Infrastructure and Physical Damages Estimated for ARkStorm

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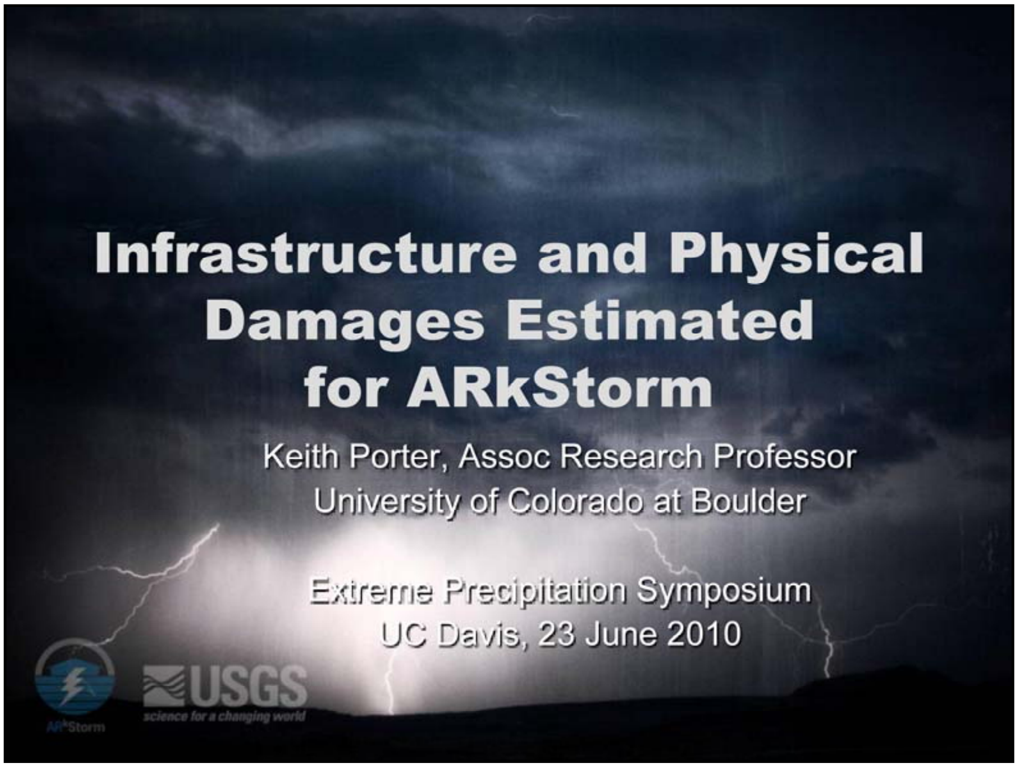
BIOGRAPHICAL SKETCH

Keith Porter is an Associate Research Professor in Structural Engineering and Structural Mechanics at the University of Colorado at Boulder. He received degrees in civil and structural engineering from UC Davis (BS 1987), UC Berkeley (MEng 1990), and Stanford University (PhD 2000). He is a licensed Professional Engineer and researcher specializing in seismic vulnerability, catastrophe risk modeling, and performance-based earthquake engineering. He helped to develop the current state-of-the-art performance-based earthquake engineering method that estimates seismic risk to buildings in terms dollars, deaths, and downtime. He is currently leading the damage-estimation aspects of the ARkStorm winter-storm scenario for the USGS. Some interesting projects include: the Global Earthquake Model, the Southern California ShakeOut earthquake emergency planning scenario, the San Francisco Community Action Plan for Seismic Safety, a study of demand surge for the Willis Research Network, and a study for the US Congress that found a 4:1 benefit-cost ratio for multihazard risk mitigation.

ABSTRACT

An event like the ARkStorm scenario would impose severe flooding and hurricane-force winds on large areas of California, potentially damaging buildings, contents, and infrastructure such as roads, bridges, electric power system, etc. We estimated physical damages in the ARkStorm scenario by three approaches. To produce a realistic outcome at the aggregate societal level, we employed the data and methods of FEMA's flagship emergency-planning software HAZUS-MH, although the calculations had to be done outside of HAZUS-MH. To examine the effects of the ARkStorm on lifelines such as the highway network, electric power, etc., a series of 12 panel discussions were held with engineers, operators, and emergency planners from the various lifelines at risk. The panel participants were presented with the meteorological and flooding inputs, and they offered their judgments about the resulting damage and restoration efforts that they would undertake if ARkStorm were to occur. In three cases, special studies were performed by individual experts. These were of demand surge (sudden temporary increases in costs resulting from the need to repair widespread damage), telecommunications, and insurance impacts.

