Estimating Economic Impacts of Multi-Hazards in USGS HayWired Scenario Using REMI
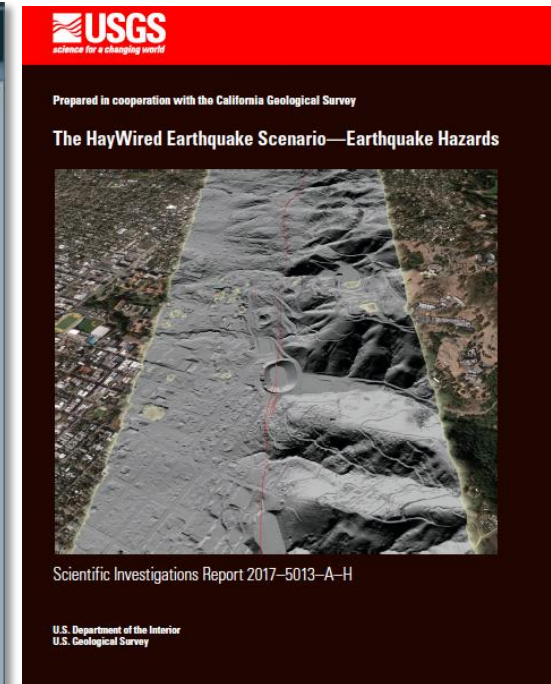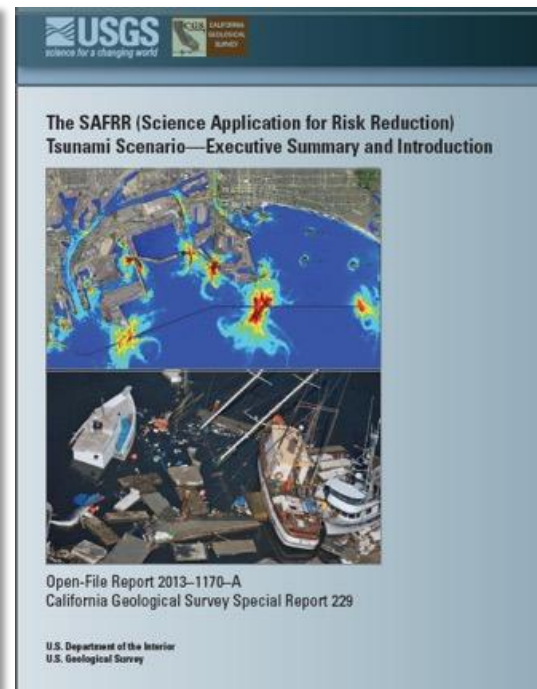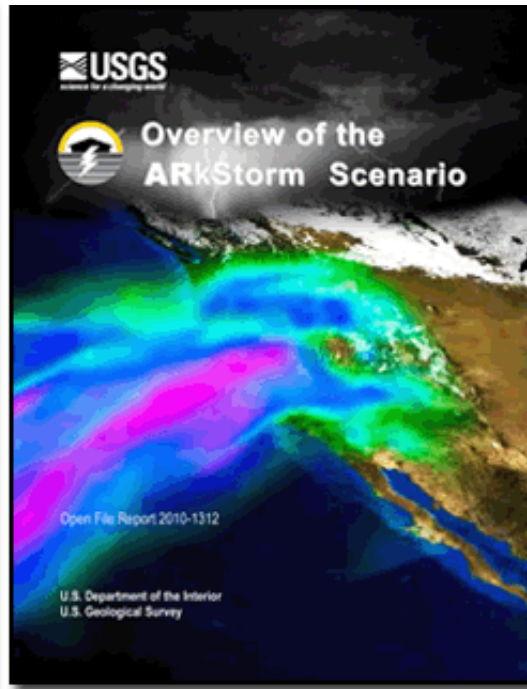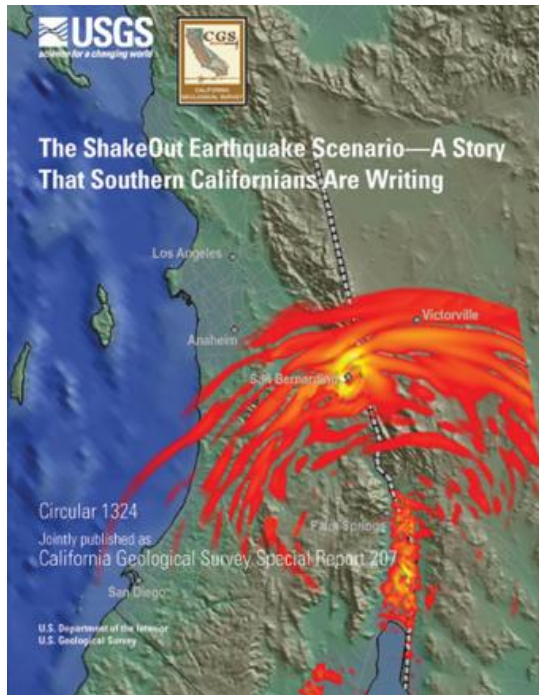## *PRELIMINARY RESULTS*

Presented by: Cynthia Kroll, Bobby Lu, ABAG and MTC

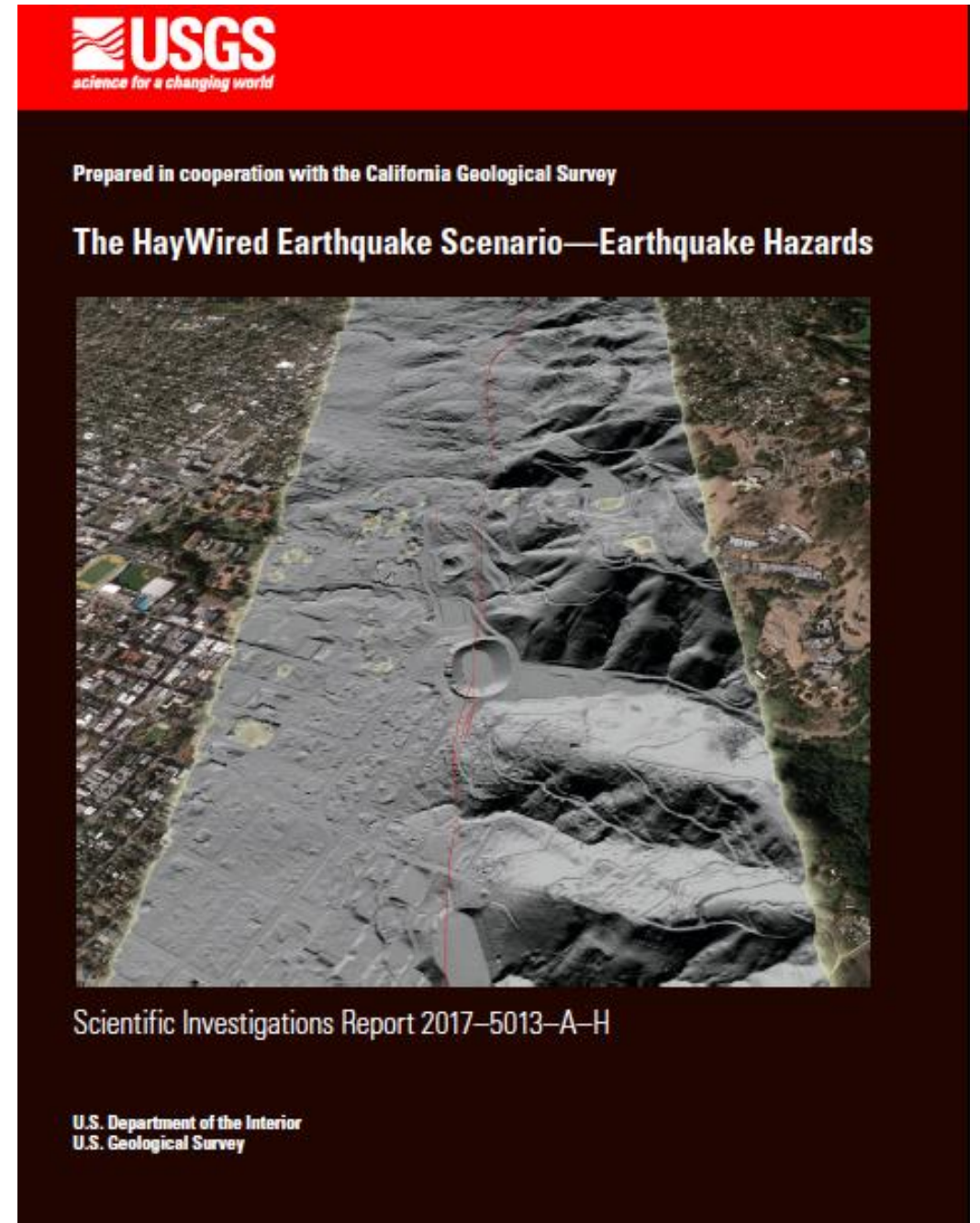REMI User's Conference, Charleston, South Carolina

10.25.2017

A SAFRR Project (USGS): HayWired

- SAFRR Project: Science Application for Risk Reduction

The HayWired Scenario

- **Hayward** fault rupture, Mag 7, 2018
  - Most urbanized fault in the US
  - Epicenter, Oakland

- Connectedness theme
  - Earthquake sequence
  - *Wired* & wireless world
  - Lifelines interdependencies
  - Fire following earthquake
  - Communities at risk
  - Digital economy

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Prepared in cooperation with the California Geological Survey

The HayWired Earthquake Scenario—Earthquake Hazards

Scientific Investigations Report 2017–5013–A–H

U.S. Department of the Interior
U.S. Geological Survey

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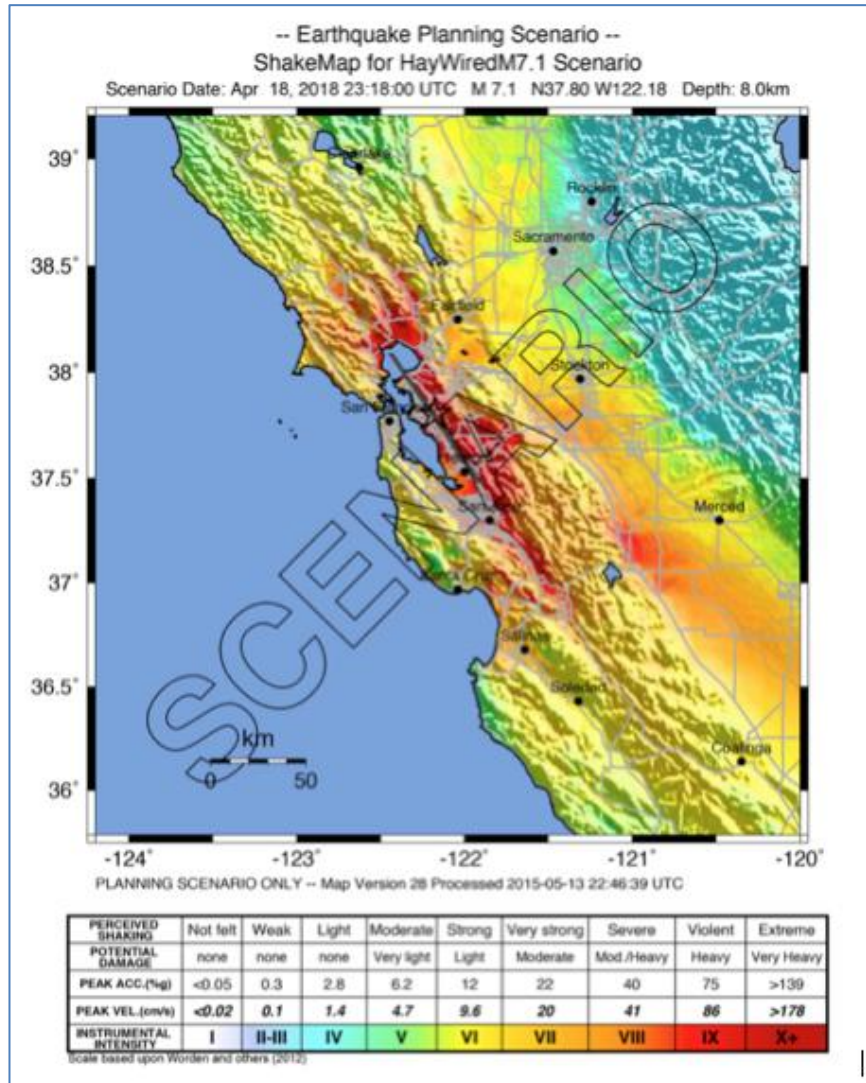*science for a changing world*

Economics Portion of HayWired

- Disaggregation of HAZUS industry impacts (Marin Economics)
- CGE Model (USC, Adam Rose)
- Commuter Analysis (Strategic Economics)
- REMI analysis

Anne Wein, USGS, Project Manager

HayWired: Estimates of Ground Shaking

-- Earthquake Planning Scenario --
ShakeMap for HayWiredM7.1 Scenario
Scenario Date: Apr 18, 2018 23:18:00 UTC M 7.1 N37.80 W122.18 Depth: 8.0km

