5. Vulnerability Methodology

5.1 Introduction

This chapter provides an overview of the methodologies used to assess existing and projected vulnerabilities from coastal hazards. Decisions on the sea level rise scenarios, sector selection, hazard models, and measures of impacts were made in concert with the City of Carpinteria (City) and consultant team with input from the City's Coastal Land Use Program/General Plan (CLUP/GP) Update Committee and are documented in Appendix A.

This Report relied on several primary data sources:

- Coastal hazards modeling analysis results (Revell Coastal and ESA 2016).
- FEMA effective and preliminary updated FIRMs (FEMA 2016).
- Spatial and locational data available from the City, Carpinteria Valley Water District (CVWD), Carpinteria Sanitary District (CSD), Santa Barbara County Planning and Development, Santa Barbara County Public Works, State Parks, California Coastal Commission (CCC), California Division of Oil, Gas, and Geothermal Resources (DOGGR), California State Water Resources Control Board (SWRCB), U.S. Environmental Protection Agency (EPA), and Environmental Systems Research Institute (ESRI) (Table 5-1).
- Economic and beach attendance data from Beach Erosion Authority for Clean Oceans and Nourishment (BEACON) and State Parks.

Projections of future coastal hazards and sea level rise were modeled as part of a separate project: *Santa Barbara County Coastal Resilience Project* (Revell Coastal and ESA 2016, Revell Coastal 2015) and this data was extracted for use in this Report.

5.2 Geospatial Data Collection

With input from the City and the public, the consultant team identified preferred sectors to be used in the analysis as well as measures of impact for each sector (Table 5-1). Data collection efforts began with available City data and were expanded to include County data and available state and federal public data libraries. For specific infrastructure data and special districts, direct data requests were made to the City Community Development Department.

Table 5-1. Description of Geospatial Data: Resource Sector, Measures of Impacts, and Data Sources

Sector	Land Use Categories Sub-Sector	Measures of Impacts	Data Source
Land Use Parcels and Structures	Agriculture	# of parcels, acreage of parcels	Parcels – County Planning Structures – Revell Coastal with input from City Community Development Department
	Commercial	# of parcels, acreage of parcels, # of structures, square feet of structures	
	Facilities (Institutions and Government)	# of parcels, acreage of parcels, # of structures, square feet of structures	
	Industrial	# of parcels, acreage of parcels, # of structures, square feet of structures	
	Residential	# of parcels, acreage of parcels, # of structures, square feet of structures	
	Open Space and Recreation	# of parcels, acreage of parcels, # of structures, square feet of structures	
Roads and Parking	Roads	length of road	County Planning Department
	Parking Lots	# of lots, acreage of lots	Revell Coastal with Input from Open Street Map
Public Transportation	Public Transportation	Length of: bike routes, bus routes, railroad lines; # of bus stops, # of train platforms	County Planning and Public Works Departments
Camping and Visitor Accommodations	Hotels and Motels	# of parcels, # of structures	County Planning Department
	Campgrounds	# of sites, acreage of sites	Revell Coastal with input from State Parks
Coastal Access and Trails	Coastal Access and Trails	# of access points, length of trail by type	Revell Coastal with input from CCC and the City

Table 5-2. Description of Geospatial Data: Resource Sector, Measures of Impacts, and Data Sources (Continued)

Sector	Land Use Categories Sub-Sector	Measures of Impacts	Data Source
Hazardous Materials Sites and Oil and Gas Wells	Geotracker Electronic Submittal of Information (ESI) Reporting Sites (Hazardous Business Materials Storage)	# of sites	SWRCB
	EPA Small Quantity Generators (SQGs)	# of sites	EPA
	Cleanup Program Active Sites	# of sites	EPA
	Oil and Gas Wells	# of wells	DOGGR
Storm water Infrastructure	Storm water Infrastructure	# of drop inlets, # of outfalls, length of drains	County Public Works Department and City Public Works Department
Wastewater Infrastructure	Wastewater Infrastructure	# of lift stations, # of manholes, length of pipes	City Public Works Department and CSD
Community Facilities and Critical Services	Community Facilities	# of: government, religious, lodges, other cultural buildings	Revell Coastal with input from County Planning Department
	Critical Services	# of: police, fire, school, medical, communication, water treatment facilities	Revell Coastal with input from City and County Planning Department
Environmentally Sensitive Habitat Area	ESHA	Types of sensitive habitats	City GP/LCP

In some cases, older data such as structures were updated using standard digitizing techniques from the most recent available aerial photograph from the Channel Islands Regional Geographic Information System (CIRGIS) Collaborative (2016). All data was checked for topological fidelity (spatial relationship), spatial accuracy, and accuracy of tabular data (attributes).

5.3 Coastal Hazards Projections

Modeling for the 2016 *Santa Barbara County Coastal Resilience Project* includes assessment of the following coastal processes:

- **Coastal Flooding:** Flooding caused by wave run-up and overtopping from a 1 percent annual chance storm.
- **Coastal Erosion:** Coastal erosion based on sea level rise and a 1 percent annual chance storm.
- **Tidal Inundation:** Tidal inundation based on a predicted monthly high tide.

Modeling methods for the Santa Barbara County Coastal Resilience Project are summarized here. Additional modeling details are available in the Technical Methods report produced as part of the Coastal Resilience modeling (Revell Coastal and Environmental Science Associates [ESA] 2016; https://maps.coastalresilience.org/california).

