LANDFILL GAS IMPACTS TO SHALLOW GROUNDWATER

What is the real issue?

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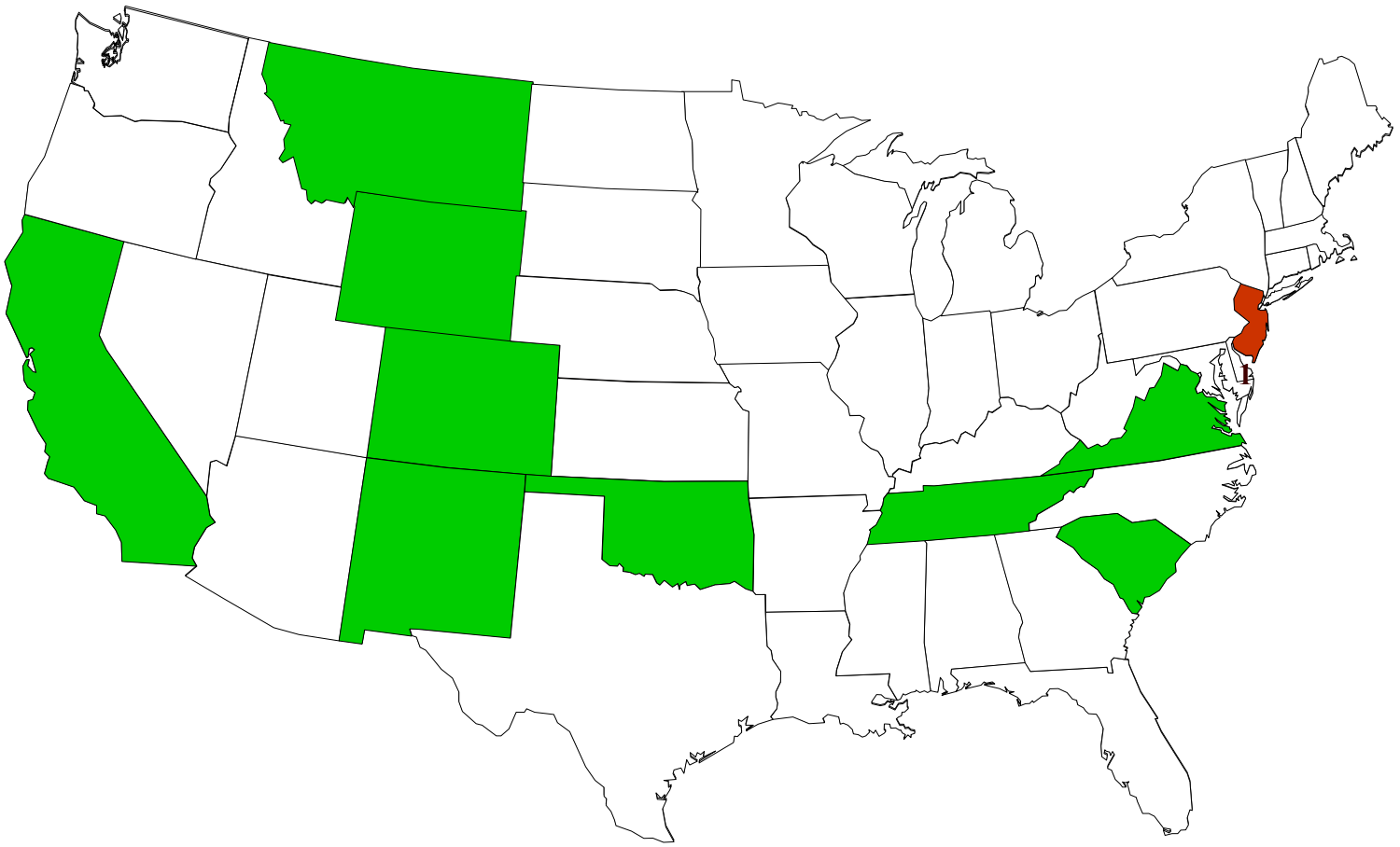
How significant are LFG groundwater impacts at MSW landfills?

- **One consultant's opinion (mine)** – ***Gas usually is the cause of groundwater impacts we have observed at landfills***
- **Another consultant's opinion (not mine)** – ***90% of groundwater issues at MSW landfills are LFG-caused***
- **A major landfill operator's opinion** – ***At modern, lined landfills, 100% of observed groundwater impacts attributed to*** **LFG**

Regulatory Agency Opinions



Regulatory agency opinions

Do you know of instances in your State where LFG is the cause of elevated VOCs concentrations at MSWLF monitoring wells?

NO	YES
	CA, CO, MT, NM, OK, SC, TN, VA, WY

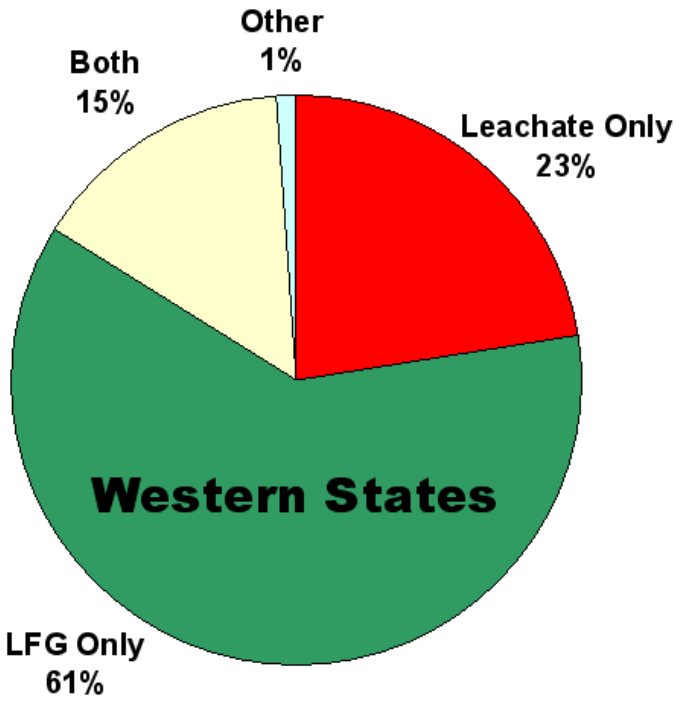
Regulatory agency opinions

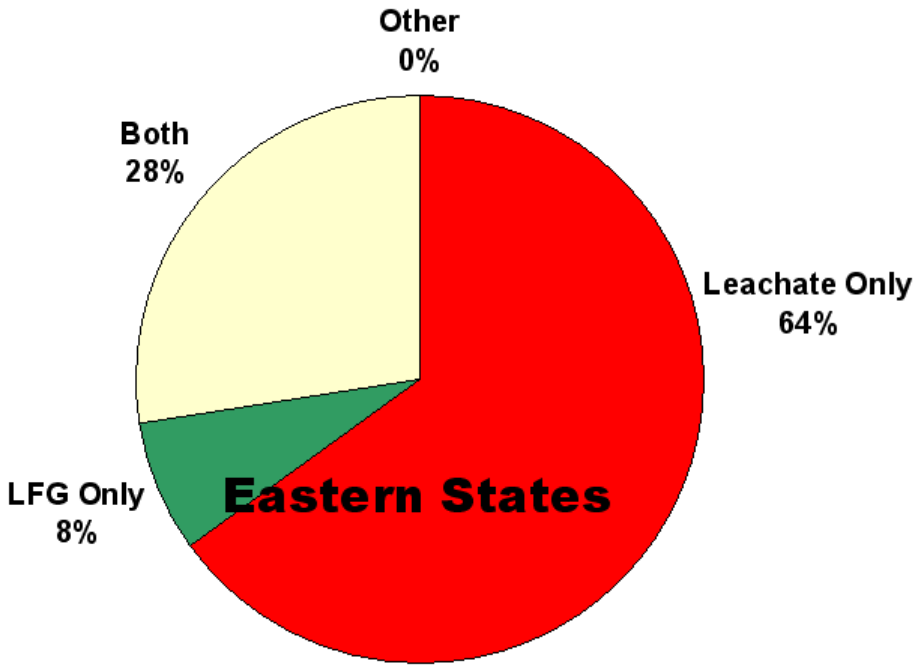
Do you know of instances in your State where LFG is the cause of elevated inorganics concentrations at MSWLF monitoring wells?