PLANNING SCENARIO ONLY -- Map Version 28 Processed 2015-05-13 22:46:39 UTC

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy
PEAK ACC.(%g)	<0.05	0.3	2.8	6.2	12	22	40	75	>139
PEAK VEL.(cm/s)	<0.02	0.1	1.4	4.7	9.6	20	41	86	>178
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Worden and others (2012)

I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

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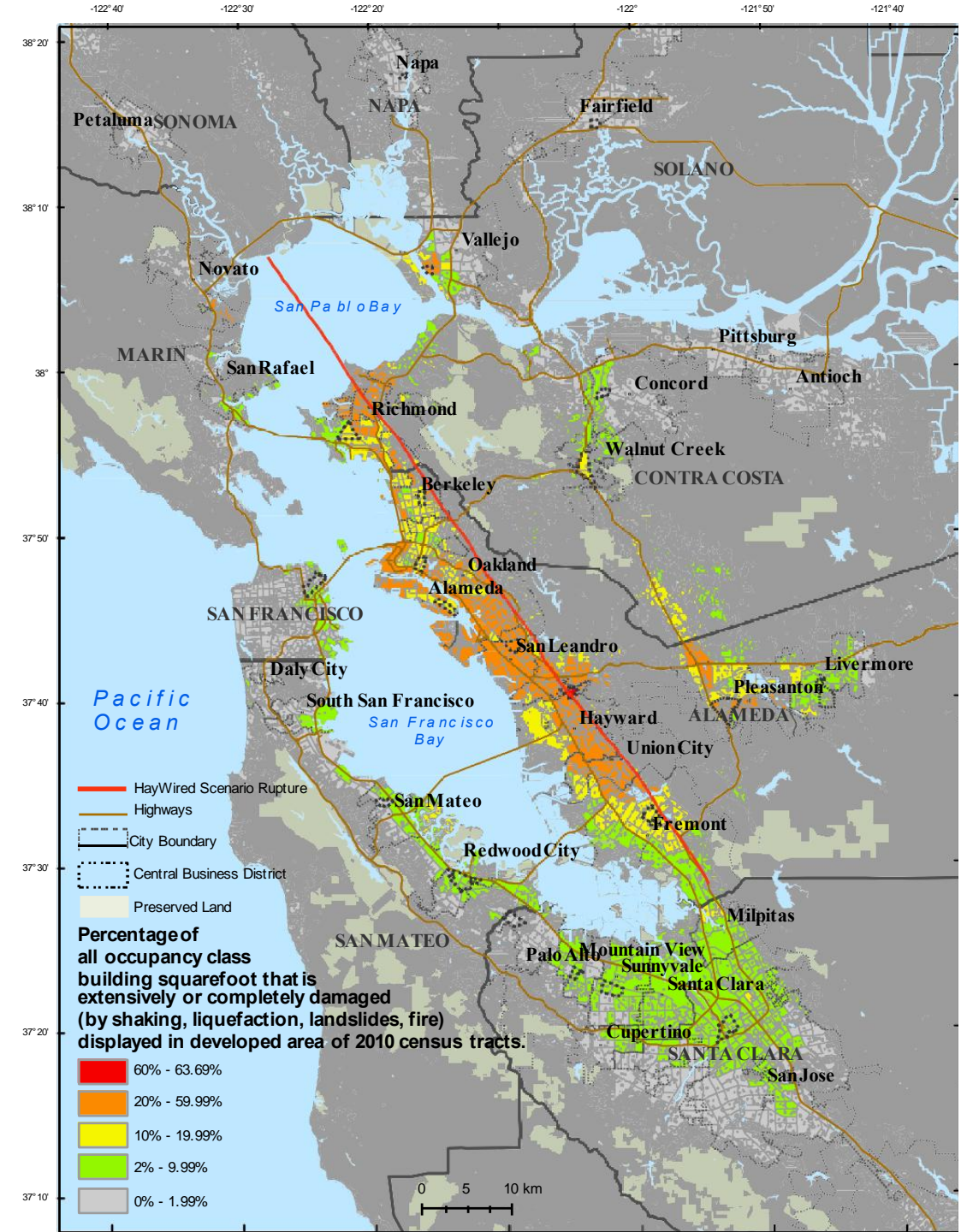
HayWired: Liquefaction and Landslides
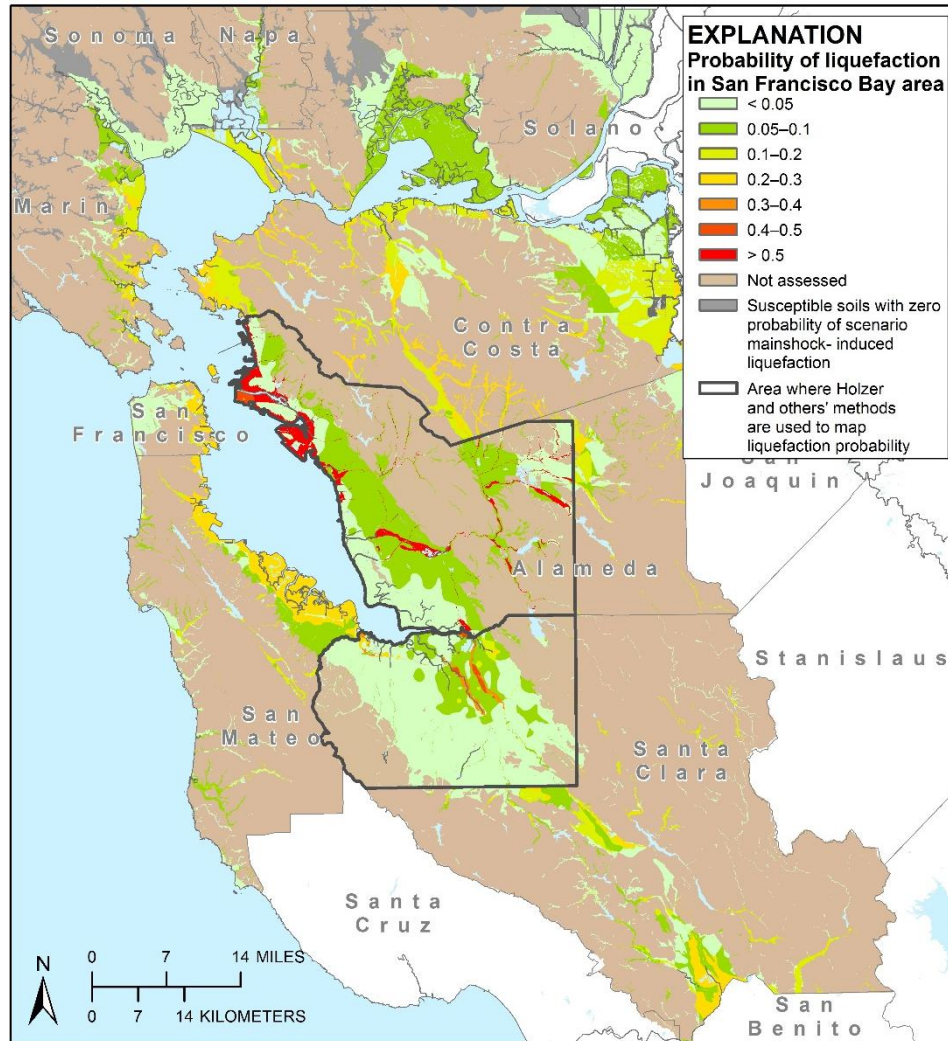
Hydrology from U.S. Geological Survey National Hydrography Dataset, 2016.
Boundary data from U.S. Census Bureau TIGER data, 2016, and Federal Emergency Management Agency Hazus-MH 2.1, 2014.
North American Datum of 1983 UTM 10N projection.
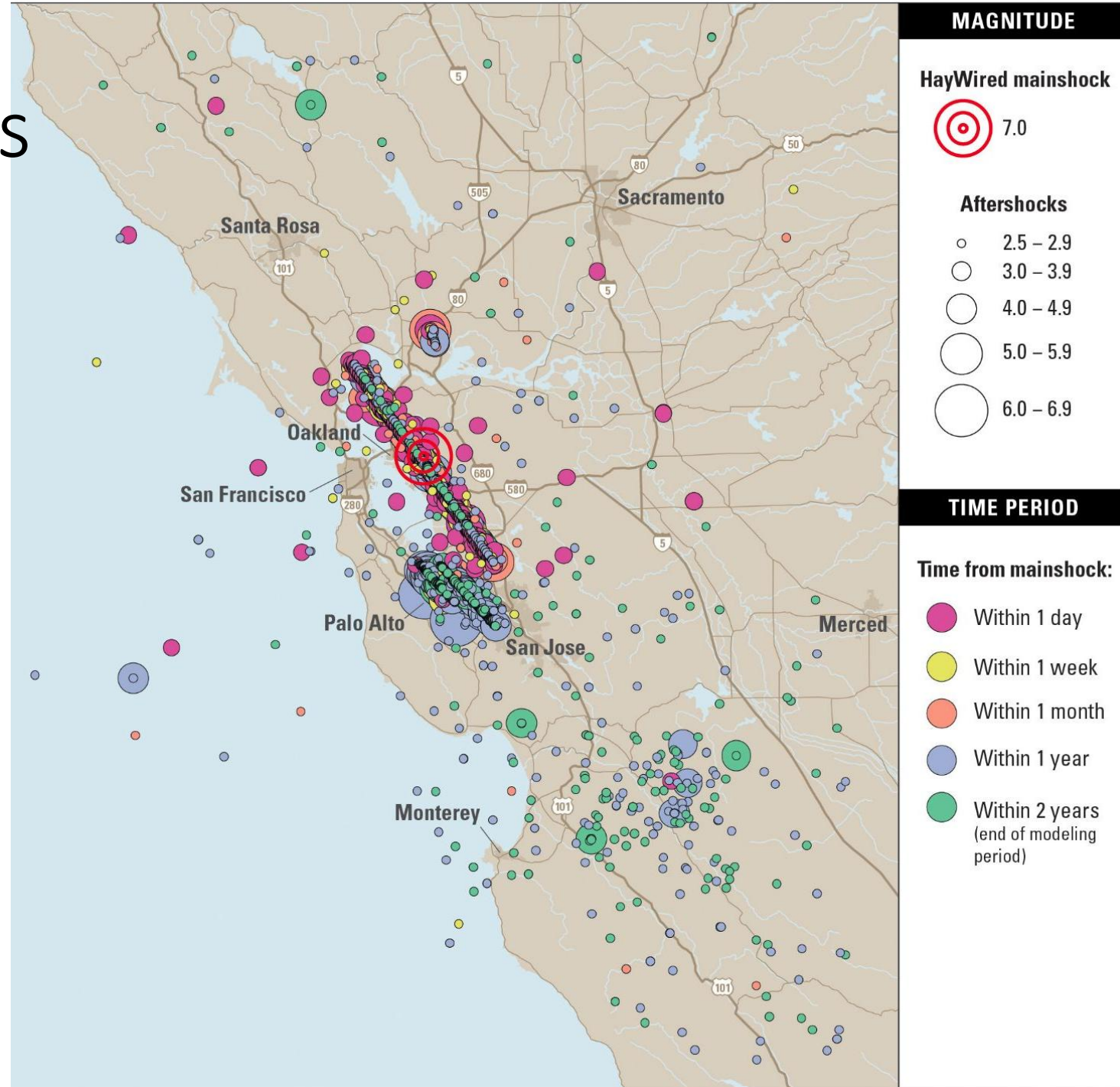Central meridian, 123° W., latitude of origin, 0.0° N.
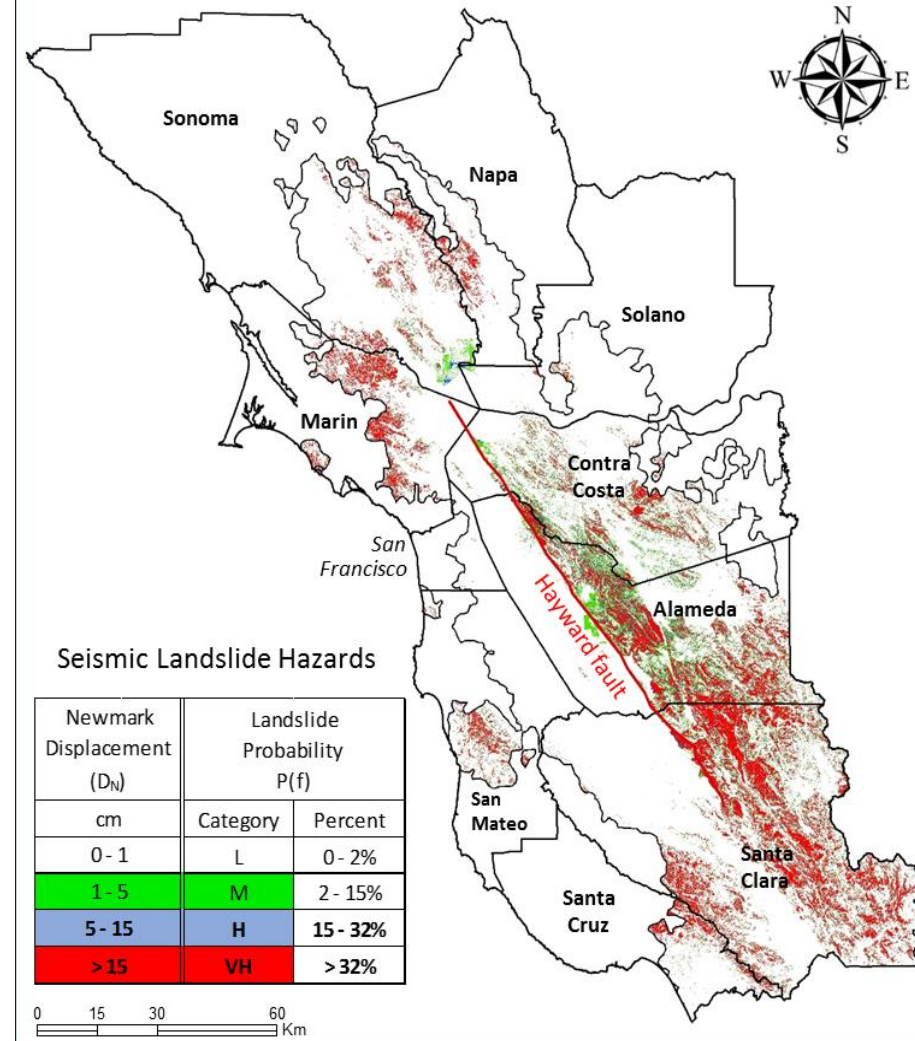
HayWired: Mainshock Damage Footprint (HAZUS)

- Percent of buildings extensively or completely damaged by
  - Shaking
  - Liquefaction
  - Landslide
  - Fire

Percentage of all occupancy class building squarefoot that is extensively or completely damaged (by shaking, liquefaction, landslides, fire) displayed in developed area of 2010 census tracts.

