Comments on the 2010 Draft Fee Study

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Letter A

STATE OF CALIFORNIA -- THE RESOURCES AGENCY

ARNOLD SCHWARZENEGGER, *Governor*

CALIFORNIA COASTAL COMMISSION

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SAN DIEGO, CA 92108-4421
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July 14, 2010

Ms. Tina Christiansen, AIA
Community Development Director
City of Solana Beach
635 South Highway 101
Solana Beach, California 92075

Re: Comments on the Draft Land Lease & Recreation Fee Report

Dear Ms. Christiansen:

Thank you for the opportunity to comment on the City of Solana Beach's Draft Land Lease / Recreation Fee Study ("Study"). Staff appreciates the time and effort that has gone into the preparation of this document, as well as the public participation and input that led to development of the plan. Staff is aware that the March 2010 study will be revised and updated in the near future, with an additional comment period allowed. Nevertheless, we would like to take this opportunity to provide these preliminary comments on the March 2010 study, with the understanding that additional comments may be provided when the Study is finalized. Our comments are divided into general and specific comments.

General Comments

Comment 1

Staff has in the past questioned the overall concept of offsets for public benefits of bluff retention devices authorized to protect private development, and continues to have serious concerns with how the concept has been defined and applied in the Study, as discussed more specifically below. As you know, the purpose of the mitigation fee for the loss of sand to the beach, and for the loss of recreational benefit is to compensate for the impact to public resources caused by shoreline protection. The beach and bluffs are publicly owned resources that are adversely impacted by the construction of shoreline protective devices. Staff remains unconvinced that there are or can be proven quantified monetary public benefits from shoreline protection, and we are very concerned that the effective outcome of this process would be to eliminate the mitigation fee at the expense of the public.

Comment 2

In addition, the Study does not appear to take into account previous beach valuation studies of Solana Beach. For example, economist Philip King has performed two beach valuation studies specifically addressing the Solana Beach shoreline which were not cited in the Study. Given the availability of this data, staff suggests that the report be revised to specifically address the findings and methodology of these and any other beach valuation studies recently performed on Solana Beach.

Comment 3

While the Study considers only the recreational impact of bluff retention devices, and therefore these comments speak only to that issue, the City should be aware that staff believes there are numerous other, and as yet unquantified, adverse impacts, such as aesthetic and habitat impacts, associated with seawalls that have a significant impact on the decision of beach visitors as to which beach they choose to visit. Loss in recreational value is not the only impact of bluff retention devices. It will be appropriate for the City to evaluate the monetary value of these non-recreational impacts, particularly when considering potential offsets.

Comment 4

The Study is based on beachgoer counts collected in 2008 and 2009, despite the fact that the fee structure is assumed to stay in place until 2081, at least for methodological purposes. If this valuation study is ultimately used to assess mitigation fees, the Study should outline a process through which the beachgoer estimate would be periodically updated, for example, every ten years.

Comment 5

The Study does not provide any specific information about the intended use of the funds from the mitigation fees collected. In order to consider whether the plan furthers the goals of the Coastal Act, considerably greater detail about the use of the funds must be provided.

Specific Comments

Comment 6

Page 3-5, Table 3-4. The Study indicates that it is applying a turnover factor to all beachgoers to compensate for "missed" beach visitors. However, staff had the opportunity to discuss the Study with Dr. King, who opined that the Study may seriously undercount beach users, in particular, surfers, by applying only a single turnover factor to all types of beach users. For example, surfers tend to arrive early in the morning and surf throughout the day, peaking around 6 am unlike users who arrive mid-day to recreate on the sand or wade. Taking a count of all beach users mid-day and applying the same turnover factor to all types of users would therefore tend to significantly undercount beach users such as surfers by a factor of 100% of more. It is likely that walkers, who also tend to arrive early in the day, are also seriously underestimated. Staff suggests that this issue be re-evaluated, and that user-specific turnover factors be developed for specific types of beach users. Available data regarding beachgoers' habits, such as the online survey of surfers maintained by Chad Nelson of Surfrider Foundation, could be used to develop these factors.

Comment 7

Pages 3-8 to 3-9. The Study indicates that it uses beachgoers' income level to calculate the value that individual users attach to the beach. The rationale for this is not clear. Please explain the reasoning behind using this factor.

Comment 8

Page 4-18, table 4-4. The Study's description of net present value (NPV) calculations, here and throughout, are not entirely clear. Staff's interpretation of Table 4-4 is that payments made over time towards a bluff retention device built in 2010 are worth \$123,571 in 2010 dollars and \$286,848 in real dollars—please confirm. However, the

Study should be clarified to make this calculation more clear, especially to non-economist readers.

Comment 9

Staff is particularly concerned that there is very little discussion of NPV in the *public benefits* methodology, so it is not clear that the costs and the benefits are measured in the same "dollars." The Study should provide NPV calculations for both benefits and costs on a side-by-side, year-by-year basis.

Comment 10

Pages 4-18 to 4-19. Because the impact fee calculations assume a planning horizon that ends in 2081, bluff retention devices built later have a much lower fee applied than devices built earlier because they are assumed to be of shorter duration. While the Study acknowledges that the study is expected to be revised and updated long before 2081, it is problematic to apply a reduced fee when there is no guarantee a given bluff retention device is likely to be removed at a given date.

Comment 11

Pages 5-1 and 5-2. The Study indicates that public offsets will be set by the Solana Beach City Council determining, on a case-by-case basis, whether a given bluff retention device is likely to lead to more significant public benefits than others of its type. Staff is concerned that the lack of specificity will lead to a politicized process less objective and less predictable than having a set formula under which each permit would cost a certain amount dependent upon objective factors such as the size of the device. The study indicates on Page 5-13 and Page 5-20 (Figure 5-8) that site-specific variables include the thickness of the sandstone and the occupancy of the beach at a particular point. The Study should provide greater detail about why these factors are likely to vary significantly based on a particular device's location on the beach. The Study should further explain why the case-by-case analysis is preferable to a more objective approach, such as one that would average these factors over the entire beach and assess fees based on the extent of the device being constructed.

Comment 12

Pages 5-5 to 5-12. The Study attempts to quantify a public benefit from bluff retention devices decreasing the likelihood of death from bluff collapse. However, the calculation on Page 5-13 seems to assume that, if a given bluff retention device is built, this risk will be reduced to *nothing* – i.e., with the bluff retention device, there will be *no* chance of anyone dying from bluff collapse. In fact, the risk of death *may* be reduced but not eliminated. Therefore, if this offset is used, the study should quantify the amount by which the risk has actually been reduced, and offset the fee only by that amount.

Comment 13

Page 5-12. The Study discusses the reasons that the private impact of bluff retention devices should be measured in terms of the cost of construction of the seawalls, rather than in the increase in property value that accrues to the private property owner. The study considers an "extreme case" – a bluff retention device that would save a $3.5 million home from otherwise being worthless – and implies that it would be unreasonable to consider the private value of that device to be $3.5 million. However, this seems off point. The study doesn't suggest that applicants must pay the full value of their private benefit, it only indicates that they may not offset any portion of the required recreational mitigation fee if they derive more benefit from them than the public does. Given that, it seems more appropriate to conclude that a homeowner must pay the entire recreational fee, provided that the sea wall does not provide any public benefits that exceed $3.5 million. It is inconsistent to consider the public benefit of increased property taxes from saving the property from destruction, but not the private benefits of that increased property value.

Thank you again for the opportunity to comment. I look forward to reviewing the revised Study and continuing to work with you on planning Solana Beach's future shoreline development policies.

Sincerely,

Diana Lilly

Diana Lilly
Coastal Planner

cc: Dan Golub
Sherilyn Sarb
Deborah Lee

Letter B

July 14, 2010

To: Ms. Tina Christiansen, City of Solana Beach

From: Philip King, Ph.D., Associate Professor, Economics, San Francisco State University

Re: Draft Land Lease and Recreation Fee Report

I would like to provide some general comments on this report. I have worked for the City of Solana Beach in the past, where I completed a study on the economic impacts of beaches. I also testified for the California Coastal Commission on the Las Brisas Case and provided an economic analysis for SANDAG's proposed nourishment project, so I am quite familiar with N. San Diego County Beaches.

I have just finished a report for the State of California examining attendance estimates (King and McGregor 2010), so most of my comments here will focus on that issue. In general the attendance estimates provided in this study are very similar to work I did several years ago for the City Carlsbad (King 2005) and I think their estimates of "sand people" (see below) are probably reasonable. I think it would have been nice to cite my work along with some of the other work done in this area. I know this was not an academic paper, but its good to know the foundation.

However since completing my Carlsbad study I have examined the issue of attendance in more detail. Here are some issues the study could have examined more closely. In at least one instance I think their estimates are far too low:

Comment 1

1. **It appears that the study applied one turnover factor to all types of recreation, (as I did in Carlsbad) however the data in my recent study indicates that the turnover factor applied to surfing should be very different--and likely much higher**. Also the peak time for surfing is in the morning, so applying a midday turnover factor to a midday count of surfers will almost certainly lead to a serious undercount of surfers.