Coastal Resilience Hazard Modeling

The Coastal Resilience modeling methodology relies on a detailed parcel-level backshore characterization that includes backshore type, geology, and local geomorphology (i.e., elevations, beach slopes). The backshore characterization spatially analyzed approximate 100-yard alongshore spacing and then statistically represented results at an approximate 500-yard alongshore distance. Calculations of wave run-up and tides are combined to identify a total water level elevation, which then drives coastal erosion and shoreline response models (Heberger et al. 2009, Revell et al. 2011). Climate change impacts—assessed using a series of sea level rise, wave climate, and precipitation scenarios—projected potential future coastal erosion and flooding hazards (Revell Coastal and ESA 2016, Revell Coastal 2015). Projected impacts are evaluated at four planning horizons: existing (2010), 2030, 2060, and 2100. All hazards were mapped on the California Coastal Light Detection and Ranging (LiDAR) Digital Elevation model at a 2-meter (6.5 feet) spatial resolution (available from the National Oceanic and Atmospheric Administration [NOAA] Digital Coast website). The year 2010 represents the existing coastal hazards baseline as the most recent LiDAR topographic data collection used for physical geomorphic parameters and mapping was conducted in 2010.

Coastal Erosion

Erosion models projected both low-lying dune-backed erosion and cliff-backed shoreline erosion hazards (Figure 5-1).

Aerial Source: *CIRGIS and the City of Carpinteria - 2016*

Map Disclaimer: *This report is advisory and not a regulatory or legal standard of review for actions that the City of Carpinteria or the Coastal Commission may take. See note on Page xv.*

Extent of Dune and Cliff Erosion

FIGURE 5-1

Dune Erosion: The coastal dune erosion hazard modeling considered a short-term response based on the erosion from a 1 percent annual chance storm. Dune erosion included three components – potential erosion impact from 1 percent annual chance storm, erosion from sea level rise, and erosion caused by historic trends in shoreline change (as a proxy for sediment supply). In modeling dune erosion, inland extents are projected using a geometric model of dune erosion originally proposed by Komar et al. (1999) for storm impact and applied with different slopes to make the model more applicable to sea level rise (Revell et al. 2011). This method is applied in the initial Pacific Institute work and is consistent with the FEMA Pacific Coast Flood Guidelines for storm-induced erosion (FEMA 2005). Erosion models were calibrated using historic photos documenting extents of past erosion from large wave events.

Cliff Erosion: Cliff erosion modeling considered the geology and geomorphic failure mechanism inherent in each geologic unit, and then accelerated historic erosion rates based on the increase in duration of wave attack at various elevations on the cliff. The accelerated historic erosion rates for each geologic unit are then multiplied by the number of years in the planning horizon. In addition, an erosion distance based on the observed extent of existing cliff failure width was included to evaluate the effects of a cliff failure occurring at the end of the future time horizon.

Coastal Storm Flooding

The coastal storm flood modeling is consistent with FEMA's Pacific Coastal Flood Guidelines (FEMA 2005). Every 10 years, erosion projections are calculated, the topography is updated to reflect actual erosion, and areas that were eroded during this time period and thus exposed to wave flooding through newly connected overland flow pathways are considered.

Wave-induced coastal flood modeling assessed the inland extents of flooding using the method of Hunt (1959), as supported in the Shore Protection Manual (U.S. Army Corps of Engineers [USACE] 1984). This method calculates a dynamic water surface profile, nearshore depth limited wave, wave run-up elevation, and inland extent of wave run-up at the end of each representative profile (Figure 5-2).

Tidal Inundation

Tidal inundation modeling represents the Extreme Monthly High Water (EMHW) level based on the tidal statistics from water levels at the Santa Barbara Tide Gauge (EMHW = 6.55 feet North American Vertical Datum of 1988 [NAVD88]). These hazard zones show the projected maximum extent of what could be tidally inundated once a month under a given sea level rise scenario (Figure 5-3).

Aerial Source: *CIRGIS and the City of Carpinteria - 2016*

Map Disclaimer: *This report is advisory and not a regulatory or legal standard of review for actions that the City of Carpinteria or the Coastal Commission may take. See note on Page xv.*

