Fall 10-8-2020

Benefits Cost Anaylsis: Options for Sea Level Rise Adaptation on West Cliff Drive

Charles S. Colgan

Philip King

David Revell

Benefit Cost Analysis

Options for Sea Level Rise Adaptation on West Cliff Drive

Prepared for

CITY OF SANTA CRUZ

Prepared by

Middlebury Institute of International Studies at Monterey

Center for the Blue Economy

Charles S. Colgan PhD, Director of Research

Philip King, PhD, Senior Research Associate

460 Pierce Street
Monterey, CA 93940

integral consulting inc.

David Revell, Ph.D.

200 Washington Street
Suite 201
Santa Cruz, CA 95060

October 8, 2020

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 EXECUTIVE SUMMARY

This report presents the results of a benefit cost analysis of various options for adapting West Cliff Drive to sea level rise as identified through extensive technical analysis and community input. This report has built on previous work completed as part of the West Cliff Drive Adaptation and Management Plan project. The previous work products provided much of the information needed for this benefit cost analysis included an existing conditions inventory, future exposure and vulnerability assessment, and an adaptation alternatives analysis. Since most of the West Cliff Drive corridor is publicly owned by the City of Santa Cruz and California State Parks, results of the future exposure and vulnerability assessment showed that little private property and only small portions of public infrastructure is at risk in the future. Thus, the benefit cost analysis focuses primarily on changes to the recreational uses of the West Cliff Drive corridor.

One challenge to adaptation planning is the uncertainty associated with the rate and elevation of sea level rise at future points of time, critical to the question of what to do and when. To deal with this uncertainty, the benefit cost analysis uses a technique called Monte Carlo analysis, a technique to test many different possible scenarios of sea level rise; in this analysis, 100,000 different scenarios were examined in every run of the analysis. The underlying sea level rise data is the same as used by the State of California in its various sea level rise planning guidance documents. This approach to the benefit cost analysis allows an estimate not only of net benefits but also the probability of positive net benefits of each adaptation strategy.

The purpose of this benefit cost analysis is to compare the economic benefits and costs of the coastal adaptation options aimed at managing coastal erosion to a future in which no additional adaptation actions beyond those routinely taken by the City are taken. The benefit cost analysis is designed to support a choice between those different adaptation strategies which involve substantial new expenditures by the City the or "business as usual" strategy. The fundamental question is whether it is economically worthwhile for the City to invest substantial resources in adapting to sea level rise along West Cliff Drive compared with continuing as they have in the past? Economically worthwhile projects have benefits greater than costs, taking into account the differences in timing of spending and receipt of benefits. This concept is called the net present value.

Four scenarios are examined:

- Business as Usual
  - No actions are taken beyond routine maintenance and irregular emergency repairs

- Managed Retreat
  - Existing armoring structures are removed, and natural erosion and shoreline processes restored.
- Recreation Focused Strategy
  - A combination of sand management, reduction in coastal armoring footprints and sand retention structures along with structural adaptation in high hazard areas such as sea caves.
- Protection Focused Strategy
  - Projects that stabilize the shoreline such as revetments, seawalls, filling of sea caves, and construction of artificial bedrock.

Costs in this analysis are defined as expenditures (construction and maintenance) by the City to take certain adaptation actions and, for some strategies, reductions in recreation users benefits. Benefits are defined as a gain in the value of recreation to users, as measured through a survey of recreational users on West Cliff Drive undertaken in 2019. The results of the survey showed annual values per household of $101.82 for general recreation visitors, including those who vist the shore, and $119.42 for surfers. The changes in recreation value are driven by changes in the number of users that result from reshaping of the shoreline and affects on beach and surf conditions over time as a result of sea level rise and the specific adaptation options chosen.

The benefits and costs permitting comparison of these strategies are calculated as net present values of economic changes over the period 2021-2100 discounted at 4% and in millions of dollars. The table shows the net present value (benefits minus costs)(NPV) and the probability that the ratio of benefits to costs will exceed 1 (that is, a positive net present value) (pBCR>1)

Table 1-1 Summary Results of Benefit-Cost Analysis

SLR Trigger (Feet Above 2000 Mean Sea Level	**0.30**		**0.88**		**1.90**	
	NPV	p BCR>1	NPV	p BCR>1	NPV	p BCR>1
Business as Usual v. Retreat	-$52.77	<.001	-$67.43	<.001	-$73.04	<.001
Business as Usual v. Recreation Focus	-$59.79	<.001	-$61.58	<.001	-$62.18	0.01
Business as Usual v. Protection Focus	-$48.21	0.12	-$55.30	<.001	-$58.05	0.03
Protection Focus	$20.60	0.65	$0.12	0.20	-$14.30	0.01
Recreation Focus	$28.35	>.99	$30.14	>.99	$30.74	0.91

Managed Retreat	$28.61	0.79	$6.72	0.37	-$13.22	0.09

Millions of Present Value Dollars

Table 1-2 Estimated Years of Deployment by Action and Zone

Sea Level Trigger (in Feet)								
0.30			**0.88**			**1.90**		
Year of Deployment								
Earliest	Likely	Latest	Earliest	Likely	Latest	Earliest	Likely	Latest
2021	2024	2034	2044	2053	2076	2044	2076	2088

To incorporate the ranges of different rates and extents of sea level rise in the comparison of adaptation options, a set of sea level rise triggers was defined. Within the 80-year period forecast in the analysis, a given adaptation alternative is deployed (the costs are incurred) in any iteration where the estimated sea level rise is equal to the trigger amount. The precise years in which this occurs are shown in Table 1-2. Three different triggers based on the OPC 2018 guidance were tested: 0.3 feet, 0.88 feet and 1.9 feet. These triggers were consistent with projections of the low, median, and medium risk scenarios from the Monterey tide gage. Two adaptation strategies were fixed in time of deployment; the sand management project in Zone 1 (Recreation Strategy) and the Artificial Bedrock in Zone 1 (Protection Strategy) project were both deployed in 2025 regardless of sea levels. Table 1-2 shows the most likely years of deployment of adaptation actions for each sea level rise trigger.

The results of the analysis show:

- ***The economically optimal strategy is to combine actions that provide erosion protection to the shoreline with enhancements to surf and shoreline recreational use.*** This is the recreation-focused strategy, which has the highest net present value in each sea level trigger scenario, as well as by far the strongest probability of a positive net present value. This alternative reduces the footprint of existing armoring and mitigates some of the secondary impacts by implementing a sand management program.
- Each of the adaptation scenarios were compared to the business as usual approach to answer the question whether or not continuing the "business as usual strategy" makes sense. The analysis shows the business as usual strategy has negative net present values at all trigger levels. ***There is almost no chance that the business as usual approach will yield a positive net present value*** compared with any of the adaptation options except by comparison with the protection-focused strategy if implemented at the highest sea level rise trigger (1.9 feet) and even then the chances are very small.
- Of the investment strategies (recreation, protection, and retreat), all have ***higher positive net present values if investments are made sooner***, that is before sea levels have

increased by about two feet rather than after sea levels have increased by about two feet. The estimated net present value and the probability of a positive net present value (benefit cost ratio greater than 1) diminish significantly with delay.

- ***Managed retreat has a positive net present value if undertaken very soon but the values diminish to negative if delayed too long.*** This finding is a bit unique in the traditional adaptation literature, basically, the sooner managed retreat is implemented, the greater the benefit. Postponing the relatively high costs of removing armoring reduces the present value costs, and delays the large benefits of retreat overcomes that cost reduction.
- ***The timing of investment decisions to implement adaptation strategies is critical when calculating future net present values.*** Delaying taking action reduces both the present value of expenditures needed and the future benefits to be received more rapidly, resulting in the reductions in net present values over time. This is a function of discounting future benefits. But implementing adaptation strategies sooner rather than later is also supported by the probability analysis indicating that sea level rise and its impacts could be more rapid in the future rather than the mean estimates. The estimates of sea level rise and the implications for the years in which adaptation actions are implemented are discussed in Section 3.3.

These results indicate that making adaptation investments in the short term associated with the recreation-focused strategy (sand placement at Pyramid Beach, reducing the footprint or placement losses on the beach from existing revetments using cave fills and soil nail wall projects, and a medium term groin in Zone 2) have the greatest probability of yielding positive net benefits. The highest probability of positive net present values result in the highest most cost effective benefits of the adaptation approaches examined.

2 DETAILED RESULTS

2.1 INTRODUCTION TO BENEFIT COST ANALYSIS

Benefit cost analysis (BCA) provides several key pieces of information needed for making decisions. It answers the question: "will we gain more than what we will have to give up?" Given that there are always too few resources to do what is needed it is vital to choose adaptation actions that have net gains and avoid those with net losses. BCA has two methods of testing this result; costs may be subtracted from benefits to produce a net benefits value (NPV) or benefits may be divided by costs to calculate a benefit cost ratio. Any adaptation approach with a positive net value or a benefit-cost ratio greater than 1 should be considered for selection. In choosing between the various adaptation approaches whose gains are greater than their costs, the option with the greatest net value is usually considered the best option because the gains are, by definition, the largest. In this sense BCA is little different from the standard analysis of investment options undertaken by businesses.

BCA goes beyond private sector investment analysis, however, to consider all gains and losses of economic value, not just budget expenditures. Budget expenditures for projects like sand management or more narrow seawalls are included in the analysis, as costs when money must be spent, but as benefits if expenditures can be avoided. BCA also considers whether and by how much people are made better off as a result of the choices analyzed. In the West Cliff Drive case, the value of recreational experiences of visitors to beach recreation or surfing may be increased or reduced with various options. Increases in these recreational values are counted as benefits; while reductions are counted as costs.

BCA addresses the problem of comparing costs and benefits likely to occur at some time in the future. Spending money today often means large outlays of money in exchange for small amounts of benefits annually for some time into the future. To compare, for example, 50 years of returns to current spending requires recognizing that people prefer to receive money sooner rather than later, so far distant returns must be accounted for at a lower value than those received sooner. This is done through a calculation called discounting. The comparison of benefits and costs is thus done on a "discounted", or "present value", basis. The discounting process uses an interest rate which represents what could be earned if the same money were put into an interest-bearing account. For this study a discount rate 4% is used, representing roughly the cost of public debt in California. The lower the discount rate, the higher the value of benefits is given to economic values received in the future.

Expecting to receive benefits decades into the future presents a particular challenge for planning related to climate change. The extent of changes possible in complex global systems are so large that, while it is possible to be reasonably certain that temperatures will increase and sea levels rise, it is not possible to know exactly how much change will occur by when or how fast changes will occur. This means that expected changes in economic values from adaptation decisions may be estimated, but there is substantial uncertainty surrounding them.

Uncertainty in projections is familiar in the weather forecasts published every day. It is not known if it will rain, but the probability that it will rain can be calculated fairly accurately. An 80% chance of rain typically indicates that 8 of 10 iterations of weather models predict rain. This is because the basic functioning of the weather system is known well enough. But what if the whole weather system (climate) changes? This becomes a problem called "deep uncertainty" (R. Lempert, 2014; Robert Lempert et al., 2012)

As with the weather forecast, a common way to deal with the uncertainty is to use estimates of risk or probability. This is the approach used in this study, where sea level rise is treated as a set of probabilities rather than a specific forecast. This approach is recommended by the California Ocean Protection Council (OPC) using an approach that uses multiple scenarios including both more likely extents of sea level rise and less likely extents. (Griggs et al., 2017; Ocean Protection Council, 2017).

The approach taken in this study is a more rigorous approach to the risk scenario-based method recommended by OPC. Rather than using single scenarios, this study uses a technique called Monte Carlo analysis to investigate the consequences of 10,000 different possible increases in sea level for each year from 2020 to 2100 based on the same data used by the Ocean Protection Council. (Kopp et al., 2014). This approach takes the full range of potential sea level rise projections much more fully into account.

The details of how benefits and costs are calculated, including the details on calculating sea level rise probabilities are discussed in sections 3 to 5.

2.2 COMPONENTS OF THE BENEFIT COST ANALYSIS FOR WEST CLIFF DRIVE

The adaptation and management plan for West Cliff Drive considers four different zones (Figure 2-1). Within each of these zones a large number of adaptation options were identified, narrowed by a multitude of outreach and engagement feedback and evaluated. Nine specific adaptation strategies were identified for economic analysis. Taken together there are is a theoretical total 45 different options to be evaluated, but since not all options are applicable in all zones the actual total of options is 19. These 19 options were grouped into four adaptation strategies with different components in each zone. (

Table 2-1)

- **Business as Usual**. This option assumes that the City takes no additional actions on West Cliff Drive beyond historical levels of regular maintenance and occasional but irregular expenditures on emergency repairs.

- **Recreation Focused Strategy**. This strategy prioritizes recreational enhancements to enhance shoreline, beach and surfing recreation. Specific adaptation projects include a sand placement program at Pyramid Beach in Zone 1, an installation of a groin to help trap sand at Mitchells Cove in Zone 2, and the replacement of existing revetments in the short term with vertical walls (seawall or soil nail walls) to reduce the footprint of the armoring structures on the recreational beaches. This strategy though also contains additional protection elements to reduce high erosion risks from the collapse of sea caves.
- **Protection Focused Strategy** This strategy prioritizes erosion protection focusing on filling of high risk caves in Zones 3 and 4 plus the construction of an artificial bedrock platform in Zone 1 designed to replace erodible areas with a stable bedrock platform for shore users. Under this strategy it would also be necessary to continue most of the same expenditures on routine maintenance and emergency repairs of existing revetments as in the business as usual strategy.
- **Managed Retreat.** Under this strategy, all existing armoring along the shore beneath West Cliff Drive would be removed and natural erosion and shoreline processes restored. This would further enhance the conditions supporting recreational activities but would also require similar expenditures to the road and recreational trail as in the business as usual strategy in addition to the expenses of removing the existing armored shoreline.

Figure 2-1 West Cliff Drive Planning Zones

West Cliff Drive Zones

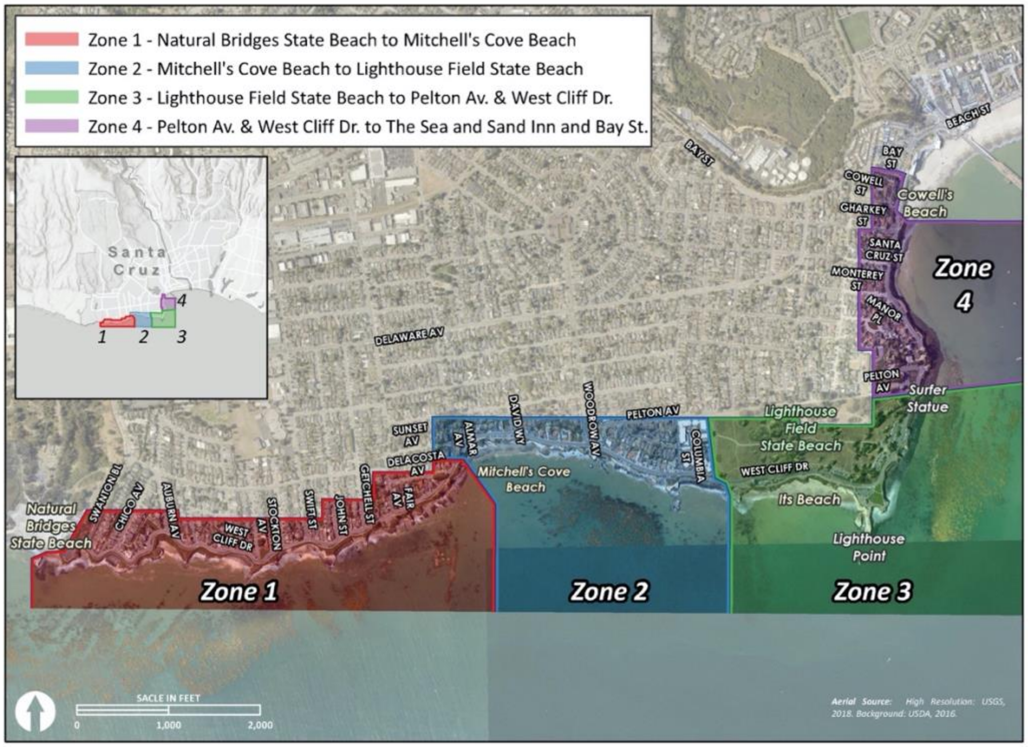


Table 2-1 Adaptation Options and Strategies by Zone

Strategy	Action	Zone 1	Zone 2	Zone 3	Zone 4
Business as usual		●	●	●	●
Managed Retreat		●	●	●	●
Recreation Focused	Sand Placement	●	•	●	●
	Groin	●			
	Cave Fill/Nail Wall		●		
	Coastal Wall		●		
Protection Focused	Artificial Bedrock	●			
	Cave Fill			●	●
	Maintain/ Emergency	●	●	●	●

•. The project is located in Zone 1 but has downcoast benefits to all zones.

The next sections provide, in turn, a more detailed description of the actions and strategies that could be taken, followed by a summary of the benefit cost analysis, and then details on the estimation of costs and benefits.

