Facility Siting Overview for Projects

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What is facility siting?

The OSHA PSM standard* includes requirement that process hazard analyses (PHAs) address "facility siting"

Facility siting can refer to:

Site Selection	Location of the process facility
Plant Layout	Placement of individual units and equipment
Building Siting	Location of occupied permanent buildings, temporary buildings, and tents

This presentation focuses on potential process safety-related consequences to personnel in occupied buildings; primarily blast hazards

To help support compliance with the PSM requirement, API developed Recommended Practices API RP752, 753, and 756.

These three RP's discuss building hazard management for permanent buildings, portable buildings, and tents.

Hazards covered include blasts, (external) fires, and toxic releases

** OSHA 1910.119 (e)(3)(v) Occupational Safety and Health Administration – Process Safety Management standard*

Blast-related incidents

BP - Texas City, TX - 2005

- Formation of a flammable vapor cloud during unit restart
- Delayed ignition resulted in a vapor cloud explosion (VCE)
- Involved occupants of portable buildings
- 15 fatalities, 180 injuries

Phillips - Pasadena, TX - 1989

- Ethylene release and VCE
- Control room in proximity of process unit destroyed
- 23 fatalities, over 100 injuries
- Most fatalities were inside buildings

PES - Philadelphia, PA - 2019

- Loss of containment (butene in HF unit)
- Vapor cloud with delayed ignition
- Bankruptcy and closure of refinery
- Abandoned control room damaged, replacement control room protected occupants

Fire and Toxics

- Facility siting considers potential impacts from fires
- Examples include:
  - Use of spacing criteria to site buildings at adequate distances from potential pool and jet fire sources
  - Use of standards to site buildings an appropriate minimum distance from potential tank fire sources
  - Consideration of potential fire exposure from pool fires, jet fires, and BLEVE's when siting project-related portable buildings and tents

- Facility siting considers potential impacts from toxic releases
- Examples include:
  - Project may introduce new toxic chemicals
  - Project may increase the inventory of existing toxic chemicals processed at the site
  - Project may change the location where toxic chemicals are present with impacts on toxic release scenarios
  - Project may include buildings in locations where toxic releases may impact selection/design of building "tightness" and/or HVAC
  - Project may provide temporary buildings or tents that require consideration of potential toxic exposures and emergency response plans

API Recommended Practices

API RP752 Permanent Buildings
API RP753 Portable Buildings
API RP756 Tents

- Published by the American Petroleum Institute
- Covers the siting and evaluation of three different types of structures to address the United States Occupational Safety and Health Administration Process Safety Management "Facility Siting" requirement
- Discusses evaluating hazards from vapor cloud explosions, fire, and toxic releases
- All three standards reaffirmed unchanged in 2020 to allow working committee to complete updates

Major factors in blast load estimation

3

Factors

- **Size** of the vapor cloud and the size congested area
- Level of **congestion** / confinement
  - More heavily congested / confined areas produce more flame acceleration and turbulence and therefore, stronger explosions
- "Reactivity" of the **fuel**
  - Higher reactivity fuels (e.g., C_2H_4, H_2) have higher flame speeds than less reactive fuels (e.g., NH_3, CH_4)
  - Higher reactivity produces stronger blast effects

Engineering design can influence all three.

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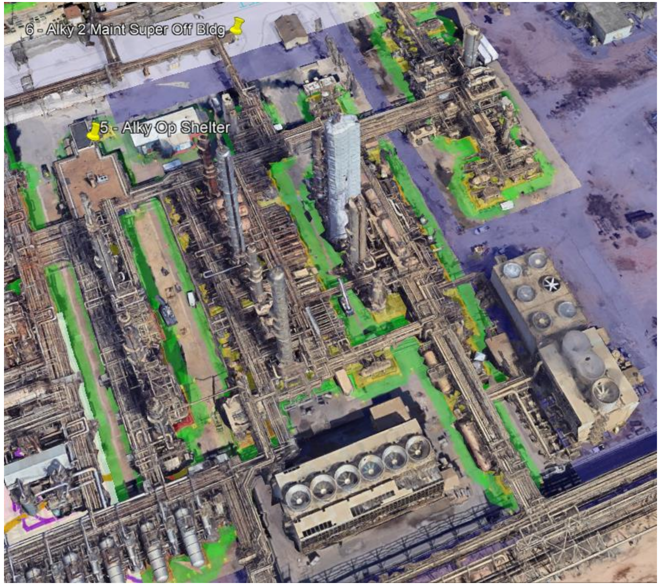
Potential Explosion Domains

Potential Explosion Domain: A volume of congestion and/or confinement that has a clear separation corridor around the perimeter.