NO	YES
CA, CO, MT, OK, SC, TN, VA	NM, WY

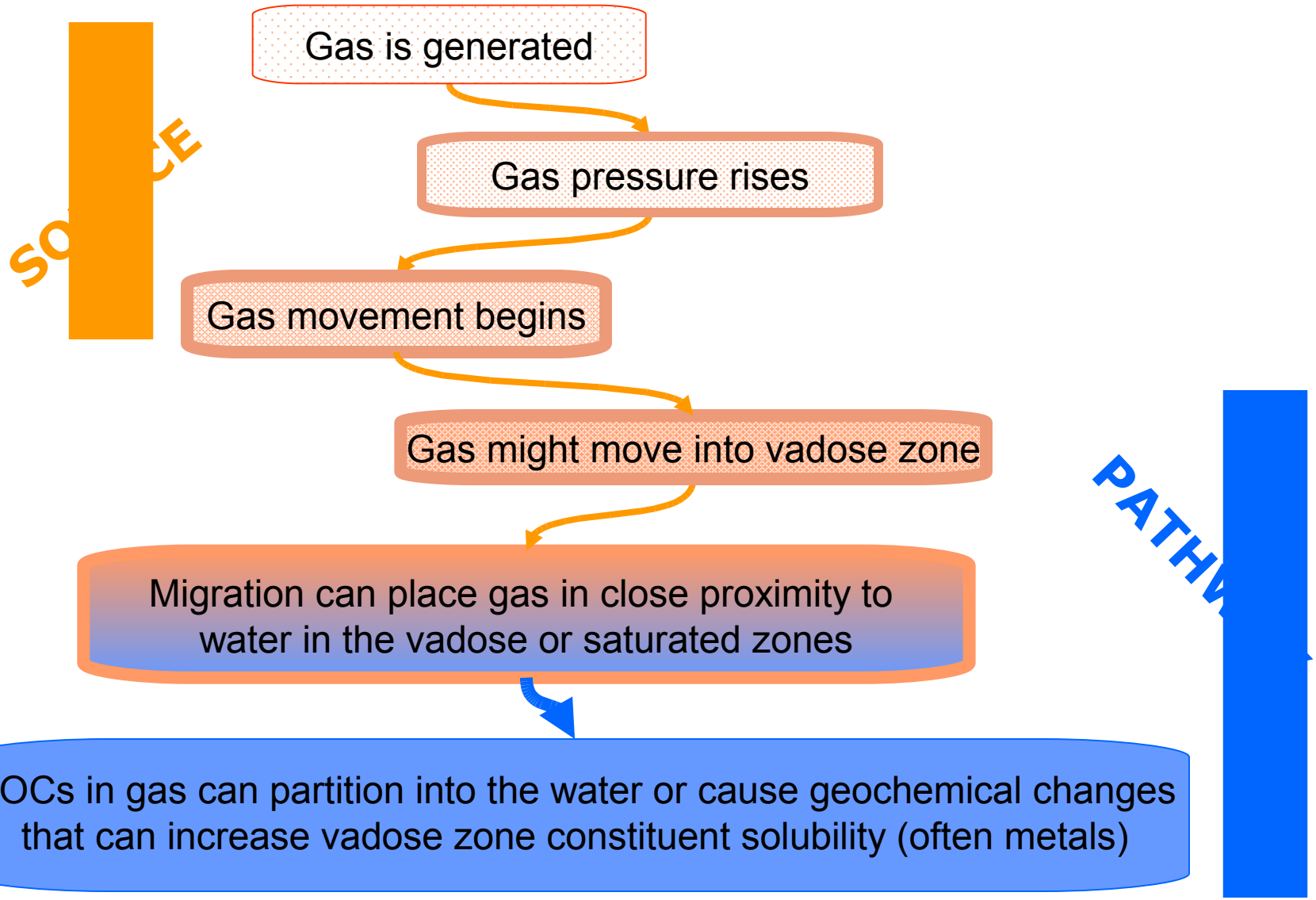
Regulatory agency opinions

Where groundwater at an MSWLF has been impacted by VOCs, can you estimate the percent of the time the following are the cause?

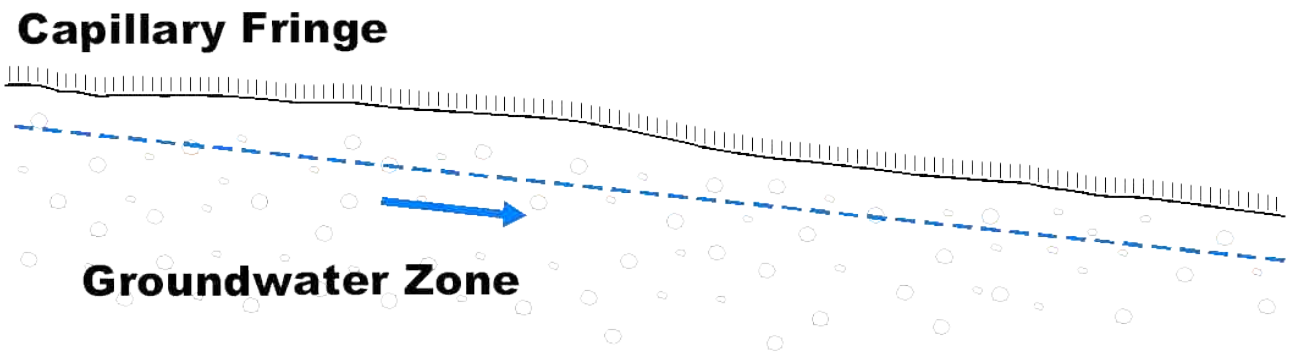


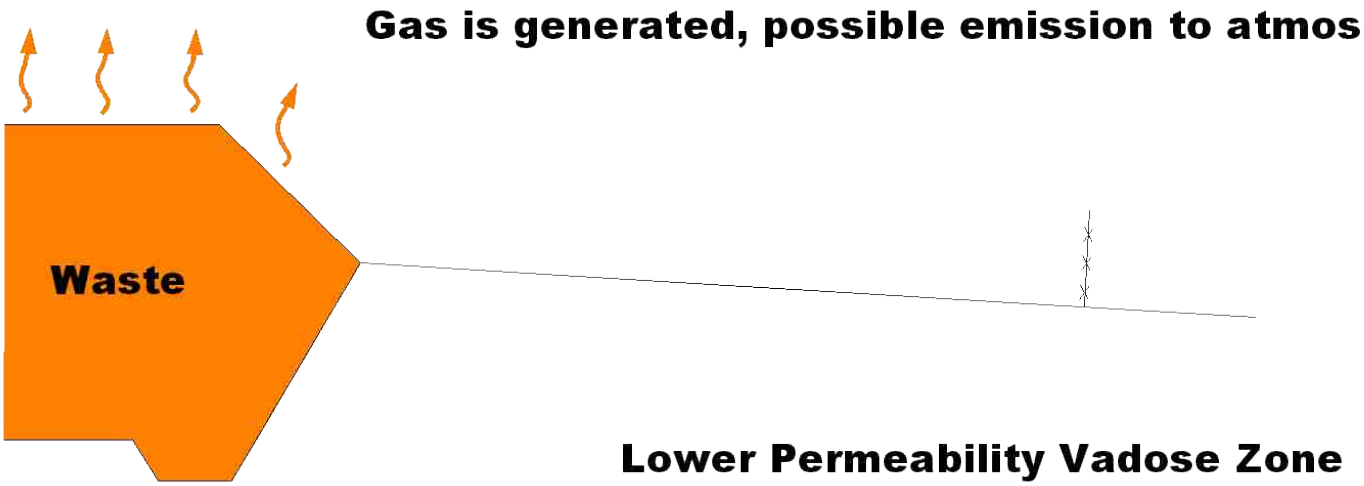


How does LFG impact groundwater?