Between the three approaches, it is deemed realistic that an event like the ARkStorm would result in property damage costing $310 to $330 billion to repair, of which approximately $200 billion is from building damage from flooding, $100 billion from content damage from flooding, $5 billion from wind damage to buildings, and the balance from infrastructure damage. Demand surge could potentially increase this amount by 20%. Some highways in steep terrain could be heavily damaged by multiple landslides, in some cases taking months or more to repair. Electric power would be unavailable for up to 2 weeks in most places, but in some places with very high winds such as the southern Sierras, commercial electric power could take months to restore. Sewer systems in heavily flooded areas are subject to damage, with some counties having half their wastewater treatment plans flooded, damaging the electrical equipment, and requiring a month or more to restore. Water service is severely impacted in some places, especially where well pumps are flooded and contaminated with untreated wastewater, in some places taking several months to restore. Lifeline service providers are being given a second opportunity to review and offer revisions to these findings.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Keith Porter, Assoc Research Professor
University of Colorado at Boulder
Extreme Precipitation Symposium
UC Davis, 23 June 2010
ARkStorm
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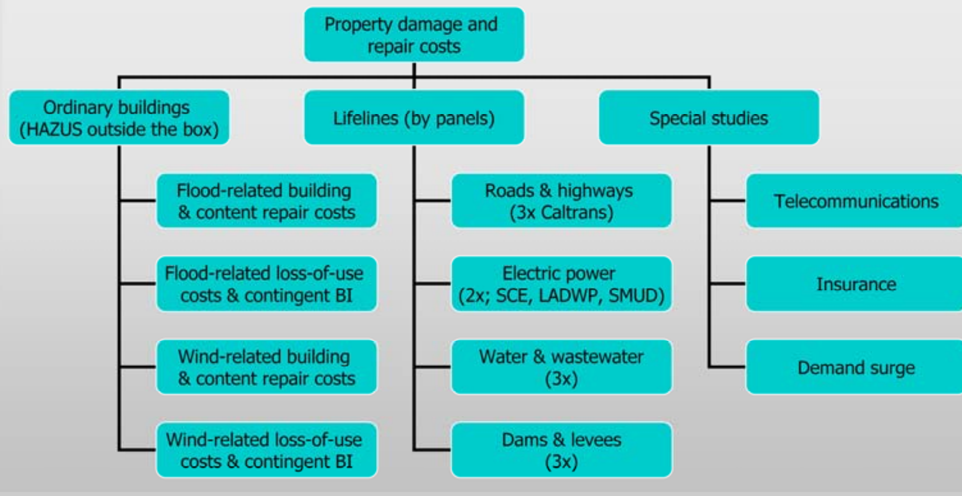
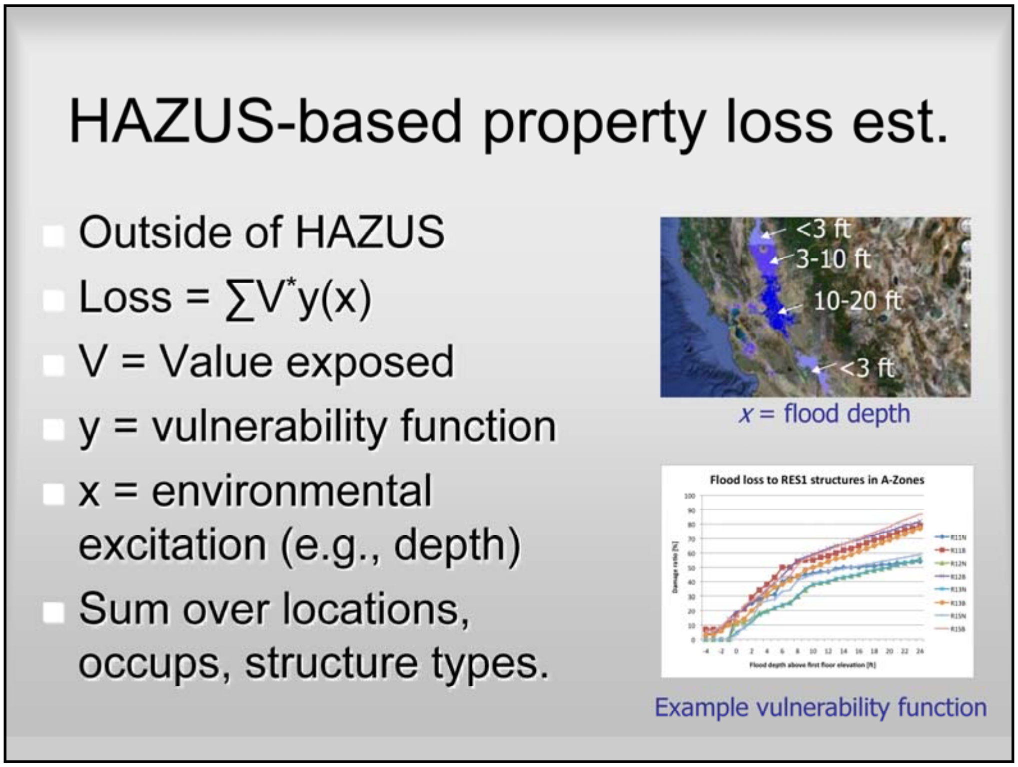
Physical damage in ARkStorm