Legend:
- 60% - 63.69%
- 20% - 59.99%
- 10% - 19.99%
- 2% - 9.99%
- 0% - 1.99%

HayWired Scenario Rupture
Highways
City Boundary
Central Business District
Preserved Land
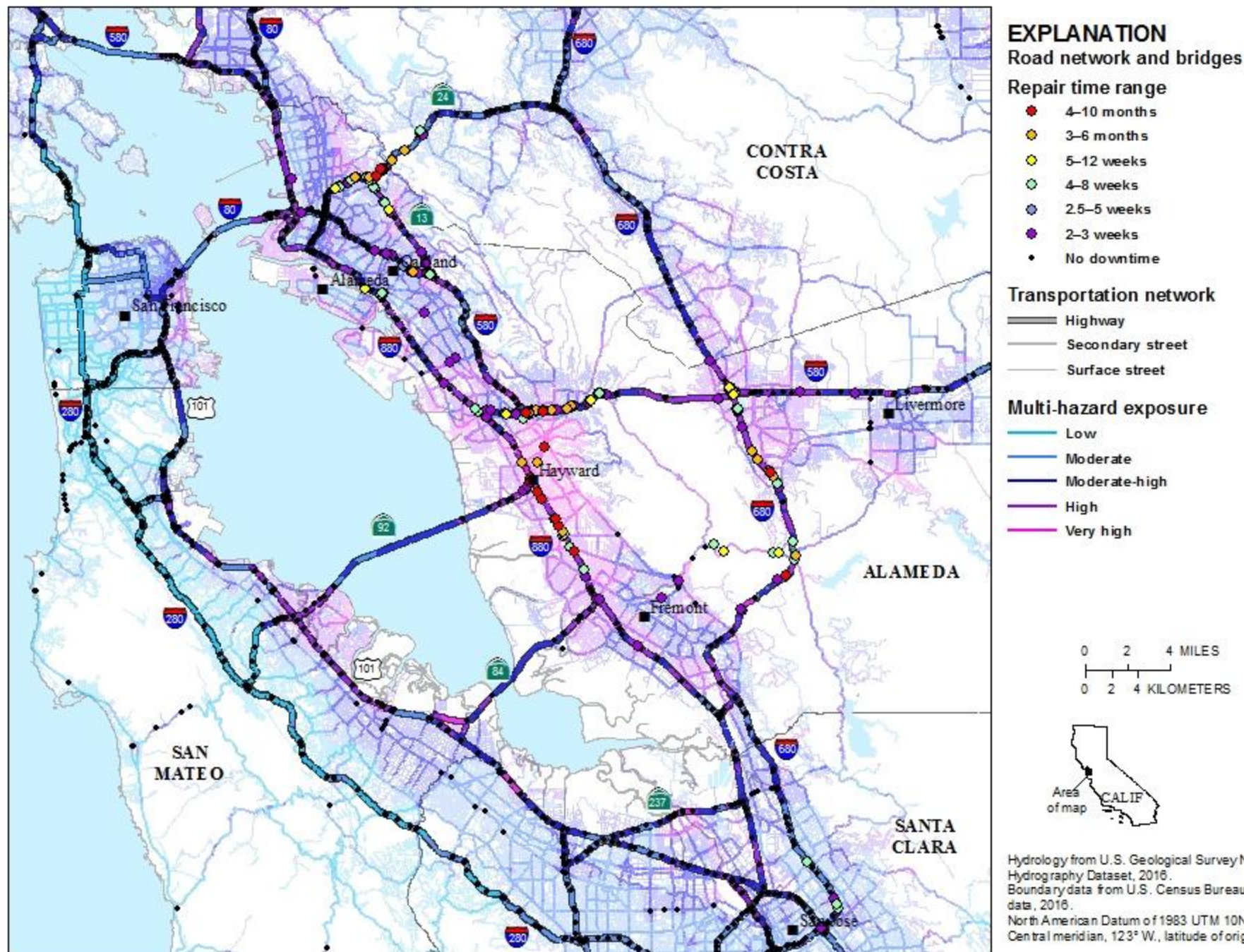
USGS
science for a changing world
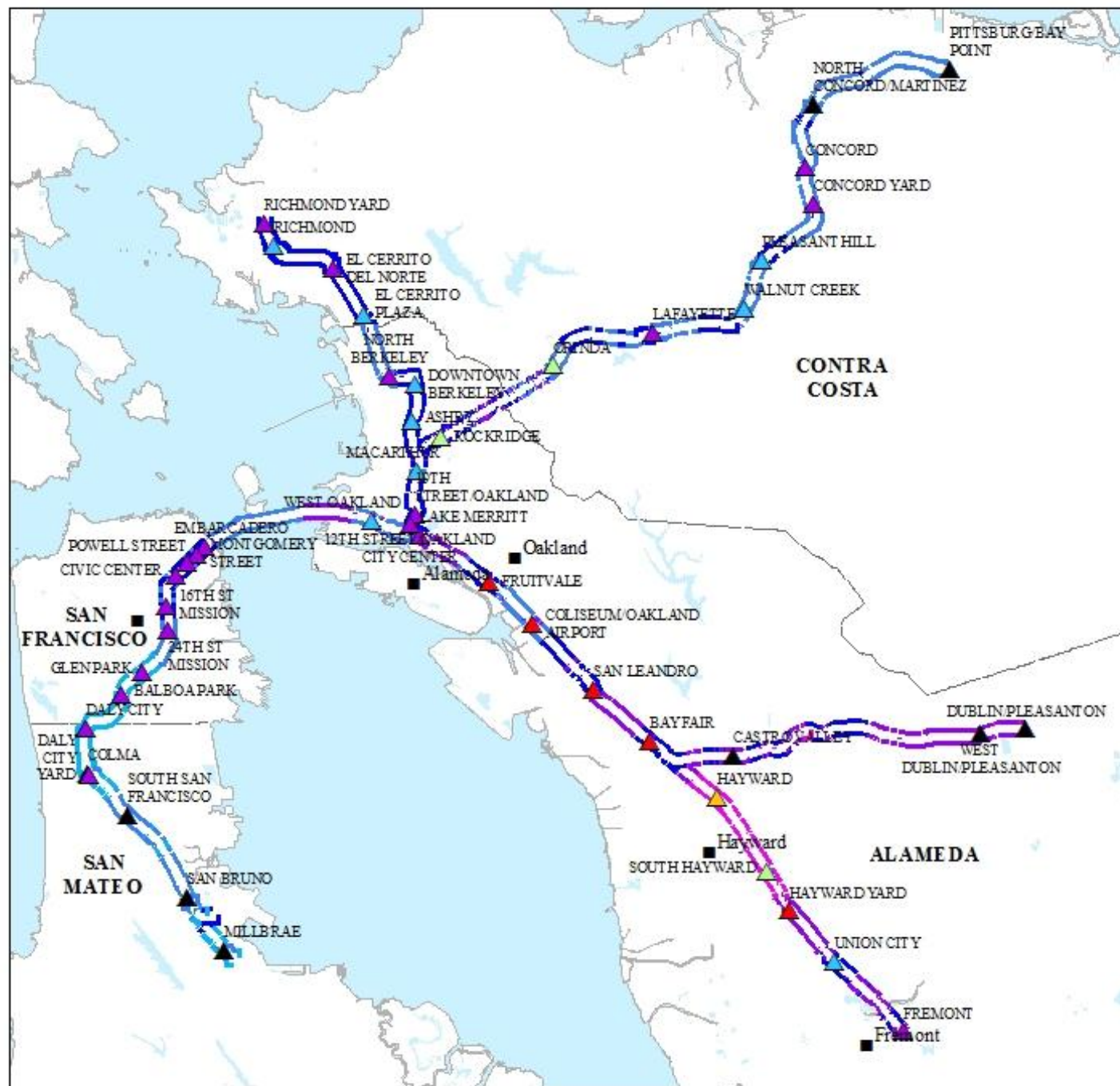
HayWired: Aftershocks

- 16 M5+ aftershocks in 2 years

- Contribute 20% of building losses
  - 12% from 3 aftershocks M6.0-6.4
  - 8% from 13 aftershocks M5.0-5.9

- Some areas more damaged by aftershocks than M7

- Repeat liquefaction damage is possible

EXPLANATION

Road network and bridges

Repair time range
- ● 4–10 months
- ● 3–6 months
- ● 5–12 weeks
- ● 4–8 weeks
- ● 2.5–5 weeks
- ● 2–3 weeks
- • No downtime

Transportation network
- Highway
- Secondary street
- Surface street

Multi-hazard exposure
- Low
- Moderate
- Moderate-high
- High
- Very high

CONTRA COSTA

ALAMEDA

SAN MATEO

SANTA CLARA

San Francisco

Oakland

Alameda

Hayward

Fremont

Livermore

San Jose

0   2   4 MILES

0   2   4 KILOMETERS

Area of map   CALIF

Hydrology from U.S. Geological Survey National Hydrography Dataset, 2016.
Boundary data from U.S. Census Bureau TIGER data, 2016.
North American Datum of 1983 UTM 10N projection. Central meridian, 123° W., latitude of origin, 0.0° N.

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ABAG REMI Model

- ABAG Regional Control in REMI Model 1.7.8
- ABAG REMI subregions:
  - East Bay: Alameda, Contra Costa; each of these two counties is bisected by the Hayward Fault; in the Haywired scenario, the epicenter of the HayWired mainshock earthquake is in the city of Oakland, Alameda county in the East Bay
  - South Bay: Santa Clara; the Hayward fault rupture extends into the northern part of the county
  - West Bay: Marin, San Francisco, San Mateo; landslides occur in Marin and Liquefaction occurs in San Mateo and San Francisco
  - North Bay: Napa, Solano, Sonoma; strong to extreme shaking occurs throughout these counties.
  - Rest of California: Remaining 49 California counties

HayWired Direct Loss from HAZUS* Results

- Capital stock (building and building contents) loss: $83 Billion (2015$)

Sub Regions	Residential	Non-Residential	Share of Residential Stock	Share of Non-Residential Stock
East Bay	24.7	17.4	8.52%	12.21%
North Bay	1.3	1.1	1.36%	2.31%
West Bay	5.7	5.8	2.31%	4.07%
South Bay	13.3	8.4	4.56%	8.35%
Rest of California	4.6	0.8	0.18%	0.06%

Source: ABAG from REMI 1.7.8 and HAZUS results

*HAZUS results were used to calculate the share of loss, which was applied to REMI baseline projections

HayWired Direct Loss Results from HAZUS

- 3-year total direct output loss: $24.55 Billion (2015$)

Sub Regions	1st year	2nd year	3rd year
East Bay	16.89	0.04	0.01
North Bay	1.69	0.01	0.00
West Bay	0.08	0.00	0.00
South Bay	4.28	0.01	0.00
Rest of California	1.54	0.00	0.00

Source: ABAG from REMI 1.7.8 and HAZUS results

*HAZUS results were used to calculate the share of loss, which was applied to REMI baseline projections