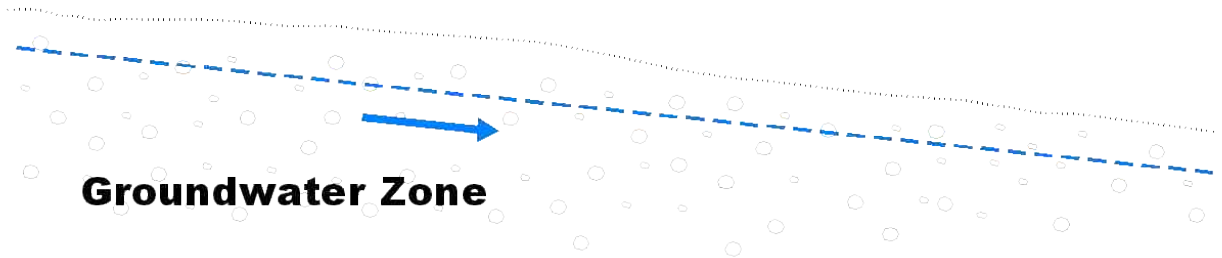


Condition before landfill gas generation and gas pressure increase

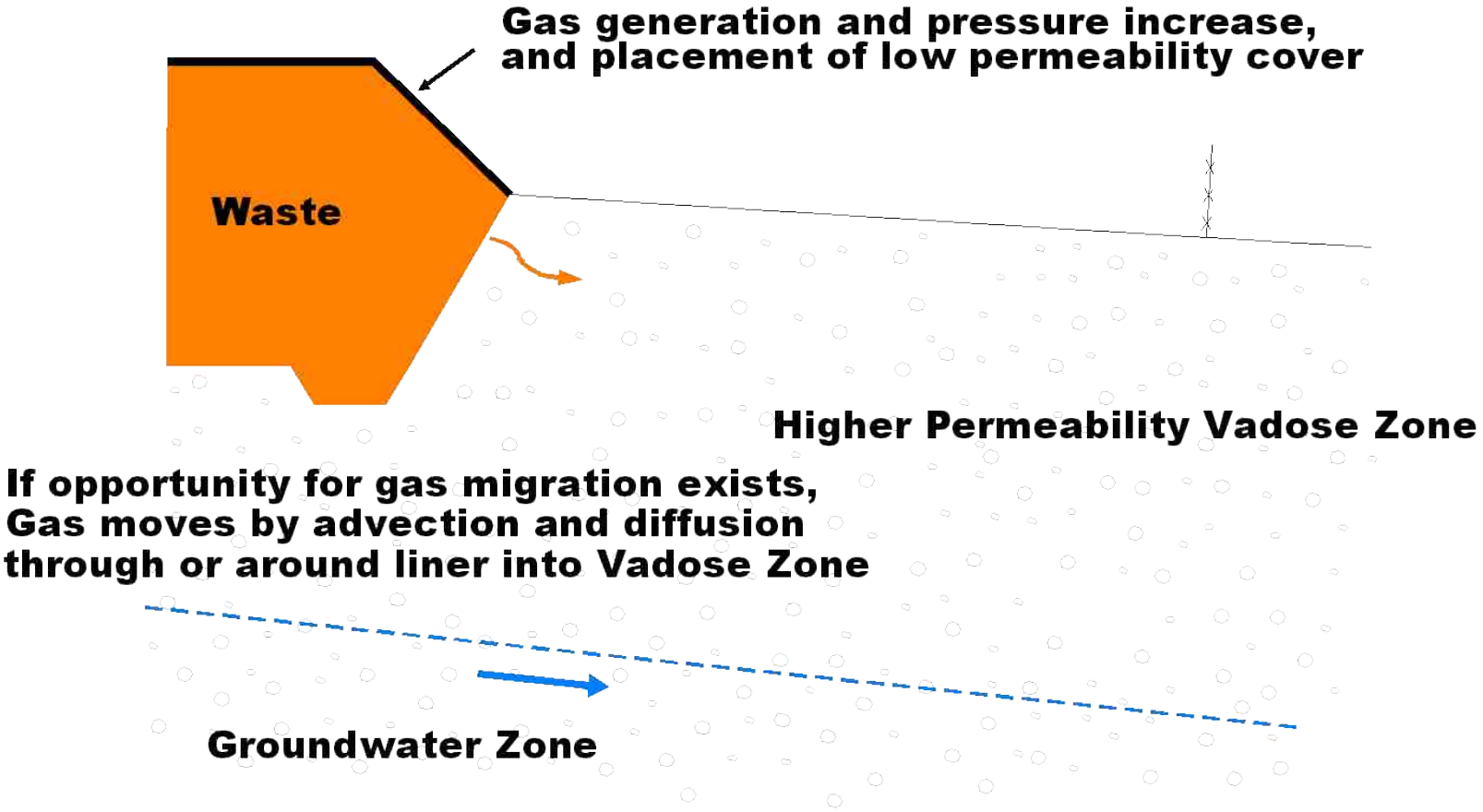


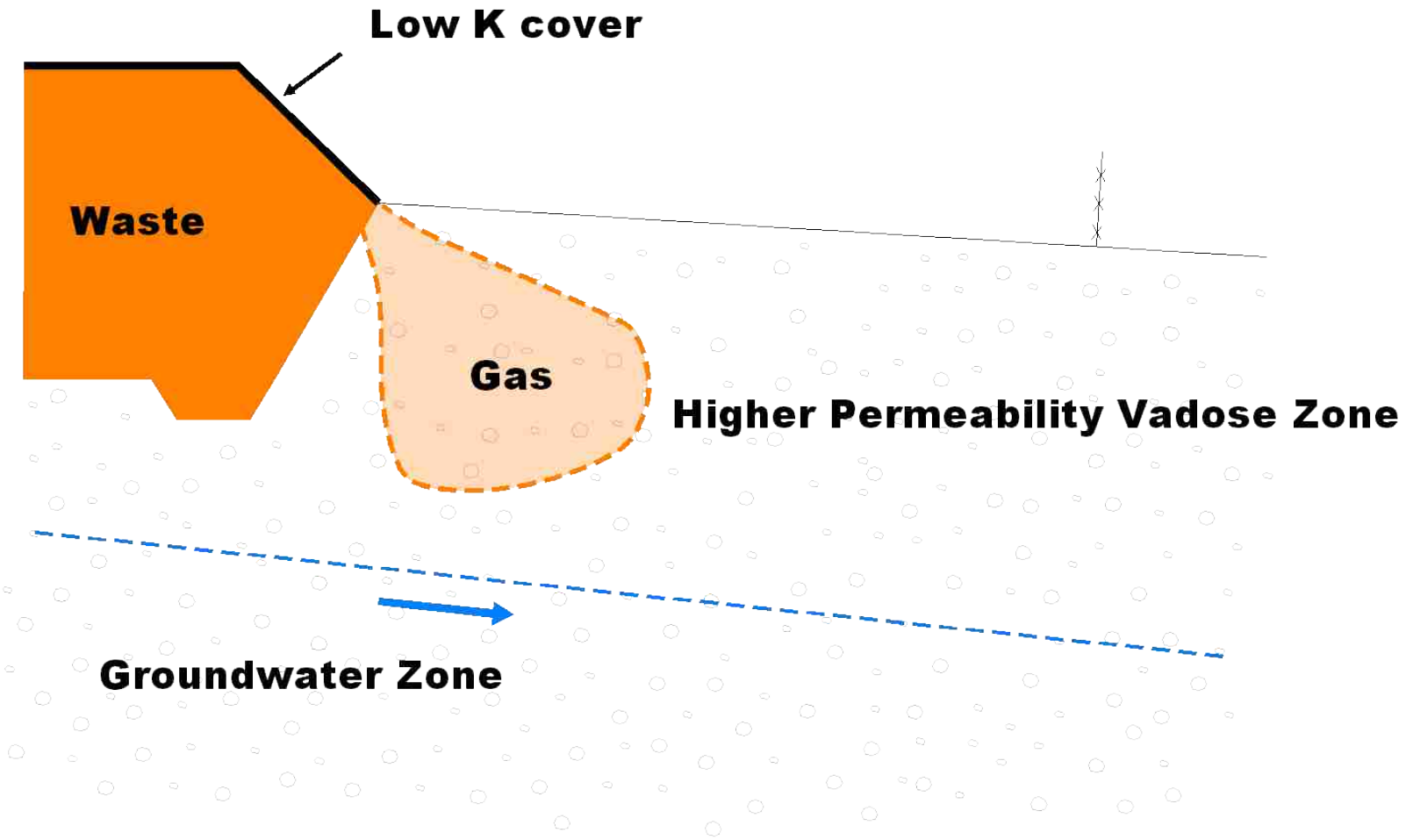


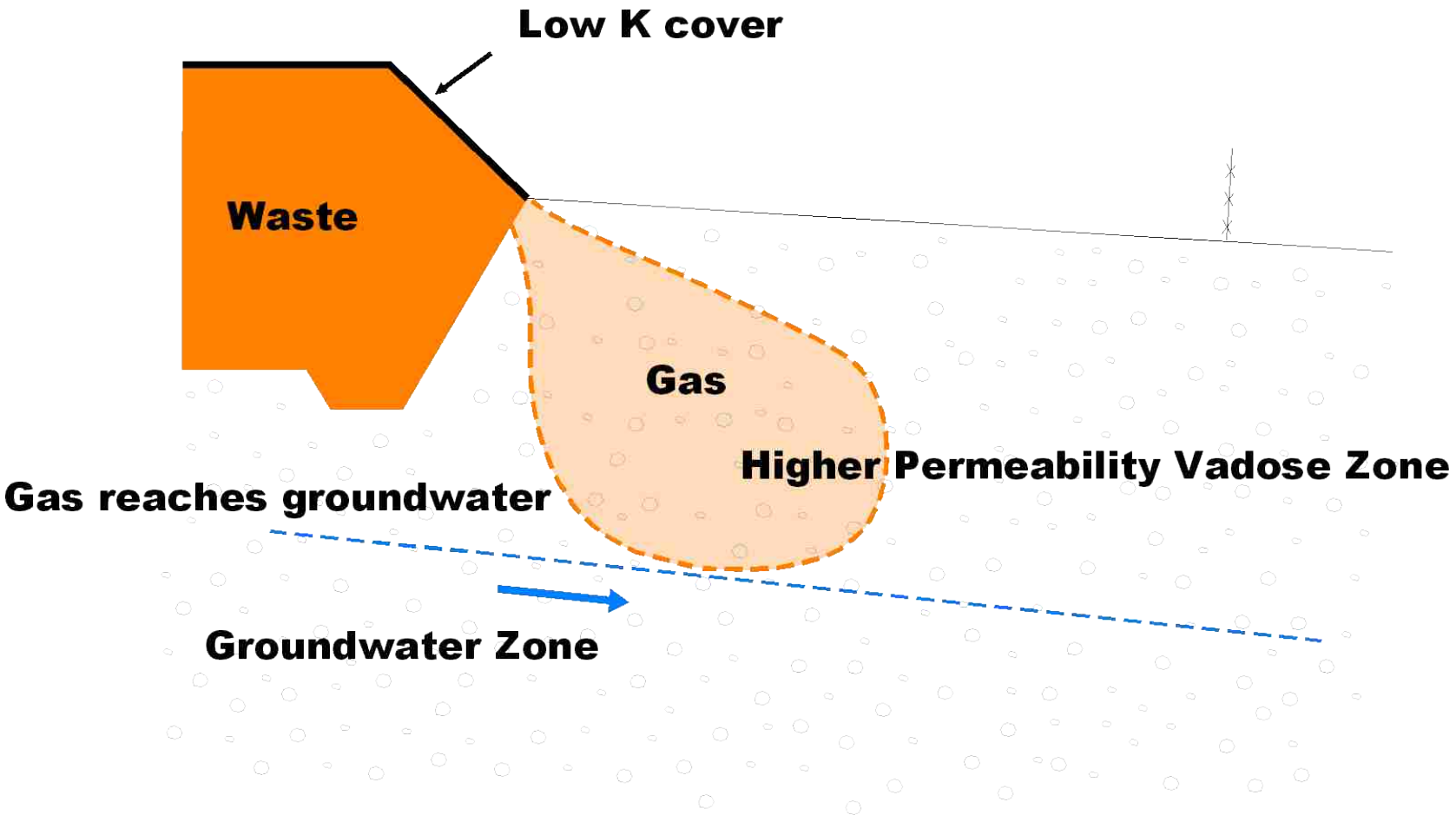
Combination of landfill liner and low K Vadose Zone prevents gas migration



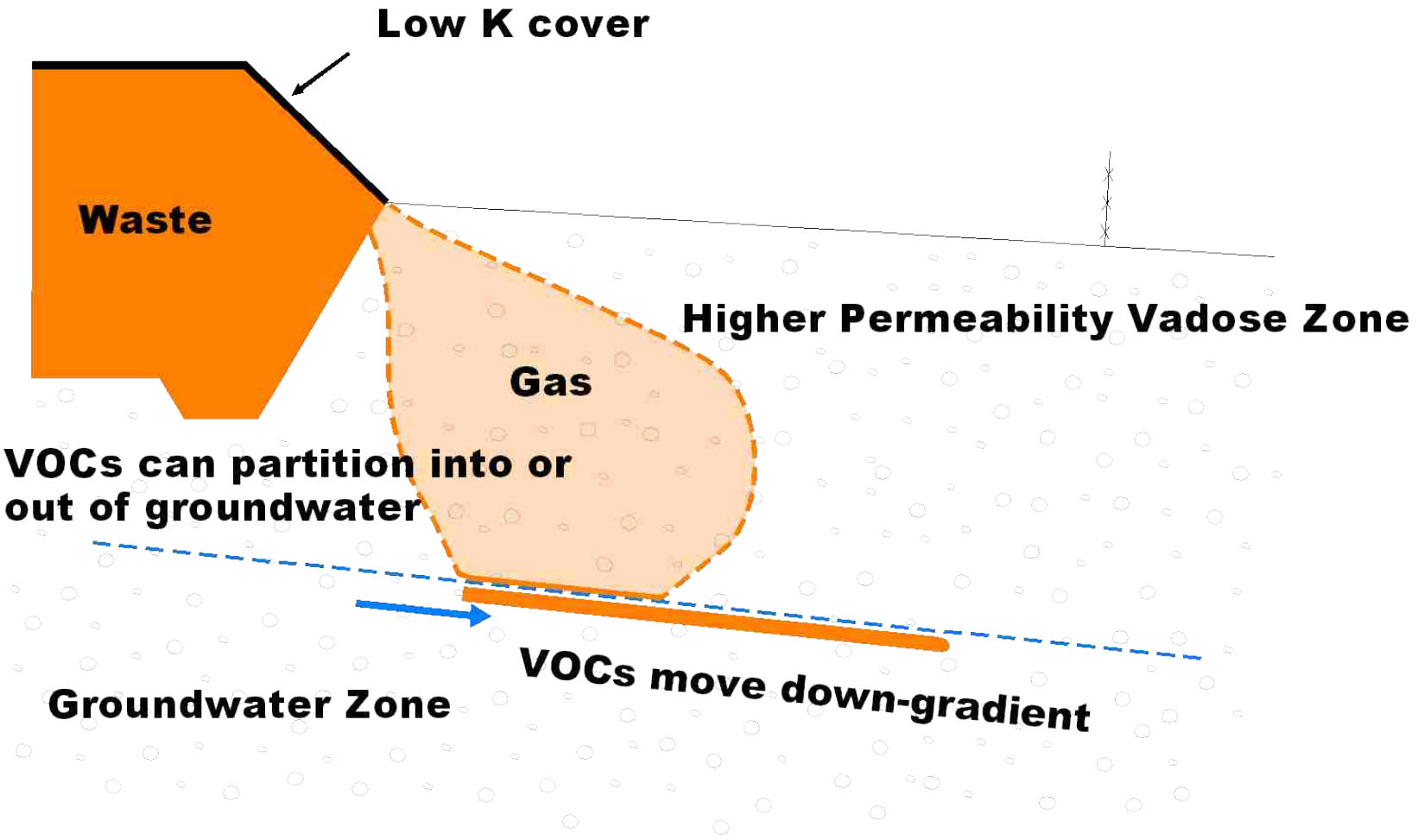
Groundwater impacts at MSW landfills are the exception, not the rule!