The summation is performed at the census block level

The value exposed is taken from HAZUS's default database

The flood depth was expressed as a range; we did some sensitivity tests & used a lower bound of these ranges, e.g., <3 ft → 1 ft; 3-10 ft → 3 ft; 10-20 ft → 10 ft

Light damage = repairs cost 1-10% of building replacement cost; extensive = 10-50%; complete = >50%

HAZUS flood vulnerability

Table 5.3 Default Damage Functions for Estimation of Structure Damage

HAZUS Occ. Class	Flooding Type/Zone	Curve Source	Curve Description
RES1	Riverine/ A- Zone	FIA "credibility-weighted" depth-damage curves (CWDD)	1 floor, no basement 2 floor no basement 2 floor, split level, no basement
	Riverine/ A- Zone	Modified FIA CWDD:	EQE-modified versions of FIA CWDD: 2 floor, w/ basement 2 floor, split level, w/ basement
	Coastal/ V- Zone	FIA V-Zone Damage function	Combined curve (average of with and without obstruction)
	Coastal/ A- Zone	FIA V-Zone Damage function	Combined curve (average of with and without obstruction)
RES2	All Zones	FIA CWDD	Mobile home
RES3	All Zones	USACE – Galveston*	Apartment

Notes:

* All depth-damage curves developed by the USACE Galveston District are assumed to represent structures with no basement.

Table 5.3 Default Damage Functions for Estimation of Structure Damage (Continued)

HAZUS Occ. Class	Flooding Type/Zone	Curve Source	Curve Description
RES4	All Zones	USACE – Galveston	Average of "Hotel" and "Motel Unit"
RES5	All Zones		No RES5 curves available – use RES6
RES6	All Zones	USACE – Galveston	Nursing Home
COM1	All Zones	USACE – Galveston	Average of 47 retail classes
COM2	All Zones	USACE – Galveston	Average of 22 wholesale/warehouse classes
COM3	All Zones	USACE – Galveston	Average of 16 personal and repair services classes
COM4	All Zones	USACE – Galveston	Average of "Business" and "Office"
COM5	All Zones	USACE – Galveston	Bank
COM6	All Zones	USACE – Galveston	Hospital
COM7	All Zones	USACE – Galveston	Average of 4 medical office/clinic classes
COM8	All Zones	USACE – Galveston	Average of 15 entertainment & recreation classes

- Damageability maps to occupancy class
- Federal Insurance Administration (now FIMA) created residential depth-damage curves ("theoretical base tables")
- More recent data from 485,000 NFIP claims
- Curves modified to account for exclusions, depreciation
- USACE's 200+ curves.

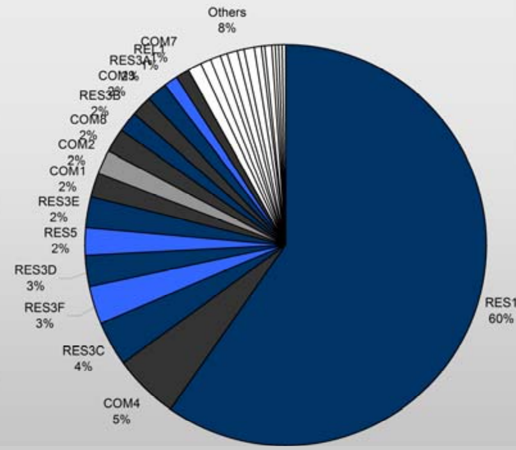
Theoretical base tables 1970-1973

Recent data compiled 1978-1998

Preliminary

HAZUS-based property loss est.

- Population, housing, and economic censuses → people by occupancy type by census block
- People x sf/person = sf by occupancy by block
- sf / (buildings/sf) = buildings by occ by block
- sf x \$/sf = \$ by occupancy by block.



Distribution of \$2.7 Tr in building replacement cost statewide

Preliminary

HAZUS-based property loss est

Flood damage

Building repair costs: $200 bn
Content losses: $100 bn
Lifeline repair costs unknown; $10 bn?
Ditto agricultural losses; $10 bn?
Ditto levee breaches; $5 bn repair, dewater?

