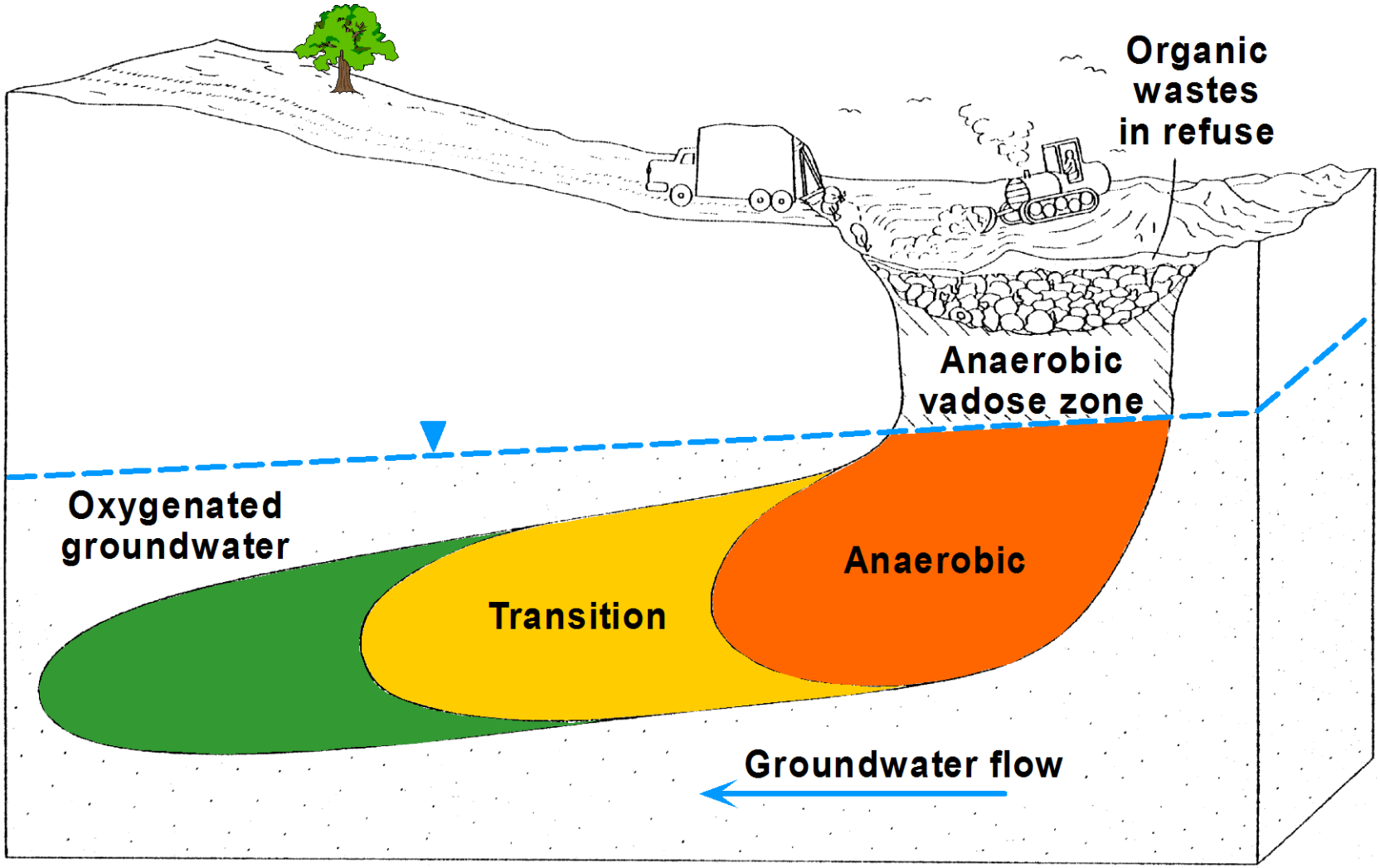
Complessità multi-fase, multi-zona, multi-K



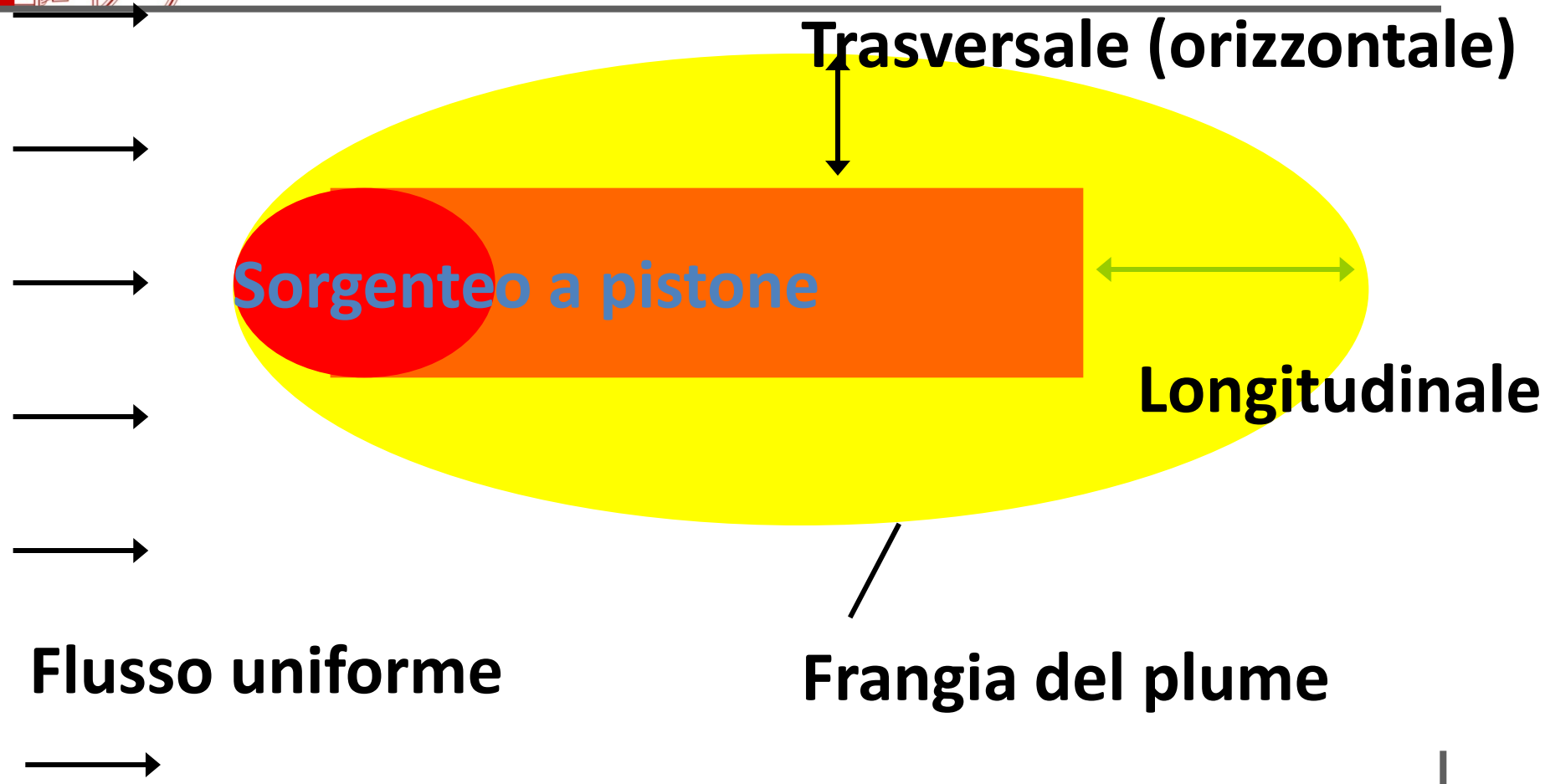
4 fasi, 2 zone (sorgente, plume), 2 tipi di permeabilità (acquifero, acquitardo)
13 compartimenti

Sale & Newell 2011 (US Department of Defense, ESTCP)

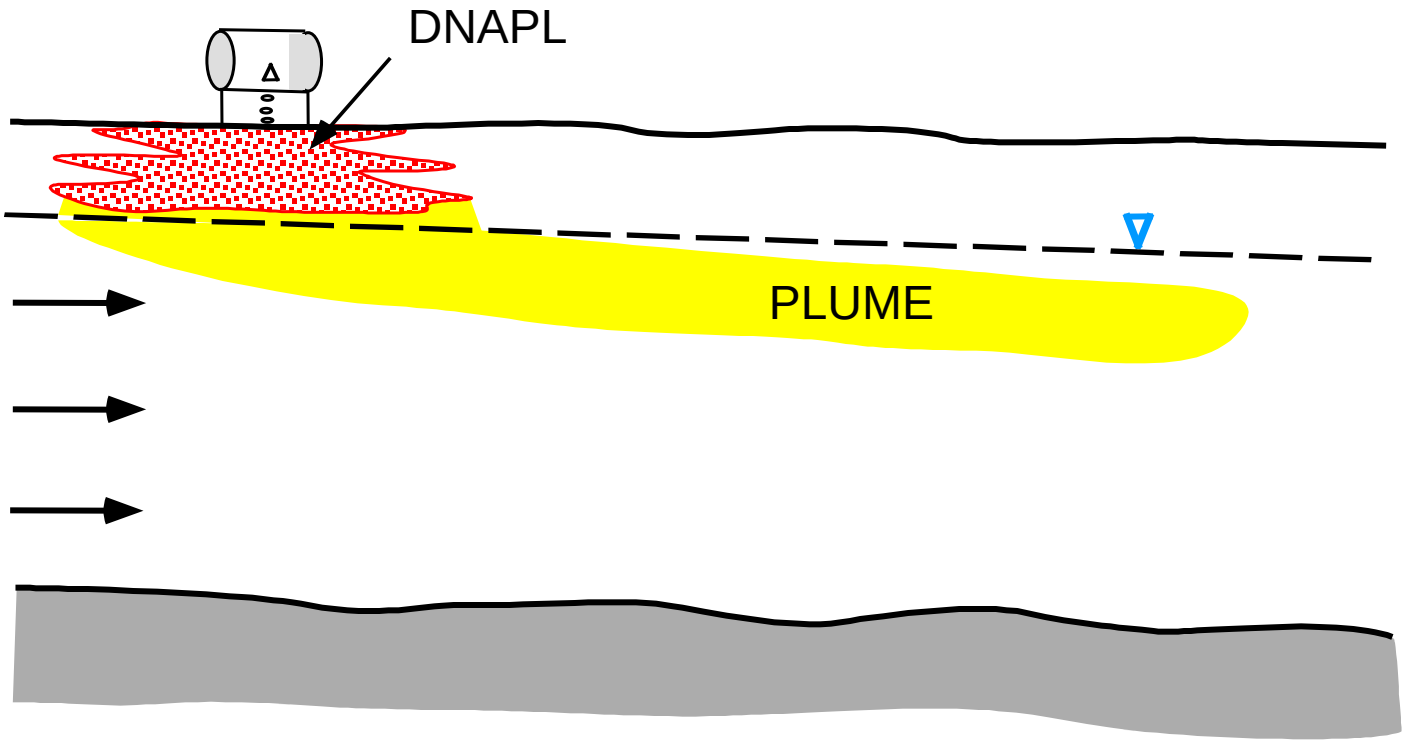
Plume "classico" da rifiuti non industriali



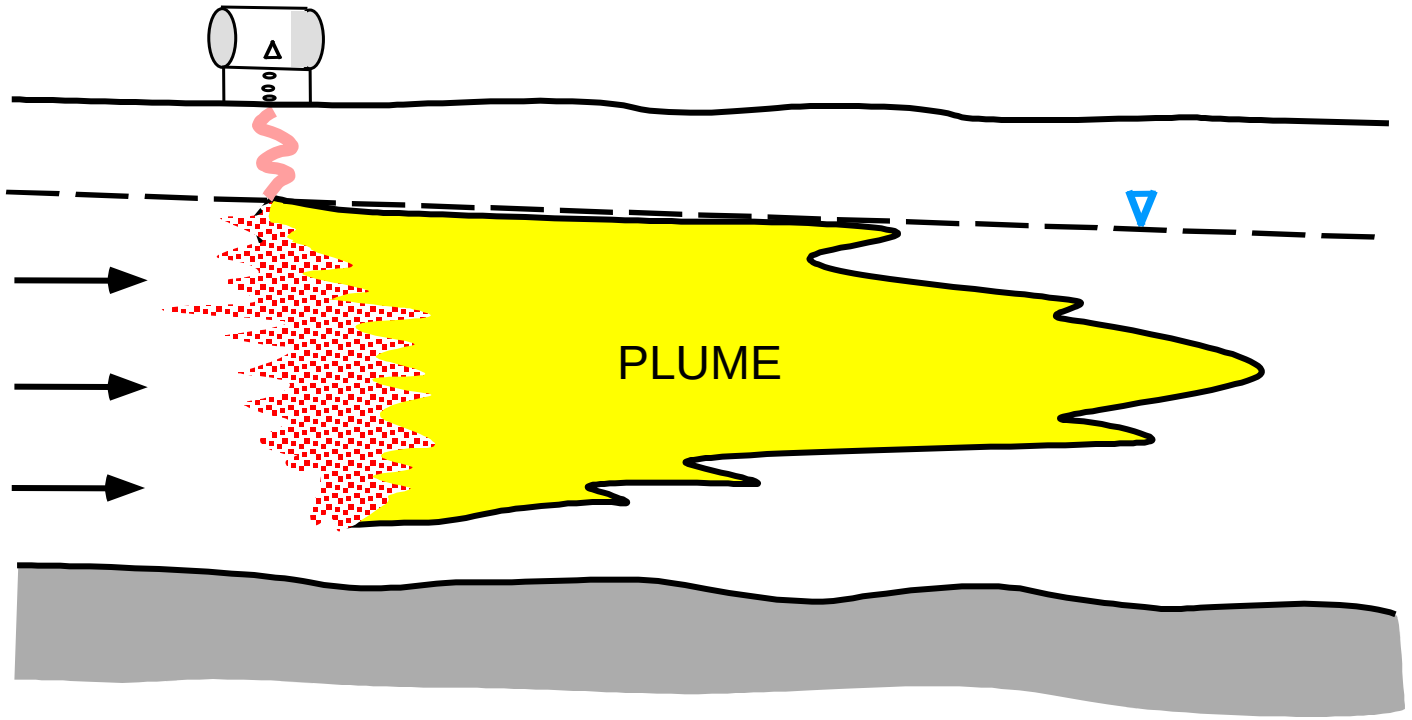
Diluizione classica per Dispersione Meccanica



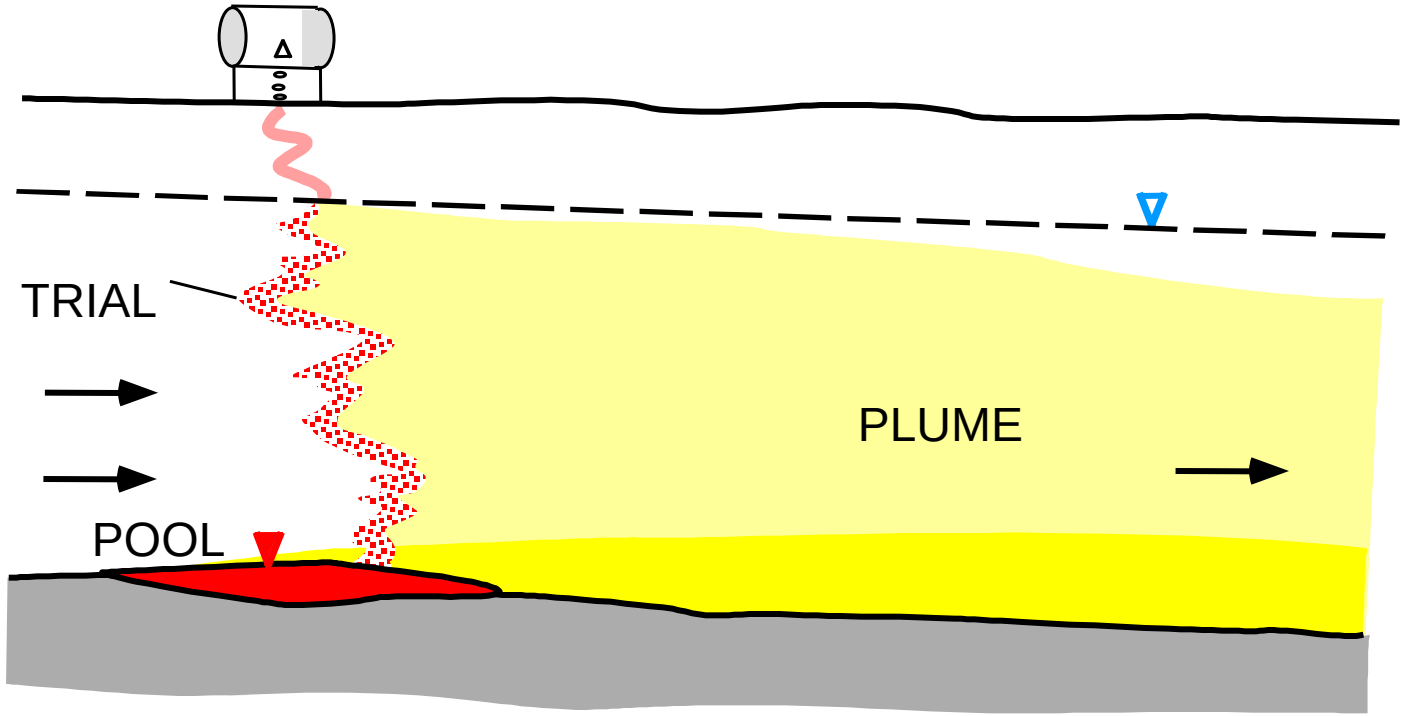
DNAPL RESIDUO NELL'INSATURO



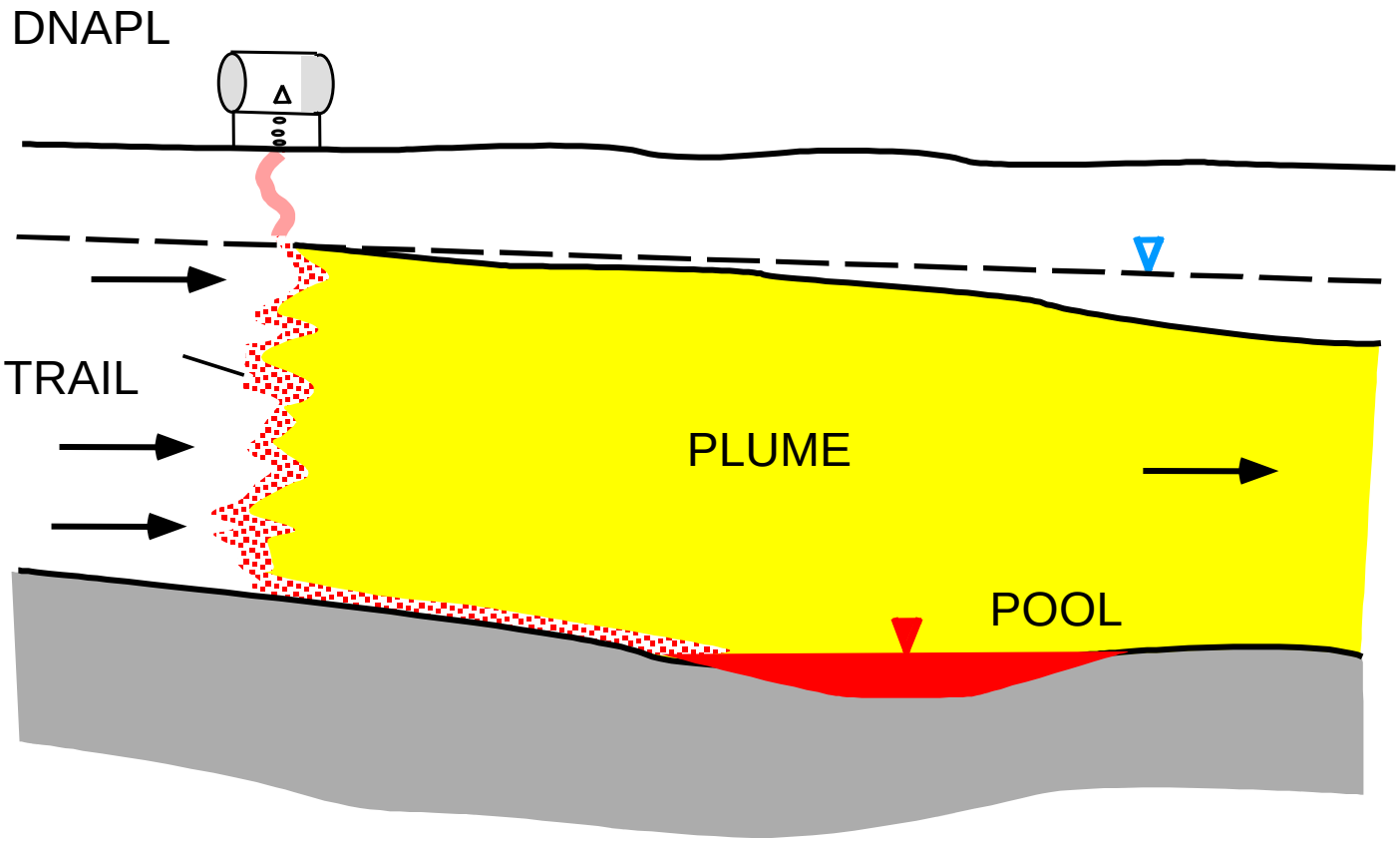
DNAPL RESIDUO SOTTO FALDA ("trail")