Traditional recreational beach goers tend to arrive late morning or early afternoon and the turnover factors used in this study reflect this fact and are very consistent with my own work (see figure 1 below for a hypothetical example). However, surfers arrive in the morning--peaking around 6 and surf throughout the day. **Thus a count of surfers taken midday (I looked briefly at their counts and most, though not all, were midday, which is very appropriate for sand people but not surfers) would seriously underestimate the # surfers**.

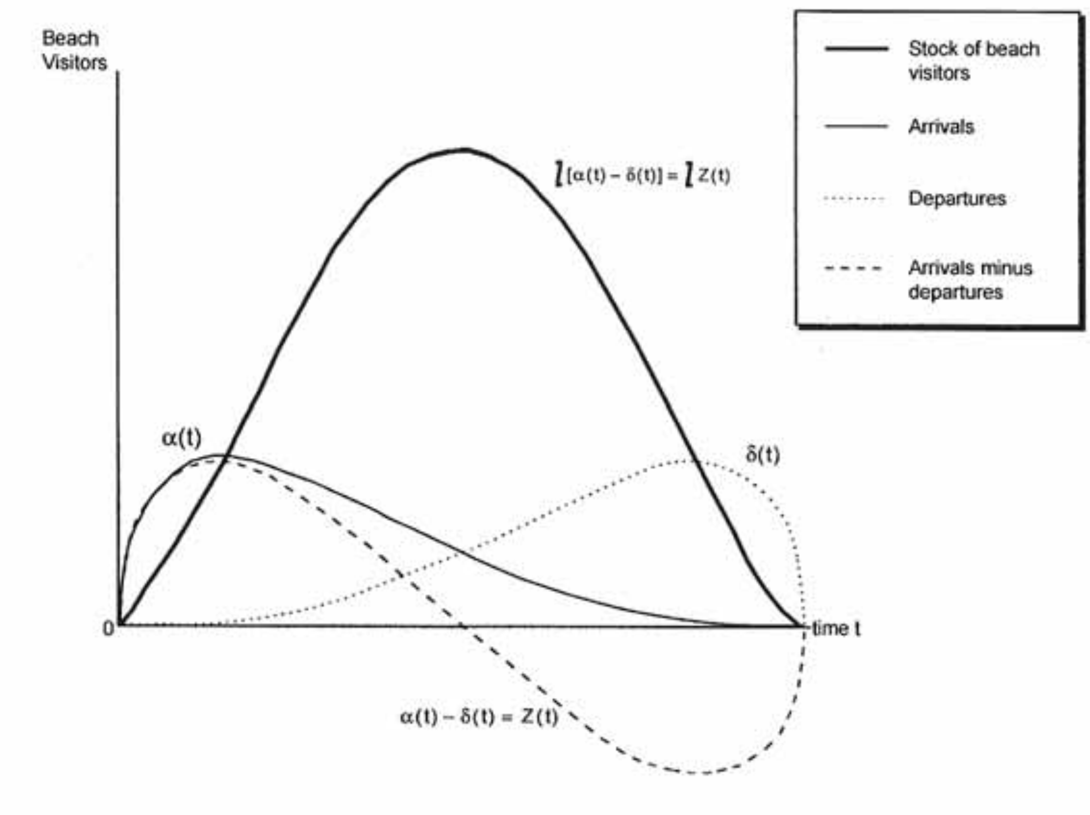

Figure 1: Hypothetical Beach Arrival/Departure Distribution for "Sand People"

(Banzhaf 1996)

My analysis (along with my research assistant Aaron MacGregor) of the surfing data supports the belief that surfers have different arrival, departure and visit durations. Figure 2 below illustrates that the frequency of arrival time for surfers and beach-goers in our sample differed greatly. Peak arrival time for surfers is between 6am to 8am whereas peak arrival time for beach-goers was from 11am to 12pm. Departure times for surfers and beach-goers were also very different. Peak departure times for surfers fell between 9am and 11am whereas peak departure time for beach-goers fell between 4pm and 6pm.

The variance in arrival time and departure time for surfers v. the majority of beach-goers validates the use of a separate turnover factor for the two groups.

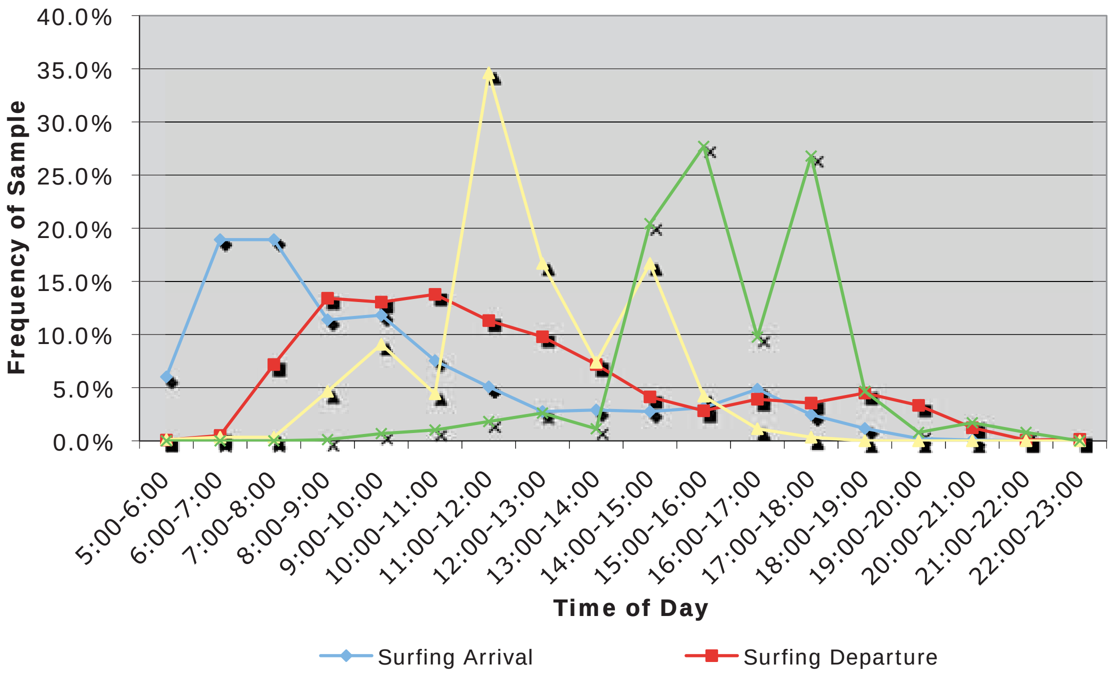

Figure 2: Actual Arrival/Departure Frequency Distribution for Surfers and Sand People (King and McGregor, 2010)

Comment 2

2. **Many of the same comments apply to walkers**. They are very hard to survey and tend to come out in the morning. It is possible that walkers are also significantly underestimated here. Again, I have had the same problem in my own work, so I am sympathetic, but ultimately there could be an issue here.

One possible solution would be to look at other studies to at least estimate the number of walkers. For example, data from the Southern California Beach Valuation Project (2001), a multi-year study evaluating potential substitution to beach attendance from changes in water quality, might be used to address the potential undercounting of walkers. Based on the SCBVP activity data, approximately 25% of all beachgoers would not be midday visitors or surfers. I am not suggesting that this is the proper metric to be applied here, but I do think walkers are undercounted.

Comment 3

3 Other losses in Recreational/Aesthetic Value

Landry, Keeler and Kriesel (2003) also found that visitors to and residents of Tybee Island, Georgia's beaches strongly preferred nourishment alternatives without coastal armoring. Their results would seem to imply that armoring, in and of itself, causes loss of recreational value, apart from the loss in beach size. Their results, which I think would apply to Solana Beach just as well, indicate that the methodology used here underestimates the damage to recreational value that seawalls cause.

Comment 4

4. Ecological Value and other issues

There is also a broader issue here. The Coastal Commission's current criteria seem to imply that loss in recreational value is the only metric for evaluating sea walls. I disagree strongly. I think the CC needs to seriously rethink this issue. Seawalls can cause damage to habitat and there may be other potential harms we don't even know exist, but assuming they are zero is not necessarily the best public policy response. The economics literature refers to the concept of "option value" when evaluating changes to the environment. The option value attempts to quantify the uncertainty about the future consequences of an action. Unfortunately, in reality, its hard to quantify uncertainty, but in my professional opinion it would be legitimate for the Coastal Commission to place the burden on those who want to permanently alter our coast by levying some fee in lieu of the permanently lost opportunity to have a natural coast

Summary

I am sympathetic to anyone who had to do this study. It was done on a limited budget and this is an extremely contentious issue in Solana Beach. Moreover, the consultant seems to have used a similar approach to one I applied a few years ago. However, my more recent work (as well as work I am currently conducting in Orange County this summer) indicates that the methodology employed here may seriously undercount surfers and walkers. Overall I would not be surprised if the counts are too low by a factor of two, though I have not looked at the data sufficiently to have any serious conviction about that conclusion.