2.3 SUMMARY RESULTS

Table 2-2 Net Present Values and Probability of a Positive Net Present Value by Scenario

	0.30		0.88		1.90	
	NPV	p BCR>1	NPV	p BCR>1	NPV	p BCR>1
Business as Usual v. Retreat	-$52.77	<.001	-$67.43	<.001	-$73.04	<.001
Business as Usual v. Recreation Focus	-$59.79	<.001	-$61.58	<.001	-$62.18	0.01
Business as Usual v. Protection Focus	-$48.21	0.12	-$55.30	<.001	-$58.05	0.03
Protection Focus	$20.60	0.65	$0.12	0.20	-$14.30	0.01
Recreation Focus	$28.35	>.99	$30.14	>.99	$30.74	0.91
Managed Retreat	$28.61	0.79	$6.72	0.37	-$13.22	0.09

Millions of Present Value Dollars

Table 2-2 shows the net present values for each of the options considered plus, since this analysis takes into account different probabilities for sea level rise, the probability that, over 100,000 different trials, the result will be a benefit cost ratio greater than 1 (that is, a positive net present value). To learn more about how this analysis produced these results, Section 2.4 contains short descriptions of the adaptation options evaluated in this analysis, while section 2.5 details for cost and benefits estimates for each of the four strategies. Data sources and calculations behind the results in Table 2-2 are discussed in sections 3 through 5, with additional details provided in Appendices 1 and 2.

Costs in this analysis are defined as expenditures by the City to take certain actions and, for some options, reductions in recreation users values. Benefits are defined as gain in the value of recreation to users, as measured through a survey of recreational users on West Cliff Drive undertaken in 2019 (see section 4.1). The changes in recreation value are driven by changes in the number of users that result from reshaping of the shoreline and surf as a result of sea level rise and the specific options chosen (see section 4.2).

To incorporate the risks of different rates and extents of sea level rise in the comparison of options, a set sea level rise triggers are defined. Within the 80-year period forecast in the analysis, a given alternative is deployed (the costs are incurred) in any iteration where the estimated sea level rise is equal to the trigger amount. The precise years in which this occurs are discussed in section 3.3. Three different triggers are tested: 0.3 feet, 0.88 feet and 1.9 feet. Two actions are fixed in time; beach nourishment project in Zone 1 (Recreation Strategy) and the Artificial Bedrock (Protection Strategy) project are both deployed in 2025 regardless of sea levels.

The benefit cost analysis is designed to support a choice between those strategies which involve substantial expenditures by the City and the “no action” or “business as usual” strategy. The fundamental question is whether it is economically worthwhile for the City to invest substantial resources in adapting to sea level rise along West Cliff Drive compared with continuing as they have in the past?

The results of the analysis show:

- ***The economically optimal strategy is to combine actions that provide erosion protection to the shoreline with enhancements to surf and shoreline recreational use.*** This is the recreation-focused strategy, which has the highest net present value in each sea level trigger scenario, as well as by far the strongest probability of a positive net present value. This alternative reduces the footprint of existing armoring and mitigates some of the secondary impacts by implementing a sand management program.
- Each of the adaptation scenarios were compared to the business as usual approach to answer the question whether or not continuing the "business as usual strategy" makes sense. The analysis shows the business as usual strategy has negative net present values at all trigger levels. ***There is almost no chance that the business as usual approach will yield a positive net present value*** compared with any of the adaptation options except by comparison with the protection-focused strategy if implemented at the highest sea level rise trigger (1.9 feet) and even then the chances are very small.
- Of the investment strategies (recreation, protection, and retreat), all have ***higher positive net present values if investments are made sooner***, that is before sea levels have increased by about two feet rather than after sea levels have increased by about two feet. The estimated net present value and the probability of a positive net present value (benefit cost ratio greater than 1) diminish significantly with delay.
- ***Managed retreat has a positive net present value if undertaken very soon but the values diminish to negative if delayed too long.*** This finding is a bit unique in the traditional adaptation literature, the sooner managed retreat is implemented, the greater the benefit. Postponing the relatively high costs of removing armoring reduces the present value costs, and delays the large benefits of retreat overcomes that cost reduction.
- ***The timing of investment decisions to implement adaptation strategies is critical when calculating future net present values.*** Delaying taking action reduces both the present value of expenditures needed and the future benefits to be received more rapidly, resulting in the reductions in net present values over time. This is a function of discounting future benefits. But implementing adaptation strategies sooner rather than later is also supported by the probability analysis indicating that sea level rise and its impacts could be more rapid in the future rather than the mean estimates. The estimates of sea level rise and the implications for the years in which adaptation actions are implemented are discussed in Section 3.3.

These results indicate that making adaptation investments in the short term associated with the recreation-focused strategy (sand placement at Pyramid Beach, reducing the footprint or placement losses on the beach from existing revetments using cave fills and soil nail wall projects, and a medium term groin in Zone 2) have the greatest probability of yielding positive net benefits and the result in the highest most cost effective benefits of the adaptation approaches examined.

Since most of the West Cliff Drive corridor is publicly owned by the City and California State Parks, results of the future exposure and vulnerability assessment showed that little private property and only small portions of public infrastructure is at risk in the future. Thus benefit cost analysis focuses primarily on changes to the recreational uses of the West Cliff Drive corridor.

The focus of this analysis is on shore users and surfers. Part of the long-term plan for West Cliff Drive is to modify the Drive itself. Costs of options to modify the structure and function of WCD and the Recreation Trail were identified, but it was determined through the transportation modeling that it is unlikely that there will be significant impacts on delays or on safety if the drive is made either one way or closed to motorized traffic entirely. The benefits of making either of these changes will most likely come from an increase or changes in the number of recreational visitors. But estimates of this change over time are too uncertain for inclusion in the model at the point. Strategies for assessing increased recreational use of WCD are available to be used in the next generation of the analysis.

2.4 DESCRIPTION OF ADAPTATION ACTIONS REVIEWED

The benefit cost analysis is built on existing inventory, future vulnerability work and community engagement described in detail in Chapters 1 through 10. Ultimately, comparing 4 different adaptation scenarios. Each adaptation scenario consisted of specific strategies identified in each zone by the City, and community engagement. Each scenario consists of a combination of adaptation strategies discussed at length in Chapter 10: Adaptation Alternatives Analysis. For each adaptation strategy, there are a complex set of consequences, costs, and regulatory considerations. The short summaries below are provided only to provide context for the benefit cost analysis and readers are urged to see the details provided in Chapter 10: Adaptation Alternatives Analysis.

- Business as Usual
- Recreation Priority focused
- Protection Priority focused
- Managed Retreat

2.4.1 Business as Usual

This strategy has been the City's historic strategy and thus is essentially the baseline adaptation alternative. The City will continue to spend money as needed every year to maintain the

Recreational Trail in an emergency response mode when storm events cause excessive erosion such as that illustrated in

Figure 2-2. Regular annual maintenance expenditures are accompanied by larger emergency expenditures for more significant events. Since these events are unpredictable in size and frequency, historical records from the City since the 1990s were used to create an annualized amount of expenditures that could be included in the model each year. These annualized expenditures were accelerated based on sea level rise using the same method as the projected historic erosion rates were accelerated to project future erosion hazards in Chapter 8.

2.4.2 Vertical Coastal Seawall or Soil Nail Wall

The Coastal Seawall and Soil Nail Wall adaptation strategies replace some of the existing revetments with a wide footprint that has buried portions of the narrow beaches in exchange for construction of a vertical seawall or contoured soil nail wall which occupies a smaller footprint on the beach and reduces footprint of the structure on the beach and reduces the wave/coastal armoring interactions in the short term.

Figure 2-2 Erosion Incident on West Cliff Drive: 2019

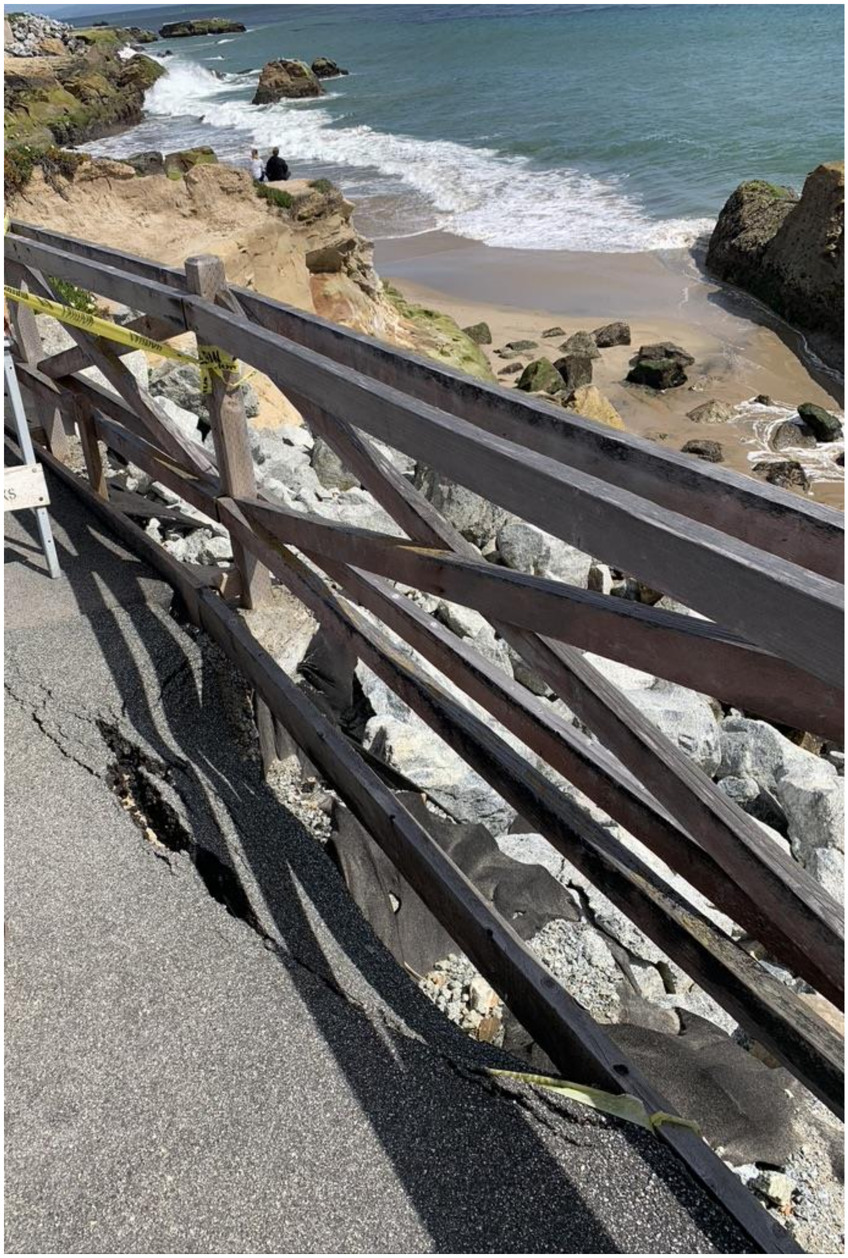
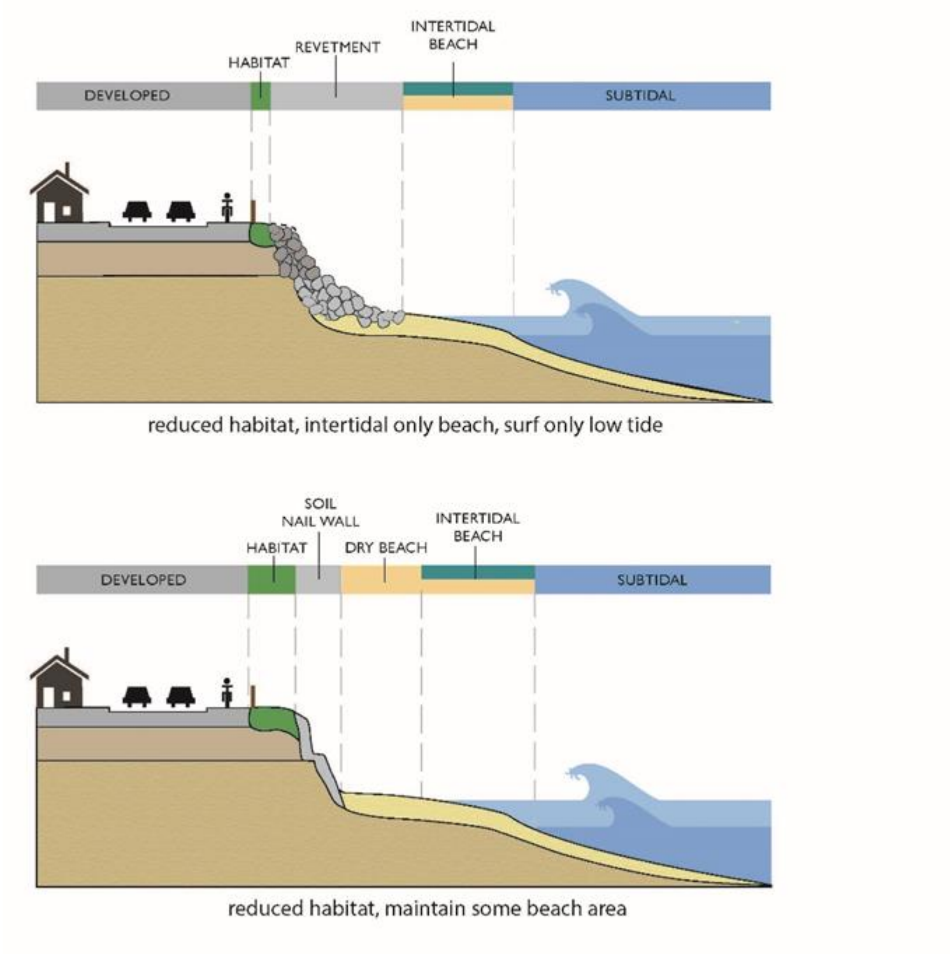


Figure 2-3 Illustration of Armoring Options



2.4.3 Artificial Bedrock

The artificial bedrock strategy is proposed for Zone 1 to mimic the Santa Cruz Mudstone geology that creates wave cut platforms through erosion and are used by shoreline visitors that cannot access the beach. The strategy would increase coastal armoring extents both in width and alongshore and serve to connect the existing bedrock platforms improving alongshore lateral access. The strategy would cement existing and additional riprap into a single armoring structure which could be textured and made more aesthetically pleasing (Figure 2-4). This would likely have a long lifespan and reduce erosion but serve to bury additional pocket beaches and increase the interaction between the waves and coastal armoring for the Zone 1 surf spots.

Figure 2-4 Artificial Bedrock example from Pebble Beach.

.

2.4.4 Groins

Groins are sand retention structures oriented perpendicular to the coast in a cross-shore direction and designed with the intention of trapping and retaining sediment to widen the beach and allow the beach to reduce wave energy and reduce erosion. This also maintains a recreational beach and can improve or maintain surf recreation. Groins at Santa Cruz Harbor (the jetty) and at Capitola (Figure 2-5) are local examples.

Figure 2-5 Example of Groin in Capitola (yellow arrow) and widened beach.

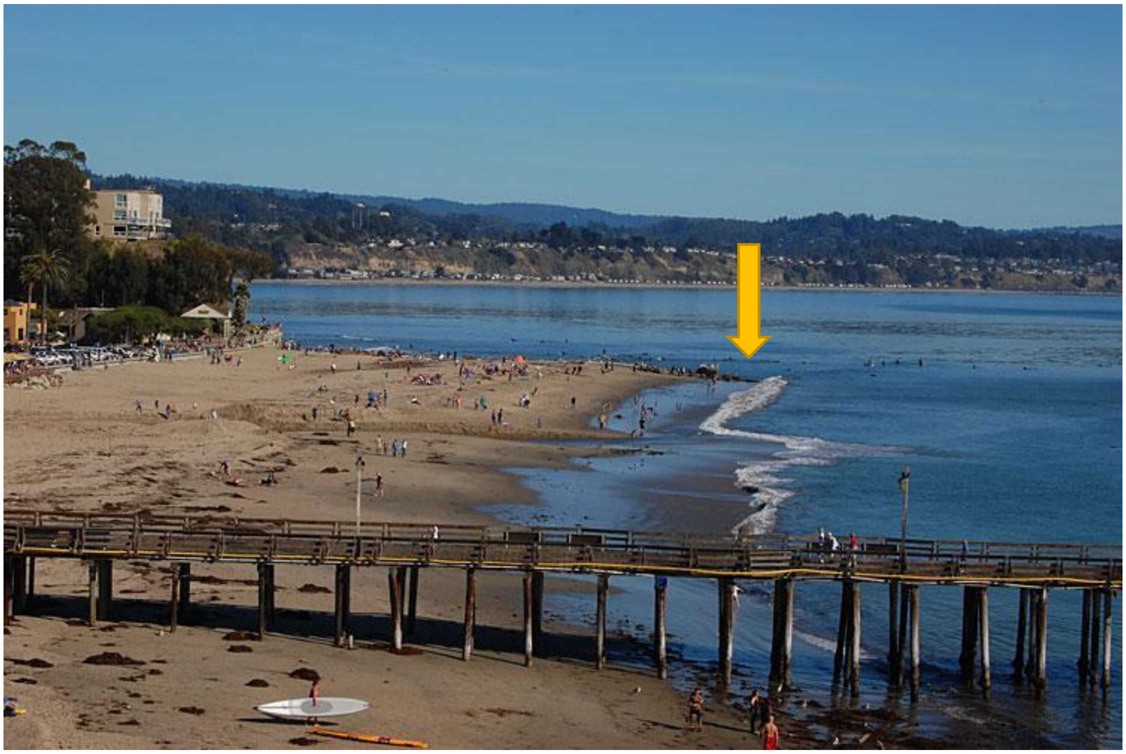


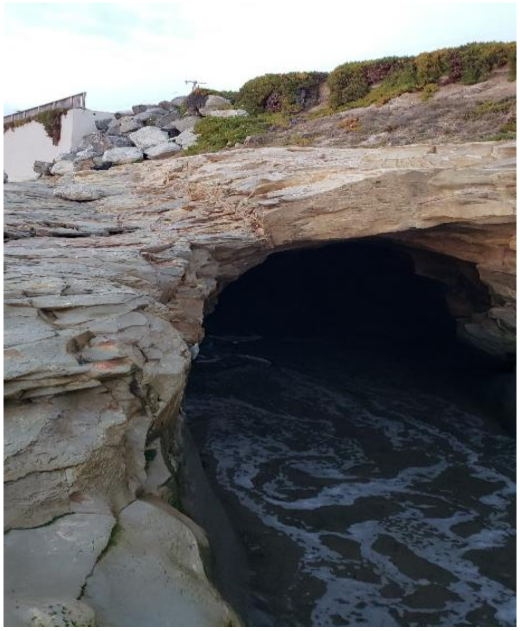
Figure 2-6. Capitola Village groin (in yellow) showing the widened recreational beach that also helps to reduce wave impacts.

