The Occurrence and Mitigation of Carbon Dioxide in Homes Built on Reclaimed Coal Mines

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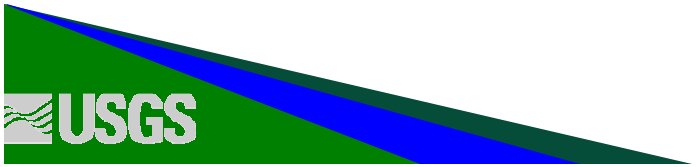
USGS Indiana Water Science Center

A cooperative investigation by the
Indiana Dept. of Natural Resources, Div. of Reclamation
and the
U.S. Geological Survey



Carbon Dioxide Generation in Spoil

$$4\,FeS_2 + 15\,O_2 + 14\,H_2O \longrightarrow 4\,Fe(OH)_3 + 8\,H_2SO_4$$

Pyrite Oxygen Sulfuric acid

$$H_2SO_4 + CaCO_3 \longrightarrow Ca + SO_4 + H_2O + CO_2$$

Sulfuric acid Calcite Carbon dioxide

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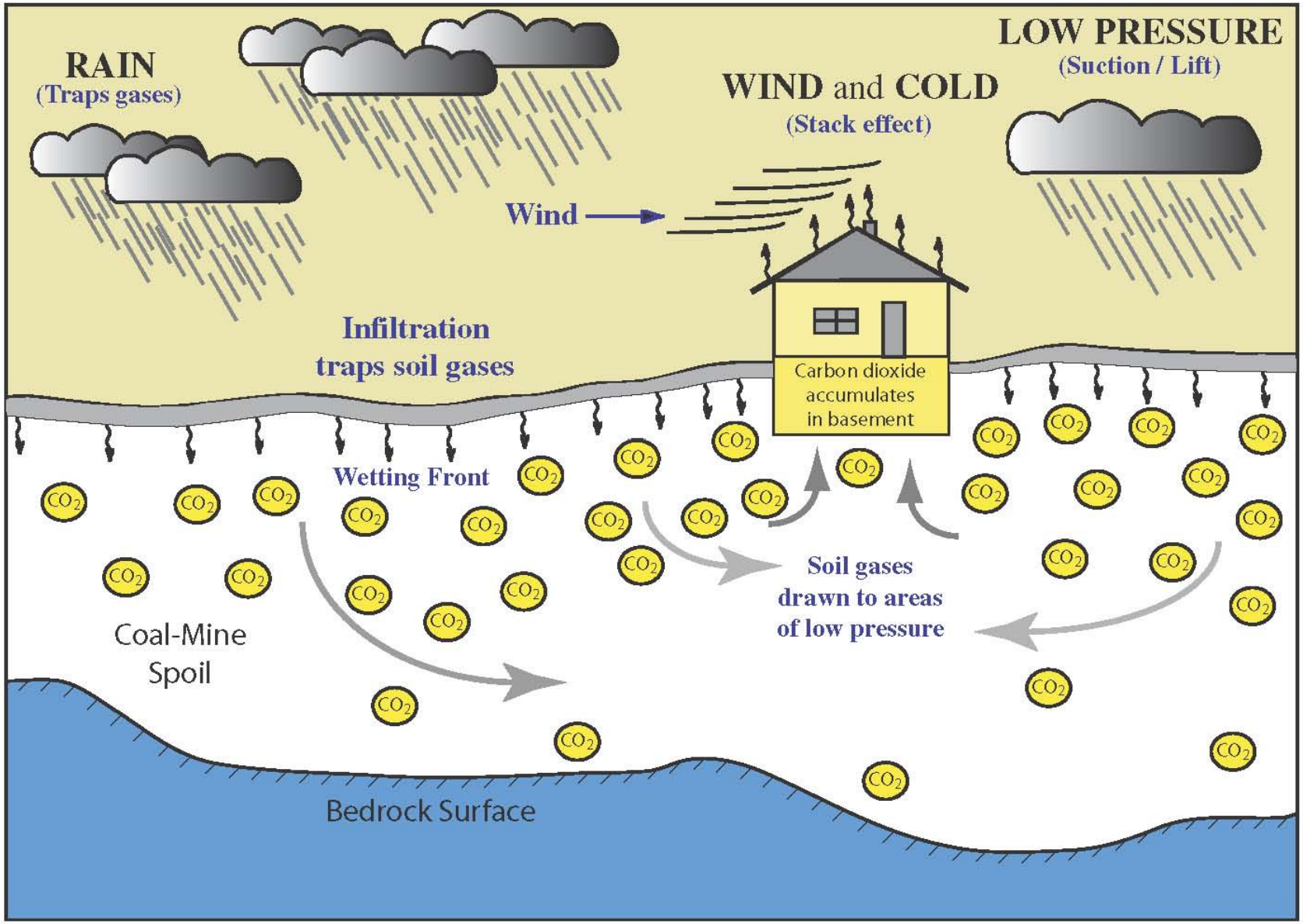
Soil-Gas Migration Model



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Health Concerns

CO_2 cloud settles to floor level

Carbon Dioxide

- Heavy (SG: 1.524)
- Asphyxiant (Displaces O_2)