Wind damage

Building repair costs: ~$6 bn

Total property loss = $330 billion (plus demand surge)

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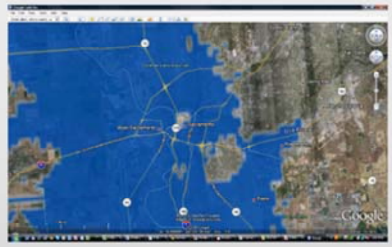
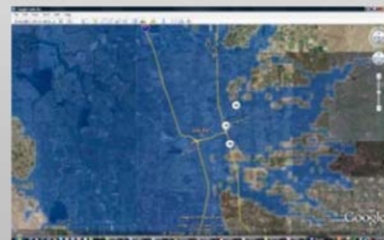
Why so much flood damage?

Silicon Valley; SF Bayshore



Sacramento

Orange & Los Angeles Counties



Stockton

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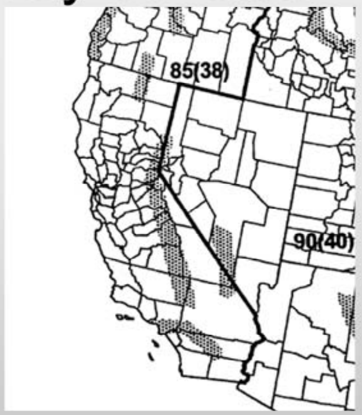
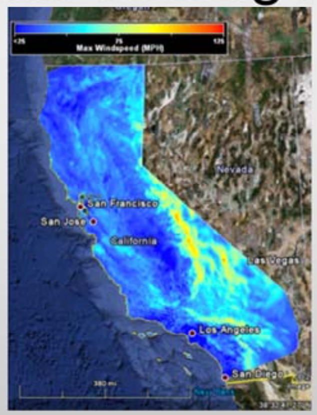
Why so “little” wind damage?



ASCE 7-05 basic windspeed map



ARkStorm windspeed map

High winds are primarily in less-populated areas of California
Still, $6bn in wind losses is a disaster in insurance terms

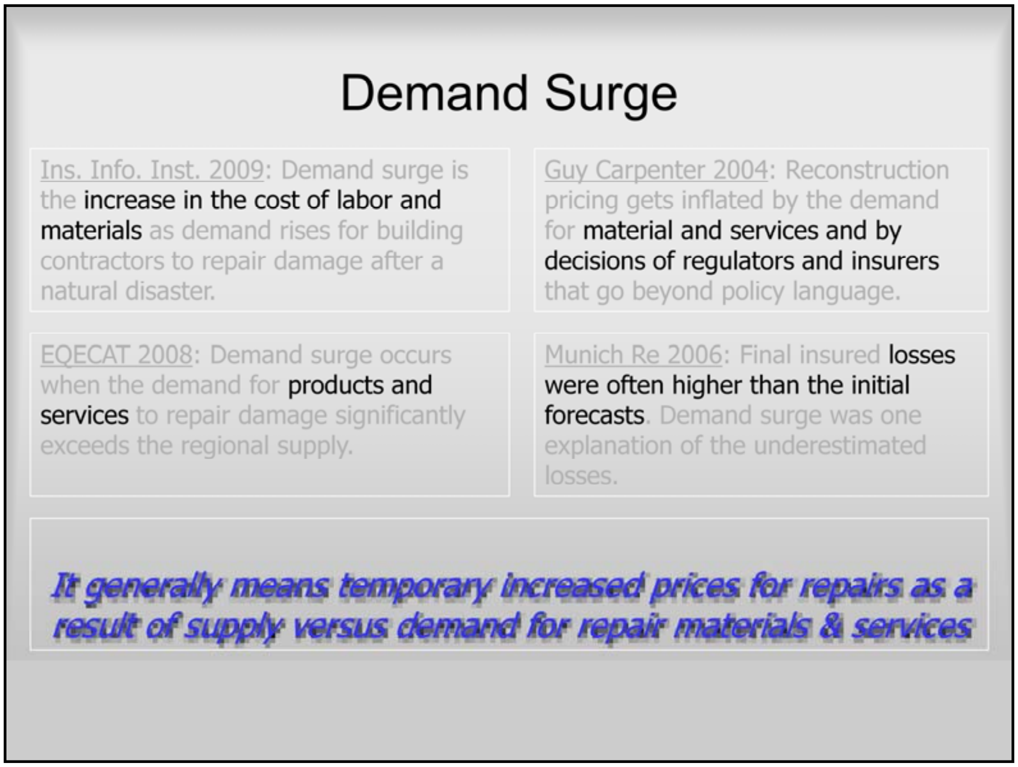
Preliminary

Is $330 bn+ realistic?

