Appendix E

Benefit Cost Analysis Technical Memorandum

APPENDIX E

Benefit Cost Analysis Technical Memorandum

E.1 Why Conduct a Benefit Cost Analysis?

Benefit cost analysis is an analog to investment analysis in the private sector. It compares future gains from some expenditure of resources and tries to identify the options that have the greatest future gains over and above the initial costs. But unlike a private sector firm, where revenues from sales of a product can be compared to the fixed and variable costs of supplying the product, benefit cost analysis uses the values of public and quasi-public goods and services[1] which there are complex mixtures of priced and unpriced goods and services.

The cost per mile of operating a motor vehicle can be derived from the amount of fuel consumed and the price of fuel. But the value of the time lost to delay has to be measured by a "shadow price," that is an observable value that may be considered to reflect what a price would be if one existed.(Mishan 1976) The use of an average hourly wage, or a proportion thereof, as a shadow price for the value of time lost in delayed traffic is an example.

There are several important advantages to undertaking a benefit cost analysis. One is a requirement for consistency and transparency. A key rule is that a change in economic value can only be a cost or a benefit; it cannot be both in the analysis of the same scenario. This means, for example, that employees hired to construct the highway must be considered a cost of the project not a benefit. To do so would provide no useful guidance as to economic consequences; if $1.00 were spent to hire someone to work on the highway and that $1.00 also counted as benefits, the net would be zero. Employment may be accounted for in separate analyses of the changes in the output of

1 Public goods are, by definition non-excludable in production and nonrival in consumption. That is, once produced a public good is available to all and any one person's consumption of the good does not diminish other's ability to enjoy the good. Elkhorn Slough's ecosystem services such as juvenile fish habitat, are public goods. Quasi-public goods have some but not all characteristics of a public good. Highway 1 is open to everyone, but there is a rivalry for space (congestion) that does reduce the ability of everyone to enjoy the mobility services provided by the highway.

goods and services in an economy (called an economic impact analysis), but this is a different accounting system from benefit cost analysis.

Secondly, benefit cost analysis allows the comparison of very different types of effects that would usually not be considered together. In this study, the effects on drivers, people who enjoy seeing sea otters in the wild, and the economic importance of wetlands can be brought together to see which factors are likely to be most important in shaping the economic outcomes of decisions on how to adapt to sea level rise at Highway 1 and Elkhorn Slough.

Third, benefit cost analysis inevitably deals with issues of great uncertainty, all the more so with an issue like climate change and sea level rise. Benefit cost analysis can address this by placing the analysis within a probability framework the consequences of the inherent uncertainty in all such analysis can be explored and more precise expression of risks used to inform the analysis.

There are also limitations, primarily related to issues of data availability and measurement. Discussions of benefit cost analysis frequently focus on the dollar values used for the various effects of changes brought about by a particular decision. While the dollar values are very important in a benefit cost analysis, the most influential factors determining the outcomes of the analysis are usually related to the estimates of the number of people affected, positively or negatively, by the options considered. For this reason, benefit cost analysis usually requires the integration of economic information about the monetized values of changes with the outputs of other types of models that estimate changes in effects. The result is requirements for substantial amounts of data, which is rarely available in the precise forms needed for a perfect set of measurements.

Benefit cost analysis cannot answer all questions about difficult choices like adaptation for Highway 1. It can make clearer the consequences of choices and identify strong and weak points in the arguments about alternative policy choices. That increased clarity arises from understanding how the benefit cost analysis is constructed.

E.2 Sources and Calculations

In this section, the assumptions, sources and calculations of each of the elements of the benefit cost analysis are identified. This is essential to understanding the results discussed above. The scenarios are as defined above:

- *Scenario C0 (No Action)* - No action is taken to adapt Highway 1 to sea level rise.
- *Scenario C1 (2-Lane Elevated Highway)* - Highway 1 is elevated on fill or piles to a height above projected sea level with 2 lanes retained.

- *Scenario C2 (Managed Retreat/Widening G12*) - Highway 1 is abandoned as a through-road and through north-south traffic is rerouted to Highway 101 and San Miguel Canyon Road (G12), both of which are widened to accommodate the increased traffic.

- *Scenario C3 (4-Lane Elevated Highway)* - Similar to C1 but Highway 1 is widened to 4 lanes through Moss Landing.

E.2.A Expenditures on Highway Projects

The expenditures on the highway were estimated by WMH, who served as the highway engineering firm for the project. WMH assumed a 10-year project planning and development period, with two years for project initiation, three years for project plans and reviews, two years for final design and engineering specifications and three years for construction. Their estimates are shown for each adaptation scenario considered in Table E-1:

TABLE E-1
HIGHWAY RELATED EXPENDITURES

	Phase	**Scenario C1 (2-Lane Elevated Highway)**	**Scenario C2 (Managed Retreat/Widening G12)**	**Scenario C3 (4-Lane Elevated Highway)**
1	Project Initiation	$0.71	$0.84	$0.93
2		$0.71	$0.84	$0.93
3	Project Approval and Environmental	$7.07	$8.41	$9.30
4		$7.07	$8.41	$9.30
5		$7.07	$8.41	$9.30
6	Plans Specification and Estimates	$30.99	$36.83	$40.73
7		$30.99	$36.83	$40.73
8	Construction	$161.87	$192.39	$212.75
9		$161.87	$192.39	$212.75
10		$161.87	$192.39	$212.75
Total Highway		**$570.24**	**$677.74**	**$749.46**

E.2.B Expenditures on Wetlands

The wetlands-related projects consist of two broad strategies. One is to create ecotones as part of the elevation and expansion options of Highway 1. The cost of these ecotones varies depending on whether Highway 1 is elevated on fill or on piles. The other major strategy is to elevate and fill a 700-acre section of wetlands in the upper reaches of Elkhorn Slough near the point where the Union Pacific rail line crosses the Slough. Estimates for these costs were provided by ESA. For purposes of the analysis the expenditures on these projects were assumed to coincide with the three years of highway construction in the adaptation scenarios, although the railroad marsh restoration project could in fact take place independent of the highway project.

Ecotones: Reach 2 of Highway 1 on fill or on piles included earth fill with flattened slopes to raise existing wetland grades and provide migration space for habitat with sea-level rise. Estimated imported earth fill amounted to 750,000 cubic yards and 80 acres of planting. With mobilization, environmental protection during construction and a 30% contingency, the estimates amounted to $124 Million for the road on piles and $130 Million for the road on fill. The similar quantities and costs are due to essentially the same footprint of fill. The costs of the roadway are not included in the ecotone costs.

Marsh Restoration: The ESA estimates were based on a rough estimated unit cost of $100,000 (2018 dollars) per acre to raise an existing tidal wetland 3 feet vertically with imported fill, based on the cost of Hester Marsh (for more information see Fountain and others 2019 [2]). The unit cost was escalated and applied to North/Estrada Marsh Complexes and Azevedo Ponds, and doubled for Parsons Slough owing to its lower elevation, resulting in a fill volume of 5.1 Million cubic yards. Infrastructure elements included raising Elkhorn Road to be above high tides and increases for mobilization, environmental protection during construction and a 30% contingency. The approximately 700 acres of wetland enhancement with improvements to Elkhorn Road is estimated to cost about $250 Million.[3]

Table E-2 shows the estimates of wetlands related costs. Table E-3 shows total project costs combining highway and wetlands aspects. Table E-3 divides options Scenario C1 (2-Lane Elevated Highway) and Scenario C3 (4-Lane Elevated Highway) into sub-options based on the approach to elevating Highway 1.

---

[2] Fountain, M., Jeppesen, R., Endris, C., Woolfolk, A., Watson, E., Aiello, I., Fork, S., Haskins, J., Beheshti, K., Wasson, K. Hester Marsh Restoration. Annual Report 2019. Elkhorn Slough National Estuarine Research Reserve. Available from https://www.elkhornslough.org/tidalwetland-program/

[3] A key question is the availability of earth for these fills amounting to 6 million cubic yards. As sea levels rise, earth fill may become a commodity of increasing value owing to the need for fill to adapt to higher sea-levels. Escalation of earth fill value was not estimated.