Coastal Storm Wave Flooding from a 1% Annual Chance Storm

FIGURE 5-2

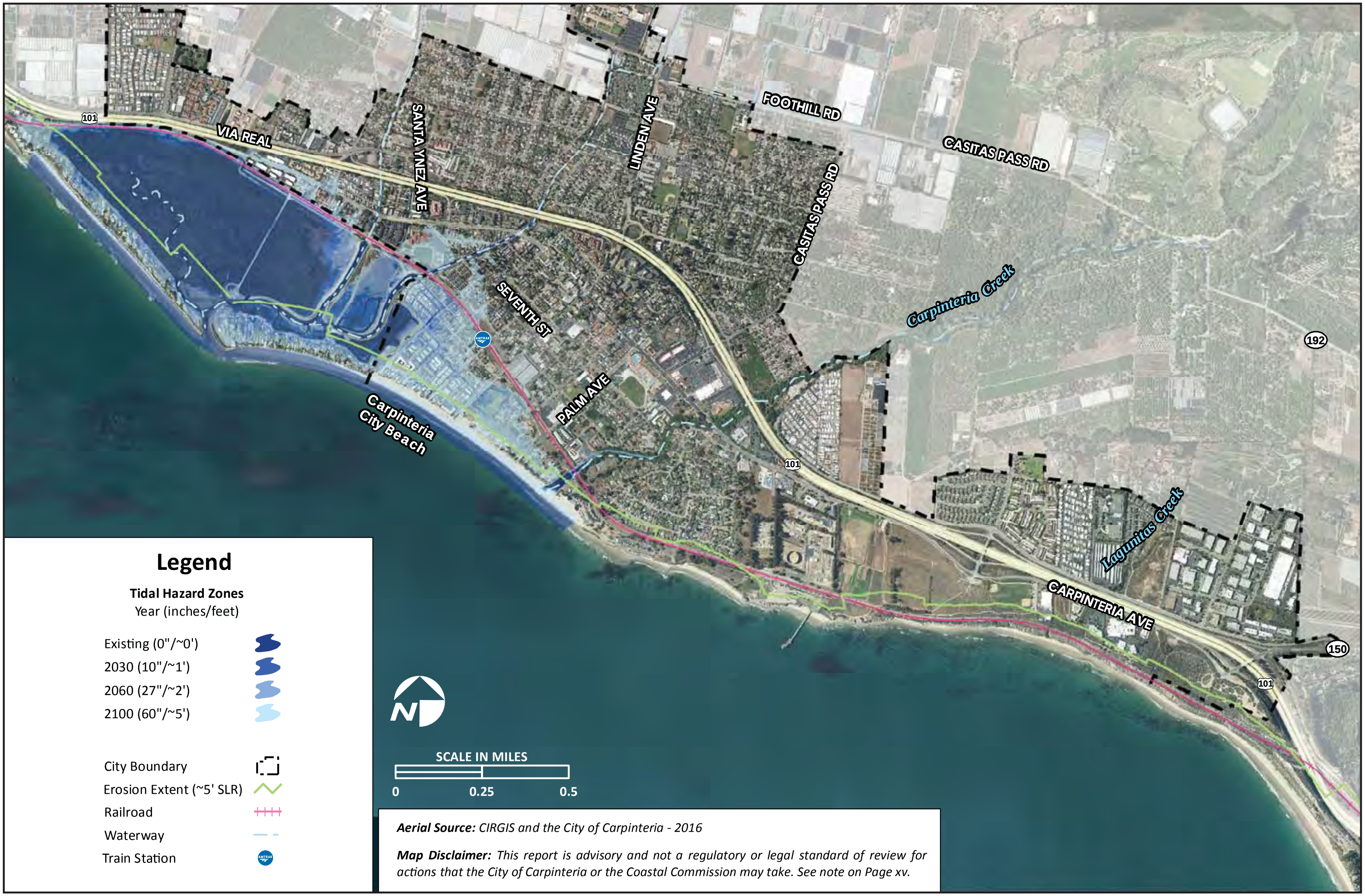


FIGURE 5-3

Tidal Inundation from an Extreme Monthly High Tide

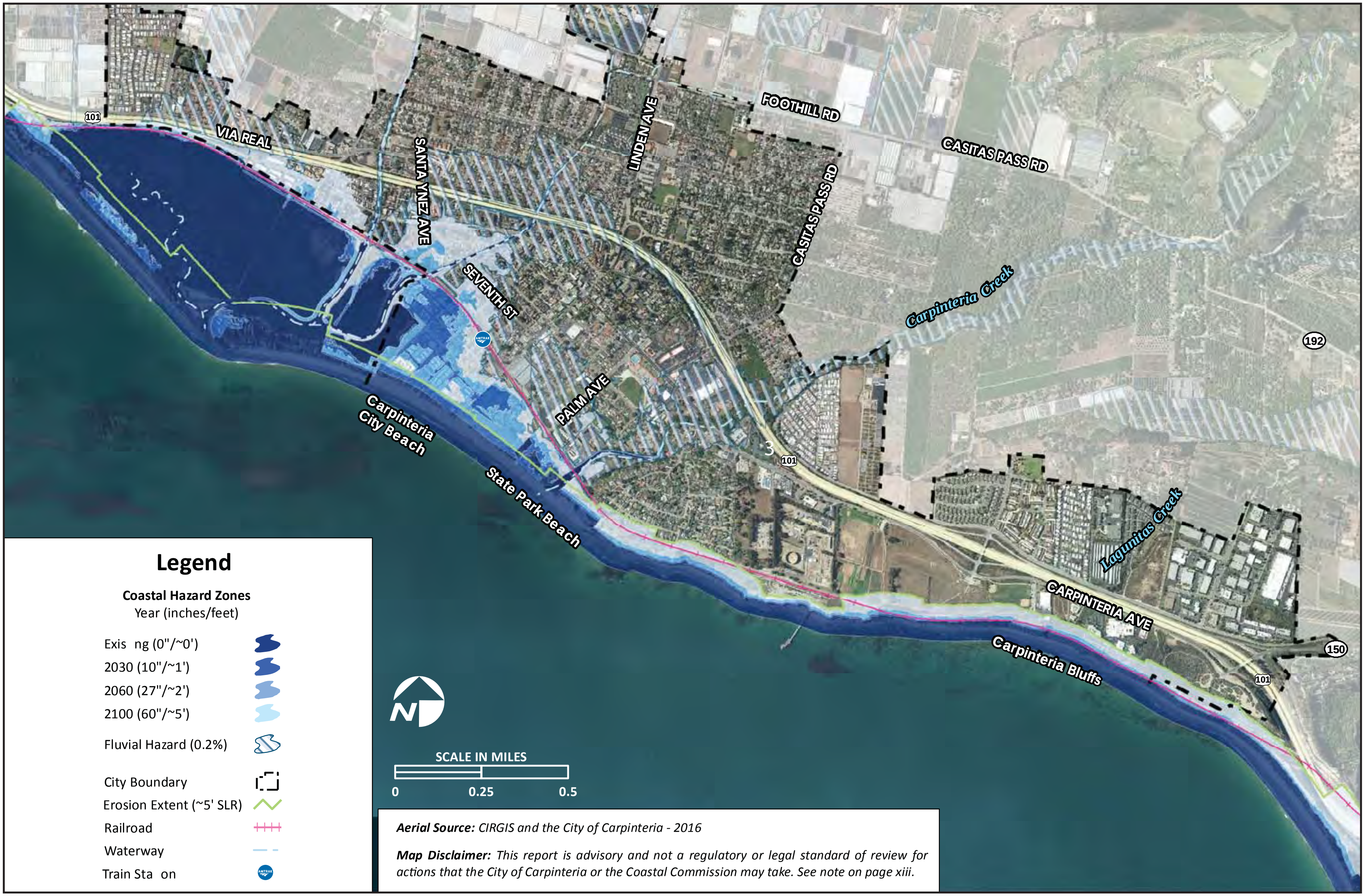
Combined Hazards

For each planning horizon, all projected hazards (except fluvial) were combined into a single hazard layer that represents the maximum extent for all of the hazard zones in the City (Figure 5-4). This combined hazard layer is displayed on all of the resource sector profiles found in Chapter 1, *Sector Profiles.*

