NTSB | National Transportation Safety Board

Potential Impact Radius: Observations from NTSB Investigated Accidents

Sara Lyons
Pipeline Accident Investigator

Transportation Research Board, October 27, 2022
The National Academies of Sciences, Engineering, and Medicine

Potential Impact Radius

- Required for High Consequence Area (HCA) definition
- Useful in Emergency Response Planning
  - Survivor Assistance
  - Firefighting
  - Isolation
- Useful for Risk Assessment Consequence Analysis

Impact Phases

Initial Ignition

- *initial shock wave*
- *flash fire*
- *fireball*
- *jet fire*

1

Prior to Isolation

- *fire propagation*
- *persistent fire*

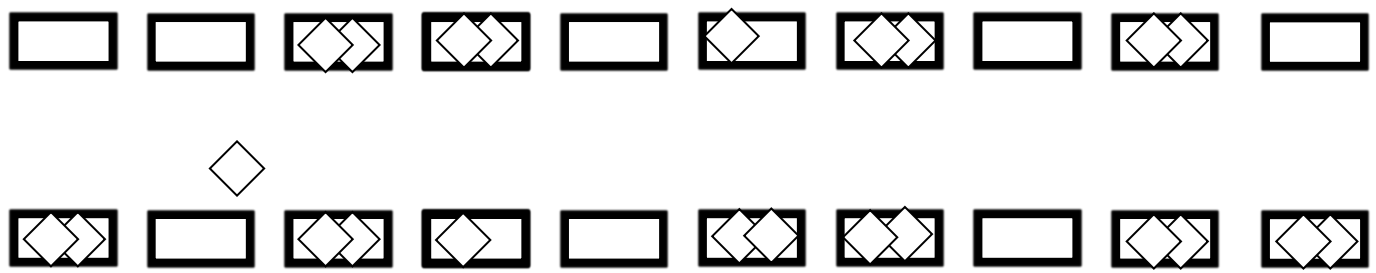
2

After Isolation

- *residual gas fire*
- *decreased intensity*
- *continued fire propagation*

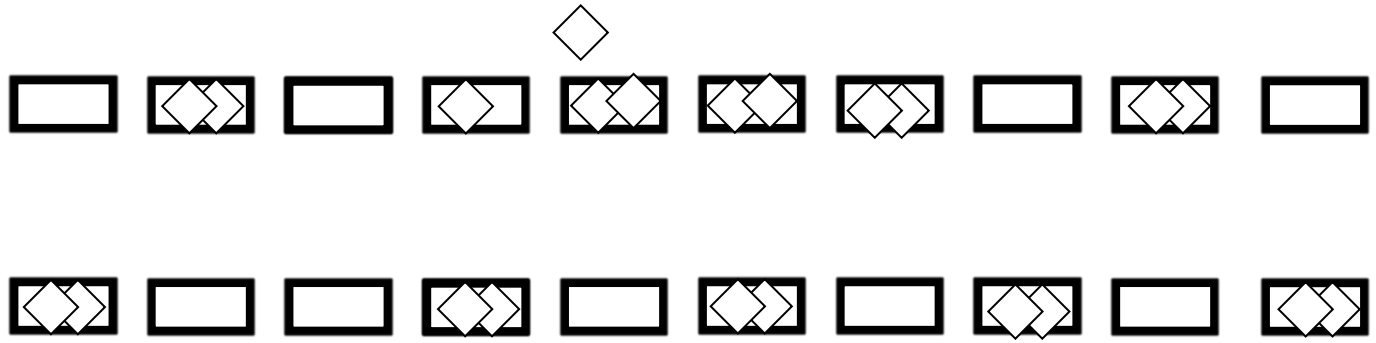
3

Area Near Rupture Origin – Notional



Person

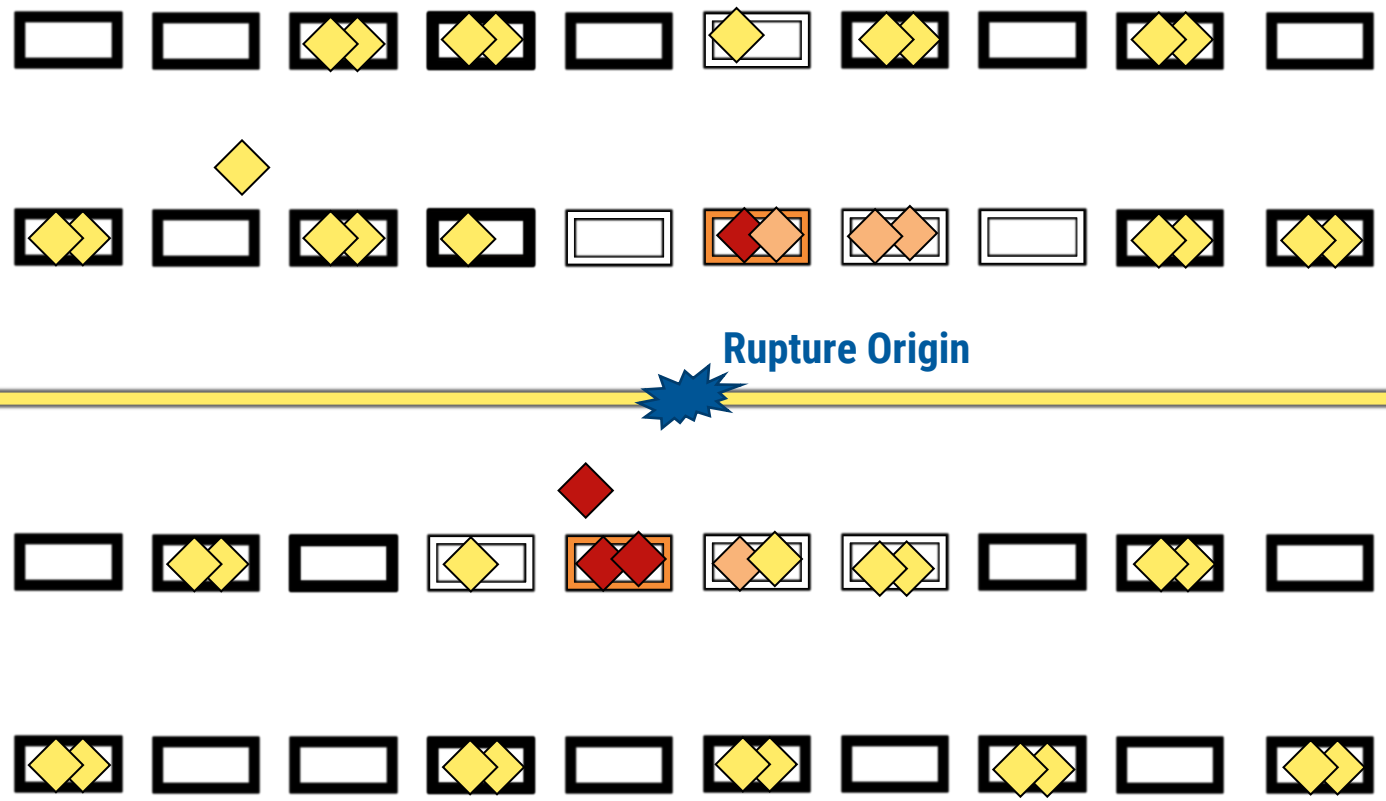
Pipeline



Residence

Pipeline

Initial Ignition Impacts – Notional



Fatality

Injured survivor

Uninjured survivor

Destroyed residence

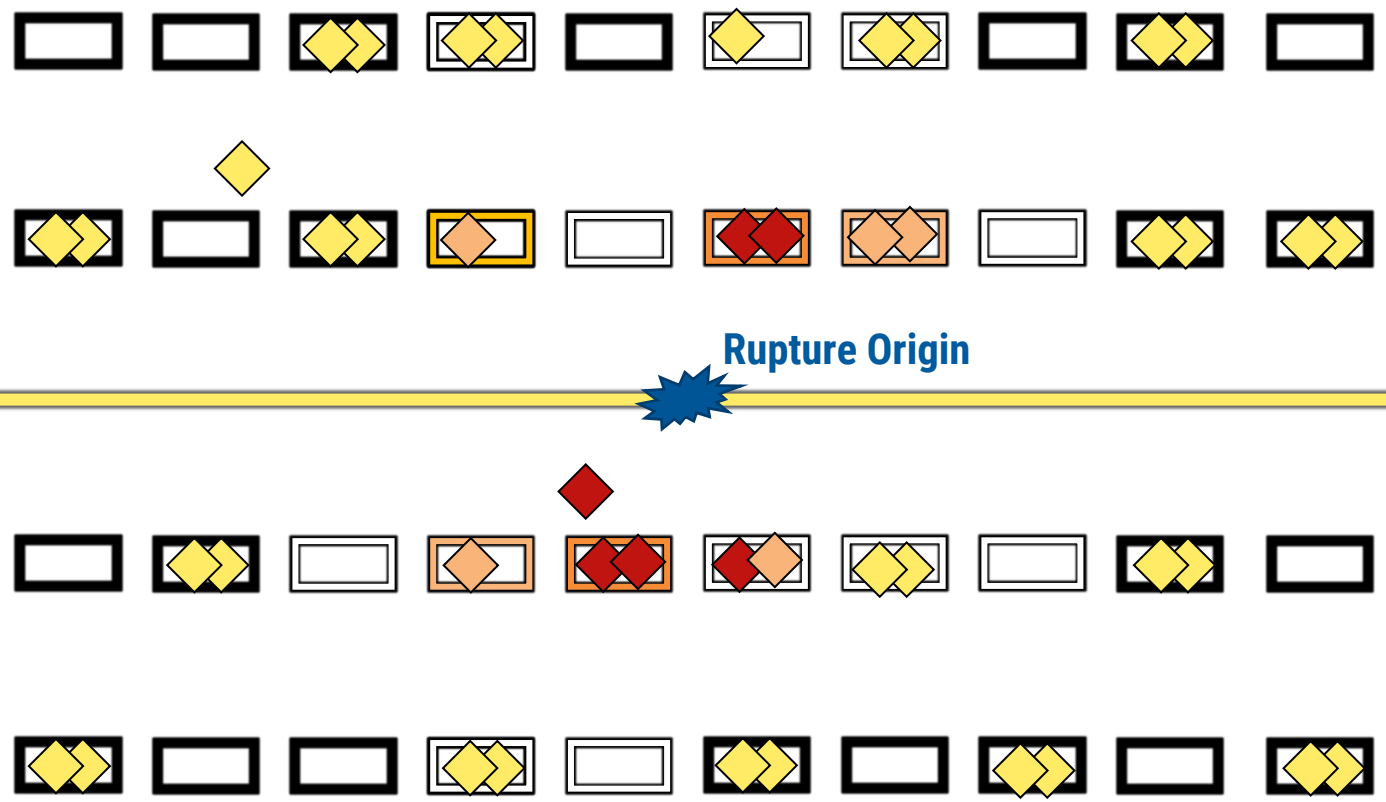
Damaged residence

Pipeline

1

NTSB

Impacts Prior to Isolation – Notional



Fatality

Injured survivor

Uninjured survivor

Destroyed residence

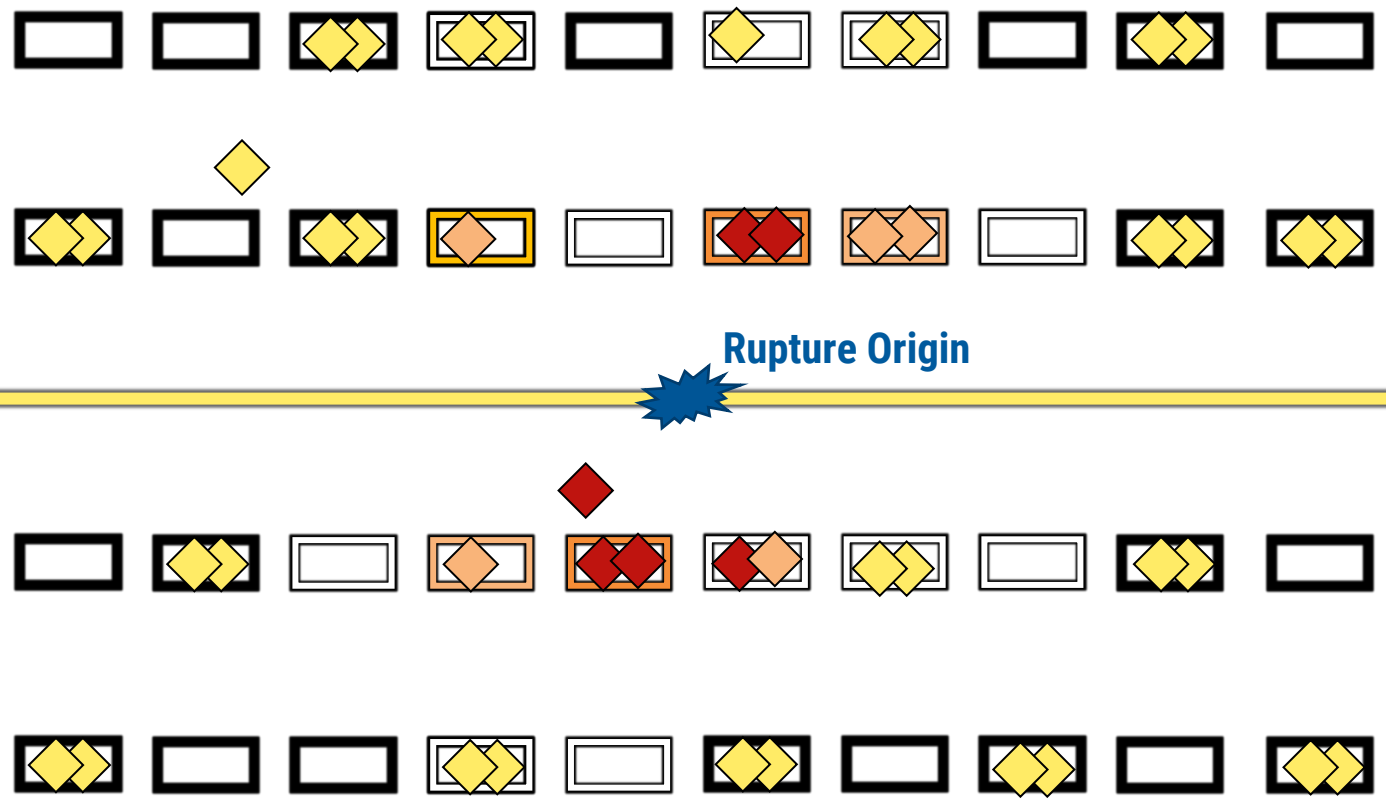
Damaged residence

Pipeline

2

NTSB

Impacts After Isolation – Notional



Fatality

Injured survivor

Uninjured survivor

Destroyed residence

Damaged residence

Pipeline

3

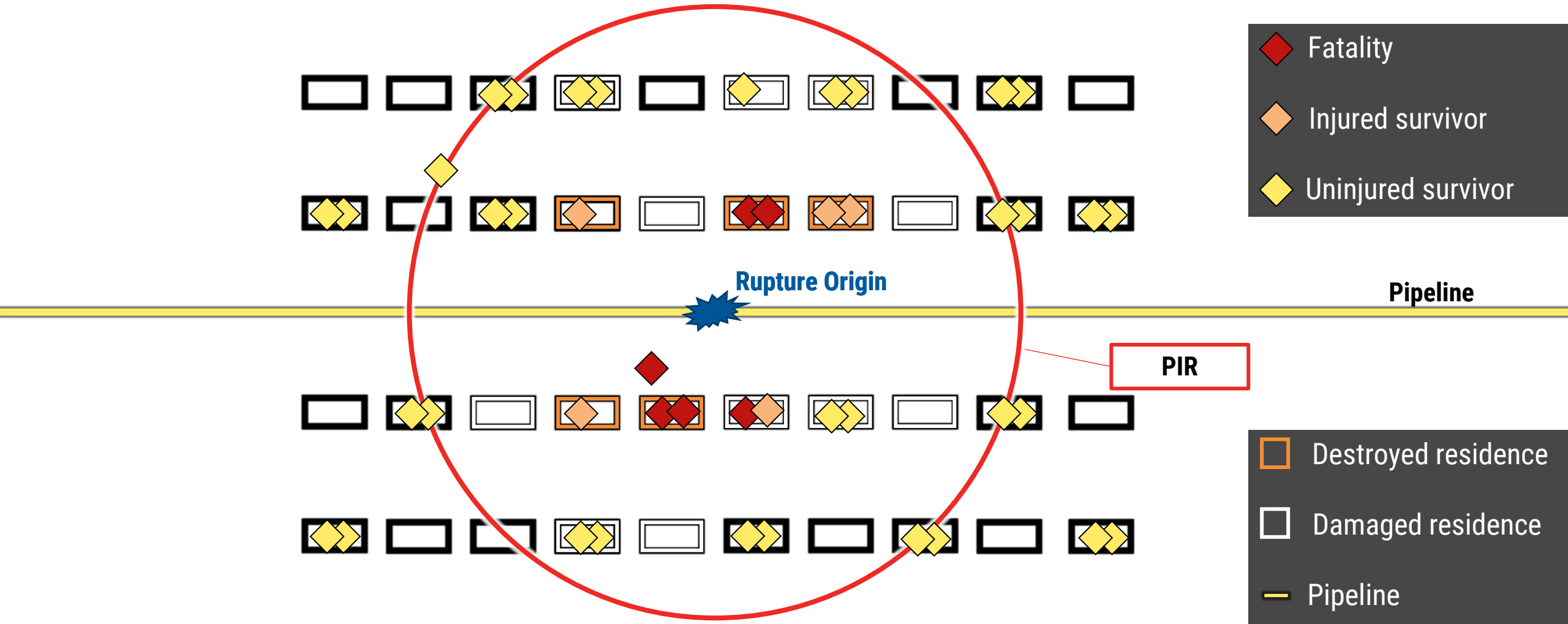