I also would strongly suggest that the Coastal Commission develop a broader array of criteria when examining seawalls, not just the recreational value of lost beach width. Seawalls permanently alter the coast and once they are established it's difficult if not impossible to undo these changes. We don't fully understand the consequences to our coast, but even the rudimentary work in economics that has already been completed indicates that just looking at loss in beach width seriously underestimates what the likely damages/economic losses are.

References

Banzhaf, S. H. 1996. Estimating Recreational Use Levels with Periodic Counts. Working Paper T-9602. Duke University. Triangle Economic Research.

Dwight, R. H., M. V. Brinks, G. Sharavana Kumar, and J. C. Semenza. 2007. Beach Attendance and Bathing Rates for Southern California Beaches. *Journal of Ocean and Coastal Management* 50: 847-858.

King, Philip G., and Aaron McGregor. 2010. Who's Counting: An Analysis of Beach Attendance Estimates in Southern California. currently under review at *Marine Resource Economics*.

King, Philip G. 2005. The Economic and Fiscal Impact of Carlsbad's Beaches: A Survey and Estimate of Attendance. Prepared for the City of Carlsbad's Beach Preservation Committee.

King, Philip and D. Symes. 2004. Potential Loss in GNP and GSP from a Failure to Maintain California's Beaches. Prepared for the California Department of Boating and Waterways.

Landry, Craig, Andrew Keeler, Warren Kriesler. 2003. An Economic Evaluation of Beach Erosion Management Alternatives, *Marine Resource Economics*. v. 18, pp. 105-127.

Summary Report on Beach Activity by Wave: A Report on Data Collected from the Southern California Beach Valuation Project. 2001. Prepared by the Research Team for the Beach Project Funders.

Wallmo, Kristy. 2003. Assessment of Techniques for Estimating Beach Attendance. Prepared for the Damage Assessment Center; National Oceanic and Atmospheric Administration.

Letter C

Donna Snider

From: Leslea Meyerhoff [Lmeyerhoff@roadrunner.com]
Sent: Tuesday, September 28, 2010 6:06 PM
To: Donna Snider
Subject: Fw: Land Lease and recreational Fees

Hi Donna - Attached is another public comment for your review.

Leslea
----- Original Message -----
From: Tina Christiansen
To: 'David Holzman'
Cc: 'Leslea Meyerhoff'
Sent: Monday, September 27, 2010 3:34 PM
Subject: RE: Land Lease and recreational Fees

Thank you for your comments they will be included in the project file for information of the consultant, the council and the public, in the followup process
Tina Christiansen

From: David Holzman [mailto:david_hlzmn@yahoo.com]
Sent: Monday, September 27, 2010 3:30 PM
To: Tina Christiansen
Subject: Fw: Land Lease and recreational Fees

Ms. Christiansen,

Not sure you got my first e-mail.

David Holzman

--- On **Fri, 9/24/10, David Holzman <*david_hlzmn@yahoo.com*>** wrote:

From: David Holzman <david_hlzmn@yahoo.com>
Subject: Land Lease and recreational Fees
To: TChristiansen@cosb.org
Date: Friday, September 24, 2010, 11:14 AM

Ms. Christiansen,

I have 30 years experience running market and public opinion surveys for IBM and GE at their corporate headquarters.

The land lease and recreational fee survey sample is neither valid nor reliable. The validity of the sample will be addressed by others and is rather technical and cannot be covered in a short message.

However, the reliability can be easily understood since reliability is the measurement of finding similar numbers of respondents behaving in the same manner upon repeating the survey a second or more times.

If the survey had been done this summer with the cold and cloudy days, the beach population count would have been much lower than last year. Climatologist predict highly volatile weather in the future yet fee payments would be based on a one year small sample that does not account for differences in weather during warm El Nino or cold La Nina summers.

I recommend that the beach count be based on a five year average determined by the life guards. Each five years the fees would be adjusted to reflect the average beach population.

In the first five years the fees should be in the range of the current $1000 to $2500, the approximate amount the Coastal Commission charged Las Brisas. The amount collected from the fees should be sufficient to fund sand replenishment efforts.

David L. Holzman, PhD
205g S. Helix Ave
Solana Beach, Ca. 92075

Letter D

Donna Snider

From: Leslea Meyerhoff [Lmeyerhoff@roadrunner.com]
Sent: Tuesday, September 28, 2010 5:30 PM
To: Donna Snider
Subject: Fw: Land Lease and Recreational Fees Survey

HI Donna - Here is another comment. The public review period ends Monday 10.4.10 at 5pm.

Leslea

----- Original Message -----
From: Tina Christiansen
To: 'David Holzman'
Cc: 'Leslea Meyerhoff'
Sent: Tuesday, September 28, 2010 5:27 PM
Subject: RE: Land Lease and Recreational Fees Survey

Mr. Holzman,
Your comment has been received will be placed and processed with the other comments you have provided in the project record,
Tina Christiansen

From: David Holzman [mailto:david_hlzmn@yahoo.com]
Sent: Tuesday, September 28, 2010 12:52 PM
To: Tina Christiansen
Subject: Fw: Land Lease and Recreational Fees Survey

Subject: Land Lease and Recreational Fees Survey

Ms. Christiansen

Has anyone on the staff or Council been aware of the fact that 28% of the beach count comes from City owned bluff property? Specifically segment 5 (Tide Park) and segments 15 and 16 (Fletcher Cove).

Why should home owners be charged for loss of land and recreation when the City is responsible?

David Holzman
205g S. Helix Ave
Solana Beach, 92075

Letter E

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ATTORNEYS AT LAW

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October 4, 2010

David Ott, City Manager
City of Solana Beach
635 S. Highway 101
Solana Beach, CA 92075

Re: BBC and COOSSA Comments to the Draft Land Lease/Recreation Fee Study

Dear Mr. Ott:

This firm represents the Beach and Bluff Conservancy ("BBC"), the Condominium Organization of South Sierra Avenue ("COOSSA"), and the following condominium homeowner's associations: Del Mar Beach Club, Solana Beach & Tennis Club, Surfsong, Seascape Chateau, Del Mar Shores Terrace, and Seascape Shores. This letter, and the reports attached to it, constitute the response of these entities to the Revised Draft Land Lease/Recreation Fee Study prepared by PMC with CIC Research, Inc., published in July 2010 ("Draft Study"). We believe the Draft Study contains significant flaws and proposes a Land Lease / Recreation Fee ("Fee") that is unfair and far in excess of the theorized impacts of bluff retention devices ("BRDs"). Please include this letter and its attachment into the administrative record with respect to the Fee and with respect to the LCP more generally.

I. INTRODUCTION

As you know, the BBC is a non-profit organization that represents the interests of the more than 1,400 oceanfront property owners in Solana Beach. Formed in 1998, its broad mission is "to restore, rebuild, maintain and preserve the safety, beauty, joy and access of our beaches and bluffs for the benefit of everyone." COOSSA is also a non-profit community group formed in 1988. Its purpose is to make local government aware of the particular interests, concerns, and consensus of the Solana Beach condominium community and organize political awareness and action on behalf of condominium residents. COOSSA's members consist of the following condominium associations:

Condominium	Units	Est. Owners
Las Brisas	36	54
Surfsong	72	108
Seascape Shores	51	76
Solana Beach & Tennis Club	152	228
Seascape Sur	188	282
Seascape I	50	75
Seascape Chateau	30	45
Del Mar Shores Terrace	87	130
Del Mar Beach Club	192	288
TOTALS	**858**	**1,286**

As a last resort, and due to existing conditions well beyond the control of bluff top property owners, my clients support the use of BRDs where needed to protect existing structures and/or public safety, as well as beach sand replenishment activities. In the spirit of the compromise LUP, the BBC and COOSSA also accept the assessment of appropriate mitigation fees where such fees are reasonable, fair, closely related to actual net impacts, and where credit is given for the public benefits associated with any particular BRD.

For the reasons stated herein, my clients wish to register their strong objections to the Fee proposed in the Draft Study because this fee is excessive and unfair. The proposed fee is not closely related to the actual net impacts of BRDs, as required by law, and therefore constitutes an unlawful exaction from bluff top homeowners who are forced to construct or maintain BRDs due to the cumulative impacts of other human activity and development.

II. CONSULANTS

Due to the complexity of the Draft Study, coupled with the excessively high fee it proposes to impose on bluff top property owners, we hired a team of highly trained experts to advise us with regard to the propriety of the methods used and calculations undertaken by PMC. This team consists of the following.