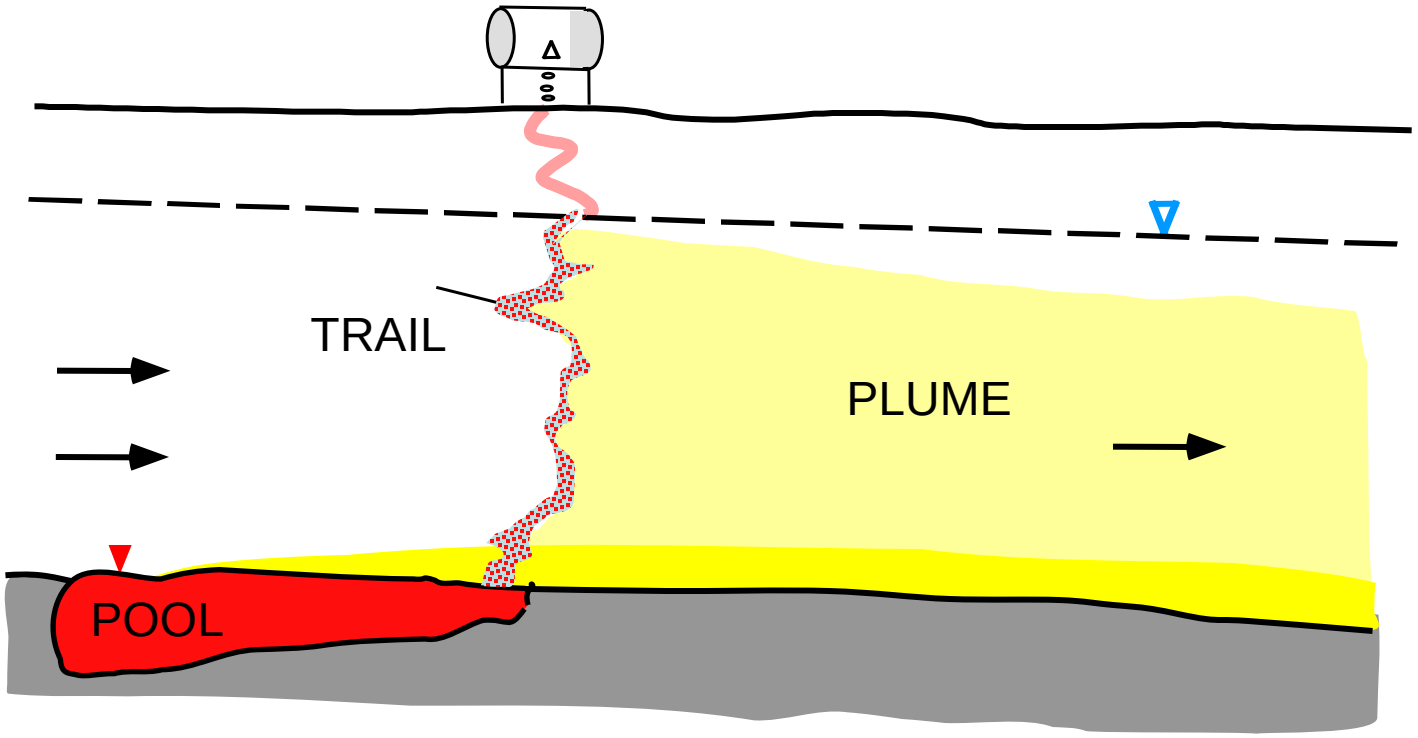
"TRAIL" SOTTO FALDA E "POOL" FASE PURA



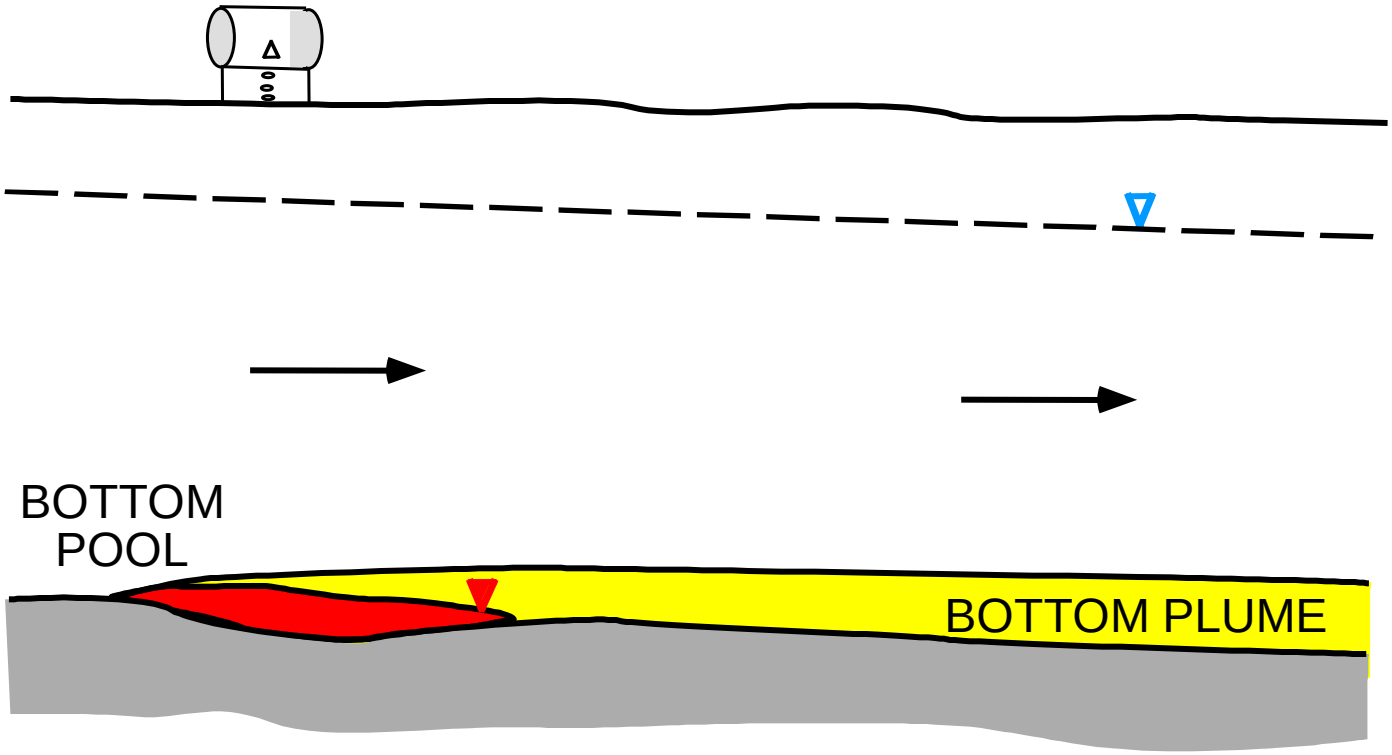
"POOL" MIGRA VALLE FLUSSO



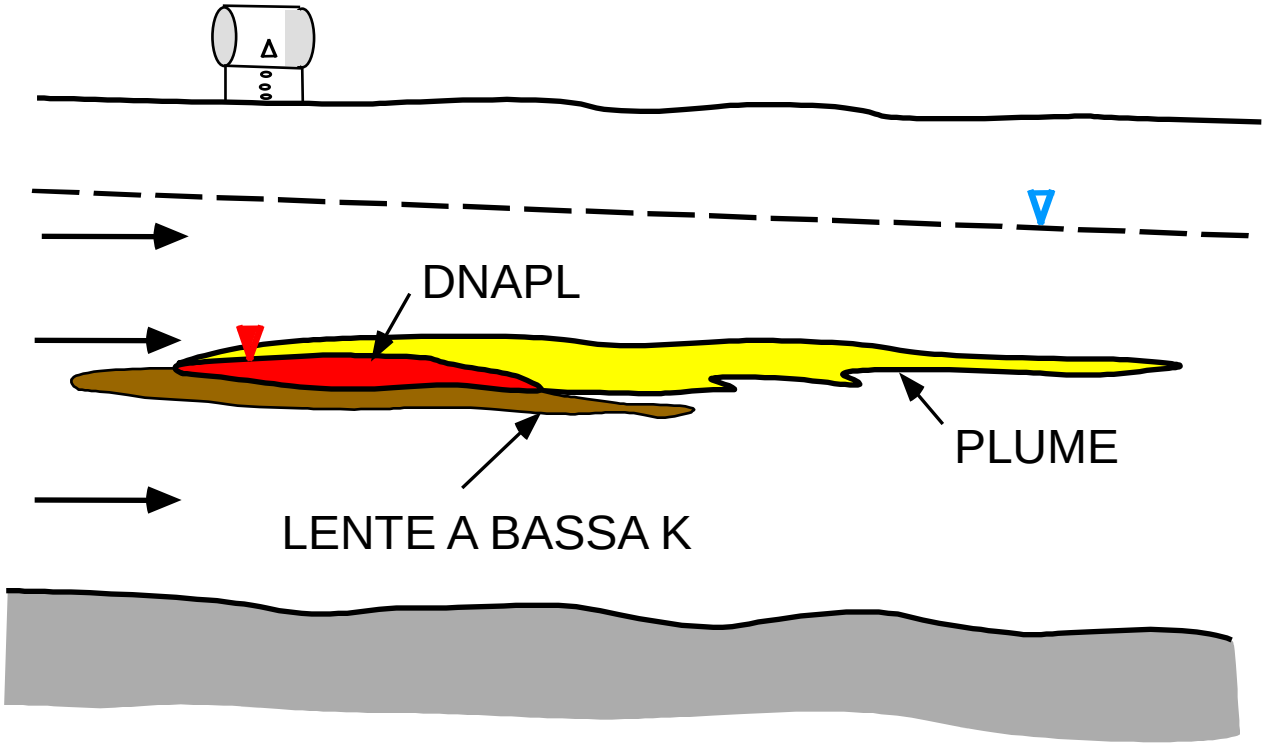
"POOL" MIGRA MONTE FLUSSO



"TRAIL" ASSIMILATO PER DISSOLUZIONE

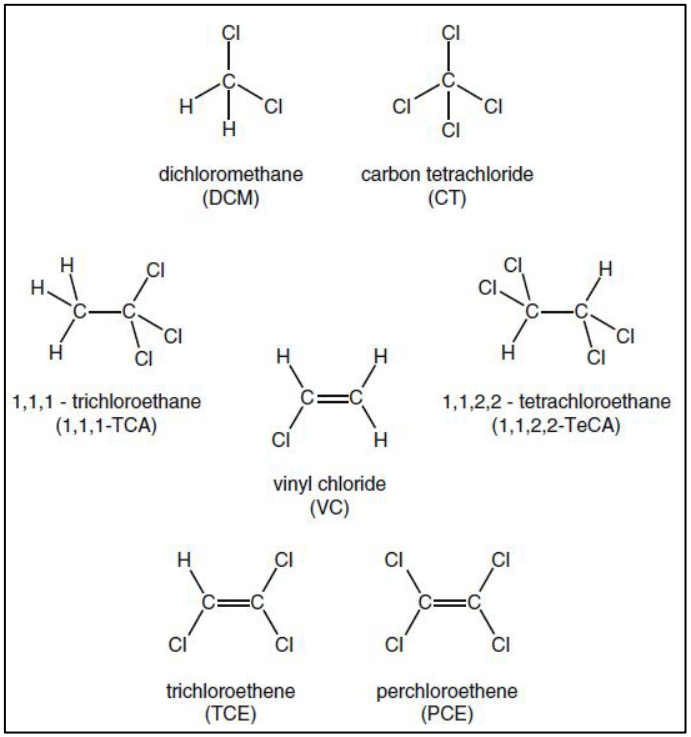


"POOL" SOSPESO

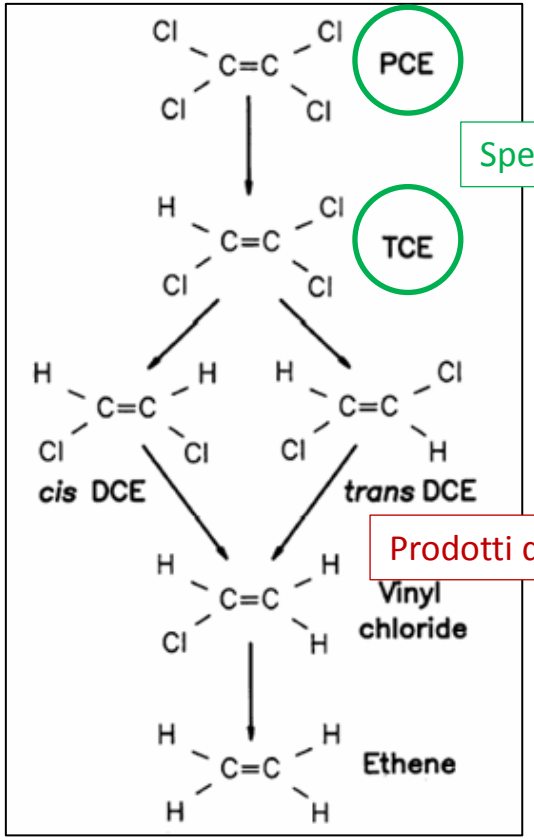


CHIMICA E DEGRADAZIONE

Composti alifatici clorurati



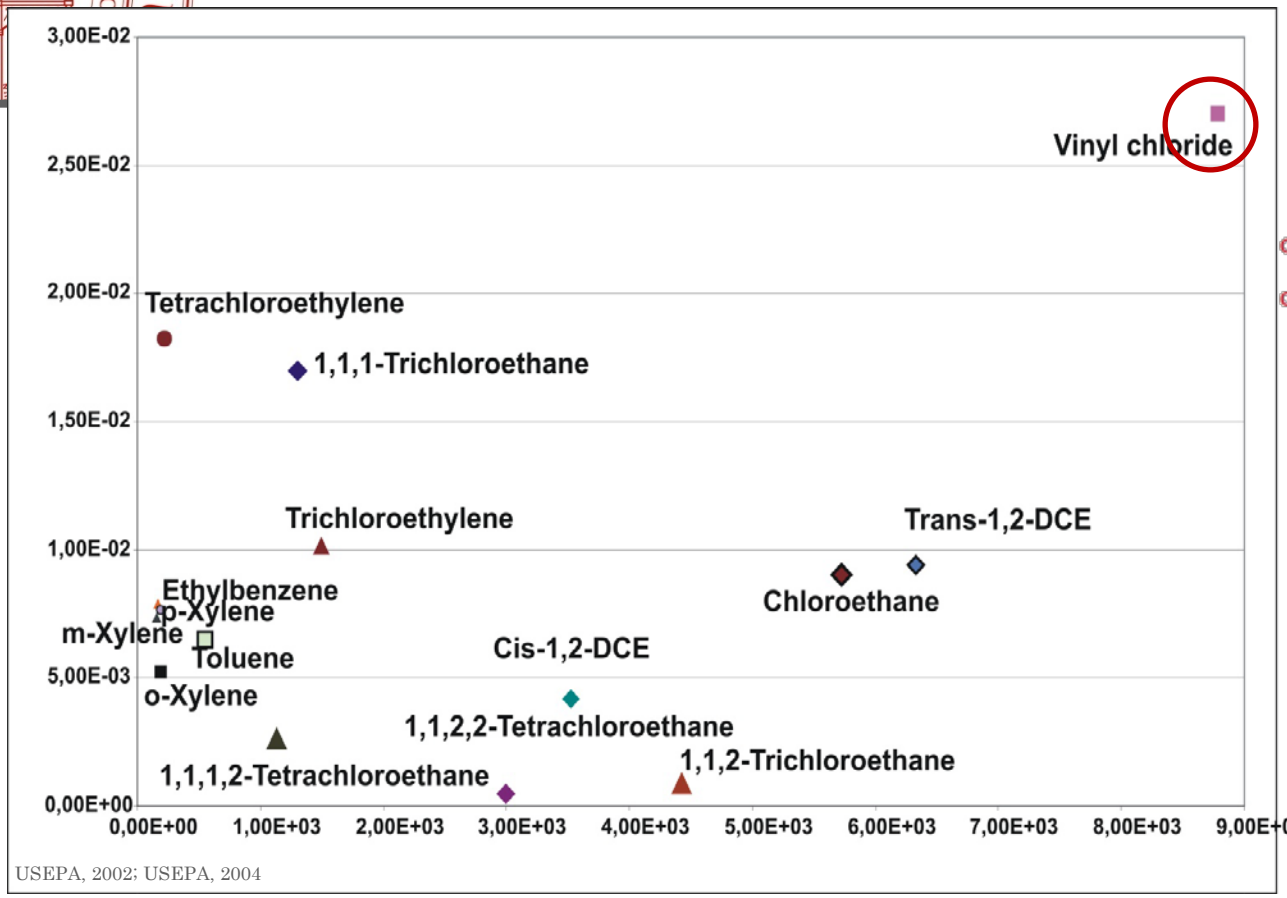
Declorurazione riduttiva degli etileni

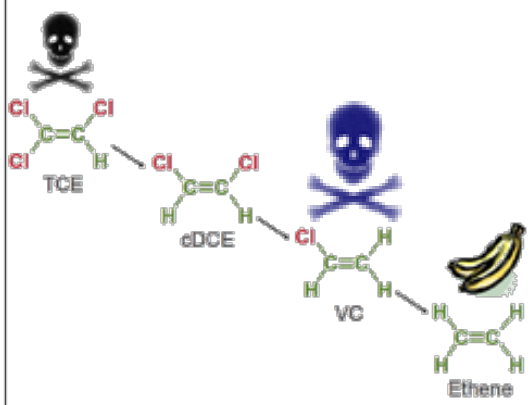


Specie primarie

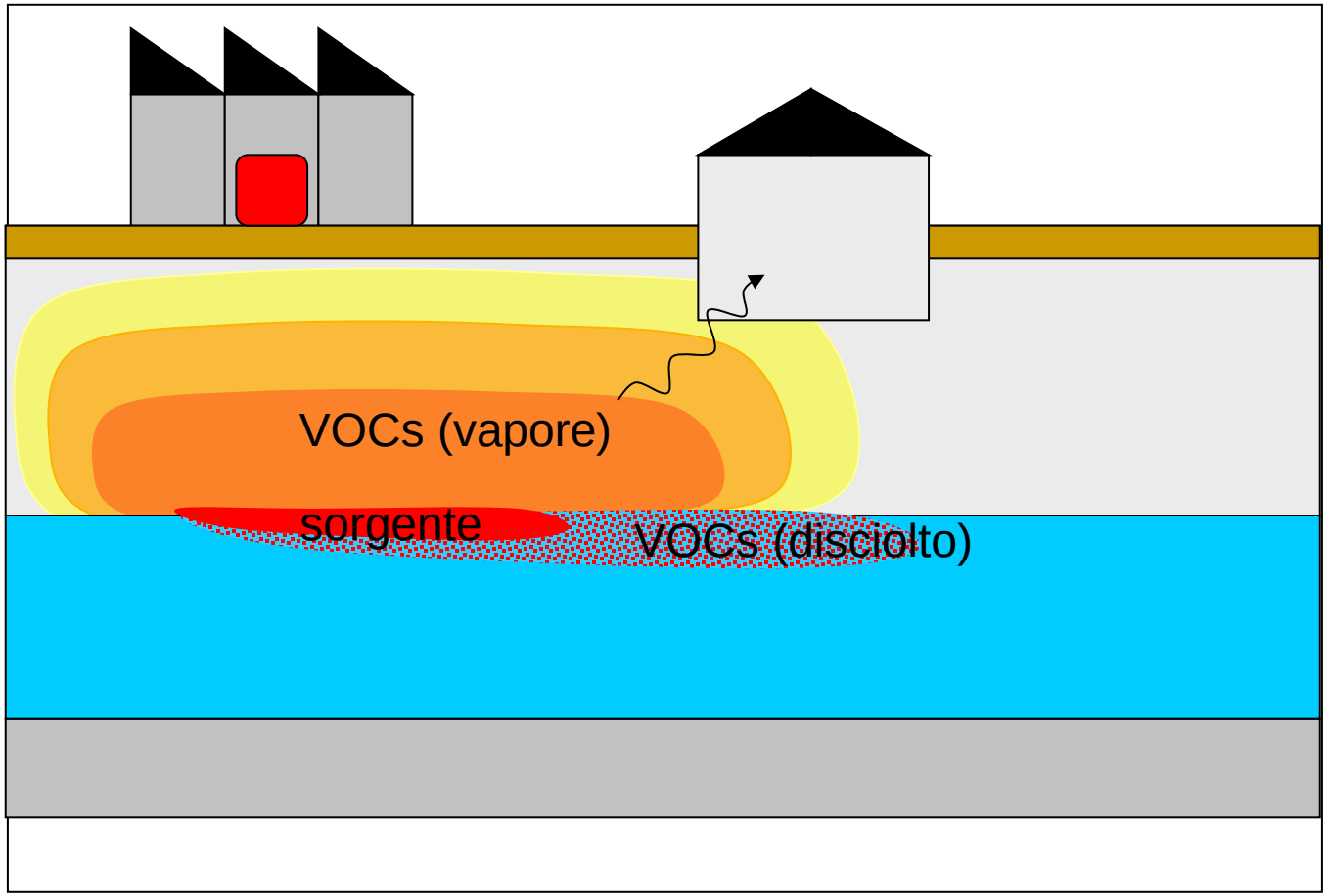
Prodotti di reazione

Cloruro di Vinile – Criticità maggiore in contaminazioni da DNAPL





Problema dell'intrusione di vapori indoor



Tipologia della sorgente

In molti siti petrolchimici diverse sorgenti puntuali si sono succedute nello spazio e nel tempo, stratificandosi e coalescendo:

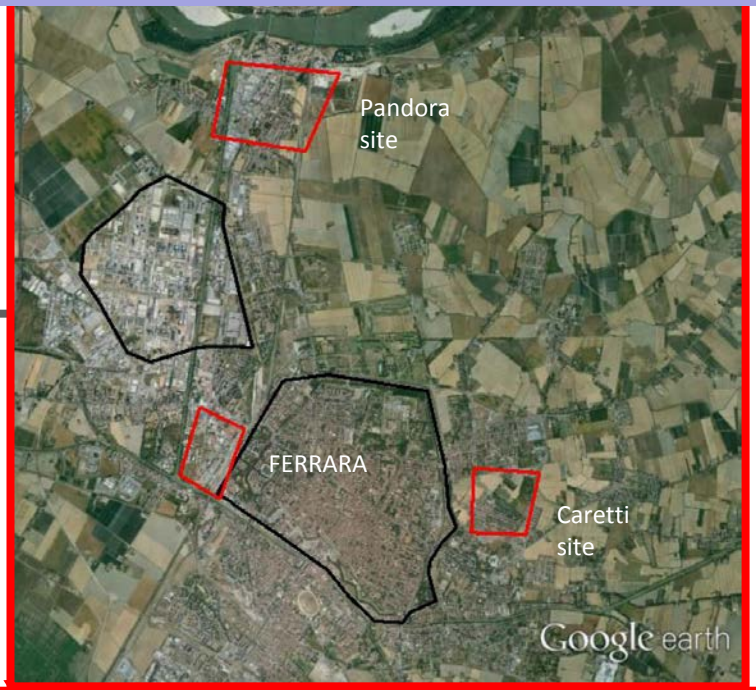
EFFETTI DIFFUSI DA SORGENTI PUNTUALI

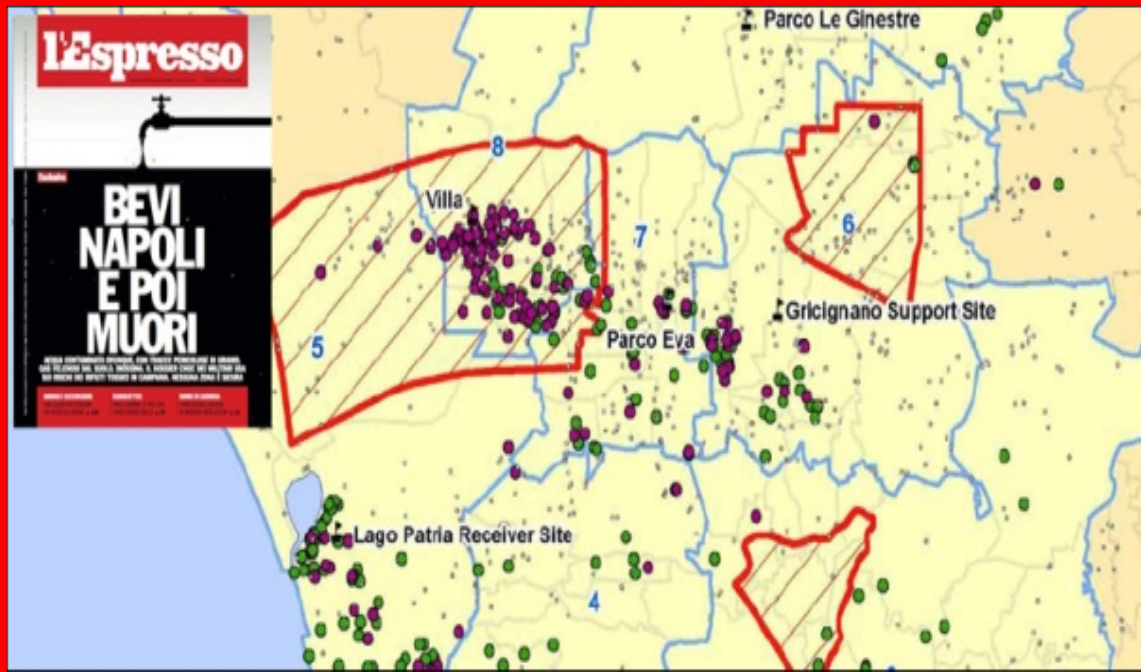
Aree contaminate da DNAPL anche in zone urbanizzate, ad uso agricolo o in aree golenali

PCE

TCE

Ferrara
Terra dei Fuochi
Bussi sul Tirino



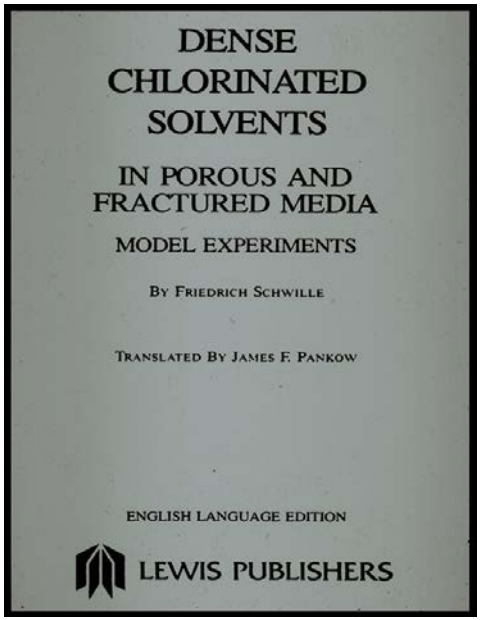


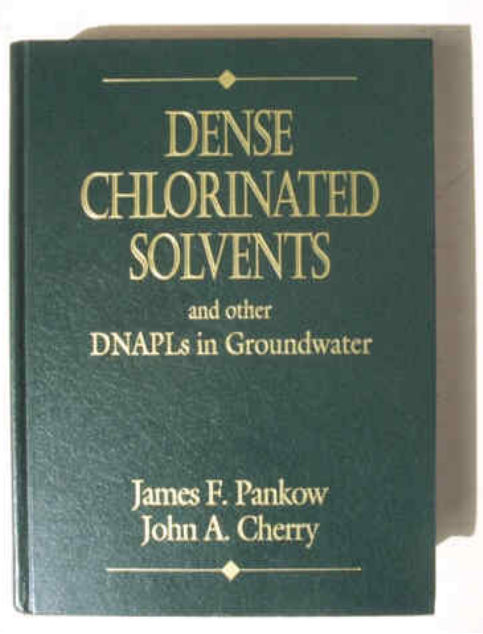
Duplicità di sorgenti puntuali ed incertezza sulle relazioni causa-effetto

LA RICERCA (assai recente)
CONTAMINANT HYDROGEOLOGY

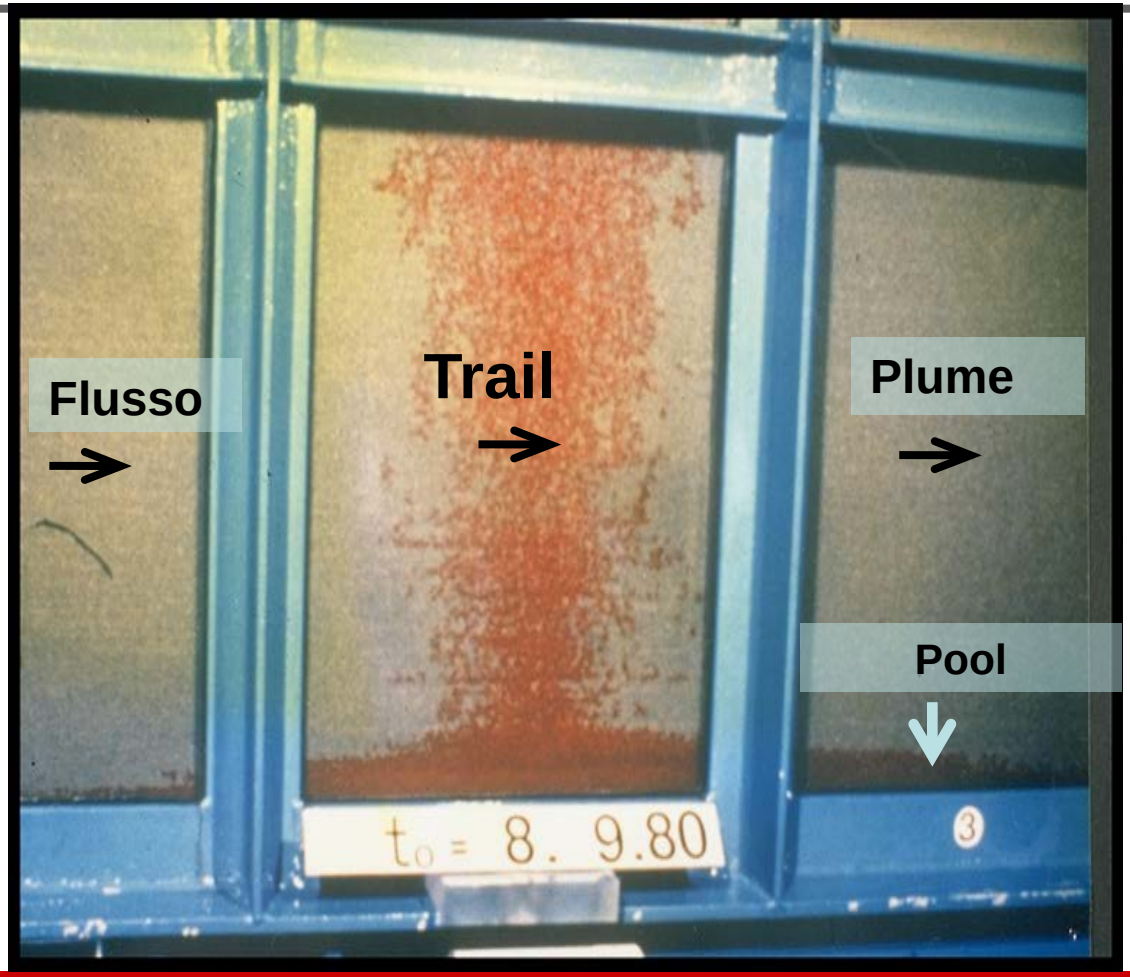
Germania: 1977-1984 (traduzione in inglese nel 1988)

Nord America (Canada): metà anni ‘80

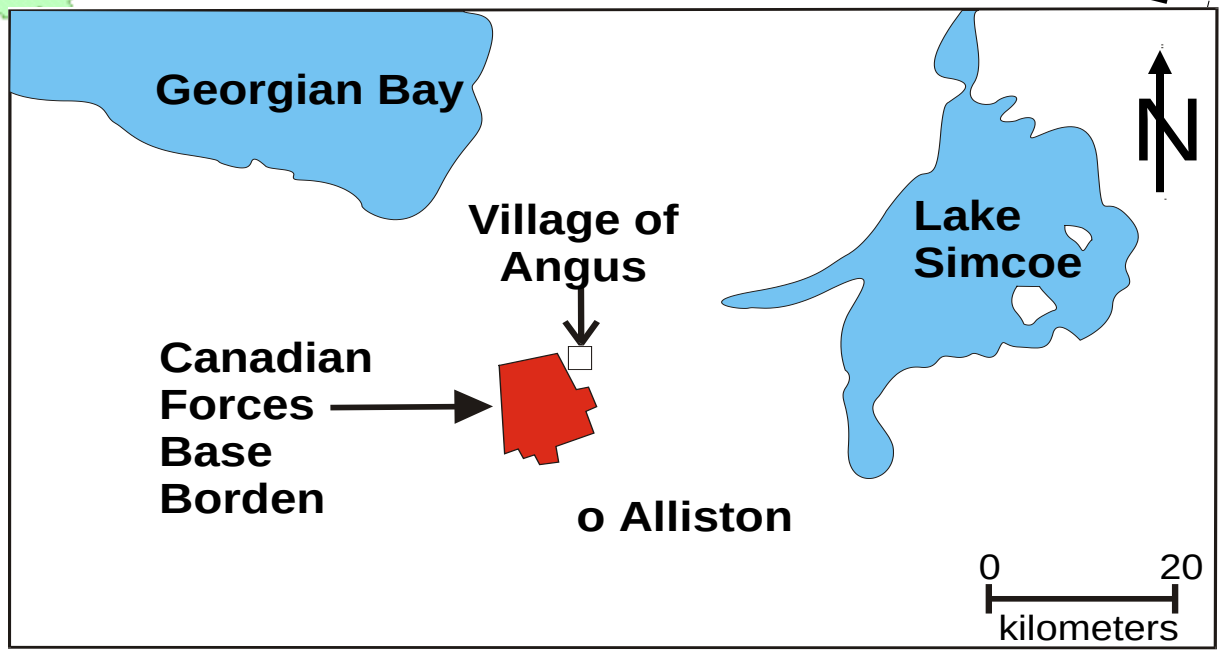




ESPERIMENTO DI SCHWILLE



Borden site
Sito sperimentale



PRIMO ESPERIMENTO SUI DNAPLs A BORDEN: 1989

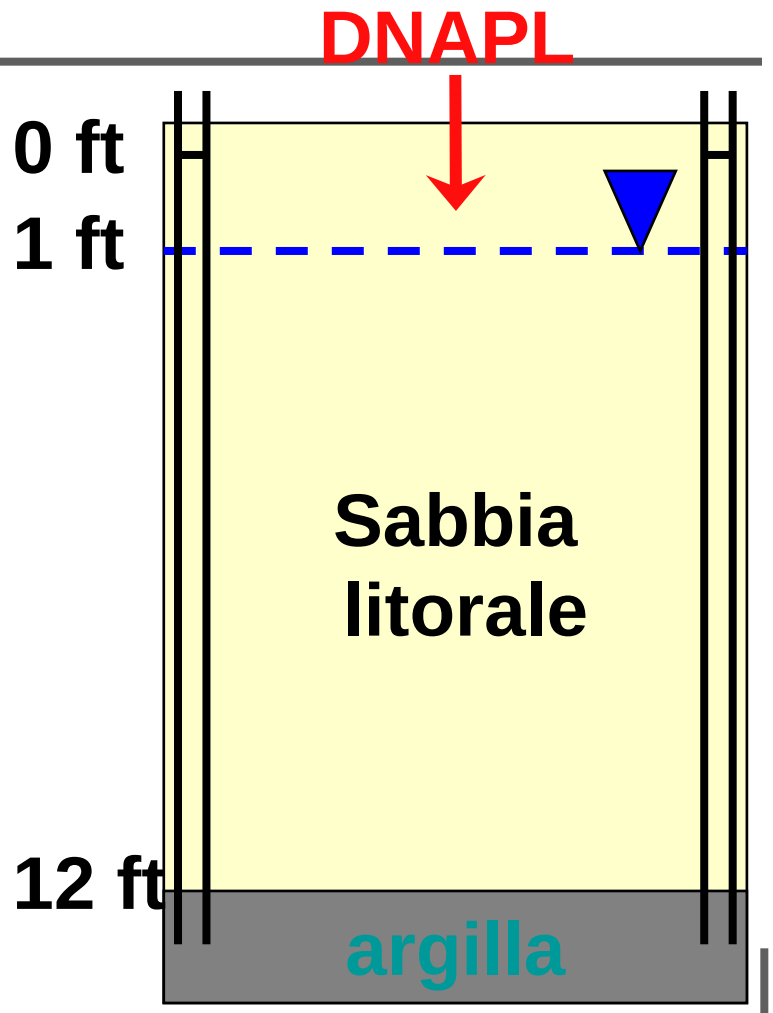
A Field Experiment to Study the Behaviour of Tetrachloroethylene in Unsaturated Media