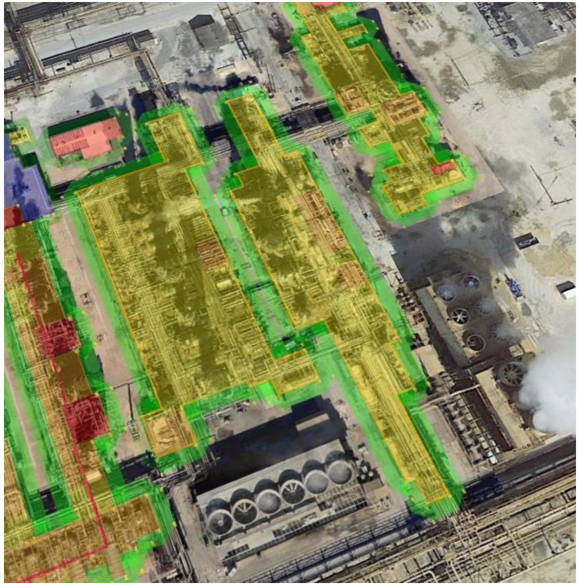


Source PEDs are those that have a vapor cloud forming source within the PED

Non-source PEDs require vapors to drift into them from other locations to produce a VCE in the PED

Congested regions shown in red, orange, and yellow

Clear separation defining PED extents shown as green margins

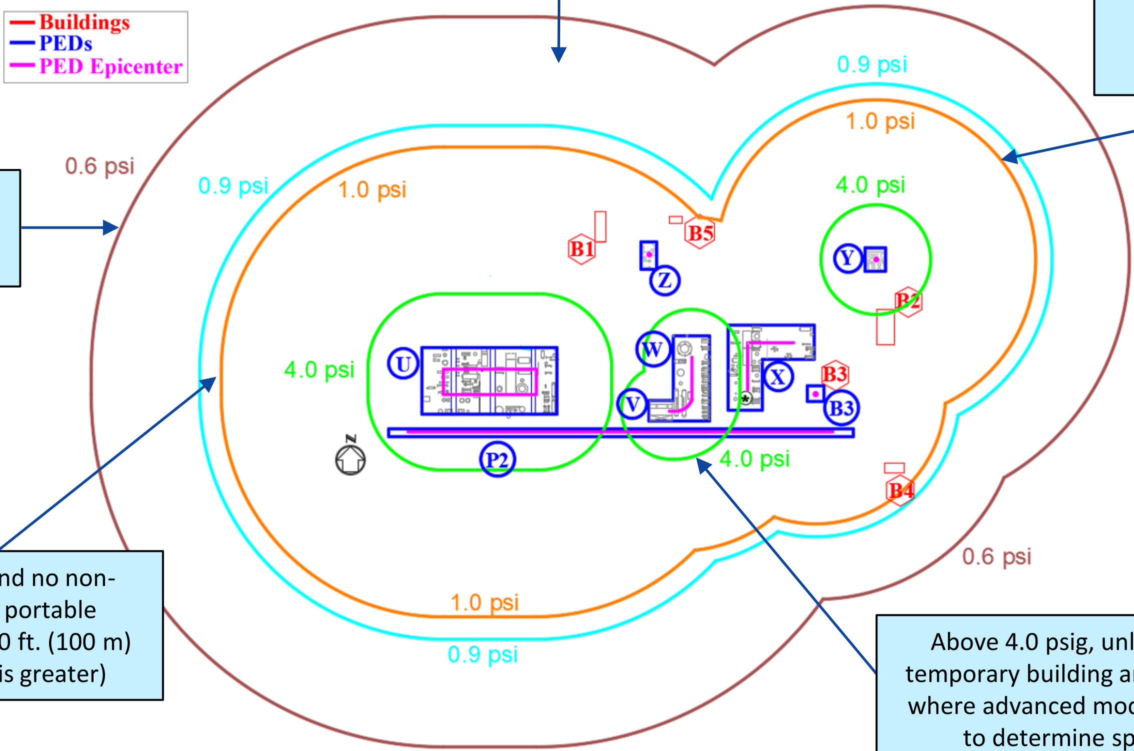


Blast map regions

Limitations on tent/trailers between 0.6 and 0.9 psig

Boundary between blast resistant and non-blast resistant construction for permanent buildings lies at 1.0 psig

Few tent/trailer restrictions outside of 0.6 psig



No light wood trailers and no non-essential personnel in portable buildings/tents within 330 ft. (100 m) or 0.9 psig (whichever is greater)

Above 4.0 psig, unlikely to find suitable temporary building and likely in “near field” where advanced modelling will be required to determine specific blast loads.

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Risk to building occupants vs. outdoors

- Buildings may collapse at relatively low overpressures and pose significant injury potential to persons*
  - ~0.8 psig – Load bearing masonry buildings
  - ~0.9 psig – Wood structures
  - ~1.5 psig – Steel-frame metal buildings
- Conversely, a person located outside could expect to survive blast pressures of ~7-8 psig
  - Does not include potential debris strikes or injury from falling/striking fixed surfaces
- In general, personnel are safer outdoors during a VCE than in a building not rated for blast load