NTSB

Potential Impact Radius (PIR)

The radius of a circle within which the potential failure of a pipeline **could have significant impact on people or property**

49 CFR 192.903

Potential Impact Radius (PIR) – Notional



Potential Impact Radius (PIR)

$$PIR = 0.69 \times \sqrt{p \times d^2}$$

where p is the maximum allowable operating pressure (MAOP) in psi
d is the nominal diameter of the pipeline in inches

There is model uncertainty associated with the use of this equation.

68 FR 69777

Gas Transmission Ruptures – PIR

Accident Investigation	PIR (ft)	MAOP (psig)	Diameter (in)	Damage and Injuries Outside the PIR
Edison, NJ (3/23/1994)	776	975	36	Destroyed buildings ~1000 ft
Indianapolis, IN (7/21/1997)	417	913	20	*Minor damage, unless adjusted for pressure*
Carlsbad, NM (8/19/2000)	599	837	30	12 fatalities ~675 ft
Palm City, FL (5/4/2009)	365	866	18	
Cleburne, TX (6/7/2010)	805	1051	36	
San Bruno, CA (9/9/2010)	414	400	30	Destroyed/Damaged homes ~600/~1100 ft
Sissonville, WV (12/11/2012)	436	1000	20	Burn limits
Danville, KY (8/1/2019)	633	936	30	Destroyed/Damaged homes ~675/~1150 ft
Hillsboro, KY (5/4/2020)	633	936	30	
Coolidge, AZ (8/15/2021)	636	944	30	Deceased animals ~700 ft

Edison, NJ – March 23, 1994

DCA94MP001

1 Initial Ignition

- Explosion propelled debris more than 800 feet
- Radiant heat ignited a nearby apartment complex
- About 1,500 residents evacuated

PAR9501.pdf (ntsb.gov)

Photo source: *The Courier-News,* Bridgewater, New Jersey