Oxygen Deficiency

- Rapid breathing
- Dizziness
- Headaches
- Confusion
- Blackout
- Death

Special concern

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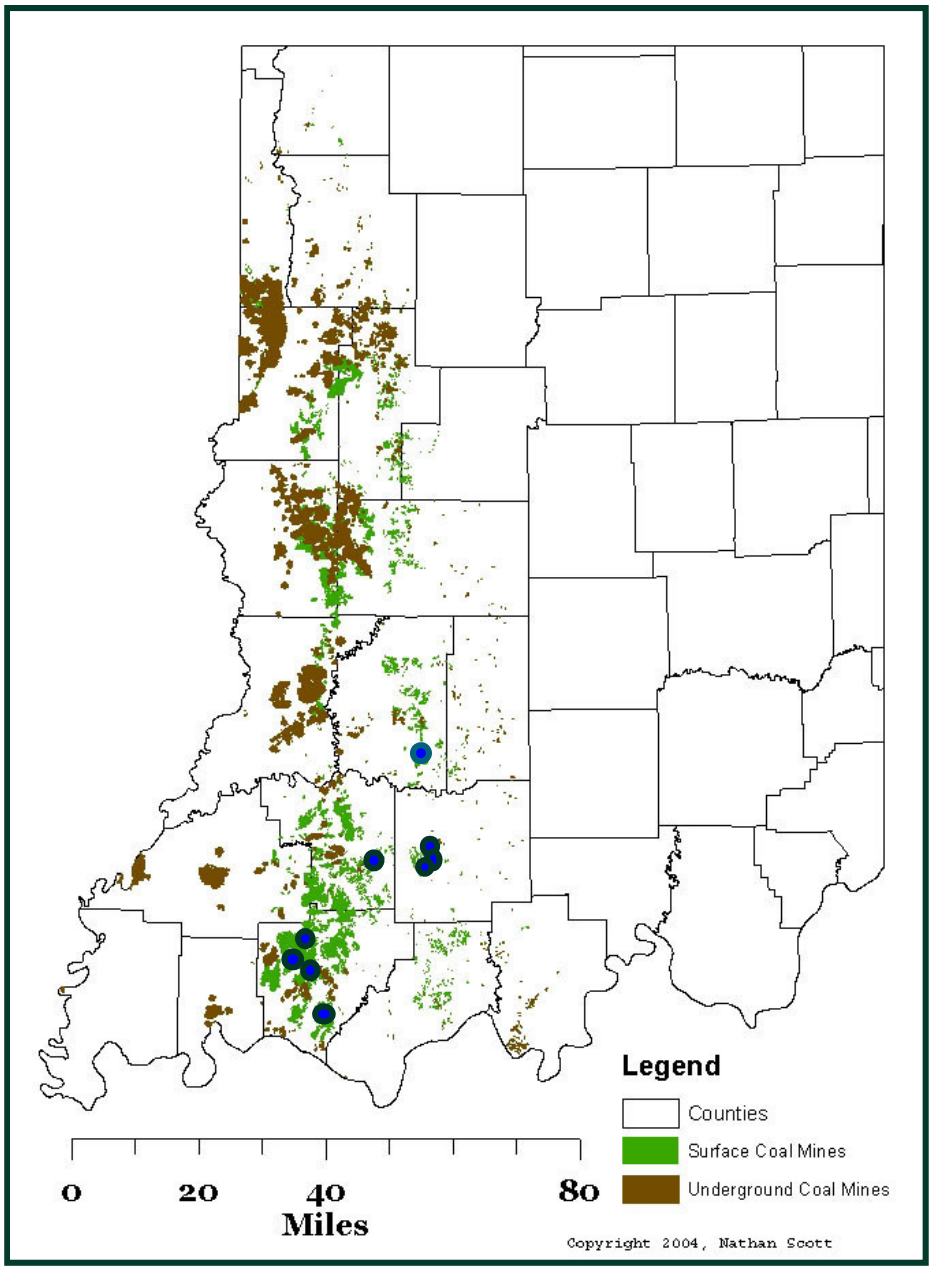
Identified CO_2 Problems

- Beginning in 2005
- New homes with basements
- On or near reclaimed mines
- Sporadic low-O_2 symptoms