Economic Analysis Elements for REMI

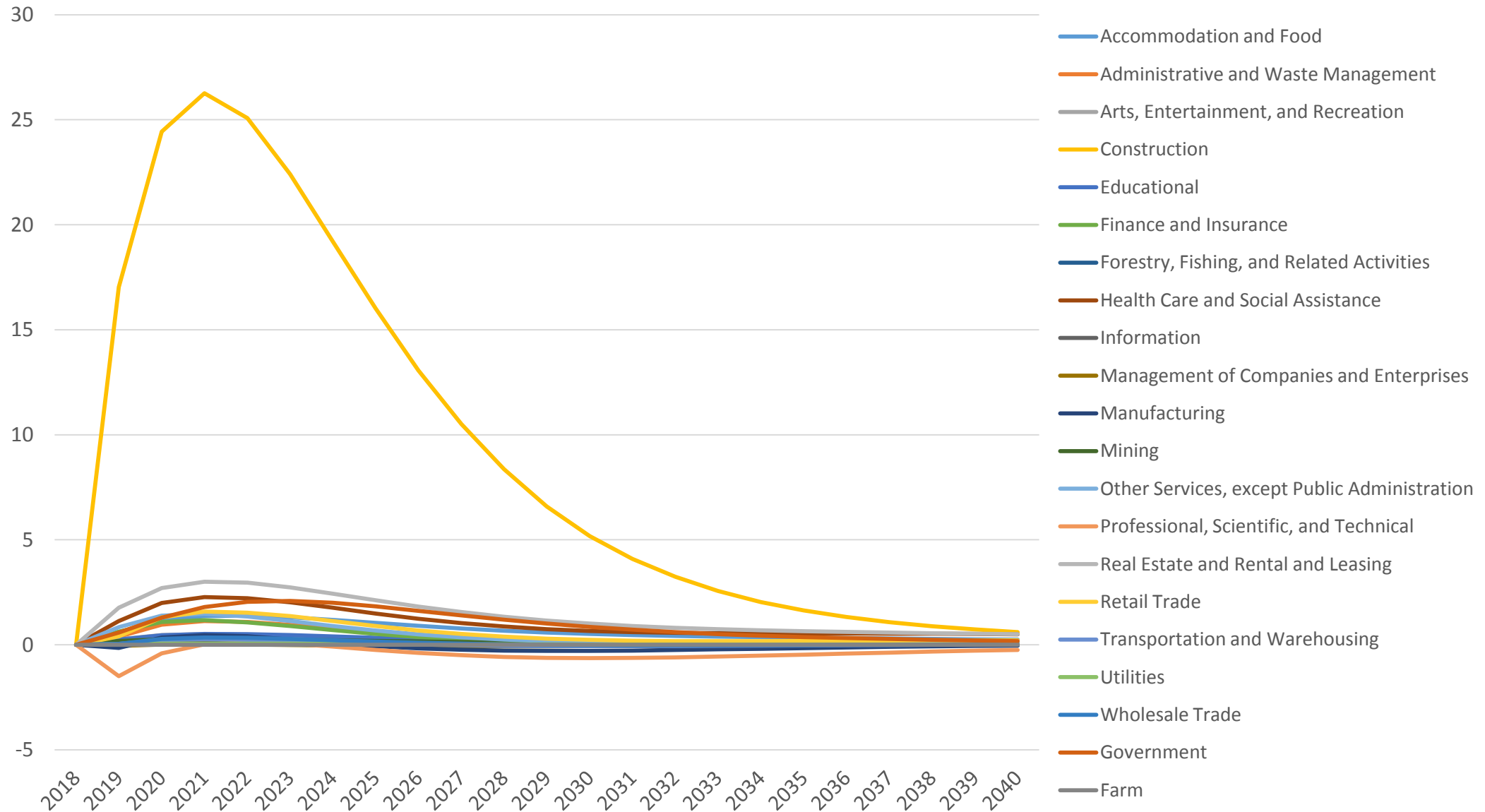| Elements	Description	Expected Results
Building Damage	Buildings with extensive or complete damage in HAZUS output	New investment, and induced employment growth
Output Loss	Direct output loss resulting from building and contents damage	Employment, GDP, population loss in short term
Employment Change	Employment loss due to disruption, gains from recovery efforts	Mixed. Temporary decline in most sectors, increase in construction, some others. Long term uncertain
Population Change	Complex mix—direct loss from damage, indirect from employment loss, other moves	Migration mixed—recovery workers in, non-economic outmigration. Negative nonpecuniary effects on population, labor force, jobs
Government Spending	Disaster relief has some boosts to the economy, but may be offset by cuts in other services	Government spending will increase employment, output and income, to the extent that it is exogenous
Government Revenue Sources	Simulate a tax increase	Sales tax may have modest increase on output, employment
Business Costs	Production cost is likely to increase for a period of time due to factors such as increase in insurance premiums, and transportation costs	Decrease in output and employment for some time

HayWired Scenario Simulation Impact in REMI

- Residential and Non-residential Capital Stock Loss in 2018
- Direct Output Loss by Industry in 2018, 2019 and 2020
- Insurance Cost Increase for Businesses for 20 years
- Non-Pecuniary (Amenity) Aspects Loss from Casualties in 2018
- Local and State Government Spending Decrease + Increase in Intermediate Demand from Disaster Recovery Investment (Local, State and Federal) for 10 years
- Sales Tax Increase for 10 years

1-1. Residential and Non-residential Capital Stock Loss in 2018

Sub Regions	Residential	Non-Residential
East Bay	24.7	17.4
North Bay	1.3	1.1
West Bay	5.7	5.8
South Bay	13.3	8.4
Rest of California	4.6	0.8

1-2. Capital Stock Loss Impacts on Employment by Sector

Legend:
- Accommodation and Food
- Administrative and Waste Management
- Arts, Entertainment, and Recreation
- Construction
- Educational
- Finance and Insurance
- Forestry, Fishing, and Related Activities
- Health Care and Social Assistance
- Information
- Management of Companies and Enterprises
- Manufacturing
- Mining
- Other Services, except Public Administration
- Professional, Scientific, and Technical
- Real Estate and Rental and Leasing
- Retail Trade
- Transportation and Warehousing
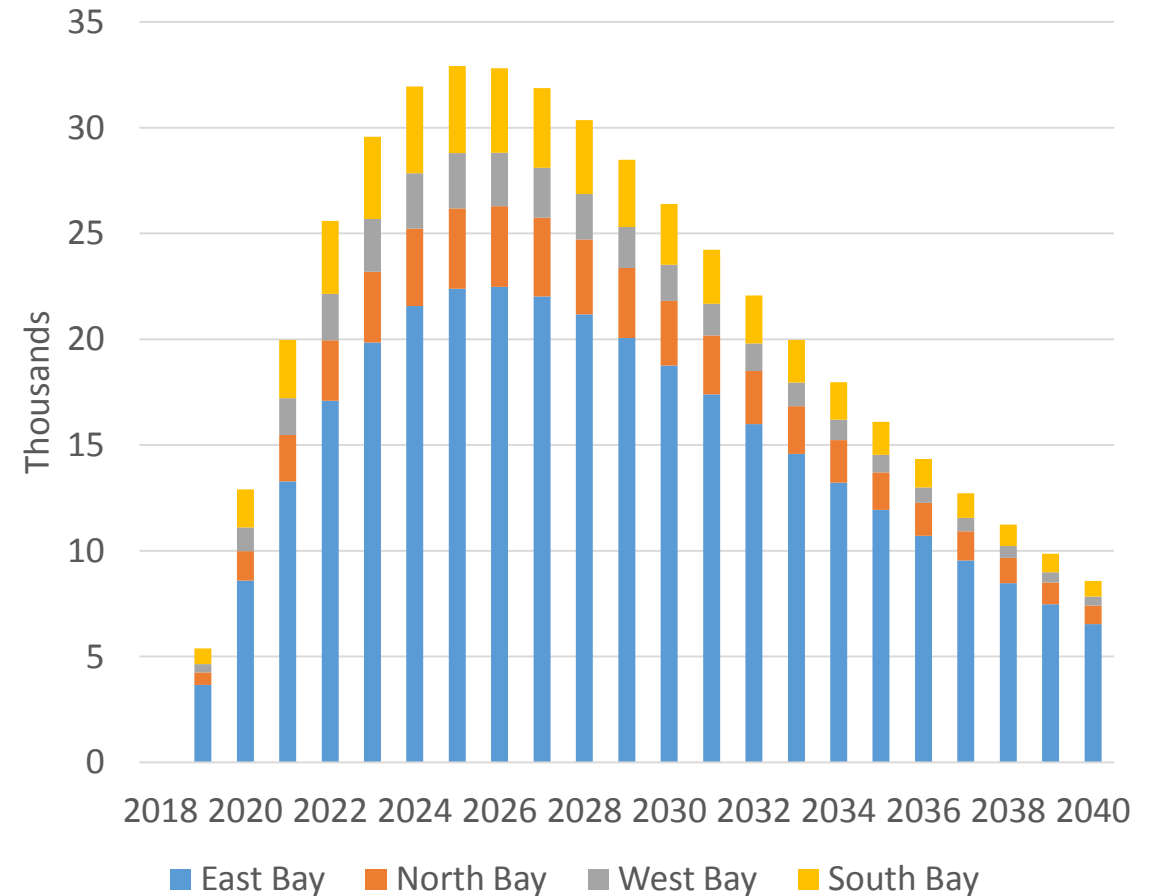- Utilities
- Wholesale Trade
- Government
- Farm

# 1-3. Capital Stock Loss Impacts on Population

Net Economic Migrants

Total Population

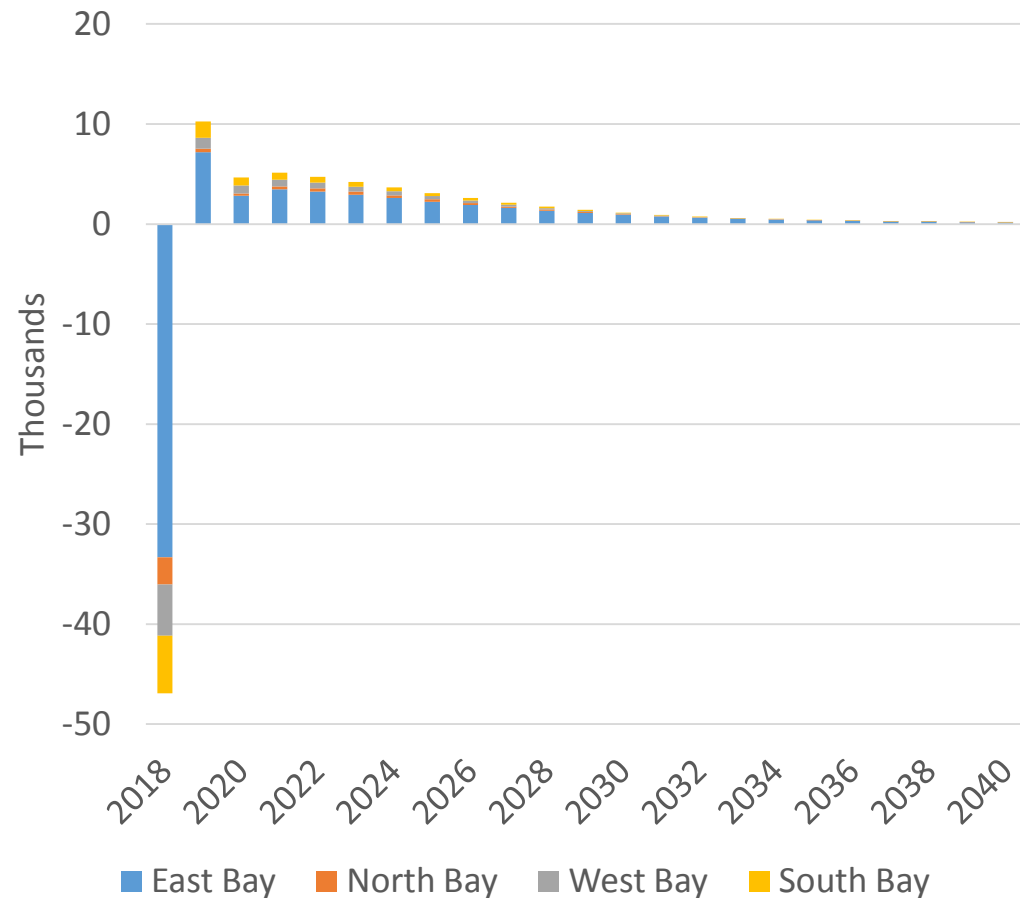# 2-1. Direct Output Loss by Industry in 2018, 2019 and 2020

