SOLAR OR WIND FARM DEVELOPMENT OVER MINED-OUT AREAS

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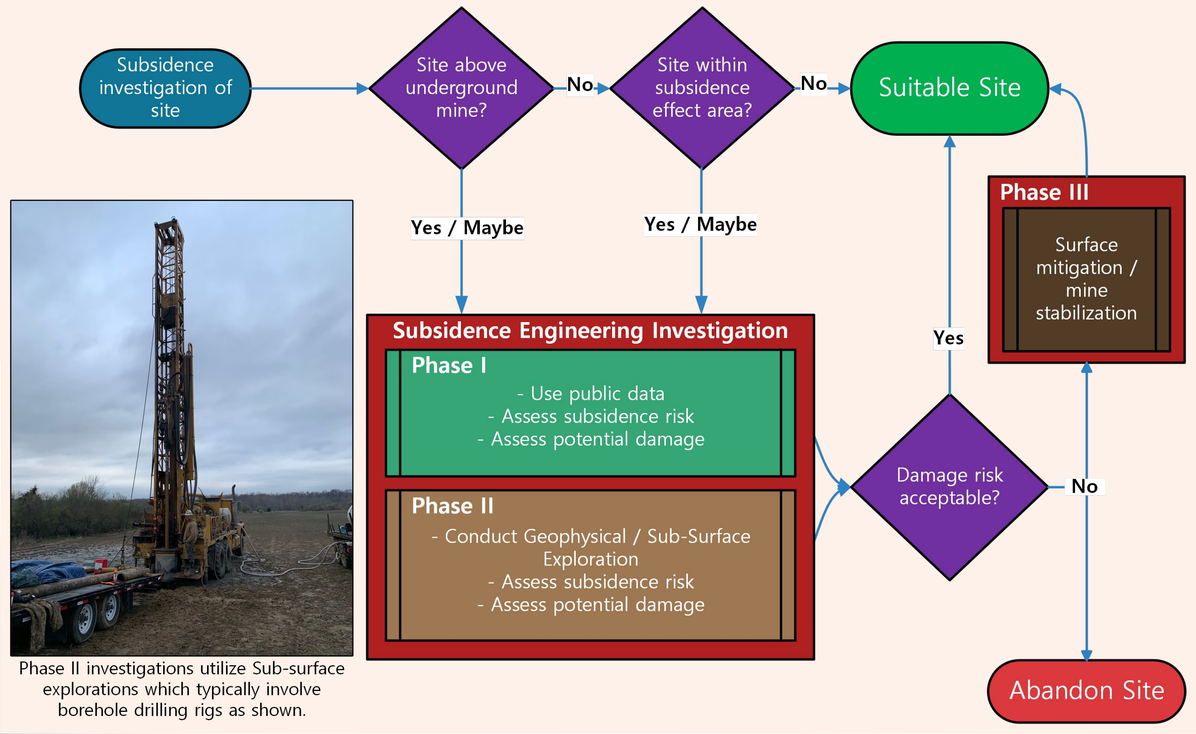
Subsidence Investigation

With the recent additional incentives for developing over Abandoned Mine Lands (AMLs), developers have started to look more towards using AMLs for their projects. While the incentives to revitalizing coal communities are high, decision makers for Solar or Wind farm projects should account for any potential subsidence or settlements (sinking mass movements) that are caused by geological instabilities in these aging and often decrepit mines. The following content addresses how AML developers can identify and mitigate the risks involved with building over AMLs.



Phase II investigations utilize Sub-surface explorations which typically involve borehole drilling rigs as shown.

1. Movement Tolerance Limits

There are many structural components to these farms such as foundations, turbines, substations, trackers, etc. Each component has specific tolerances for rotational, tilt, lateral, and vertical movement. The tolerances range from allowable to repairable limits, which all need to be identified. These tolerances are also dependent on the risk acceptability of the developer.