A. Stephen Conroy, Ph.D., Economist;

B. Ryan Bosworth, Ph.D., Economist;

C. Richard Levine, Ph.D., Statistician;

D. Walter Crampton, P.E., Coastal Engineer

The comments in this letter are based on the opinions and assessments of these learned experts, along with legal analysis by the undersigned. Their reports are also attached hereto for your further reference. Please review these reports in their entirety as they provide critical detail and reasoning in support of the concerns summarized below.

III. <u>THE BBC AND COOSSA SUPPORT A FAIR AND WELL REASONED FEE; UNFORTUNATELY, THE FEE PROPOSED BY PMC DOES NOT MEET THIS CRITERIA</u>

The BBC and COOSSA are aware that Joseph Steinberg, through his attorneys, submitted a comprehensive letter in response to the Draft Study that makes a number of arguments against the imposition of the Fee and questions its legal validity. These arguments include:

- BRDs are needed today due to the historically unprecedented over development of the coastal zone and massive public and government interference with normal coastal processes;
- This over development and interference has irreversibly interrupted the natural flow of upland sediments to the beach, and has transformed the beach in Solana Beach from one that was generally stable, to one that is actively eroding, unsightly and dangerous;
- Passive erosion occurs, if at all, due to human intervention in the coastal processes that normally deliver beach sediments to the coastal environment;
- The majority of the beach area theoretically impacted by BRDs is attributable to passive erosion, as opposed the mere footprint of the BRD, that would not occur *but for* the public's interference with coastal processes;
- The Fee assumes continual beach erosion despite the fact that the Fee and Sand Mitigation fees, along with beach replenishment projects (e.g., RBSP II, SCOUP, and USACOE), will be used to replenish the beach and reverse beach erosion;
- A fee to compensate the public for "lost recreation" makes no sense when the area occupied by BRDs is objectively unsafe for recreation;
- A fee to compensate the public for "lost recreation" makes no sense when BRDs increase the width of <u>useable</u> beach and thereby enhance coastal recreation opportunities;

- The Coastal Commission's already sand mitigation fee formula takes into account the impacts theoretically mitigated by the LL/R fee.

The BBC and COOSSA agree with the factual underpinnings of each of these statements, and incorporate Mr. Steinberg's letter, and its attachments, herein by reference. Nevertheless, in the continued spirit of the Citizen's Group compromise, the BBC and COOSSA currently remain supportive of the LUP and its framework for a fair Fee as long as the Fee is reasonable and derived using sound methodology and principles.

That being said, the BBC and COOSSA wish to register their strong objections to the Fee proposed in the Draft Study because it contains numerous flaws that have materially and unfairly biased its conclusions. These flaws are summarized in this letter and its attachments. The undersigned and the consultants identified above are available for further discussion, and to answer any questions that you, your staff, or PMC may have as it reviews this letter and its attachments. We would like to be a part of any plan developed going forward to address the deficiencies noted herein.

IV. <u>TRAVEL AND TIME COST METHOD INAPPROPRIATE AND A MISTAKE</u>

To determine the value of a "day at the beach," PMC choose an economic model called the Travel and Time and Cost ("TTC") model from a field of several other applicable economic models. According to Dr. Conroy, however, this model was "a poor choice, and perhaps inappropriate, because its results can be highly inaccurate and not reproducible." (Exhibit A, Conroy Report, page 3). Dr. Conroy's well-supported principal criticism of the TTC model for this assignment is that it does not account for "substitution." Dr. Bosworth agrees with this criticism and states that PMC's failure to account for substitutes was a "mistake" that "would substantially bias the result in the form of an artificially high value for Solana Beach." Dr. Bosworth also states that the PMC failed to address the "well-known 'multiple destination problem' [inherent] in time/travel cost models." (Exhibit B, Bosworth Report, page 2).

In its report, PMC acknowledges the shortcomings of the TTC model, including the fact that it does not address the substitution effect (See, Draft Study, page 2-2), but PMC used it anyway even while it acknowledged that the Random Utility Maximization ("RUM") model would have captured and evaluated the "substitution effect in the site visit decision." According to Dr. Conroy, the RUM is the "state of the art in nonmarket valuation" and "the best economic model in cases such as this where there are many substitutes available." (Exhibit A, Conroy Report, page 3). Frankly, based on PMC's own summary of the advantages and disadvantages of the TTC and RUM models, it appears that PMC chose the TTC model, not because it was the best, but because it fit the City's budgetary constraints. (See, Exhibit A, Conroy Report, page 3). Unfortunately, this was false economy as this mistake essentially renders the Draft Study completely invalid for the reasons summarized herein.

A. <u>PMC's Failure to Account for "Substitution" Biased the Entire Study</u>

According to both Dr. Conroy and Dr. Bosworth, the single largest problem with the Draft Study is that it does not account for substitution, which addresses the ability of a beachgoers to simply choose another nearby beach. Dr. Bosworth found that "[t]he key mistake in the PMC study is that the value of a day of recreation at Solana Beach is not the same thing as the value of Solana Beach because visitors to Solana Beach have numerous substitute destinations including the adjacent beaches in Del Mar and Encinitas, not to mention numerous parks and other attractions that San Diego has to offer." (Exhibit B, Bosworth Report, page 3).

What this means is that because a visitor to the Solana Beach coastline has a variety of substitute destinations that are similar in quality and character, he or she could simply choose another similar destination without much additional time or expense. That is, if a visitor traveled to Solana Beach only to find it unusable due to BRDs (an extreme and unrealistic suggestion given that BRDs only occupy, at most, a small portion of the beach and actually result in a <u>net</u> increase in useable beach), she would be still be able to enjoy a day at the beach by the simple expedient of traveling down the road to Del Mar, Cardiff, or Encinitas in a matter of minutes. However, in the Draft Study "PMC assumption that beachgoers to the Solana Beach area had no other alternatives to attending Solana Beach – a very unrealistic assumption, which was driven by using the less-expensive TCM approach – results in a greatly exaggerated value!" (Exhibit A, Conroy Report, pages 5 - 6).

Undoubtedly, the availability of these substitute destinations must be taken into account in a proper economic analysis of the value of a day at the beach in Solana Beach. PMC's failure to do so here resulted in a dramatic over-estimation of beach valuation. (Exhibit A, Conroy Report, page 4). PMC's mistake in this regard may have caused their conclusion that a "day at the beach" in Solana Beach is worth \$21.15 to be more than ***20 times higher*** than it is when you account for substitutes.

This conclusion is supported by an oft-cited study conducted by DK Lew and DM Larson in 2005. In that study, Lew and Larson used a RUM model to estimate economic values associated with beach recreation in San Diego County, and determined economic values of a beach day for various locations. Undertaking this analysis, and accounting for substitutes, the value of a day at the beach for Fletcher Cove and Tide Park combined was just \$0.14. (Exhibit A, Conroy Report, page 5).

By way of further explanation, Dr. Conroy points out that the \$0.14 per day effect only considers Fletcher Cove and Tide Park, so the result for all of Solana Beach would be marginally higher. However, he also states that the Lew and Larson study found that, when you consider substitutes, the value of a day of the beach at Mission Beach was just \$1.00 per day. Given that PMC found the value of a day at the beach in Solana Beach to be more than ***21 times*** the daily rate for all of Mission Beach – which is considerably larger, has considerably more sand on its beaches, better parking, is located closer to San Diego's population centers and airports, receives more visitors, and has far more amenities and accommodations.

Clearly, PMC's failure to consider substitutes resulted in a huge error. Please review the Conroy and Bosworth reports for a more detailed analysis. It may also help to review the published reports that are cited by Dr. Conroy. We will provide these reports to you under separate cover. To us, the question now is not how you revise the Draft Study to account for substitution, but do you use the Draft Study at all given that it did not include a substitution analysis? According to Dr. Conroy, one solution is to simply use the Lew and Larson study, expanded to include all of Solana Beach and adjusted for inflation, to determine the value of a day at the beach, in lieu of the Draft Study. (Exhibit A, Conroy Report, page 6).

B. <u>PMC Also Failed to Account for the "Multiple Destination" Problem</u>

Another problem with the TTC model, and more particularly, PMC's application of it to its Solana Beach study, is that it failed to account for the "multiple destination" problem. According to Dr. Bosworth, this is a well-known problem in TTC models. (Exhibit B, Bosworth Report, page 2). The multiple destination problem concerns the situation where a beach survey interviewee's visit to the beach was incidental to the primary purpose of his trip. For example, if an interviewee traveled from Minnesota to Solana Beach to visit his sister, and happened to go to the beach one day where he was interviewed by PMC observers, PMC's TTC model will attribute the entire cost of his travel and time from Minnesota to his beach visit, leading to an artificially high cost value for that person's visit.

The problem is that PMC's beach survey does not attempt to gather multiple destination data. As a result, their averages for explicit and implicit cost of a beach visit are unreliable. Without the data, it is impossible to state how much this biased the result. However, it is fair to conclude that this additional mistake did, in fact, result in an artificially high value for an average day at the beach. How we deal with this deficiency after the fact, however, is unknown.