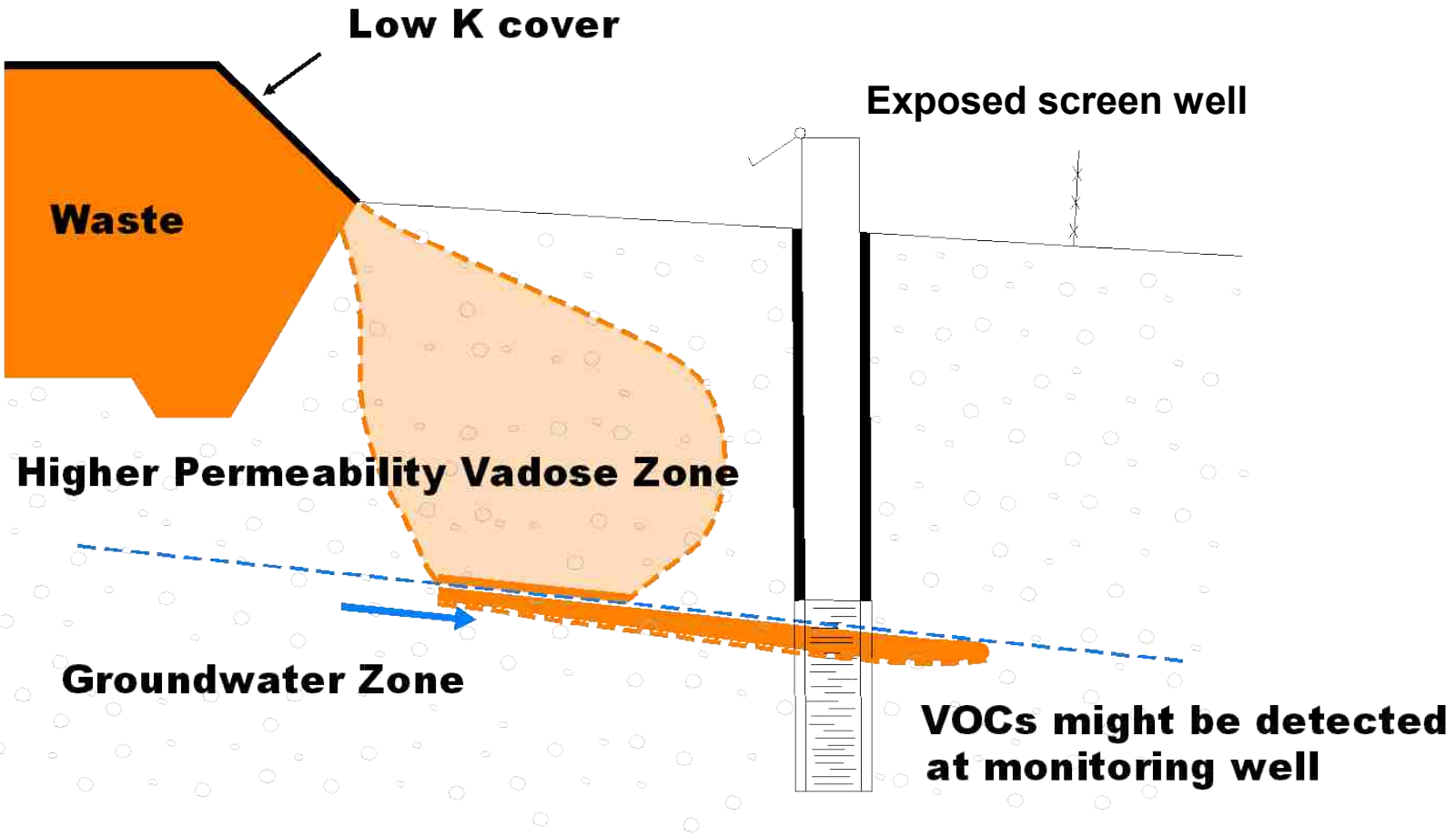

Gas generation and pressure increase,
and placement of low permeability cover
Waste
Higher Permeability Vadose Zone
If opportunity for gas migration exists,
Gas moves by advection and diffusion
through or around liner into Vadose Zone
Groundwater Zone