Solar module on concrete ballast foundation

SOLAR FARMS FOUNDATIONS AND TRACKERS

Uneven or Subsided Terrain

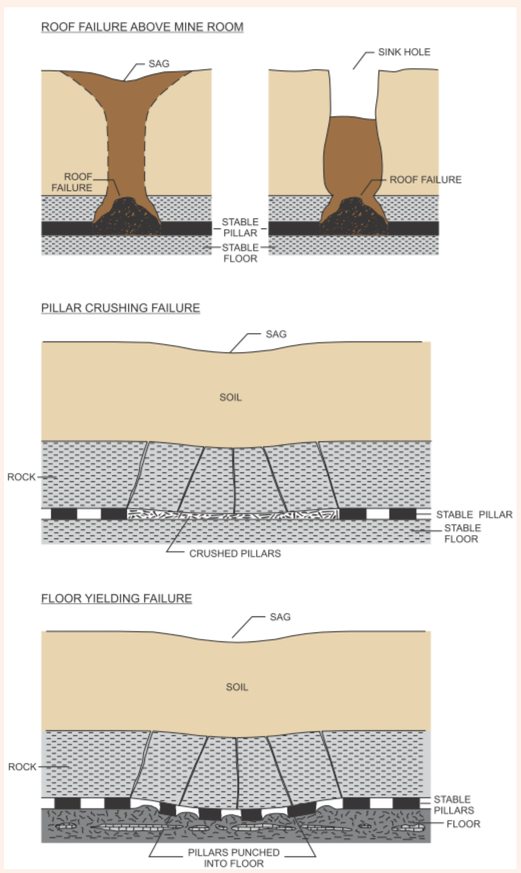
Solar panel tracker

WIND FARMS FOUNDATIONS

Toppled wind turbine

2. Assess Stability of Mines and Subsidence Risk

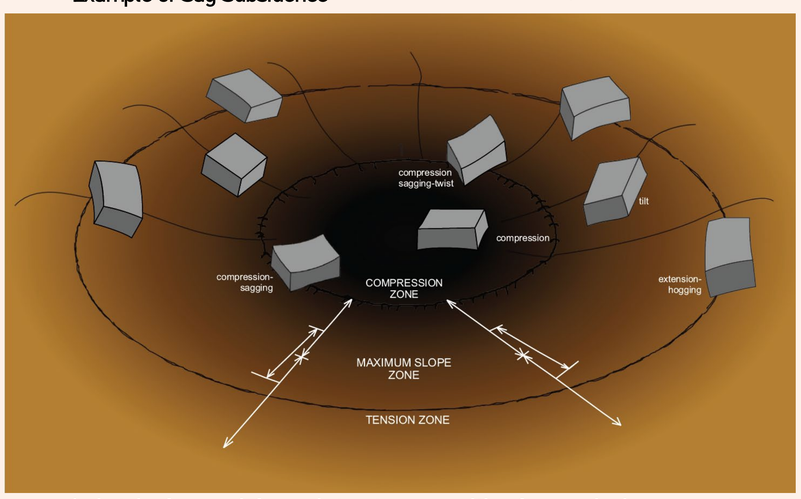
There are several different approaches to mining. The stability of the mines and resulting subsidence depends on several variables such as site geology and the mining method used. The failure of mines can be initiated from the roof, pillar, or floor of that mine. The sags vary in size up to 1000ft in diameter, whereas sinkholes / pits can grow up to 30ft in diameter.



<-- Mine Failure

Example of Sinkhole / Pit

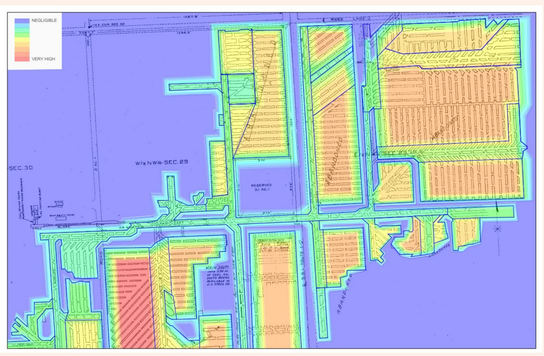
Example of Sag Subsidence



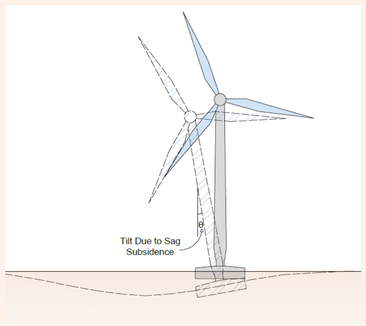
A sketch of some deformed structures resulting from a single sag event over an abandoned mine

3. Assess Damage Potential

Empirical data is used to predict the subsidence characteristic features such as maximum subsidence, maximum tilts, and maximum curvatures at the developer's acceptable confidence intervals. These values are then compared with the established risk tolerances to identify the possibility of damage and its severity to each structural component of the project.



Negligible to very high subsidence risk map



Tilting of turbine due to ground movement

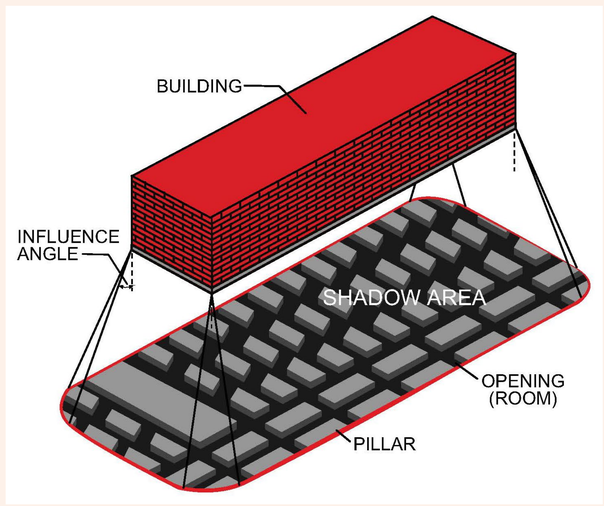
4. Subsidence Frequency Predictions

Per previous records of subsidence activity at the site, the mine depth, mode of failure, and mine conditions at the site, a statistical model is developed to predict the frequency and size of subsidence events for the life span of the project. This risk-based assessment tool will provide the expected contingencies that need to be in place for the life span of the project which may play a significant role in the financial decision-making process of a project.

5. Subsidence Mitigations

For critical, limited, and expensive areas of the farm that have very stringent subsidence tolerances, surface and underground subsidence mitigation alternatives can be implemented. The surface measures consist of providing further flexibility to that structure to subsidence induced movements. The underground measures may include, partial or full filling of the underground space with low strength grouts. In general, the subsidence damage mitigation can be any of the following:

- Ignore subsidence risk (not recommended)
- Abandon Project Site
- Move Farm Areas
- Implement Subsidence Resistant Measures at or Near the Ground Surface
- Employ Mine Stabilization Measures for Substations



Sketch of showing mine level area that needs to be stabilized to protect a building on the surface.

Image Sources

(unlabeled = internal figures)

(1) - https://www.solarreviews.com/

(2) - https://igws.indiana.edu/Hazards/Subsidence

(3) - https://pv-magazine-usa.com/

(4) - https://energy5.pl/en/the-first-solar-farm-on-energy5-trackers/

(5) - http://www.steelwindtower.com/wind-turbine-foundation-5-foundation-types-explained-for-onshore-wind-turbine/

(6) - https://www.windtech-international.com/editorial-features/optimisation-of-onshore-wind-turbine-foundations

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