- HAZUS estimated direct output loss for 3 years
  - Taking into account overall repair time and cost, and recaputure factor for buildings in each occupancy class
  - Loss in second and third year concentrates in accommodation sector and nursing homes
- Bay Area:
  - $25 Billion loss (2016$)
  - 3.2% of Bay Area 2016 GDP
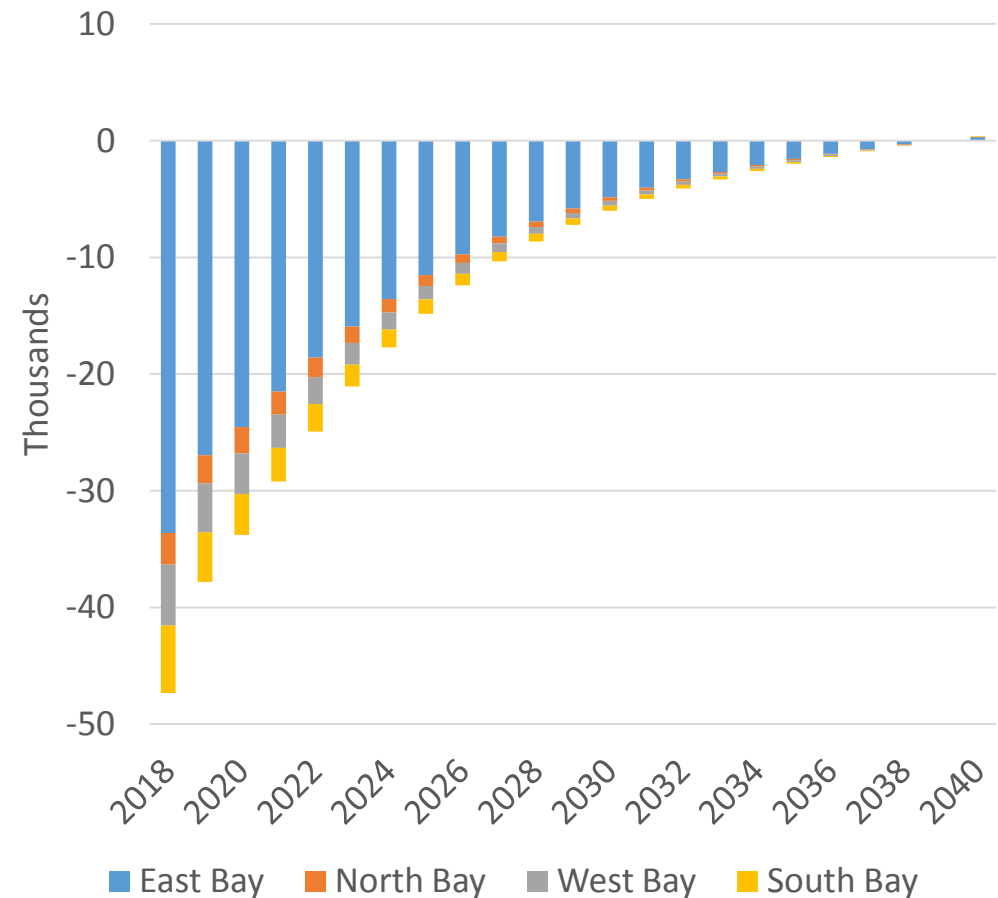
2-2. Direct Output Loss Impacts on Employment by Sector
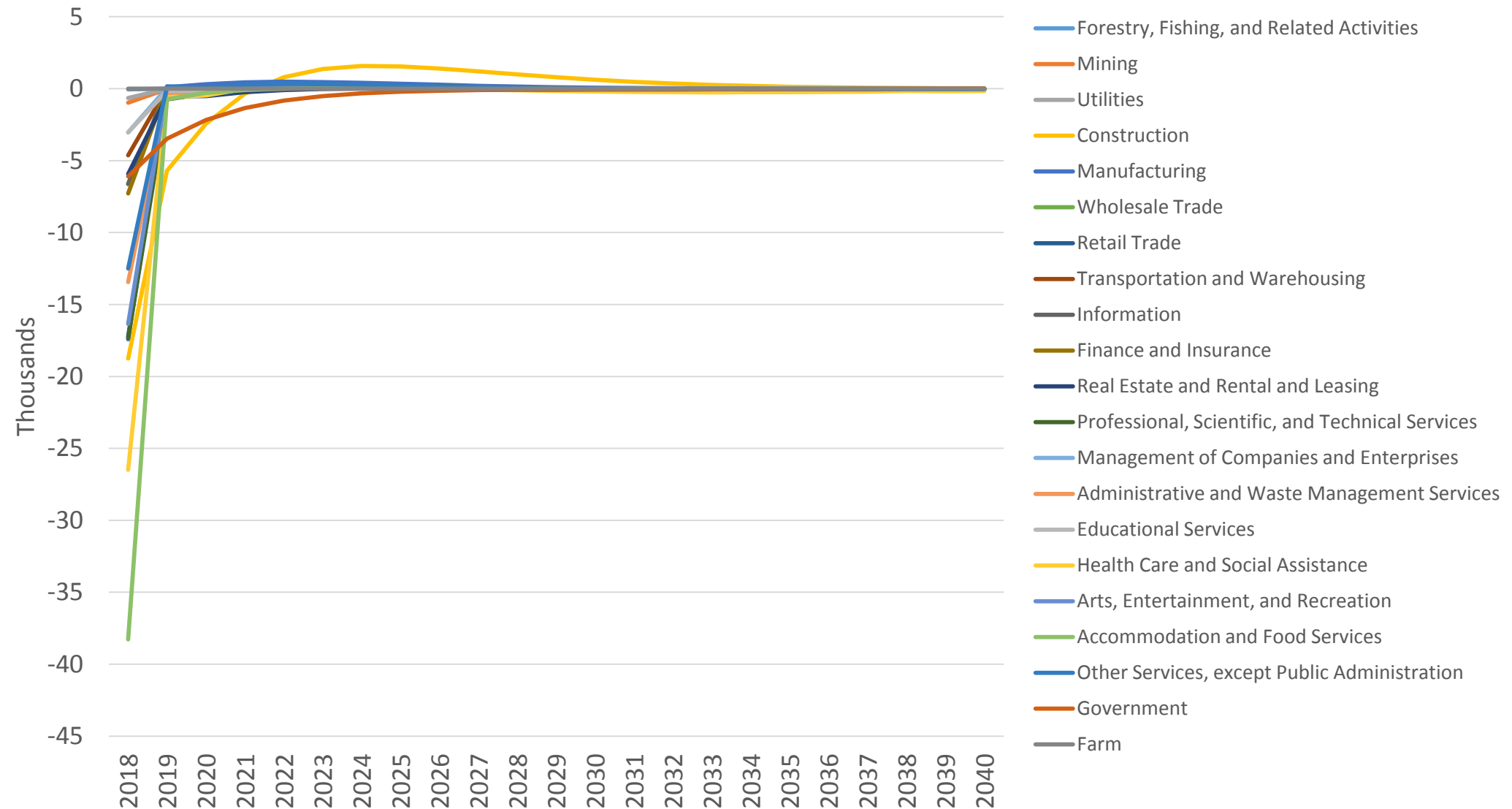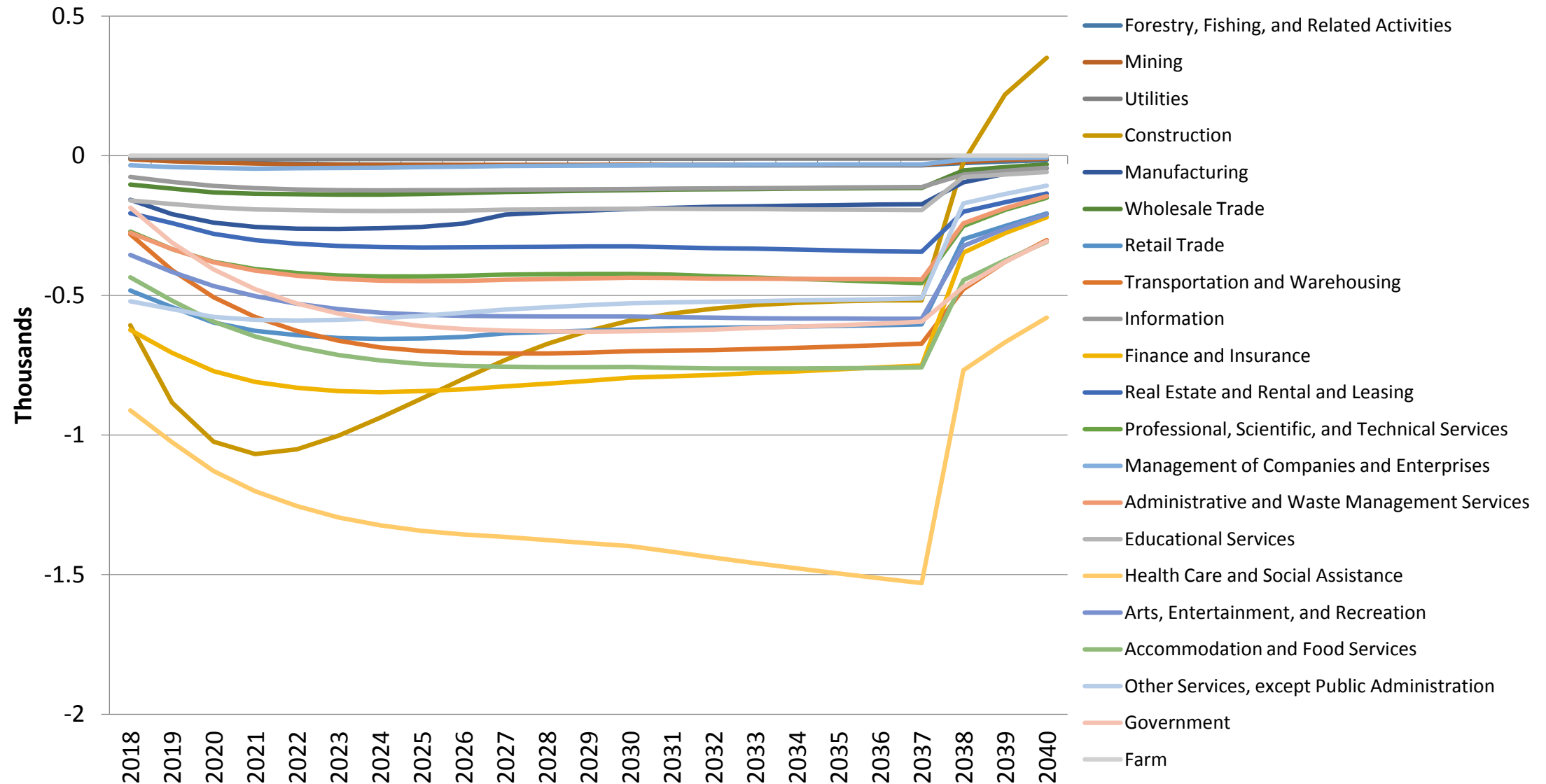
2-3. Direct Output Loss Impacts on Population
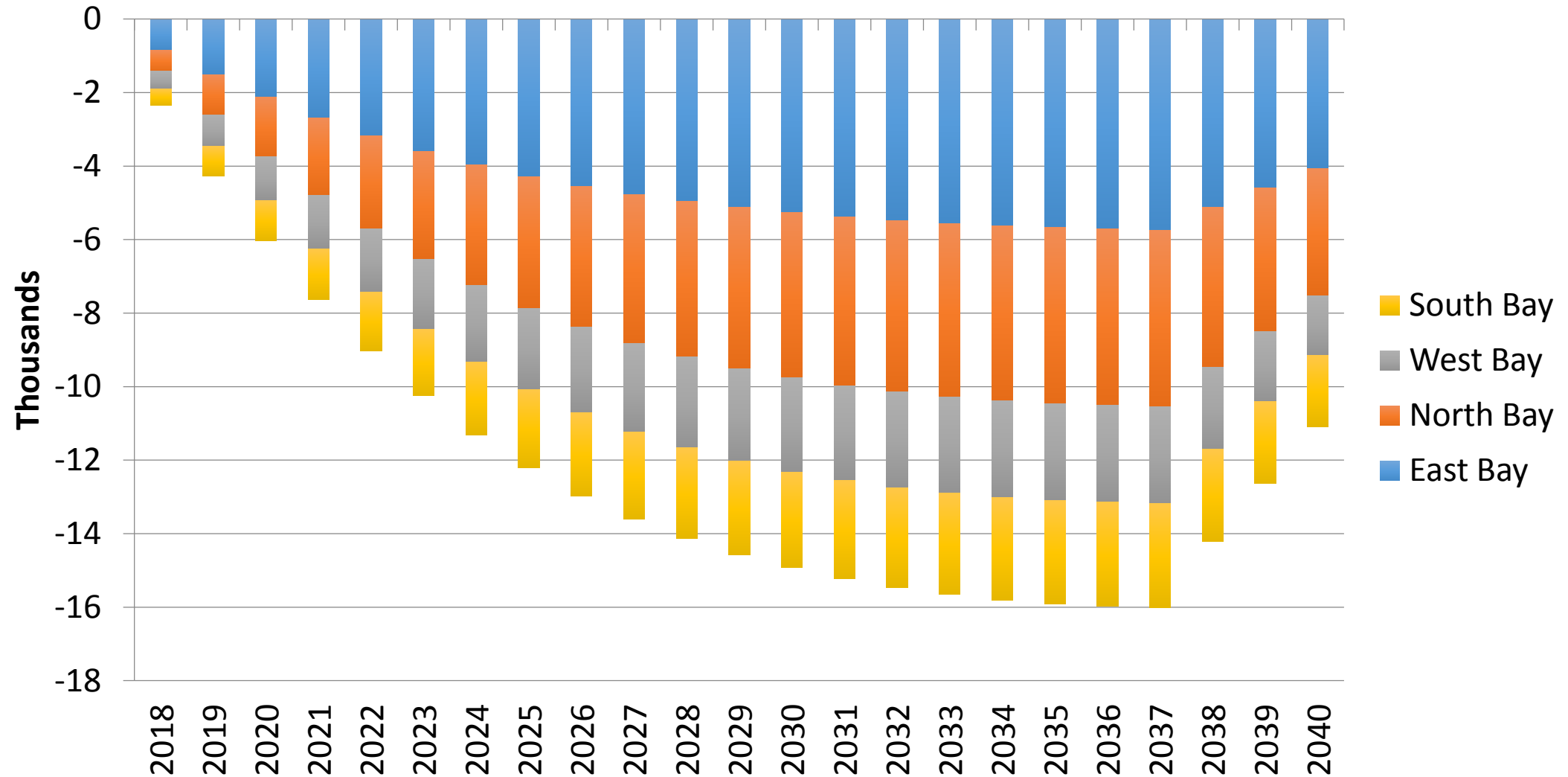