- Katrina: $81 - $105 bn property damage (Blake et al. 2007, St Onge and Epstein 2006)
- If $81 bn uses 75% ACV, repairs cost ~ $108 bn
- Say ½ to ¾ ($54 to $81 bn) in New Orleans
- ~1 million New Orleanians flooded
- → $54,000 to $81,000/person, say $60k/person
- ARkStorm floods 6.5 million Californians
- $60k x 6.5 million = $390 bn

$330 billion roughly agrees with Katrina experience

Also roughly agrees with one scenario of the Delta Risk Management Study where they overlap spatially



We performed a literature review of industry and academic publications. Part of the review was understanding definitions and usages of the term “demand surge.”

We found several types of definitions for demand surge:

1.(e.g. III 2009) limited to increased costs of materials and labor—no single “labor cost” or “materials cost”—which costs, where, when?

2.(e.g. EQECAT 2008) increased costs of materials, labor, and services—but what services?—and what region? Dist from epicenter/landfall/etc

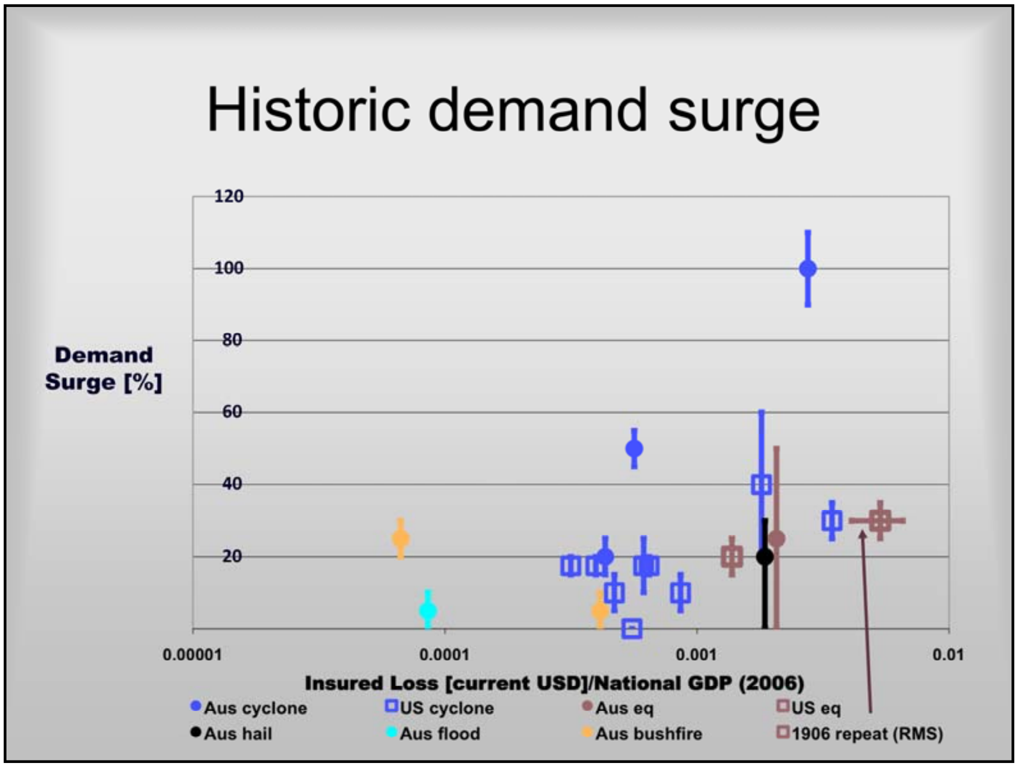
3.(e.g. Guy Carp 2004) expand definition to include other issues—regulator and insurer decisions just one example—what decisions?

4.(e.g. Munich Re 2006) comparison of final to initial/estimated losses—note the necessity of a cat model

5.(e.g. AIR 2007 & RMS 2008) very general definitions—how useful in practice?—increase relative to what?—is loss amplification a subs new term?

Emphasize these are *examples*; other people/institutions have used similar language.

Hope to have a handout containing a timeline of more quotes and analysis of “demand surge” definitions and usages.



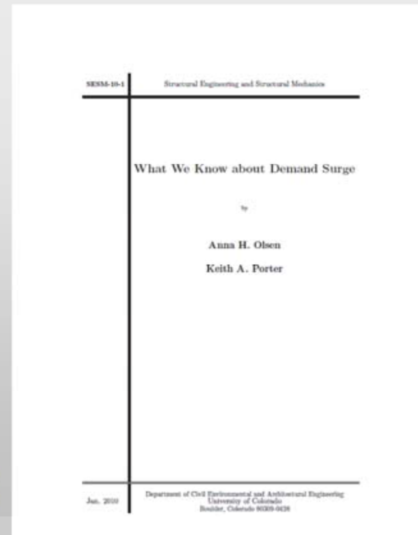
USGDP = $15 tr. $400-800 bn = 0.02.