Edison, NJ – March 23, 1994

DCA94MP001

2 Prior to Isolation

12:02 AM Firefighters arrived (~7 minutes after rupture)

12:30 AM Firefighters had contained fire to 8 buildings

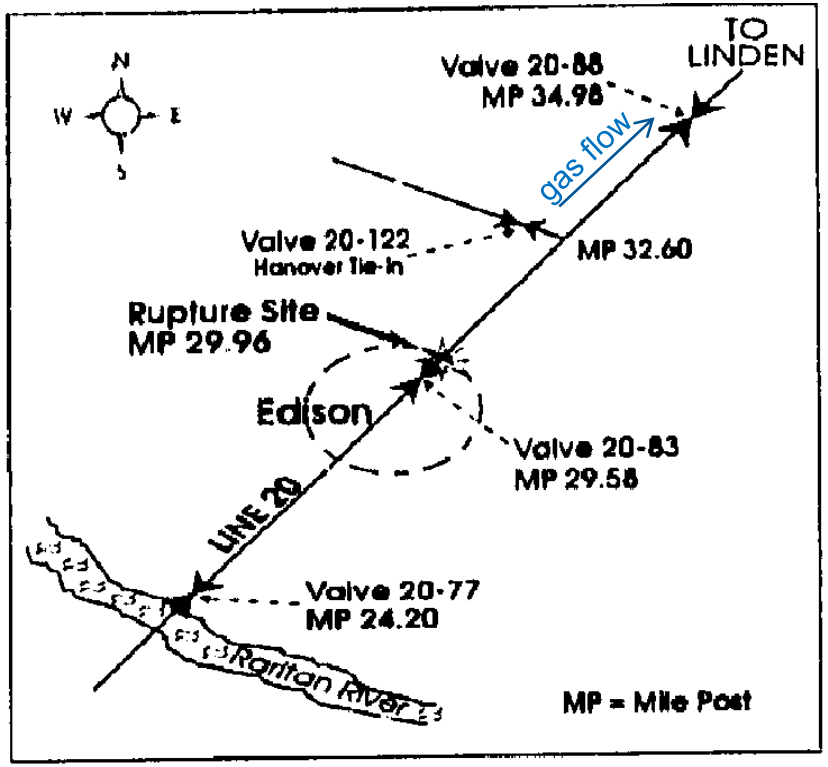
Photo source: *The Courier-News,* Bridgewater, New Jersey

Edison, NJ – March 23, 1994 – Isolation

DCA94MP001

2 Prior to Isolation

12:02 AM	Firefighters arrived (~7 minutes after rupture)
12:07 AM	Gas control alerted to “fireball in the sky”
12:30 AM	Firefighters had contained fire to 8 buildings
1:15 AM	Personnel arrived at valve 20-83 (not operable)
1:35 AM	Personnel closed valve 20-88
2:00 AM	Personnel closed valve 20-122
2:25 AM	Personnel closed at valve 20-77 and then 20-83, completing isolation



Edison, NJ – March 23, 1994
112 injured, 1,500 evacuated, 8 apartment buildings destroyed

$$PIR = 0.69 \times \sqrt{(975\ psig) \times (36\ in.)^2}$$

$$PIR = 776\ feet$$

3 After Isolation

Photo source: Google Earth

Indianapolis, IN– July 21, 1997

DCA-97-FP-005

1 Initial Ignition

Reports of

- “shaking,” flames on car in driveway, home engulfed in flames
- blinds melting, intense radiant heat, fire moving rapidly across grass
- witnesses observed wall of flames crossing N. Settlement Dr.
- large mushroom cloud-type explosion

PAB/99-02.pdf (ntsb.gov)

Indianapolis, IN– July 21, 1997

DCA-97-FP-005

2 Prior to Isolation

2:33 PM	Firefighters immediately responded (~0 minutes after rupture – already in vicinity)
2:35 PM	Operator alerted to rupture
3:05 PM	Gas isolated