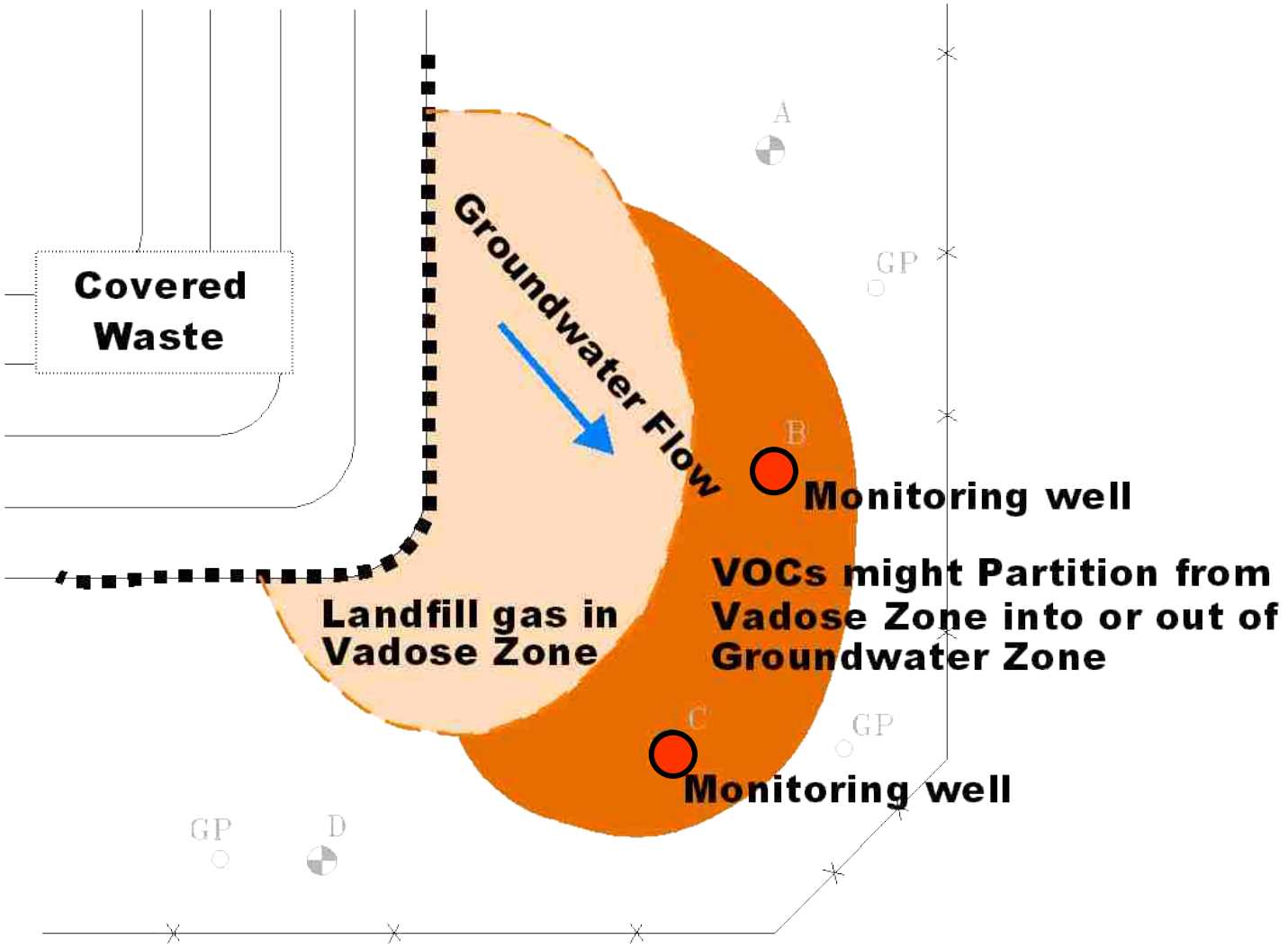

Low K cover
Waste
Gas
Higher Permeability Vadose Zone
Groundwater Zone

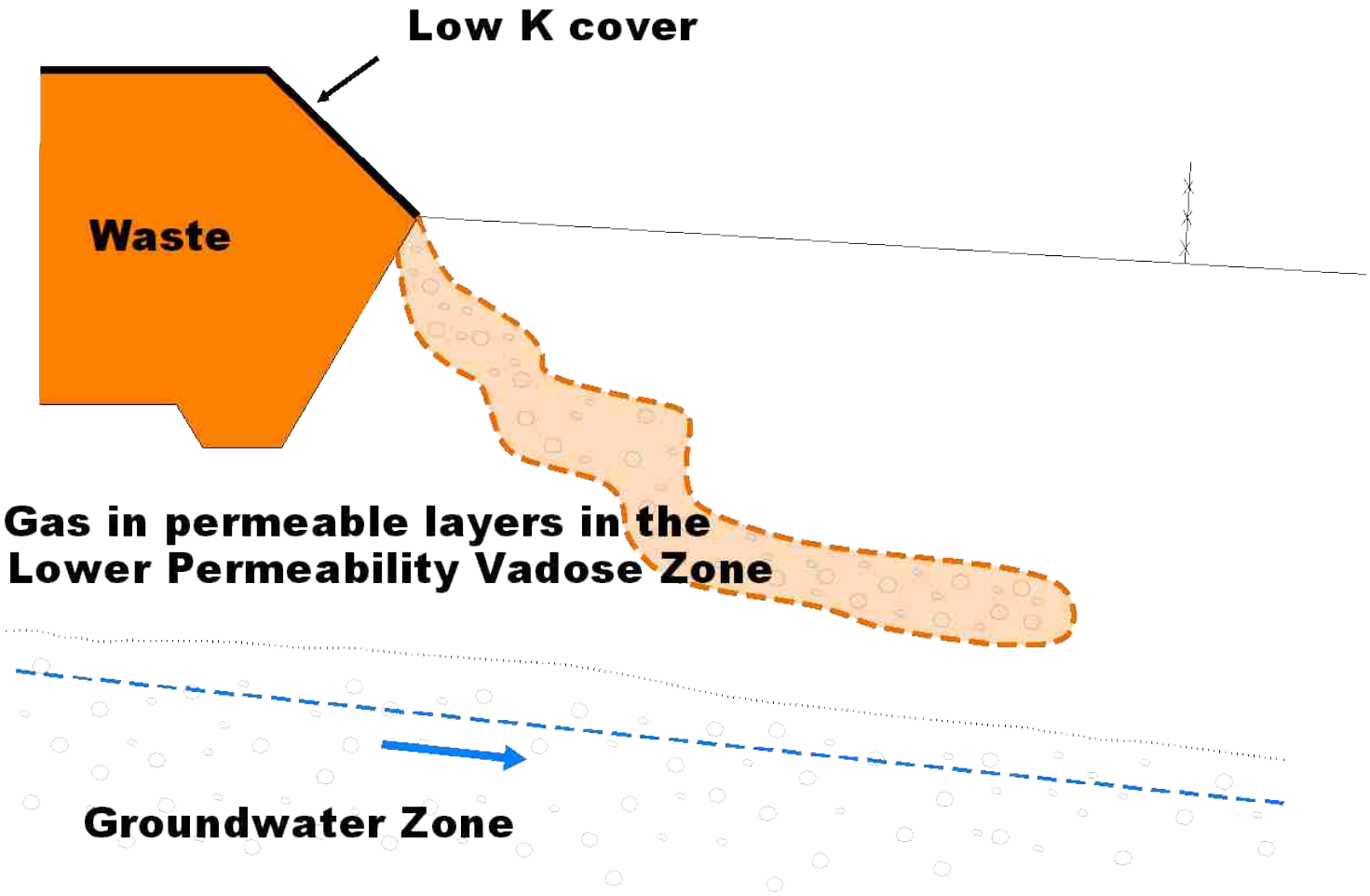


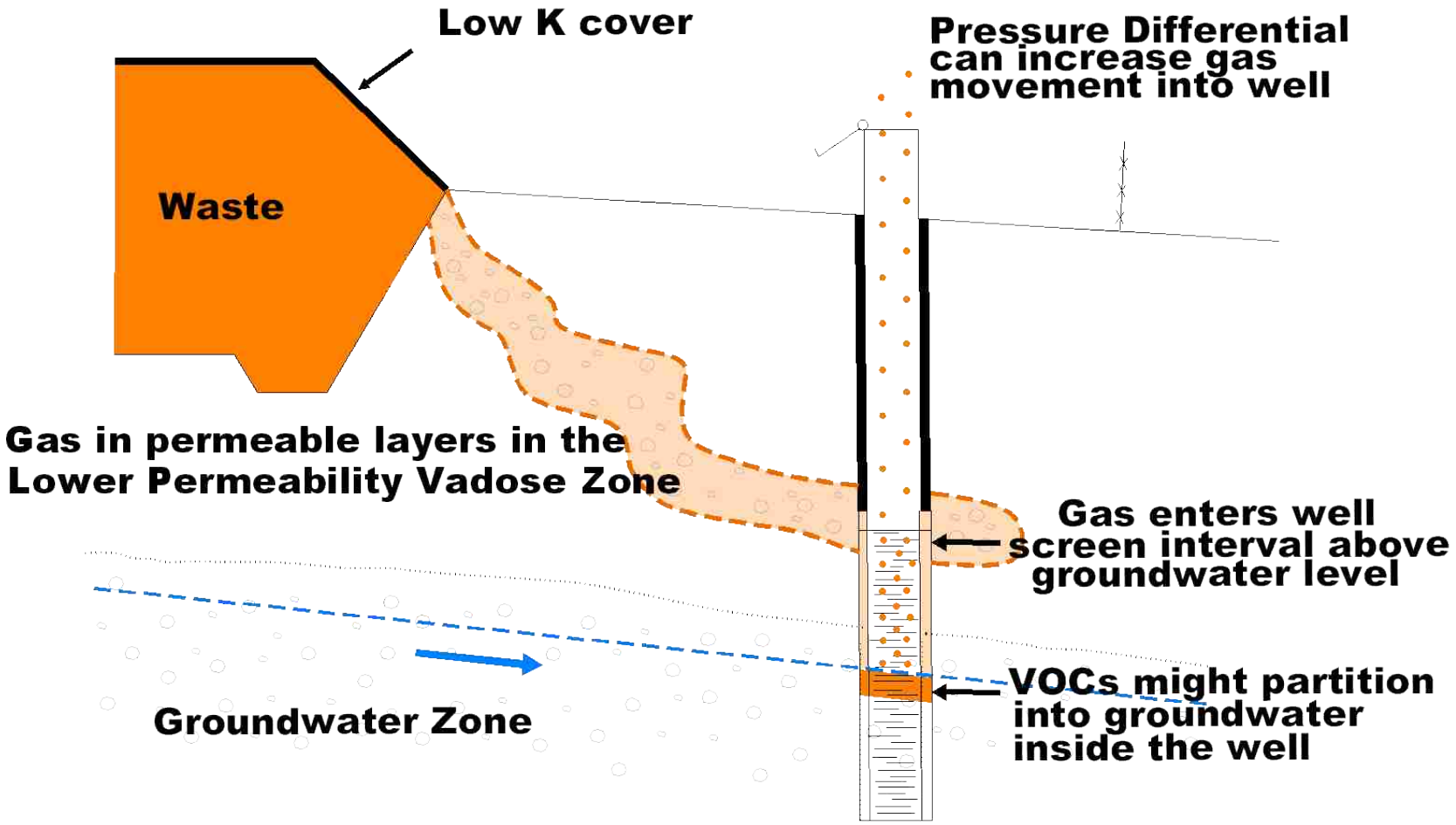
The 'Areal' Pathway


Low K cover
Waste
Higher Permeability Vadose Zone
Gas
VOCs can partition into or
out of groundwater
VOCs move down-gradient
Groundwater Zone

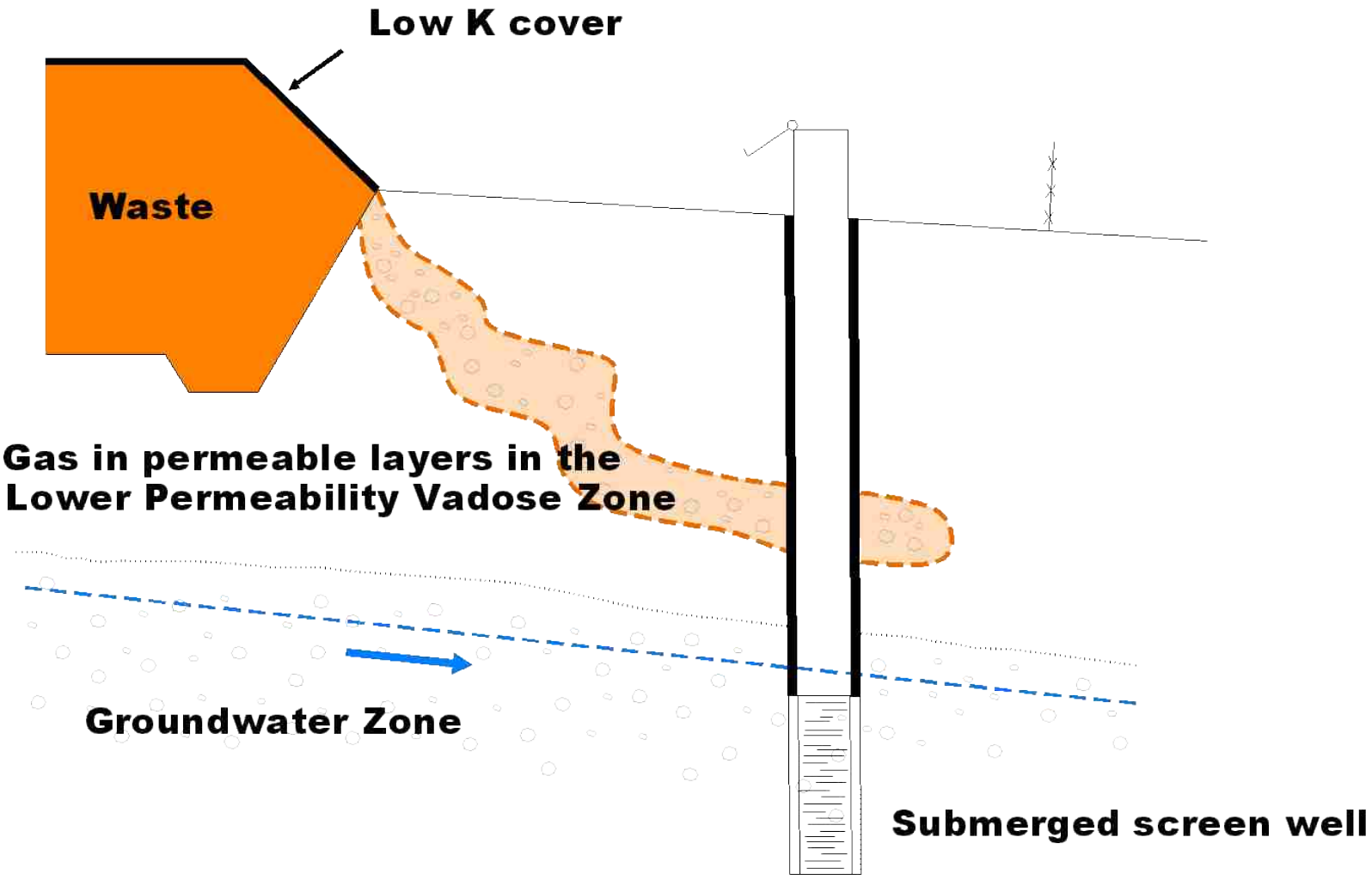

Low K cover
Exposed screen well
Waste
Higher Permeability Vadose Zone
Groundwater Zone
VOCs might be detected
at monitoring well