TABLE E-2
WETLANDS RELATED EXPENDITURES

<table>
<tr><th></th><th>Phase</th><th>Scenario C1 (2-Lane Elevated Highway)</th><th>Scenario C2 (Managed Retreat/ Widening G12)</th><th>Scenario C3 (4-Lane Elevated Highway)</th></tr>
<tr><td rowspan="3">Wetlands</td><td>Ecotones for Piles</td><td>$128.47</td><td rowspan="2"></td><td>$128.47</td></tr>
<tr><td>Ecotones for Fill</td><td>$119.13</td><td>$119.13</td></tr>
<tr><td>Restoration</td><td>$221.78</td><td>$221.78</td><td>$221.78</td></tr>
</table>

TABLE E-3
TOTAL PROJECT EXPENDITURES

<table>
<tr><th></th><th>Phase</th><th>Scenario C1 (2-Lane Elevated Highway)</th><th>Scenario C2 (Managed Retreat/ Widening G12)</th><th>Scenario C3 (4-Lane Elevated Highway)</th></tr>
<tr><td rowspan="2">TOTAL PROJECT</td><td>With Piles</td><td>$920.49</td><td rowspan="2">$899.52</td><td>$1,099.71</td></tr>
<tr><td>With Fill</td><td>$911.15</td><td>$1,090.37</td></tr>
</table>

E.2.C Travel Delay

Passenger Delay

The analysis of the effects on traffic was done with the AMBAG Regional Travel Demand Model (RTDM) described above. The geographic focus of the changes in the characteristics of highway travel was in the project area of interest, a rectangle within the RTDM network. The area of interest (AOI) is depicted in Figure E-1.

In the RTDM, delay hours are estimated by comparing the estimated number of vehicles on a particular stretch of road on a given day and hour to the capacity of that stretch of road. The number of vehicles is driven by the number and purpose of trips generated by the population and

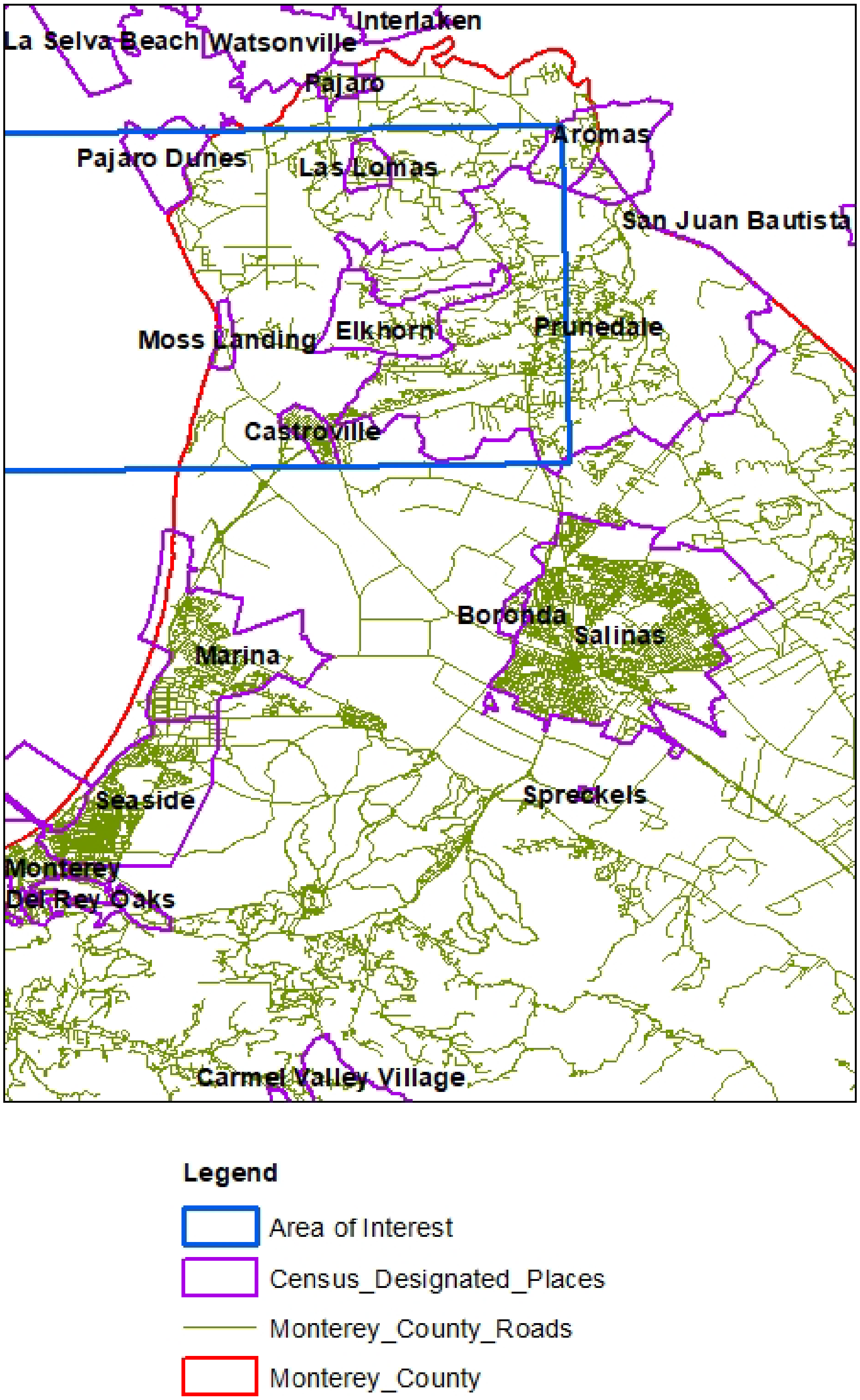

Figure E-1
Area of Interest for Travel Analysis

employment of the transportation analysis zones (TAZs) in the region as a whole. Capacity is calculated as a function of the posted speed limit and the number of lanes in each road segment.

If more trips are taken during certain periods, such as the morning and afternoon commuting periods, the RTDM calculates congestion as reductions in speed and the reductions in speed relative to normal speed (defined as the posted speed limit translate into hours of delay, which can then be cumulated across all roads in the area of interest, and then adjusted to annual totals for the region.

The resulting changes in the hours of delay for each scenario are shown in Table E-4. These represent the comparison of the no action scenario with the base case scenario for 2040 adjusted for population growth (as described below), and the comparisons of the C1 - C3 scenarios with Scenario C0 (No Action). Table E-4 also shows the distribution of trips by purpose for the AMBAG region as a whole and the consequent distribution of delay hours by trip purpose (the percent of trips by purpose times the total delay hours in each scenario).

TABLE E-4
CHANGE IN ANNUAL HOURS OF DELAY BY TRIP PURPOSE AND SCENARIO

			Change in Annual Hours of Delay by Trip Purpose			
		Share of Trips	**Scenario C0 (No Action)**	**Scenario C1 (2-Lane Elevated Highway)**	**Scenario C2 (Managed Retreat/Widening G12)**	**Scenario C3 (4-Lane Elevated Highway)**
Home Based	Work	12.3%	(22,687)	25,093	39,705	(127,678)
	Shop	7.9%	(14,516)	16,055	25,404	(81,692)
	School	4.0%	(7,456)	8,246	13,049	(41,960)
	University	1.5%	(2,773)	3,067	4,853	(15,605)
	Other	33.7%	(62,221)	68,820	108,895	(350,170)
Non-Home Based	Work	7.6%	(14,026)	15,514	24,548	(78,937)
	Other	22.9%	(42,176)	46,649	73,813	(237,360)
Visitors	Shop	6.7%	(12,350)	13,660	21,614	(69,505)
	Tourist	3.4%	(6,210)	6,868	10,868	(34,948)
	Total	100.0%	(184,414)	203,971	322,748	(1,037,854)

To translate the change in delay hours to dollar values, the average hourly wage for the region is used as a measure of the opportunity cost of time.(American Association of State Highway and Transportation Officials 2003) For this study that hourly wage is estimated as $34.77 per hour, which is a weighted average of the average hourly wage plus supplements to wages (benefits) for the Monterey-Santa Cruz County region, calculated as follows:

Table E-5 shows the average weekly wage for Monterey and Santa Cruz counties as reported by the Quarterly Census of Employment and Wages (QCEW) from the Bureau of Labor Statistics (www.bls.gov). The average hourly wage was calculated as the average weekly wage divided by 35 hours. Information about actual average hours worked per week is not available, so a lower amount of hours than 40 per week to reflect part time employment.

TABLE E-5
CALCULATION OF AVERAGE WEEKLY WAGE

	Average Weekly Wage	Average Hourly Wage	Wage Supplement Rate	Total Hourly Compensation
Santa Cruz	$986.00	$28.17	29.3%	$36.42
Monterey	$924.00	$26.40	27.4%	$33.62
Weighted	$946.56	$27.04		$34.77
Hours Per Week	35			

The weights in Table E-5 are shown in Table E-6. The weights are derived from the total annual wages for Monterey and Santa Cruz counties from the Quarterly Census of Employment and Wages.

TABLE E-6
WAGE WEIGHTS

	Total Annual Wages	Weight
Santa Cruz	$5,373,743	0.364
Monterey	$9,396,529	0.636
TOTAL	$14,770,272	

Supplements to wages were estimated from the personal income data for the Salinas and Santa Cruz-Watsonville metropolitan statistical areas from the Bureau of Economic Analysis (www.bea.gov). The ratio of wage supplements to wages provided the adjustment rate for supplements to wages.