by

Mette M. Poulsen and Bernard H. Kueper

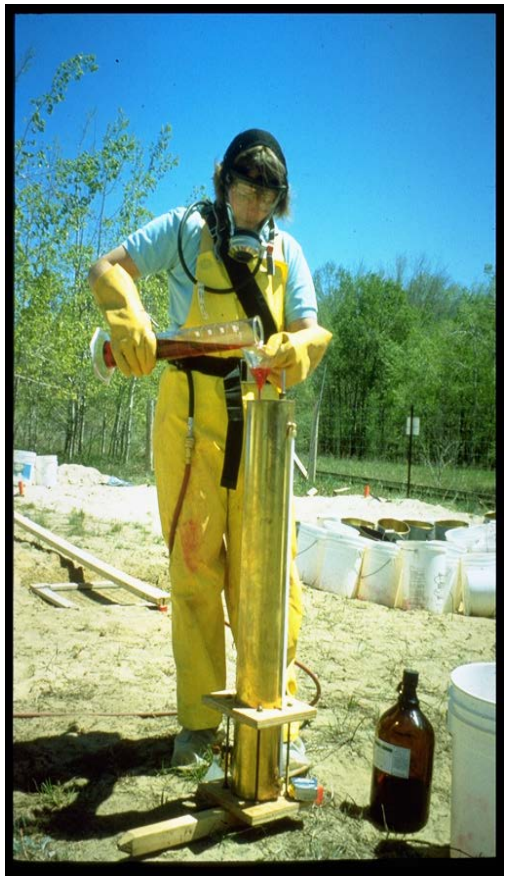
Environmental Science and Technology

Vol. 26, 1992

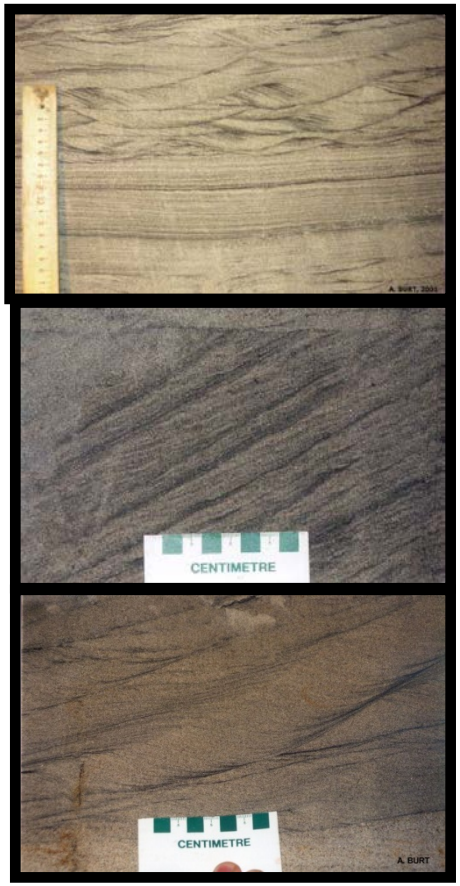


Borden site
Foreste di alberi e di piezometri

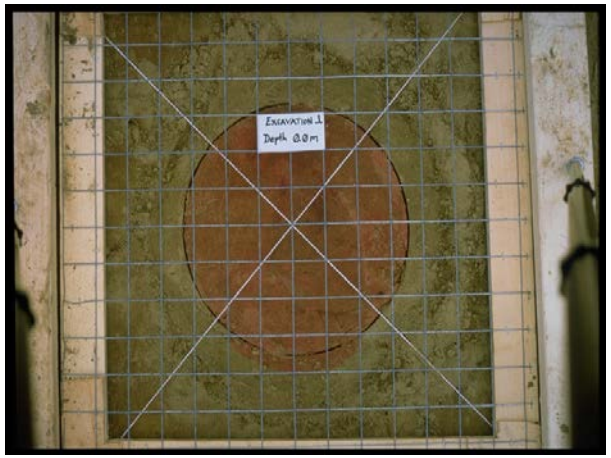
Rilasci controllati e definiti
Sorgente totalmente controllata

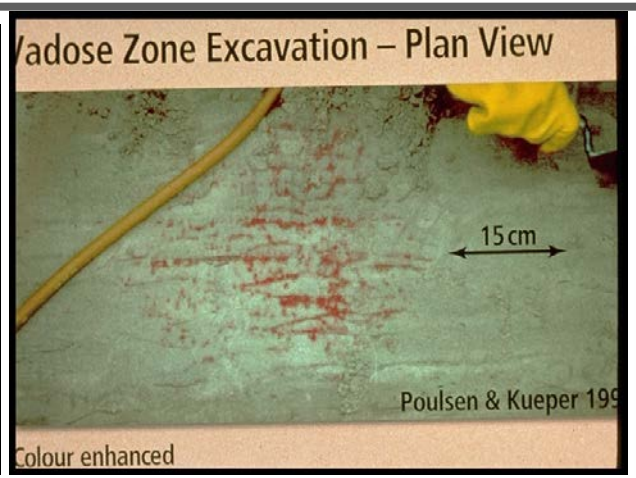


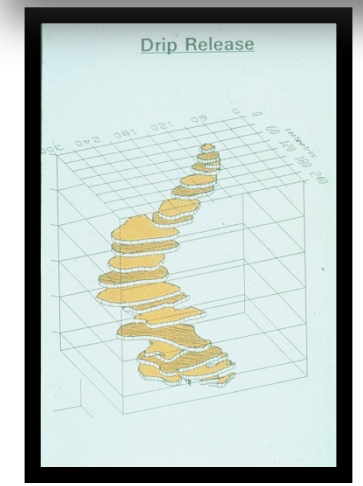
Caratterizzazione geologica ad altissima risoluzione