Indianapolis, IN – July 21, 1997
1 fatality, 1 injury, 75 evacuated, 6 homes destroyed, 65 homes damaged

3 After Isolation

Photo source: Google Earth

Indianapolis, IN – July 21, 1997
1 fatality, 1 injury, 75 evacuated, 6 homes destroyed, 65 homes damaged

$$PIR = 0.69 \times \sqrt{(913\ psig) \times (20\ in.)^2}$$

$$PIR = 417\ feet$$

...but the line was operating at 310 psig which would have corresponded to a

PIR of 243 feet

3 **After Isolation**

Photo source: Google Earth

Carlsbad, NM– August 19, 2000

DCA00MP009

1 Initial Ignition

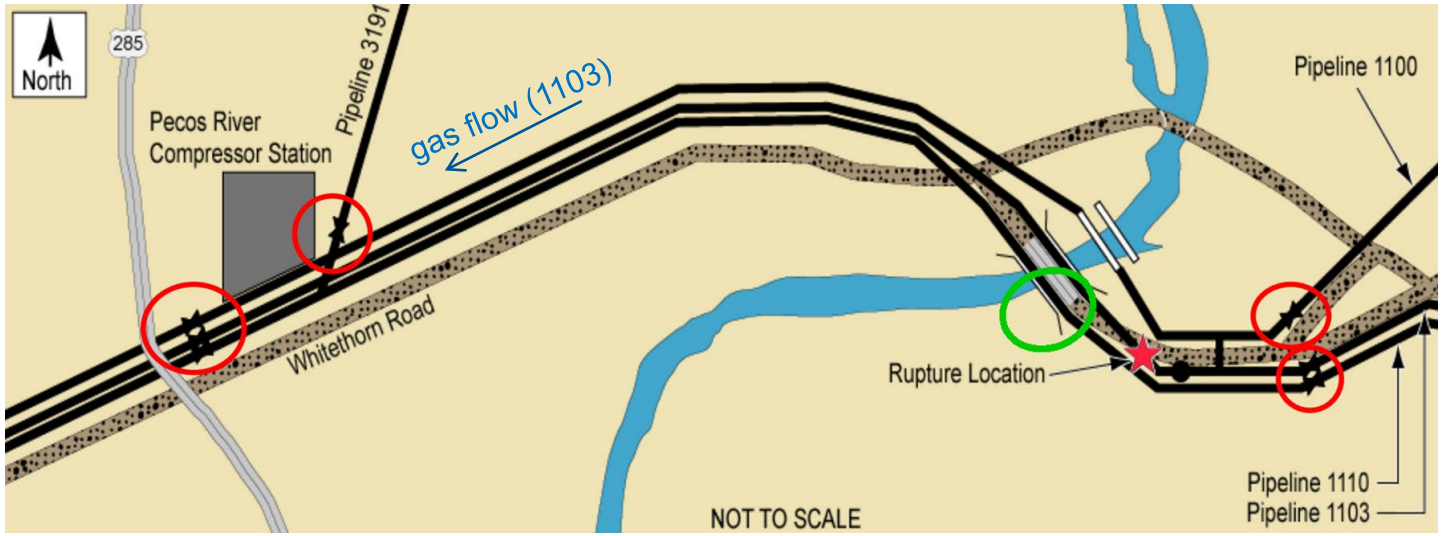
- SCADA alarms
- Compressor shut down and isolated automatically
- 49-foot section of pipe ejected from crater
- Flames about 500 feet high

PAR0301.pdf (ntsb.gov)

Carlsbad, NM

DCA00MP009

2 Prior to Isolation



5:30 AM	Personnel dispatched to Pecos River compressor station (~4 minutes after rupture)
5:45 AM	First worker arrived at accident site
	Personnel began closing downstream valves – did not know which line had ruptured
6:05 AM	Personnel began closing upstream valves
6:21AM	Fire out (~55 minutes after rupture)

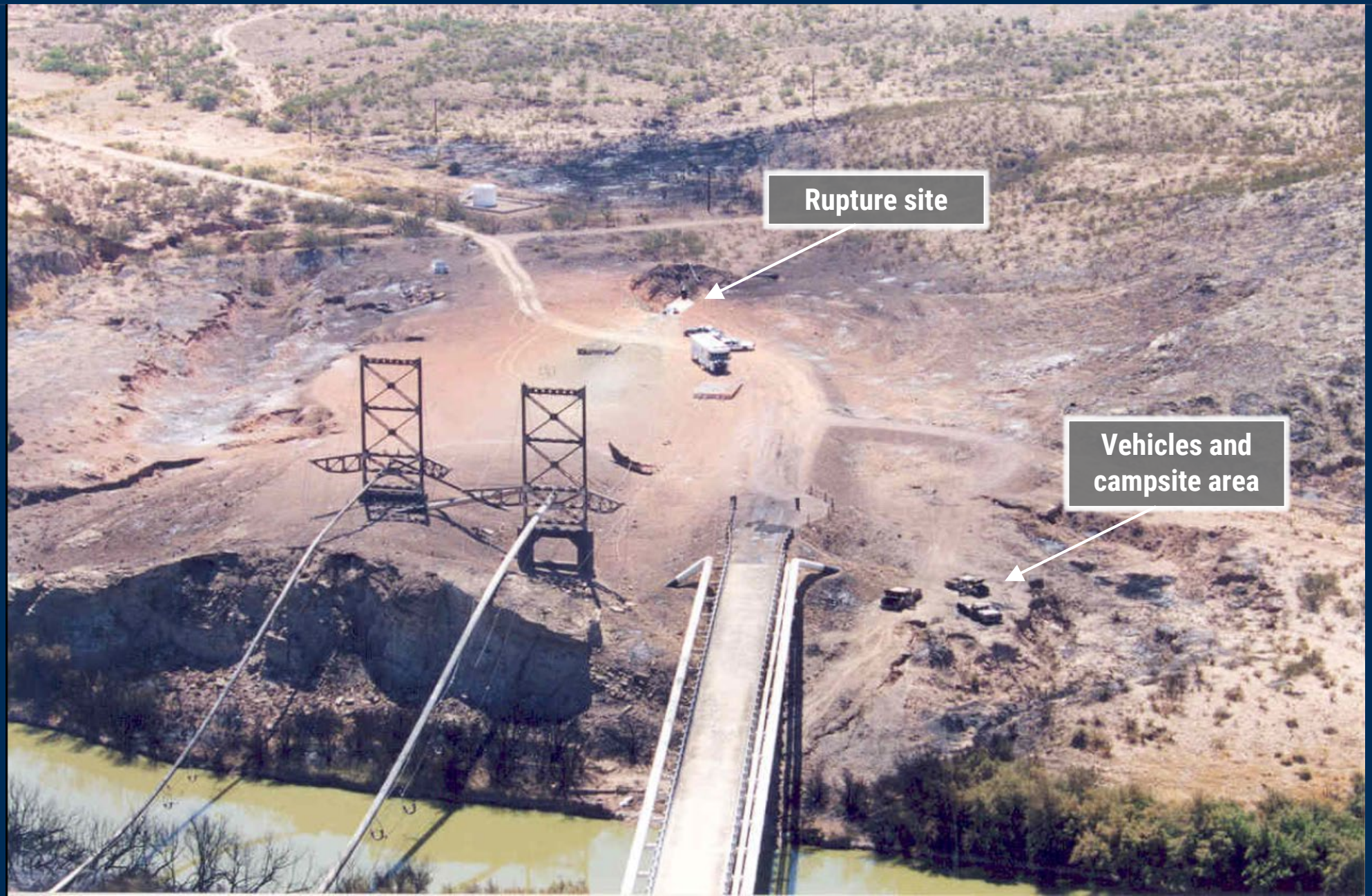
Carlsbad, NM– August 19, 2000

DCA00MP009

2 Prior to Isolation

5:30 AM	Personnel dispatched to Pecos River compressor station (~4 minutes after rupture)
5:31 AM	911 calls reporting fire and explosion
5:45 AM	First worker arrived at accident site
	Personnel began closing downstream valves – did not know which line had ruptured
6:05 AM	Personnel began closing upstream valves
6:21AM	Fire out (~55 minutes after rupture)
	Ambulance escorted to accident site. 6 victims found alive and 6 deceased.