Preliminary

Demand surge

- DS = *f*(demand:supply)
- $300 bn is large compared with repair resources; 5-10 years of construction, >2% of GDP
- Flood-insurance market penetration is low
- Much of the loss might not be repaired for a long time
- ARkStorm: 20% DS realistic

DS adds $60 to 70 bn to loss



SESM-10-1 | Structural Engineering and Structural Mechanics

What We Know about Demand Surge

by

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Keith A. Porter

Jan. 2010

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Benefit of flood warning

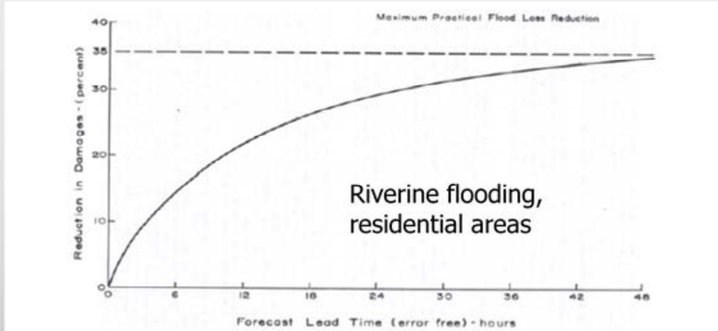

Figure 5.9 Day Curve for Residential Areas (Source: USACE, New York District, 1984)

- Harold Day late 1960s: 35% loss reduction (100% response rate, 48 hr)
- USACE New York Dist modified for location, dissemination, response…

Warning conceivably reduces ARkStorm flood loss by $100bn+


Lifeline panels
ARkStorm
USGS
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Lifeline panels

- 11 panels of 82 operators, engineers, & emergency managers from 47 agencies (Jan-Feb 2010)
  - Roads & highways
  - Electric power
  - Dams & levees
  - Water & wastewater
- Flood damage to agriculture

NorCal highways

Route	Extent	25%	75%	90%	Issues
I80	Sac to Reno	2 weeks	3 mos	6 mos	L/s (deep-seated & debris flow), embankment washout at plugged culverts
US50	Sac to Tahoe	2 mos	3 mos	3 mos	L/s (more deep-seated & debris flow), downed trees, embankment washout at
I5	Redding to OR	1 week	1 mo	1 mo	Washouts, flooding
US 101	Hopland, Ukiah	1 day	3-7 dd	3-7 dd	Localized flooding, possibly washout
US 101	Ukiah to Crescent C	2 weeks	2 mos	3 mos	Large l/s, debris flow, knocks bridges off piers both directions at 1-2 locations
US 101	Ventura Cou to San Jose	3 weeks	2 mos	3 mos	Rockfall, downed trees, localized flooding, debris flows, washouts
CA299	Redding to Eureka	2 weeks	2 mos	4 mos	L/s, trees, etc.
CA99	Sacto to Grapevine	1-3 dd from fl	1 week	1-2 weeks	Localized flooding like I5 N
CA58	Bakersfield to Barstow	3-5 dd	2 weeks	3 weeks	Debris, rockfalls
CA395	Palmdale to Reno	3 mos	4 mos	4 mos	Walker R Cyn: roadway washout from erosion & scour
CA1	Santa Cruz to Pacifica	6 mos	6 mos	6 mos	Deep-seat landslide; some rockfalls
I280	San Jose to San Francisco	12 hr	1 day	1 day	flooding through Sunnyvale, 2 small deep-seated landsliding between Crystal
US101	Gilroy to San Jose	12 hr	3 mos	3 mos	flooding; scour to SB lanes of bridge nr Morgan Hill damages bridge causing i
US101	San Jose to San Francisco	12 hr	12 hr	12 hr	flooding along most of its length from SJC to SFO
US101	Golden Gate in Marin	12 hr	1-3 dd	1-3 dd	flooding near Sausalito, Larkspur, and San Rafael; deep-seated landsliding or
US101	Sonoma Cou	12 hr	12 hr	12 hr	Debris flow near Cotati on NB lanes; various locations where alluvial fan flood
I880	San Jose to Oakland	12 hr	12 hr	12 hr	flooding near Milpitas and Oakland Coliseum
I680, I780	San Jose to Vallejo	12 hr	12 hr	12 hr	flooding near Dublin, debris flow landslides between Fremont and Sunol, debr
I80	San Francisco to Vacaville	12 hr	12 hr	12 hr	flooding near toll plaza, Berkeley and Fairfield, debris flow landsliding near He
CA37	Novato to Vallejo	12 hr	12 hr	12 hr	flooding along entire route, landsliding near Novato
CA121	Sonoma to Napa	1 dd to 50%		3 dd	100s of small slides, trees on roadway
CA17	San Jose to Santa Cruz	7-14 dd to 50%		2 weeks	~2-3 deep-seated landslides, 100s of small slides, trees on roadway
CA152	Gilroy to I5	12 hr	12 hr	12 hr	dozens of debris flows, dozens of rockfalls esp at cuts