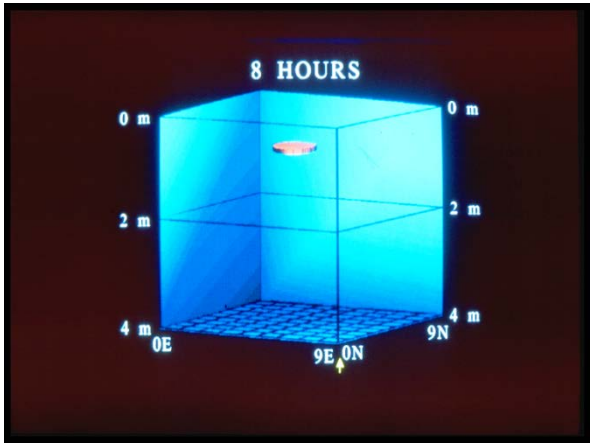
Tracciamento diretto del DNAPL

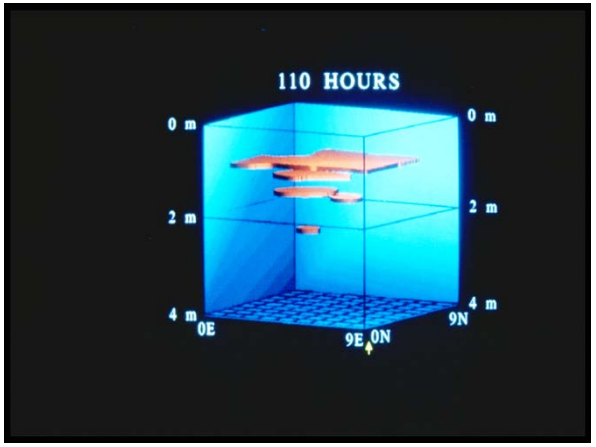


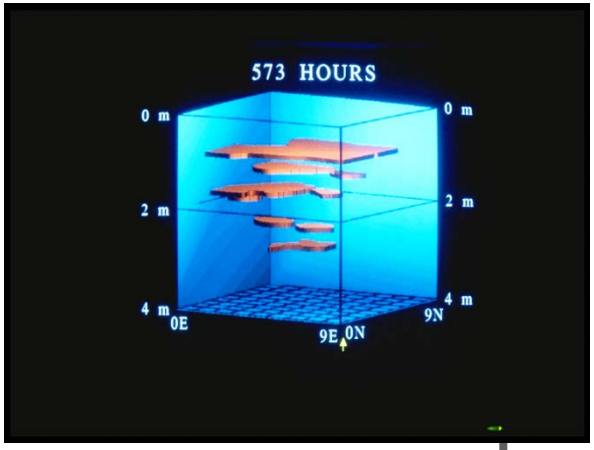




Tracciamento indiretto del DNAPL





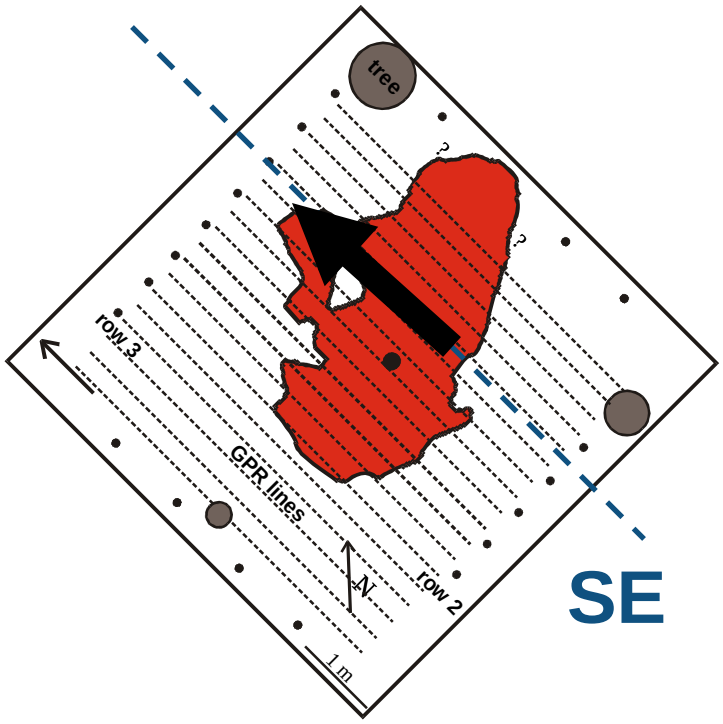


Geometria della sorgente

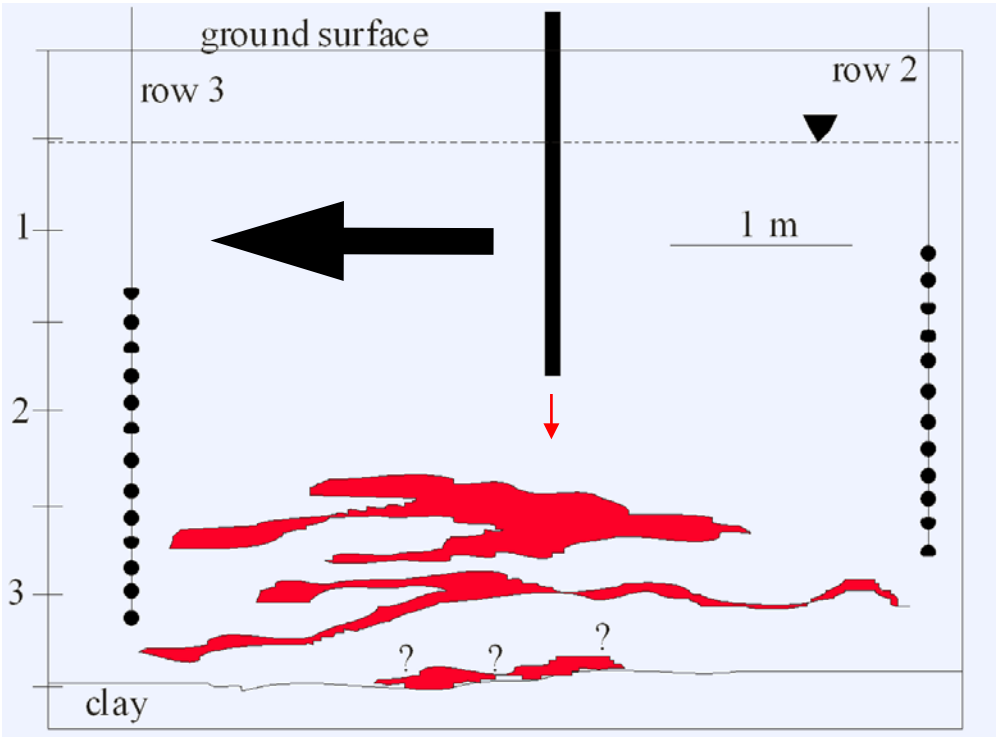
DNAPL riflettore geo-radar

NW

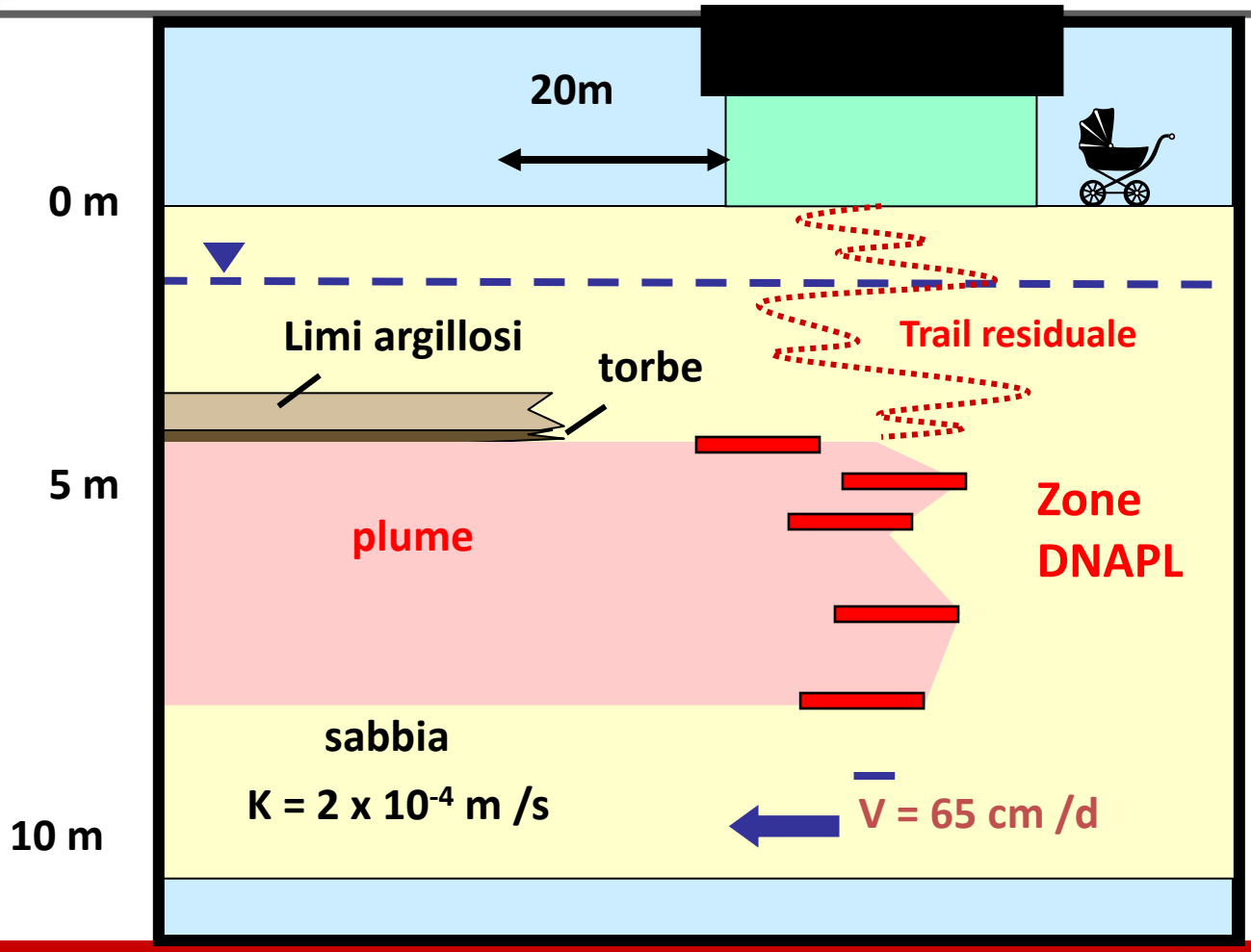
SE



K. Laukonen, 2001

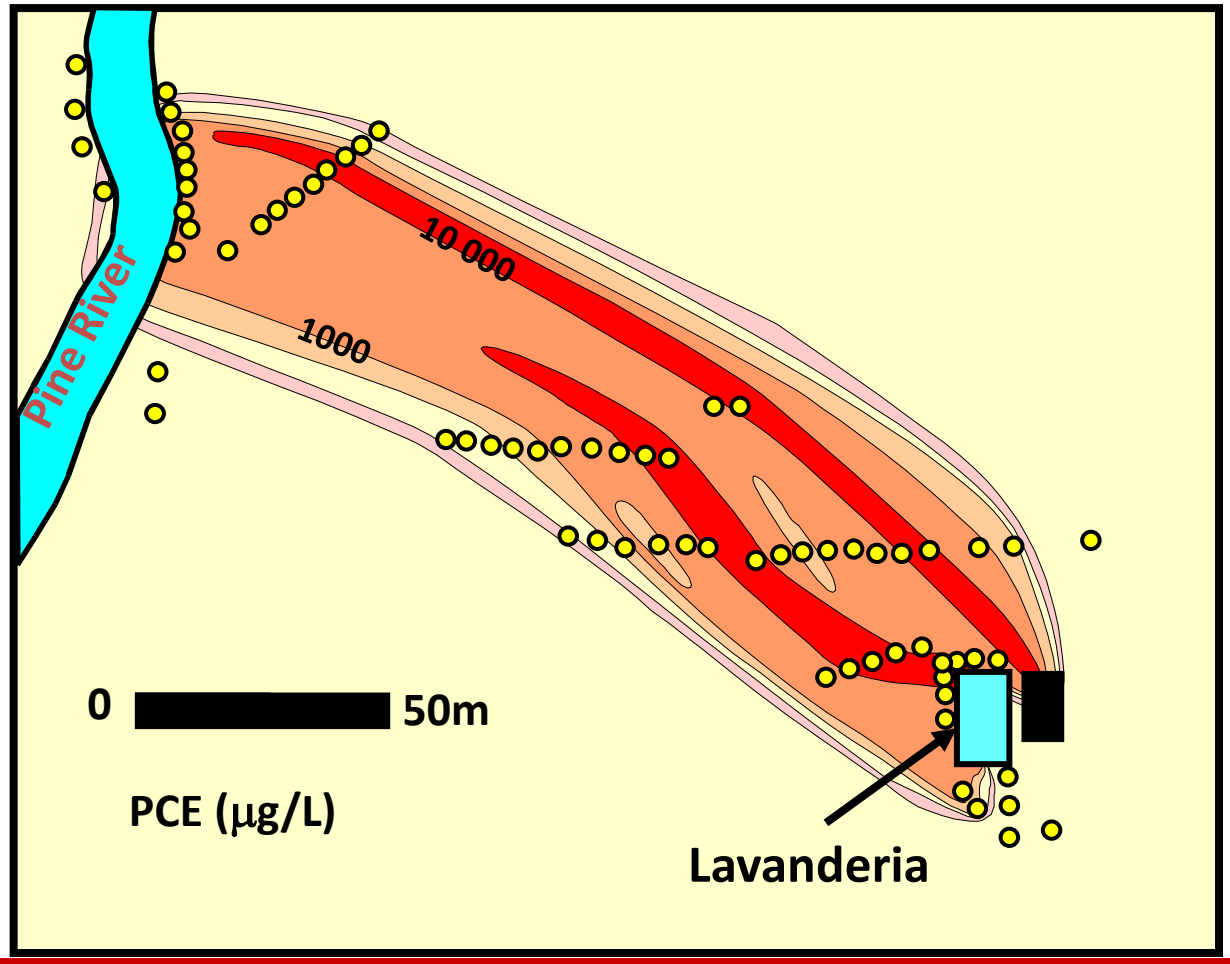


Fattori geologici
Eterogeneità per stratificazione



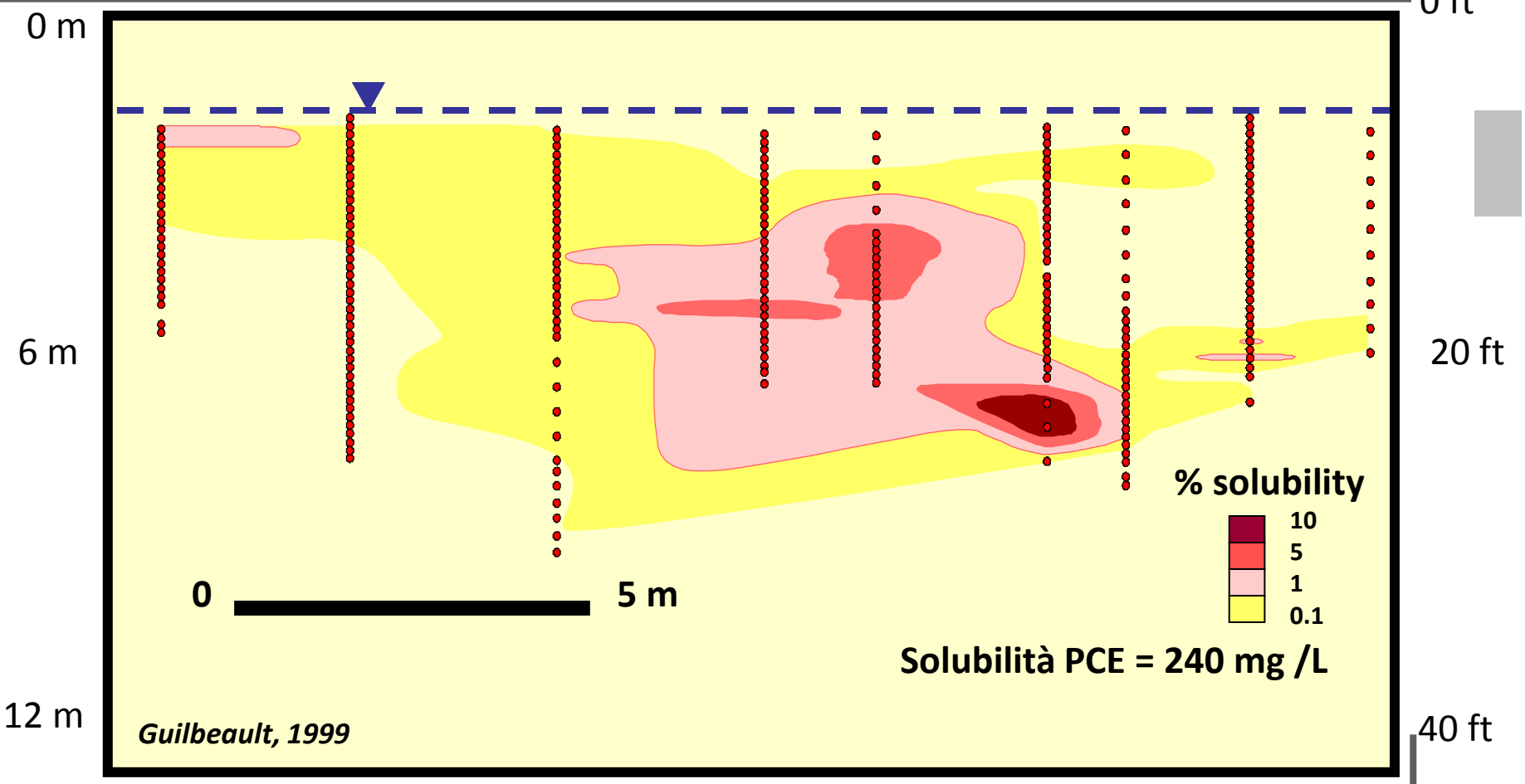
Guilbeault, 1999

Plume di Angus (Ontario)
Formazione di mini-plumes ("pencil plumes")

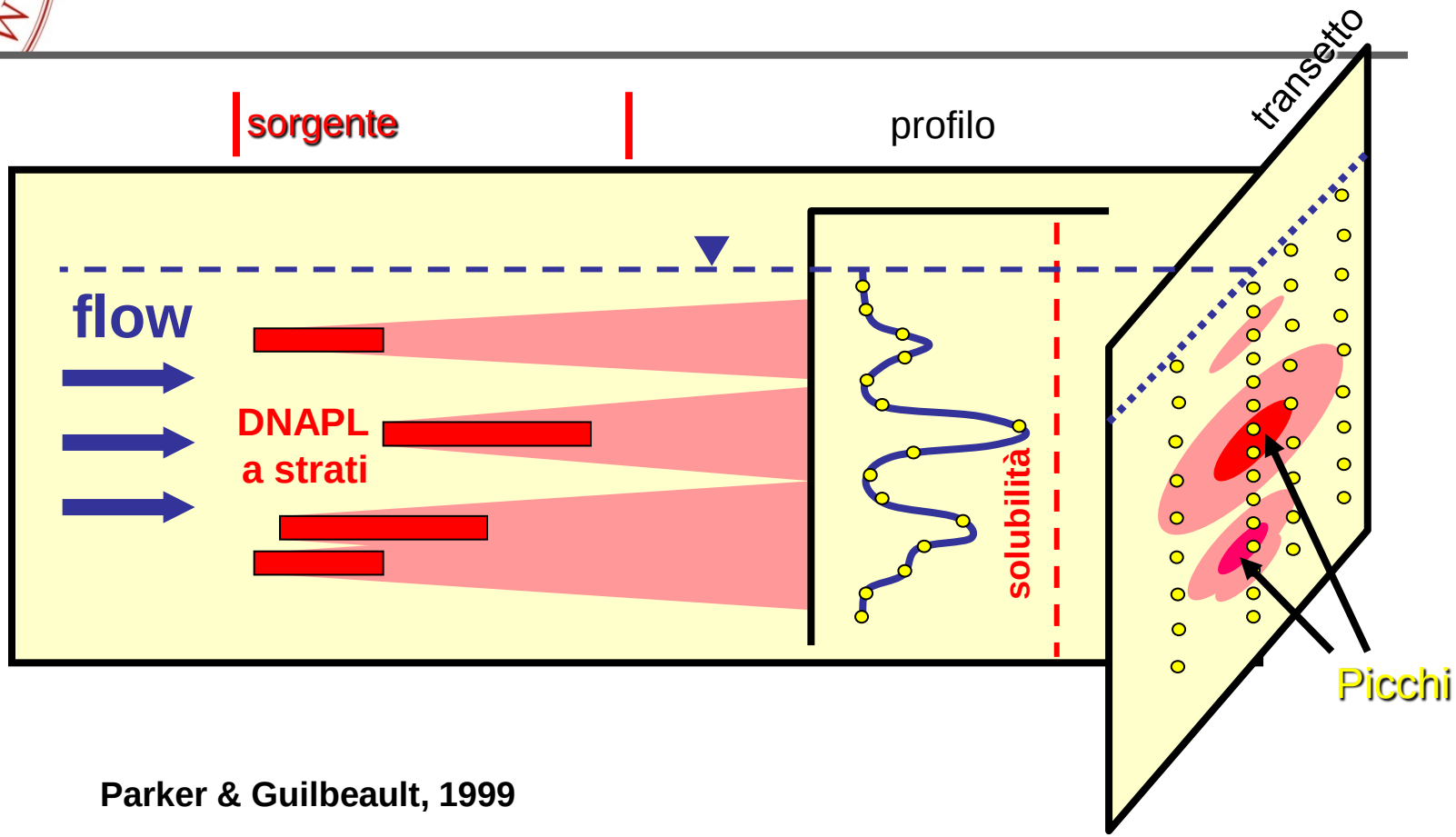


Dati da Pitkin (1994), Writt (1996), Conant (2001), Guilbeault (1999)

Transetto

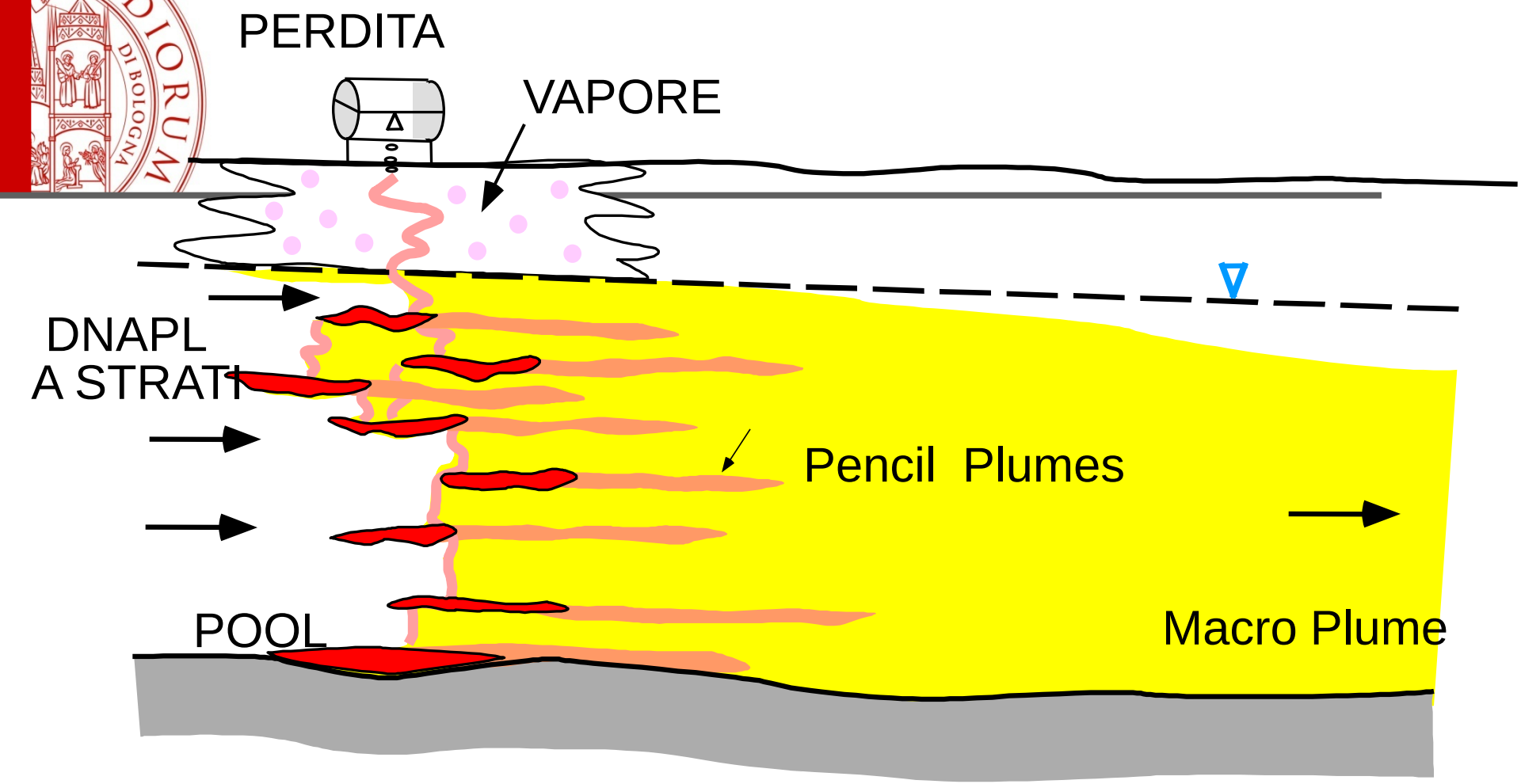


Modello concettuale alternativo



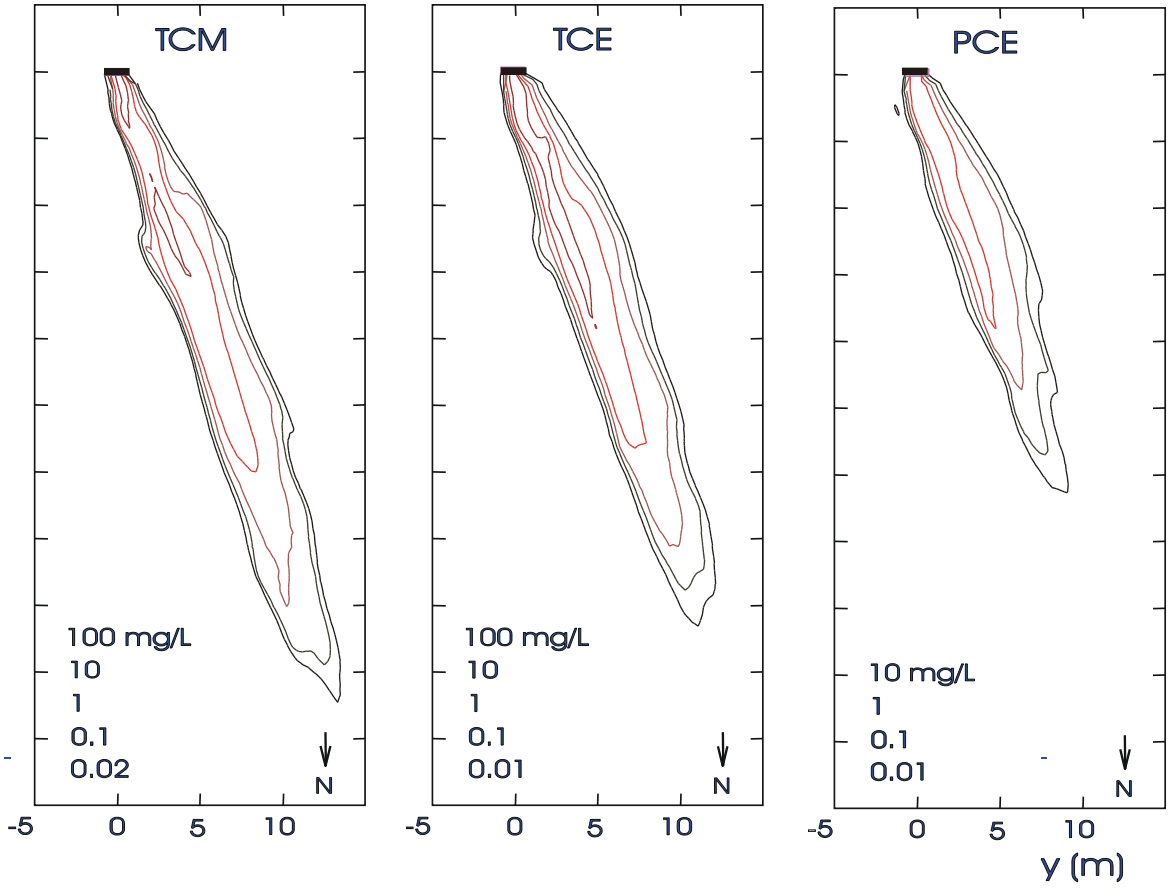
Parker & Guilbeault, 1999

Pencil plumes

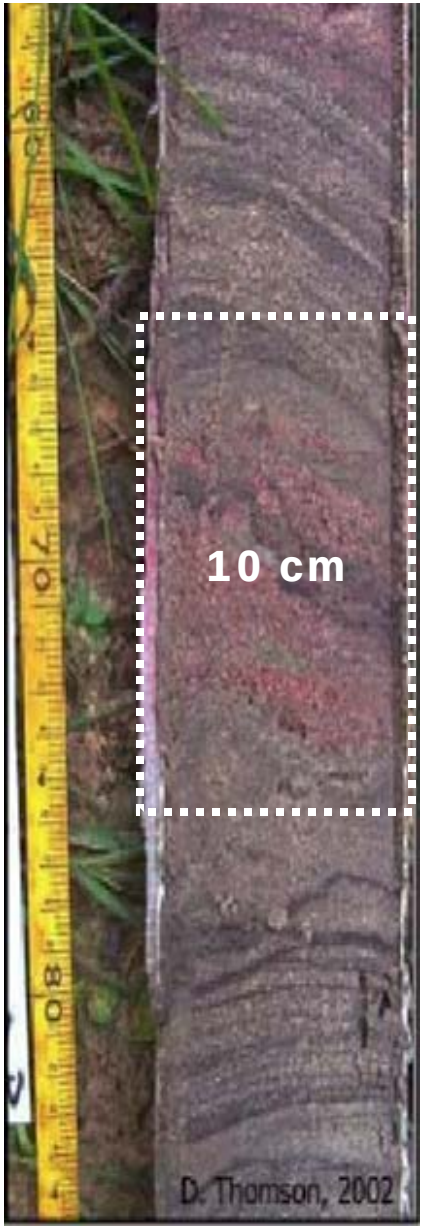


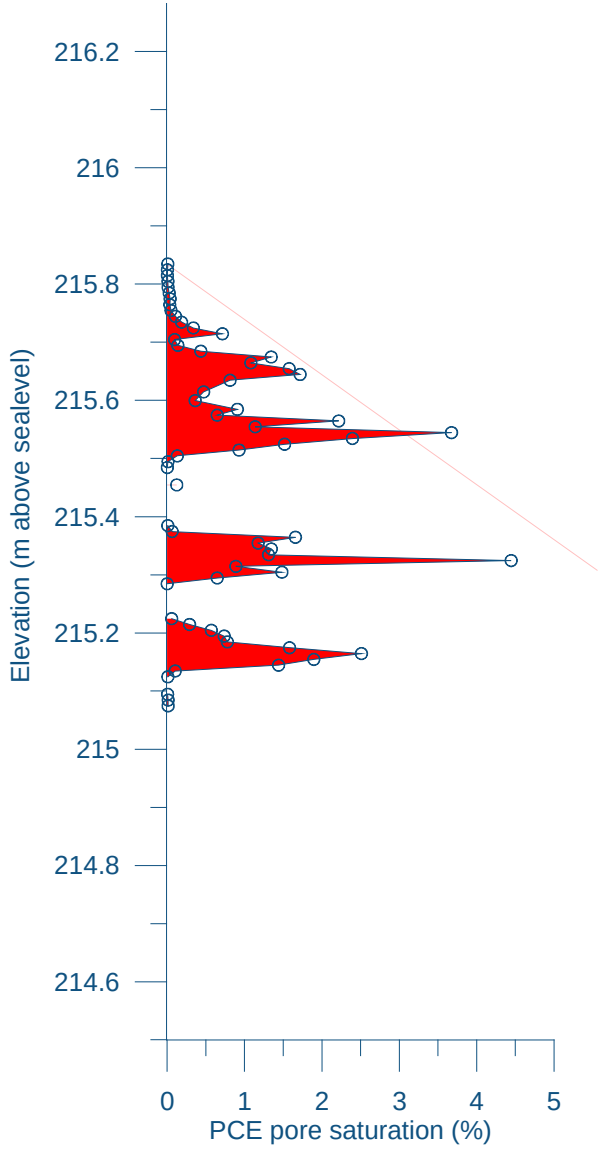
SORGENTE	MIXING	DISPERSIONE DEL PLUME

PENCIL PLUMES RICREATI A BORDEN



Elevata variabilità nella distribuzione del grado di saturazione relativo con passo di campionamento 1 cm