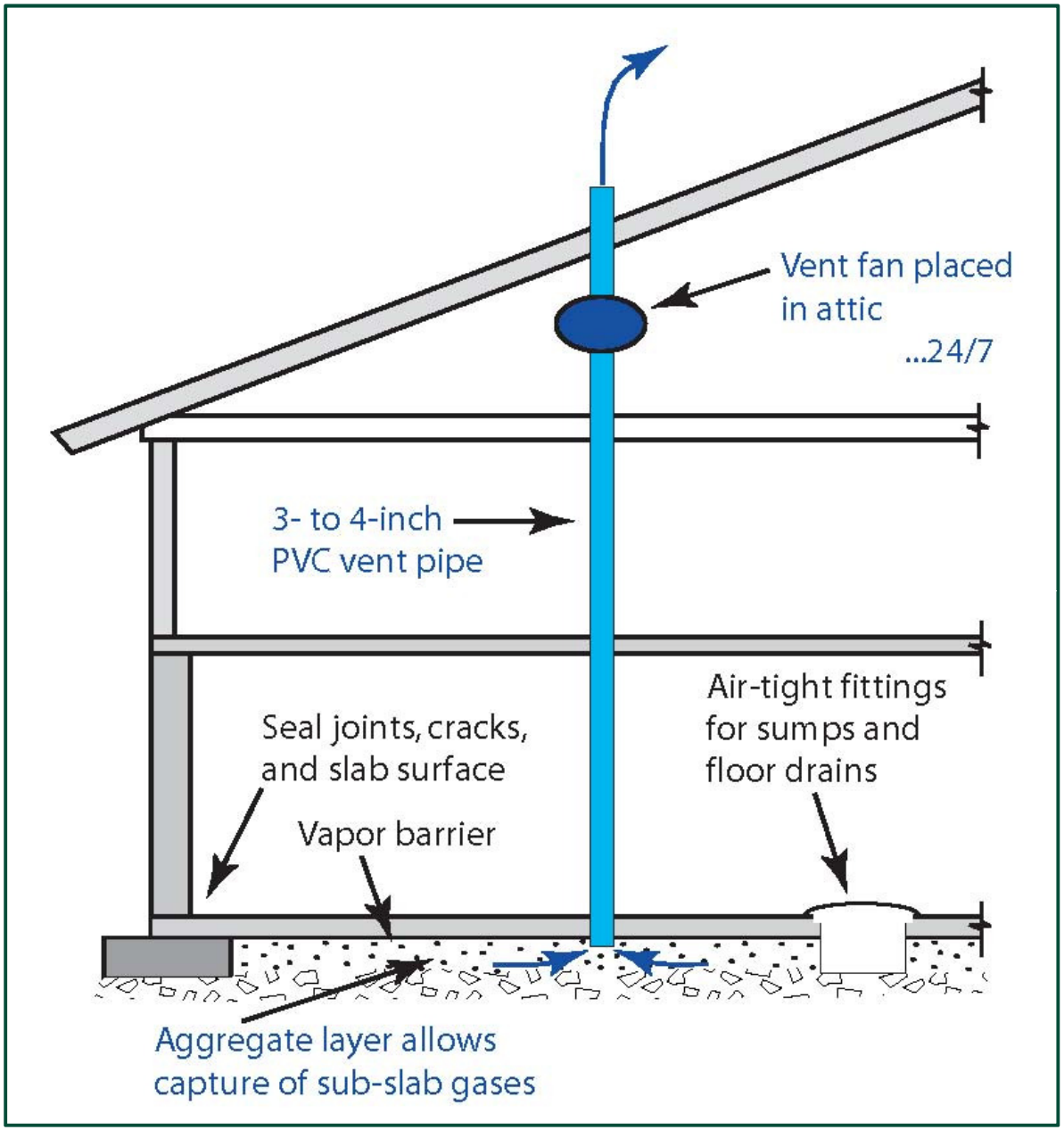


Southwest Indiana's Mined Lands

USGS

"Radon Approach" to Mitigation

Sub-slab depressurization



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Pike Co. Home

Classic CO_2 symptoms

- Pilot lights
- Loss of 5 cats
- Many health issues

Fresh air:

O_2 21%

CO_2 0.03%

Pike Co. Home:

O_2 <9%

CO_2 >15%

(no sub-slab aggregate)

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Soil-Gas Flux Distribution

85 Sampling Nodes

- CO_2 Flux
  (Soil temperature)
- Soil pH
- Air temperature
- Barometric pressure

Results:
Fairly even flux distribution

USGS

Carbon Dioxide Pathways

USGS

Groundwater's Role

Three pairs of nested wells

- Up gradient pair
- House pair
- Down gradient pair

Lake staff gage

Results:

- Five wells are dry.
- Lake is losing to groundwater.
- Groundwater is not a significant driver.

USGS

Site Specific Chemistry

Results?

Masonry samples from walls and slabs

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On-site Weather Station

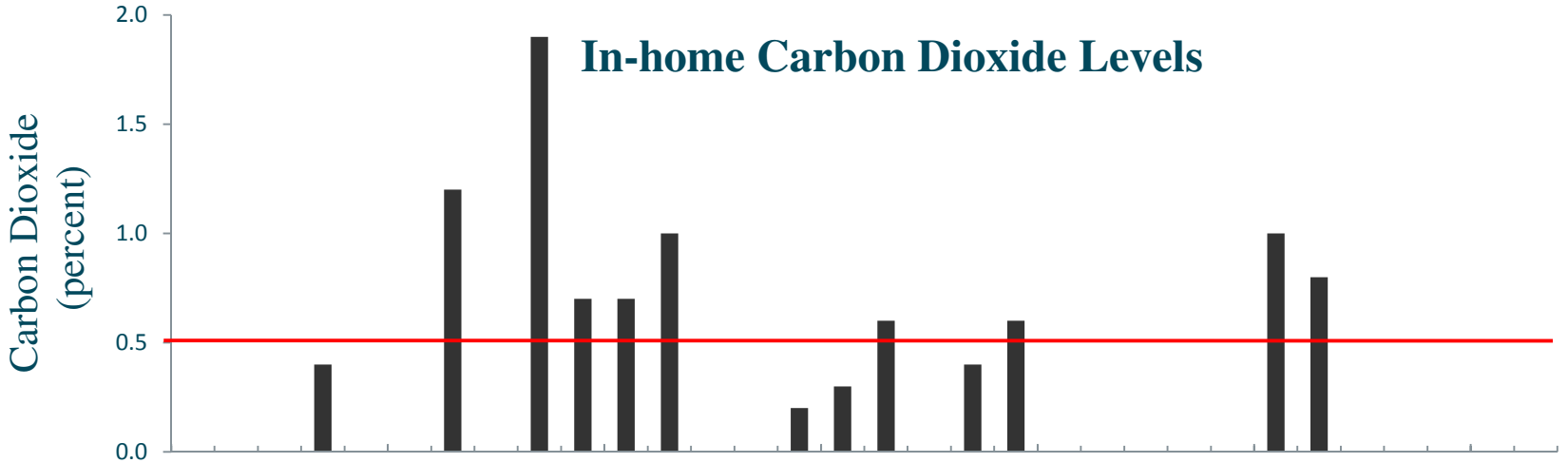
- Precipitation
- Temperature
- Pressure
- Relative humidity
- Wind speed
- Wind direction