Table E-7 shows the distribution of adjustments to wages by trip purposes from Table E-4.

TABLE E-7
ADJUSTMENTS TO WAGE-BASED VALUE OF TIME BY TRIP PURPOSE

		Share of Average Hourly Wage Assigned to Trip Purpose			
		Scenario C0 (No Action)	Scenario C1 (2-Lane Elevated Highway)	Scenario C2 (Managed Retreat/Widening G12)	Scenario C3 (4-Lane Elevated Highway)
Home Based	Work	50.0%	50.0%	50.0%	50.0%
	Shop	70%	70.0%	70.0%	70.0%
	School	50%	50.0%	50.0%	50.0%
	University	70%	70.0%	70.0%	70.0%
	Other	50%	50.0%	50.0%	50.0%
Non Home Based	Work	100%	100.0%	100.0%	100.0%
	Other	50%	50.0%	50.0%	50.0%
Visitors	Shop	50%	50.0%	50.0%	50.0%
	Tourist	50%	50.0%	50.0%	50.0%

The resulting estimates of changes in the value of delay are shown in Table E-8:

TABLE E-8
CHANGES IN VALUE OF TIME FOR DELAY BY SCENARIO AND TRIP PURPOSE ($ MILLIONS)

		Scenario C0 (No Action)	Scenario C1 (2-Lane Elevated Highway)	Scenario C2 (Managed Retreat/Widening G12)	Scenario C3 (4-Lane Elevated Highway)
Home Based	Work	-$0.39	-$0.44	-$0.69	$2.22
	Shop	-$0.35	-$0.39	-$0.62	$1.99
	School	-$0.13	-$0.14	-$0.23	$0.73
	University	-$0.07	-$0.07	-$0.12	$0.38
	Other	-$1.08	-$1.20	-$1.89	$6.09
Non Home Based	Work	-$0.49	-$0.54	-$0.85	$2.74
	Other	-$0.73	-$0.81	-$1.28	$4.13
Visitors	Shop	-$0.21	-$0.24	-$0.38	$1.21
	Tourist	-$0.11	-$0.12	-$0.19	$0.61
	TOTAL	-$3.57	-$3.95	-$6.25	$20.09

Freight Delay

Highway borne freight delay has two aspects. First there is delay that results in higher labor costs because of the extra time on the road. This is measured using the average wage rates for freight transport drivers, which is $36.54 per hour for the Monterey-Santa Cruz county region, calculated as described above. The hours of freight delay are estimated for the entire Monterey-Santa Cruz-San Benito county planning area used by the AMBAG model rather than for the area of interest. The calculations are shown in Table E-9:

TABLE E-9
CHANGES IN HIGHWAY FREIGHT DELAY HOURS AND VALUE OF TIME

	Scenario C0 (No Action)	Scenario C1 (2-Lane Elevated Highway)	Scenario C2 (Managed Retreat/Widening G12)	Scenario C3 (4-Lane Elevated Highway)
Change in Annual Delay Hours	(96,082)	98,072	75,290	(41,149)
Change in Annual Delay Costs ($Millions)	-$3.51	$3.58	$2.75	$1.50

E.2.D Vehicle Operating Costs

Vehicle operating costs are calculated as the change in vehicle miles traveled (VMT) in each scenario multiplied by 16 cents per mile. Table E-10 shows the changes in VMT estimated by the AMBAG RTDM by scenario for the road types included in this analysis. These are changes within the area of interest.

TABLE E-10
CHANGES IN VEHICLE MILES TRAVELED BY SCENARIO AND ROAD CLASSIFICATION

	Scenario C0 (No Action)	Scenario C1 (2-Lane Elevated Highway)	Scenario C2 (Managed Retreat/Widening G12)	Scenario C3 (4-Lane Elevated Highway)
TOTAL	46.55	129.81	82.39	(3.25)
Freeways-Expressways	(20.68)	16.45	(23.76)	3.40
Principal Arterial	81.86	83.18	121.73	(13.20)
Minor Arterial	(1.34)	24.06	0.10	0.13
Major Collector	(0.47)	0.91	(0.53)	0.07
Minor Collector	(17.78)	(14.49)	(18.09)	2.84
Local	(16.09)	(7.46)	(17.70)	3.05

Table E-10 Changes in Vehicle Miles Traveled by Scenario and Road Classification

The 16 cents per hour figure represents variable costs (primarily fuel) of vehicle operation for the U.S. vehicle fleet as a whole. It is taken from the AASHTO report cited above. That report estimated operating costs at 11 cents per mile in 2010. This figure was brought to 2019 values using the consumer price index for motor vehicle fuels from the Bureau of Labor Statistics which showed a 96% increase from 2010. But the vehicle fleet has become more fuel efficient since 2010. To measure this change, fuel economy data from the Environmental Protection Agency was used to calculate an average for the U.S. fleet as a whole (data is not available at the state or local level). This showed a 26% increase in fuel economy, resulting in a net estimate of 16 cents per mile.

Table E-11 shows the resulting changes in vehicle operating costs by road type and scenario.

TABLE E-11
CHANGES IN VEHICLE OPERATING COSTS BY ROAD TYPE AND SCENARIO

	Scenario C0 (No Action)	Scenario C1 (2-Lane Elevated Highway)	Scenario C2 (Managed Retreat/Widening G12)	Scenario C3 (4-Lane Elevated Highway)
Freeways-Expressways	$3.40	-$3.31	$2.63	-$3.80
Principal Arterial	-$13.20	$13.10	$13.31	$19.48
Minor Arterial	$0.13	-$0.22	$3.85	$0.02
Major Collector	$0.07	-$0.07	$0.14	-$0.09
Minor Collector	$2.84	-$2.84	-$2.32	-$2.89
Local	$3.05	-$2.57	-$1.19	-$2.83
TOTAL	-$3.25	$7.45	$20.77	$13.18

E.2.E Traffic Safety

The costs of motor vehicle accidents represent a significant burden on. Because the risks of accidents, both in terms of their frequency and severity, varies with the volume of traffic and the types of roads used, the shifts in traffic which would be a consequence of the decisions about adaptation for Highway 1 will alter the risks of both frequency and severity of accidents.

In order to estimate these effects, data on reported accidents in the area of interest around Moss Landing was secured from the California Highway Patrol (CHP) Statewide Integrated Traffic Records System (SWITRS). All police agencies use the CHP reporting system to report on motor vehicle accidents. Figure E-2 shows the location of all reported accidents in the area of interest for the years 2013-2018. Table E-12 shows the distribution of the severity of incidents in the area of interest using the 5-point scale recorded by the investigating police officer.