Effects on Persons	Incident Peak Overpressure psi (mbar)
Annoying noise of continuous type at 10-15 Hz and 137 dB	0.02 (1.4)
Loud noise at 143 dB	0.04 (2.8)
Sound 'noted' as an unusual event - an "explosion"	0.005 (0.34)
Threshold for temporary loss of hearing	0.20 (13.8)
Threshold for eardrum rupture	2.0 (138)
50% Eardrum rupture threshold	4.8 (331)
Threshold of skin laceration by missiles	1.0 - 2.0 (69 – 138)
Personnel knocked down or thrown to the ground	1.5 – 2.9 (103 – 200)
Possible death of persons projected against obstacles	2.0 (138)
Low personnel risk when inside a resistant structure	1.0 (69)
50% probability of eardrum rupture	5.0 - 7.0 (345 – 483)
90% probability of eardrum rupture	10.0 - 15.0 (689 – 1034)
Threshold of internal injuries by blast	7.0 (483)
Serious missile wounds giving about 50% fatality	4.0 - 5.0 (276 – 345)
Serious missile wounds of near 100% fatality	7.0 - 10.0 (483 – 689)
Threshold of lung hemorrhage	12.0 - 15.0 (827 – 1034)
50% fatality from lung hemorrhage	20.0 - 25.0 (1379 – 1724)
99% fatality from lung hemorrhage	30.0 – 35.0 (2068 – 2413)
People standing up will be thrown a distance	8.0 - 16.0 (552 – 1103)
People lying flat on the ground are picked up and hurled about	12.0 - 24.0 (827 – 1655)
Immediate blast fatalities	70 – 200 (4826 – 13,790)

** Values provided are approximate, do not consider impulse, and are not intended to represent a building strength rating for design or evaluation.*