V. PMC INCORRECTLY CALCULATED THE VALUE OF A DAY AT THE BEACH

Even if the TTC model was appropriate for this task, and ignoring PMC's failure to evaluate the substitution effect or account for the multiple destination problem, PMC made several key mistakes in its execution of the TTC model. These mistakes substantially biased the Fee in a manner that is, once again, prejudicial to bluff top homeowners, and must be re-evaluated.

A. For Most People, Leisure Time is Valued Less Than Time Spent at Work

"PMC miscalculated the LLR because it assumes that the value of time available for leisure activities is always equal to the compensation that one actually receives from his or her labor. *** This mistaken assumption led PMC to calculate an incorrect and materially flawed LLR fee. Further, since beaches are actually busiest on the weekends and holidays, the overestimation is exacerbated." (Exhibit A, Conroy Report, pages 6 - 7). This occurred because PMC's beach visitor survey did not discern between workers at a so-called "interior" solution versus workers at a "corner" solution.

To determine the value of a day at the beach, PMC randomly interviewed 563 beach visitors and asked them a series of questions designed to ferret out the explicit and implicit costs they incurred to get to and from the beach. In this context, "implicit cost" refers to the value of the individual's time which is determined *with reference to* the wage the persons earns at his primary employment. However, when conducting the interview it was critical to ask questions that would have allowed PMC to determine whether the interviewee works at an "interior" or a "corner" solution.

An interior solution worker is one who is able to easily trade between leisure time and work time (e.g., a busy consultant who is paid by the hour or a lawyer who has such a busy practice that she could essentially bill unlimited hours and still not complete all her work). For the interior worker, the value of leisure time is roughly equivalent to his or her net hourly wage rate.[1] On the other hand, a corner solution worker is one who is does not have the option to earn more wages in lieu of leisure time (e.g., a worker who is "salary exempt" from overtime rules or an hourly worker whose employer limits him or her to 40 hours per week to avoid paying the overtime rate). For the corner worker, the value of leisure time is worth *significantly less* than his or her net hourly wage. This principal is well known and is comprehensively covered in several oft-cited economic studies. (See, Exhibit A, Conroy Report, pages 6 – 9).

To be valid, therefore, a TTC survey must discern between corner and interior solution workers. If you do not ask such questions, then your survey assumes that all interviewees have an interior solution – a false assumption, especially on weekends and holidays – and your resulting calculation for the value a day at the beach will be upwardly biased. This upward bias is likely to be substantial given that the majority of workers are at a corner solution [Exhibit A, Conroy Report, page 8 (at least 2/3 of workers are at a corner solution)], and "since most beaches are actually busiest on the weekends and holidays, the overestimation is exacerbated." (Exhibit A, Conroy Report, page 7).

Despite the fact that this principal is well known and is comprehensively covered in several oft-cited economic studies, the PMC survey did not discern between the interior and the corner, and therefore made the false assumption that the value of every interviewee's time is simply equal to his or her hourly wage. "In what is perhaps the most often-cited paper in this area (Google Scholar reported 290 citations as of October 4, 2010), Cesario (1976, p. 37) states it succinctly, 'It is clear from these findings that the use of the marginal wage rate for the value of travel-time values in recreation benefit estimation is *inappropriate* (emphasis in original), both from the theoretical and practical points of view.'" (Exhibit A, Conroy Report, page 8). In this case, PMC did exactly what Professor Cesario declared "inappropriate." PMC simply equated

[1] The "net hourly rate" will be explained in Section V.B. below.

wages with the value of leisure time. "This mistaken assumption led PMC to calculate an incorrect and materially flawed LLR fee." (Exhibit A, Conroy Report, page. 8).

Based on his analysis, and the published reports cited therein, Dr. Conroy believes that this problem can be perhaps retroactively addressed by adjusting the reported hourly wages through a 40% discount. (Exhibit A, Conroy Report, page 9).

B. <u>The Rate Used Should Be Net of Taxes (i.e., Disposable Income)</u>

In addition to the corner versus interior issue described above, there exists another problem. The value of time, which the TTC model seeks to measure as the implicit cost of travel to and from the beach, should be equated not to gross wages, but to net income, i.e., net of taxes. (Exhibit A, Conroy Report, pages 9 - 10). The reasoning behind this is that disposable income, not gross wages, is "what matters most to individuals." (Exhibit A, Conroy Report, page 9). In other words, to value the implicit cost of time, PMC should look at disposable income, not gross wages.

According to Dr. Conroy, this principal was addressed in McConnell and Strand's 1981 paper in which they model this explicitly applying a proportional tax to the gross wages collected by the survey. To resolve this deficiency retroactively, Dr. Conroy recommends that the average wage rate as determined by PMC, discounted by 40% to account for corner solution workers, should be reduced further by applying the standard IRS deduction for 2009 and by assuming that every survey respondent was a head of household. This solution is more conservative than the one recommended and used by McConnell and Strand where they simply applied a proportional tax rate to the whole study.

C. <u>PMC Miscalculated the Midpoint of the $0 to $20,000 Income Category</u>

Although relatively minor compared to the failure to account for substitutes, interior versus corner solutions, and gross versus net income, there lurks another error in PMC's average income calculation. In its survey, PMC used a question to determine approximate income by asking interviewees to indicate what income range best estimated their gross wages (e.g., $0 to $20,000). They then used the midpoint of each range in their overall calculation. With respect to the bottom income range ($0 to $20,000), PMC calculated the midpoint at $15,000, instead of $10,000. This problem must be corrected as well. (Exhibit A, Conroy Report, page 10).

VI. PMC MISCALCULATED THE NUMBER OF ANNUAL VISITORS

For the reasons set forth below, PMC's estimate of 101,415 annual adult visitors is highly inaccurate and represents a gross overstatement of the true number of beach visitors that come to the beach in Solana Beach. This mistake is problematic because the number of visitors is such an important component of the TTC model, this over count is a large part of PMC's problem-plagued and inaccurate Fee. As described below, if it is possible to correct the statistical aspects of this over count, it would then be necessary to further reduce the number to account for the uneven distribution of beach visitors as further described below.

A. PMC Used Poor Statistical Methodology and Failed to Consider Relevant Factors

As mentioned at the beginning of this letter, the BBC and COOSSA hired Richard Levine, Ph.D. to assess the statistical methodology employed by PMC to estimate the annual total of adult beach visitors. Dr. Levine's resulting report and curriculum vitae are attached hereto as Exhibit C. Dr. Levine has a Ph.D. in Statistics, is a Professor of Statistics at San Diego State University, and is also a principal in Forestat, LLC, a statistics-consulting firm. Dr. Levine's expertise includes survey/questionnaire design and analysis, among several other relevant sub-disciplines.

Dr. Levine's critique of the PMC's statistical methodology is well explained in his 14-page report, which should be read in its entirety. Suffice it to say, Dr. Levine believes PMC made several critical errors that caused its adult beach visitor count to be high by at least 18%, and that a more precise estimate of annual adult visitors is 82,724 – not 101,415 as estimated by PMC. (Exhibit C, Levine Report, pages 5 – 6). However, PMC's annual estimate is based, in part, on information that PMC obtained through its beach visitor survey, which also suffers from imprecision and numerous other problems as documented by Dr. Levine. Accordingly, his re-estimate of annual adult visitors at 82,724 is subject to additional downward adjustment that is not possible at this time due to the deficiencies in the PMC data set.

By way of summary, however, Dr. Levine's assessment of PMC's statistical methodology is described below. His conclusions are supported by Dr. Bosworth who also has significant experience in the design and execution of survey methodology (Exhibit B, Bosworth Report, page 2).

Summary of Dr. Levine's Criticisms of PMC's Statistical Methodology

1. *Sample Size.* The samples selected in each survey are not representative of either the population of beach days occurring during the study period nor the beach visitor population leading to a potential bias/inaccuracy in the annual adult beach visitor count estimate. The sample sizes are too small to draw reasonably precise estimates of the annual number of adult beach visitors.

2. *Sampling Plan.* The number of beach visitors varies by tide condition, weather, month/season, time of day, and location. The surveys do not account for these factors leading to imprecise and biased estimates of annual adult beach visitor counts if not completely unreliable inferences.

3. *Precision.* The annual beach visitor count is estimated with error inherent within the survey sampling mechanisms, the undercount adjustment, and data collection/measurement. A quantification of this uncertainty is not provided nor considered in the report and, due to the deficiencies in the sample plan, may be excessive.

Based on the deficiencies noted by Dr. Levine in his report, the number of annual beach visitors must be reduced to a baseline of at least 82,724, with consideration given to a further downward revision after considering the deficiencies beach visitor survey, upon which the beach visitor count is, in part, based.