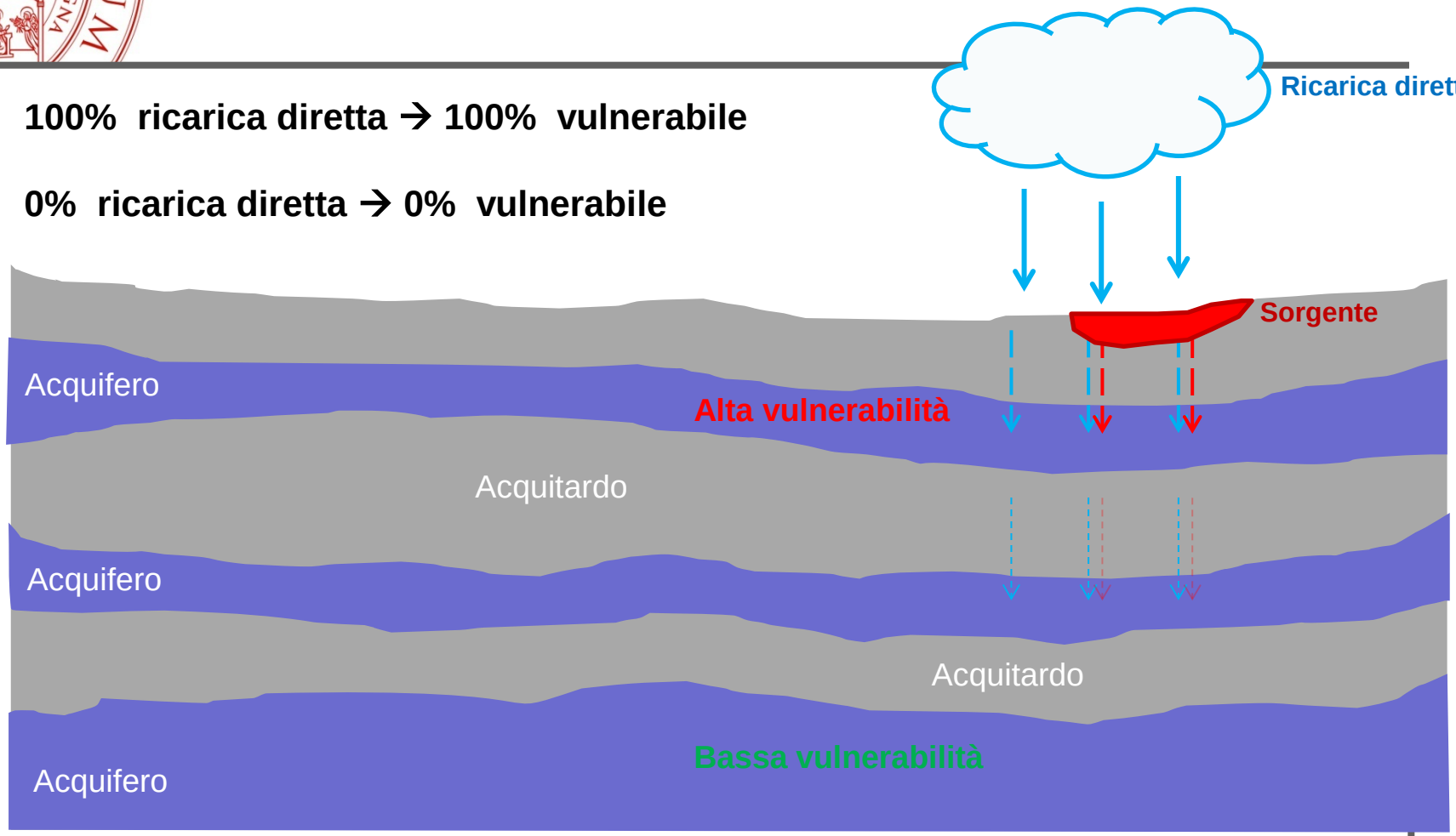


DNAPL ed acquitardi

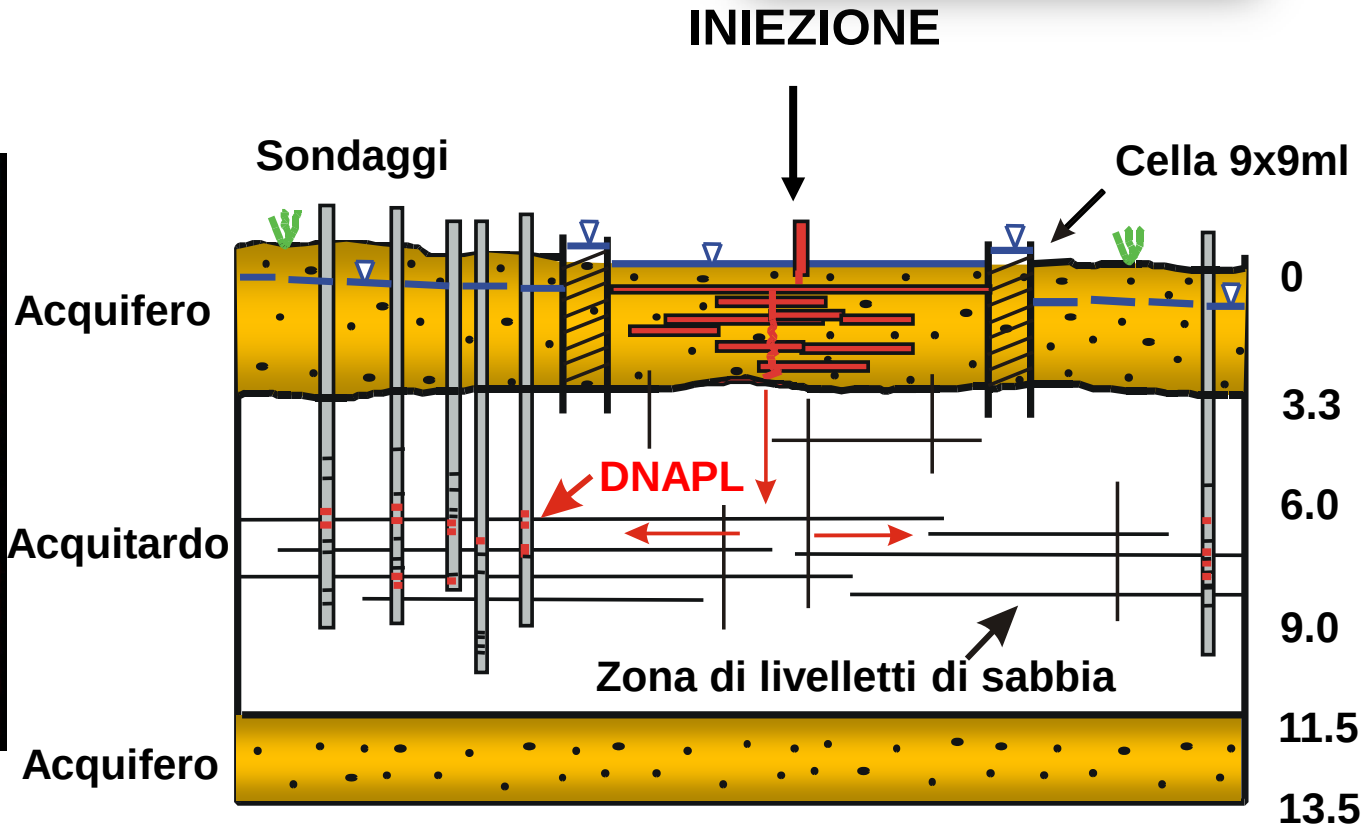
Il modello classico è adeguato?

100% ricarica diretta → 100% vulnerabile

0% ricarica diretta → 0% vulnerabile



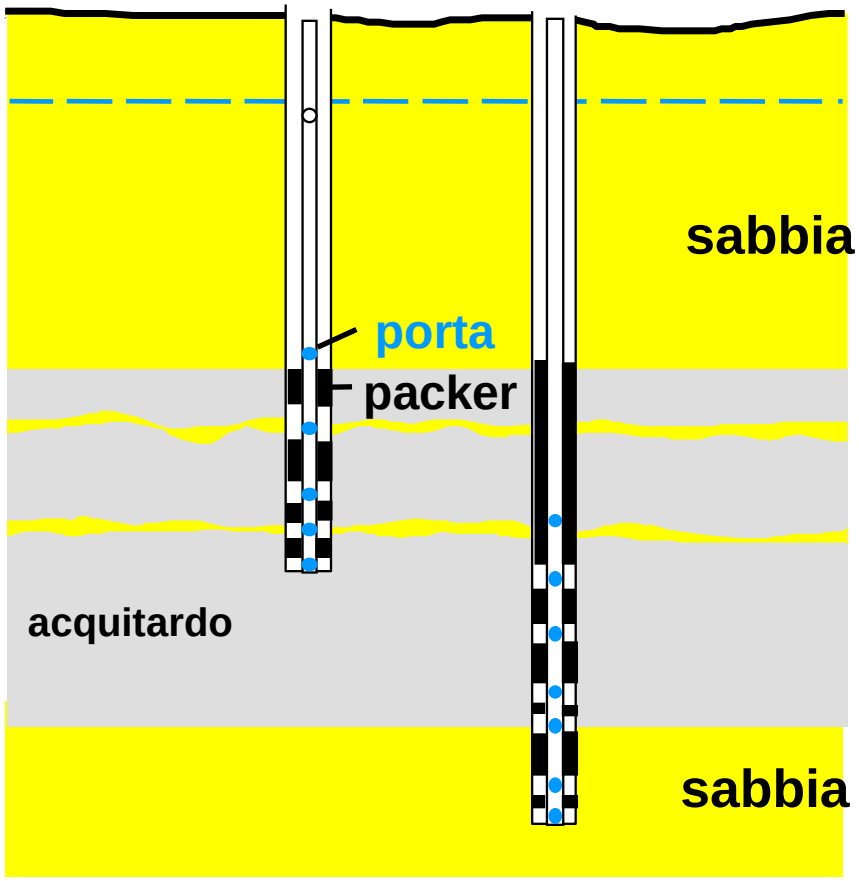
Approccio sperimentale al Borden site

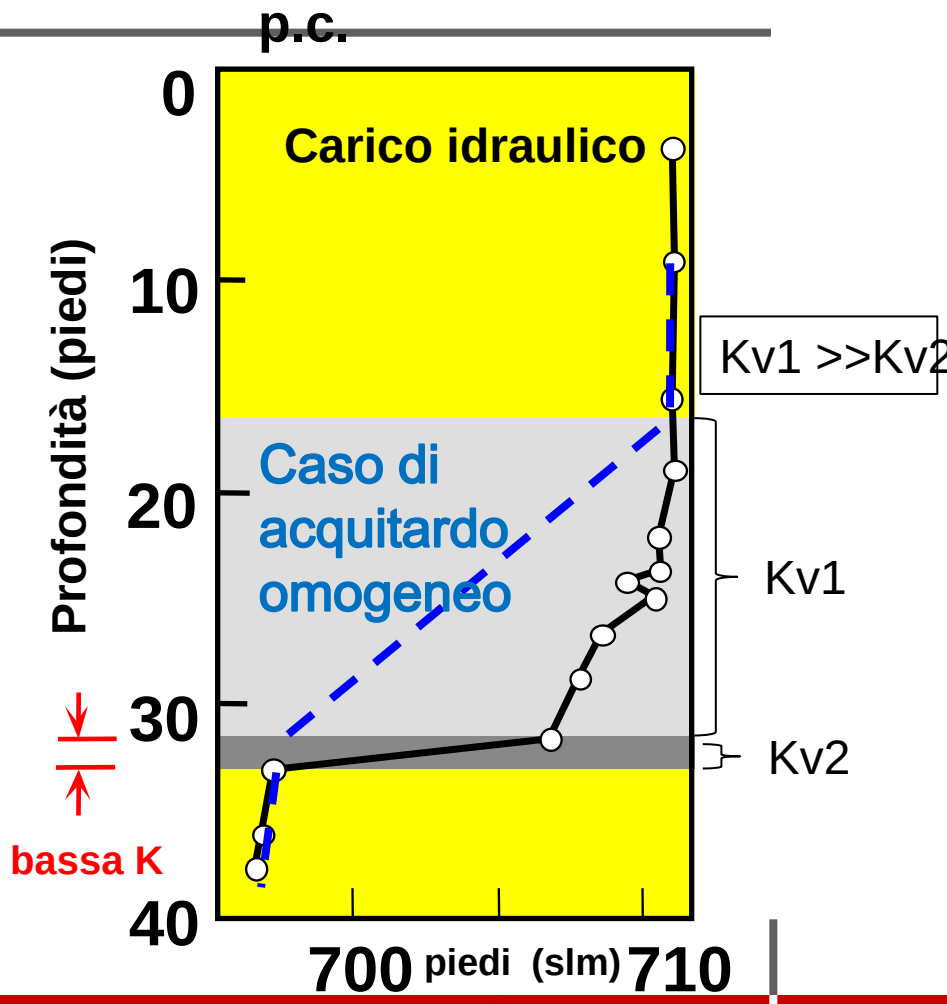


Borden site
Profilo di carico idraulico
La resistenza idraulica è concentrata in 60 cm

"The shape of the head profile is everything" J.A.Cherry

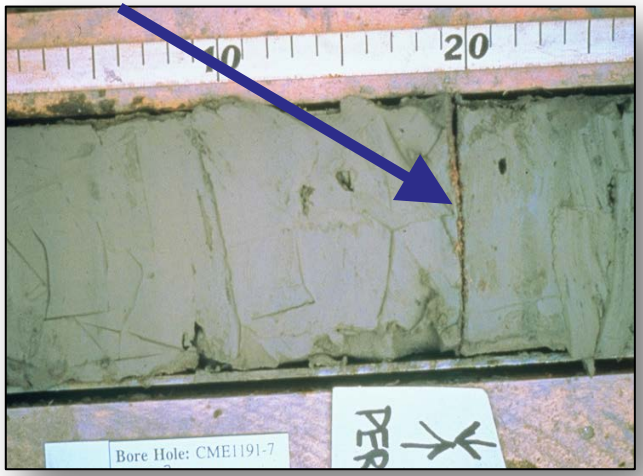
CMT MLS

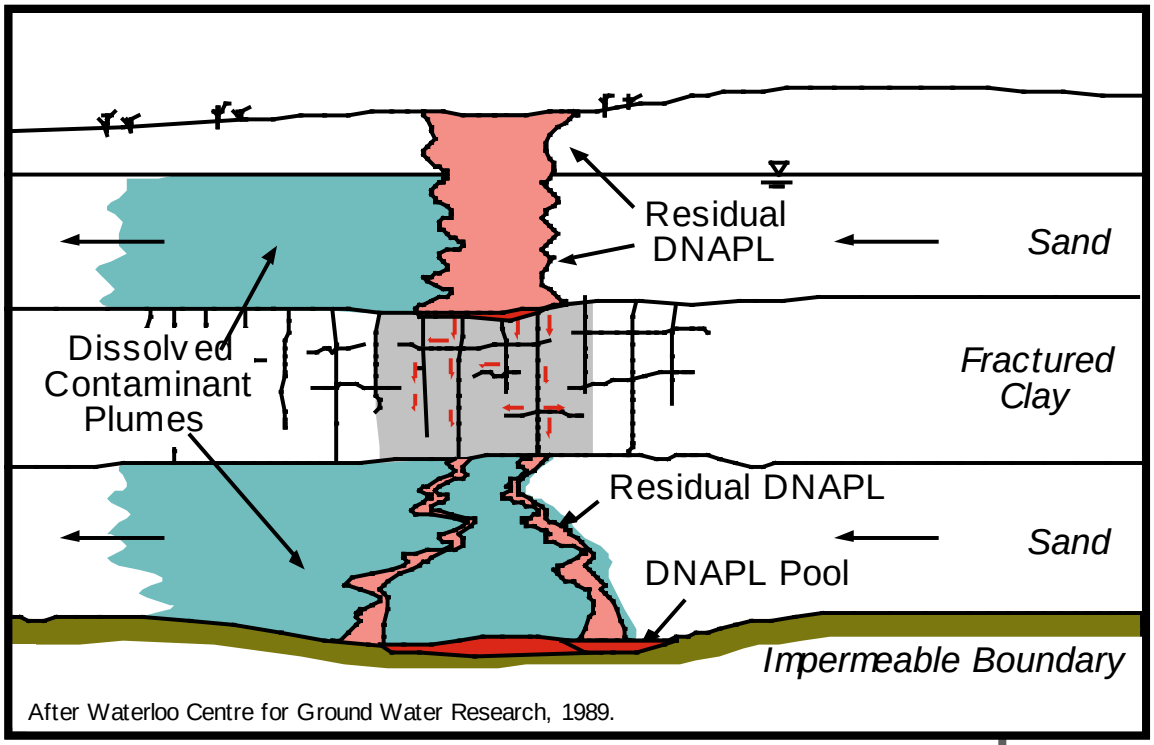




(Meldrum, 1999)