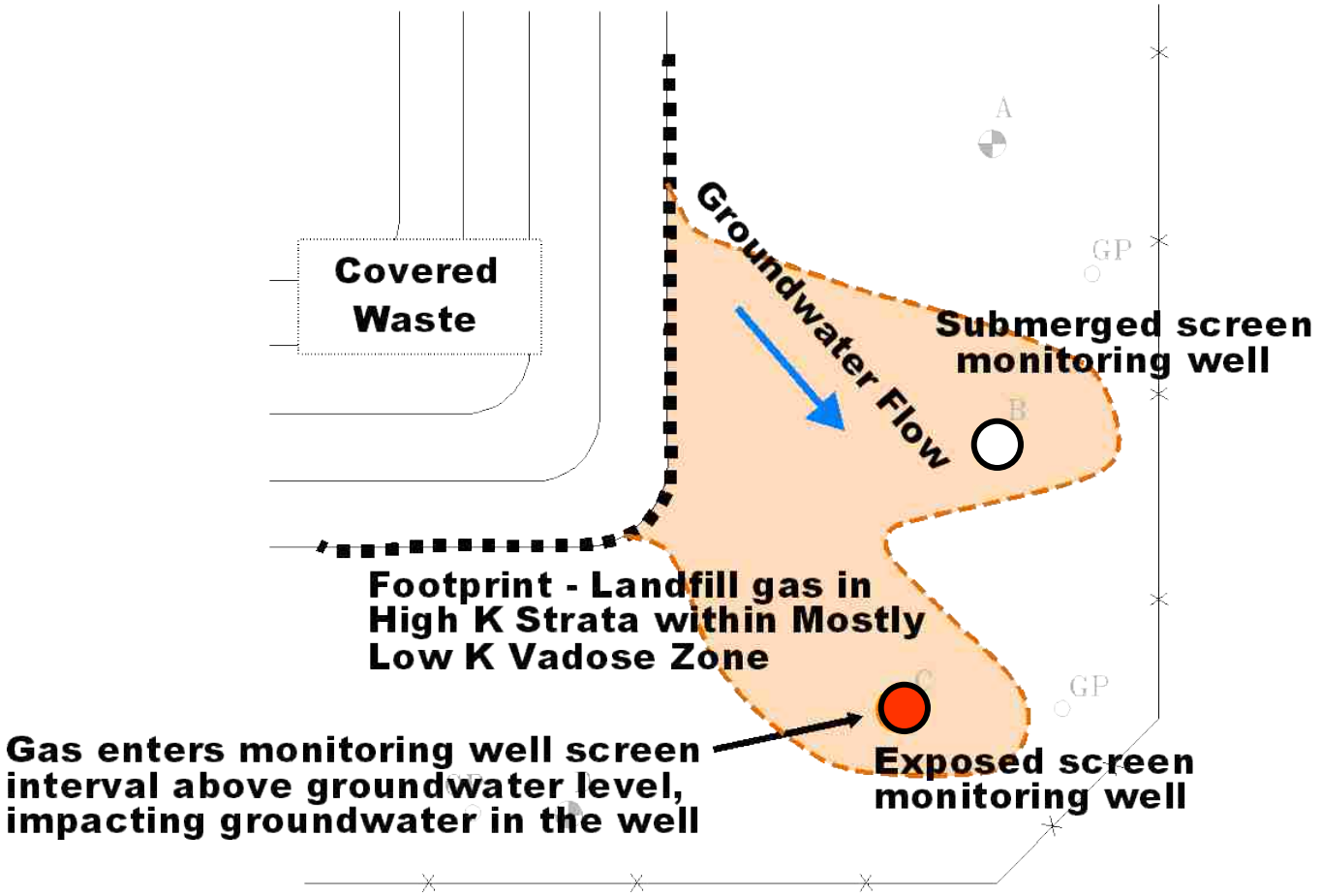

Covered Waste
Groundwater Flow
Landfill gas in Vadose Zone
A
GP
B
Monitoring well
VOCs might Partition from Vadose Zone into or out of Groundwater Zone
C
GP
Monitoring well
GP
D


Low K cover
Waste
Gas in permeable layers in the
Lower Permeability Vadose Zone
Groundwater Zone



The 'Intrawell' Pathway


Low K cover
Waste
Gas in permeable layers in the
Lower Permeability Vadose Zone
Groundwater Zone
Submerged screen well


Covered
Waste
Groundwater Flow
Submerged screen
monitoring well
Footprint - Landfill gas in
High K Strata within Mostly
Low K Vadose Zone
Gas enters monitoring well screen
interval above groundwater level,
impacting groundwater in the well
Exposed screen
monitoring well
A
B
C
GP
GP

Source / Pathway
Determine the cause of the observed groundwater impacts

- Determine that the cause is not leachate
- Determine that the cause is not an ‘alternate source’ (not related to the landfill)
- If not leachate or another cause, it’s likely LFG moving along:
  - *LFG areal pathway*
  - *LFG intra-well pathway*
  - *Combination*

Is LFG the cause of the observed groundwater impacts?

FIRST: **"Desktop Study" to consider the available information**

Use available information to determine if conditions appear to support the hypothesis that LFG has caused the observed impacts

NEXT: **Collect additional information**

If available are not conclusive, supplemental data collection can 'fill the gaps'

If characteristics not consistent with an LFG-cause are identified in this process, the explanation likely lies elsewhere

Review Available Information

- ✓ What are the observed impacts?
- ✓ Where do the observed impacts occur?
- ✓ Do they relate to known sources? (sumps, recent construction, gas system changes)
- ✓ Is LFG (CO_2, Methane and VOCs) present in
  - ➢ perimeter gas probes?
  - ➢ groundwater monitoring wells?

Are VOCs present in groundwater among those often associated with LFG?

benzene
dichlorodifluoromethane
1,1-dichloroethane
dichloromethane (methylene chloride)
tetrachloroethene
trichloroethene
1,1,1-trichloroethane
vinyl chloride
xylene

Are inorganic SSIs among those often associated with LFG?

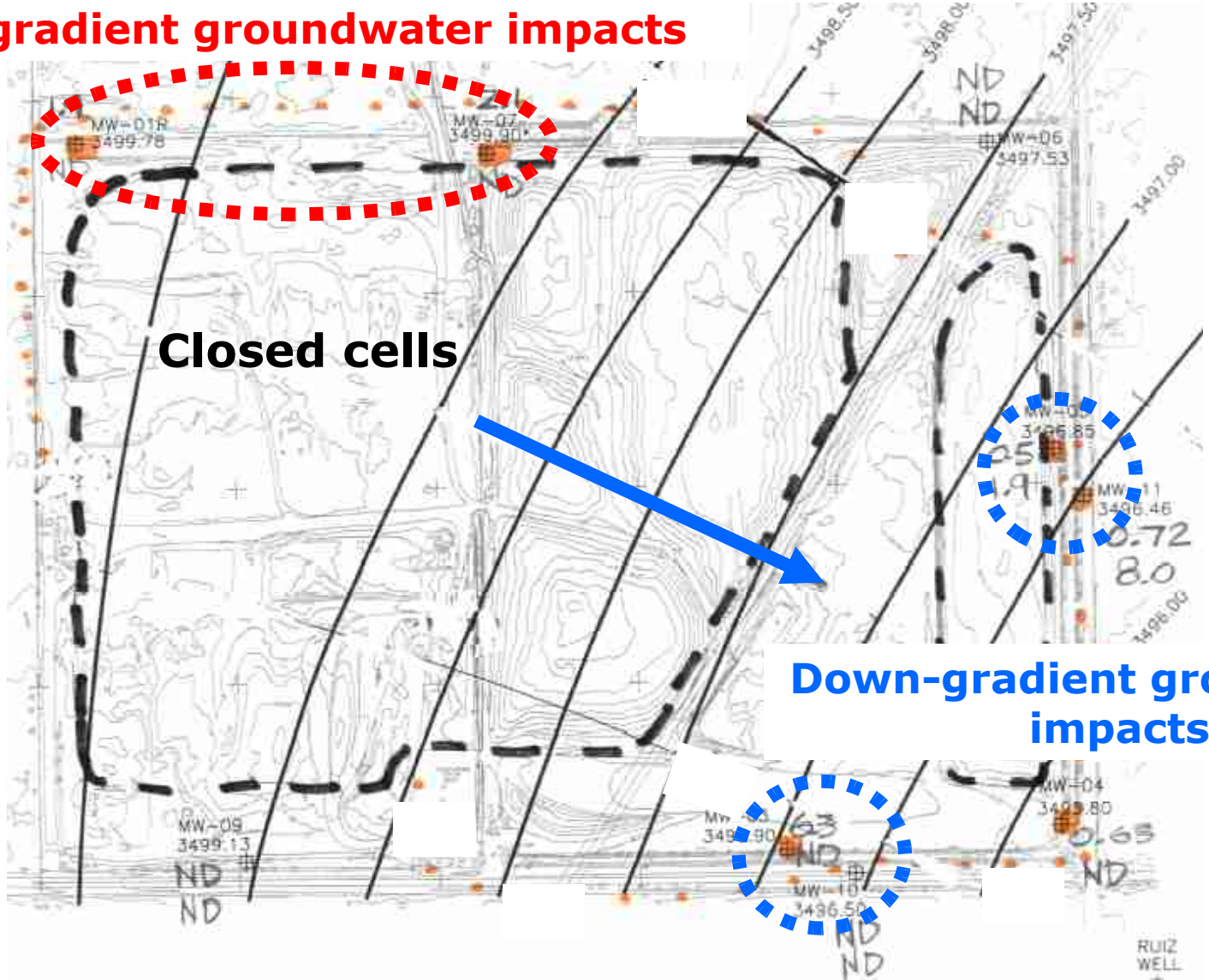
Why would inorganic compounds occur in groundwater affected by LFG?

Which inorganic compound concentrations might show significant increase?