2.4.5 Cave Fills

This strategy addressed potential sea cave failures and is highly context-dependent and variable based on cave depth, access, geology, wave exposure, and longevity of solution. Short-term solutions include chemically grouting the marine terrace deposits, which can increase the strength of the overlying deposits providing additional time to find a longer-term solution. More commonly along West Cliff, the entrance of the cave is blocked, usually by revetments to reduce the rate of erosion in the cave. The sea cave can then be filled, often by sealing the entrance with a bulkhead, cap (Figure 2-7), or boulders and then filling the void behind with a sand/slurry concrete mix.

Figure 2-7. Cave fill near the Sea and Sand Inn above Cowells Beach.

Figure 2-8 Cave Hazard near David Way in Zone 2.



2.4.6 Sand Placement and management

The sand placement program proposes to nourish the beach at Pyramid Beach with an estimated 30,000 cubic yards of sand (Figure 2-9). This sand is anticipated to be placed on a 3-year cycle and then to be transported by waves and longshore currents from the western site in Zone 1 eastward along all of the West Cliff Drive Zones and fill in gaps in the reefs and nourishing the small pocket beaches. This alternative is anticipated to offset some of the impacts of coastal armoring by maintaining sandy beaches and improve some of the quality of surf breaks.

Figure 2-9. Potential sand placement at Pyramid Beach with longshore transport

2.4.7 Seawall

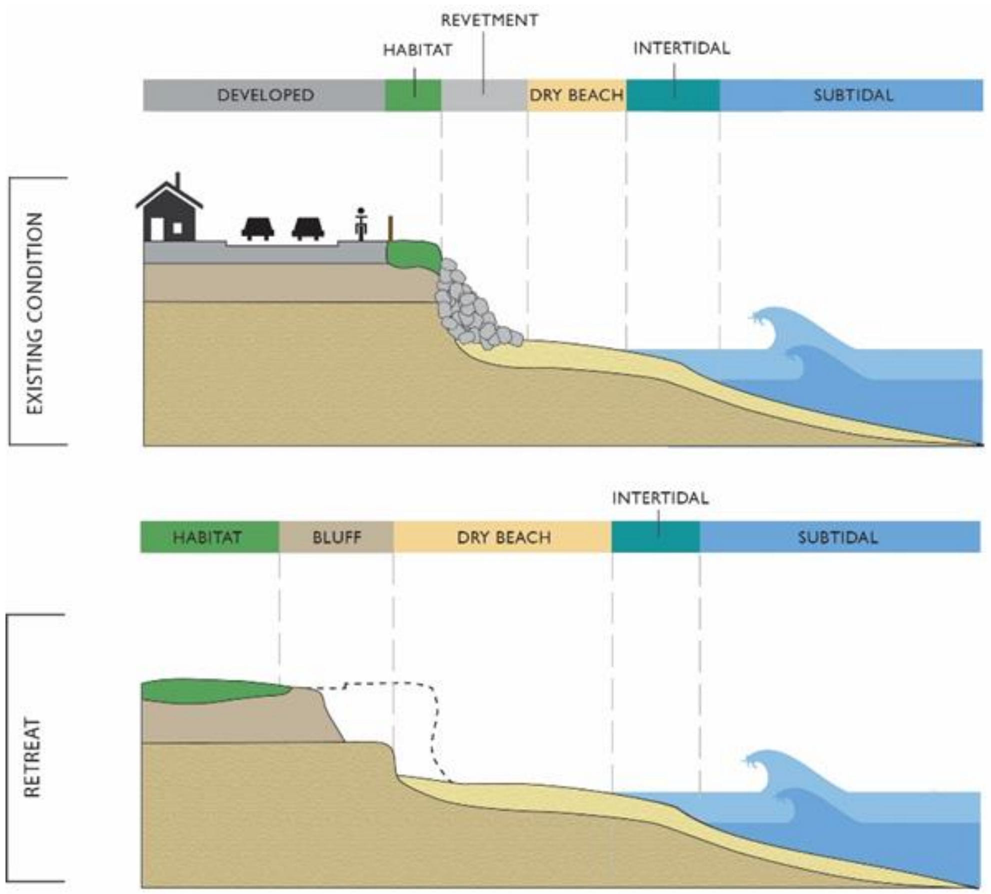
There are already a number of seawalls that have been put in place along the shore of West Cliff Drive. (Figure 2-10). Additional seawalls are proposed as options for specific locations in zones 2 and 4 to address areas of very high erosion potential.

Figure 2-10 Seawalls along West Cliff Drive

2.4.8 Managed Retreat

The managed retreat strategy assumes that over time the existing coastal armoring would be removed, and natural erosion would be allowed to occur. As coastal erosion continued choices about the best use of the cliff top public space for transportation and recreation (e.g. two-way vehicular traffic with no Recreational Trail, one-way vehicle traffic with Recreational Trail, rerouting vehicular traffic) are described in the Transportation Alternatives Conceptual design. This strategy was required for evaluation by both the Caltrans and the California Coastal Commission funders.

Figure 2-11 Illustration of Managed Retreat



2.5 COSTS AND BENEFITS OF EACH STRATEGY

This section breaks down the summary of net present values reported in Table 2-2 into their component cost and benefits estimates. Sections 3 and 4 discuss how these estimates were derived.

In this discussion, changes in the value of recreation are separately reported for "shore" and "surf". "Shore" refers to recreational visitors who use the shoreline in addition to the cliff-top recreational trail. Shore users may visit a beach, climb on rocks, go swimming, or walk a dog. Surfers are shore users who access the shoreline and the water for surfing. The values of these recreational values in the analysis are driven by different levels of change in the number of participants and by different values. The value of recreational experiences at West Cliff Drive were determined in a survey of over 900 users of the Drive area in 2019. The results of the survey showed that general recreation visitors valued their experience at $101.82 per household per year and $119.42 for surfers. The way in which changes in the number of users of each type are derived are discussed in section 4.

2.5.1 Business as usual strategy

- Costs:
  - Spending limited to routine and emergency maintenance/repairs of existing armoring structures. Emergency repairs are unpredictable in either time or amount, so the cost estimates include an annualized level of expenditures greater than just routine maintenance.
  - A business as usual strategy foregoes the opportunity to maintain or expand recreation use and value. These foregone benefits are part of the costs of business as usual. Because there are different levels of recreation benefits that may result from the three other investment options, the business as usual strategy must be separately compared to each of them.
- Benefits
  - The principal benefits of the business as usual strategy is avoiding making the expenditures of any of the other strategies. This is another reason why the business as usual case must be evaluated in comparison with each of the other options.

Table 2-3 Costs and Benefits of Business as Usual Strategy

		SLR Trigger Point in Feet		
		0.30	0.88	1.90
Costs	Maintain/ Emergency Repairs	-$16.18	-$16.18	-$16.18
	Shore*	-$4.89	-$4.89	-$4.89
	Surf*	-$53.68	-$53.68	-$53.68
	Total Costs	-$74.76	-$74.76	-$74.76
Benefits	Avoided Costs (Retreat)	$21.99	$7.32	$1.71
	Avoided Costs (Recreation)	$14.97	$13.17	$12.57
	Avoided Costs (Protection)	$26.54	$19.46	$16.70
Net Present Value Business as Usual v. Retreat		-$52.77	-$67.43	-$73.04
Probability of Positive Net Present Value v. Retreat		<.001	<.001	<.001
Net Present Value Business as Usual v. Recreation		-$59.79	-$61.58	-$62.18

		SLR Trigger Point in Feet		
		0.30	0.88	1.90
Probability of Positive Net Present Value v. Recreation		<.001	<.001	0.01
Net Present Value Business as Usualv. Protection		-$48.21	-$55.30	-$58.05
Probability of Positive Net Present Value v. Protection		0.12	<.001	0.03

Millions of Present Value Dollars

- Findings
  - The ongoing costs of maintenance and emergency repair plus the loss of recreational benefits, particularly to surfers, are greater than the savings from not spending on any of the other strategies.
  - The losses in recreational values of the business as usual strategy compared with the recreation focused strategy are the largest for the higher SLR triggers and the probabilities are very low that a positive net present value can be obtained.
  - The estimate is for a negative present value when compared with the recreation or protection strategies, but there is a very small (3%) probability that a positive present value could occur.

2.5.2 Recreation Focused Strategy

- Costs:
  - Sand placement at Pyramid Beach in Zone 1. Sand placement requires regular renewal; in this analysis the expenditure on sand placement is assumed to occur every 3 years after the initial sand placement in 2025. This placement cycle assumption must be further evaluated with future modeling and analysis. Implementation of this option is fixed at 2025 and does not vary with sea level rise.
  - Three protective structures are built: a seawalls to replace existing revetments in Zones 2, a new wall in Zone 4, a groin in Zone 2, and a sea cave would be filled in Zone 2.
- Benefits: Increases in Recreation relative to business as usual

Table 2-4 Costs and Benefits of Recreation Focused Scenario

		SLR Trigger Point in Feet		
		0.30	0.88	1.90
Costs	Sand Placement	-$12.43	-$12.43	-$12.43
	Cave Fill / Nail Wall	-$0.44	-$0.13	-$0.03
	Sea Wall	-$0.63	-$0.19	-$0.02

	Groin	-$1.47	-$0.43	-$0.10
	Total Costs	-$14.97	-$13.17	-$12.57
Benefits	Shore Users	$13.89	$13.89	$13.89
	Surfers	$29.43	$29.43	$29.43
	Total Benefits	$43.32	$43.32	$43.32
Net Present Value		$28.35	$30.14	$30.74
Probability of Positive Net Present Value		>.99	>.99	0.91

Millions of Present Value Dollars

- Findings
  - The recreation focused strategy has high net present values and probabilities of positive net present values greater than 99% compared to the business as usual strategy.
  - The timing of the deployment of the actions in the recreation strategy is not critical; there is very little variation in the level of benefits or net present value between the different sea level rise trigger scenarios; what differences there are not visible at the two-decimal place figures in millions of dollars.

2.5.3 Protection focused strategy

- Costs:
  - This strategy primarily consists of structural adaptation options to reduce coastal erosion, including the construction of an artificial bedrock platform in Zone 1, cave fills in Zones 2 and 4, and the development of a revetment maintenance plan and continuation of annual maintenance not under emergency repair conditions.
- Benefits:
  - Increases in Recreation values relative to business as usual.

2-5 Costs and Benefits of Protection Focused Strategy

		SLR Trigger Point in Feet		
		0.30	0.88	1.90
Costs	Artificial Bedrock	-$8.17	-$2.63	-$0.38
	Cave Fill	-$2.19	-$0.64	-$0.13
	Maintain/ Emergency	-$16.18	-$16.18	-$16.18
	Total Costs	-$26.54	-$19.46	-$16.70
Benefits	Shore Users	$4.52	$1.89	$0.26
	Surfers	$42.62	$17.69	$2.13
	Total Benefits	$47.15	$19.58	$2.40

		SLR Trigger Point in Feet		
		0.30	0.88	1.90
Net Present Value		$20.60	$0.12	-$14.30
Probability of Positive Net Present Value		0.65	0.20	0.01

Millions of Present Value Dollars

- Findings
  - The economic case for the protection focused strategy is moderately strong if investments are made relatively soon (before about 1 foot of sea level rise), but very weak thereafter. If not deployed until about 2 feet of sea level rise, there is very little probability of positive economic returns.

2.5.4 MANAGED RETREAT

- Costs: Removal of existing armoring structures in all zones.
- Benefits: Increases in recreation values relative to business as usual

Table 2-6 Costs and Benefits of Managed Retreat Strategy

		SLR Trigger Point (Feet)		
		0.30	0.88	1.90
Present Value Costs	Retreat Costs	-$21.99	-$7.32	-$1.71
	Maintain/ Emergency Costs	-$16.18	-$16.18	-$16.18
	Retreat Total Costs	-$38.17	-$23.51	-$17.90
Present Value Benefits	Retreat Benefits Shore	$10.42	$3.16	$0.29
	Retreat Benefits Surfers	$56.36	$27.07	$4.39
	Retreat Benefits Total	$66.78	$30.23	$4.68
Net Present Value		$28.61	$6.72	-$13.22
Probability of Positive Net Present Value		0.79	0.37	0.09

Millions of Present Value Dollars

- Findings
  - Like the protection focused strategy, the managed retreat strategy has its best returns if implemented soon. The greater enhancement of recreation opportunities through

managed retreat means that the net present value is notably higher than the business as usual strategy and the chances of a positive net present value higher through at least half a foot of sea level rise. It is also notable that the probability of a higher net present value over all of the trigger sea level rise elevations is more likely than the protection strategy.

2.6 COSTS AND BENEFITS BY ZONE

This section compares the costs and benefits of each option by zone. This permits a more detailed examination of the various options, but the analysis is misleading in some cases. Costs and benefits of each option in that zone are examined, but some options affect more than one zone. For example, the sand placement option for Zone 1 will have costs registered in Zone 1 but benefits registered in all four zones. Care should be taken to assess the economics of an option both in terms of individual zonal effects reported here and its West Cliff Drive-level effects reported above.