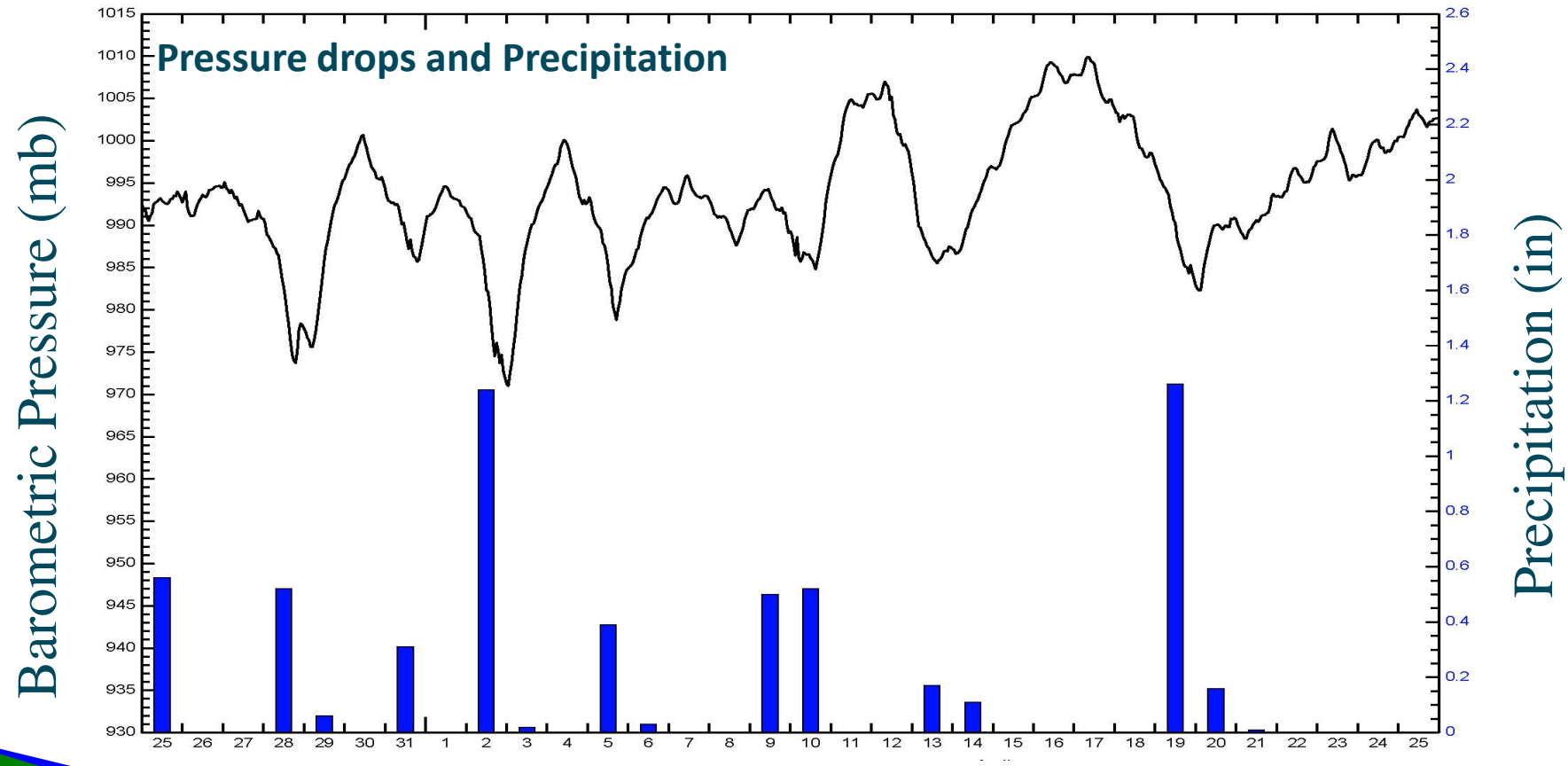
Records and transmits (near real-time web)

Results:

Pressure drops and **precipitation** are significant drivers

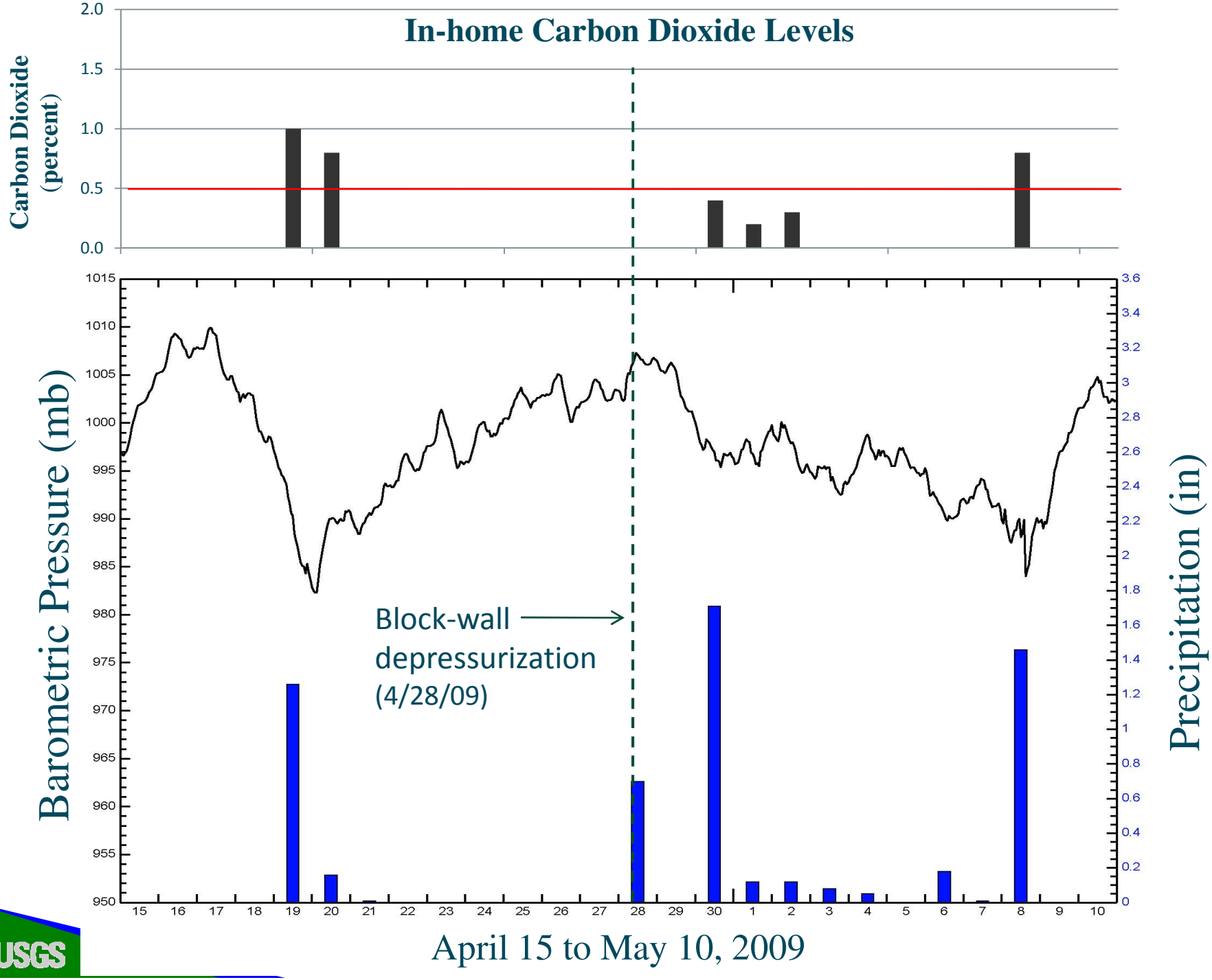
USGS





March 25 to April 25, 2009

Mitigation …Block-wall depressurization


In-home Carbon Dioxide Levels
Carbon Dioxide (percent)
2.0
1.5
1.0
0.5
0.0
Barometric Pressure (mb)
Precipitation (in)
1015
1010
1005
1000
995
990
985
980
975
970
965
960
955
950
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10
Block-wall depressurization (4/28/09)
April 15 to May 10, 2009