Carlsbad, NM – August 19, 2000
12 fatalities



Carlsbad, NM – August 19, 2000
12 fatalities

$$PIR = 0.69 \times \sqrt{(837\ psig) \times (30\ in.)^2} = 599\ feet$$

3 **After Isolation**

Photo source: Google Earth

San Bruno, CA– September 9, 2010

DCA10MP008

1 Initial Ignition

- SCADA pressure drop and alarms
- 28-foot section of pipe ejected from crater
- About 300 homes evacuated

par1101.pdf (ntsb.gov)

San Bruno, CA– September 9, 2010

DCA10MP008

2 Prior to Isolation

6:13 PM	Firefighters onsite (~2 minutes after rupture)
6:24 PM	Police report some houses are engulfed in flames
	Firefighters report fire hydrants are dry
6:40 PM	Firefighters request two water tenders
7:46 PM	Natural gas transmission system isolated
11:32 PM	Natural gas distribution system isolated

San Bruno, CA– September 9, 2010

DCA10MP008

2 Prior to Isolation

6:18 PM	Worker notifies operator (~7 mins after rupture)
6:23 PM	Worker dispatched to confirm reported explosion
6:30 PM	Some SCADA staff realize pipeline ruptured
6:41 PM	First worker arrives on-scene
7:29 PM	Martin Station valves closed remotely
7:30 PM	Upstream valve closed manually
7:42 PM	Fire decreased, firefighters begin containment effort

NTSB

San Bruno, CA – September 9, 2010
8 fatalities, 58 others injured

3 **After Isolation**

Photo source: Google Earth

San Bruno, CA – September 9, 2010
8 fatalities, 58 others injured

$$PIR = 0.69 \times \sqrt{(400\ psig) \times (30\ in.)^2} =$$

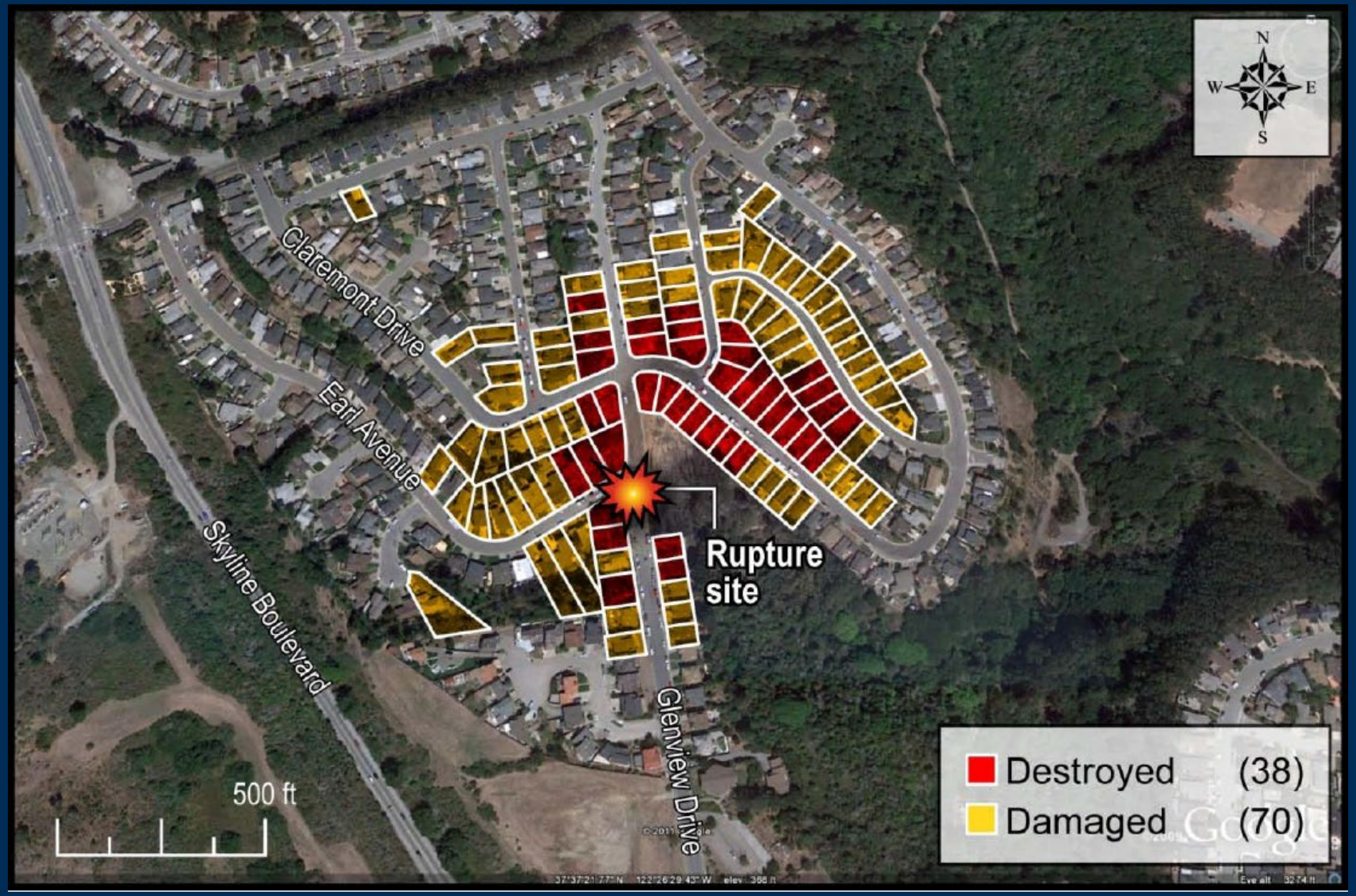
$$414\ feet$$

3 After Isolation

Photo source: Google Earth

*Residences with minor damage were excluded from this figure.