Net Economic Migrants

Total Population

3-1. Insurance Cost Increase Impact on Employment by Sector

Legend:
- Forestry, Fishing, and Related Activities
- Mining
- Utilities
- Construction
- Manufacturing
- Wholesale Trade
- Retail Trade
- Transportation and Warehousing
- Information
- Finance and Insurance
- Real Estate and Rental and Leasing
- Professional, Scientific, and Technical Services
- Management of Companies and Enterprises
- Administrative and Waste Management Services
- Educational Services
- Health Care and Social Assistance
- Arts, Entertainment, and Recreation
- Accommodation and Food Services
- Other Services, except Public Administration
- Government
- Farm

Y-axis: Thousands (0.5, 0, -0.5, -1, -1.5, -2)

X-axis: 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026, 2027, 2028, 2029, 2030, 2031, 2032, 2033, 2034, 2035, 2036, 2037, 2038, 2039, 2040

3-2. Insurance Cost Increase Impact on Total Population

4-1. Non-Pecuniary (Amenity) Aspects Loss

- Total Number of Deaths: 2025
- Bay Area Air Quality Management District Estimated Value of Health Endpoint for Mortality: $8.8M (2015$)
- Total Value of Amenity Loss: $17.82B

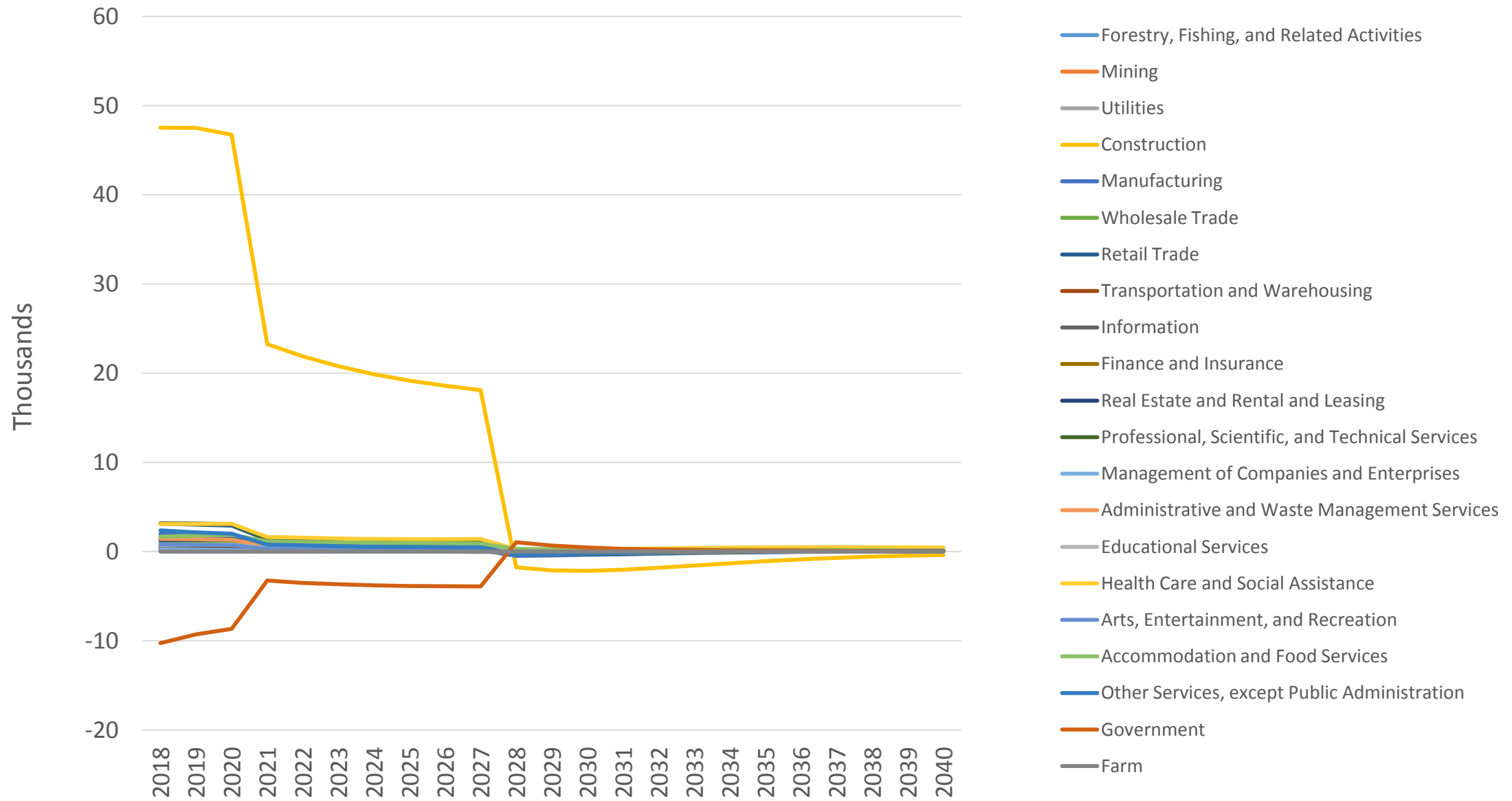| Time of day	Casualties severity level	Total Casuality
Day (2 p.m.)	Level 1 (First aid only)	13029
	Level 2	3059
	Level 3	464
	Level 4 (Death)	840
	Total	17392
Night (2 a.m.)	Level 1 (First aid only)	8562
	Level 2	1549
	Level 3	180
	Level 4 (Death)	341
	Total	10632
Commute (5 p.m.)	Level 1 (First aid only)	11305
	Level 2	3034
	Level 3	1342
	Level 4 (Death)	844
	Total	16525

4-2. Non-Pecuniary (Amenity) Aspects Loss Impacts on Employment and Population
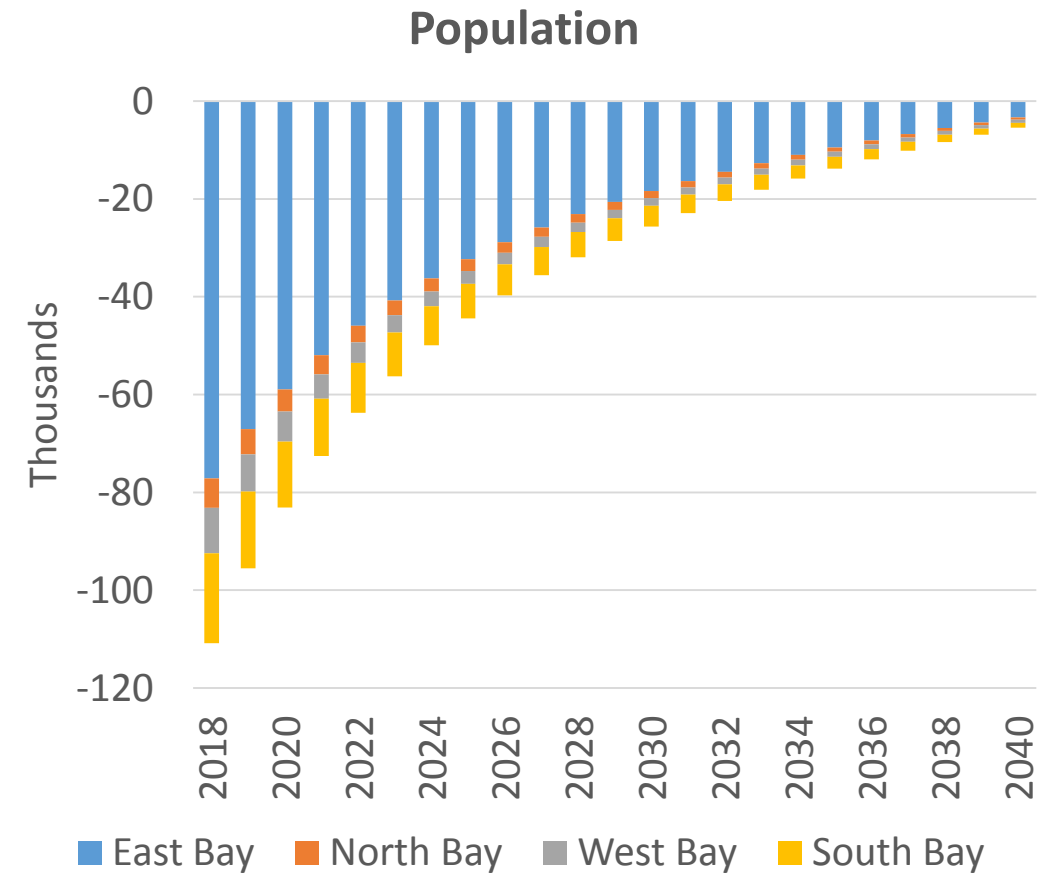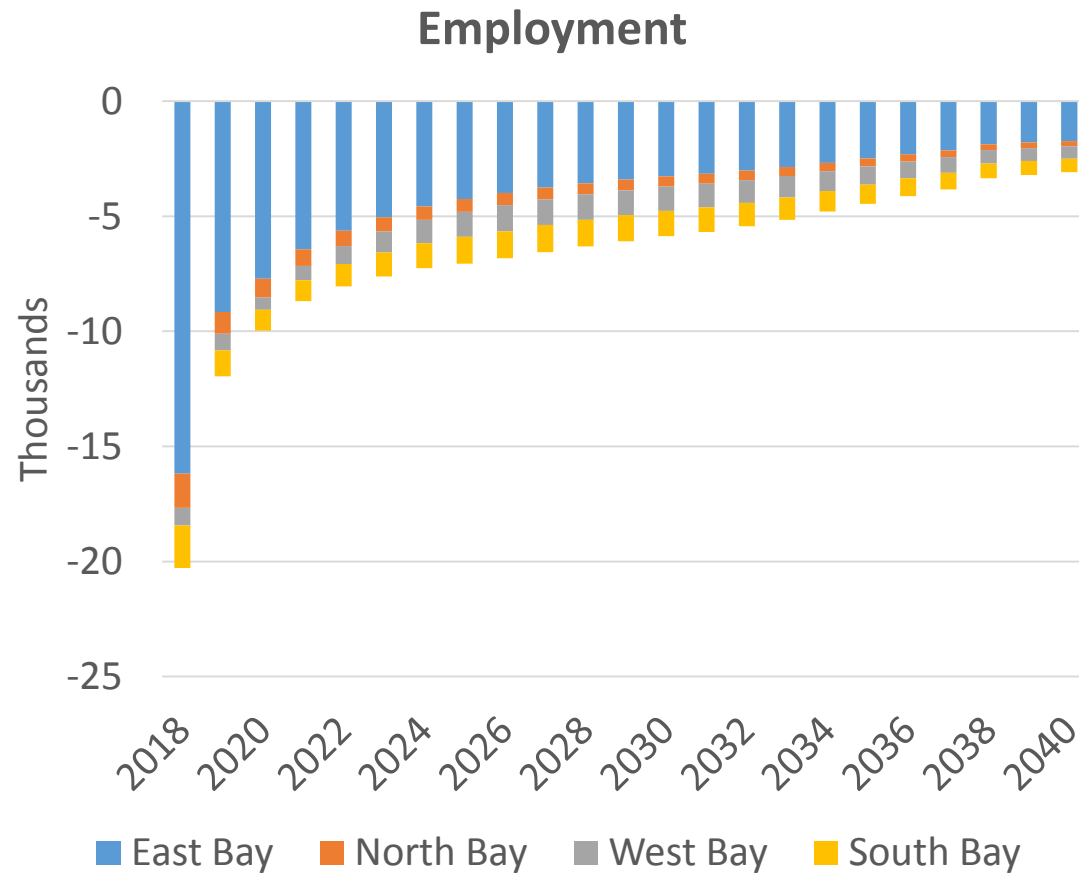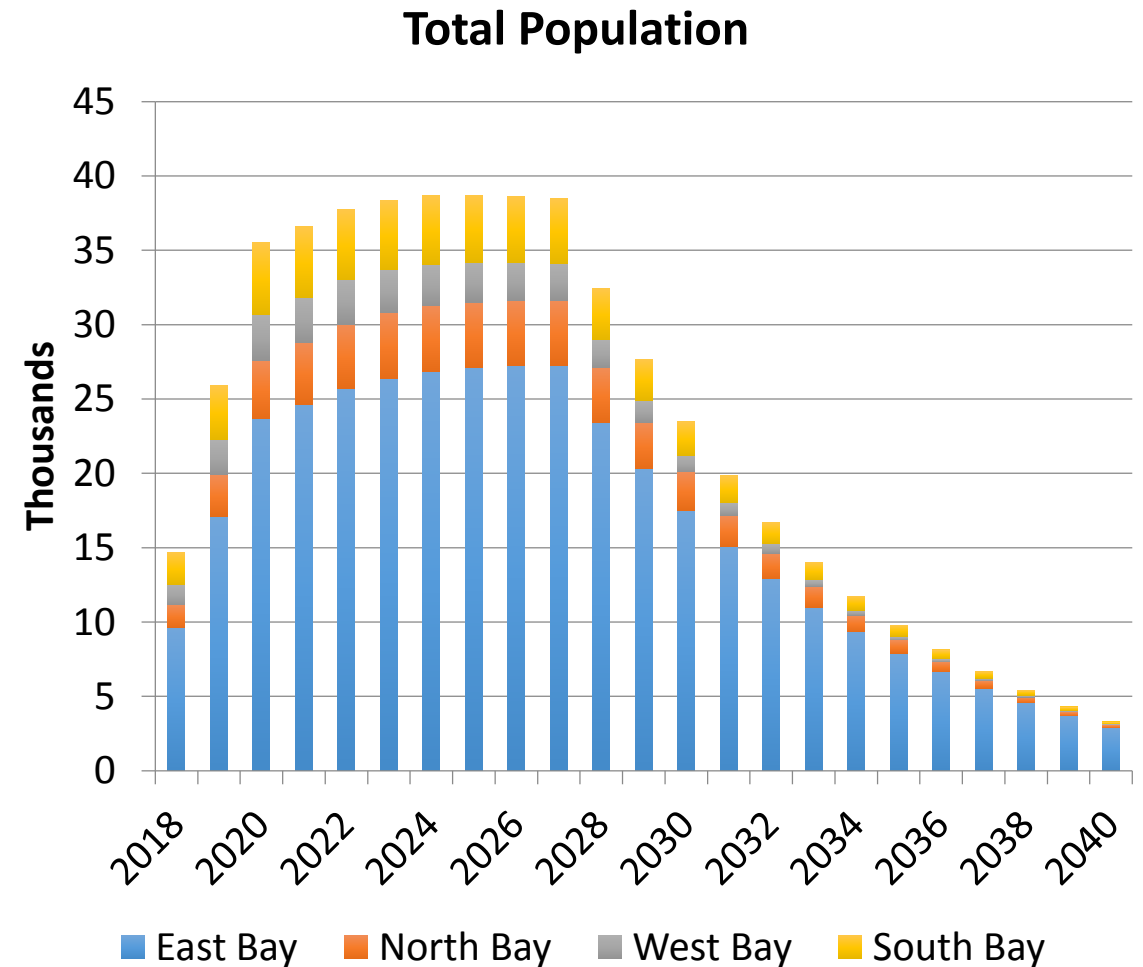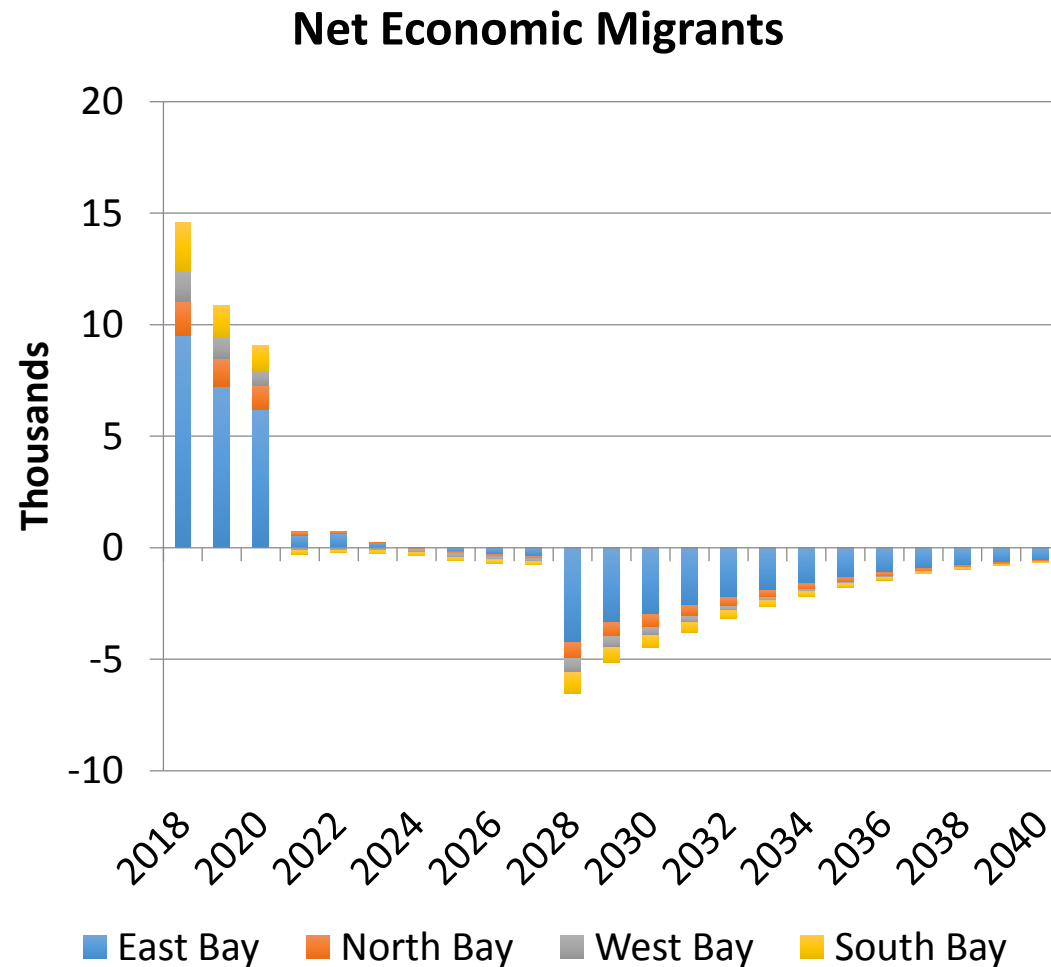
5-1. Disaster Relief