…Sub-slab depressurization

1. Core through slab

2. Excavate a soil-gas suction pit

3. Hope for desiccation cracks

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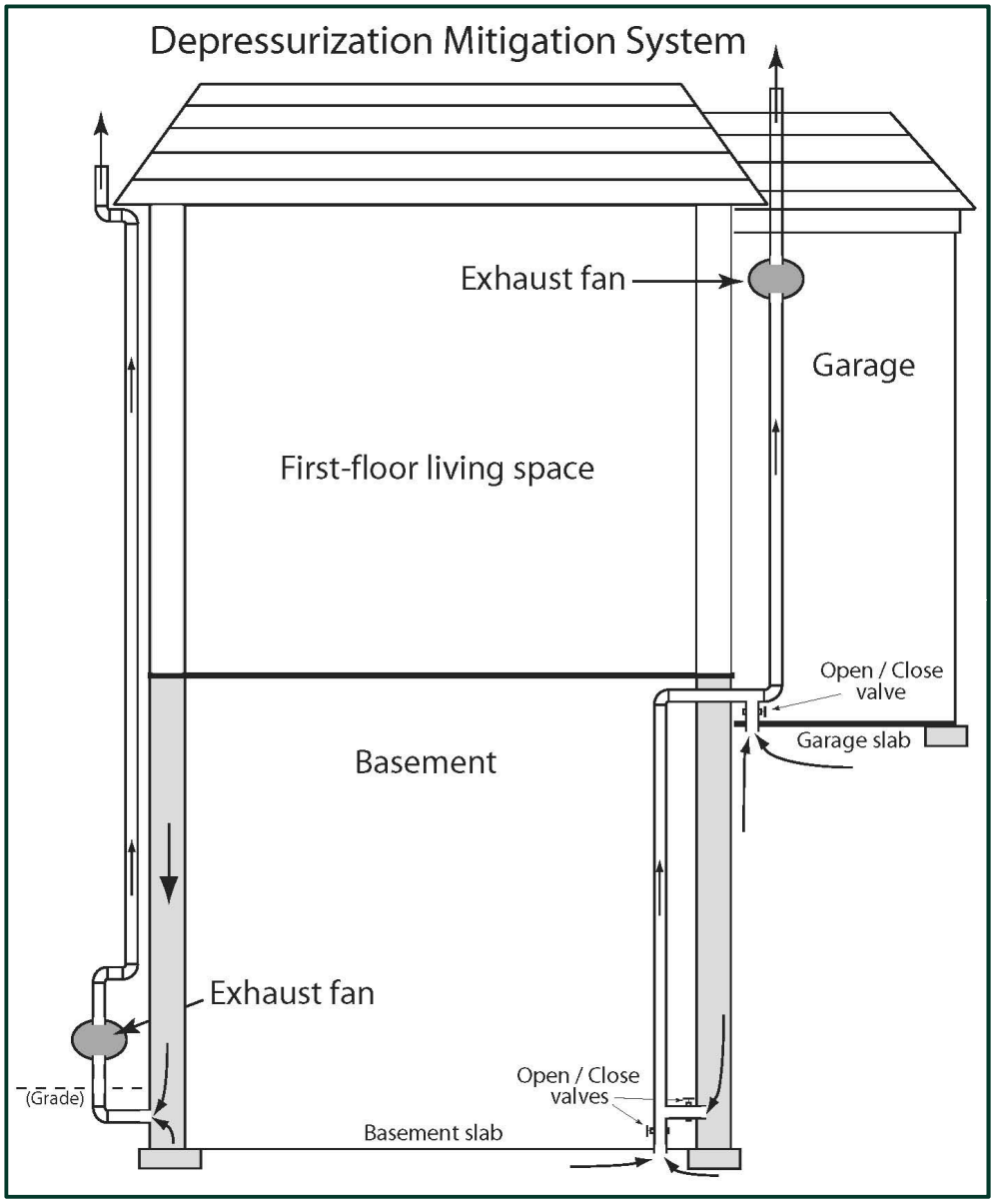
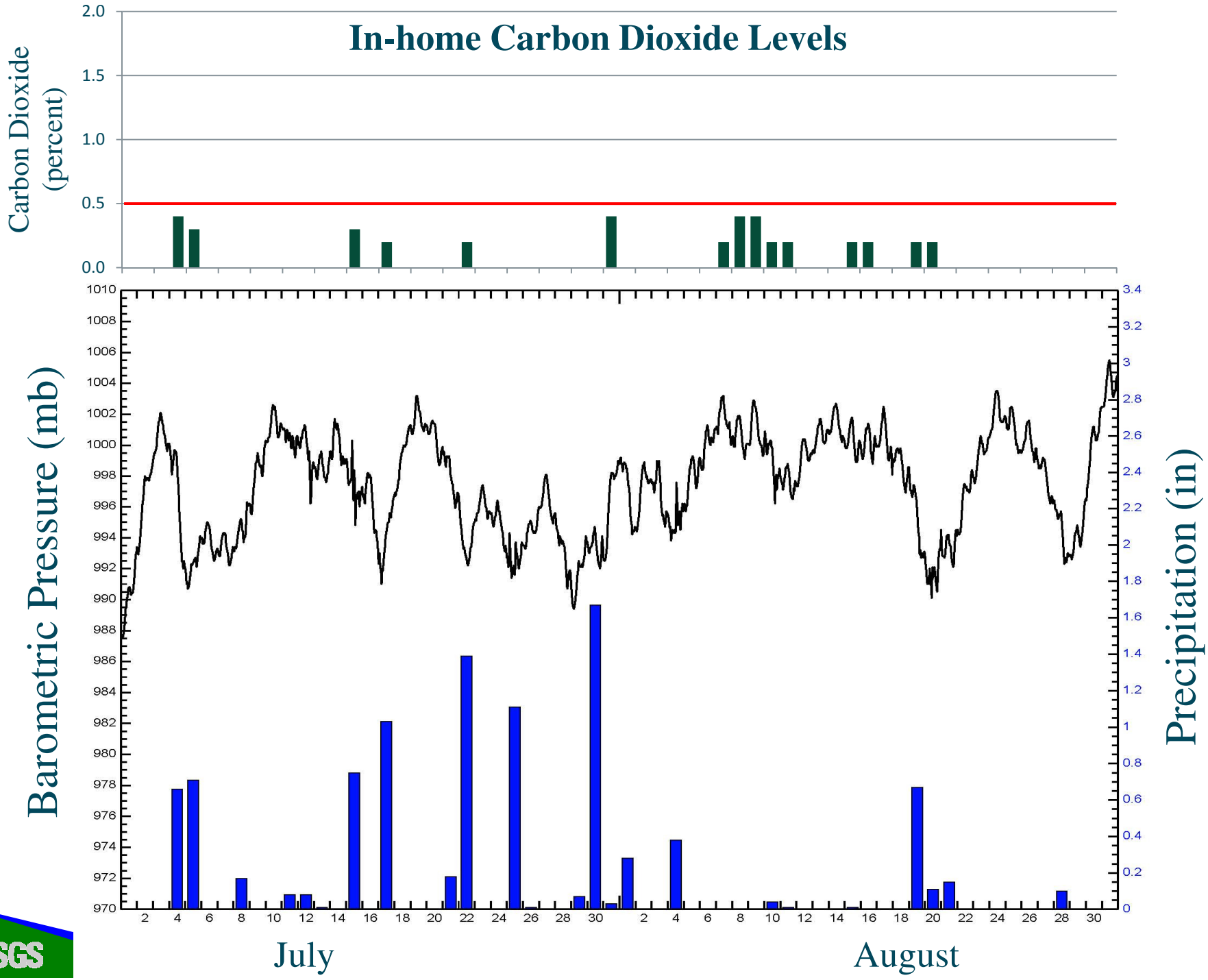
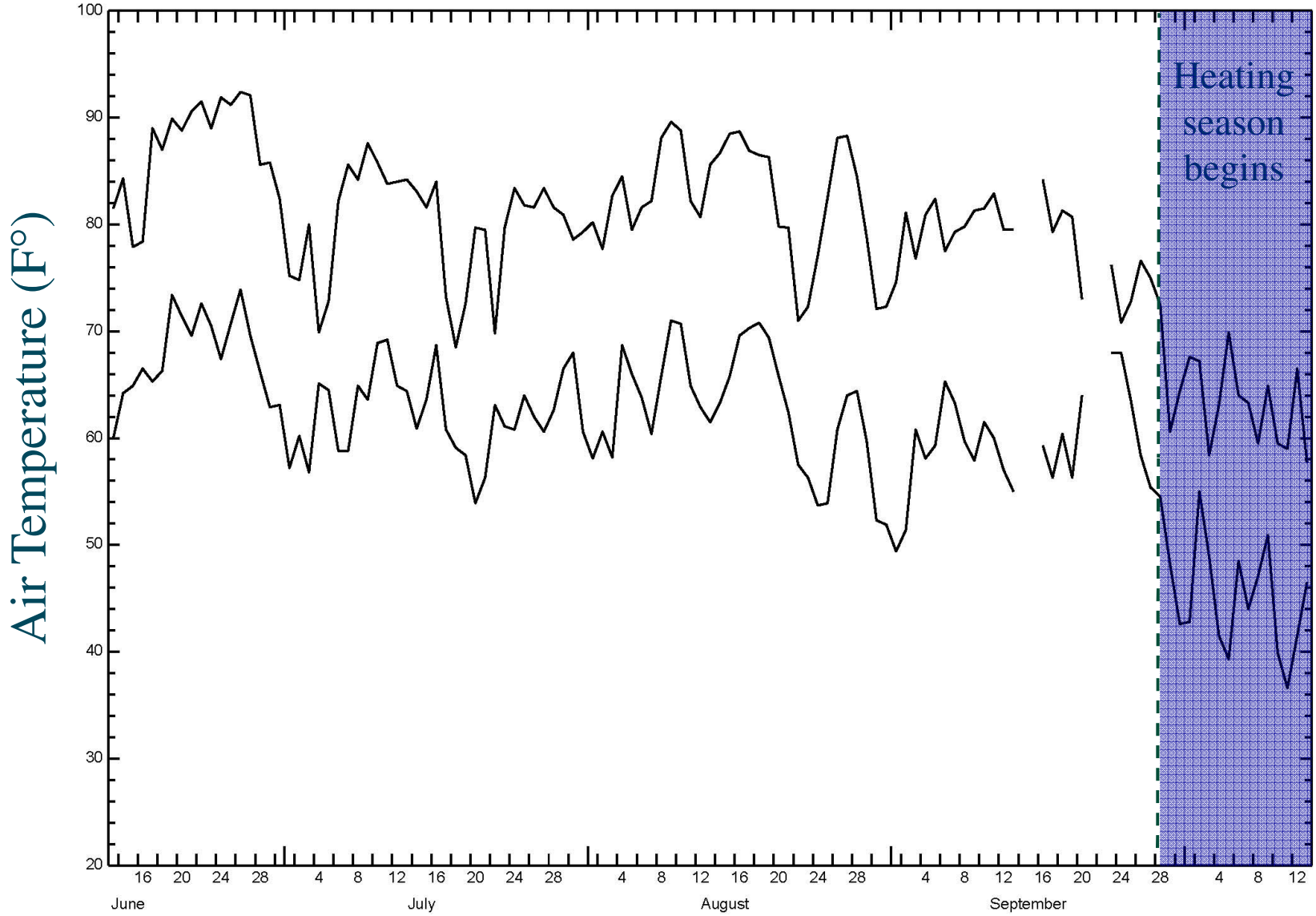
Mitigation Design