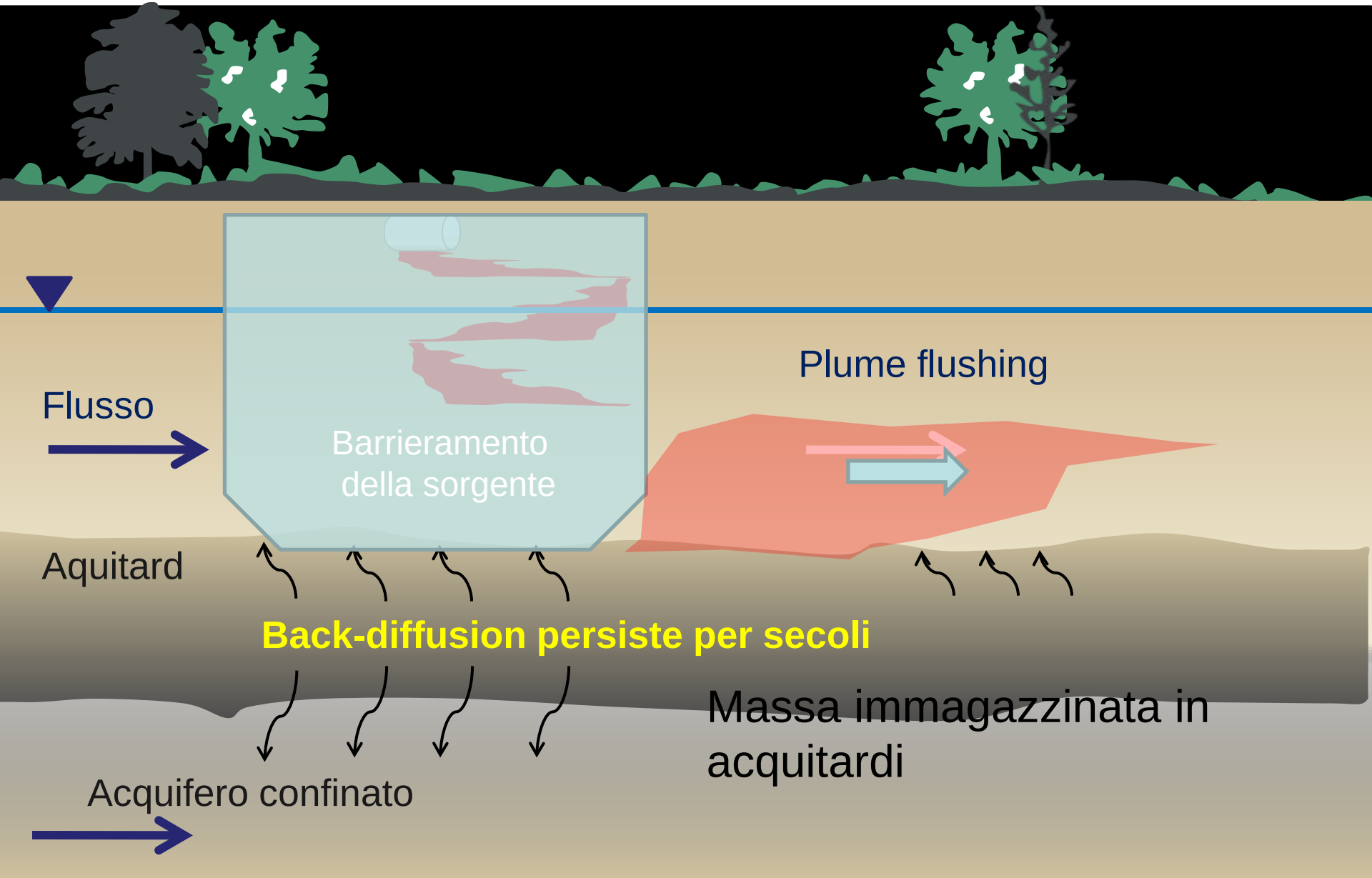
Acquitardi non sono barriere per i DNAPL



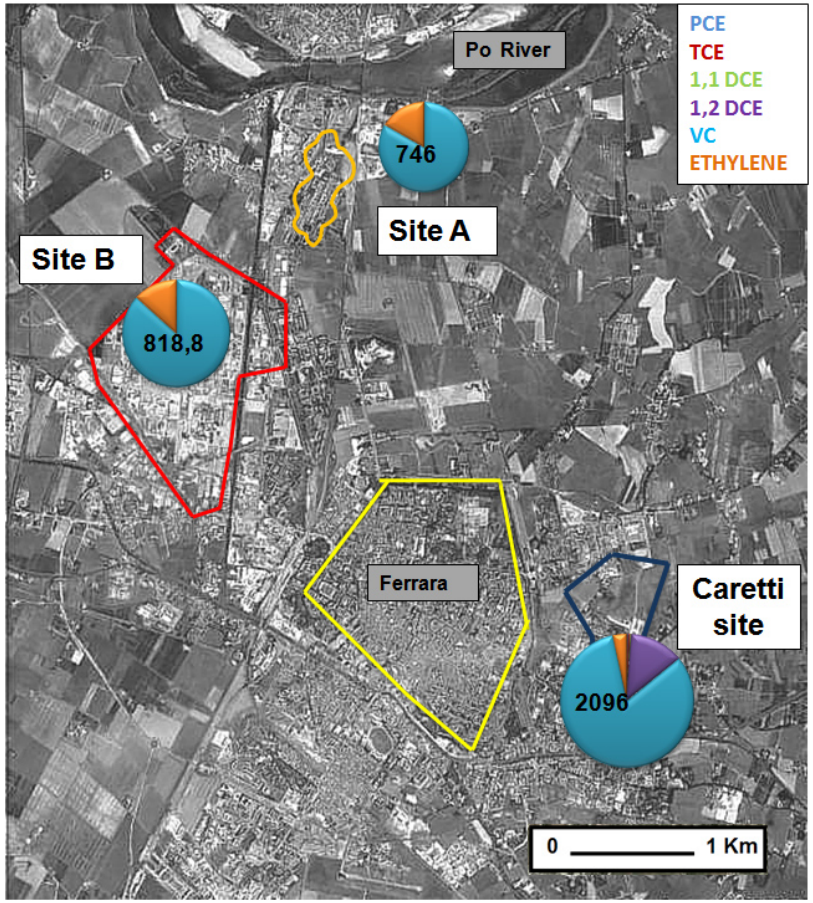


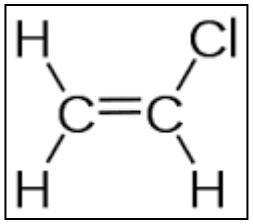
After Waterloo Centre for Ground Water Research, 1989.

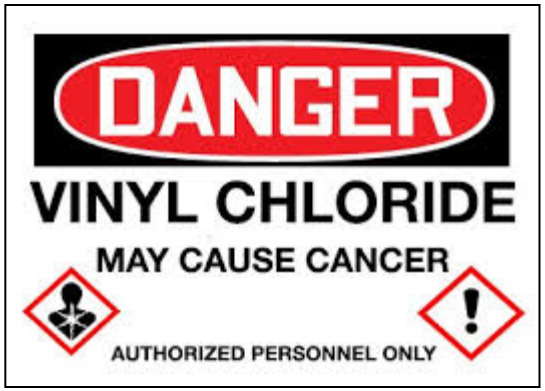
Persistenza del plume per back-diffusion dall'acquitardo



Condizioni di formazione del Cloruro di Vinile
Peculiarità del sito di Ferrara







Le sfide
1- Approccio multilivello della caratterizzazione

"To exploit at the most one single borehole is better than use several simple boreholes"

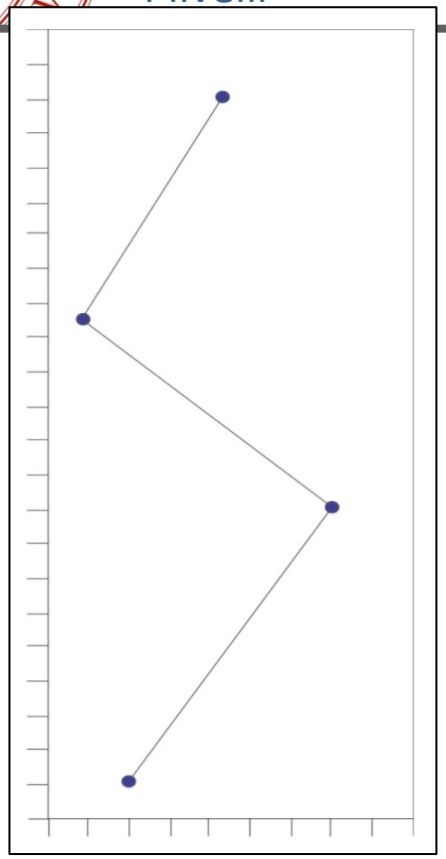
J.A. Cherry and B.L. Parker

Profili verticali di dati

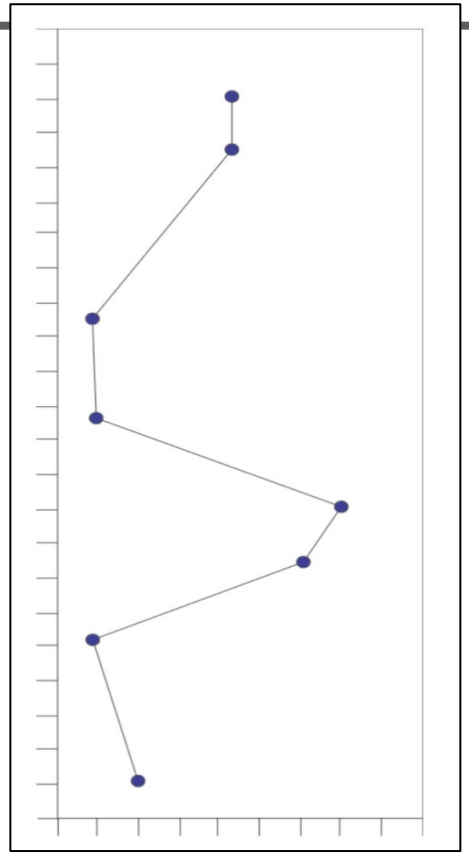
"The shape of the head profile is everything" J.A.Cherry

Profondità

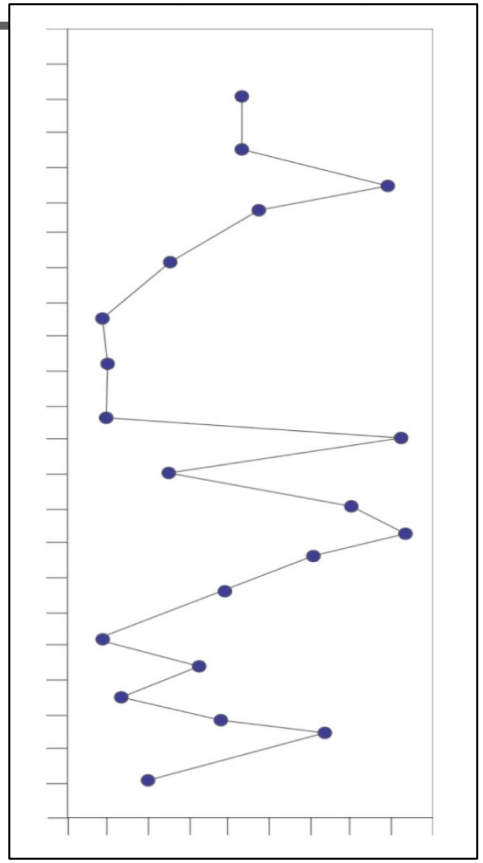
4 livelli



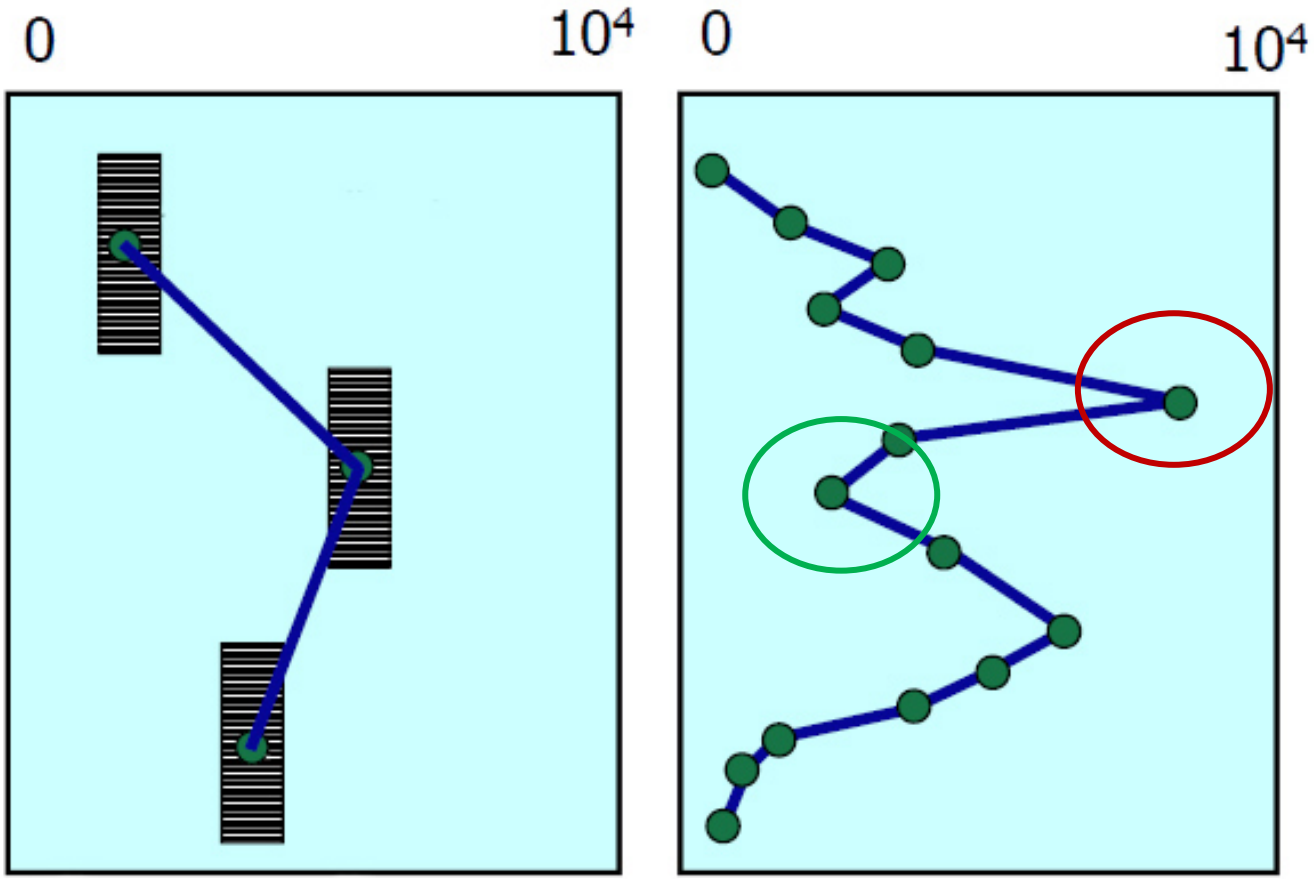
8 livelli



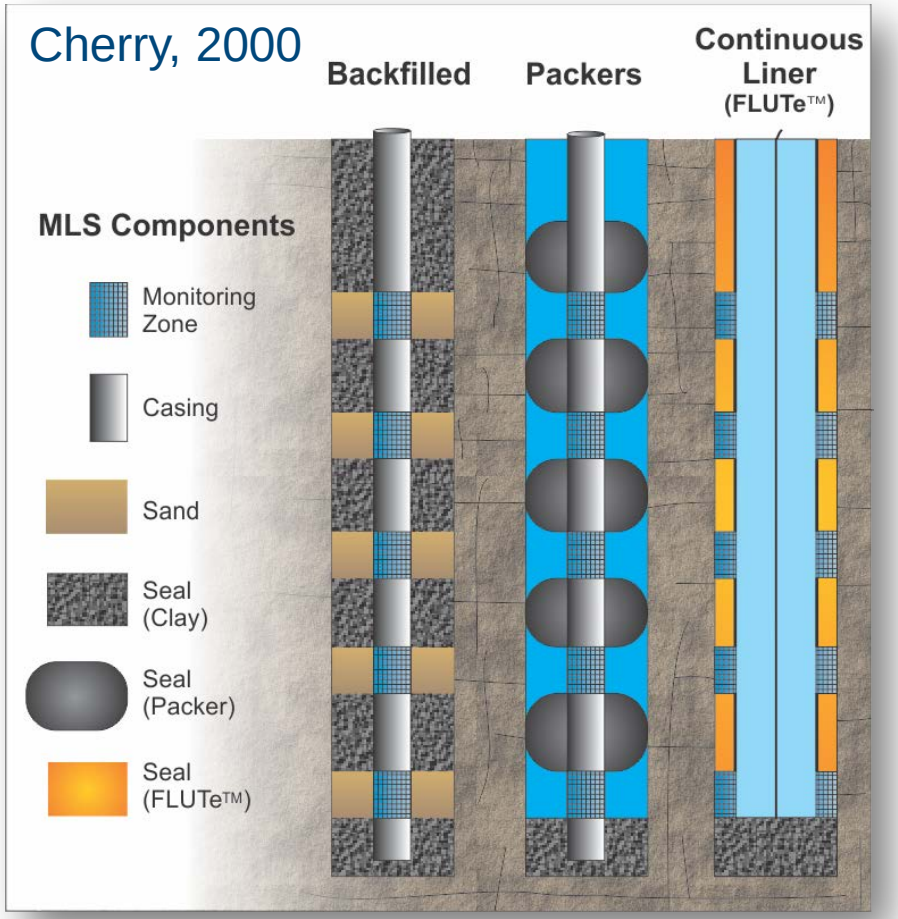
20 livelli



Evidente inadeguatezza dei piezometri "classici"



Monitoraggio multilivello a profondità discreta (MLS)



Sistema multilivello (MLS)

Partizione di un singolo foro in porte discrete per il campionamento

MLS commerciali disponibili sul mercato

Westbay

Schlumberger WATER SERVICES

Waterloo

Solinst®

Water FLUTe

FLUTe™
Flexible Liner Underground Technologies, Ltd. Co.
A medley of innovative designs

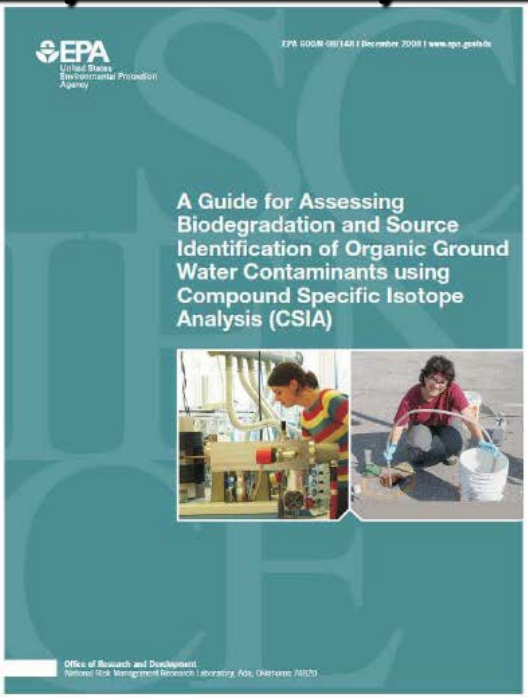
CMT

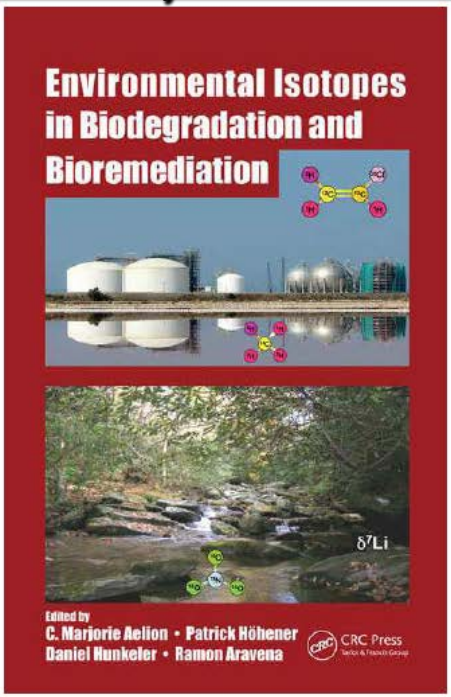
Solinst®

Le sfide

2- "Pays polluter principle"