B. No Justification for Abandoning North/South Segmentation

Once the new baseline is established based on Dr. Levine's report, it will also be necessary to remove from the count all visitors from Segments 15 and 16, the visitors to Fletcher Cove. This is necessary because the TTC model presumes that the value of the beach is inextricably tied to the annual visitors it receives. In observance of this principle, PMC appropriately broke the beach into 35 perpendicular segments and collected beach count data within each segment. This approach clearly showed that the distribution of visitors to the beach was not even, that beach visitors strongly preferred, and therefore placed more value on, some areas of the beach over other areas. Notably, the area of the beach that received the most visitors was the "public" area at Fletcher Cove, with its ease of access, availability of parking, bathrooms and other amenities. Despite taking great efforts to collect the segmented data, and despite the fact that the data clearly showed that beachgoers placed much higher value on the Fletcher Cove beach, PMC collapsed the beach into one giant segment and averaged all data. This is unacceptable to the BBC and COOSSA.

The only explanation that PMC gave for doing this was that "the beach is subject to dynamic process that ultimately affect beach density on a daily, weekly, and yearly basis" and that beach densities *could* change over the next 72 years due to sand replenishment. (See, Draft Study, pages 1-2 and 4-1). However, these conclusory, unsupported statements do not justify PMC's wholesale abandonment of its original segmentation analysis. While it is true that a beach is subject to "dynamic processes," the number of visitors to Fletcher Cove results from its proximity to vertical beach access, parking, amenities, and its central location. Nothing about dynamic processes on the beach will change these facts, and it is far more likely that sand replenishment projects will favor, rather than disfavor, Fletcher Cove. Underscoring this point, SANDAG's Regional Beach Sand Project II, scheduled for April 2012, is set up to deposit 146,000 cubic yards of sand on Fletcher Cove, and no where else in Solana Beach. (Exhibit E, SANDAG's Construction Cost Schedule for RBSP II).

PMC's data, the empirical evidence, and commonsense uniformly show that the "value" of the beach varies depending on various factors, and it is inappropriate to charge all bluff top homeowners the same Fee with regard to the reality of their actual impact. Drs. Bosworth and Levine both conclude that PMC's disregard of its own data in this regard is a grave error that resulted in a substantially inflated and unfair Fee. (Exhibit A, Conroy Report, pages 11 – 15; Exhibit B, Bosworth Report, page 3). Please read Dr. Conroy's report from pages 11 to 15 for a thorough and well-reasoned explanation as to why this approach is inappropriate and unfair to bluff top homeowners.

In this section of his report, Dr. Conroy explains his point of view by drawing an analogy to a dinner at a restaurant attended by 3 couples where 1 couple eats salad and drinks water, but is asked by the other 2 couples, who ate steak and lobster and drank expensive wine, to split the check evenly. Clearly, this is unfair to the first couple whose meals cost far less than the meals enjoyed by the other 2 couples. Similarly, if you ask a bluff top homeowner who impacts with her BRD a lightly used area of the beach (e.g., segments 7 and 8 with a combined total of 1,680 annual adult visitors) to share equally with the property owner whose BRD impacts a more heavily used area of the beach (e.g., segments 15 and 16 with a combined total of 24, 212 annual adult visitors), that person will pay ***14 times*** what he would otherwise pay (assuming the segments are approximately the same size), effectively subsidizing the cost of impacts that she does not create.

The BBC and COOSSA agree with Dr. Conroy that at an absolute minimum, the Fee calculation should not include Fletcher Cove. That is, while retention of complete perpendicular segmentation in the analysis of the Fee represents perhaps the most appropriate way to approach the LUP fee mitigation fee structure, it may be more practical to simply take Segments 15 and 16 (Fletcher Cove) out of the analysis. The justification for this being that Segments 15 and 16 represent the one holistically public area of Solana Beach – public beach, backed by public bluffs, public property, public bathrooms, a public community center, a public park, the lifeguard headquarters, and public parking.

C. PMC Assumed a Uniform East/West Distribution of Visitors and Erroneously Placed the Same Value on the Dangerous and Safe Areas of the Beach

Another major deficiency of the Draft Study is that it places the same value on all areas of the beach, be they safe, dangerous, used, or unused. This mistake (addressed, in part, above) was significant, resulting in an artificially high Fee, because it makes the false assumption that beach visitors place the same value on the dangerous area of the beach – the area that can kill them or their loved ones without warning – as they do the portions where they can safely recreate.[2] Since BRDs occupy the former and not the latter, this omission likely resulted in a material upward bias of the Fee.[3]

In the initial scoping sessions with PMC, David Winkler and Dr. Conroy requested that PMC design the beach count survey such that it would not only measure north/south distribution, but also east/west distribution. (Exhibit A, Conroy Report, page 17). Unfortunately, PMC and the City ignored this request, and the resulting beach count survey is materially deficient as a

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[2] Since 1995, 5 people have been crushed by falling bluff material between North Torrey Pines State Beach and South Carlsbad State Beach. Please watch the video entitled *Cliff Collapse Kills Las Vegas Man* found at http://videos.nctimes.com/p/video?id=2098563.

[3] As evidenced by the fact that PMC monetized the public safety benefit of BRDs, they implicitly acknowledge that the back of the beach has a safety problem, but still failed to conduct its beach count in a manner that accounted for this circumstance.

result. (Exhibit A, Conroy Report, pages 15 – 19; Exhibit B, Bosworth Report, page 3).[4] It is unclear what can be done to remedy this defect.

Both Dr. Bosworth and Dr. Conroy found PMC's omission in this regard to be significant. According to Dr. Bosworth, "[b]y failing to address the heterogeneity of value, PMC undoubtedly overvalued the portions of the beach that are most impacted by BRDs, as it is the area of the beach that is subject to the danger of bluff collapse and receives less visitation." (Exhibit B, Bosworth Report, page 3). Concurring with this conclusion, Dr. Conroy states, I believe this is a potentially a very important omission, since the value of the beach for which the ... BRD owners are being charged, namely the toe of the bluff, has the lowest value. * * * Clearly, this creates an upward bias on the amount of the fee that BRD owners are expected to pay." (Exhibit A, Conroy Report, page 17).

The problem inherent in PMC's approach to this problem can be illustrated by the following example. Suppose an individual's property borders on a 50-acre public park and that the property owner needed to build a retaining wall on park property to provide lateral support to her land. Further, suppose the area of the park where she will install the retaining wall is a dangerous landslide area, located a far distance from the park's amenities (e.g., parking, bathrooms, swing sets, etc.) that receives very few visitors.[5]

When she asks the park for permission to build the retaining wall on park property, the park officials agree, but tell her she has pay the public for taking up some of its land that would otherwise be available for recreation. The park then undertakes an economic survey, using the TTC model, to determine the value per square foot of the park area that the private property owner's retaining wall would occupy. In doing so, they determine the value per square foot by multiplying average round trip travel cost (explicit and implicit) by the number of <u>all</u> adult visitors that the park receives, and then divides the product by the park area. They undertake this calculation even though 80% of the park's visitors stay within 100 feet of the parking lot, and

[4] This also points up to another reason PMC should have used the RUM method, as the RUM method allows "individuals to express a value for the improved safety and increased usability of the beach…." (Exhibit B, Bosworth Report, page 3).

[5] It is no accident that this scenario is the same circumstance in which bluff top property owners now find themselves. To complete the analogy, perhaps we should add that the public that is demanding the fee, is the same public that caused the landslide conditions in the first place?

clear evidence that very few park visitors recreate in the area where the retaining wall will be constructed, not only because it is far from parking and amenities, but because it is dangerous.

Like the Fee in the Draft Study, the resulting fee imposed on the private property owner would be disproportionate to her actual impact on public recreation because her edifice is occupying space that is used by less than 20% of park visitors, yet she is charged as if all park visitors visit all portions of the park equally. This false assumption of equal distribution and use results in an unfair fee, far higher than it should be. To arrive at a fairer fee, the park should have collected data regarding the distribution of visitors within the park to estimate the actual use of the area that would be occupied by her retaining wall. This extra data collection would have allowed the park officials to charge a realistic fee commensurate with the actual impact based on the number of park visitors to the area impacted by the retaining wall.

For comprehensive discussion of this overall problem, please read Exhibit A, Conroy Report, pages 16 through 19.

D. <u>The Visitor Count Should Not Give Equal Weight to People in Water</u>

In fairness to its own chosen methodology, PMC should not have given equal weight to all persons in the water without including the surfing area in its estimate of total beach area. By doing so, PMC made the false assumption that everyone in the water would also use the beach without determining the probability that they would *actually* use the beach and then be (theoretically) impacted by the placement of BRDs on the back beach. While this may have been a reasonably acceptable assumption for adult waders (as waders probably are using the beach), it likely led to a gross over count with respect to surfers and boogie boarders. (Exhibit A, Conroy Report, page 18).

Speaking from experience, many surfers spend no time on the beach, other than walking across it to access the water and to then to return home. The sole purpose of their trip to the coast is to go surfing in the ocean, not recreate on the beach. Accordingly, since PMC did not include the surfing areas in its beach area estimation, it was improper for PMC to include all surfers, on a 1:1 basis with people actually seen using the beach or wading in the nearshore, in the total beach count.