Table 2-7 Zone 1 Costs and Benefits

	SLR Trigger Point (Feet)	Costs	Benefits Shore	Benefits Surf	Benefits Total	NPV
Business as Usual	0.30	-$4.97	$1.28	$8.65	$9.93	$4.97
	0.88	-$4.97	$1.28	$8.65	$9.93	$4.97
	1.90	-$4.97	$1.28	$8.65	$9.93	$4.97
Sand Placement	0.30	-$12.43	$8.31	$4.85	$13.17	$0.74
	0.88	-$12.43	$8.31	$4.85	$13.17	$0.74
	1.90	-$12.43	$8.31	$4.85	$13.17	$0.74
Artifical Bedrock	0.30	-$8.17	$3.10	$4.32	$7.42	-$0.74
	0.88	-$2.63	$1.47	$2.99	$4.46	$1.83
	1.90	-$0.38	$0.23	$0.17	$0.40	$0.01
Retreat	0.30	-$8.84	$2.77	$9.00	$11.77	$2.93
	0.88	-$2.95	$0.86	$4.02	$4.89	$1.94
	1.90	-$0.69	$0.06	$0.48	$0.55	-$0.14

Millions of Present Value Dollars

Table 2-8 Zone 2 Costs and Benefits

	SLR Trigger Point (Feet)	Costs	Benefits Shore	Benefits Surf	Benefits Total	NPV
Business as Usual	0.30	-$7.21	$1.06	$1.43	$2.49	-$4.72
	0.88	-$7.21	$1.06	$1.43	$2.49	-$4.72
	1.90	-$7.21	$1.06	$1.43	$2.49	-$4.72
Sand Placement	0.30		$2.21	$0.90	$3.10	$3.10
	0.88		$0.17	$2.71	$2.88	$2.44
	1.90		-$0.81	$0.02	-$0.79	-$1.42

	SLR Trigger Point (Feet)	Costs	Benefits Shore	Benefits Surf	Benefits Total	NPV
Cave Fill/Nail Wall	0.30	-$0.44	$0.17	$2.71	$2.88	$2.44
	0.88	-$0.13	-$1.39	$1.27	-$0.12	-$0.25
	1.90	-$0.03	$0.06	$0.17	$0.23	$0.20
Coastal Wall	0.30	-$0.63	-$0.81	$0.02	-$0.79	-$1.42
	0.88	-$0.19	-$1.50	$0.02	-$1.48	-$1.66
	1.90	-$0.02	$0.06	$0.02	$0.09	$0.07
Groin	0.30	-$1.47	$0.14	$1.49	$1.63	$0.17
	0.88	-$0.43	$0.14	$0.77	$0.91	$0.48
	1.90	-$0.10	$0.13	$0.12	$0.25	$0.15
Retreat	0.30	-$9.65	$3.34	$1.47	$4.80	-$4.85
	0.88	-$3.22	$0.99	$0.74	$1.74	-$1.48
	1.90	-$0.75	$0.10	$0.10	$0.19	-$0.56

Millions of Present Value Dollars

Table 2-9 Zone 3 Costs and Benefits

	SLR Trigger Point (Feet)	Costs	Benefits Shore	Benefits Surf	Benefits Total	NPV
Business as Usual	0.30	-$2.24	$2.22	$28.25	$30.47	$28.23
	0.88	-$2.24	$2.22	$28.25	$30.47	$28.23
	1.90	-$2.24	$2.22	$28.25	$30.47	$28.23
Sand Placement	0.30		$2.95	$13.92	$16.87	$16.87
	0.88		$2.95	$13.92	$16.87	$16.87
	1.90		$2.95	$13.92	$16.87	$16.87
Cave Fill	0.30	-$1.91	$1.32	$24.93	$26.25	$24.34
	0.88	-$0.56	$0.39	$9.07	$9.46	$8.90
	1.90	-$0.12	$0.03	$1.23	$1.27	$1.15
Retreat	0.30	-$3.21	$3.99	$3.99	$7.98	$4.77
	0.88	-$1.07	$1.19	$1.19	$2.38	$1.31
	1.90	-$0.25	$0.12	$0.12	$0.23	-$0.02

Millions of Present Value Dollars

Table 2-10 Zone 4 Costs and Benefits

		Costs	Benefits Shore	Benefits Surf	Benefits Total	NPV
Business as Usual	0.30	-$1.76	$0.33	$15.35	$15.68	$13.91
	0.88	-$1.76	$0.33	$15.35	$15.68	$13.91
	1.90	-$1.76	$0.33	$15.35	$15.68	$13.91
Sand Placement	0.30		$0.42	$0.42	$0.85	$0.85
	0.88		$0.42	$0.42	$0.85	$0.85
	1.90		$0.42	$0.42	$0.85	$0.85
Cave Fill	0.30	-$0.29	$0.10	$13.37	$13.47	$13.19
	0.88	-$0.08	$0.03	$5.63	$5.66	$5.58
	1.90	-$0.02	$0.00	$0.73	$0.73	$0.72
Retreat	0.30	-$0.29	$0.32	$16.03	$16.35	$16.07
	0.88	-$0.08	$0.11	$8.29	$8.40	$8.32
	1.90	-$0.02	$0.01	$1.35	$1.37	$1.35

Millions of Present Value Dollars

3 EXPENDITURE (COST) ESTIMATES

3.1 OVERVIEW

All expenditure estimates for the analysis were provided by Haro, Kasunich & Associates (HKA), the coastal engineers on the project team with over 40 years of experience along West Cliff Drive. Their estimates were based on information from past expenditures by the City of Santa Cruz as well as their extensive experience with coastal engineering projects in Santa Cruz and elsewhere. The expenditure costs for adaptation projects for West Cliff Drive are measured in terms of:

- **Construction Costs**: These are the outlays that required to construct a project. All initial cost estimates are assumed to occur over one calendar year, though in reality some may be split into more than one year depending on exact project needs, budgets, etc. Because of the uncertainties in cost estimating at this level of detail, the cost estimates are randomly varied on each iteration between 25% below and 300% above base estimates.
- **Maintenance Costs**: In some cases, after the initial outlay there is an assumption of annual costs for maintaining the structure. These are included in the cost estimates. Maintenance costs begin the year after the construction cost is incurred and continue for the life of the project. These costs are also randomly varied in the same manner as construction costs.
- **Useful Life**. The project's useful life is assumed to be 50 years in most cases. After 50 years, there is an assumption of reconstruction of the project at the same cost as the initial construction. Projects deployed before 2050 will have a reconstruction project equal to year of deployment plus 50 (e.g., a project deployed in 2040 would be reconstructed in 2090).

The sand placement project in Zone 2 is assumed to have a useful life of 3 years and the initial cost is repeated every three years.

Cost estimates for projects such as those examined in this study are very difficult because they are conceptual projects only; the many detailed elements that ultimately determine costs require substantially more resources than available for this study. In order to accommodate the uncertainty associated with the cost estimates, a method similar to that used to measure the probabilities associated with sea level rise.

In the sea level rise case, the probability calculations are based on the underlying data provided by Kopp et al. (2014). In the case of the cost estimates, a technique called PERT analysis is used. This calculates a probability curve linking a most likely estimate, a lower estimate and a higher estimate, both of which are less likely to occur. For this analysis all of the estimates from HKA were taken as the most likely estimate. The lower estimate was calculated as 75% of the HKA estimate and the higher at 300% of the HKA estimate. This means that on every iteration of the model, a cost ranging from 25% below to 300% above the HKA estimate for any given project could be selected. Because the resulting curve is biased towards the right side (that is towards the higher costs), the result is a conservative approach to cost estimates.

3.2 EXPENDITURE ESTIMATES

Table 3-1 Estimated Expenditures for Business as Usual Maintenance and Emergency Costs

					Zone 1	Zone 2	Zone 3	Zone 4
					Zone Share of Total WCD Expense			
Action	Time Frame	Total Amount	N Years	Avg Expend/ Year	31%	45%	14%	11%
Maintain and Repair Coastal Protection Structures (<10 yr life structures without action; some are in critical need of repair now)	2020 - 2030	*$6,960,000*	10	$696,000	$215,760	$313,200	$97,440	$76,560
Maintain and Repair Coastal Protection Structures When Needed In 2030 to 2050 (10-30 yr life structures without action)	2030 - 2050	*$5,380,000*	20	$269,000	$83,390	$121,050	$37,660	$29,590
Maintain and Repair Coastal Protection Structures When Needed In 2050 to 2100 (30+ yr life structures without action)	2050 - 2100	*$8,270,000*	50	$165,400	$51,274	$74,430	$23,156	$18,194

Table 3-2 Estimated Expenditures for Actions in Zone 1

	Initial Expenditure	Useful Life (Years)	Annual Maintenance
Sand Placement/Pyramid Beach	$1,070,000	3	$356,667
Artificial bedrock platforms providing lateral access (from Site 11 to 22)	$5,960,000	50	$39,800
Managed Retreat	$10,740,000	n/a	

Table 3-3 Estimated Expenditures for Actions in Zone 2

Action	Initial Expenditure	Useful Life	Annual Maintenance
Cave Fill (Areas of Erosion Concern 23, 24c, 27b & 31a)	$420,000	50	$2,000
Soil Nail Wall Along Mitchells Cove Beach (Sites 23 to 27)	$3,880,000	50	$26,000

Groin (150' long, initially charge with 20k CY of sand)	$1,470,000	50	$9,400
Groin (150' long, initially charge with 40k CY of sand)	$2,470,000	50	$9,400
Managed Retreat	$11,720,000		

Table 3-4 Estimated Expenditures for Actions in Zone 3

Action	Initial Expenditure	Useful Life	Annual Maintenance
Cave Fill	$1,680,000	50	$11,200
Managed Retreat	$3,900,000		

Table 3-5 Estimated Expenditures for Actions in Zone 4

Action	Initial Expenditure	Useful Life	Annual Maintenance
Cave Fill (Areas of Erosion Concern 45, 46b, 47)	$260,000	50	$1,800
Coastal Wall Along Toe of Bluff & Rip-Rap Removal (Site 52)	$5,300,000	50	$27,600
Managed Retreat	$2,080,000		

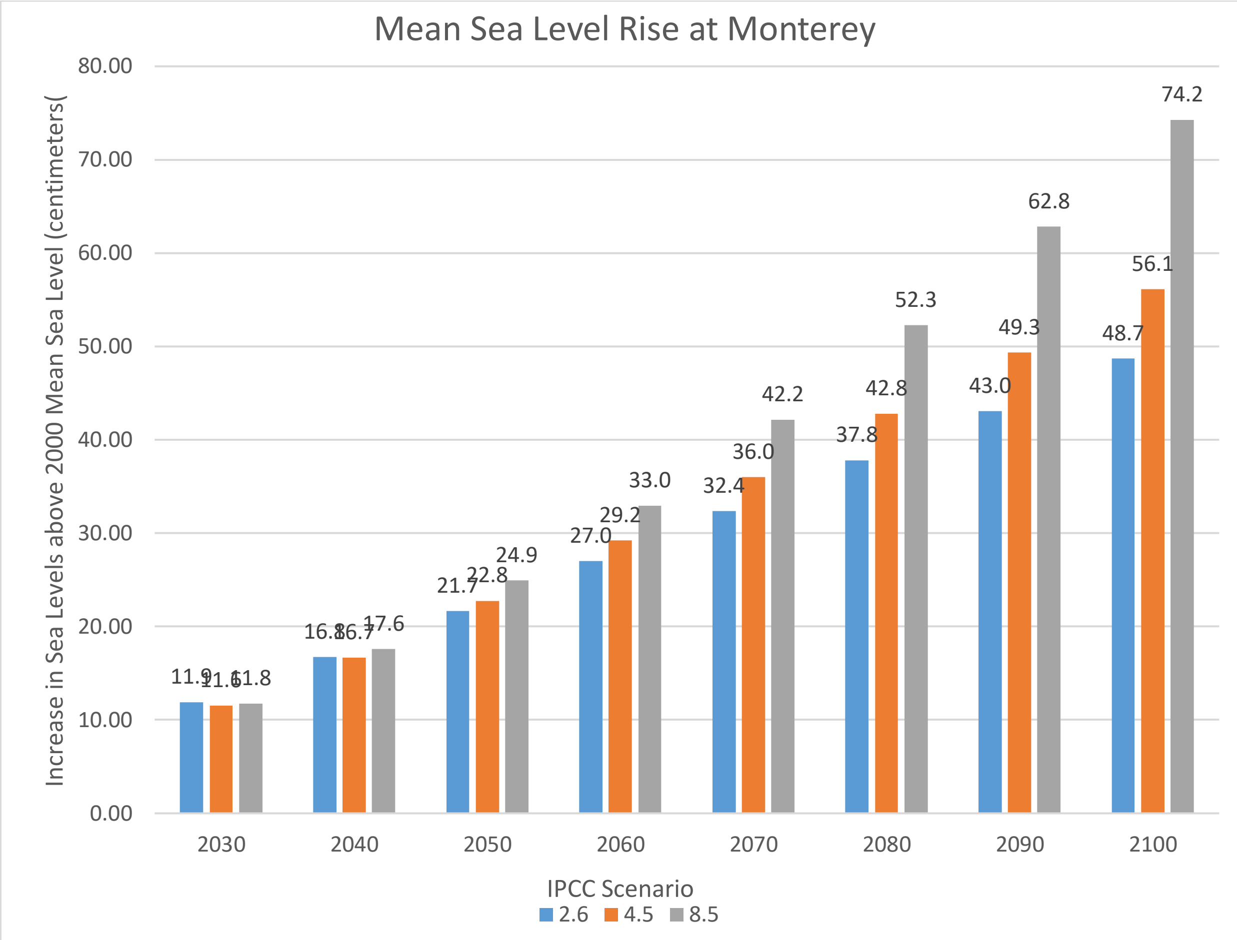
3.3 TIMING OF EXPENDITURES

A critical feature of this benefit cost analysis is the relationship between sea level rise and the decision to deploy any of the project options that are being examined. The discussion of benefits and costs in section 2 shows how the concept of sea level rise triggers is employed. This section discusses how the estimates of sea level rise are calculated.

Projections of sea level rise are typically depicted as in Figure 3-1, that is as linear projections. Figure 3-1 is derived from Kopp et al. (2014) and shows the median of a set of probabilistic projections of sea level rise at the Monterey tide station (the only tide station in Monterey Bay). These projections were made assuming three different possible extents of climate change as represented by the Intergovernmental Panel on Climate Change (IPCC) scenarios designated Representative Concentration Pathways 2.6, 4.5, 8.5. (Intergovernmental Panel on Climate Change, 2014)

But the projections in Figure 3-1 are simply the points in each forecast with a 50/50 probability of occurring. In fact, sea level rise may be more or less than the median levels, depending on a variety of factors including the extent of atmospheric heating, runoff from land, and melting of glaciers. Sea level rise may most probably be at the median level, but it could be much lower or much higher. The Ocean Protection Council guidance for sea level rise planning is that plans should include low probability but high consequence possibilities.

Figure 3-1 Projected Sea Level Rise at Monterey: Mean Estimates



Using the approach in this benefit cost analysis takes into account the full range of possibilities including the extreme possibilities. This range of possibilities is shown in

Figure 3-2 through Figure 3-5. These are histograms of iterations of the sea level rise variable in the benefit cost model. The values are calculated using equations fit to the Kopp et al. data for Monterey. Estimates for sea level values are for decadal years (2020, 2030, 2040, etc.). In the model the values for sea level rise in years between decadal years are estimated through interpolation. The sea level rise estimates used in the benefit cost analysis are for the IPCC 8.5 scenario, the highest rate of climate change, in accordance with OPC guidance.