San Bruno, CA – September 9, 2010
8 fatalities, 58 others injured



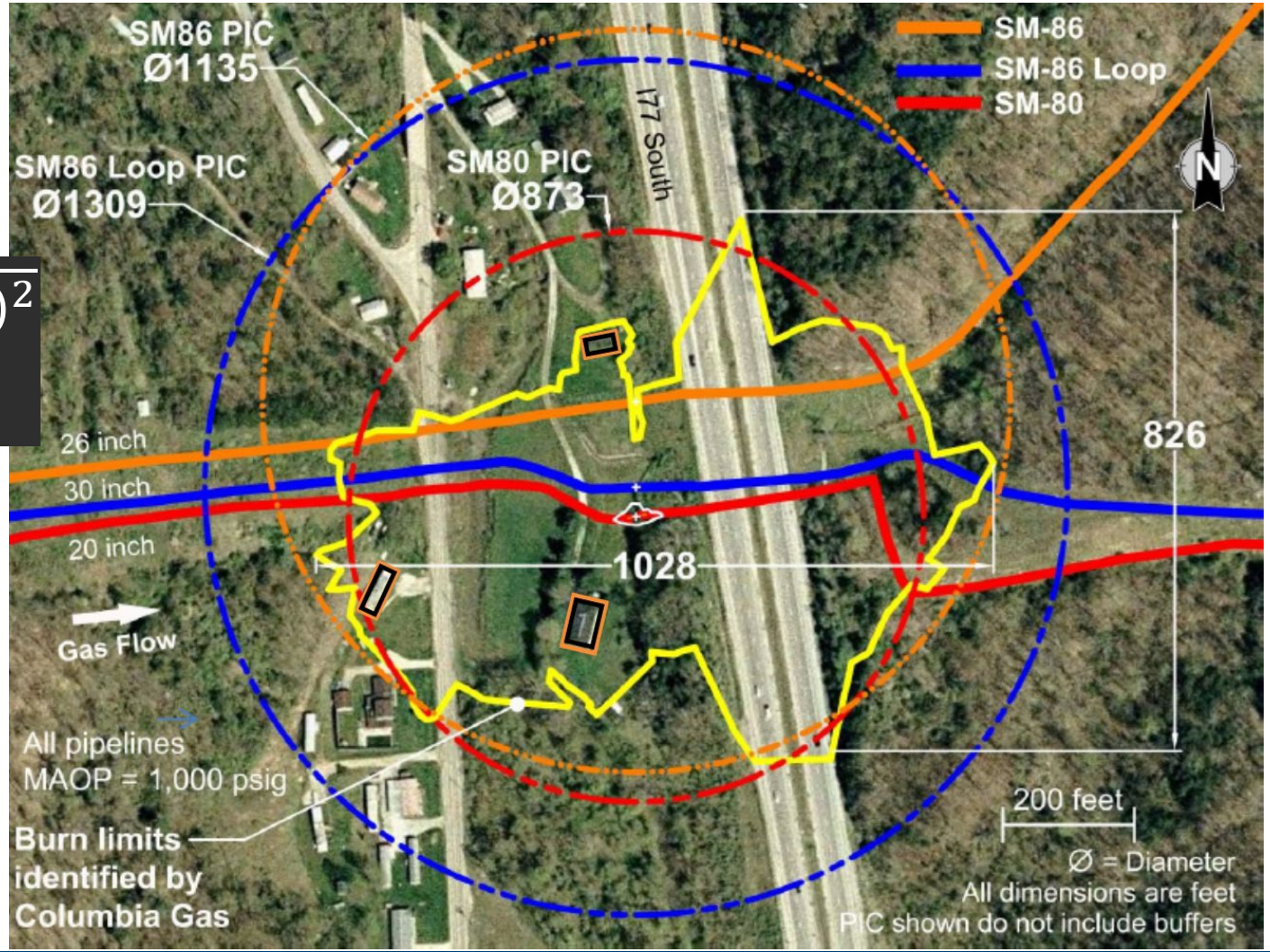
Sissonville, WV– December 11, 2012

DCA-13-MP003

$$PIR = 0.69 \times \sqrt{(1000\ psig) \times (20\ in.)^2}$$

$$= 436\ feet$$

Destroyed residence



par1401.pdf (ntsb.gov)

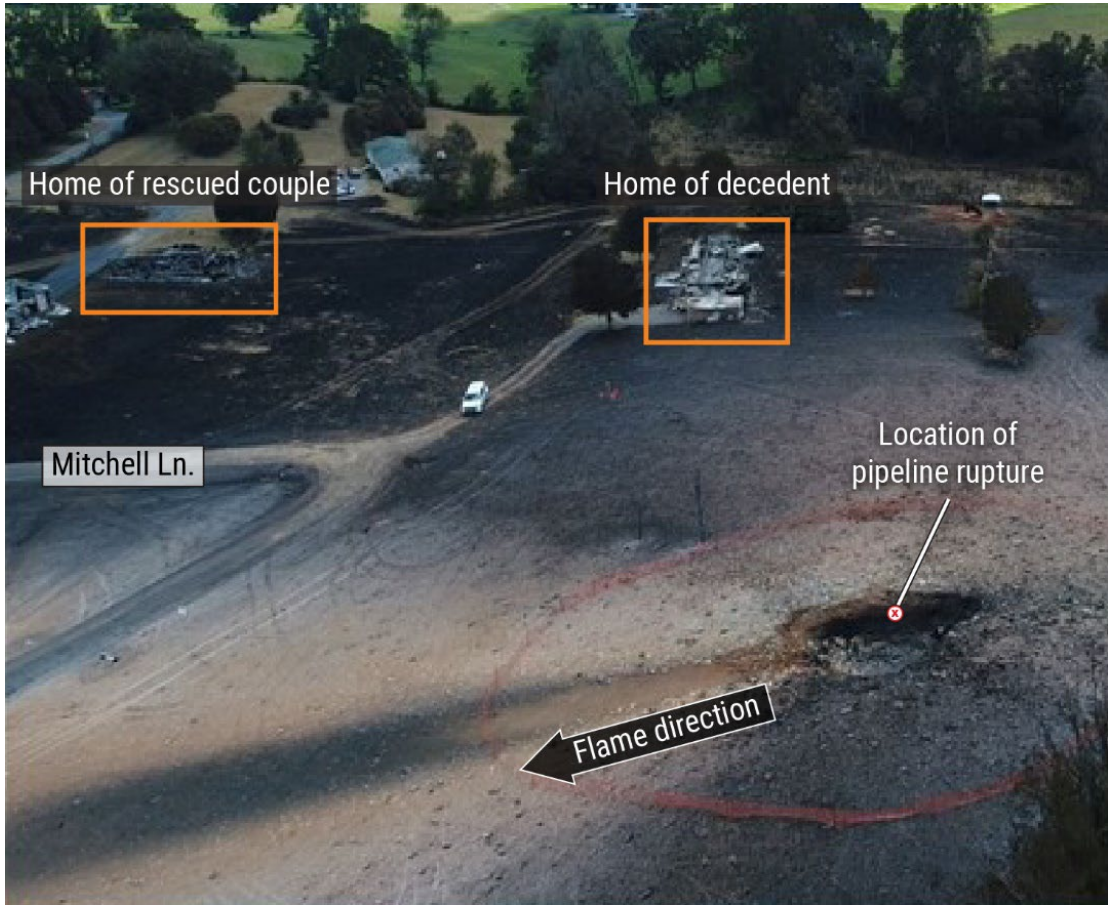
NTSB

Danville, KY – August 1, 2019

PLD19FR002

1 Initial Ignition

- SCADA pressure drop and alarms
- 33-foot section of pipe ejected from crater
- About 75 people evacuated

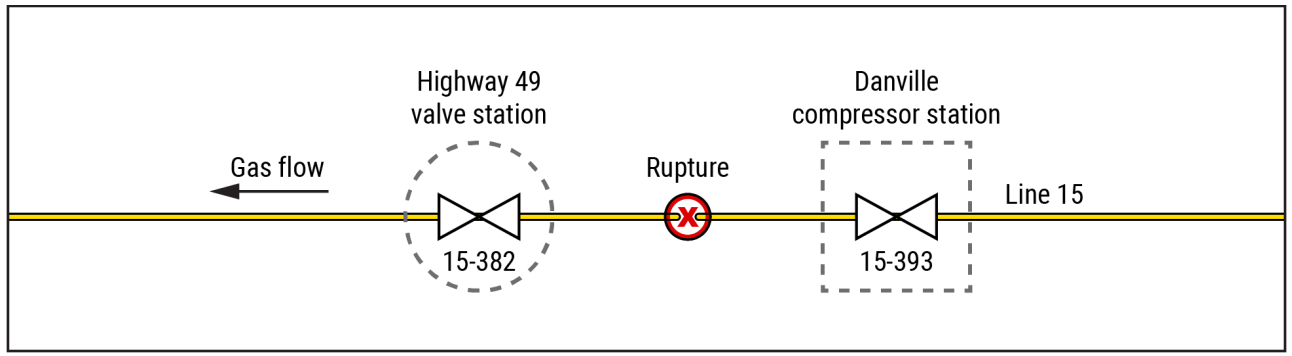


PLD19FR002.aspx (ntsb.gov)

Danville, KY – August 1, 2019

PLD19FR002

2 Prior to Isolation



1:28 AM Employee dispatched to South side (valve 15-382)