I-80 Sac to Reno: landslides and embankment washouts interrupt thru traffic for 2 weeks. 3 months required to reach 75% capacity; 6 month to restore

I-80 SF to Vacaville: flooding near toll plaza, Berkeley & Fairfield; debris flow near Hercules interrupt traffic for 12 hr

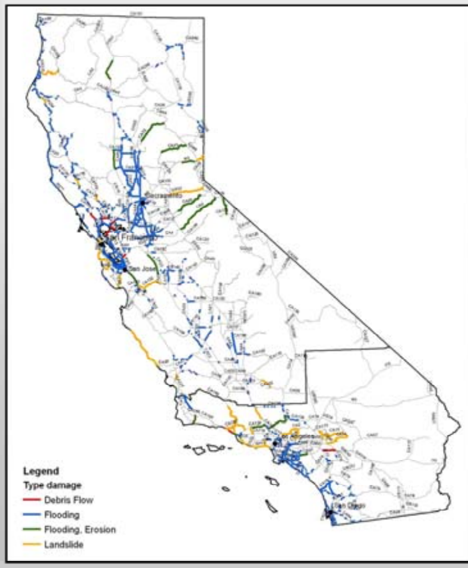
Highways

1/10/2005 Hwy 1 Ventura County

1/10/2005 Hwy 39 San Gabriel Mts

Preliminary

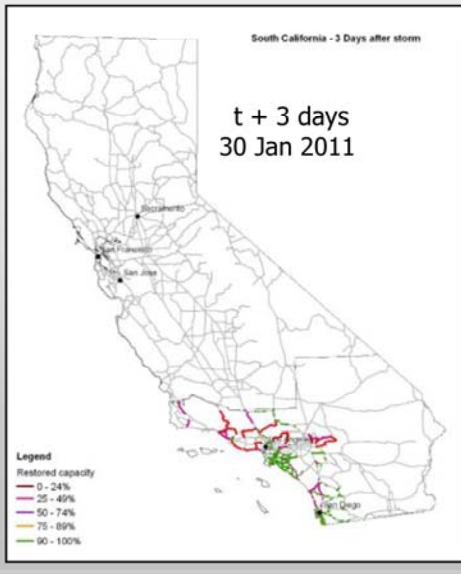
Highways



- Flooding (blue) and landslides (yellow) disrupt traffic statewide
- Some bridge scour & collapses occur; can takes weeks or months to repair
- Culverts can be blocked, scour roadway
- Roads mostly passable once flooding recedes
- Landslides & debris flows can take weeks or months to clear

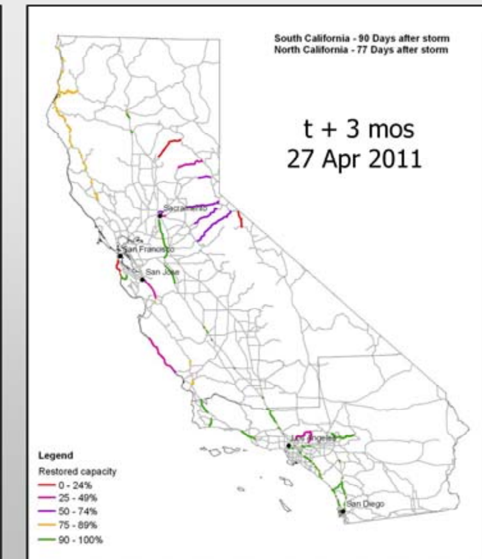
Preliminary

Highways



Preliminary

Highways



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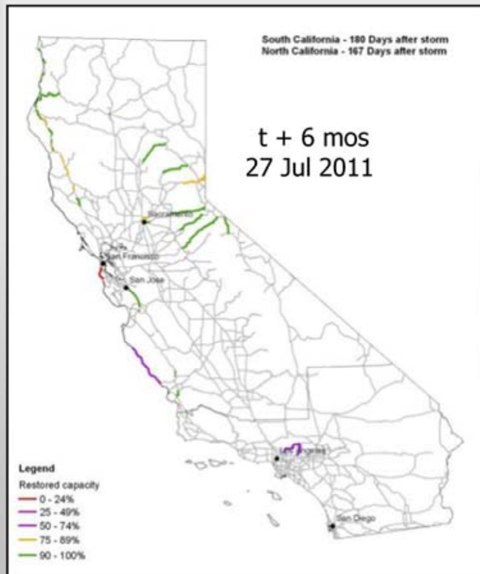
Highways