Depth of Flooding Assumptions

The Coastal Resilience modeling did not provide depth of flooding estimates, except for future tidal inundation, so a method was devised to fill this data gap. For coastal flooding, depths were needed in the economic analysis to determine structural and content losses during large storm events. The following assumptions were used to identify specific vulnerable structures and support the economic analysis, consistent with the methodology used in the City of Oxnard *Sea Level Rise Vulnerability Assessment and Fiscal Impact Document* and the *Ventura County Resilient Vulnerability Assessment*.

- For any parcels inside the coastal erosion zone, a depth of 3 feet is assumed based on the cut-off depth of flooding in the FEMA guidelines for high velocity wave zones which cause erosion. Because the depth damage curves do not distinguish between standing water and water with momentum, scour is not considered in this analysis and these estimates may be conservative.
- For parcels outside the coastal erosion/high wave velocity hazard zone but inside the coastal flood hazard zone, the depth of flooding is assigned a value of 1 foot.
- For each planning horizon, the corresponding amount of sea level rise increase is added to the baseline depth of flooding:
  - In 2030, 1 foot is added for a total flooding depth of 4 feet in coastal erosion/high velocity wave zones and 2 feet in coastal flood zones outside the high wave velocity hazard zone.
  - In 2060, 2 feet are added for a total flooding depth of 5 feet in coastal erosion/high velocity wave zones and 3 feet in coastal flood zones outside the high wave velocity hazard zone.
  - In 2100, 5 feet are added for a total flooding depth of 8 feet in coastal erosion/high velocity wave zones and 6 feet in coastal flood zones outside the high wave velocity hazard zone.
- If at any time the coastal hazard escalates from tidal or coastal flooding to erosion, then 3 feet is added to the flood depth for that horizon year.



Aerial Source: *CIRGIS and the City of Carpinteria - 2016*

Map Disclaimer: *This report is advisory and not a regulatory or legal standard of review for actions that the City of Carpinteria or the Coastal Commission may take. See note on page xiii.*

Combined Coastal Hazards Considered in the Vulnerability Assessment

FIGURE 5-4

Modeling Assumptions

As with all modeling, assumptions had to be made to complete the work. Presented below are the modeling assumptions used in the *Santa Barbara County Coastal Hazard Modeling and Vulnerability Assessment*, which were also used for analysis in this Report (Table 5-2; Revell Coastal and ESA 2016).

Table 5-2. Hazard Model Assumptions and Biases

Geospatial Data	Potential Bias	Type of Bias	Reason for Bias
Not accounting for existing structures	Too High	Spatial	Erosion rate of sand dunes would be higher than erosion rates of asphalt roads and concrete structures.
Storm duration	Too High	Spatial and Temporal	Duration of a single storm event may not be enough to reach the maximum potential erosion distance.
2010 morphology as existing conditions	Too Low or Too High	Spatial	Management activities (e.g. winter berms) or natural events (e.g. seasonal beach cycles, post-Thomas Fire January 2018 storm debris flows) may alter the topography and the results.
Sediment supply	Too Low	Attribute	Assumes sand supply and harbor bypassing remains constant, allowing for beaches to rise with sea level. If reductions in sand supply or bypassing occur, beaches may be lost and potential hazards could be greater.

Coastal Erosion and Flood Hazard Projections Do Not Consider Existing Shoreline Protection and Development

The coastal hazard projections do not consider the influence of existing development and shoreline protection on changes to coastal erosion and coastal flood hazard projections. Instead, erosion was assumed to occur on a natural dune or cliff system without human alterations regardless of the presence of existing shoreline protection. This may result in an overstatement of some of the erosion potential, as erosion extent of a sand dune would differ than erosion extent of asphalt roads and concrete structures.

Projections of Potential Erosion Do Not Account for Uncertainties in the Duration of a Future Storm

Erosion projections assume that the coast would respond to the combination of high tides and large waves inducing wave run-up. Instead of predicting future storm-specific characteristics (waves, tides, and duration), the potential erosion projection assumes that the coast would erode under a maximum high tide and storm wave event with undefined duration. This assumption may overstate the potential dune erosion from a single storm event, and estimates should therefore be considered a maximum potential erosion distance.

Mapping of Coastal Flood Hazards Uses Geomorphology from 2010 Topography

At the time of the modeling, the most current comprehensive topographic data available was the state-funded 2009-2011 LiDAR data. Although this was the best available elevation data at the time, it only offers information on a single “snapshot” in time. This data was used to map existing and future hazards., and any changes resulting from human activities or natural episodic events (e.g. post-Thomas Fire January 2018 storm debris flows) that occurred since this topographic data was collected are not accounted for in the modeling.

Sediment Supply Remains Constant

Mapping of the coastal hazards assumes that sediment supply to the beaches remains constant. Therefore, the beach elevations and beach widths are assumed to have similar capacity to rise in elevation with sea level rise, close off the barrier beach creek mouths, and buffer wave run-up. Additionally, it is assumed that the sand being bypassed from Santa Barbara Harbor would continue with similar volumes. Given the documented trapping of sand behind dams on the Santa Maria and Santa Ynez Rivers (Willis and Griggs 2003; Patsch and Griggs 2007), as well as the debris basins throughout the small coastal drainages, this assumption is likely inaccurate. History also attests to the downcoast erosion caused when sand was not bypassed from the Santa Barbara Harbor (Revell et al 2008). The impact of this assumption is that the mapped projections of coastal hazards may underestimate the erosion and coastal flood hazard extents.