Another problem with counting surfers on a 1:1 basis with people on the beach is that it was likely very difficult for PMC's observers to discern which surfers were over 16, as required by PMC's chosen methodology. It is difficult enough to ascertain age while standing near someone on the land. To do so from the beach with respect to a group of people all wearing black wetsuits in the water is likely to lead to significant imprecision.

Given the absence of any PMC data on the number of surfers who would also recreate on the beach, Dr. Conroy suggests that a correction should be made to account for "differential weighting based on actual impact." (Exhibit A, Conroy Report, page 18). He is careful to point out, as is the undersigned, that surfers and boogie boarders are NOT "worth" less than those on the beach. Instead, we are suggesting a technique that preserves the intellectual honesty and integrity of the Draft Study. Again, the question is this: what percentage of surfers would also recreate on the beach during that beach visit? PMC's analysis assumes that the answer to this question is 100% despite the fact that it did not conduct any such counts or conduct a probability analysis. The empirical evidence, however, indicates that PMC's assumption is false, and a proper weighting needs to be conducted.

VII. PMC INCORRECTLY CALCULATED OFFSETS

A. PMC Underestimated the Public Benefits of BRDs

PMC correctly concluded that BRDs bring a substantial and much needed safety benefit to the beach going public. However, PMC's approach to determining the value of this public safety benefit was incorrectly performed with an actuarial analysis that likely resulted in an underestimated assessment of these public safety benefits. (Exhibit B, Bosworth Report, page 3). According to Dr. Bosworth, the actuarial analysis likely underestimated the public safety benefits of BRDs because actuarial analyses ignore "the fact that the risk of death or injury can be mitigated by individuals staying away from the bluffs." In other words, since many people will in fact observe the City's warning signs, heed warnings from the City's lifeguards, and use common sense, the fatal consequences of bluff failures can be and are largely avoided. Thus, the actuarial analysis does not capture actual risk because most individuals can and will choose to avoid the known risk. According to Dr. Bosworth, the more appropriate means to determine the value of the safety benefit is to use the RUM model discussed above as this approach would have allowed PMC to determine the value that the average beachgoer assigns the wall.

> Even individuals who would not be at risk of death or injury because of their behavioral response to the danger would benefit from the presence of

> the BRD due to increased beach usability and decreased stress. A random utility approach that allowed individuals to express a value for the improved safety and increased usability of the beach could capture this benefit. (Exhibit B, Bosworth Report, page 3).

An additional problem with PMC's actuarial approach is in the manner of its execution. Once again, according to Dr. Bosworth, PMC's decision to only look at bluff failure data from Solana Beach and Encinitas is "arbitrary" and fails to account for the 4 additional deaths that have occurred on other nearby beaches in the same time period. (Exhibit A, Conroy Report, pages 19 – 20; Exhibit B, Bosworth Report, pages 3 – 4). In the absence of using the RUM model to monetize the real value of BRD safety benefits, PMC should undertake a new analysis with a complete data set that brings in all relevant factors.

B. <u>PMC Overestimated the Private Benefits of BRDs</u>

We agree with PMC that the value of a bluff top home increases when a BRD is in place, and that the amount of the increase is equal to the cost of the BRD. However, PMC seems to ignore the fact that the bluff top homeowner had to spend this money to achieve the increase in value. Thus, the increase is value due to the existence of the BRD is completely eliminated by its cost. Therefore, the private benefit of the BRD is **net zero**, and an offset should be applied in the amount of the total public benefit. Accordingly, even if PMC's final report does not increase the amount of the public benefit (although it should) based on the comments in the Section VII.A above, the offset should be $192,860 since there is zero private benefit for the BRD. (Exhibit A, Conroy Report, page 20).

VIII. THE DISCOUNT RATE SUGGESTED BY PMC IS TOO LOW

PMC correctly concluded that under the LUP, bluff top property owners have two payment options when paying the land lease/recreation fee, less applicable offsets, applicable to their BRD project. Under Payment Option One, bluff top property owners may pay 33% of their total fee upfront, with the remaining 67% of their total fee paid in equal annual installments for the remaining years of the permit. Under Payment Option Two, bluff top property owners may pay their entire fee upfront, discounted for present value.

In the Draft Study, PMC did not attempt to determine the applicable net discount rate. However, for illustrative purposes only, they used 2%. According to Dr. Conroy's analysis, however, this number is too low. For the reasons set forth in his report, we believe the actual discount rate applicable to Payment Option Two is 4.63%. This number is the difference between the appropriate discount rate of 7.0% and the applicable inflation rate of 2.37%. (Exhibit A, Conroy Report, pages 20 – 24).

IX. CONCLUSION

As summarized in this letter, and explained in more detail in Exhibits A, B, C and D, the Draft Study contains many significant flaws that have materially biased the Fee against bluff top homeowners. As a first step to remedy these problems, the BBC and COOSSA suggest that the City convene a roundtable discussion and/or public workshop where the issues raised in this letter, as well as the issues and concerns raised by other individuals and groups, can be more fully discussed directly with City staff and PMC. At the meeting, each of the consultants who contributed to this report should be present and perhaps all can agree on the next course of action.

Respectfully submitted,

THE AXELSON CORN LAW FIRM

By: ______________________

Jonathan C. Corn

Expert Report on: *City of Solana Beach Draft Land Lease/Recreation Fee Study*, March 2010 by PMC
Prepared by Stephen J. Conroy, Ph.D
Date: October 4, 2010

I. Assignment

I was retained by Jonathan Corn, Esq. of the Axelson Corn Law Firm, to study and analyze the report entitled *City of Solana Beach: Draft Land Lease / Recreation Fee Study*, Revised July 2010, by CIC Research, Inc. and PMC (the "Draft Report"), and to submit a written summary of my findings, the report herein.

II. Qualifications

An Associate Professor of Economics at the University of San Diego, I hold a Ph.D. and M.A. in Economics from the University of Southern California and a B.A. in Economics (with honors) from Creighton University. I have published several peer-review journal articles, presented original research findings at academic conferences and won awards for both research and teaching at two universities. One of my recent publications, forthcoming in the *Journal of Real Estate Finance Economics*, estimates the "coastal premium" for residential property near the coast in San Diego County.[1] At USD, I teach a combination of undergraduate and graduate (MBA) courses in economics and business. I also maintain a growing consulting practice that includes work in the areas of economic base analysis, urban and regional economic development, and nonmarket valuation. My CV is attached in the Appendix.

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[1] Conroy, Stephen J. and Jennifer L. Milosch. 2009. "An Estimation of the Coastal Premium for Residential Housing Prices in San Diego County," *Journal of Real Estate Finance and Economics*. Available at http://www.springerlink.com/content/37010067tn4up317/fulltext.pdf through "Online First" and Open Access to the public.

III. Documents Reviewed

In addition to the Draft Report, I reviewed the documents: *City of Solana Beach: Draft Land Lease / Recreation Fee Study*, March 2010 (and revised July 2010), by CIC Research, Inc. and PMC; *Analysis of Beach Sand Contribution from Coastal Bluffs at Solana Beach, CA*, by Flick, Reinhard E. and M. Hany S. Elwany, July 31, 2006; and Memo from Donna Snider to David Ott, Leslea Meyerhoff and City of Solana Beach, re: Solana Beach Land Lease/Recreation Fee, June 2, 2010. I have also analyzed and considered more than a dozen scholarly publications that discuss the valuation of nonmarket resources or assets. In addition, my analysis herein draws on the numerous other articles, documents and reports I have read, analyzed, and written over the course my professional career.

IV. Findings

After conducting my analysis of PMC's report, including their methodology and results, I have several concerns which I will outline below.

A. PMC Used the Wrong Economic Model

A public beach area is what is known as a "non-market" commodity. That is, because it is not a commodity or asset that is actively and freely traded in the open market, it is not possible to determine its monetary value through conventional means (e.g., comparable sales). As a result, the monetary value of non-market commodities, such as the public beach area within the City of Solana Beach, is typically determined with reference to an established economic model. There are a number of established economic models that can be used to estimate the value of a non-market commodity so it is critical to choose the model that is the best option given the particular circumstances of the assignment at hand. The model that should be selected is the one that will produce the most accurate and verifiable results, and thereby provide the best possible estimate of the commodity that is the subject of the study.

As stated in the Draft Report, and as published elsewhere (see, for example, Randall, 1994) the Travel and Cost Methodology (TCM), the economic model employed by PMC to determine the LLR, is clearly not the best choice for the task at hand (see Haab and McConnell, 2002 for a good summary of methods to estimate nonmarket valuations) because its results can be highly inaccurate and not reproducible. It appears PMC and its TCM approach to the LLR determination was chosen because it was the least expensive of the applicable alternatives, not because it was the best or most appropriate. Further, the costs may actually be transferred to private homeowners who will be assessed a fee that is incorrect.

