Overview of Seismic Source Characterization for the Diablo Canyon Power Plant

Steve Thompson (LCI and SSC TI Team), for SWUS GMC Workshop 1, March 19, 2013
Questions from TI Team

• Summarize tectonic setting.
• What is the range of dip angles (min and max) and faulting styles?
• What is the seismogenic thickness?
• Are you including deep ruptures in the upper mantle (~30 km)?
• What is the largest magnitude in your sources (due to linked faults)?
• Do you have a complex multi-segment rupture with different rake/dip along strike?
• Do you have splay faults or overlapping segments?
DCPP Tectonic Setting for SSC

- Transpressional environment
- Pacific plate – Sierra Nevada microplate boundary

Source: W. Lettis, 2012, Diablo Canyon SSC Workshop 2 presentation
DCPP
Active
Fault Map

- ~80 km from San Andreas fault
- ~4 km from Hosgri fault zone
- Strike-slip, reverse, oblique, and thrust faulting

Sources: Map is internal PG&E work product (S. Thompson, LCI)
DCPP Tectonic Setting:
Faulting style, dips and tectonic history

- RL Strike-slip
  - (dips ~70-90°)
- Reverse and oblique
  - (dips ~45 to 70)
- Thrust
  - (dips ≥ 15°)

- Complex geologic and tectonic history:
  - subduction/accretion (Mesozoic-Eocene)
  - transtension and basin formation (Eocene-Miocene)
  - transpression and basin inversion (Miocene-Quaternary)
Implications of Complex Tectonic History

• Complex velocity structure (3-D; not 1-D story)
• Reactivation of pre-existing faults
• Opportunity for buried, blind faults not easily detectable (especially if in pre-Tertiary Franciscan)
• Possibly important lower boundary condition in the ancestral slab (more on this later)
single-event focal mechanisms


Source: J. Hardebeck, 2012 DCPP SSC Workshop 2 presentation
EXPLANATION

- Event location that is poorly constrained
- Event location that is within 20 km and generally within 10 km

MAGNITUDES

- 5.0 - 5.9
- 6.0 - 6.9
- 7.0 - 7.9

Source: M. McLaren, 2011 DCPP SSC Workshop 1 presentation
What is the seismogenic thickness?

- **Microseismicity:**
  - 10 to 15 km range

- **2003 M6.5 San Simeon**
  - Hypocenter = 10 km
  - Aftershocks ≤ 12 km

Sources: McLaren et al. (2008), McLaren and Savage (2001), Hardebeck (2010), Hardebeck (2013); DCPP SSC Workshop 1 presentations by McLaren and Hardebeck in 2011

Figure from Hardebeck (2011)

SSC Workshop 1
Are you including deep ruptures (~30 km)?

Not at present, but we want to learn more. Two reasons we are NOT including deep ruptures:

1. Impression is that deep (upper mantle) rupture doesn’t contribute to strong ground shaking (frequency content of interest) and don’t otherwise factor into SSC or GMC. Is this true?

2. The top of the former subducting slab is assumed to be a key boundary condition for DCPP that limits depth of rupture
Seismic refraction profiles interpret slab (oceanic crust) at 12 to 20 km depth

Questions:
• Do any faults penetrate the slab? Probably not.
• Is the slab a detachment? Perhaps; are there ground motion implications?

Source: W. Mooney, 2011 DCPP SSC Workshop 1 presentation
What is the largest magnitude in your sources (due to linked faults)?

- **M 8.5**, on the San Andreas and Hosgri-San Gregorio-northern San Andreas. This cap is there for at least three reasons:
  - It is big enough, at 0.3 magnitude units larger than the largest global continental strike-slip earthquake.
  - Magnitude-area relations (e.g., WC94, HB02) used to balance moment on faults should not be subject to extrapolation beyond this magnitude (probably not beyond **M ~8.0**).
  - UCERF3, which allows such high magnitude events, is getting results showing the rate of such events is very low for the Hosgri fault.
Diablo Canyon SSC
Sensitivity Logic Tree

Hosgri source length

- Hosgri only (110 km)
- Hosgri-San Simeon (200 km)
- Hosgri-San Gregorio (410 km)
- Hosgri-San Andreas N (760 km)

Source: S. Thompson, 2012 DCPP SSC Workshop 2 presentation
UCERF3 simulated rupture: Hosgri to Mendocino Fracture Zone (M8) (Annual rate 1E-10)

Source: UCERF3 and N. Abrahamson, 2012 DCPP SSC Workshop 2 presentation
Do you have a complex multi-segment rupture with different rake/dip along strike?

• Yes, two cases are under consideration at the moment
  – strike-slip Hosgri fault and reverse San Luis Bay fault
  – strike-slip Hosgri fault and reverse or oblique Los Osos fault
Do you have splay faults or overlapping segments?

- Not at the moment. Only linked cases where faults jump from one fault (or segment) to another.
- No cases where multiple, overlapping faults or segments rupture together...
Summarize tectonic setting.
- Haiku: *Dextral transpression / two to five mm per year / many fault sources*

What is the range of dip angles (min and max) and faulting styles?
- Minimum of ~15° being considered on a blind ramp source; most weight to 45° to 90°
- Strike slip, reverse, and oblique

What is the seismogenic thickness?
- About 12 km; considering range of 10 to 15 km

Are you including deep ruptures in the upper mantle (~30 km)?
- No, but this is an interface issue of interest
- Also no because the deep seismic refraction suggests an unbroken slab at depth
Questions from TI Team (p. 2 of 2)

• What is the largest magnitude in your sources (due to linked faults)?
  – $M_{8.5}$ currently considered Mmax at $+2\sigma$ based on $M$-$A$ relations and global historical strike-slip events

• Do you have a complex multi-segment rupture with different rake/dip along strike?
  – Yes; considering multi-fault rupture of
    • Reverse-slip San Luis Bay with strike-slip Hosgri
    • Reverse- or oblique-slip Los Osos with strike-slip Hosgri

• Do you have splay faults or overlapping segments?
  – No; considering the strike-slip Shoreline fault as able to link to the Hosgri, but are not considering cases of simultaneous rupture
References for DCPP SSC

• SSC Workshop 1 materials available online: http://www.pge.com/mybusiness/edusafety/systemworks/dcpp/SSHAC/workshops/ws1.shtml

• SSC Workshop 2 materials available online: http://www.pge.com/mybusiness/edusafety/systemworks/dcpp/SSHAC/workshops/ws2.shtml

Thank you