CSIA
Compound Specific Isotope Analysis





http://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1002VAI.PDF

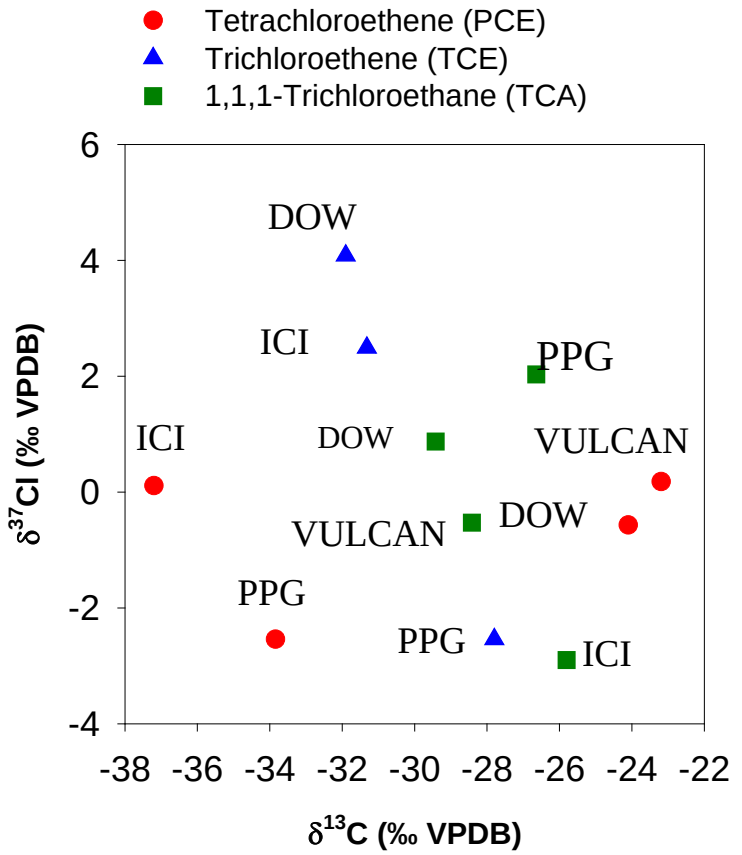
RAPPORTO ISOTOPICO MEDIO DI COMPOSTI NATURALI DEL CARBONIO

$$\delta^{13}C = \left(\frac{^{13}C/^{12}C_{Sample}}{^{13}C/^{12}C_{Standard}} - 1 \right) \cdot 1000 \quad \textbf{(‰ VPDB)}$$

	$^{13}C/^{12}C$	$\delta^{13}C$
Carbonati	0.01124	**0**
CO_2 atmosferica	0.01116	**-7**
Biomassa	0.01096	**-25**
Metano biogenico	0.01045	**-70**

Più PESANTE ^{13}C

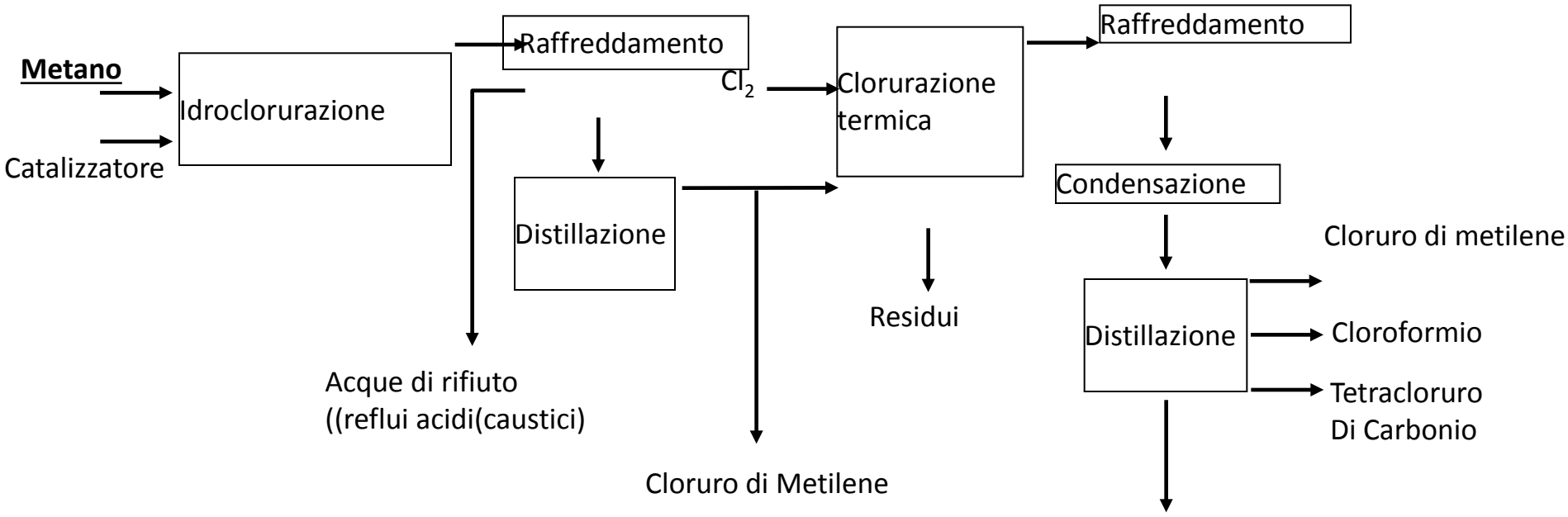
Firma isotopica di solventi in commercio



Van Warmerdam et al., 1995

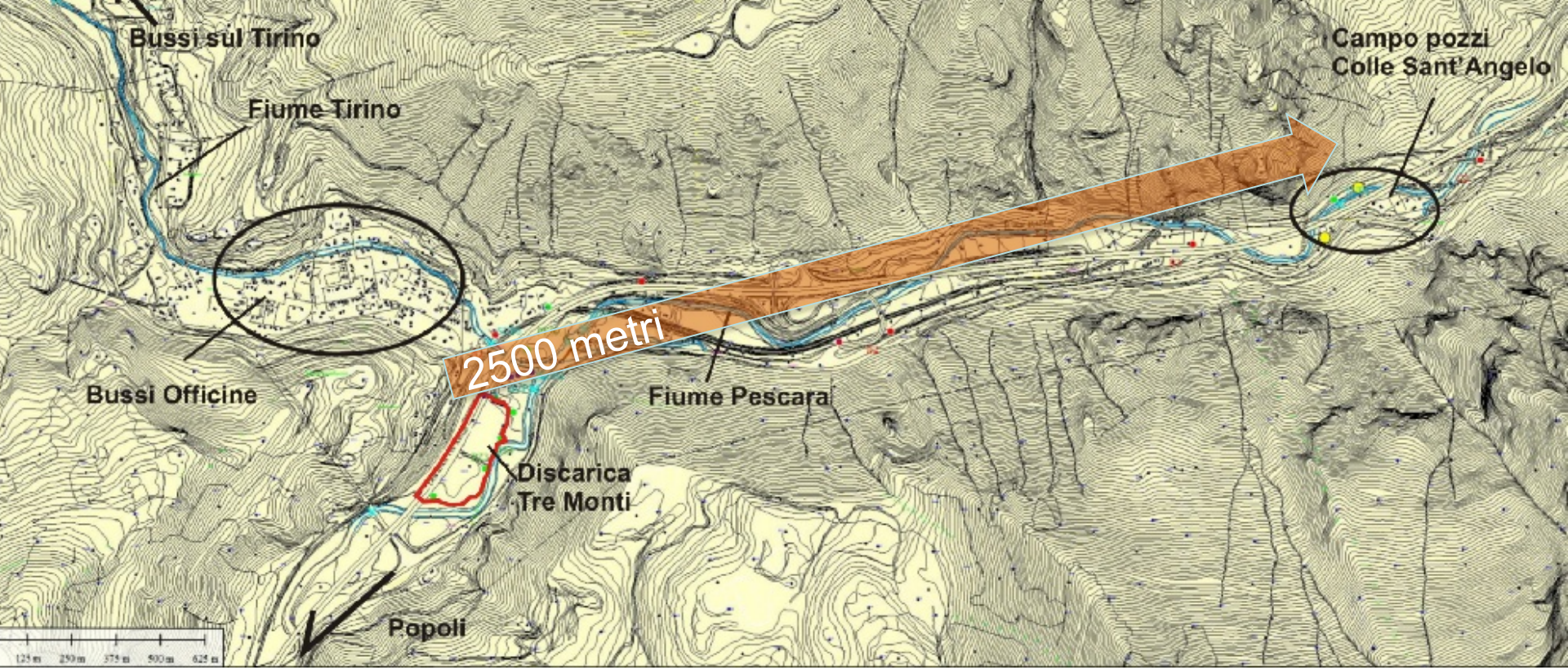
PROCESSO PRODUTTIVO TIPICO DI UNO STABILIMENTO DI CLORO-METANI

Si parte da Metano e Cloro e si producono cloro-metani



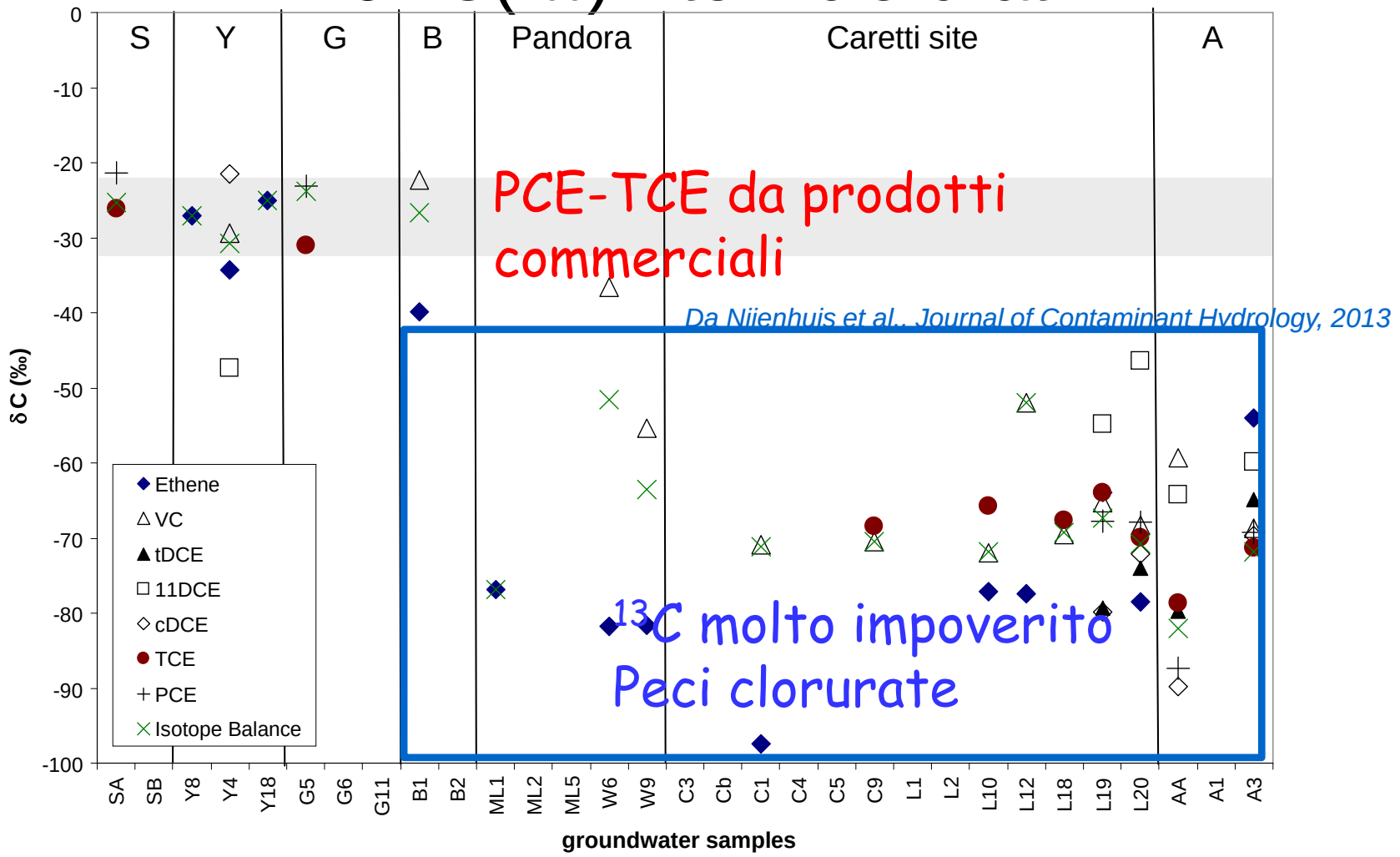
RIFIUTI: PECI CLORURATE MORCHIE LIQUIDO/OLEOSE RICCHE DI PCE, TCE, ESACLOROETANO, TETRACLORURO DI CARBONIO Etc..

Sito "Caretti" (Ferrara)
Sito "I Tre Monti" (Bussi sul Tirino)



Sito di Bussi sul Tirino (Pescara)

Fingerprinting isotopico siti di Ferrara
$\delta^{13}C$(‰) Eteni clorurati

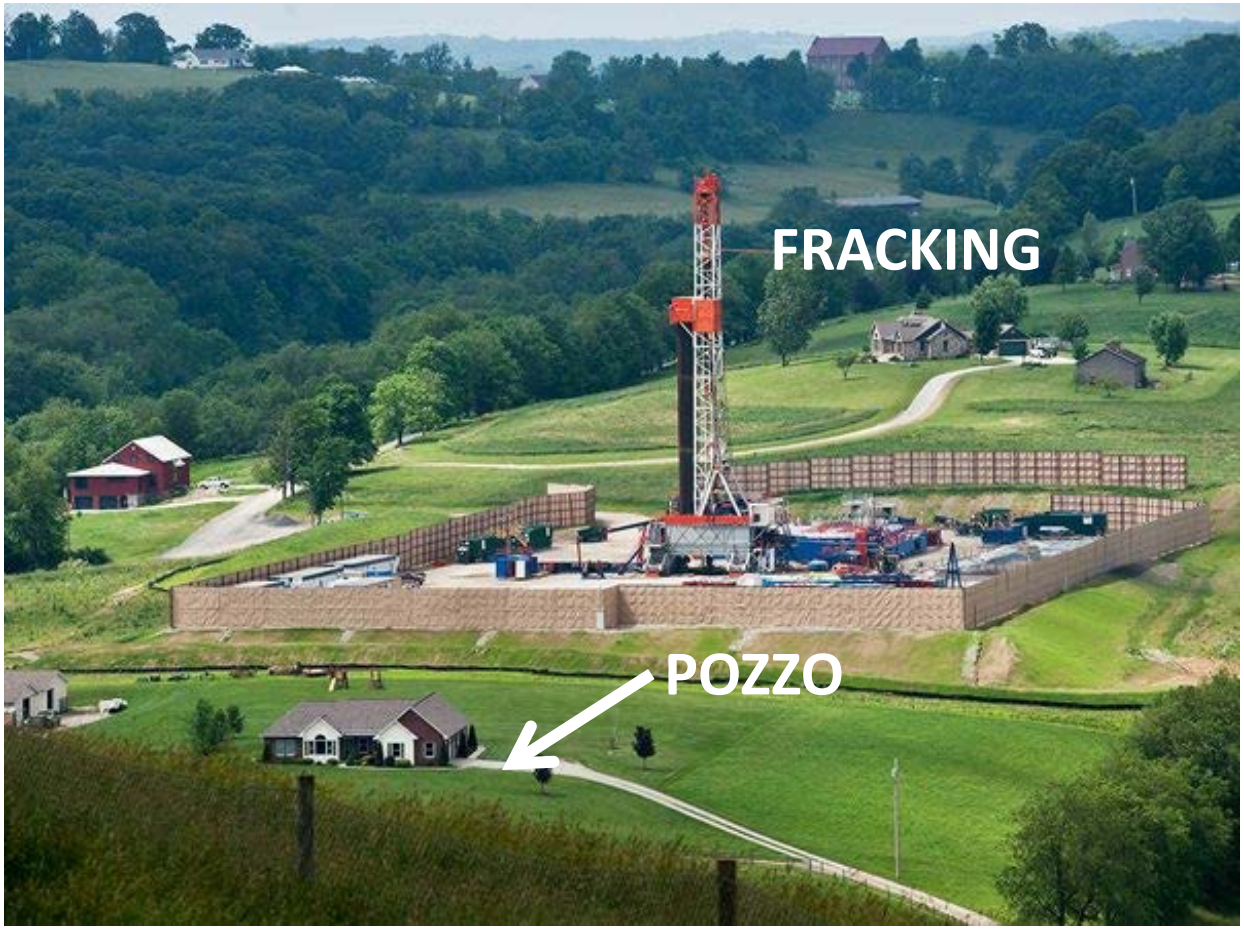


Le sfide
3-Assimilation Capacity (Capacità di assimilazione)

Definizione: la capacità di un recettore idrico (lago, fiume, mare, acquifero, groundwater dependent ecosystem) di assimilare acque di rifiuto o sostanze tossiche **senza effetti dannosi per la biocenosi e gli esseri umani che consumano l'acqua**

Cherry (2014)

Quale è la distanza di sicurezza?



(National Geographic)

Quale concentrazione posso dichiarare "sostenibile/assimilabile" in falda

- Dispersione
- Diffusione
- Adsorbimento (reversibile)
- Reazioni chimiche (alcune reversibili)
- Degradazione biologica
- Volatilizzazione

I processi sono sito specifici e legati al sistema idrogeologico

CONSIDERAZIONI CONCLUSIVE

1) *L'idrogeologia dei solventi clorurati riflette situazioni di estrema complessità che richiedono modelli concettuali ed approcci del tutto innovativi*

2) *Oltre che strumenti innovativi (MLS, isotopi) la caratterizzazione accurata della geologia e idrogeologia del sito diventa essenziale*

3) *NON POSSIAMO PENSARE DI AVERE LE RISORSE PER BONIFICARE TUTTI GLI ACQUIFERI CONTAMINATI DA SOLVENTI. URGE UNA RIFLESSIONE SUL CONCETTO DI PUNTO DI CONFORMITA' ALLA CSC AL LIMITE DI PROPRIETA' ED UN INCANALARE LE RISORSE SECONDO UN A CLASSIFICA DI PRIORITA' CONDIVISA DA TAVOLI TECNICI DECISORI*

Ringraziamenti

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Minister of the Environment and Protection of Land and Sea