Risk to building occupants

$$Risk = f[O * V * F]$$

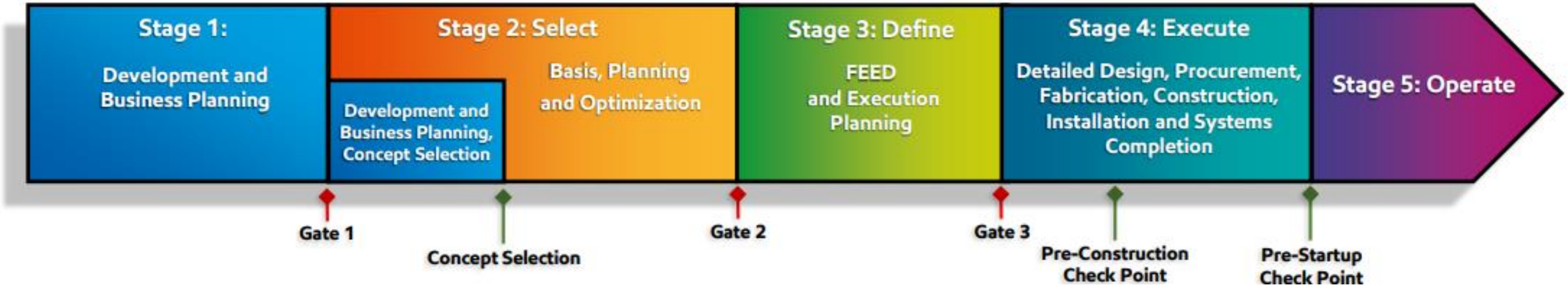
- Risk to building occupants is a function of:
  - **Occupancy:** Number of persons in a vulnerable structure
  - **Vulnerability:** % likelihood that an occupant in the structure will be seriously injured or fatally exposed based on the blast load, predicted building damage, and building construction details
  - **Frequency:** Per year likelihood of a vapor cloud explosion impacting the vulnerable building
- A project may increase risk to occupants even if predicted blast loads are equal to or below existing blast loads on a structure.

Parameter	Potential Impact
Occupancy	Project may result in additional persons (temporary or permanent) in vulnerable structures
Vulnerability	Project may increase the predicted damage on a building by increasing the predicted blast load from an existing PED or introducing new PEDs. If the overpressure or impulse is increased, the occupant vulnerability may increase
Frequency	Project may introduce a new potential blast scenario (e.g., VCE in the new unit) that increases the overall probability of building damage from a VCE.

Fenceline impacts

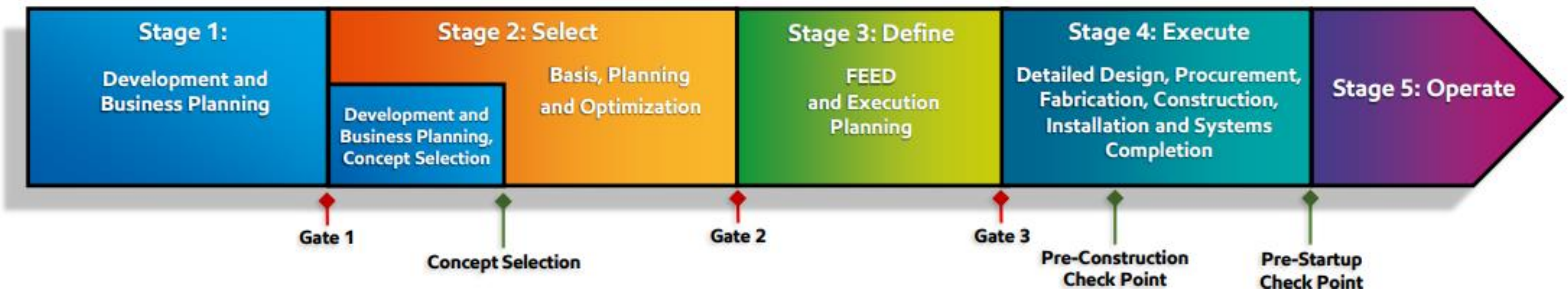
- Consideration should be given to
  - the potential impacts from 3rd parties on the project's temporary and permanent structures
  - The potential impacts on 3rd party facilities from VCE events associated with the project facilities
- Many locations do not have a regulated maximum allowable fenceline overpressure limit (e.g., no fence-line blast limit in US)…potential impacts at the fence line should be understood
- Some locations do have a regulated maximum allowable fenceline overpressure limit (e.g., Singapore via local quantitative risk assessment criteria) that must be met
- Impacts on most structures below 0.6 psig are expected to be less significant. Window breakage can be expected down to 0.2 psig.
- Risk assessment and management considerations may be required where overpressures in excess of 0.6 psig may impact structures beyond the fenceline.