In-home Carbon Dioxide Levels
Carbon Dioxide (percent)
2.0
1.5
1.0
0.5
0.0
Barometric Pressure (mb)
Precipitation (in)
1010
1008
1006
1004
1002
1000
998
996
994
992
990
988
986
984
982
980
978
976
974
972
970
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30
July
August

Daily High and Low Air-Temperatures



2009

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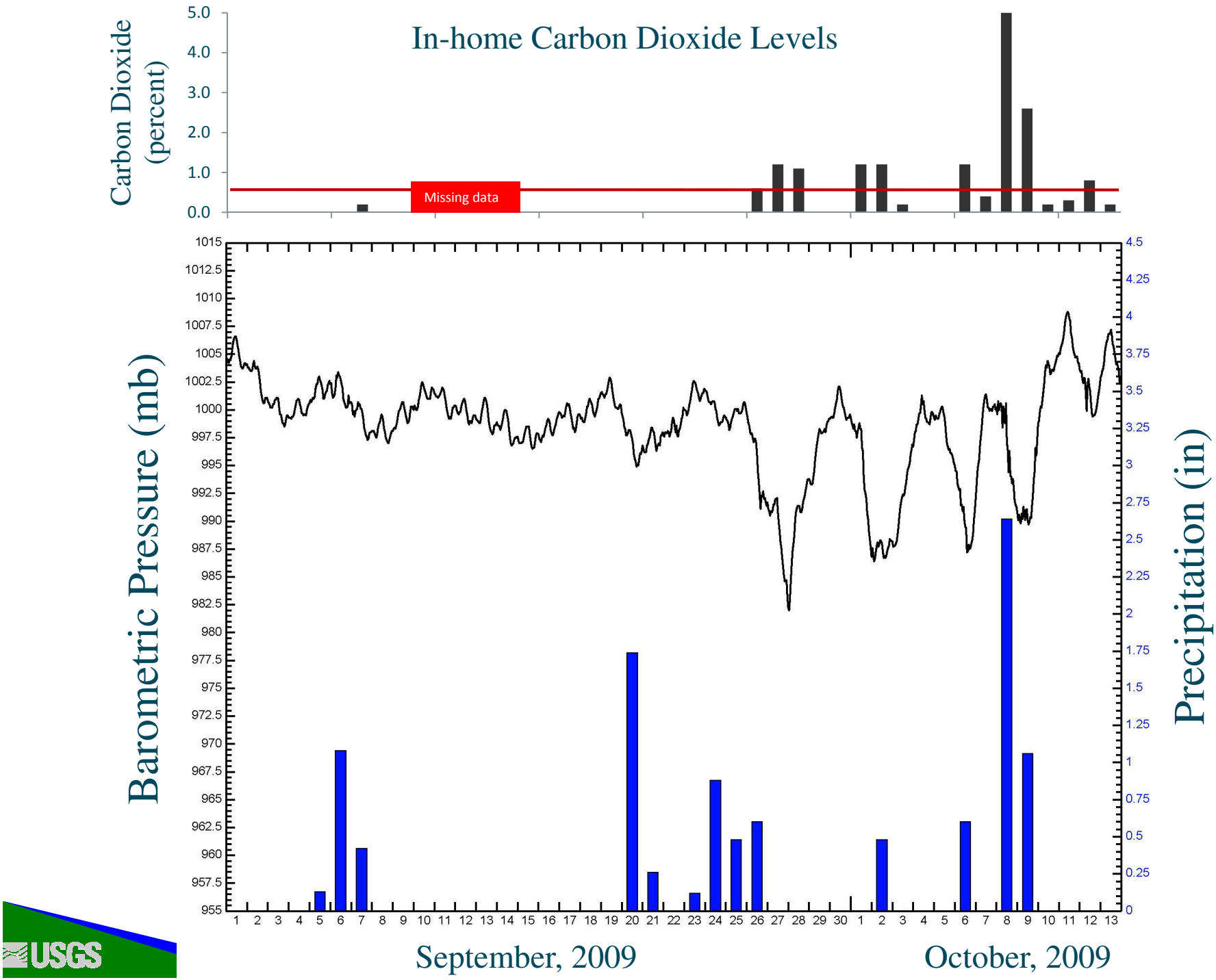
In-home Carbon Dioxide Levels
Carbon Dioxide (percent)
5.0
4.0
3.0
2.0
1.0
0.0
Missing data
Barometric Pressure (mb)
1015
1012.5
1010
1007.5
1005
1002.5
1000
997.5
995
992.5
990
987.5
985
982.5
980
977.5
975
972.5
970
967.5
965
962.5
960
957.5
955