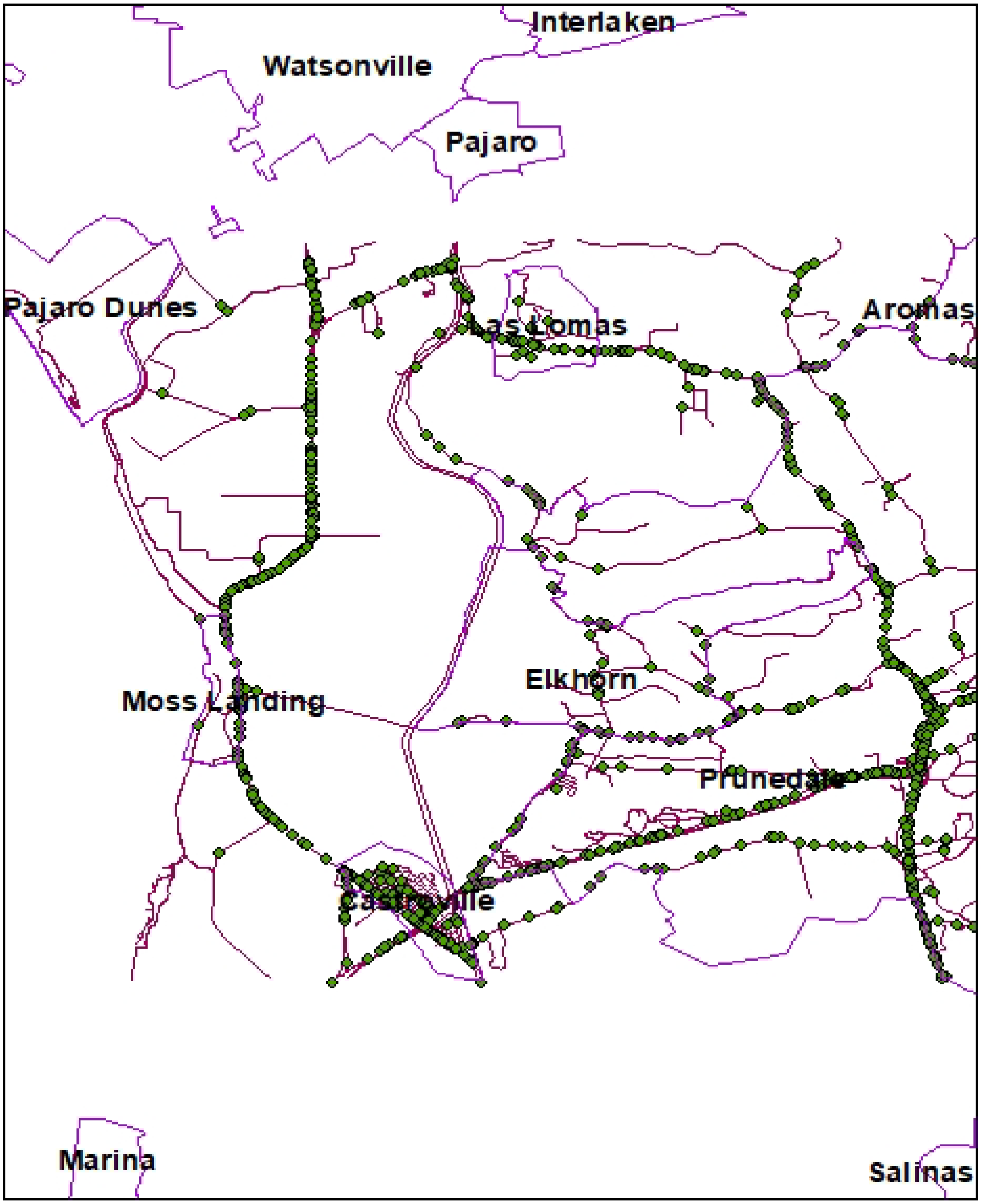

Figure E-2

Estimating the shifts in possible accidents requires translating the historical CHP data into accident rates that can be projected using the data from the AMBAG RTDM. This was done by estimating the rate of incidents from the CHP data by severity of incident and by road type per (million) vehicle miles traveled. These rates are shown in Table E-12 which are calculated from the average number of incidents over six years and applied to the 2015 AMBAG base data. These same rates are then applied to the 2040 VMT estimates and for those of each of the scenarios. The distribution of incidents by severity on each road type was calculated using the information in Table E-12 for each scenario. The differences in numbers of incidents by severity between the scenarios are then used to calculate the economic effects.

TABLE E-12
DISTRIBUTION OF 2015 INCIDENTS IN AREA OF INTEREST BY SEVERITY

	Percent of 2015 Incidents
Property Damage Only	67.3%
Fatal	0.9%
Severe Injury	2.8%
Other Visible Injury	10.8%
Pain Complaint	18.2%

TABLE E-13
COLLISIONS IN AREA OF INTEREST IN 2015, ESTIMATES FOR 2040 AND FOR SCENARIOS

	Number of Collisions per Million VMT	Total Estimated Collisions in 2015	Total Estimated Collisions in 2040	Total Estimated Collisions by Scenario			
				Scenario C0	Scenario C1	Scenario C2	Scenario C3
Total	1.43	657	739	710	777	896	828
Freeways-Expressways	2.66	175	340	397	342	440	333
Principal Arterial	0.44	142	134	98	134	134	151
Minor Arterial	3.68	124	126	129	124	218	130
Major Collector	0.59	3	3	3	3	4	3
Minor Collector	5.50	17	23	120	22	40	21
Local	12.36	196	308	544	345	452	325

TABLE E-14
ESTIMATED COSTS BY SEVERITY OF ACCIDENT

Property Damage Only	$3,313
Pain Complaint	$23,113
Other Visible Injury	$154,218
Severe Injury	$905,637
Fatal	$1,815,452

The economic costs of accidents were taken from a study for the National Highway Traffic Safety Administration (Blincoe et al. 2014). The costs by CHP severity classification are shown in Table E-14. These costs were originally estimated for 2010. They were adjusted to 2019 dollars using the consumer price index for medical services and motor vehicle repair from the Bureau of Labor Statistics.

The composition of costs making up the estimates of total social costs is shown in Table E-15.

TABLE E-15
COMPOSITION OF TRAFFIC SAFETY COST ESTIMATES

Injury Related	Medical Care
	Emergency Medical Services
	Lost Workplace Productivity
	Lost Household Productivity
	Insurance Administration
	Workplace Costs
	Legal Costs
Noninjury Related	Congestion at Scene
	Property Damage

The results of combining the change in the estimated number of incidents by severity type and road type and the costs by severity yields the safety economic effects shown in Tables E-16 to E-19 for each scenario.

TABLE E-16
ESTIMATED SAFETY COSTS BY ROAD TYPE AND ACCIDENT SEVERITY FOR SCENARIO C0 (NO ACTION)
($MILLIONS)

Scenario C0 (No Action)						
	Property Damage Only	**Fatal**	**Severe Injury**	**Other Visible Injury**	**Pain Complaint**	**TOTAL**
Freeways-Expressways	-$0.13	$0.00	-$0.91	-$0.77	-$0.23	-$2.04
Principal Arterial	$0.07	$1.82	$0.91	$0.77	$0.19	$3.76
Minor Arterial	-$0.01	$0.00	$0.00	$0.00	-$0.02	-$0.03
Major Collector	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Minor Collector	-$0.18	-$3.65	-$4.53	-$2.78	-$0.44	-$11.57
Local	-$0.54	-$3.65	-$8.15	-$3.86	-$0.84	-$17.04
TOTAL	-$0.79	-$5.47	-$12.68	-$6.63	-$1.35	**-$26.92**

TABLE E-17
ESTIMATED SAFETY COSTS BY ROAD TYPE AND ACCIDENT SEVERITY FOR SCENARIO C1 (2-LANE ELEVATED HIGHWAY)
($MILLIONS)

Scenario C1 (2-Lane Elevated Highway)						
	Property Damage Only	**Fatal**	**Severe Injury**	**Other Visible Injury**	**Pain Complaint**	**TOTAL**
Freeways-Expressways	$0.18	$0.00	$0.91	$0.15	$0.12	$1.36
Principal Arterial	-$0.12	-$1.82	-$0.91	-$0.15	-$0.12	-$3.12
Minor Arterial	$0.02	$0.00	$0.00	$0.00	$0.00	$0.02
Major Collector	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Minor Collector	$0.32	$3.65	$4.53	$0.77	$0.42	$9.69
Local	$0.66	$1.82	$6.34	$1.08	$0.49	$10.39
TOTAL	$1.06	$3.65	$10.87	$1.85	$0.91	**$18.34**

TABLE E-18
ESTIMATED SAFETY COSTS BY ROAD TYPE AND ACCIDENT SEVERITY FOR SCENARIO C2 (MANAGED RETREAT/WIDENED G12 ($MILLIONS)

Scenario C2 (Managed Retreat/Widened G12)						
	Property Damage Only	**Fatal**	**Severe Injury**	**Other Visible Injury**	**Pain Complaint**	**TOTAL**
Freeways-Expressways	-$0.10	$0.00	-$0.91	-$0.62	-$0.19	-$1.81
Principal Arterial	-$0.07	-$1.82	-$0.91	-$0.77	-$0.19	-$3.76
Minor Arterial	-$0.20	-$1.82	-$0.91	-$1.23	-$0.42	-$4.59
Major Collector	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Minor Collector	$0.15	$1.82	$3.62	$2.31	$0.35	$8.26
Local	$0.21	$1.82	$2.72	$1.54	$0.33	$6.62
TOTAL	-$0.02	$0.00	$3.62	$1.23	-$0.12	**$4.72**

TABLE E-19
ESTIMATED SAFETY COSTS BY ROAD TYPE AND ACCIDENT SEVERITY FOR SCENARIO C3 (4-LANE ELEVATED HIGHWAY) ($MILLIONS)

Scenario C3 (4-Lane Elevated Highway)						
	Property Damage Only	**Fatal**	**Severe Injury**	**Other Visible Injury**	**Pain Complaint**	**TOTAL**
Freeways-Expressways	$0.15	$0.00	$1.81	$0.93	$0.26	$3.14
Principal Arterial	-$0.11	-$1.82	-$1.81	-$1.08	-$0.26	-$5.08
Minor Arterial	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Major Collector	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
Minor Collector	$0.18	$3.65	$4.53	$2.78	$0.44	$11.58
Local	$0.50	$3.65	$7.25	$3.55	$0.77	$15.71
TOTAL	$0.72	$5.47	$11.77	$6.17	$1.21	**$25.35**

E.2.F Recreation

Elkhorn Slough has become a popular spot for recreation. The uniqueness of the Slough in California's coast, the presence of unique wildlife resources such as sea otters and an abundance of birds, and its accessibility to a large population have resulted in the growth of a small but robust local industry supporting recreational visitors. Visitors can buy or rent kayaks or stand-up paddleboards, take guided tours in kayaks or motorboats, or they can use their own equipment. Visitors can access the large amount of conservation land around the Slough for hiking and bird watching.