Figure 3-2 Probability Distribution of Sea Level Increases at Monterey 2030

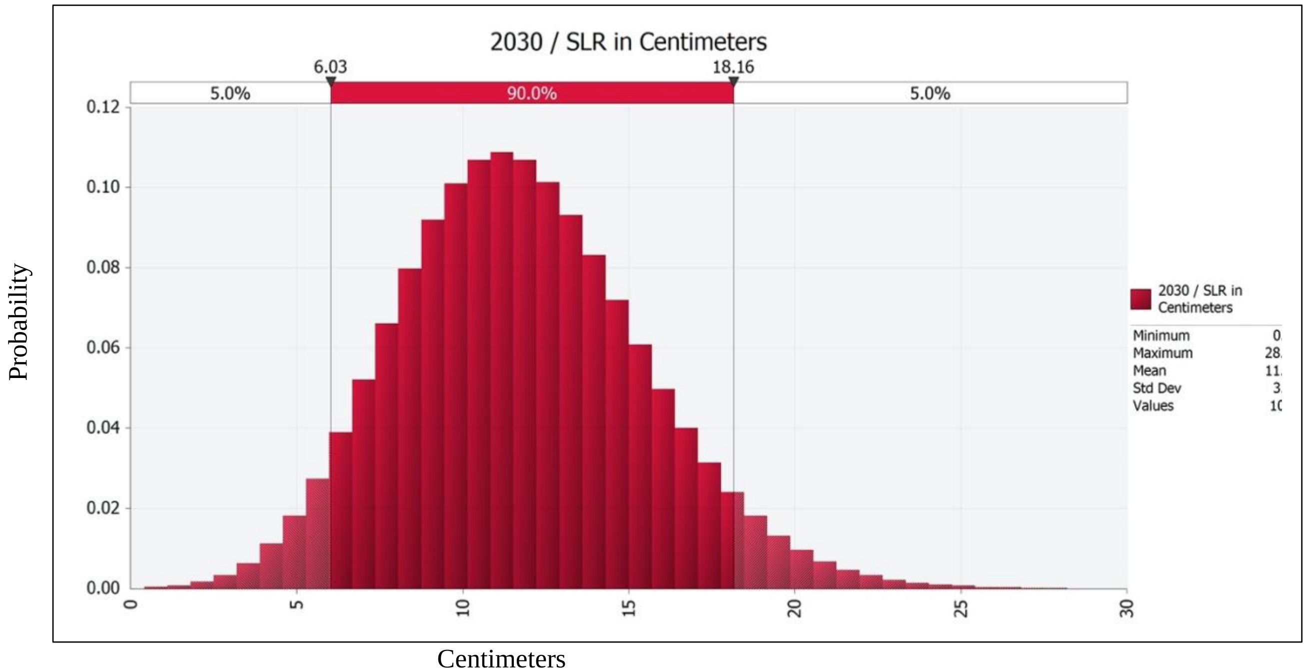


Figure 3-3 Probability Distribution of Sea Level Increases at Monterey 2050

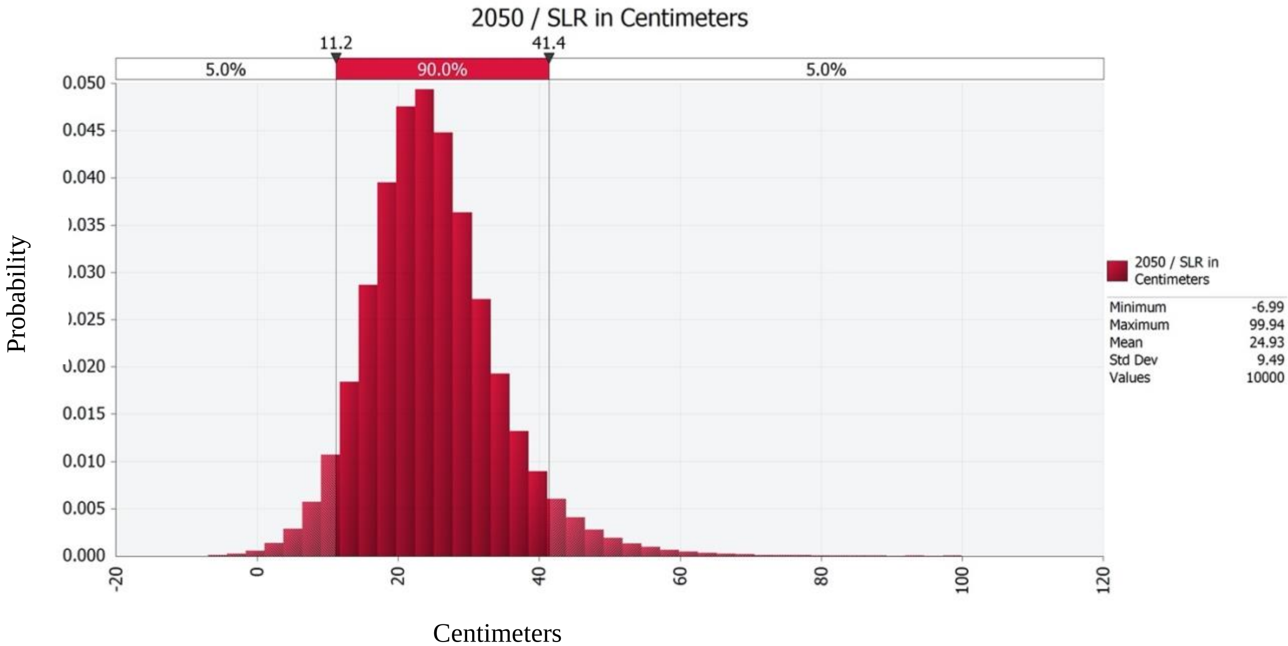


Figure 3-4 Probability Distribution of Sea Level Increases at Monterey 2070

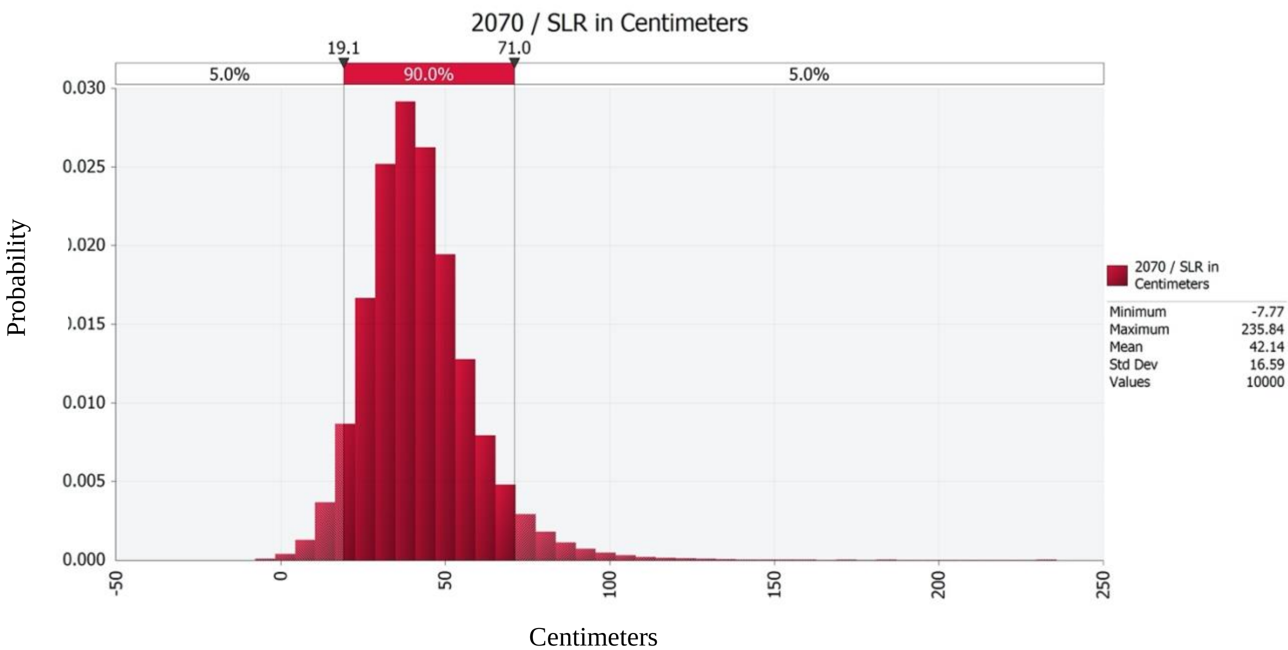
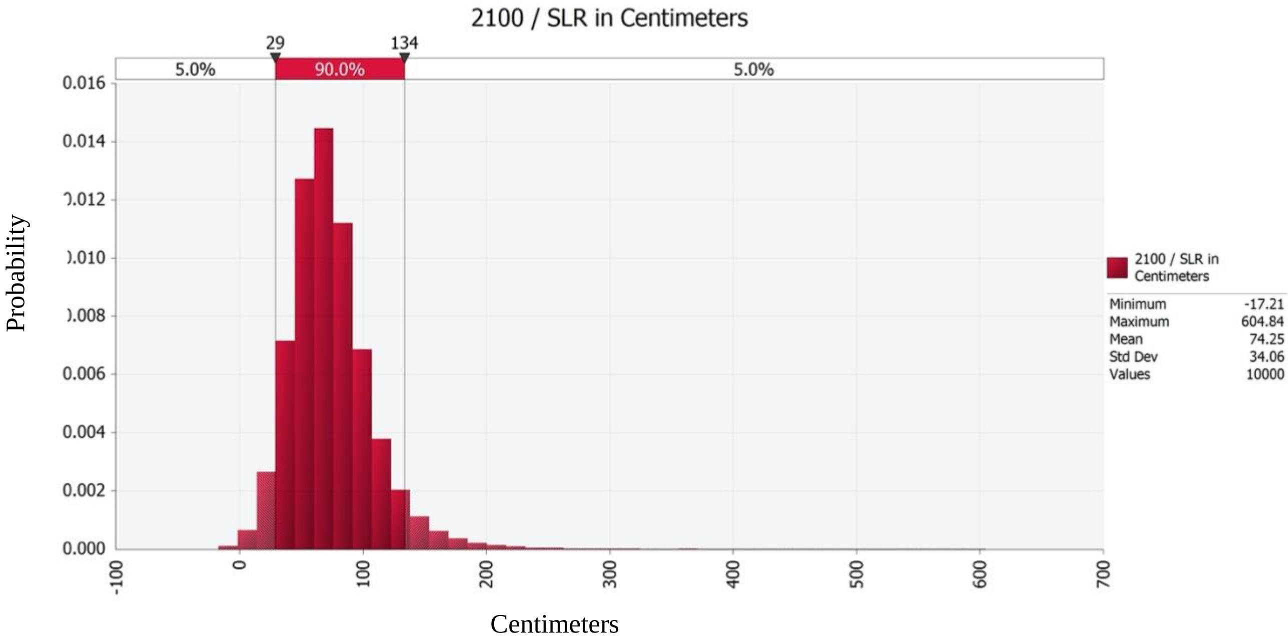


Figure 3-5 Probability Distribution of Sea Level Increases at Monterey 2070



2100 / SLR in Centimeters
29
134
5.0%
90.0%
5.0%
Probability
0.016
0.014
0.006
0.004
0.002
0.000
-100
0
100
200
300
400
500
600
700
Centimeters
2100 / SLR in Centimeters
Minimum -17.21
Maximum 604.84
Mean 74.25
Std Dev 34.06
Values 10000

Figure 3-2 through Figure 3-5 show the estimated sea level rise for 2030, 2050, 2070, and 2100 respectively as examples of the model outputs for sea level rise. As the century progresses, the most probable sea level rises (the highest bars) increase and the probability of extremely high sea level rises increases (the range of possibilities shown along the horizontal axis). Each of these possibilities is examined in at least one iteration of the benefit cost model. Using 100,000 iterations allows very low frequency (but high impact) probabilities to be included in the analysis. The results of the model shown in the tables represent the median points of the iterations.

The link between the sea level rise projections and the deployment of the adaptive actions along West Cliff Drive is shown in Table 3-6. This table shows the range of possible years across the iterations of the model for each trigger level chosen. This is expressed, as is the case with the sea level rise estimates, in terms of the most likely along with earlier and later possible deployments which are less likely (there are fewer such examples of each across all the iterations in the model).

The timing of spending and receipt of benefits has a large effect on a benefit cost analysis as money spent or received in the future are worth less than money spent or received today; the difference being determined by the discount rate. Fixed dates (2025) were chosen to test model performance and a discount rate of 4% was used.

Table 3-6 Estimated Years of Deployment by Action and Zone

Sea Level Trigger (in Feet)								
0.30			**0.88**			**1.90**		
Year of Deployment								
Earliest	Likely	Latest	Earliest	Likely	Latest	Earliest	Likely	Latest
2021	2024	2034	2044	2053	2076	2044	2076	2088

4 CHANGES IN RECREATION VALUES

4.1 ESTIMATING THE VALUE OF RECREATION

The economic value of recreation activities was measured using an intercept survey. There are many different types of economic value. In benefit cost analysis, the appropriate measure is the value to users over and above whatever they spend. Spending to travel to West Cliff Drive or in shops or restaurants and hotels are measured in impacts in the local economy, but they are not the value to the recreational users themselves. Many visitors to West Cliff Drive are locals who walk or ride a bicycle to the area and spend nothing. Yet the experience still has value to them. Similarly, visitors who come from a distance and stay in Santa Cruz do not consider what they spend on a hotel as the value of their visit. So the value to the users is different than what they spend. (Freeman et al., 2014)

Survey research is the most common way to measure this "surplus" value, that is the value over what is spent. There are several different ways to measure this value, but the accepted method is to use a "referendum format" question. (Carson, 2012) In this type of question, the asset being value is described, a change in that asset is posited, and the respondent is asked whether they would pay a specified amount to maintain, restore, or otherwise affect the asset. A version of this approach is to ask a second question. If the respondent answers they would pay the specified amount, they are then asked if they would pay a somewhat higher amount; if they say they would not pay the specified amount, they are asked if they would pay a somewhat lower amount. This type of survey is called a double bid-dichotomous choice. Double bid means that respondents offer information about two amounts through a dichotomous choice (yes or no).

The economic value of recreation was estimated from the 2019 survey of West Cliff Drive visitors. The survey was administered from July 12, 2019 to March 8, 2020. A total of 926 responses were recorded by interviewers who intercepted people at various locations along West Cliff Drive in all four zones (see Figure 2-1 above). Of the respondents, 59% were residents of the City of Santa Cruz and an additional 7% were residents of Santa Cruz County. Fifty five percent of respondents were male and 45% female. The ages of respondents tended towards younger respondents, which is not surprising given the active recreation character of West Cliff Drive. (Table 4-1)

Table 4-1 Age Range of Survey Respondents

Age	Frequency	Percent
18-29	195	23.1
30-39	138	16.4
40-49	147	17.4
50-59	160	19.0
60-69	131	15.5
70+	72	8.5

Twenty one percent (21%) of respondents reported that they were either at West Cliff Drive that day to go surfing or regularly go to WCD for surfing. These respondents were designated as “surfers”. Eighty two percent (82%) of respondents reported they visited the shoreline on their visits to West Cliff Drive; twenty six percent (26%) of respondents visit the shoreline “most of the time” or “always”. These are designated as “shore users”.

Overall, West Cliff Drive is frequently visited. Fifty seven percent (57%) of respondents indicated they visit at least once a week (10% report visiting every day); an additional 13.3% report visiting monthly. Eleven percent (11%) of respondents were visiting for the first time, and 90% of these reported they would return. The estimation of the total number of visitors to West Cliff Drive for various recreational purposes is shown in Table 4-2. The frequency of visitation has implications for the estimates of annual visitation needed to calculate benefits that are discussed in Section 5.

Table 4-2 Annual Recreational Visitors by Zone

	Shoreline Users	Surfers
Zone 1	3,900	32,145
Zone 2	5,600	8,379
Zone 3	13,400	103,560
Zone 4	1,000	89,943
Total	23,900	234,025

The survey responses were subdivided into two groups:

- Shore users: Those who reported visiting the shoreline during a trip to West Cliff Drive.
- Surfers: Those who reported that they visited West Cliff Drive in order to surf.

Of these groups, only the shoreline users and surfers are examined to elicit the economic value of their West Cliff Drive experience. The number of users on the trail/roadway was also estimated. But the current information is that these "cliff top" users are unlikely to be affected by adaptation options to an economically significant extent. The proposals to change West Cliff Drive from two-way to one-way will reorganize traffic patterns in the neighborhood to a minor extent according the traffic modeling conducted for this study by Fehr & Peers.

The estimates of the number of users were derived from a combination of data sources, including the WCD surveys and expert assessments. Data was estimated for the number visits and then converted to visitors, adjusting for frequency of visitation. The origins of these estimates are discussed in section 4.2 and Appendices 1 and 2.

The amount suggested to respondents varies randomly with each respondent. Table 4-3 shows the amounts suggested in the survey for both the initial and supplementary bids. In general, more people agree to lower amounts than to higher amounts. The distribution of answers can then be analyzed statistically to estimate the "surplus" value. (Aizaki et al., 2015)

Table 4-3 Bid Amounts in Santa Cruz Valuation Survey

Initial Amount	Amount if Yes	Amount if No
$10	$20	$5
$20	$30	$10
$30	$40	$20
$40	$50	$30
$50	$60	$40

Four versions of the valuation question were asked, two were for general West Cliff Drive visitors and two were for surfers. Slightly different versions were asked depending on whether the respondent was a resident of the City of Santa Cruz. Residents were asked if they would vote for a city bond issue to protect the recreation of West Cliff Drive if the bond issue were to cost their household the specified amount per year for 20 years. Nonresidents were asked if they would contribute to a fund to preserve West Cliff Drive. The exact questions asked are shown in Appendix 3.

The resulting values, in dollars per household per year, are:

- Shore users: $101.81
- Surfers: $119.42

4.2 ASSUMPTIONS OF CHANGE IN VISITORS

The values estimated in the survey described in section 4.1 were multiplied by the changes in the number of shore users and surfers to derive the benefit and cost estimates discussed above.

Table 4-4 and Table 4-5 show the percent changes in users by extent of sea level rise. Two factors influence these changes: sea level rise itself, and the effects of the adaptation options selected. The adaptation options may increase usage in some ways but diminish it in others. For example, sand placement at Pyramid Beach will increase the number of shoreline users in Zone 1 as well as in other zones. But it will also increase surfing use in all zones. Sea level rise also has complex effects. Sea level rise will reduce the number of surfers significantly over time if nothing is done because the hours of usable surf will steadily diminish, offering fewer and fewer surfing opportunities.

In both these tables, the percent changes are based on the decision confronting the City, which confronts a choice between doing nothing additional to manage West Cliff Drive beyond what it has done in the past and the choice to invest in specific projects to adapt to sea level rise. The "base case" for the analysis is thus "business as usual", which has the benefit of saving substantial City funds that would be need to support the adaptation projects.

The general pattern of benefits and costs are reflected in these two tables since it is the change in the number of users that drives the change in economic values. The "business as usual" choice shows losses in both shoreline users and surfers compared with current levels of use. But the adaptation projects cannot be compared with current use, but the current situation will not continue into the future; either the future will be "business as usual" or something else. So, all of the adaptation options should be compared to the usage levels in the business as usual projections.

The business as usual choice reduces both shore users and surfers by significant amounts, in some zones by as much as 100% at higher levels of sea level rise. All of the adaptation options show significant declines in recreational use after two feet of sea level rise, except for sand management and the creation of an artificial bedrock structure in Zone 1. These structures are able to maintain some platforms for shore users. On the other hand, structures such as seawalls, the artificial bedrock, and groins reduce surfing after two feet of sea level rise because of deterioration of wave conditions due to interactions between the waves and coastal armoring.

Additional details on changes in shore use and surfers are provided in Appendices 1 and 2.