5.4 Vulnerability Assessment Methodology

The vulnerability assessment involves spatial analysis on sector data from a wide variety of sources. The sector data, sea level rise, and model selection decisions were made with input from the public, the City, and the consultant team. These decisions are documented in Appendix A. In addition, some data was obtained directly from CCC staff in order to identify appropriate resource sectors and measures of impact. The coordination with CCC staff provided insight that while there was some spatial information on shoreline protection, spatially explicit permit data for the City and official mapping of beach accesses and the California Coastal Trail alignment are currently unavailable; this required additional effort to estimate and document. All spatial data was evaluated for accuracies (Table 5-1).

All geospatial analysis was conducted in ArcGIS. For each resource sector and measure of impact, the respective data set was queried, and summary statistics were calculated by planning horizon (or sea level rise elevation) and by each type of coastal hazard.

Table 5-3. Geospatial Bias and Error

Geospatial Data	Potential Bias	Type of Bias	Reason
Land Use Structures	Too High	Spatial	Some structures are spot checked and digitized based on rooflines visible from aerials. This may overestimate the structure footprint.
Residential Land Use Parcels	Too Low	Attribute	Commonly held residential parcels (condominium, apartment, and mobile home parking lots and landscaped areas) are excluded from analysis results. These parcels have no appraisal valuation and overlap with parcels included in the analysis.
All Land Use Parcels	Too High	Spatial	Parcels that contain or abut intermittent water channels (e.g. a drainage ditch) may appear to be vulnerable to coastal flooding. The actual vulnerability to the property can only be assessed on a case-by-case basis.
All Land Use Parcels	Too High	Spatial	Some parcels are remnants of legacy legal frameworks (e.g. Spanish Land Grants) and may contain land that is currently inundated. The actual vulnerability is likely known, and these cases can only be assessed on a case-by-case basis.
Residential Units	Too High or Too Low	Attribute	Unit counts for multi-family units and large apartments are estimates based on general details from parcel attribute tables and attributes that may under- or over-predict the total number of units. All information is post-processed to ensure accuracy. In addition, assessors' data will not include illegal accessory dwelling unit additions.
Roads	Too Low	Spatial	Features are represented as linear features rather than areas.
Roads/Bus Routes/ Bike Routes/ Pipes	Too High	Spatial	Bridges may be considered in the hazard zone when they intersect flooded water channels (pipes may be cantilevered under these bridges as well). Bridge elevation is not considered in this study.
Bus Routes	Too High	Spatial	Features are represented as linear features rather than areas. Bus routes include both incoming and outgoing buses that may cover the same section of road.
Bike Routes	Too Low	Spatial	Features are represented as linear features rather than areas. The street centerline is used for bike route location.
EPA SQGs, Cleanup Program Sites	Too Low	Spatial	Location is represented as a point rather than an area.

Table 5-3. Geospatial Bias and Error (Continued)

Geospatial Data	Potential Bias	Type of Bias	Reason
Electronic Submittal of Information (ESI) Reporting Sites	Too Low	Spatial	Points are matched to the centroid of the nearest business location and the location is represented as a point rather than an area.
Drop Inlets, Outfalls, Manholes	Too High or Too Low	Spatial/ Attribute	Height relative to ground is unknown.

Vulnerability points (e.g. oil wells) and line features (e.g. roads) are determined by the spatial intersection of the various coastal hazard horizons with the various resource/infrastructure assets. Vulnerability counts for smaller polygons with specific categories (e.g. structures) are determined by dissolving the entire polygon with attributes from the first (i.e. lowest) coastal hazard horizon intersection. Therefore, if a structure is flooded across multiple horizons, only the first instance is documented. Vulnerability for larger polygons (e.g. Environmentally Sensitive Habitat Areas [ESHA], where the area affected across horizons is a relevant statistic) is determined in the same manner as points and lines. Results are collated into a master vulnerability table and summarized in the sector profiles found in Chapter 1, *Sector Profiles*. The complete vulnerability table of results can be found in Appendix B.

5.5 Economic Analysis Methodology

The economic analysis prepared for this Report estimates the economic value of assets at risk from coastal hazards, which will be exacerbated by continuing sea level rise. Understanding current and projected vulnerabilities from coastal hazards is the first step a community must take to identify appropriate adaptation pathways including development of LCP policies and regulatory strategies.

The economic analysis estimates and evaluates the impacts of three coastal hazards: 1) tidal inundation, 2) coastal erosion, and 3) coastal wave flooding. Damage estimates are separated for each of the individual sectors. The sources of all spatial data analyzed are found in Table 5-1.

While not specifically assessed, any large flooding/storm event that damages resources or assets City would have a longer-term negative effect on tourism spending and associated tax revenue that would otherwise come to the City.

Land Use Parcels and Structures

For land and structures subject to property tax (i.e., land/structures not owned by a governmental entity or non-profit entity), this Report uses Santa Barbara County parcel data from 2017, which contains detailed information on the size of the parcel as well as the size of the structure. In California, any increase in the assessed value of the land/structure is capped at 2 percent a year by Proposition 13 until the parcel is either resold or improved. Since the rate of housing inflation in Carpinteria has exceeded 2 percent for many years, the original sale price of the parcel (land and structures) was adjusted to estimate current market value of the property using a housing price index (HPI) from local housing sales data created specifically for this Report. Due to a lack of more reliable or adequately refined price indices, this Report also updated non-residential parcel values using the Consumer Price Index for real estate sales (Zillow 2018; U.S. Bureau of Labor Statistics 2018).