The appropriate measures of the value of recreation of inclusion in a benefit cost analysis are what economists term "consumer surplus" and "producer surplus." "Producer surplus" is difficult to estimate and is not included here; see discussion below. "Consumer surplus" is the difference between what one is willing to pay and what one actually pays. For example, a visitor to Elkhorn Slough who rents a kayak and takes a guided tour might pay $40 for the experience. The value of that experience must be *at least* $40 but it could be quite a bit more. And someone who comes to the Slough with their own kayak would pay only the costs of getting there. If the value of experience were equal to what was paid to a kayak rental company, then the kayak owner's experience would be valued at zero.

For this reason, the concept of consumer surplus is needed to capture all the values that people place on the recreational experience. To estimate consumer surplus requires discovering what people are willing to pay in addition to what they actually paid. For Elkhorn Slough this was done through a survey of visitors conducted during the summer of 2019 by the Center for the Blue Economy. The survey was sponsored by the Monterey Bay Aquarium to learn about the economic value of the sea otters that the Aquarium had been instrumental in reintroducing to the Slough. The survey included estimation of values of the overall Elkhorn Slough experience in addition to the value of experiencing sea otters. The sum of these values is used in this study.

The survey was conducted by intercepting visitors in Moss Landing or at the Elkhorn Slough National Estuarine Research Reserve headquarters on Elkhorn Road. A total of 432 surveys were completed. Survey respondents were asked questions about their Elkhorn Slough experience and were also asked questions which allowed estimation of their willingness to pay for their recreational experience.

Standard practice in measuring willingness to pay through surveys is to define a characteristic or bundle of characteristics and to ask whether the respondent would or would not pay a specified price for that bundle of characteristics. Because the question only asks for a yes/no response, this form of question is called a referendum format, or a dichotomous choice question. The specified value is varied randomly across all respondents. It is also possible to ask a second question depending on the answer to the initial question. If the respondent agrees to the initial specified price they can be asked if they would pay a somewhat higher specified price. If they disagree to the specified price, they a somewhat lower price is suggested, and they are asked if they will agree to that.

The question related to the value of Elkhorn Slough included in the survey was:

> *Elkhorn Slough is a special place, but the slough and its wildlife are constantly challenged by changes in water levels, erosion, the effects of development, and other factors. Keeping it a special place requires constant attention to the many parts of its natural systems. It may be necessary one day to impose a fee for visitors to the region to assure the slough and its wildlife are sustained into the future.*
>
> *This fee would be charged at entrance points for walking access, as an additional fee for tours or rentals, or as a special license fee for watercraft.*
>
> *Though no such fee is currently contemplated we would like to ask a couple of questions to gauge reactions to this idea. The first is whether you would be willing to pay an access fee of $10 for the general preservation of the slough and its wildlife.*

A similar question addressed the experience of seeing otters.

The initial values suggested ranged from $10 to $50 and the second values suggested ranged from $5 to $60. The range of responses is then statistically analyzed to estimate average willingness to pay across all respondents. (Aizaki, Nakatami, and Sato 2015). The results showed an average willingness to pay for the Elkhorn Slough experience at $40.44 per person per year and for sea otters at $43.74 per person per year, for a total $84.18 per person per year.

The 2019 survey of recreational visitors focused attention on visitors to the Slough via water trips and in the vicinity of the headquarters of the Elkhorn Slough National Estuarine Research Reserve off Elkhorn Road. The survey was conducted from June to September, the peak user period for water-based recreational visits. But the survey omitted, except as a random part of the sample drawn from the ESNERR visitors, those who visit the Slough for bird watching, which is one of the major natural features of he Slough. ESNERR estimates that around 15,000 people visit each year for bird watching particularly during the fall and spring migrations as the Slough is a major stopover point on the Pacific coast flyway.

It is not clear how sea level rise or changes in Elkhorn Slough will affect bird watching, except as access to the Slough may change as described below. But the large population of bird watchers should be acknowledged as part of the benefit cost analysis. To do that, the estimated population of 15,000 bird watchers is assigned the recreational value for all Elkhorn Slough visitors (excluding the value of otters). The total values of recreation are adjusted upwards to reflect bird watching. However, a specific study of bird watcher values should be included in future analyses.

The effects of responding or not responding to sea level rise on recreation in Elkhorn Slough are likely to be complex. The shifting nature of the Slough, with more open water and less marsh and tidal flats, will likely alter the mix of wildlife in the slough, probably diminishing some types and perhaps enhancing others. Whether and to what extent these changes would alter the value of the Slough to recreationists and in what direction is not known. Therefore, a somewhat simpler approach is taken to measuring the altered value of recreation based on the changes in road access in each of the scenarios.

To estimate changes in access to the Slough from the scenarios, a subset of the area of interest in the travel demand model was analyzed. This subset is shown if Figure E-3. Within this area, called the visitor area of interest, the per cent change in VMT between scenarios was calculated and that change was then applied to the estimate of the total number of visitors to Elkhorn Slough (30,000 per year). The assumption is that changes to recreational values are driven by changes in access to the Moss Landing area associated with the adaptation scenarios. Table E-20 shows the resulting calculations:

TABLE E-20
CHANGES IN VMT IN VISITOR AREA OF INTEREST AND IN RECREATION BENEFITS BY SCENARIO

	No Action	**C1**	**C2**	**C3**
% Change in Traffic in Visitor AOI	-88%	790%	93%	1109%
Change in Recreation Benefits ($ Millions)	-$2.83	$2.98	$0.88	$3.93

	No Action v Base
% Change in Traffic in Visitor AOI	-88%
Change in Recreation Benefits %$ Millions)	-$2.83

	C1 v. No Action	**C2 v. No Action**	**C3 v. No Action**
% Change in Traffic in Visitor AOI	790%	93%	1109%
Change in Recreation Benefits %$ Millions)	$2.98	$0.88	$3.93

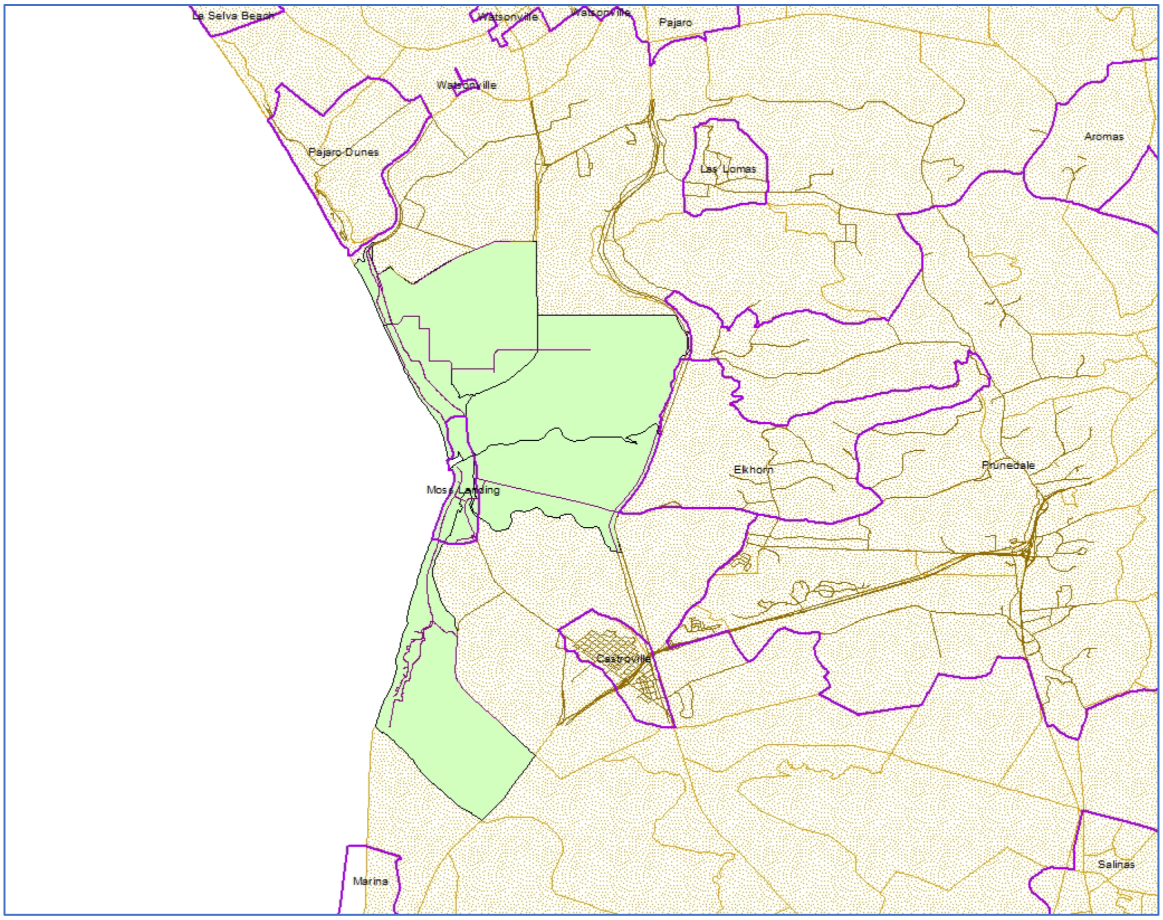

Figure E-3
Visitor Area of Interest (Transportation Analysis Zones in Green)

E.2.G Non-Recreation Wetland Values

Estimating the economic value of wetlands and estuaries is widely recognized as an essential part of understanding the importance of these natural systems. That economic value is designated as the value of the ecosystem services of the Slough. Ideally a study of the specific economic values affected by changes in the Slough, the extent of change in the ecosystems, and the resulting change in services would be identified to assess the changes in the value of wetlands in the Slough resulting from sea level rise and its response.