1:30 AM Gas control began remote actions to reduce gas coming from the North

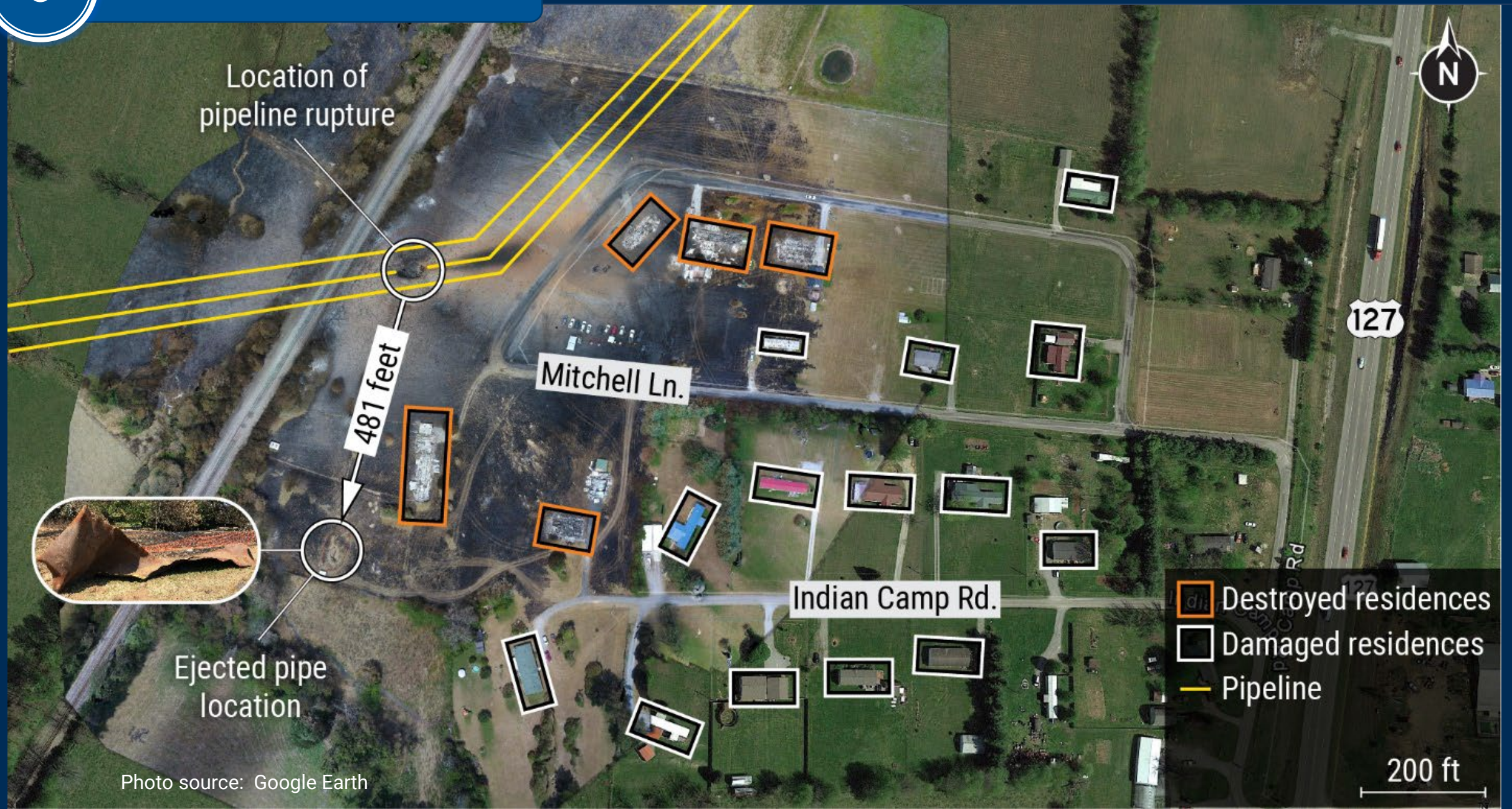
1:37 AM Firefighters onsite (~14 min after rupture)

1:39 AM North side (valve 15-393) isolated

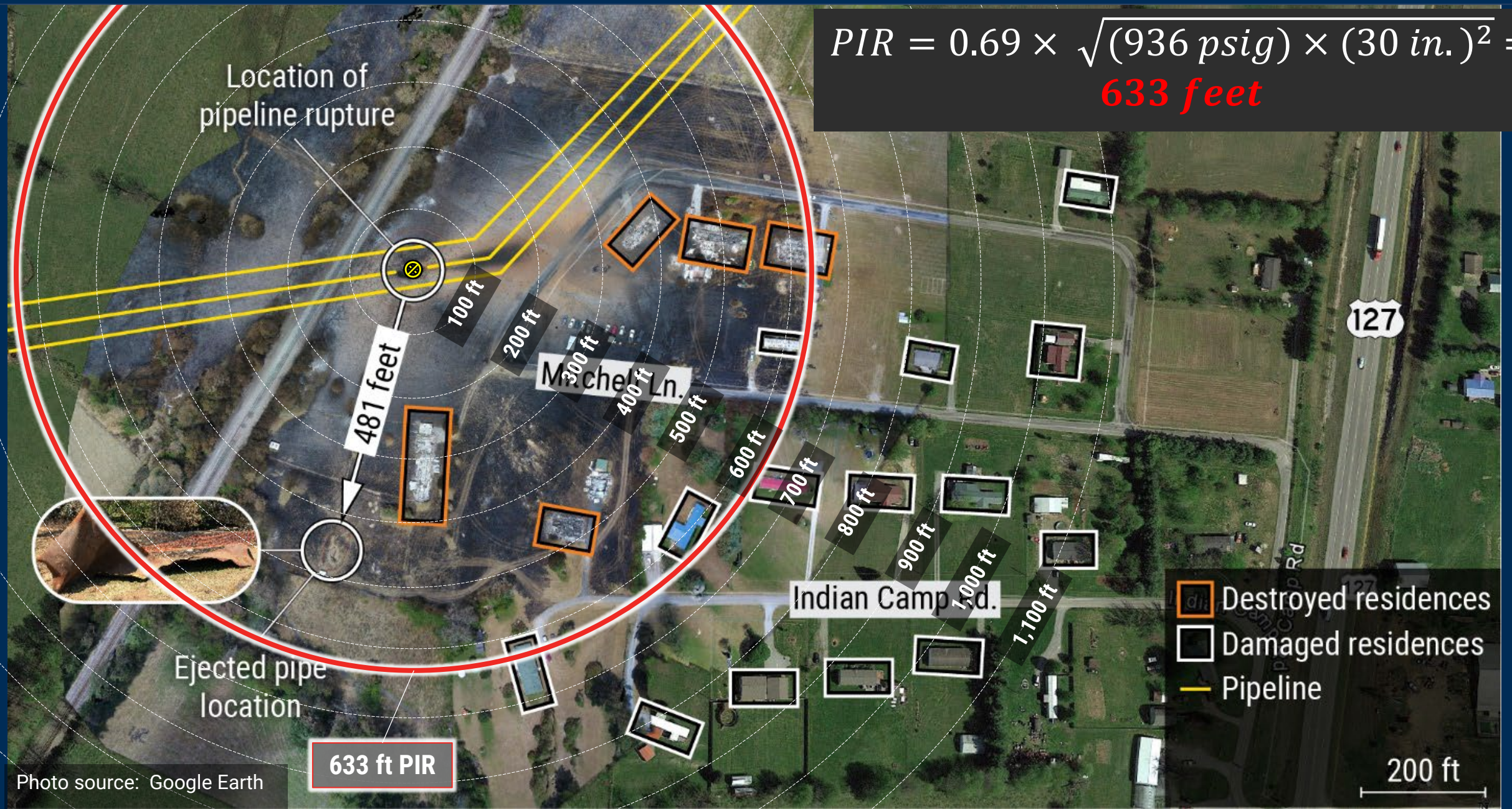
2:19 AM South side (valve 15-382) isolated – Complete segment isolation

3 After Isolation

Danville, KY – August 1, 2019
1 fatality, 6 others injured, 5 homes destroyed, 14 damaged



Danville, KY – August 1, 2019
1 fatality, 6 others injured, 5 homes destroyed, 14 damaged



Coolidge, AZ – August 15, 2021

PLD21FR003

1 Initial Ignition

- Rupture
- Ignition, shock wave, fire
- Felt 17 miles away
- Fatality attributed to initial blast