Table 4-4 Changes in Shoreline Users by Extent of Sea Level Rise and Zone

Sea Level Rise (Feet)		1	2	3	4	5
Percent Change in Surfers for Business as Usual Relative to 2020)						
Business As Usual	Zone 1	-10.0%	-30.0%	-50.0%	-70.0%	-90.0%
	Zone 2	-5.0%	-20.0%	-35.0%	-50.0%	-65.0%
	Zone 3	-5.0%	-15.0%	-25.0%	-35.0%	-45.0%
	Zone 4	-10.0%	-30.0%	-50.0%	-70.0%	-90.0%
Percent Change in Surfers Relative to Business as Usual						
Sand Nourishment	Zone 1	122.2%	228.6%	400.0%	866.7%	2850.0%
	Zone 2	10.5%	18.8%	30.8%	50.0%	85.7%
	Zone 3	10.5%	17.6%	26.7%	38.5%	54.5%
	Zone 4	22.2%	35.7%	70.0%	150.0%	550.0%
Soil Nail Walls/Cave Fills	Zone 1					
	Zone 2	21.1%	25.0%	30.8%	30.0%	14.3%
	Zone 3	5.3%	5.9%	6.7%	7.7%	9.1%
	Zone 4	5.6%	7.1%	10.0%	16.7%	50.0%
Seawalls	Zone 1					
	Zone 2	21.1%	25.0%	30.8%	30.0%	14.3%
	Zone 3					
	Zone 4	5.6%	7.1%	10.0%	16.7%	50.0%
Managed retreat	Zone 1	38.9%	57.1%	60.0%	100.0%	250.0%
	Zone 2	31.6%	37.5%	46.2%	60.0%	114.3%
	Zone 3	15.8%	17.6%	20.0%	23.1%	27.3%
	Zone 4	16.7%	28.6%	50.0%	100.0%	350.0%
Artificial Bedrock	Zone 1	33.3%	100.0%	220.0%	566.7%	1950.0%
Groins	Zone 2	0.00%	0.00%	69.23%	100.00%	157.14%

Table 4-5 Percent Change in Surfers by Sea Level Rise and Zone

Sea Level Rise (Feet)		1	2	3	4	5
Percent Change in Surfers for Business as Usual Relative to 2020)						
	Zone 1	-9.5%	-13.0%	-11.1%	-29.8%	-45.0%
	Zone 2	-5.3%	-10.8%	-14.3%	-25.5%	-46.3%
	Zone 3	-9.4%	-15.2%	-24.5%	-34.6%	-41.6%
	Zone 4	-5.3%	-10.8%	-14.3%	-25.5%	-46.3%
Percent Change in Surfers Relative to Business as Usual						
Sand Nourishment	Zone 1	5.4%	15.0%	20.8%	42.6%	80.5%
	Zone 2	2.9%	12.1%	24.0%	45.1%	118.2%
	Zone 3	4.3%	16.0%	41.6%	72.3%	102.0%
	Zone 4	2.9%	12.1%	24.0%	45.1%	118.2%
Soil Nail Walls/Cave Fills	Zone 1	10.5%	15.0%	12.5%	42.5%	81.7%
	Zone 2	5.6%	12.1%	16.7%	34.1%	86.4%
	Zone 3	10.3%	18.0%	32.4%	53.0%	71.3%
	Zone 4	5.6%	12.1%	16.7%	34.1%	86.4%
Seawalls	Zone 1	0.0%	0.0%	-29.8%	-45.0%	-64.1%
	Zone 2	0.0%	0.0%	-25.5%	-46.3%	-81.8%
	Zone 3	0.0%	0.0%	-34.6%	-41.6%	-43.2%
	Zone 4	0.0%	0.0%	-25.5%	-46.3%	-81.8%
Managed retreat	Zone 1	10.5%	27%	34.6%	81.1%	206.1%
	Zone 2	5.6%	18%	24.0%	56.6%	170.5%
	Zone 3	10.3%	30%	66.6%	140.4%	285.5%
	Zone 4	5.6%	18%	30.9%	66.3%	191.8%
Artificial Bedrock	Zone 1	-10%	-74%	-32.5%	-16.3%	-10.0%
Groins	Zone 2	-5%	-16%	-21.7%	-27.6%	-36.9%

5 ESTIMATING BASELINE RECREATION USE FOR WEST CLIFF DRIVE

5.1 RECREATIONAL USE DATA

Estimating the number of visitors of various types to as large and complex an area as West Cliff Drive has significant challenges. People come for short and long periods, engage in single or multiple activities on the same or different days. Surfers are much harder to measure than those who stay on the Recreation Trail. The attendance estimates for this study were pieced together from several sources.

First, it utilized data from counts of visitors conducted in 2019-2020 along West Cliff Drive as well as some data from a survey of visitors conducted during the same time frame. The counts were mostly taken by student interns working for the City of Santa Cruz. They observed the recreational activities taking place at specific locations along West Cliff Drive and recorded their observations. Observers counted the participants in various activities both in the water and along the shore/West Cliff. These observational counts generally took place in late-morning and mid-afternoon, on both weekends and weekdays. The data from the observational counts included a wide range of activities that were condensed. Most generally, we sorted the data into water and land activities. The more specific categories comprise the most common activities; boating, surfing, running, walking, and sightseeing.

In addition, for estimates of surfing at various surf spots in Santa Cruz, we reached out to local experts with a brief survey. Finally, we spoke with the Marine Safety Division for the City of Santa Cruz for estimates of visitation to the small pocket beaches along West Cliff Drive.

The observations were also categorized based on the conditions at the time of observation, including the weather (Sunny, Cloudy, Rain, Fog), the season, and weekend or weekday. As expected, West Cliff Drive has more recreators in the summer and on sunny days. Land activities are generally much more popular than water activities, except for certain fall days which appeared to have good surfing conditions.

Cowell's Beach was surveyed, but not included in our calculations of recreational demand due to its location outside of the project area and independent demand. Additionally, Cowell's beach is largely within the more protected extent of Monterey Bay and less exposed to wave action and erosion than the project area.

The second data set comes from an on-site intercept survey which asked participants to discuss their usage habits on West Cliff Drive. This survey was used to improve estimates of annual recreation at West Cliff Drive and attempt to account for frequent visitors who may go many times in a year. Many respondents claimed to go quite frequently, "Several Times a Week" or "Every day."

A third data set provided estimates of surfing along West Cliff Drive. This data relies on estimates by a group of experts well versed in the area surfing, who provided insight on attendance. They also informed the analysis with estimates of how utilization differed throughout the year, and how popular each spot is.

5.2 ANALYSIS AND RESULTS

Using the visitor counts conducted by the City of Santa Cruz, we estimated daily average recreation activity for a range of both conditions and activities. This analysis showed high average daily demand for recreation in the summer and fall, and the popularity of certain activities (e.g. sightseeing, walking).

Using the estimates of daily recreational use for each season, we estimated annual recreation. Given that the surveys were typically conducted only once per day at a given location, we factored in the expected turnover of recreational users along West Cliff Drive.[1]

Table 5-1: Annual Visits to West Cliff Drive by Season and Type of Activity.

Season	Other water	Biking	Sight Seeing	Running	Walking	Other Road/Cliff	Total Recreational Users
Winter (Dec-Feb)	3,060	5,400	21,735	2,925	28,710	2,880	64,710
Spring (March-May)	5,505	3,675	18,150	4,020	14,820	6,420	52,590
Summer (June-Aug)	8,781	10,002	53,542	2,935	32,306	12,502	120,068
Fall (Sept-Nov)	5,483	10,260	28,163	3,531	23,012	4,195	74,645
Total, annual	22,829	29,337	121,590	13,411	98,848	25,998	312,012

Table 1 above indicates that West Cliff Drive receives an estimated 312,012 visits per year, not including Cowell Beach.

Please note that these calculations estimate of *individual visits per year,* rather than *individual visitors.* To estimate *visitors,* we estimated the number of visits per year the average individual takes from the results of an intercept survey along West Cliff Drive. These results were adjusted for avidity, essentially the likelihood of intercepting frequent visitors and thus inflating the estimate of yearly visits (see appendix for a more in-depth discussion). From this survey, we estimate an average of 2.85 trips per year for each individual visitor. Applying this

[1] Allowing for 2 hours of use per person in a 12-hour daylight window, we estimate a turnover factor of 6.

to our estimate of recreational use, we estimate 109,478 individual recreational visitors to West Cliff Drive in a given year.

We then extend these corrections to approximate the individual visitors to West Cliff Drive for each recreational activity annually.

Table 5-2: Estimated number of individual visitors to West Cliff Drive annually. This calculation accounts for the fact that some visitors frequent the area

Season	Other water	Biking	Site Seeing	Running	Walking	Other Road/Cliff	Total Recreational Users
Winter (Dec-Feb)	1,074	1,895	7,626	1,026	10,074	1,011	22,705
Spring (March-May)	1,932	1,289	6,368	1,411	5,200	2,253	18,453
Summer (June-Aug)	3,081	3,509	18,787	1,030	11,335	4,387	42,129
Fall (Sept-Nov)	1,924	3,600	9,882	1,239	8,074	1,472	26,191
Total, annual	8,010	10,294	42,663	4,705	34,684	9,122	109,478

The above estimates do not include Cowell's Beach, nearby the West Cliff Drive project area. Cowell's Beach was included as a location for observation despite technically being just beyond the boundary of the project. As table 3 below shows, Cowell's Beach receives a significant number of visitors, estimated at 110,661 annually. Adding in Cowell's Beach approximately doubles the overall visitation to an estimated 627,395 visits per year and similarly the number of visitors doubles to 220,139.

Table 5-3: Avidity corrected estimates of annual visitors to Cowell's Beach by activity and season.

Conditions	Other water	Biking	Site Seeing	Running	Walking	Other Road/Cliff	Total Recreational Users
Winter (Dec-Feb)	442	189	1,705	0	1,895	253	4,484
Spring (March-May)	1,516	1,832	3,442	2,811	11,400	4,042	25,042
Summer (June-Aug)	6,324	4,192	21,268	995	18,024	1,468	52,271
Fall (Sept-Nov)	2,211	4,611	6,316	1,642	13,832	253	28,863
Total, annual	10,492	10,824	32,732	5,447	45,150	6,016	110,661

Table 5-4: Estimates of annual visits and visitors to West Cliff Drive, including Cowell's Beach

Conditions	Other water	Biking	Site Seeing	Running	Walking	Other Road/Cliff	Total Recreational Users
Total Visits Including Cowell's	52,731	60,184	214,875	28,936	227,526	43,143	627,395

Annual Visitors Including Cowell's	18,502	21,117	75,395	10,153	79,834	15,138	220,139

5.3 SURFING

Surfing data was collected from expert observations of the different surfing spots along West Cliff Drive (and Cowell's Beach) to better inform our estimates of annual surfing activity. These estimates yielded not only data on the number of surfers using each spot, but also how popular a spot is and when it is most heavily used. We used their insight to construct both a "carrying capacity" for each spot, and an expected use.

Table 5-5: Estimates of Carrying Capacity for Surf Spots Along West Cliff Drive

Surf Spot	Hours of Surfing Estimate	Turnover Factor	Max Surfers at One Time	Estimated Carrying Capacity	Annual Carrying Capacity
Natural Bridges	4.75	3.16	23.75	75	27,451
Gas Chambers	2.25	1.5	10.00	15	5,475
Stockton Avenue	4.50	3	7.75	23	8,486
Swift Street	5.00	3.33	19.25	64	23,421
John Street	4.00	2.66	17.50	47	17,033
Getchell's	4.50	3	17.00	51	18,615
Mitchells Cove	3.50	2.33	25.00	58	21,292
Saber Jets	2.75	1.83	14.00	26	9,368
The Slot	8.50	5.66	23.75	135	49,123
Middle Peak	7.50	5	27.50	138	50,188
Indicators	6.00	4	33.75	135	49,275
Cowells	5.20	3.46	77.50	269	98,063
Total				**1,035**	**377,790**

The expected use data draws on weighted estimates for maximum, average, and slow days at each spot, alongside how often those days occur. Comparing the expected annual use to the carrying capacity suggests that overall, surfers at West Cliff Drive use an estimated 62% of the carrying capacity in the area.

Table 5-6: Estimated Annual Surfing Visits

Surf Spot	Hours of Surfing Estimate	Turnover Factor	Weighted Daily Estimate	Weighted Annual Estimate
Natural Bridges	4.75	3.16	22	7,960
Gas Chambers	2.25	1.5	1	546
Stockton Avenue	4.50	3	13	4,566
Swift Street	5.00	3.33	11	3,975
John Street	4.00	2.66	17	6,376
Getchell's	4.50	3	24	8,721
Mitchells Cove	3.50	2.33	23	8,379
Saber Jets	2.75	1.83	3	952
The Slot	8.50	5.66	102	37,317
Middle Peak	7.50	5	93	33,804
Indicators	6.00	4	86	31,486
Cowells	5.20	3.46	246	89,943
Total			**641**	**234,025**

As with the estimates of other visitation, it is important to note that the estimates of annual surfing visits *do not* take into account the difference between individual surfing visits and *surfing visitors,* which we accounted for in our estimates for other recreation. Our experts generally agreed on the proportion of surfers at each location who were local (within ten miles of Santa Cruz), which varied heavily between beaches with some *very* local (Stockton Avenue) and others less local (Cowell's Beach).

As with the recreational data, we estimated an average number of trips for year for both local surfers and out of town vacationers. Based on the intercept survey, we calculate an average of 4.05 trips per year taken by 57,783 individual surfers visiting annually, with an estimated 234,025 *trips* taken by those surfers.

With the surfing data included, estimated recreation annually at West Cliff Drive increases to 861,420 annual *visits* to West Cliff Drive. As mentioned, many of these visits are likely residents or individuals who frequent the area. Thus, correcting for avidity we estimate 277,922 annual *visitors.*

Table 5-7: Total Estimated Visits and Visitors, including surfers

	Estimated Annual Visits	Estimated Annual Visitors
All Recreation, West Cliff	312,012	109,478
All Recreation, Cowell's	315,383	110,661
Surfing (including Cowell's)	234,025	57,783
Total	**861,420**	**277,922**

5.4 VISITS TO POCKET BEACHES ALONG WEST CLIFF DRIVE

Understanding the recreational value of the numerous small pocket beaches along West Cliff Drive is also important for planners, since beach nourishment may be a cost-effective option. Some visitors to West Cliff Drive (already estimated in Table 7 above) visit one of the many pocket beaches along West Cliff Drive. To estimate these visits, we also interviewed an official at the Marine Safety Division of the City of Santa Cruz to obtain estimate of daily visitation. Our estimates are presented in Table 8.

Table 5-8: Total Estimated Visits and Visitors, at Pocket Beaches

Zone	Location	Estimated Daily # of people (Assumes the crowd rotates 3x p/day)	**Estimated Annual**	**Avidity Corrected Annual**
3	It's Beach	500	182,500	11,469
2	Mitchells Beach under the Seawall	80	29,200	1,835
2	Mitchells Beach	130	47,450	2,982
1	Cove at the end of Fair St.	30	10,950	688
1	Cove at end of Getchell's St.	15	5,475	344
1	Cove at end of Swift St.	50	18,250	1,147
1	Cove at end of Auburn St.	50	18,250	1,147
	Total	855	312,075	19,612

5.5 LIMITATIONS

There were some limitations with both data sets. While the observational data set covered a broad range of locations and activities occurring along West Cliff Drive, the observational data was not uniformly collected throughout the day, or throughout the year. As a result, there are insufficient observations of *early* morning recreation, when many surfers, walkers, and joggers many visit the West Cliff Drive area.

Additionally, an intercept study, as mentioned, is rarely a perfectly accurate representation of visitation patterns. We were able to correct for avidity bias and determine an approximate true mean of the number of visits per year, but as responses were verbal ranges (such as “Once a Month”, “Several Times a Week”, or “Every day”), the accuracy of this mean may not truly reflect visitation patterns. Additionally, the survey relied on visitors own estimates of their visitation patterns, which may reduce the validity of responses.

Finally, the estimates of surfing from the observational study were very limited and taken at times when surfers are less likely to be in the water. To account for this, we consulted a group of expert surfers highly familiar with the area to provide estimates of attendance and usage at West Cliff Drive Surf Spots.

6 REFERENCES

Aizaki, H., Nakatami, T., & Sato, K. (2015). *Stated Prefernce Models Using R*. CRC Press.

Carson, R. T. (2012). Contingent Valuation: A Practical Alternative when Prices Aren't Available. *Journal of Economic Perspectives*.

Freeman, A. M., Herriges, J., & Kling, C. L. (2014). *The Measurement of Environmental and Resource Values* (Third). Resources for the Future.

Griggs, G., Árvai, J., Cayan, D., DeConto, R., Fox, J., Fricker, H., Kopp, R., Tebaldi, C., & EA, W. (2017). *Rising Seas in California* (Issue April). http://www.opc.ca.gov/webmaster/ftp/pdf/docs/rising-seas-in-california-an-update-on-sea-level-rise-science.pdf

Intergovernmental Panel on Climate Change. (2014). *Projections of Global Average Sea Level Change for the 21st Century*.

Kopp, R., Horton, R. M., Little, C. M., Mitrovica, J. X., Oppenheimer, M., Rasmussen, D. J., Strauss, B. H., & Tebaldi, C. (2014). Probabilistic 21st and 22nd century sea-level projections at a global network of tide-gauge sites. *Earth's Future*, *2*, 383–407. https://doi.org/10.1002/2014EF000239

Lempert, R. (2014). Embedding (some) benefit-cost concepts into decision support processes with deep uncertainty. *Journal of Benefit Cost Analysis*, *5*(3), 487–514.

Lempert, Robert, Sriver, R., & Keller, K. (2012). Characterizing Uncertain Sea Level Rise Projections To Support Investment Decisions. In *California Climate Change Center*.

Ocean Protection Council. (2017). *State of California Sea-Level Rise Guidance Document 2018 Update*.