Fiscal Land Use Impacts were assessed by:

1. Escalating County Assessors database to Fair Market Value (2017 $)
2. Estimating losses due to sea level rise/storms/ coastal erosion (2017 $)
    - Erosion impacts based on percentage of land and structural damage
    - Flooding impacts based on depth of flooding and replacement

This Report assumes a complete loss for small residential parcels (< 0.25-acre) subject to coastal erosion, but assumes that larger open space parcels such as State and City Parks and land trusts diminish in value in proportion to the amount of land subject to erosion. This method may overstate existing damages since several of the City's oceanfront parcels have multiple condominiums, apartments, or other accessory structures on them.

For coastal flooding, this Report applies the USACE depth damage curves for losses to residential and other buildings based on projected flood depths from the coastal flood hazard modeling. Since these curves are calibrated for standing water, they may underestimate the damage caused by rapidly moving waves during a large coastal storm event (USACE 2003).

For tidal inundation, this Report identifies which parcels are subject to tidal inundation during various time horizons. However, it should be noted that many properties in Carpinteria and elsewhere are already subject to tidal inundation, particularly on the oceanfront where many parcels have a Mean High Water (MHW) tideline property boundary. There are currently no standards for evaluating tidal inundation or determining when a property may become red-tagged and deemed uninhabitable. Minor tidal inundation may be considered a nuisance, but it likely impacts (lowers) the value of the property. Precisely how much tidal inundation impacts property values is unknown. This Report presents data on total "property at risk" from tidal inundation.

Flood damages to structures are estimated by applying the USACE depth damage curves, which approximate flood damages as a percentage of the total value of the structure. The USACE method also estimates the average damage to the contents of the structure; e.g. furniture, appliances, and other contents (USACE 2003).

One limitation of using parcel data is that parcels such as those owned by local, state, or federal government agencies (e.g. schools, post offices, city hall, administration buildings, etc.) or non-profits are not subject to property tax. For these properties, this study estimated the value of land using data provided by the County for recent land acquisitions by government and non-government agencies. Because some of these government transactions may be below market value, the estimates for the loss of such potentially undervalued land should be considered a lower bound. Additionally, non-assessed parcels typically do not have information regarding onsite structures onsite, and thus it is likely that this Report's estimates do not include all structures on non-assessed parcels.

Roads and Parking

This Report identified portions of existing roads in the City that could be subject to erosion and flooding. Where erosion occurs, it assumes that these roads would be removed and replaced with the cost of road removal and replacement based on engineering construction costs. However, this Report does not estimate the cost of land acquisition for roads, which could be high, nor does it consider costs for elevating roads. Additional study is warranted to fully estimate costs to repair or relocate roadways that are vulnerable to coastal hazards, and will be further refined as part of the City's California Department of Transportation (Caltrans) Sea Level Rise Transportation Policy and Infrastructure Adaption Planning Grant. Further, this Report does not estimate economic losses from delays due to impaired traffic on roads subject to flooding, or if employees working in the City cannot commute from neighboring jurisdictions. Because U.S. Highway 101 is subject to flooding, there is a significant potential for non-estimated costs including lost work days and extra travel expenses.

Public Transportation

This Report did not estimate economic losses from public transportation disruptions; it only reports the distances of potentially vulnerable routes.

Camping and Visitor Accommodations

This Report relies on attendance data from State Parks (2017) to estimate camping and other attendance at Carpinteria State Beach. For Carpinteria City Beach, this Report relies on beach attendance data from BEACON (2009), adjusted for population growth in the County and California. Using these attendance estimates, in conjunction with survey data (King and Symes 2004; BEACON 2009), this Report provides estimates of current recreational value, local spending, and tax revenue to the City generated by beach-related spending. The Report also describes the potential for losses in camping and beach recreation due to coastal flooding, erosion, and tidal inundation.

This Report also identifies the key economic (spending) and tax impacts from loss of coastal recreation. Coastal recreation generates a great deal of economic activity, including sales and transient occupancy taxes (TOT) for the City and its residents (the current TOT for Carpinteria is 12 percent). This Report focuses on the economic value of beach visitation using the standard metric Day Use Value. This Report estimated spending on beach recreation based on estimates from BEACON (2009) as well as King and Symes (2004), which show consistent spending patterns for beach recreation. All spending estimates were updated using the U.S. Consumer Price Index to reflect 2017 prices (U.S. Bureau of Labor Statistics 2018). Differences in spending at different beaches depend primarily on whether visitors are overnight visitors that rent accommodations within the City (generally from outside the Carpinteria Valley) or day-use visitors from within the region. Since campground users do not generate TOT for the City, spending for these visitors was treated differently.

Presently, many of the oceanfront properties in the Beach Neighborhood are short-term vacation rentals and contribute a substantial amount to the City tax base from TOT. The specific properties which are short-term vacation rentals are not parcel specific but rather specified in certain areas in the Beach Neighborhood. A significant portion of visitors to Carpinteria City Beach stay overnight, so any diminishment in short-term vacation rentals could impact beach tourism and associated spending and tax revenues (BEACON 2009). Results of the first year of the Short-Term Rental program are summarized in Chapter 6.3, *Camping and Visitor Accommodations*.

Coastal Access and Trails

Data on coastal trail use is extremely limited. This Report uses the scarce available data to identify the length of coastal trails subject to flooding and erosion. However, estimating usage on the portions of coastal trails subject to erosion or flooding is beyond the scope of this Report. The economic losses associated with the loss of coastal trails can be estimated in several ways. First, the replacement cost of the trail could be estimated, assuming that the City would replace these trails. The City of Goleta's *Coastal Vulnerability and Fiscal Impact Assessment* (2015) estimated the replacement cost of trails per linear foot, based on a recent trail project. However, the cost of replacing a trail varies significantly based on alignment and materials needed, and thus using one standard unit cost is not always accurate. In addition, municipalities may decide not to replace or improve existing coastal trails. Given this uncertainty, this Report only reports length of trail lost (see Chapter 6.4, *Coastal Access and Trails*).