But the very complexity and dynamic nature of wetlands and estuaries that makes them so important within natural systems also makes them extremely difficult to assess in economic terms. Estimating economic values for wetlands and estuaries requires complex integrated social and ecological research, but ecological researchers seldom examine key economic characteristics and economic researchers frequently lack the ecological information that is needed for valuation. The problem is greater when, as in this case, it is necessary to identify values for relatively fine scale changes in habitat types.

This study uses an approach based on the purchase price of conservation lands around Elkhorn Slough. The valuation is thus based in market transactions in which the purchasers were buying land principally for their ecological values and not for development or other uses. The Elkhorn Slough National Estuarine Research Reserve provided data on the purchase of the various parcels of land around the Slough since the 1980s, including the original purchase price and an adjustment for inflation. This data was matched to GIS representations of the parcels recorded in the Monterey County property tax records. The parcel data updated with the purchase price was then intersected with the output from the SLAMM model (see above) showing the distribution of habitat types in 2020. See Figure E-4. Twelve separate parcels were included in the analysis, though some of these parcels are combinations of smaller parcels.

Distributing the total purchase price across the 2020 habitat types identified in the SLAMM model yields the per acre values shown in Table E-21. The values exclude open water (fresh and salt) as no property rights are assigned to open waters.

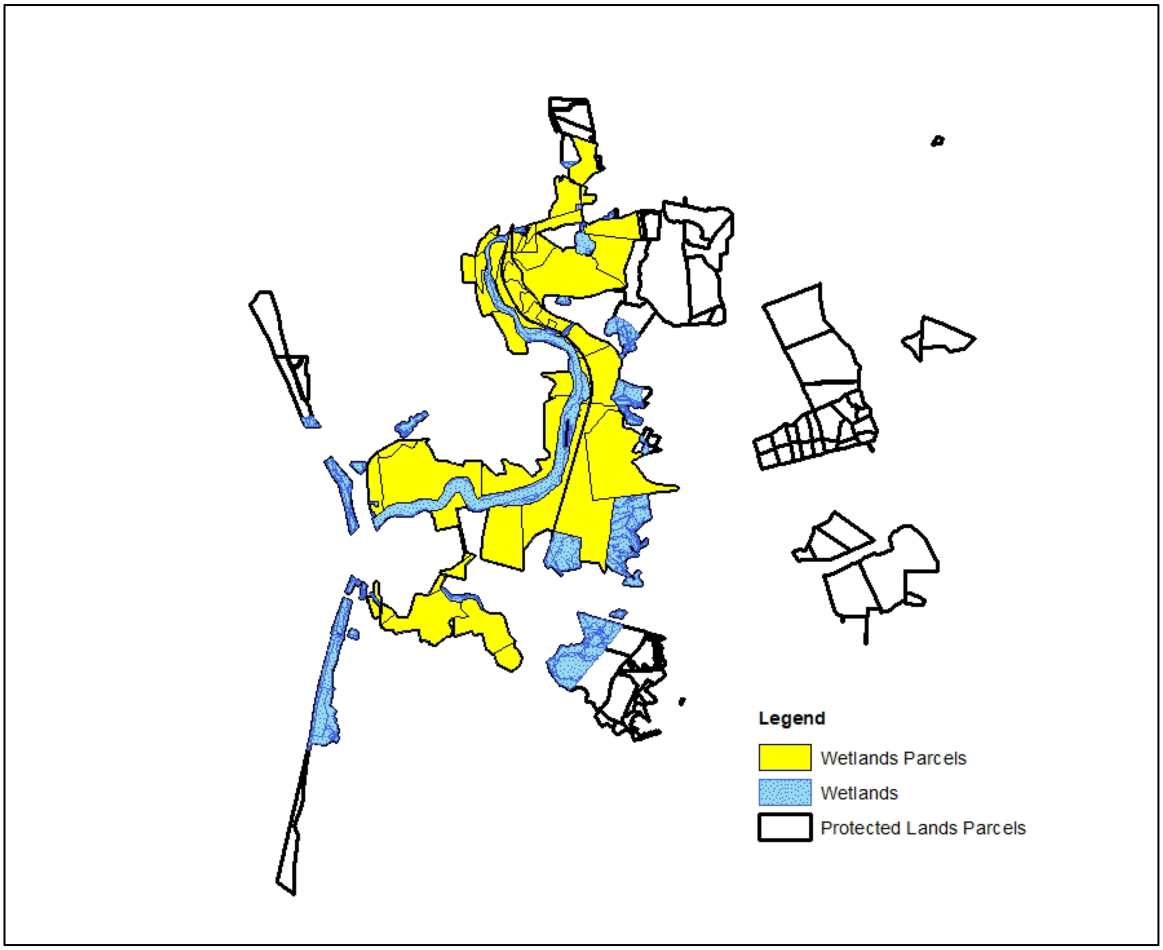

Figure E-4
Wetlands Parcels in Elkhorn Slough Conservation Lands

TABLE E-21
ESTIMATED PRICE PER ACRE FOR HABITAT TYPES IN ELKHORN SLOUGH

	Price Per Acre
Agriculture	$9,621
Developed	$12,483
Salt Marsh	$5,706
Tidal Flat	$6,705
Freshwater Marsh	$12,307
Undeveloped Dryland	$7,910

The changes in value associated with each scenario were then estimated by calculating the change in acreage of various habitat types from the SLAMM model and multiplying these changes by the per acre value in Table E-21. There are two differences in this analysis from those of the other economic factors. One is that the differences between Scenarios C1 (2-Lane Elevated Highway) and C3 (4-Lane Elevated Highway) are influenced by whether the design of Highway 1's elevation to avoid sea level rise is done with fill or piles. The increased rate of flow of tidal waters if piles are used influences the distribution of habitat in the Slough. So separate analyses of fill and pile are done and applied to both Scenarios C1 (2-Lane Elevated Highway) and C3 (4-Lane Elevated Highway). Separate scenarios for Scenarios C1 (2-Lane Elevated Highway) and C3 (4-Lane Elevated Highway are thus run in the benefit cost analysis. Scenario C0 (No Action) and C2 (Managed Retreat/Widening G12) are considered as elsewhere in the analysis.

The second change is that the effects on the wetlands varies with the extent of sea level rise. In general, certain types of habitat will increase in the Highway 1/Restoration alternatives scenarios but decline after around three feet of sea level rise (around 2070 in the OPC sea level rise scenario). Thus, there are important changes in the values of habitat in Elkhorn Slough that are driven by factors other than those directly associated with the choice of adaptation scenario. The values entered in the benefit cost analysis must reflect those factors.[4]

Tables E-22 to E-25 show the changes in habitat type and the associated changes in habitat values. There are no changes in the "outer coast" and "tidal channel" habitat types, so these are omitted from the tables.

---

[4] The SLAMM model outputs are in decadal years so the changes in intradecadal years are interpolated for purposes of the benefit cost model.