Stage 1



- Stage 1 blast analysis is very conceptual, looking to identify any show-stoppers or significant onsite/offsite concerns
- Useful for identifying options for further development or elimination for consideration
- Conservative "max distances" from PEDs to overpressure contours are often employed
- Given early stages of the project, assumptions are made with best available project layouts

Stage 2



- Stage 2 blast analysis based on conceptual project layouts and conservative assumptions

- With increased detail from Stage 1, can further aid in concept selection
  - Review still likely based on large fixed equipment; limited plot details

- Key blast issues to consider:
  - New or modified PEDs impacts on existing occupied buildings or fence line impacts
  - Start to consider risks of portable building siting for the construction phase

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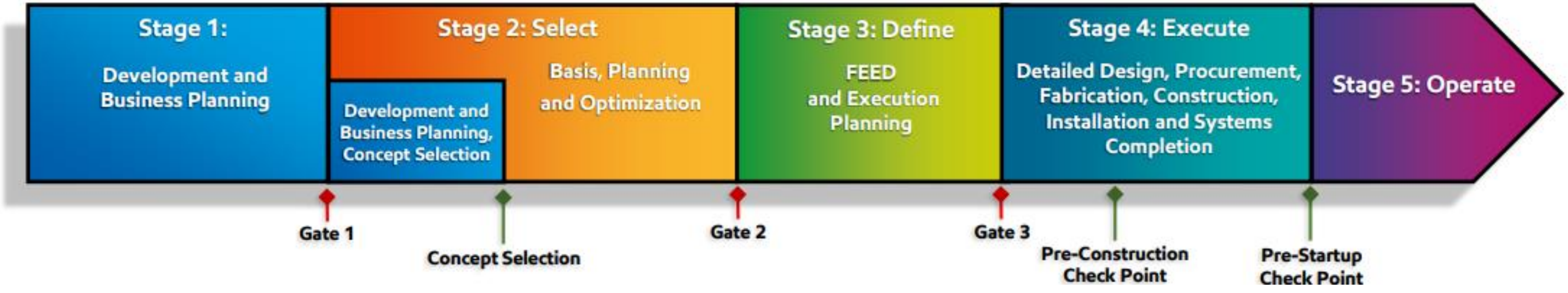
Stage 3

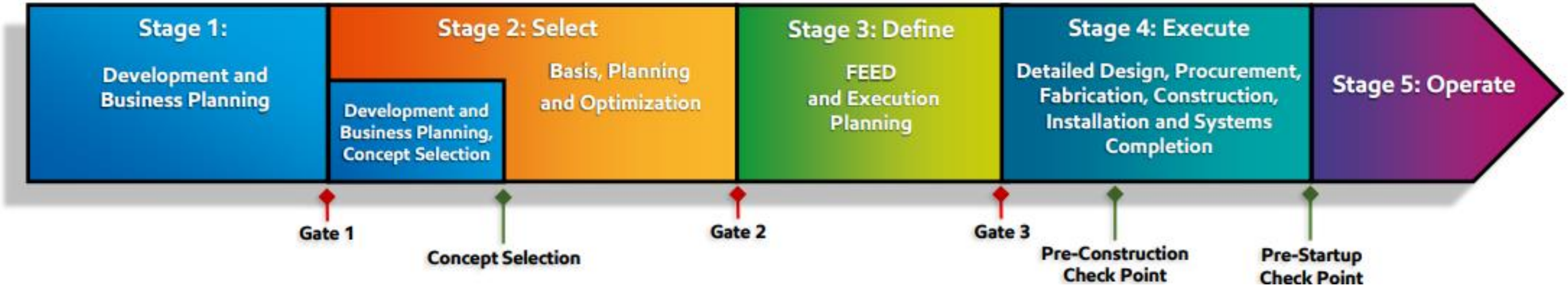


- Stage 3 blast analysis reduces assumptions due to availability of 3D models and more detailed P&IDs

- Focus on retention of separation corridors from prior stage reviews (layout)
  - Violation of separation corridors can increase overpressure contours and result in analysis of additional occupied buildings