Hazardous Materials Sites, and Oil and Gas Wells

This Report identified various hazardous materials sites, including small business and light industrial sites, oil and gas wells, and active clean-up sites (Table 5-1). However, due to lack of data availability it did not attempt to quantify all of the costs involved, such as permitting, mitigation, and site restoration.

The City has a wide array of oil and gas infrastructure, much of it in the form of legacy inactive wells and associated infrastructure. For example, the former oil processing facility within Carpinteria Bluff 0 contains oil storage, processing and cleaning facilities used to support offshore oil production. While this Report does identify these sites and structures, the economic analysis only evaluates sites and structures to the extent to which data is available. In many cases little data about the cost of mitigation was available.

The City also contains other hazardous materials sites, including four sites designated by the EPA as "small quantity generators" (SQGs) of hazardous waste such as dry cleaners and gas stations. One issue with hazardous materials that cities should consider is their potential liability, especially if hazardous materials are released into the environment. This economic analysis identifies these sites as a potential liability for the City, should the responsible party go bankrupt or otherwise default. Typically, the costs of cleanup for these sites are much higher after a release occurs.

In addition to abandoned or previously capped legacy wells in the City, there are several other oil wells offshore of the City. These wells represent a danger given the combustible chemical nature of their historic use; should the cap on a well fail, an event which has happened previously in Summerland. This Report uses estimates of recent flood cleanup and mitigation efforts (e.g., 2015 Plains All American Pipeline Oil Spill at Refugio State Beach) to provide an estimate of the potential for possible remediation and damages, which should not be considered a worst-case scenario.

Although estimates for damages to hazardous materials sites and oil and gas wells are not identified due to lack of data, this is not an indication that these issues should be ignored. The potential for serious groundwater contamination, leakage of toxic material, and other damages could be considerable and should be studied further.

Storm water Infrastructure

Storm water infrastructure data (Table 5-1) was evaluated for each hazard type, using the GIS methods described in Chapter 5.4, *Vulnerability Assessment Methodology*. Critical City infrastructure including storm water pipes were valued at replacement cost. The cost of infrastructure replacement was estimated using publicly available data including the City's Capital Improvement Program (2017) as well as other available data described in Table 5-4. While the cost of storm water infrastructure replacement has been estimated, ongoing coordination with the City and County is being conducted to further refine the final cost estimates of replacement. Given this ongoing coordination effort, the economic costs of storm water infrastructure replacement are not presented in this Report.

This Report also identified and estimated the flood costs to structures – residential structures in particular – and applied estimates of flood cleanup costs from the USACE depth damage curves (USACE 2003a; USACE 2003b). However, flooding entails numerous other costs that this Report was not able to quantify, including the costs of debris cleanup and the costs of road closures (in terms of lost time and the inability of employees to get to work on time). Given these uncertainties, this Report provides no specific estimates for the costs of flood cleanup, though it does provide recent estimates of flood cost cleanup for other municipalities in the region. For example, debris cleanup costs from the 2017 Thomas Fire, and 2018 Montecito debris flows could be used to improve these estimates. Similarly, the City of Goleta identified flood cleanup costs for the 2005 and 1998 floods as $500,000 and $4 to $5 million (in 2017 dollars) respectively.

Wastewater Infrastructure

Wastewater infrastructure data (Table 5-1) was evaluated for each hazard type, using the GIS methods described in Chapter 5.4, *Vulnerability Assessment Methodology*. Critical City infrastructure including wastewater infrastructure was valued at replacement cost. The cost of infrastructure replacement was estimated using publicly available data including the City's Capital Improvement Program (2017) as well as other available data found in Table 5-4. The cost of replacing sewer pipes was estimated from an engineering cost study for the CSD's *Wastewater Master Plan* (Dudek and Associates 2005).

Water Supply Infrastructure

Water supply infrastructure data (Table 5-1) was evaluated for each hazard type, using the GIS methods described in Chapter 5.4, *Vulnerability Assessment Methodology*. Critical City infrastructure including water supply infrastructure was valued at replacement cost using the City's Capital Improvement Program (2017) as well as other available data found in Table 5-4. The cost of replacing water pipes was estimated from an engineering cost study for the CSD's *Wastewater Master Plan* (Dudek & Associates 2005).

Community Facilities and Critical Services

Community facilities and critical services data (Table 5-1) was evaluated for each hazard type, using the GIS methods described in Chapter 5.4, *Vulnerability Assessment Methodology*. The community facilities were extracted from the County Assessor's parcel data land use category.

Environmentally Sensitive Habitat Areas (ESHA)

Performing Geographic Information System (GIS) analysis of acreages on dated and generalized mapped habitats substantially lessens the accuracy of estimations for habitat vulnerability or complex ecological interactions, changing physical processes, and other climate variables. All habitats could be affected by climate change.

ESHAs were evaluated qualitatively by interpreting the range of potential climate variables and their cumulative impact on the various ESHA habitats. There was no habitat evolution modeling conducted, and a review of recent literature on wetland habitats (Largier et al 2010, Coastal Ecosystem Vulnerability Assessment [CEVA] 2017) as well as regional observations from the current extended drought were extrapolated to provide interpretation. Additional work including revised mapping is strongly recommended.

Additionally, beaches and other coastal ecosystems have many other benefits not incorporated in this Report, such as the ability to buffer storm waves, filter water, or provide shade and cooler temperatures for sensitive fish species. However, the inability of this Report to quantify the economic value does not indicate a lack of value. The City should consider the loss or degradation in sensitive biological resources when evaluating different adaptation options, although economic valuation may be difficult given the limited habitat and climate data available for this analysis. Ongoing planning analysis related to the CLUP/GP Update and the Caltrans Sea Level Rise Transportation Policy and Infrastructure Adaptation Planning Grant should refine the extent of sensitive resources, as well as the effects of sea level rise upon such resources.