7 APPENDIX 1 DETAILED ANALYSIS OF RECREATION USE

Table 7-1 : Average daily recreation observed at West Cliff Drive under different weather conditions and days of the week

	Activity						
Conditions	**Other water**	**Biking**	**Site Seeing**	**Running**	**Walking**	**Other Road/Cliff**	**Total Rec Users**
Winter (Dec-Feb)	5.7	10.0	40.3	5.4	53.2	5.3	119.8
Weekday	6.7	11.3	47.8	6.2	61.4	3.7	137.1
Sunny	10.25	9	73	5	76.25	3.5	177.0
Cloudy	4.33	12.83	31.00	7.00	51.50	3.83	110.5
Weekend	0.5	3.5	2.5	1.5	12	13.5	33.5
Sunny	0.5	3.5	2.5	1.5	12	13.5	33.5
Cloudy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spring (March-May)	10.2	6.8	33.6	7.4	27.4	11.9	97.4
Weekday	12.83	9.17	40.22	11.22	30.56	9.83	113.8
Sunny	11.36	7.36	33.27	11.18	28.27	10.27	101.7
Cloudy	20.40	14.20	66.40	14.60	38.20	8.60	162.4
Weekend	7.56	4.44	27.00	3.67	24.33	13.94	80.9
Sunny	9.50	2.75	29.00	2.50	25.50	13.13	82.4
Cloudy	6.14	6.71	33.29	5.71	29.14	20.14	101.1
Summer (June-Aug)	16.3	18.5	99.2	5.4	59.8	23.2	222.3
Weekday	18.68	17.87	108.48	5.06	58.77	26.52	235.4
Sunny	14.86	12.79	89.86	4.29	43.64	13.64	179.1
Cloudy	29.38	24.13	93.13	2.13	62.13	19.75	230.6
Weekend	11.27	19.87	79.87	6.20	62.00	16.20	195.4
Sunny	1.00	21.67	52.17	5.67	49.17	2.83	132.5
Cloudy	18.67	19.67	117.33	6.00	77.17	28.17	267.0
Fall (Sept-Nov)	10.2	19.0	52.2	6.5	42.6	7.8	138.2
Weekday	12.11	17.67	62.22	6.22	42.78	6.78	147.8
Sunny	13.38	17.50	67.88	4.88	44.38	3.25	151.3
Cloudy	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Weekend	5.75	22.00	29.50	7.25	42.25	10.00	116.75
Sunny	5.75	22.00	29.50	7.25	42.25	10.00	116.75
Cloudy	N/A	N/A	N/A	N/A	N/A	N/A	N/A

7.1.1 Avidity Corrections of Observational Estimates

To estimate how many individual visitors use West Cliff Drive's recreation annually, we utilized the second survey, which asked respondents about their use. Specifically, we used their responses to the question "About how many times a year do you come here to West Cliff Drive for recreation of any kind in a year? Your best guess will do."

However, the results from this survey had to be adjusted. The average number of times a year someone comes to West Cliff Drive for recreation was quite high, over 119 times per year. This is most likely due to *avidity bias*, the fact that frequent visitors are more likely to be overrepresented in intercept and/or on-site surveys. Thomson (1991) explains this bias as the result of the probability that a given individual is selected for a survey. If the probably of selection is based on the number of trips an individual takes as a factor of the total number of trips, a frequent user has a much higher chance of selection, as they take many more trips than a single user.

To correct for avidity bias, we followed Thompson's (1991) methods to account for the high probability of selecting an avid user. We corrected our estimate of the average number of trips per year using her equation:

$$T/_N = \frac{n'}{\Sigma(1/_{Ti})}$$

Table 7-2: Summary statistics for the Thomson avidity adjustment, using data from on-site intercept survey of visitors.

Thompson Calculation		
n'	**sum of inverse trips**	**Estimated T/N**
876	306.9	2.85

We applied the same methodology to surfing as well. The avidity estimate accounts for the fact that our surfing experts are likely to observe many frequent Santa Cruz surfers in the water alongside those who may only surf the area once. In our intercept survey, 179 respondents indicated they come to West Cliff Drive to surf, with an average of 97 visits annually. This high number corresponds to the fact that many locals were surveyed, and that many West Cliff Drive surf spots are predominantly local, according to our experts. Applying the same calculation, the avidity correction for surfers results in an average of 4.05 trips per surfer.

The following tables present various measures of dispersion for our recreational and surfing data. Both datasets rely on observations of activity, with some estimates more tightly grouped around the mean than others.

Table 7-3 Standard Error for Recreation Observational Data

	Activity						
Conditions	**Surfing**	**Other water**	**Biking**	**Site Seeing**	**Running**	**Walking**	**Other Road/Cliff**
Winter (Dec-Feb)	10.8	2.4	2.1	11.2	1.5	15.0	2.0
Weekday	12.84	2.74	2.26	12.02	1.65	16.89	1.16
Sunny	32.8	6.6	2.7	18.9	4.1	36.2	1.2
Cloudy	3.44	1.48	3.34	12.25	1.13	16.79	1.85
Weekend	0.71	0.50	3.50	2.50	0.50	6.00	11.50
Sunny	0.5	0.5	3.5	2.5	0.5	6.0	11.5
Cloudy	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Spring (March-May)	1.2	2.3	1.7	5.8	2.0	3.4	3.0
Weekday	1.60	4.23	3.20	10.69	3.76	5.44	2.41
Sunny	2.22	3.03	3.54	7.08	4.74	3.69	3.67
Cloudy	3.29	13.99	8.63	34.57	9.05	18.78	3.20
Weekend	1.68	1.98	1.27	4.18	0.97	4.03	5.45
Sunny	2.77	2.98	1.29	4.99	1.13	6.06	6.53
Cloudy	3.08	3.65	2.59	7.59	1.84	6.99	11.94
Summer (June-Aug)	3.0	3.1	2.7	15.4	0.9	8.0	8.8
Weekday	4.40	4.24	3.06	21.06	1.13	10.15	12.24
Sunny	9.33	5.16	2.45	23.29	1.38	8.47	8.06
Cloudy	0.52	11.83	8.30	27.95	1.36	22.45	15.34
Weekend	1.45	3.56	5.28	18.25	1.26	13.03	9.63
Sunny	2.54	0.63	11.78	20.85	2.20	23.15	1.51
Cloudy	2.68	5.91	6.56	36.44	2.00	20.38	23.02
Fall (Sept-Nov)	9.5	2.7	3.8	14.1	1.7	7.7	3.3
Weekday	13.45	7.87	5.68	39.09	2.10	18.83	22.72
Sunny	15.00	3.69	5.68	21.32	1.32	9.91	1.11
Cloudy	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weekend	7.00	3.25	5.60	5.74	4.13	17.47	7.39
Sunny	7.00	3.25	5.60	5.74	4.13	17.47	7.39
Cloudy	n/a	n/a	n/a	n/a	n/a	n/a	n/a

Table 7-4 presents different methods for calculating annual surfing visits from our expert estimates. Because we asked about “Max”, “Average”, and “Slow” days as well as the frequency of those days in a year, we settled on a weighted means method, accounting for the prevalence of slow, average, and max days annually.

Table 7-4 Dispersion of Expert Observations of Surfing Measured by calculating different estimates of Annual Visits

Estimates of Surfers Attendance ('Surfing Visits/Days')		
Method	Daily Visits	Annual Visits
Carrying Capacity Method	1035	377,790
Average of Average Method	736	268,489
Highest Average Method	1997	728,783
Lowest Average Method	395	144,236
Average	*1042*	*380,503*
Weighed Means Method	**641**	**234,025**

Figure 7-1 Range of annual estimates from the different methods of calculating annual attendance

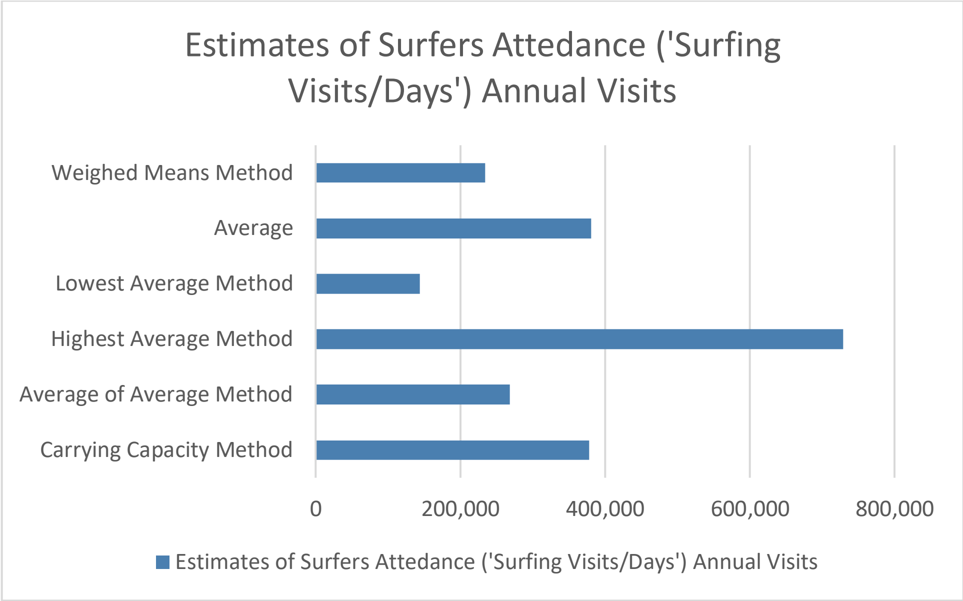


Table 7-5 Mean and Dispersion Measures for Surfing Estimates from Experts

	1. How many surfers do you think can be in the water at this spot (max number of surfers before people leave or go elsewhere)?				*2. How many days in a year would you say the spot is at max capacity?*				*3. About how many surfers are in the water at once on an average day?*			
Surf Spot	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**
Natural Bridges	23.75	6.50	2.90	42.19	25.00	7.07	3.16	50.00	8.67	0.94	0.42	0.89
Gas Chambers	10.00	3.54	1.58	12.50	3.33	4.71	2.11	22.22	2.50	0.87	0.39	0.75
Stockton Avenue	7.75	2.28	1.02	5.19	45.00	15.00	6.71	225.00	5.50	0.87	0.39	0.75
Swift Street	19.25	9.83	4.40	96.69	10.00	0.00	0.00	0.00	4.00	2.83	1.26	8.00
John Street	17.50	7.50	3.35	56.25	33.33	4.71	2.11	22.22	7.50	4.33	1.94	18.75
Getchell's	17.00	8.77	3.92	77.00	60.00	0.00	0.00	0.00	8.75	4.15	1.85	17.19
Mitchells Cove	25.00	5.00	2.24	25.00	30.00	0.00	0.00	0.00	10.50	0.87	0.39	0.75
Saber Jets	14.00	7.11	3.18	50.50	8.33	2.36	1.05	5.56	5.25	1.64	0.73	2.69
The Slot	23.75	4.15	1.85	17.19	123.33	20.55	9.19	422.22	16.25	2.17	0.97	4.69
Middle Peak	27.50	4.33	1.94	18.75	96.67	4.71	2.11	22.22	22.50	7.50	3.35	56.25
Indicators	33.75	4.15	1.85	17.19	93.75	26.78	11.98	717.19	22.00	8.03	3.59	64.50
Cowells	77.50	22.78	10.19	518.75	140.00	14.14	6.32	200.00	87.00	40.20	17.98	1616.00

	4. How many surfers on a slow day?				*5. How many slow days a year?*				*6.On a typical day how many hours of good surf are there at this spot?*			
Surf Spot	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**
Natural Bridges	4.00	1.22	0.55	1.50	220.00	28.28	7.07	250.20	4.75	1.30	0.58	1.69
Gas Chambers	0.50	0.50	0.22	0.25	286.67	75.42	2.02	20.43	2.25	0.43	0.19	0.19
Stockton Avenue	1.50	1.50	0.67	2.25	146.67	37.71	1.14	6.47	4.50	1.12	0.50	1.25
Swift Street	2.00	2.12	0.95	4.50	210.00	42.43	16.76	1405.07	5.00	1.73	0.77	3.00
John Street	4.50	1.50	0.67	2.25	226.67	18.86	9.21	424.45	4.00	1.41	0.63	2.00
Getchell's	5.25	0.43	0.19	0.19	223.33	23.57	12.92	834.76	4.50	0.87	0.39	0.75
Mitchells Cove	7.00	3.00	1.34	9.00	193.33	18.86	4.27	91.00	3.50	0.87	0.39	0.75
Saber Jets	0.75	0.83	0.37	0.69	326.67	18.86	8.65	373.92	2.75	1.30	0.58	1.69
The Slot	10.00	1.26	0.57	1.60	43.33	9.43	2.88	41.54	8.50	0.87	0.39	0.75
Middle Peak	9.00	5.02	2.24	25.20	143.33	61.28	8.85	391.31	7.50	0.87	0.39	0.75
Indicators	8.00	2.45	1.10	6.00	90.00	42.43	9.71	471.55	6.00	1.41	0.63	2.00
Cowells	23.00	8.72	3.90	76.00	70.00	30.00	275.09	378368.16	5.20	0.98	0.44	0.96

Surf Spot	*7. What would you consider to be high season?*	*8. Low season?*	*9. What percentage of surfers at this spot live in or near (<10 miles) Santa Cruz?*			
Natural Bridges	**Most Estimate**	**Most Estimate**	**Mean**	**Standard Deviation**	**Standard Error**	**Variance**
Gas Chambers	Winter	Summer	78%	2.5%	1%	0%
Stockton Avenue	Winter	Summer	85%	5.0%	2%	0%
Swift Street	Summer/Winter	Split	99%	2.2%	1%	0%
John Street	anything but summer	Summer	73%	7.5%	3%	1%
Getchell's	anything but summer	Summer	70%	11.7%	5%	1%
Mitchells Cove	winter/spring	Summer	66%	15.2%	7%	2%
Saber Jets	Fall-Spring	Summer	68%	5.6%	3%	0%
The Slot	Split	Split	93%	4.3%	2%	0%
Middle Peak	Year Round	Spring/Summer	63%	14.0%	6%	2%
Indicators	Fall-Spring	Summer	57%	11.7%	5%	1%
Cowells	Fall-Spring	Summer	48%	7.5%	3%	1%
Surf Spot	Year Round	Spring	32%	9.3%	4%	1%

8 APPENDIX 2 DETAILED ANALYSIS OF CHANGES IN SURFING USE

The benefit cost analysis for West Cliff Drive depends on comparisons between the business as usual baseline condition, and the three other adaptation strategies. The benefits measured are changes in the value of recreational use both for shore users and surfers. This appendix describes the methods and assumptions used to project the differences in surfing use resulting from physical changes caused by sea level rise and the implementation of the various adaptation scenarios.

The surf breaks or surf spots along West Cliff Drive are world renowned and are collectively designated as a World Surfing Reserve by the Save the Waves Coalition. Along the West Cliff Drive corridor, there are 12 identified surf breaks, each with their own unique tide windows and wave characteristics. It is important to note that the surf in Santa Cruz, is unique and there is no exact substitute for the surfing resources. The unique shoreline orientation facing south, the large swell corridor, and the prevailing offshore wind conditions (conducive to quality surf conditions), are unmatched anywhere else on the U.S. West Coast.

Information on the unique tide and wave characteristics for each break were gathered from expert knowledge interviews collected during part of the West Cliff Drive focus group and outreach effort. For this purpose, surf was considered to only occur during daylight hours and so the hours of daylight within each tide window was calculated from the projected 2019 and 2020 tides (Figure 8-1). Under existing conditions for each surf break, the daylight hours were calculated and used to evaluate the existing and future benefits under each adaptation strategy (Table 8-1).

Figure 8-1 Tidal and Daylight Windows for Surfing in Santa Cruz

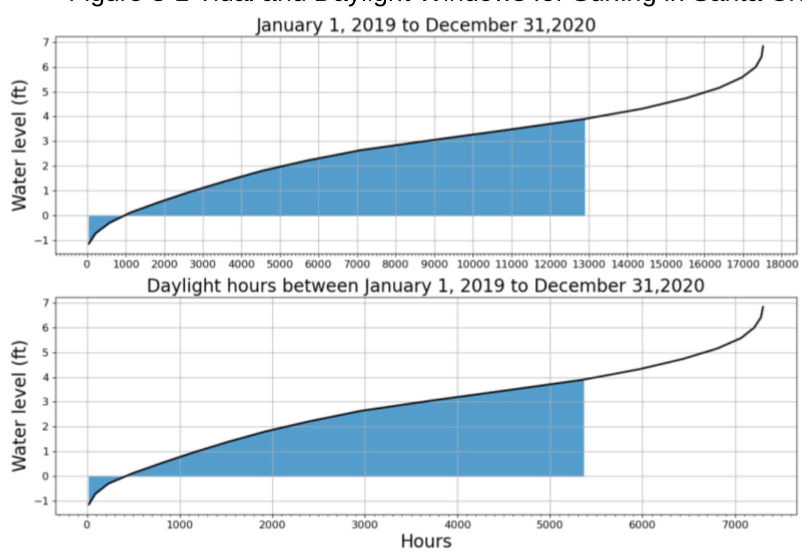


Table 8-1. Breakdown of percent of year surfable by tide per calendar year for each surf break

Surf Spot	Doable Tide Range relative to MLLW		Current Daylight Hours Annual	% of Year
	Lowest	Highest		3800 hrs/yr
Natural Bridges	0	5	3150	83%
Gas Chambers	-1	2	1050	28%
Stockton Avenue	-1	2.5	1400	37%
Swift Street	0	4	2500	66%
John Street	0	3	1550	41%
Getchell's	0	3	1550	41%
Mitchells Cove	-1	3.5	2250	59%
Saber Jets	-1	3	1750	46%
The Slot	1	5	2760	73%
Middle Peak	0	5	3150	83%
Indicators	-1	5	3350	88%
Cowells	-1	3.5	2250	59%
Casinos (wharf)	1	4	2110	56%
The Rivermouth	0	4	2500	66%
The Harbor	0	3	1550	41%

Each adaptation strategy has secondary consequences (described in detail in Chapter 10), that affect the footprint of the strategy on the beach, and the amount of time that the tide elevation interacts with the adaptation strategy. Key secondary impacts that may affect the surfing conditions include reflected wave energy off coastal armoring structures that reduce the quality and condition of the breaking waves suitable for surfing.