- ***alkalinity***
- ***bicarbonate***
- ***calcium***
- ***magnesium***

Consider the location of impacts relative to possible sources

Up-gradient groundwater impacts



Down-gradient groundwater impacts

Continue review of available data

Consider VOC partitioning potential using Henry's Law

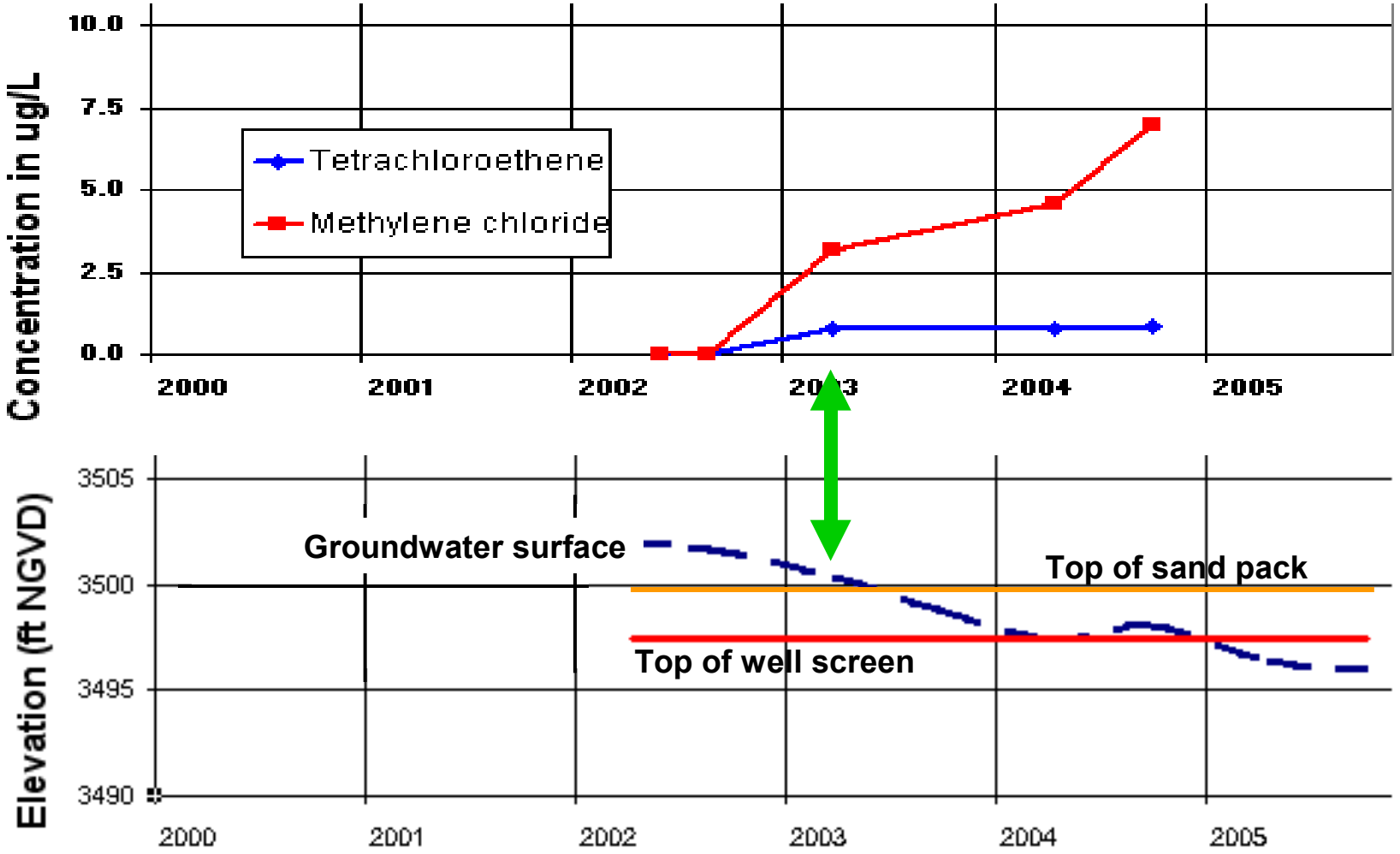
Compare leachate inorganic chemistry to up-gradient and down-gradient groundwater chemistry

- **Use Stiff and Trilinear (Piper) diagrams to consider changes in groundwater and leachate chemistry over time**

Consider site hydrogeology and the characteristics of the monitoring system

- **Vadose zone stratigraphy**
- **Well construction**

Monitoring well screened interval can be important



Supplemental Data Collection

Leachate sampling and analyses

- ✓ Determine site-specific leachate chemistry

Isotope analyses

- ✓ Attempt to differentiate the natural groundwater from groundwater containing leachate

Well headspace sampling

- ✓ Test the hypothesis that the well does/does not provide a gas migration pathway

Vadose zone gas sampling

- ✓ Test the hypothesis that the vadose zone does/does not provide a gas migration pathway.

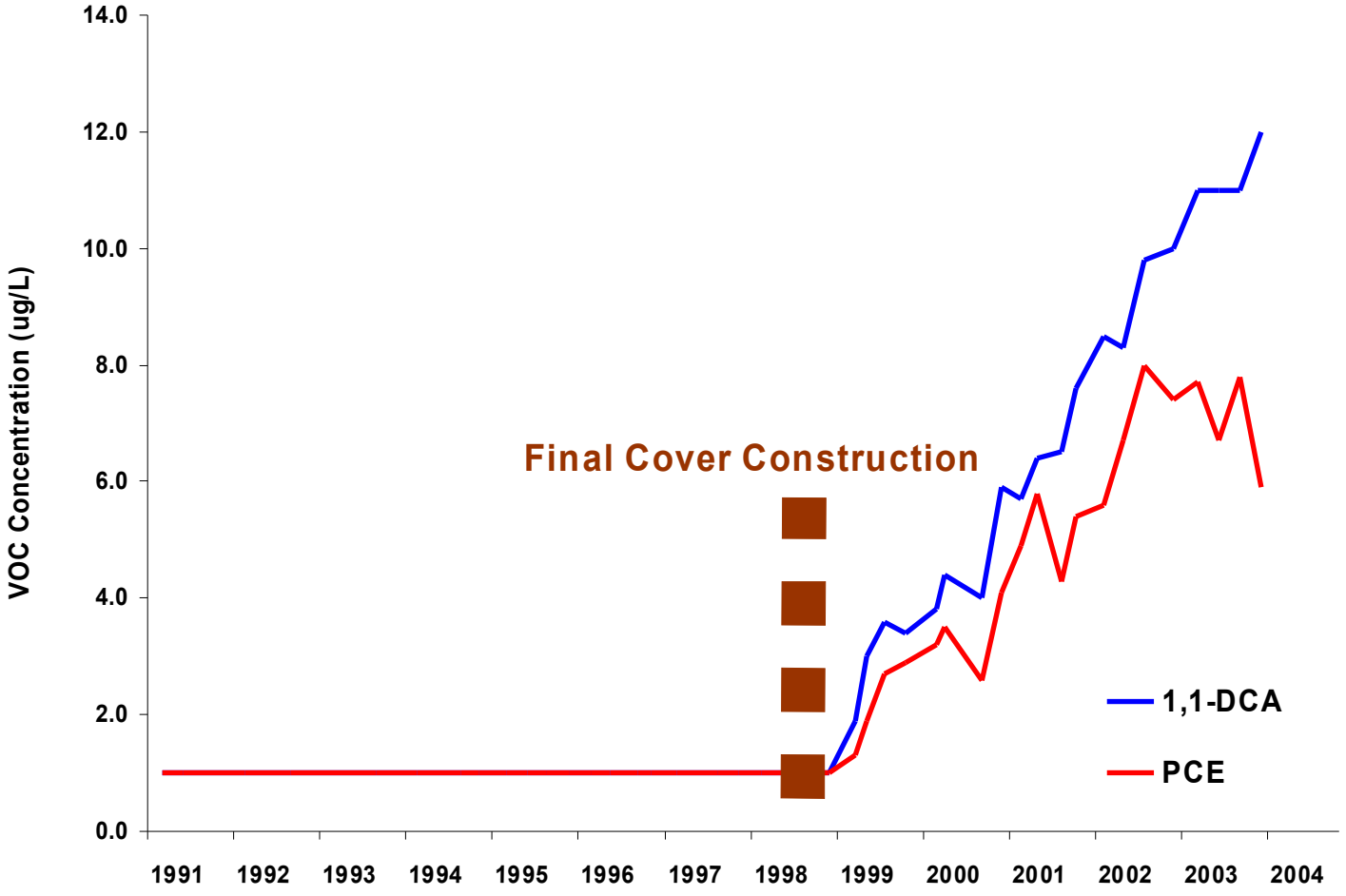
Groundwater sampling

- ✓ Obtain representative sample from below the groundwater surface while removing gas from the well

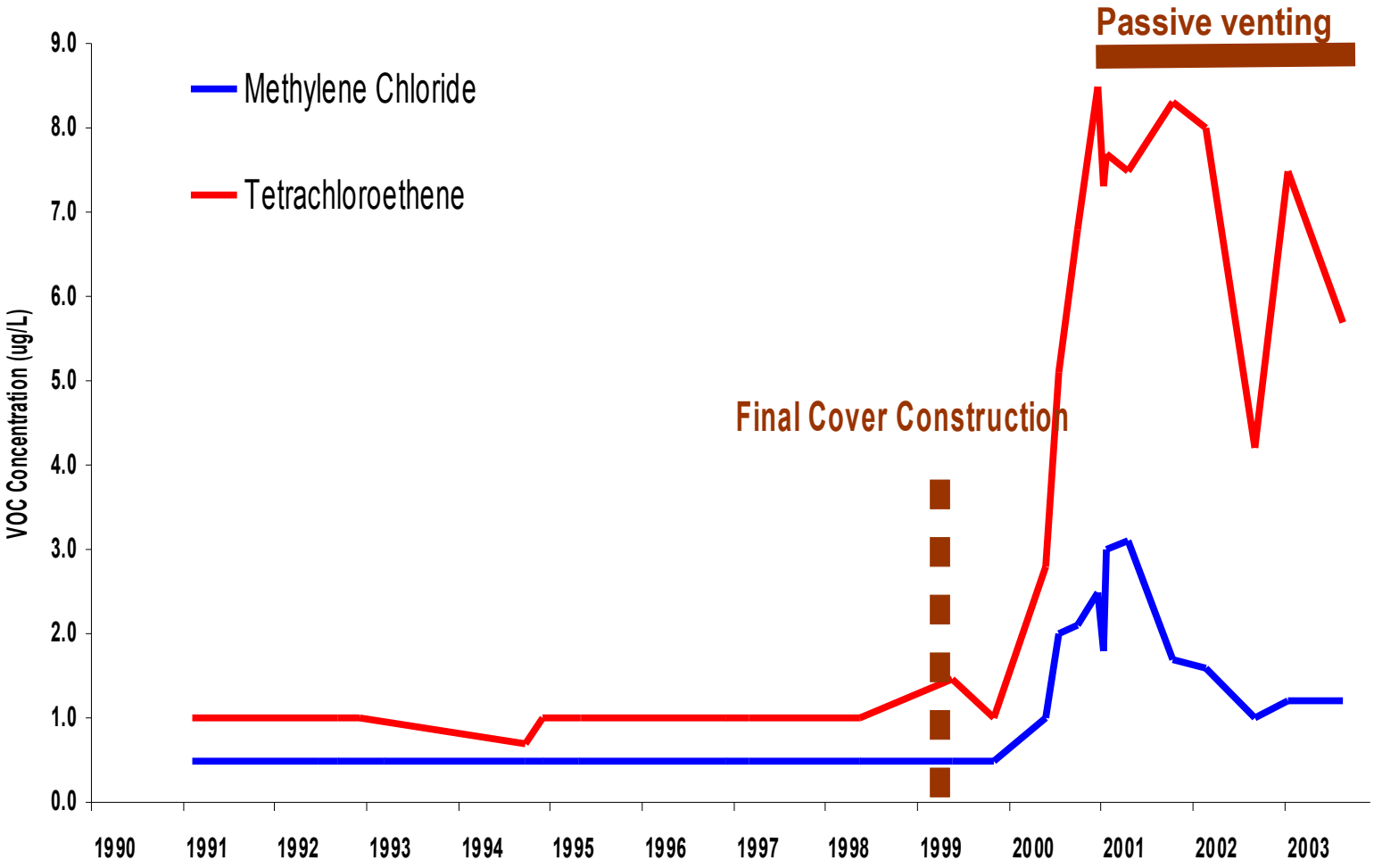
What influences the onset of LFG impacts to groundwater?