TABLE E-22
CHANGES IN HABITAT TYPE AND ASSOCIATED ECONOMIC VALUES:
NO ACTION SCENARIO

Scenario C0 (No Action)

	Feet of Sea Level Rise	2.0	2.5	3.1	4.0	4.7	5.3
Agriculture	Acres	-407	-582	-727	-828	-888	-951
	$ Millions	-$3.10	-$4.45	-$5.55	-$6.32	-$6.78	-$7.26
Developed	Acres	-47	-76	-97	-118	-135	-151
	$ Millions	-$1.06	-$1.73	-$2.21	-$2.69	-$3.07	-$3.42
Salt Marsh	Acres	-522	-671	-752	-789	-879	-978
	$ Millions	-$9.10	-$11.69	-$13.11	-$13.74	-$15.31	-$17.05
Tidal Flat	Acres	144	-52	-211	-441	-710	-949
	$ Millions	$1.41	-$0.51	-$2.07	-$4.33	-$6.96	-$9.31
Open Saltwater	Acres	1229	1836	2317	2777	3268	3734
	$ Millions	$0.07	$0.11	$0.14	$0.17	$0.20	$0.22
Fresh Marsh	Acres	-132	-158	-183	-197	-208	-219
	$ Millions	-$2.28	-$2.72	-$3.16	-$3.41	-$3.60	-$3.78
Undeveloped Dry Land	Acres	-78	-102	-125	-149	-171	-194
	$ Millions	-$2.57	-$3.35	-$4.14	-$4.91	-$5.63	-$6.38
Open Freshwater	Acres	-74	-76	-79	-80	-81	-81
	$ Millions	-$2.43	-$2.51	-$2.59	-$2.62	-$2.66	-$2.66
TOTAL	$ Millions	-$19.05	-$26.86	-$32.69	-$37.85	-$43.83	-$49.64

TABLE E-23
CHANGES IN HABITAT TYPE AND ASSOCIATED ECONOMIC VALUES:
SCENARIOS C1 AND C3, HIGHWAY REACHES 1-4 ON PILES

Scenarios C1 and C3 Highway 1, Reaches 1-4 on Piles							
	Feet of Sea Level Rise	***2.0***	***2.5***	***3.1***	***4.0***	***4.7***	***5.3***
Agriculture	Acres	0	-1	-1	0	0	0
	$ Millions	$0.00	-$0.01	-$0.01	$0.00	$0.00	$0.00
Developed	Acres	-7	-5	-4	-3	-2	-2
	$ Millions	-$0.16	-$0.11	-$0.09	-$0.07	-$0.05	-$0.04
Salt Marsh	Acres	48	48	9	16	17	16
	$ Millions	$0.84	$0.84	$0.15	$0.29	$0.30	$0.29
Tidal Flat	Acres	48	48	9	16	17	16
	$ Millions	$1.13	$2.91	$3.69	$3.23	$2.58	$1.23
Open Saltwater	Acres	-149	-333	-373	-339	-275	-137
	$ Millions	-$0.01	-$0.02	-$0.02	-$0.02	-$0.02	-$0.01
Fresh Marsh	Acres	-2	-2	-2	0	0	0
	$ Millions	$0	$0	$0	$0	$0	$0
Undeveloped Dry Land	Acres	-4	-5	-5	-4	-4	-3
	$ Millions	-$0.26	-$0.27	-$0.27	-$0.21	-$0.22	-$0.20
Open Freshwater	Acres	-1	-1	-1	0	0	0
	$ Millions	-$0.02	-$0.02	-$0.02	$0.00	$0.00	$0.00
TOTAL	$ Millions	$1.49	$3.29	$3.40	$3.21	$2.59	$1.27

TABLE E-24
CHANGES IN HABITAT TYPE AND ASSOCIATED ECONOMIC VALUES:
SCENARIOS C1 AND C3 ON FILL, HIGHWAY REACHES 1, 3, 4 ON PILES, REACH 2 ON FILL

Scenarios C1 and C3 Highway 1, Reaches 1, 3, 4 on Piles, Reach 2 on Fill							
	Feet of Sea Level Rise	***2.0***	***2.5***	***3.1***	***4.0***	***4.7***	***5.3***
Agriculture	Acres	0	-1	-1	0	0	0
	$ Millions	$0.00	-$0.01	-$0.01	$0.00	$0.00	$0.00
Developed	Acres	-3	0	1	2	3	4
	$ Millions	-$0.07	$0.01	$0.03	$0.05	$0.07	$0.09
Salt Marsh	Acres	63	63	25	34	33	32
	$ Millions	$1.09	$1.10	$0.44	$0.59	$0.58	$0.55
Tidal Flat	Acres	116	298	378	329	257	115
	$ Millions	$1.14	$2.92	$3.70	$3.23	$2.53	$1.13
Open Saltwater	Acres	-172	-357	-399	-364	-292	-149
	$ Millions	-$0.01	-$0.02	-$0.02	-$0.02	-$0.02	-$0.01
Fresh Marsh	Acres	-2	-2	-2	0	0	0
	$ Millions	-$0.03	-$0.03	-$0.03	$0.00	$0.00	$0.00
Undeveloped Dry Land	Acres	-1	-2	-2	-1	-2	-2
	$ Millions	-$0.05	-$0.09	-$0.12	-$0.08	-$0.10	-$0.11
Open Freshwater	Acres	-1	-1	-1	0	0	0
	$ Millions	-$0.02	-$0.02	-$0.02	$0.00	$0.00	$0.00
TOTAL	$ Millions	$2.04	$3.86	$3.97	$3.77	$3.05	$1.65

TABLE E-25
CHANGES IN HABITAT TYPE AND ASSOCIATED ECONOMIC VALUES:
SCENARIO C2

Scenario C2 (Managed Retreat/Widening G12)							
	Feet of Sea Level Rise	***2.0***	***2.5***	***3.1***	***4.0***	***4.7***	***5.3***
Agriculture	Acres	0	-1	-1	0	0	0
	$ Millions	$0.00	-$0.01	-$0.01	$0.00	$0.00	$0.00
Developed	Acres	-7	-6	-5	-4	-3	-2
	$ Millions	-$0.16	-$0.13	-$0.12	-$0.09	-$0.07	-$0.05
Salt Marsh	Acres	69	70	17	4	2	1
	$ Millions	$1.20	$1.22	$0.29	$0.07	$0.04	$0.02
Tidal Flat	Acres	113	297	392	365	294	150
	$ Millions	$1.11	$2.91	$3.85	$3.58	$2.89	$1.47
Open Saltwater	Acres	-173	-358	-400	-366	-294	-150
	$ Millions	-$0.01	-$0.02	-$0.02	-$0.02	-$0.02	-$0.01
Fresh Marsh	Acres	-2	-2	-2	0	0	0
	$ Millions	-$0.03	-$0.04	-$0.03	$0.00	$0.00	$0.00
Undeveloped Dry Land	Acres	1	1	0	1	1	1
	$ Millions	$0.05	$0.03	$0.02	$0.08	$0.06	$0.06
Open Freshwater	Acres	0	0	0	0	0	0
	$ Millions	$0.00	$0.00	$0.00	$0.00	$0.00	$0.00
TOTAL	$ Millions	$2.16	$3.97	$3.98	$3.61	$2.90	$1.49

E.2.H General Assumptions Used in the Analysis

In addition to the factors discussed in detail above, the benefit cost analysis is shaped by several general assumptions that affect the outcome or the interpretation of the results. These include:

a. Time Period of Analysis

The benefit cost analysis assumes a 10-year development period and forty-year lifespan for the highway projects. The lifespan assumption reflects the period before major reconstruction of the road is required and is consistent with general practice for major infrastructure. Some of the elements of the highway projects, such as interchange reconstruction, may have shorter lifespans before major upgrade, but these are ignored in the analysis.

The analysis does not presume any particular starting year. As the discussion of risks in the main text implies, the actual starting year will depend on assessments of changing levels of risk related to climate change and sea level rise.

b. Discount Rates

The discount rate is used to calculate the present value of flows of future goods and services. The general form of this calculation is:

$$PV = \sum_{i=1}^{n} \frac{FV}{(1+i)^n}$$

Where: PV=Present Value
FV=Future Value
I=the discount rate
n=the number of periods over which the discounting is done.

The discount rate chosen, 3% is an approximation of the long term real (without inflation) opportunity cost of capital in the public sector. Discounting has the effect of reducing the value of benefits received in the future because people have an inherent preference for receiving money sooner rather than later. The discount rate defines a rate of interest that, if the State had the opportunity to make a safe investment paying 3% then those options with a positive net present value would be a good deal. For anything with a negative net present value, Caltrans would be better off economically making the other investment.

c. Inflation

Projects envisioned over long periods of time inevitably raise questions about how price changes will affect the economic values being assessed. Including assumptions about future inflation in a benefit cost analysis risks a situation in which the assumption about inflation complicate the results of the analysis. Goods and services have different price increases; there is no single rate of inflation that applies to everything. Medical costs, for example, tend to rise in prices faster than most other parts of the economy, as noted in the discussion above about price adjustments in the safety benefits estimates. Moreover, assuming a rate of inflation also requires incorporating that rate into the discount rate; otherwise inflation would simply offset the effects of discounting.