5.6 Cost Estimates Used in the Economic Analysis

Table 5-4 summarizes the measures used to estimate the costs employed in this Report.

Table 5-4. Economic Cost Estimates Used in this Report

Item	Cost/Value	Cost Basis	Source
Road Replacement	$280	per linear foot	Environmental Science Associates (2016)
Railroad Replacement	$340	per linear foot	Compass International Inc. (2017)
Water Pipeline Replacement	$230	per linear foot	Dudek & Assoc. (2005)
Sewer Pipeline Replacement	$230	per linear foot	Dudek & Assoc. (2005)
Wastewater Lift Station	$1,000,000	per lift	Ventura County Public Works Agency (2016)
Property Tax Parcel	Updated with HPI	Sale Price	Zillow (2018), Federal Reserve Economic Data (2018)
Flood Damages to Buildings	Current Market Value	Depth Damage Curves	USACE (2003)
2005 Goleta Flood Clean Up Costs	$500,000	Goleta	City of Goleta (2015)
1998 Goleta Flood Clean Up Costs	$4-5,000,000	1998 flood adjusted	City of Goleta (2015)
Capping Oil well-on land	$100,000	per well	City of Goleta (2015)
Capping Oil Well-in water	$800,000	per well	City of Goleta (2015)
Refugio Oil spill costs	$257,000,000	total cost	Los Angeles Times

These values were obtained in the following three ways:

- The County Assessor Parcel Data was updated to accurately reflect the market value of the parcel/structures and the replacement value of the structures in the City.
- This Report includes data obtained from the City as well as state and County officials (Table 5-1).
- Finally, standard cost estimates were used to estimate other costs (e.g., cost of replacing sewer lines) as obtained from the sources indicated in Table 5-4.

5.7 Assumptions Used in the Economic Analysis

The economic analysis of the Land Use Parcels and Structures sector contained in this Report is based upon the best available economic data today. There remain, however, limitations in this analysis. First, the analysis depends crucially upon future projections of erosion and flooding, which are subject to uncertainty. Second, the damage curves used for flooding from the USACE may underestimate the actual damages caused by waves with a high velocity.

Furthermore, this Report's analysis of tidal inundation only examines combined property that is exposed or at risk (land and structure values) since there is no widely accepted method for estimating the damages and losses from tidal inundation.

This Report evaluated losses to the Roads and Parking sector solely in terms of replacement cost. A more detailed analysis of reductions in economic activity and other economic impacts was beyond the scope of this Report. Similarly, the Public Transportation sector was evaluated solely in terms of potential flooding and erosion to bus and bike routes along with losses to UPRR line along the Carpinteria Bluffs.

This Report's analysis of the Camping and Visitor Accommodations sector provides information on current beach recreation and projects future demand based on population growth. Beach erosion, or flooding and erosion losses to parking lots or access roads may, however, limit future beach recreation. As indicated, many residential structures in the Beach Neighborhood are short-term vacation rentals. Further study of the impacts of coastal erosion and flooding on beach recreation is warranted. While this Report does provide preliminary estimates of potential camping loss due to erosion and flooding, these results need additional refinement before substantive use by decision makers.

While the analysis of the Coastal Access and Trails sector examines the length of trails impacted by flooding and erosion, it does not estimate the loss in recreation or the cost of replacing these trails, as necessary data on levels of use, types of trails and specific costs was not available.

This Report's analysis of the Hazardous Materials Sites, and Oil and Gas Wells sector indicates that the City has several hazardous material sites including inactive legacy oil and gas wells and facilities, most notably the oil and gas processing facilities at Bluff 0. Although the liability for mitigating these sites does not lie with the City, the costs of mitigating these sites will likely be high and the City should be aware of potential negative consequences.

This Report estimated the cost of replacing certain storm water, wastewater, and water supply infrastructure components, most notably pipes damaged by erosion based on available data. However, the full costs of repairing valves, hydrants, pressure regulators, etc. or rerouting this infrastructure is not included in this Report.

Table 5-5 identifies the potential biases in the economic methods and estimates contained within this Report, and attempts to determine the direction of the bias. Some of this Report's estimates (e.g., property damages from tidal inundation) may overstate the actual impacts. Other estimates of damages to infrastructure and hazardous materials may not include all components or costs, and thus may be too low. A sensitivity analysis of the impact of changing these assumptions would help clarify the impact of these biases on the results, although this was beyond the scope of this Report.

Table 5-5. Economic Bias and Error

Sector Type and/or Coastal Hazard	Potential Bias	Reason
Property damage from Tidal Inundation	Too High	Many coastal structures already elevated. Assumes total exposure of all structures on parcel if any parcel is exposed. Damage and repair cost metrics unavailable.
All damage from Coastal Flooding 1% Annual Chance Storm	Too Low	Flooding damage curves do not account for wave velocity. 1% annual chance storms may become more frequent or severe. No actual City cleanup cost data available.
Multifamily Unit damage from Coastal Flooding 1% Annual Chance Storm	Too High	Only part of parcel may be flooded/eroded.
Property damage from Coastal Erosion 1% Annual Chance Storm	Too High	Assumes total loss of entire parcel and all structures for parcels less than 0.25-acre.
Damages to Infrastructure	Too Low	Rerouting pipes, roads, etc., not factored in completely. Cost of land acquisition not factored in. Cleanup costs to infrastructure unavailable for 1% annual chance storms.
Beach Recreation	Too High	Substitution to other beaches/sites not accounted for. Does not account for loss in recreation value due to narrowing of beach width which will largely depend on choice of future adaptation strategies.
Beach Recreation	Too Low or Too High	Demand for beach tourism may grow more or less than population/economy.
Hazardous Materials	Too Low	Mitigation may be more expensive, especially if hazards are not mitigated before a severe storm.

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