- Gas generation changes
- Landfill operations changes
- Placement of low K interim and final covers
- Vadose zone stratigraphy
- Gas travel time through the vadose zone

On-set of VOC detections after final cover construction – Washington



On-set of VOC detections after final cover construction – New Mexico



The occurrence of LFG impacts to groundwater can be prevented by:

Corrective measures for gas

- ✓ passive or active venting

Delay final cover placement

- ✓ construct based on gas generation

Use alternative final cover

- ✓ gas-permeable cover
- ✓ methane oxidation possible

After gas-related impacts occur, the effective responses are:

Targeted control of the gas source in the waste mass

- ✓ passive gas venting
- ✓ active gas venting

Use modified procedures to obtain representative groundwater samples

- ✓ submerged screen wells
- ✓ gas purging during sampling
- ✓ low-flow or no-flow sampling methods

Regulatory agency opinions

Might you view an instance of groundwater impacts caused by LFG as possibly different from one caused by leachate with regard to your regulatory requirements for: **ASSESSMENT or CORRECTIVE ACTION?**

No Comment: (none)

Never: **OK, TN**

Maybe: **CA, CO, MT, NM, SC, VA, WY**

What do the regulations require?

A verified exceedence of a water-quality criterion triggers a variety of requirements under Federal and or State regulations

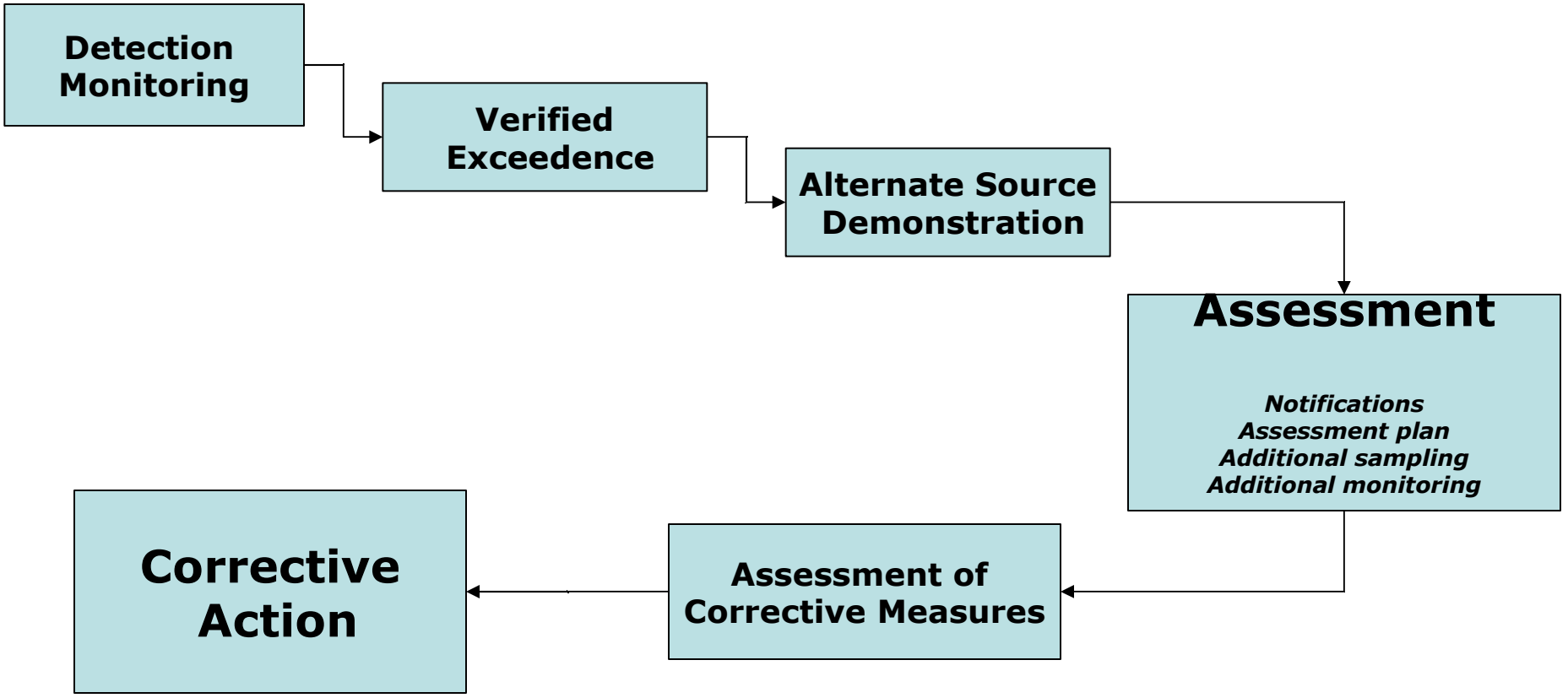
- **U.S. - 40 CFR 258.54(c)**
- **Colorado - 6 CCR 1007, B4(C) in CO**

Under strict application of the regulations, the cause of the exceedence is irrelevant.

While considering the regulations, remember that

effectively addressing gas impacts to groundwater requires the combination of source control and alternate monitoring methods.

Requirements that follow a verified VOC detection or other SSI



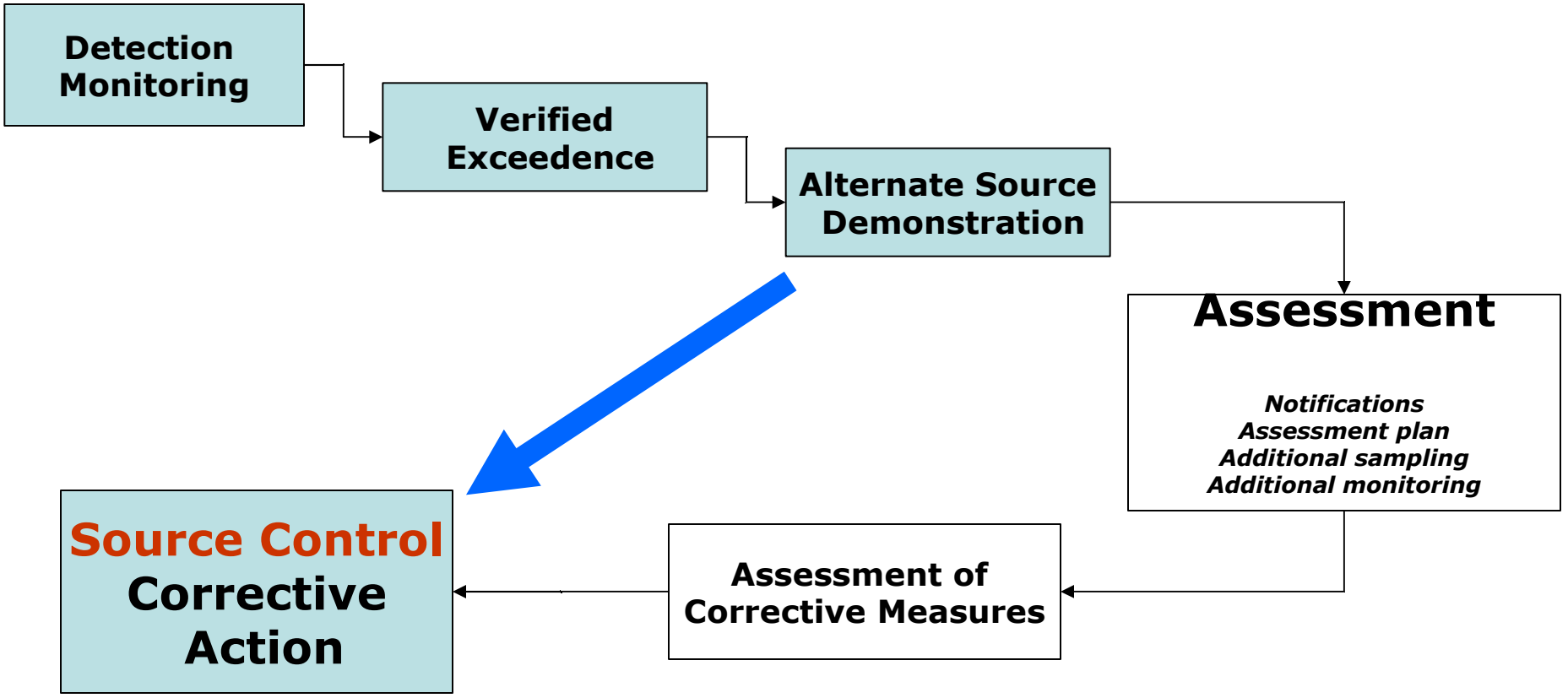
If the cause is LFG, could there be a more direct route to regulatory compliance?

If the cause of the observed impact is determined to be LFG

AND

- **The extent of impacts is small (on-site)**
- **The concentrations are low, probably well below risk-based criteria**
- **The distance or groundwater travel time to potential human receptors is large**

There is a more direct route to regulatory compliance!



LANDFILL GAS IMPACTS TO SHALLOW GROUNDWATER

These impacts do occur,

They can be recognized,

This is a problem that often can be corrected relatively quickly, and

The OWNER/OPERATOR and the REGULATOR can work together to accomplish this !