For this reason, the best way to approach benefit cost analyses that extend over many years is do them in "real" (without inflation) dollars. Past prices can be brought to current price levels, but no further changes in prices are assumed. This way, the evaluation of economic viability (net present values) and the comparison among different options rests on the underlying values rather than inflation. assumptions. This analysis is thus done all in real dollars and the discount rate is assumed to be a real (without inflation) discount rate.

d. Growth

While inflation should not be included, the benefit cost analysis depends on understanding the values affecting people, and the total values depends on the number of people affected. Some assumption about population growth is appropriate. The AMBAG travel demand model is driven by an external forecast of the regional economy. That model uses a 0.6% per year growth for the period from 2015 to 2040. The 2040 base levels of traffic incorporate this growth rate. This population growth is assumed to continue through the analysis period.

E.3 Limitations and Scenarios Not Examined.

There are a number of assumptions and limitations due to data availability and other factors that affect the results of the analysis. Some missing data results in overestimates of economic values and some in underestimates. Other issues involve decisions of what to include and exclude from the analysis. Benefit cost analysis should also point to scenarios that have not been but should be considered based on the results of the analysis. These are discussed in this section

E.3.A Overestimates

Value of Time. The value of time is based on average hourly wages. But data at the regional level is only available for the average weekly wage. This has to be converted to an hourly wage using some figure on weekly hours worked. For this study, weekly hours worked is assumed to be 35 hours. This does not reflect part time employees and may overstate hourly wages. However, the number of part time employees (and the hours worked of part time employees, which can be highly variable).

Vehicle Operating Costs. The costs of vehicle operations are estimated primarily as the costs of fuel per mile. Fuel ("pump") prices will vary over time but are assumed to remain constant on average in real terms. But it is likely that fuel efficiencies will improve, resulting in a long-term decline in fuel used and thus lower variable costs of travel. Unfortunately, the extent of fuel economy improvements is currently a matter of considerable policy dispute, so no assumption of future reductions in fuel use and operating costs are included in the analysis.

E.3.B Underestimates

Freight. The value of delays in highway freight transport expressed as increased labor costs are included in the analysis. There can also be significant costs to demurrage, the term used for delays in the delivery of freight goods. The current system of "just in time" deliveries that are used throughout goods-related industries designed to minimize inventory costs, puts a premium on timely delivery of goods. This is even more the case with transportation of perishable food items such as the agricultural and fisheries products typical of the Monterey County economy.

However, data is not available on the movement of goods such as the number of trips, origins and destinations, and the exact goods moved. It is thus not possible to include the costs of delay in freight movement, which could be substantial particularly at certain times of the year. The lack of data on demurrage applies to both highway and rail-borne freight.

Rail. The rail line that runs through Elkhorn Slough, and which is already vulnerable to interruption at times of extreme high tides, provides three different services. The first is freight movement. The effects on rail freight movement are similar to those on highway freight movement, except that the volume of goods affected by delay is probably much larger. But as with highway freight transport, there is no available data on rail freight transport, so this is not included in the analysis.

The second rail service through Elkhorn Slough is provided by AMTRAK. The Pacific Starliner is a service from Los Angeles to Seattle that transits the Slough twice a day (north and south bound).

The third service is as a commuter rail line. Such a line between Salinas and San Jose has been envisioned by the Transportation Agency for Monterey County (TAMC) for some time. It would provide hourly service for commuters from northern Monterey County to the Bay area and could connect to Monterey and Santa Cruz through subsidiary lines. The travel model analyses conducted for this study include the operation of the Salinas-Gilroy commuter rail service in place by 2040. This means that the rail service is available to alleviate congestion and reduce delays on the highway network in 2040 and that assumption is maintained through the analysis of the various scenarios for Highway 1. This rail service has the effect of reducing demand on the roads in the region as trips shift from road to rail so the delay costs estimated reflect the reduce traffic on roads.

Maintaining the rail line or rail services is primarily the responsibility of the rail line's owner, the Union Pacific Railroad. Elevation of the rail line above sea level will likely continue on a regular basis through the century, but the expenditures by Union Pacific are out of scope for this study. The economic costs and benefits of rail elevation projects will have to compare the revenues earned by Union Pacific from its own, AMTRAK's, and the commuter rail services against the costs.

Recreation. The analysis of recreation values used for this study focused on recreational visitors who, for the most part, were involved in water-based recreation. The sample drawn was insufficient to measure the recreational activity of those in the Slough who were involved in other activities such as bird watching, which is likely to be a very large population. It is not clear how the changes in habitat associated with sea level rise and the adaptation options might affect the bird watching experience, but the changes in access to Moss Landing would affect these recreationists as with water-based recreationists. The lost benefits to bird watchers in the Slough have not been explicitly measured. Some of this effect is included in the analysis, but the extent is unknown.

The analysis includes the consumer surplus (what visitors are willing to pay) but not producer surplus. Producer surplus is the supply side equivalent to producer surplus and is defined as the amount that businesses are paid in excess of their costs of production, or essentially profits. Data on the change in gross sales of the recreation-related businesses can be estimated from the Elkhorn Slough survey data, but the profits are not known and so are not included in the analysis.

Vehicle Operating Costs. The analysis of vehicle operating cost effects of the changes in vehicle miles traveled from each scenario were calculated using only variable costs (costs of fuel). An alternative value is to use total vehicle costs, including the values of ownership, insurance, and other fixed costs. Using only variable (operating) costs assumes that the marginal cost of travel consists only of the distance traveled. People would still take trips so the only change in cost is determined by the variable costs of route; the fixed costs of ownership and insurance would be covered by the number of trips and the route would not be relevant. This assumption of constant trips is used in the AMBAG model. If it is relaxed and differences in trips due to changes in costs of transportation were included, then the full costs of travel should be used.

Highway Costs. Only the costs of constructing the highway are included in this analysis. The costs of maintenance of the highway, which would increase with additional lane miles, were not estimated and are not included. This should not, therefore, be considered a full life-cycle cost analysis of the highway projects.

E.3.C Boundaries of the Analysis

The discussion of changes in wetland habitat types discussed above in Section 6.C points out that the changes depend in part on whether decisions are made to protect agricultural land, developed land, or both from the effects of sea level rise. Protection of these lands is not, however, in scope for the project. Neither specific actions nor costs of protection, so the analysis is based on the "no agricultural protection" option.

E.3.D Scenarios to be Evaluated

Alternate Highway Projects This analysis considers three highway options each of which involves a complete alteration in Highway 1 or the Highway 1 corridor. However, as the discussion of probabilities of sea level rise indicates, there are a number of different possible configurations of the future hazards from sea level rise and the adaptation options. Phasing of the different components of the Highway 1 projects has not been evaluated but may affect the economic assessment. This is particularly true for Scenario C1 (2-lane Elevated Highway). This scenario is not viable if all costs are paid up front but phasing of the project may make it economically justified.

On the other hand, phasing is unlikely to affect Scenarios C2 (Managed Retreat/Widening G12) or C3 (4-Lane Elevated Highway). Phasing C2 by delaying the widening of San Miguel Canyon Road (G12) and Route 101 may affect the costs of the project but the delays from traffic diverted onto these roads in their current configuration could offset the benefits of delayed expenditures. C3, a widening of Highway 1 to four lanes, would probably not make sense; widening part of the highway and not another part would still create delays in the lane narrowing section.

Restoration of the Railroad Wetland. The wetland on the inner (landward) side of the rail line in the upper part of Elkhorn Slough represents a major opportunity to expand the acreage of salt marsh in Elkhorn Slough. But the costs of this project are high. This project comprises between 20 and 25% of total project costs being evaluated. At an estimated $221 million dollars, the per acre cost of restoration costs for the 700-acre site would be $315,500, far in excess of anything that has been paid for either purchase or restoration of salt marsh in Elkhorn Slough.

The benefits of this restoration are uncertain. Recreation benefits may increase for visitors to the upper part of the Slough at Kirby Park, but these are not likely to be large enough to justify those expenditures. At an expenditure level of $221 million, annual benefits would have to be $8.7 million to justify that expenditure at a 3% discount rate ($5.65 million at an unlikely 1% discount rate). It is the case that this benefit cost analysis shows that the expenditure on the railroad wetland is justified if included in a package that widens Highway 1 to four lanes. But the benefits of a reduced delay on Highway 1 cannot really be used to fund the marsh restoration.

References

Aizaki, Hideo, Tomoaki Nakatami, and Kazumi Sato. 2015. *Stated Preference Methods Using R*. Boca Raton, FL: Taylor & Francis.

American Association of State Highway and Transportation Officials. 2003. “User Benefit Analysis For Highways,” no. c: 1–293. https://doi.org/10.15713/ins.mmj.3.

Blincoe, Lawrence, Ted R. Miller, Eduard Zaloshnja, and Bruce A. Lawrence. 2014. “The Economic and Societal Impact of Motor Vehicle Crashes, 2010.” *Motor Vehicle Crashes: Economic and Societal Impact, In Depth*. Vol. 2015.

Mishan, E.J. 1976. *Cost-Benefit Analysis*. New York: Holt, Rinehart & Winston.