- Federal post-disaster recovery spending coverage (CNN, 2017):
  - 72% of Hurricane Katrina, $114.5B of $160B estimated loss
  - 80% of Hurricane Sandy, $56B of $70B estimated loss
- Assumption:
  - Government aids from all levels covers two thirds of estimated loss, $52B
  - Local and State Government is responsible for 1/4 of government aids, the rest is exogenous federal spending into the region
- REMI Translation:
  - $13B (2015$) decrease in local and state government spending (2015$) in 10 years
  - $52B (2015$) increase in intermediate demand of Construction sector in 10 years

5-2. Disaster Relief Impacts on Employment by Sector

Legend:
- Forestry, Fishing, and Related Activities
- Mining
- Utilities
- Construction
- Manufacturing
- Wholesale Trade
- Retail Trade
- Transportation and Warehousing
- Information
- Finance and Insurance
- Real Estate and Rental and Leasing
- Professional, Scientific, and Technical Services
- Management of Companies and Enterprises
- Administrative and Waste Management Services
- Educational Services
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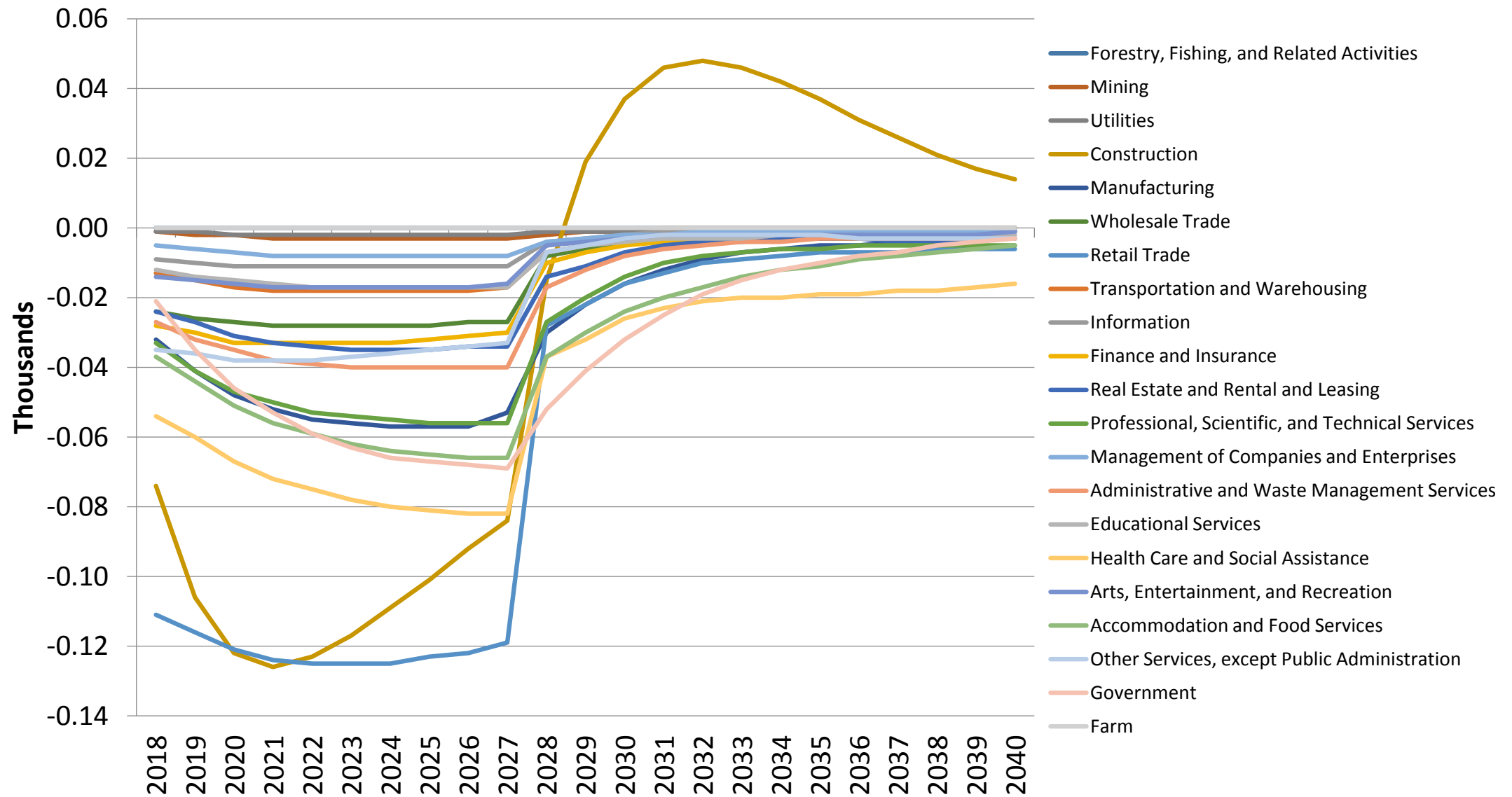- Farm