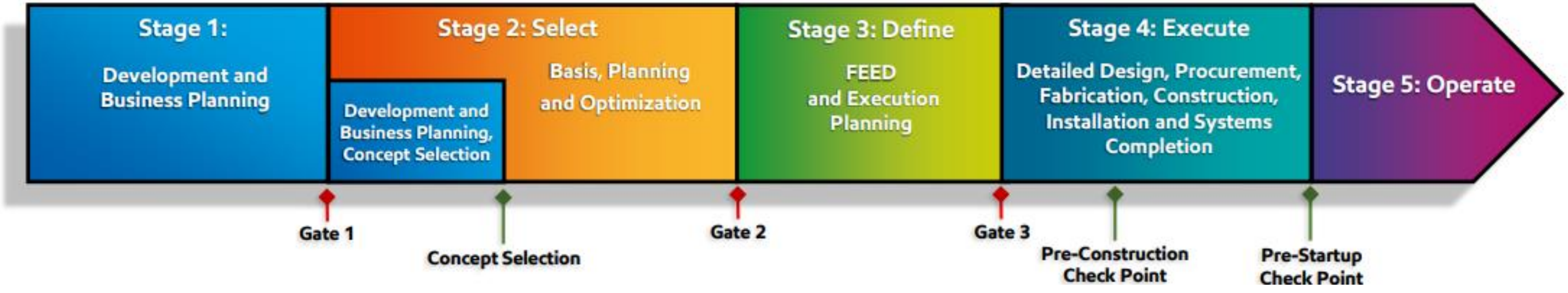
- Finalize temporary facility siting for construction phase
  - For builds in existing sites, consider overpressure changes as build occurs

Stage 4



- Detailed information at Stage 4 allows for verification/modification of prior assumptions on PED boundaries and congestion
- Verify that small bore piping and associated kit have not violated previously established separation corridors
- Discovery of overpressure concerns on occupied structures at this stage can yield costly building reinforcements or relocations

Stage 5



- Stage 5 blast work focuses on finalizing the overpressure contours based upon actual installation

- Confirm separation corridors are still valid, focusing on field routing of small bore piping and instrumentation/panels/etc.

Brownfield projects

Issue	Example
New PEDs	A project includes a new air-fin installation with associated pumps and controls. The area is identified as a new site PED
Changes to PED Size or Congestion	A project seeks a spacing deviation to add additional process equipment into a process structure. The additional equipment increases the congestion level, resulting in larger predicted blast loads
Loss of separation	A project adds a new filter skid in a separation corridor between two existing PEDs. The PEDs are now joined as a single larger PED with greater blast impacts on existing buildings
New chemicals	A process unit will be modified to include hydrogenation equipment. The addition of hydrogen to the unit introduces a more energetic vapor source that increases the potential blast effects. In another case, volatile flammable storage is added near a utilities area that previously had no nearby hydrocarbon sources. The combination of the new fuel and the existing utilities area congestion creates a new potential explosion domain
Temporary facilities	A trailer park for construction personnel is placed near a brownfield construction site. The arrangement of trailers creates sufficient congestion to trigger designation as a potential explosion domain
Changes to building occupancy	A project adds new consoles, operations staff, and mechanical support members to an existing control center. The greater occupancy in the building results in more significant potential consequences from a damaging vapor cloud explosion

Greenfield projects considerations

- As blast impacts have a large potential impact radius, it is possible that there could be blast impacts on existing structures located at a distance from the greenfield project site
- Since blast has typically not been a consideration in the vicinity of the greenfield site, attention must be paid to ensure that blast loads from operations adjacent to the site are considered
- With (potentially) fewer constraints than brownfield projects, greenfield sites may have more opportunity to reconfigure the plot layout to reduce or eliminate PEDs
- Placement of portable buildings and tents may need to consider start-up sequencing as their siting may be highly dependent on "activating" the new PEDs. In a brownfield project, the siting is often influenced from the beginning by existing site overpressure contours present from Day 1.

Conclusion

- Consideration of facility siting issues is a required part of managing site risk
- Toxic, fire, and vapor cloud explosion (blast) risks need to be considered
- Changes introduced by capital projects can increase potential facility siting risks
- Standard approaches guide the evaluation of these risks
- Awareness of the factors that influence blast risk can help limit the blast-related impacts associated with projects