Precipitation (in)
4.5
4.25
4
3.75
3.5
3.25
3
2.75
2.5
2.25
2
1.75
1.5
1.25
1
0.75
0.5
0.25
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13
September, 2009
October, 2009
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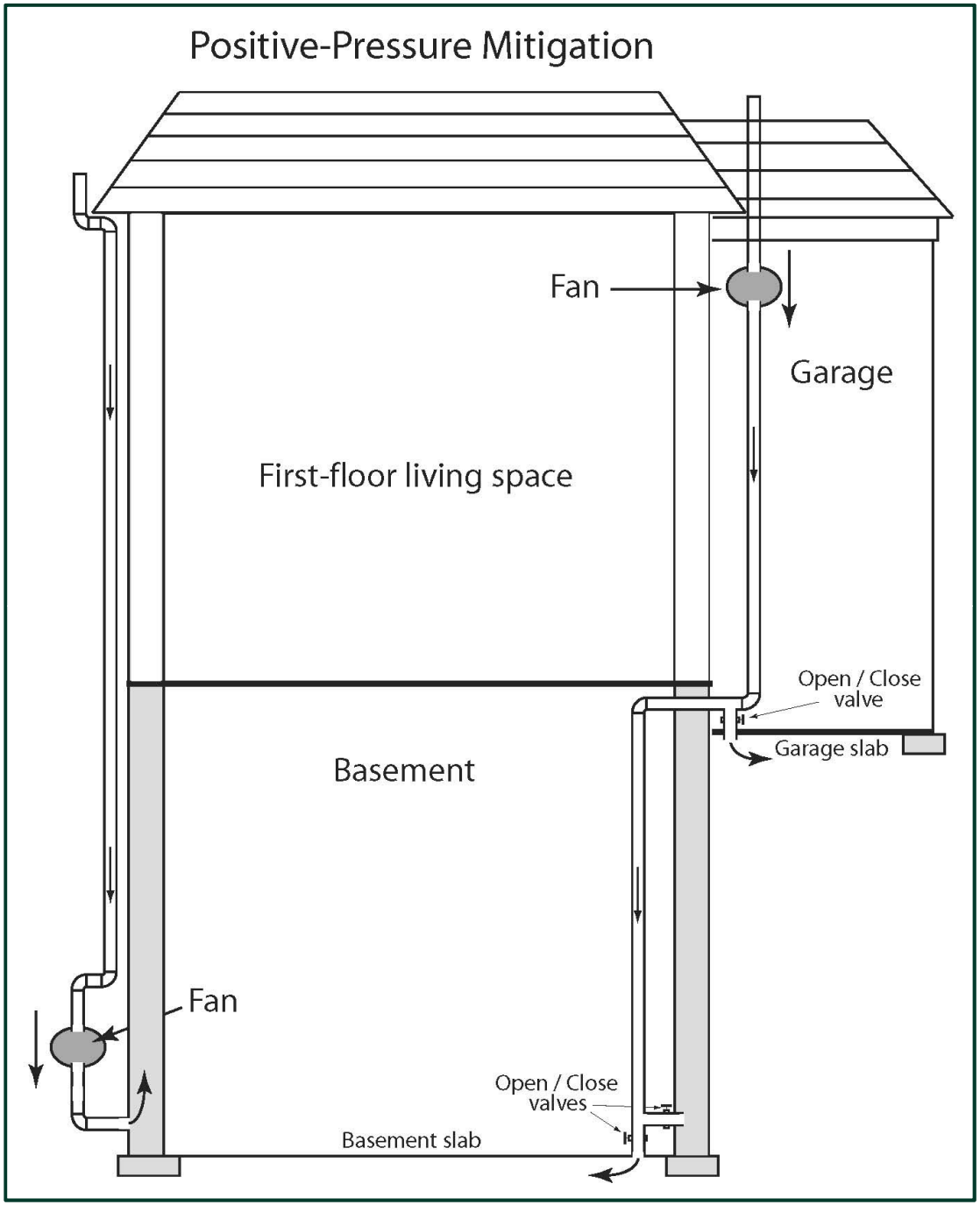
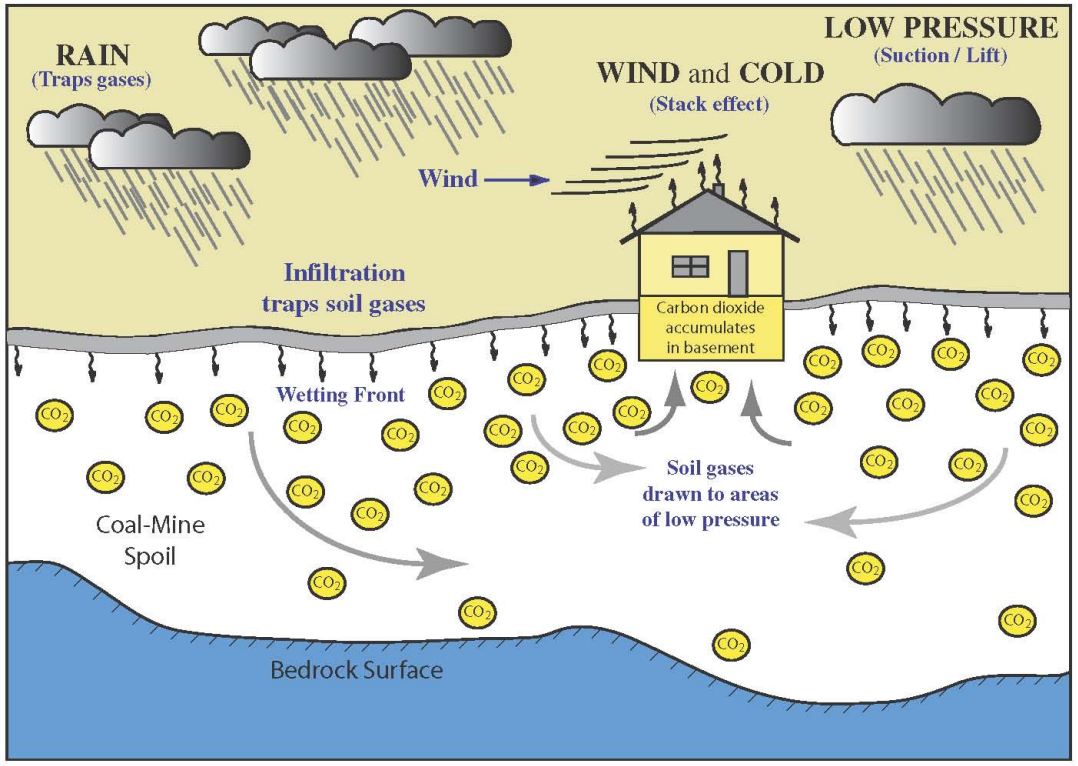
Present configuration
(10/21/2009)



Significant Findings

Occurrence

- Precipitation / Infiltration trap soil gases
- Heating a cold house causes a chimney effect
- Barometric pressure drop draws soil gases in and up



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- "Radon-s
  …ma
- Remembe

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