5-3. Disaster Relief Impacts on Population

6-1. Three Quarters Per Cent Sales Tax Increase

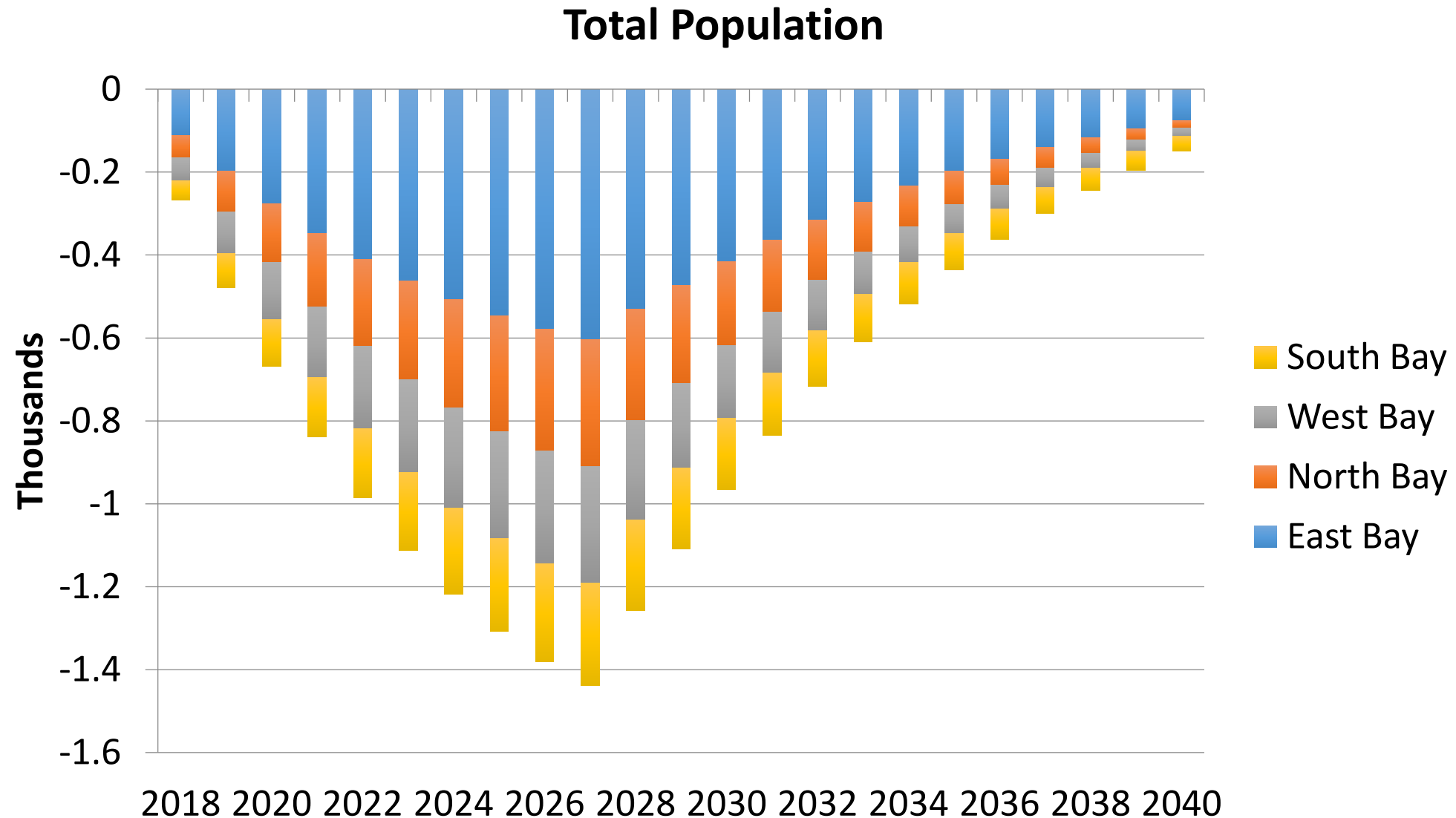- Annual Increase in Sales Revenue:
  - East Bay: $25.6M
  - North Bay: $10.9M
  - West Bay:$22.6M
  - South Bay:$22.6M
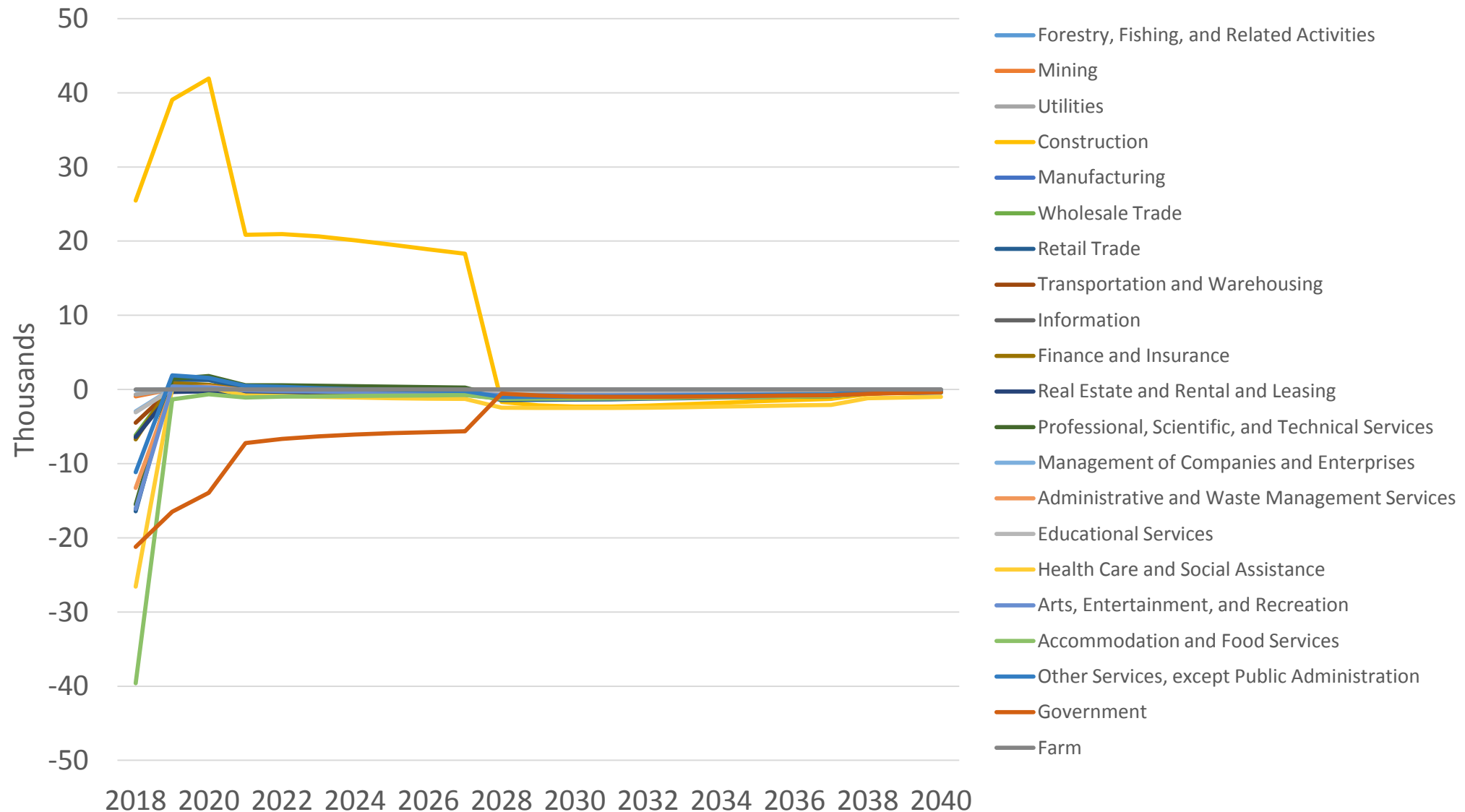 - Bay Area Total: $81.7M

  Source: Calculated Using CA BOE Data

6-2. Sales Tax Increase Impacts on Employment by Sector
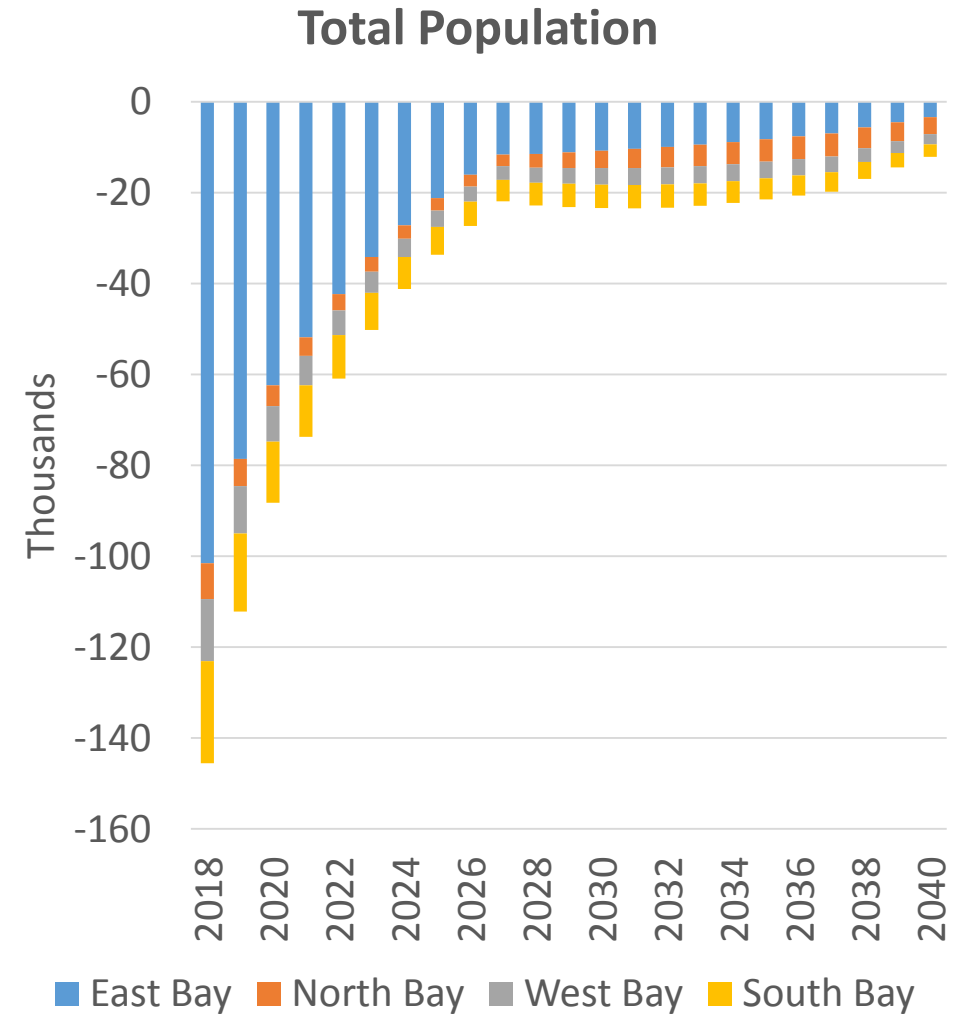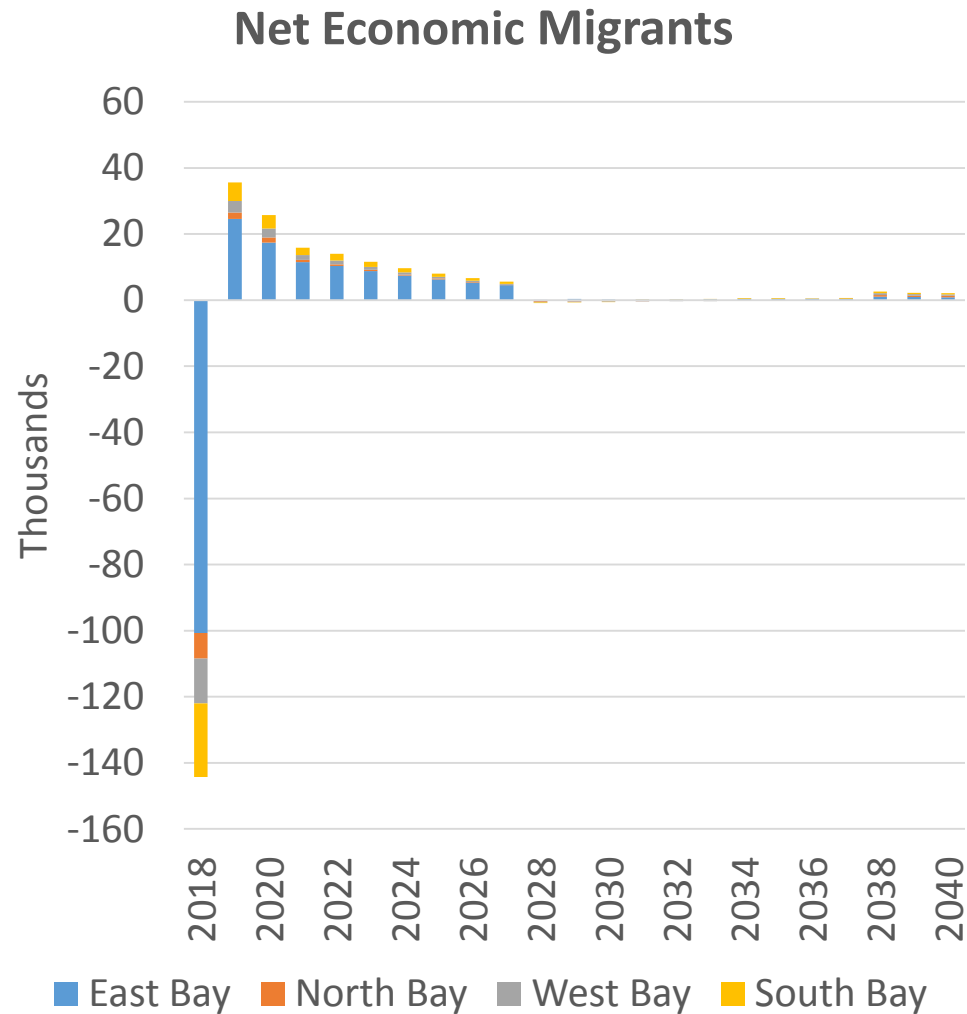
6-3. Sales Tax Increase Impacts on Population

Total Population

7-1. Combined Impacts on Employment

Legend:
- Forestry, Fishing, and Related Activities
- Mining
- Utilities
- Construction
- Manufacturing
- Wholesale Trade
- Retail Trade
- Transportation and Warehousing
- Information
- Finance and Insurance
- Real Estate and Rental and Leasing
- Professional, Scientific, and Technical Services
- Management of Companies and Enterprises
- Administrative and Waste Management Services
- Educational Services
- Health Care and Social Assistance
- Arts, Entertainment, and Recreation
- Accommodation and Food Services
- Other Services, except Public Administration
- Government
- Farm

7-2. Combined Impacts on Population

Net Economic Migrants

Total Population

Legend: East Bay, North Bay, West Bay, South Bay

Remaining Limitations, Questions and Next Steps

- Limitations and Questions
  - Model assumptions that labor substitutes for capital stock
  - Avoiding double counting of capital stock impacts.
  - Sales tax measure tiny relative to stimulous. What else would be feasible in the model?
  - How do we estimate and factor in productivity loss so that it results in further output decrease?

- Next Steps
  - Hay*Wired* aspects
    - Resilience due to ability to work remotely
    - Relocation due to ability to work remotely
    - Disruption or stimulus due to changes in wireless services?
  - Household, community and transportation disruptions
  - Real estate prices