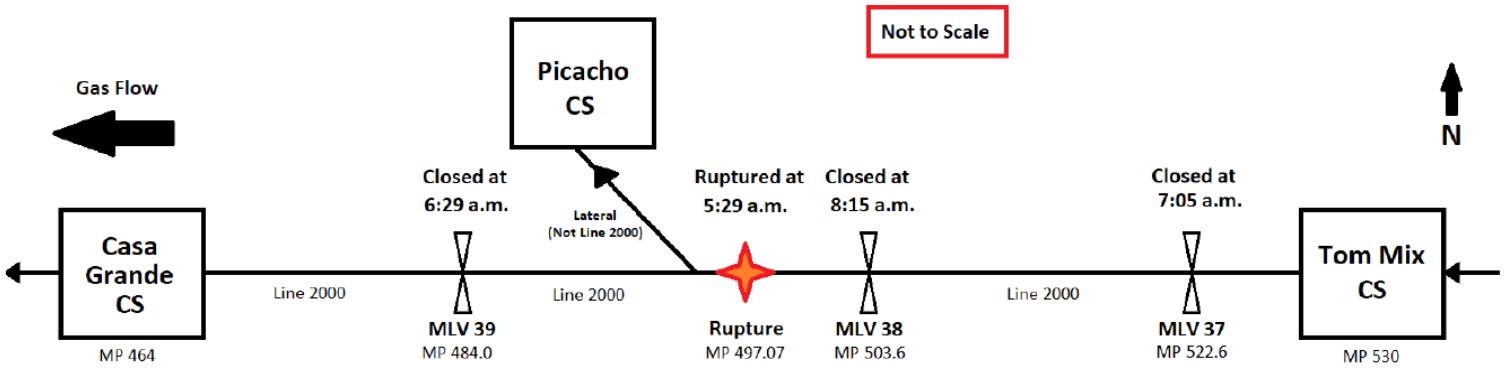
PLD21FR003 Docket

Photo source: Coolidge Fire Department

Coolidge, AZ – August 15, 2021

PLD21FR003

2 Prior to Isolation



5:29 AM Rupture occurred

5:55 AM Gas control began remote actions to reduce gas in ruptured segment

6:29 AM MLV 39 closed

7:05 AM MLV 37 closed

8:15 AM MLV 38 closed

8:20 AM Gas fire extinguished

3 After Isolation

Coolidge, AZ – August 15, 2021
2 fatalities, 1 other injured

Photo source: Global Geomatics Engineering, Inc.

Coolidge, AZ – August 15, 2021
2 fatalities, 1 other injured

$$PIR = 0.69 \times \sqrt{(944\ psig) \times (30\ in.)^2} =$$

636 feet

Pipeline Operator PIR = 636+40 = 676 feet

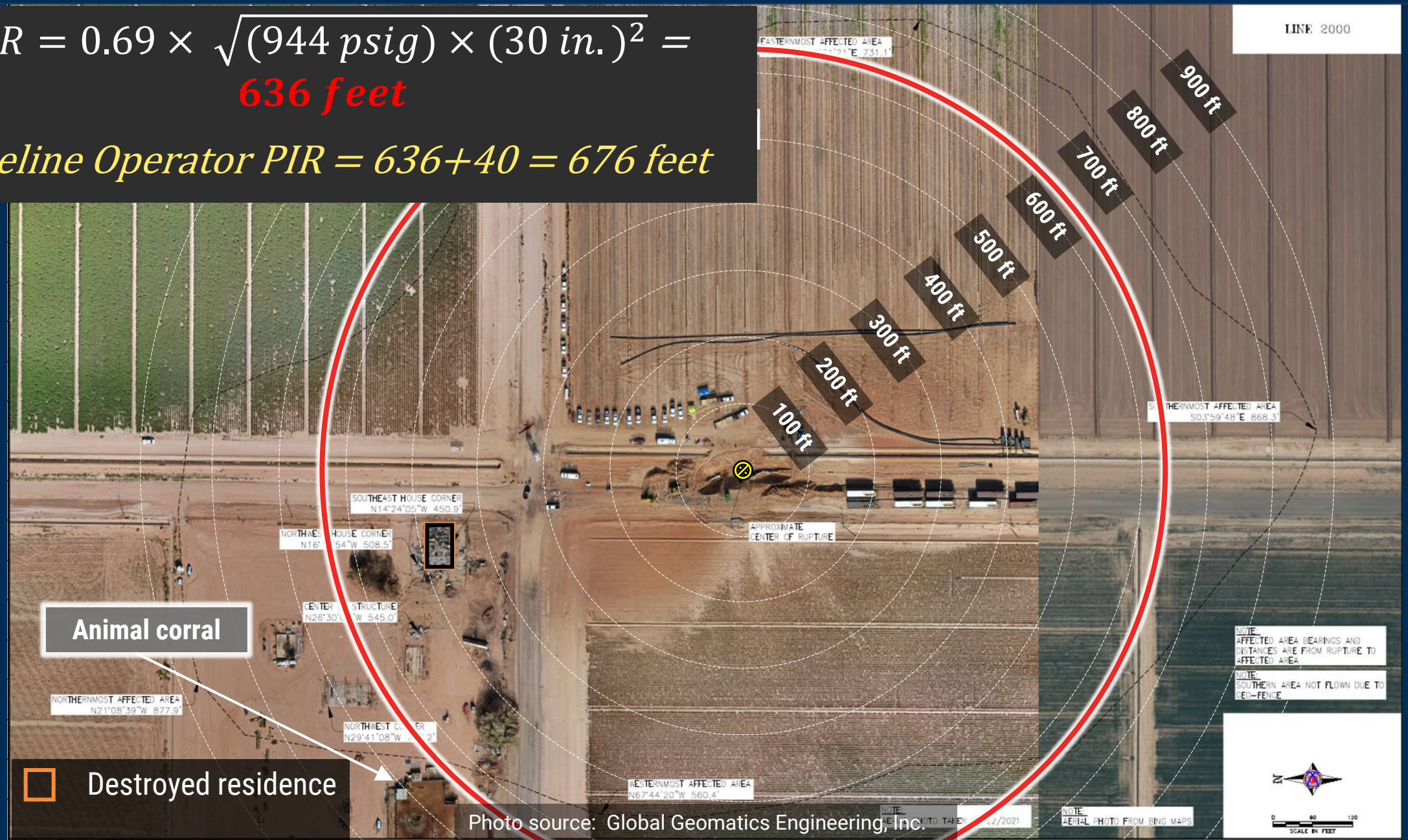


Photo source: Global Geomatics Engineering, Inc.

SAN BRUNO
California

Open NTSB Recommendations

PAR-11-01	To PHMSA: Amend Title 49 Code of Federal Regulations 192.935(c) to directly require that automatic shutoff valves or remote control valves in high consequence areas and in class 3 and 4 locations be installed and spaced at intervals that consider the factors listed in that regulation.
P-22-001	To PHMSA: Revise the calculation methodology used in your regulations to determine the potential impact radius of a pipeline rupture based on the accident data and human response data discussed in this [Danville, KY] report.

Gas Transmission Ruptures – References

Accident Investigation	NTSB ID
Edison, NJ (3/23/1994)	DCA94MP001*
Indianapolis, IN (7/21/1997)	DCA-97-FP-005*
Carlsbad, NM (8/19/2000)	DCA00MP009*
Palm City, FL (5/4/2009)	DCA09FP007*
Cleburne, TX (6/7/2010)	DCA10FP004
San Bruno, CA (9/9/2010)	DCA10MP008
Sissonville, WV (12/11/2012)	DCA13-MP-003
Danville, KY (8/1/2019)	PLD19FR002
Hillsboro, KY (5/4/2020)	PLD20LR001
Coolidge, AZ (8/15/2021)	PLD21FR003

* Not yet available on our public website.

Access docket items by:

- visiting www.ntsb.gov
- clicking “Search Dockets”
- entering NTSB Accident ID


NATIONAL TRANSPORTATION
E PLURIBUS UNUM
SAFETY BOARD