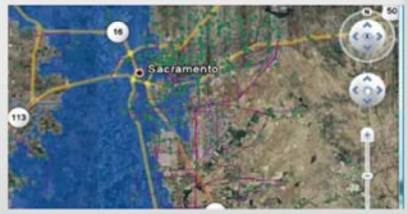
Preliminary

Highways

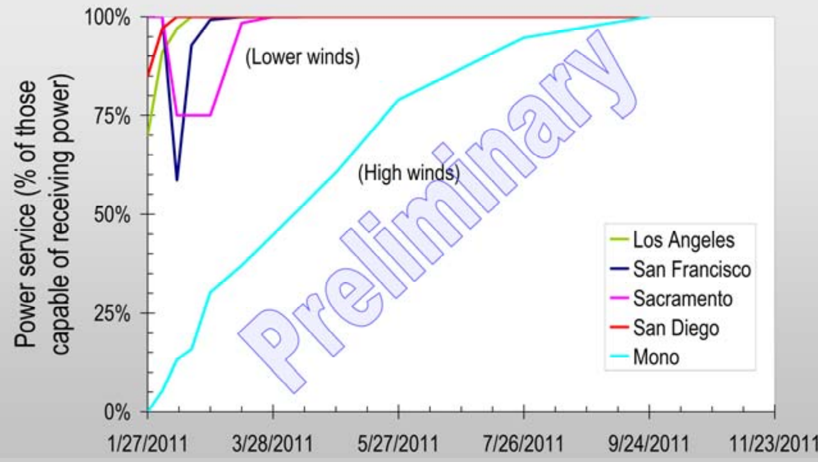
- LA & Orange Counties cut off to north & west for 1-2 weeks
- Sacramento cut off to north, west, & south ~1 week
- Some routes impaired for 6-12 mos

Electric power

- Debris, crossbars, poletop transformers (low winds)
- Transmission towers (high wind)
- Substation flooding



Electric power



Preliminary

Levees

- DWR tries to keep levees in place long enough to evacuate
  - (Similar to building code objectives for earthquake)
- Urban levees ~60-75 critical sites, 15-20 realistically breach
- Delta levees: 30 breaches realistic, 2-3 breaches per island
- Total 50 breaches is realistic
- Jones Tract: $100M to repair, dewater, protect interior levees, elevate interior levees, bring in riprap; $8M to repair breach); 3 weeks to repair levee & 10 weeks to dewater

Preliminary

Levees

- Material & labor limitations to repairing 50 breaches
- Dewatering raises hazmat issues
- Interruption of flow to SoCal for 3 months
- 6-9 mos storage for SoCal south of the Delta
- Levee failure would not leave SoCal without water
  - Alternate supplies
  - Reduced seasonal demand
  - Conservation

What if it takes more that 3 months to repair water transport to SoCal?

- Repairs could take longer or could require more materials & equipment than are available
- At what point in repair duration does saltwater intrusion become a problem?
- What happens to hydrodynamics of Bay Delta if islands are not dewatered or during the year(s) of repairs?
- How do other environmental issues (e.g., species protection) affect repair decisions?

ARkStorm doesn't answer these questions but it's important to ask them

Preliminary

Enhancing levee resiliency

- Enough resources to repair 1/2 of breaches by water, the other 1/2 from land side.
- Improve forecast & evacuation & sheltering policies.
- Remediation cost: $25B to bring all 1500 project-levee miles to accredited status, not counting 3500 miles of other levees
- Addition of hardened Peripheral Canal would eliminate problem of supplying water to SoCal in case of damage to Delta and urban levees
- Peripheral Canal is only part of the problem; south bay aqueduct and north bay aqueduct also a problem

Lifeline Interaction

- Pipes & fiber run on bridges
- Need roads to deliver chlorine
- Need power to pump groundwater
- Need telecom to coordinate repairs
- ….

Lifeline panel review

IN-PROGRESS DRAFT DO NOT DISSEMINATE

AN OVERVIEW OF THE ARKSTORM SCENARIO

Prepared for the USGS Multihazards Demonstration Project
Lucile Jones, Chief Scientist
Dale Cox, Project Manager

By

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Julie Serakos
Willis Re

Marcia Eymann
Center for Sacramento History

18 June 2010

Panelists reading overview doc:

- Damage degree & modes?
- Restoration curves ok?
- Lifeline interaction captured?
- Resiliency opportunities?
- Research needs?
- 15 July 2010 revision

Preliminary conclusions

- $400 billion property loss if the ARkStorm occurred
  - Compare with flood control enhancement @ $10s of bns
- Warning could conceivably reduce losses by $100 bn
- It could take months to repair the lifeline damage
- Maybe not enough resources to repair buildings – a true catastrophe

Property damage 3-4x greater than ShakeOut
A wind disaster & a flood catastrophe
Affects most of the population
Worse than living memory but ***not a worst case***
Discussing risk can inform mitigation decisions.


Thanks
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