The benefits from each surf spot or surf break was identified based on the annual estimate of use, and changes in the suitable tide windows for each surf break during daylight hours as sea levels rise and each adaptation strategy is implemented (Based on Table 8-1 and the assumptions below.

Changes to surfing benefits were projected as a reduction in the use of the surf break from both an increase in sea level rise and the estimated percent change in the annual use of the surf spot. Estimates of the number of surfers for each zone were calculated by taking the annual estimate in each surf sport and multiplying this by the daylight hours and then the estimated reduction per foot of sea level rise in the following tables. The number of surfers in the business as usual case with sea level rise was compared with the baseline current user estimates and changes in adaptation options were compared with the business as usual estimates. The results are discussed in Section 2.4.

8.1 BUSINESS AS USUAL

The Business as Usual adaptation strategy is the baseline condition and includes a maintaining and emergency repair of existing armoring structures.

Table 8-2 Change in Surfers by Surf Spot- Business as Usual

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7,960	83%	73%	61%	42%	17%	0%
Gas Chambers	1	2.25	1.50	1	546	28%	22%	12%	0%	-18%	-43%
Stockton Avenue	1	4.50	3.00	13	4,566	37%	32%	21%	9%	-9%	-34%
Swift Street	1	5.00	3.33	11	3,975	66%	56%	43%	25%	0%	-17%
John Street	1	4.00	2.67	17	6,376	41%	31%	18%	18%	0%	-25%
Getchell's	1	4.50	3.00	24	8,721	41%	31%	18%	18%	0%	-25%
Mitchells Cove	2	3.50	2.33	23	8,379	59%	54%	44%	32%	13%	-12%
Saber Jets	3	2.75	1.83	3	952	46%	41%	31%	18%	0%	-25%
The Slot	3	8.50	5.67	102	37,317	73%	61%	42%	17%	0%	-7%
Middle Peak	3	7.50	5.00	93	33,804	83%	73%	61%	42%	17%	0%
Indicators	3	6.00	4.00	86	31,486	88%	83%	73%	61%	42%	17%
Cowells	4	5.20	3.47	246	89,943	59%	54%	44%	32%	13%	-12%
Total				641	234,025						

Projected changes to surfing recreational use under the business as usual adaptation strategy assumed that as sea level rises that the amount of time that the surf spot would work would be reduced by the same elevation of sea level rise and that the reduction in the number of daylight hours () would correspond with a similar reduction in the use and recreational benefit of each of the surf spots (Table 8-2).

Benefits of each of the adaptation strategies by zone were then compared to this business as usual estimate of surf recreation benefits over time.

8.2 BEACH NOURISHMENT

The beach nourishment adaptation alternative proposes to nourish the beach at Pyramid Beach with an estimated 30,000 cubic yards of sand. This sand is anticipated to be transported by waves and longshore currents from the western placement site in Zone 1 eastward along all of the West Cliff Drive Zones and fill in gaps in the reefs and nourishing the small pocket beaches .

This adaptation alternative is anticipated to offset some of the impacts of coastal armoring and improve some of the quality of surf breaks.

Table 8-3 Change in Surfers by Surf Spot- Beach Nourishment

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7960	83%	78%	73%	66%	51%	29%
Gas Chambers	1	2.25	1.50	1	546	28%	25%	22%	17%	6%	-9%
Stockton Avenue	1	4.50	3.00	13	4566	37%	34%	32%	27%	15%	0%
Swift Street	1	5.00	3.33	11	3975	66%	61%	56%	49%	34%	12%
John Street	1	4.00	2.67	17	6376	41%	36%	31%	24%	9%	-13%
Getchell's	1	4.50	3.00	24	8721	41%	36%	31%	24%	9%	-13%
Mitchells Cove	2	3.50	2.33	23	8379	59%	57%	54%	49%	38%	22%
Saber Jets	3	2.75	1.83	3	952	46%	44%	41%	36%	24%	9%
The Slot	3	8.50	5.67	102	37317	73%	66%	61%	51%	29%	8%
Middle Peak	3	7.50	5.00	93	33804	83%	78%	73%	66%	51%	29%
Indicators	3	6.00	4.00	86	31486	88%	83%	78%	73%	61%	42%
Cowells	4	5.20	3.47	246	89943	59%	57%	54%	49%	38%	22%
Total				641	234025						

Projected changes to surfing recreational use under the beach nourishment adaptation strategy assumed that as sea level rises that the amount of time that the surf spot would work would be reduced by half of the sea level rise elevation up to 3 feet of sea level rise at which time it would be reduced at a similar rate as sea level rise. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the surf spots (Table 8-3).

8.3 CAVE FILL/ NAIL WALL

The Cave Fill and Soil Nail Wall adaptation strategy fills the existing sea caves to prevent further erosion and removes some of the existing revetments in exchange for the construction of a soil nail wall which occupies a smaller footprint on the beach and reduces the wave/coastal armoring interactions.

Table 8-4 Change in Surfers by Surf Spot- Cave Fill/Nail Wall

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7960	83%	83%	73%	61%	42%	17%
Gas Chambers	1	2.25	1.50	1	546	28%	28%	22%	12%	0%	-18%
Stockton Avenue	1	4.50	3.00	13	4566	37%	37%	32%	21%	9%	-9%
Swift Street	1	5.00	3.33	11	3975	66%	66%	56%	43%	25%	0%
John Street	1	4.00	2.67	17	6376	41%	41%	31%	18%	18%	0%
Getchell's	1	4.50	3.00	24	8721	41%	41%	31%	18%	18%	0%
Mitchells Cove	2	3.50	2.33	23	8379	59%	59%	54%	44%	32%	13%
Saber Jets	3	2.75	1.83	3	952	46%	46%	41%	31%	18%	0%
The Slot	3	8.50	5.67	102	37317	73%	73%	61%	42%	17%	0%
Middle Peak	3	7.50	5.00	93	33804	83%	83%	73%	61%	42%	17%
Indicators	3	6.00	4.00	86	31486	88%	88%	83%	73%	61%	42%
Cowells	4	5.20	3.47	246	89943	59%	59%	54%	44%	32%	13%
Total				641	234025						

Projected changes to surfing recreational use under the Cave Fill/ Nail Wall adaptation strategy assumed that as sea level rises that the amount of time that the surf spot would work would be improved up to a foot of sea level rise elevation by the removal of revetments that occupy more space on the beach and thus interact with the waves during more of the tide cycle. After the initial benefit however, the recreational use and benefit would be reduced at a similar rate as sea level rise. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the surf spots (Table 8-4).

8.4 COASTAL WALL

The Coastal wall adaptation strategy removes existing revetments and replaces them with a smaller footprint vertical or recurved seawall structure. This smaller footprint reduces the wave/coastal armoring interactions over the short term.

Table 8-5 Change in Surfers by Surf Spot- Coastal Wall

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7960	83%	73%	61%	17%	0%	-7%
Gas Chambers	1	2.25	1.50	1	546	28%	22%	12%	-18%	-43%	-67%
Stockton Avenue	1	4.50	3.00	13	4566	37%	32%	21%	-9%	-34%	-58%
Swift Street	1	5.00	3.33	11	3975	66%	56%	43%	0%	-17%	-24%

John Street	1	4.00	2.67	17	6376	41%	31%	18%	0%	-25%	-49%
Getchell's	1	4.50	3.00	24	8721	41%	31%	18%	0%	-25%	-49%
Mitchells Cove	2	3.50	2.33	23	8379	59%	54%	44%	13%	-12%	-36%
Saber Jets	3	2.75	1.83	3	952	46%	41%	31%	0%	-25%	-49%
The Slot	3	8.50	5.67	102	37317	73%	61%	42%	0%	-7%	-7%
Middle Peak	3	7.50	5.00	93	33804	83%	73%	61%	17%	0%	-7%
Indicators	3	6.00	4.00	86	31486	88%	83%	73%	42%	17%	-7%
Cowells	4	5.20	3.47	246	89943	59%	54%	44%	13%	-12%	-36%
Total				641	234025						

Projected changes to surfing recreational use under the Coastal Wall adaptation strategy assumed that as sea level rises that the amount of time that the surf spot would work would be improved up to a foot of sea level rise elevation by the removal of revetments that occupy more space on the beach and thus interact with the waves during more of the tide cycle. However, after the initial benefit however, the recreational use and benefit would be reduced at an accelerated rate after 2 feet of sea level rise as wave/armoring interactions increase. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the surf spots (Table 8-5).

8.5 MANAGED RETREAT

The managed retreat adaptation scenario assumes that over time the existing coastal armoring would be removed, and natural erosion would be allowed to occur. This strategy was required to be evaluated by both Caltrans and the California Coastal Commission.

Table 8-6 Change in Surfers by Surf Spot- Managed Retreat

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7960	83%	83%	83%	78%	73%	66%
Gas Chambers	1	2.25	1.50	1	546	28%	28%	28%	17%	12%	6%
Stockton Avenue	1	4.50	3.00	13	4566	37%	37%	37%	27%	21%	15%
Swift Street	1	5.00	3.33	11	3975	66%	66%	66%	61%	56%	49%
John Street	1	4.00	2.67	17	6376	41%	41%	41%	36%	31%	24%
Getchell's	1	4.50	3.00	24	8721	41%	41%	41%	36%	31%	24%
Mitchells Cove	2	3.50	2.33	23	8379	59%	59%	59%	49%	44%	38%
Saber Jets	3	2.75	1.83	3	952	46%	46%	46%	36%	31%	24%
The Slot	3	8.50	5.67	102	37317	73%	73%	73%	73%	66%	61%
Middle Peak	3	7.50	5.00	93	33804	83%	83%	83%	78%	73%	66%
Indicators	3	6.00	4.00	86	31486	88%	88%	88%	83%	78%	73%
Cowells	4	5.20	3.47	246	89943	59%	59%	59%	54%	49%	44%
Total				641	234025						

Projected changes to surfing recreational use under the Managed Retreat adaptation strategy assumed that as sea level rises that the amount of time that the surf spot would work would not change until two feet of sea level rise at which point the removal of the existing coastal armoring would allow for natural erosion and allow the recreational benefit to deteriorate at half the rate without managed retreat. This assumption would allow for some reclamation of the beach from removal of the coastal armoring and some erosion which would offset sea level rise and decrease the interaction of the waves during more of the tide cycle. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the surf spots (Table 8-6).

8.6 ARTIFICIAL BEDROCK- ZONE 1

The artificial bedrock adaptation strategy in zone 1 would increase the extents both width and alongshore of the existing coastal armoring and serve to connect the existing bedrock platforms. The strategy would basically cement existing and additional riprap into a single structure. This would likely have a long lifespan and reduce erosion but serve to bury additional pocket beaches and increase the interaction between the waves and coastal armoring for the Zone 1 surf spots.

Table 8-7 Change in Surfers by Surf Spot- Artificial Bedrock Zone 1

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Natural Bridges	1	4.75	3.17	22	7960	83%	73%	61%	17%	0%	-7%
Gas Chambers	1	2.25	1.50	1	546	28%	22%	12%	-18%	-43%	-67%
Stockton Avenue	1	4.50	3.00	13	4566	37%	32%	21%	-9%	-34%	-58%
Swift Street	1	5.00	3.33	11	3975	66%	56%	43%	0%	-17%	-24%
John Street	1	4.00	2.67	17	6376	41%	31%	18%	0%	-25%	-49%
Getchell's	1	4.50	3.00	24	8721	41%	31%	18%	0%	-25%	-49%

Projected changes to surfing recreational use under the Artificial bedrock adaptation strategy applied to Zone 1 assumed no change until the project is implemented around 3 feet of sea level rise at which point this would impact the Zone 1 surf spots by adding an additional foot of sea level rise reductions. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the Zone 1 surf spots (Table 8-7).

8.7 GROINS – ZONE 2

This adaptation strategy assumes that a cross shore structure (groin) would be built down drift of Mitchells Cove near the Bethany Curve bridge. The groin would impound sand and result in a wider beach at Mitchells Cove.

Table 8-8 Change in Surfers by Surf Spot- Groins

Surf Spot	Zone	Hours of Surfing Estimate	Multiplier	Weighted Daily Estimate	Weighted Annual Estimate	Current Daylight %	1 Foot of Sea Level Rise	2 Feet of Sea Level Rise	3 Feet of Sea Level Rise	4 Feet of Sea Level Rise	5 Feet of Sea Level Rise
Mitchells Cove	2	3.50	2.33	23	8379	59%	54%	44%	38%	32%	22%

Projected changes to surfing recreational use under the Zone 2 groin adaptation strategy assumes no change from business as usual until the project is implemented around 2.5 feet of sea level rise at which point the impact to the Zone 2 surf spot would only be to by 0.5 feet of the sea level rise reductions. These reductions in the number of daylight hours (Table 8-1) would correspond to the reduction in the use and recreational benefit of each of the Zone 1 surf spots (Table 8-8).

9 APPENDIX 3 SURVEY VALUATION QUESTIONS

Resident Recreational Use

Initial Bid

West Cliff Drive, like all of the California coastline, is threatened by continuing erosion, which will increase as sea levels rise. It is possible that in the foreseeable future large parts of the path and roadway could be lost to the sea without action.

The City is currently considering a number of options to reduce the threat of erosion, which will likely have high costs. Funding may involve state or local bond issues,

In deciding what to do, it is very helpful to know how users of W. Cliff Drive value the experience. No bond issues are currently planned but If there were a bond issue to prevent or reduce damage to West Cliff we would like to know if you would vote for it if it would raise you household's taxes by $10[2] *per year for ten years.*

If Yes:

Would you be willing to approve a bond issue if it raised your taxes by $20[3] *per year for 10 years?*

If No

Would you be willing to approve a bond issue if it raised your taxes by $5[4] *per year for 10 years?*

Resident Surfers

West Cliff Drive, like all of the California coastline, is threatened by rising seas. This could result in significant changes in future surfing such as reducing the time when surfing is possible, reducing the number of surf spots, or the elimination of beaches.

The City is currently considering a number of options to reduce the threat of erosion, which will likely have high costs. Funding may involve state or local bond issues,

In deciding what to do, it is very helpful to know how users of W. Cliff Drive value the experience. No bond issues are currently planned but If there were a bond issue to prevent or reduce damage to West Cliff we would like to know if you would vote for it if it would raise you household's taxes by $10 per year for ten years.

---

[2] Amounts randomly vary from $10 to $50.
[3] Higher amounts are $10 over initial bid.
[4] Lower amounts are $10 under initial bid except in the case of the $10 initial bid.

Follow up questions as above.

Nonresident Recreation Users

West Cliff Drive, like all of the California coastline, is threatened by continuing erosion. Erosion is expected to significantly increase as sea levels rise and storms intensify. It is possible that in the foreseeable future large parts of the walkway and roadway could be lost without action.

The City of Santa Cruz is considering a number of options to reduce the threat of erosion, which are likely to have high costs. Visitors to Santa Cruz might one day be asked to contribute to a fund that would help reduce or prevent future damage to West Cliff Drive.

In deciding what to do, it is very helpful to know how users of W. Cliff Drive value the experience. No such fund exists, but we would like to know if you would contribute $10 to such a fund. Your contribution would be voluntary and could be made any time.

Follow up questions as above.

Nonresident Surfers

West Cliff Drive, like all of the California coastline, is threatened by rising seas. This could result in significant changes in future surfing such as reducing the time when surfing is possible, reducing the number of surf spots, or the elimination of beaches.

The City is currently considering a number of options to reduce the threat of erosion, which will likely have high costs. Visitors to Santa Cruz might one day be asked if they would contribute to a fund to be used to reduce or or prevent future damage to surfing along West Cliff Drive.

In deciding what to do, it is very helpful to know how users of W. Cliff Drive value the experience. No such fund currently exists, but we would like to know if you would contribute $10 to such a fund at some time in the future. Your contributions would be voluntary and could be made any time.

Follow up questions as above.