The state of the art in nonmarket valuation is the Random Utility Model (RUM) (see, for example, Lew and Lawson, 2005). RUM is the best economic model in cases such as this where there are many substitutes available. Using an RUM probably would have been more costly, though, as it involves a household telephonic survey (e.g., see Lew and Larson 2005). A recent report by three leading experts in this field (Hanemann, Pendleton and Mohn, 2005) addresses this issue directly. They indicate that (pp. 2, 3):

> The value of a beach day could bear a variety of meanings. At one end of the continuum of meanings is the value of being able to make a trip to a specific beach rather than not being able to make a trip to any beach (i.e., the beach goer simply stays home). In reality, many substitution possibilities exist for the beach goer. The other end of the continuum of possible meanings is that the value under consideration represents the value of being able to make a trip to a specific beach rather than not being able to go to that beach while still being able to go to any other beach in the relevant choice set of beaches. Which interpretation of value is the most realistic depends on the particular circumstances at hand.

They suggest that the case of the American Trader oil spill at Huntington Beach in 1990 is an example of the former case, since it was such a large spill that it reduced possibilities for beach visitation among many different sites along the Southern California coast. In that case, site-specific demand estimation (including, perhaps, TCM) would have been appropriate. However, in the case where just one beach closes (or may be reduced in size as is alleged with BRDs) while other beaches remain available, this would be an example of the latter case mentioned in the Hanemann et al. quote. In this (latter) case, researchers should use a methodology that includes the availability of substitutes. More specifically, in this case, beach goers faced with declining area in Solana Beach could go up or down the coast (e.g., to Encinitas Beach, Del Mar Beach, Torrey Pines Beach, La Jolla Beach, etc.). Thus, the model that PMC should have used should have included the availability of substitutes.

Using a correct model that takes into consideration the availability of substitute beaches actually has a dramatic effect on the estimated value. For example, when Hanemann et al. estimate the value of a day at the beach in Los Angeles and Orange Counties with this substitution approach, they determine the value to be around $11.20 per visitor per day. That value is much lower than estimates that use a one-site demand estimation approach (such as that used by PMC). They note on p. 4,

> This value is lower than many of the values for beach visits in Southern California estimated by previous analyses (see Table 1). But those estimates typically involved single-site demand models rather than multi-site demand models and therefore did not account adequately for inter-site substitution possibilities among the beaches of Southern California which are captured in our Beach Valuation Model.

Note that among the reported results in Hanemann et al.'s Table 1 are those from a study by Philip King (2001) "The Economic Analysis of Beach Spending and the Recreational Benefits of

Beaches in the City of San Clemente" in which the estimated consumer surplus/day for Solana Beach is estimated to be $14.58 (King's method 1) and $17.35 (King's method 2). Adjusting these values for inflation using the Consumer Price Index, they would be $15.76 and $18.76 in 2010. Even though these were done using the one-site valuation approach which has already been shown to be incorrect for the issue at hand, these are well below PMC's estimate of $21.15.

Lew and Larson (2005) actually take this approach a step further and use a more sophisticated RUM for their study of San Diego beaches, including 31 San Diego County beach sites. They also employ an econometric technique for imputing incomes. When they account for the substitution among beaches in San Diego County the estimated value falls even more dramatically. (Again, this would be the relevant approach for the Solana Beach study since only one beach area—Solana Beach—would be affected, while the rest of the beaches in San Diego County—e.g., Encinitas Beach, Torrey Pines Beach, La Jolla Beach, etc.—would be unaffected by the building of BRDs in Solana Beach). One difference of note for the Lew and Larson study is that they define the beaches very narrowly. For example, among the 31 beaches in their study are Fletcher Cove Park and Tide Beach Park. In other words, they did not include the entire length of Solana Beach that was included in the PMC study. As such, their results are not, strictly speaking, comparable values. Still, their estimated values are much lower than even those of Haneman et al. (2005), as they estimate the loss of recreational value from closing Fletcher Cove Park to be about $0.10 and Tide Beach Park only $0.04. While these values are not strictly comparable for the entire length of Solana Beach, they are instructive. It is interesting to note that the highest-valued beach in Lew and Lawson's study is $1.00/day (Mission Beach). PMC's assumption that beachgoers to the Solana Beach area had no other alternatives to attending Solana Beach—a very unrealistic assumption, which was driven by using the less-expensive TCM approach—results in a greatly exaggerated value!

To their credit, PMC acknowledges the benefits of the RUM, as compared to the TCM in their report, but seem to justify the TCM approach based more on cost/expediency rather than on its overall efficacy. This is false economy, however, and PMC's "efficiency" comes at a very high cost to those who will pay the inflated LLR fees. In my estimation, the actual value using the correct methodology, is closer to $1 than $20. A way to salvage what has already been done by PMC would be to ignore their "survey" portion (substituting Lew and Larson's estimated value for a day at the beach, and adjusting for inflation from 2005 to 2010) and then use PMC's "beach counts" information to determine the value per square foot of beach. Using $1/visitor/day instead of $21.15 results in a value per square foot of $0.28, instead of $6.02. Even though this is the fairest and most accurate approach, I will assume for the purposes of argument below that PMC's survey information is used.

B. PMC Made Critical Errors in Determining the Value of a Day at the Beach

1. Value of Leisure Time is Not the Same as Labor

PMC miscalculated the LLR because it assumes that the value of time available for leisure activities is always equal to the compensation that one actually receives from his or her labor. This assumption is incorrect because most people do not have the ability to choose freely—at any given moment of the day, week, month, etc.—between work and leisure. This mistaken assumption led PMC to calculate an incorrect and materially flawed LLR fee. Further, since beaches are actually busiest on the weekends and holidays—when most salaried employees cannot work for pay—the overestimation is exacerbated.

This issue has been discussed extensively in published papers on the topic. A seminal paper in this field is by Bockstael, Strand and Hanemann (1987), who provide a theoretical framework for analysis in a labor-leisure tradeoff model. Their model assumes that individuals may have some fixed amount of income, E, and a wage income, which is the product of hourly wage (wp) and the amount of time spent in "production" (Tp) in a typical, fixed work week. This results in "kinked" budget constraints for individuals in which it is possible for "corner solutions" to occur (i.e., not be able to trade off labor for leisure at their typical hourly rate). Put differently, the fact that many individuals do not have complete discretion over their work hours, the value of a leisure hour spent in recreation is not likely to be the value of their hourly wage—it would be less. According to the authors (p. 297), "the marginal value of the individual's time in other uses is not equal to the wage rate he faces. This does not imply that the opportunity cost of time is zero for this individual. Rather his opportunity cost is not equal to an observable parameter." As a possible solution to this problem associated with TCM estimations, Bockstael, Strand and Hanemann (p. 297) recommend the following: "In addition to the usual questions about income and the time and money costs of the recreational activity, one need only ask (a) the individual's total work time and (b) whether or not he has the discretion to work during recreational time. If he does, his discretionary wage must be elicited." Casey, Vukina and Danielson (1995) offer a slightly different solution to the same problem. They suggest adding a contingent valuation-type question to the TCM survey. Their recommended question is: "If someone offered you an opportunity to work overtime instead of visiting (this recreational location), at what hourly rate would they have to pay you to accept the offer?"

How significant is this problem? In their empirical illustration of this problem, Bockstael, Strand and Hanemann find that 2/3 of the sample were at corner solutions. This implies that PMC's assumption that all individuals in the sample are at interior solutions (i.e., able to easily trade off labor for leisure at their typical hourly rate) is an invalid assumption that (a) could have been avoided with a few simple additions to their survey and (b) biases the estimated time value upward, resulting in higher LLRs. In what is perhaps the most often-cited paper in this area (Google Scholar reported 290 citations as of October 4, 2010), Cesario (1976, p. 37) states it succinctly, "It is clear from these findings that the use of the marginal wage rate for the value of travel-time values in recreation benefit estimation is *inappropriate* (emphasis in original), both from the theoretical and practical points of view."

Given that the survey has already been conducted, how should this problem be addressed now? One method is to simply adjust the reported hourly wage rates to correct for their upward bias. For example, Cesario (1976) corrects for this by multiplying the reported wage rates by one-third. According to Cesario (p. 34):

> . . . it seems farfetched to assume that the recreation tripmaker is trading off time for travel with time for work. It seems much more likely that the trade-off is between time for travel and time for leisure activities, which we loosely define to be activities conducted during non-work hours, whether they be in the form of rest, sleep, gardening, outdoor sport, etc. The value of travel time in a recreation tripmaking context thus reflects the value placed on alternative uses of leisure time by the individual, for this is the relevant opportunity cost.

He goes on to summarize the results of several other published papers that estimate the value of travel time, particularly in the context of commuting. Cesario concludes that the value of time should be set between one-fourth and one-half of the wage rate. In another, more recent analysis, McConnell and Strand (1981) find that agents in their sample value their leisure time at about 60 percent of their wage rate. Casey, Vukina and Danielson (1995) suggest that

McConnell and Strand's 0.60 is the "most widely cited approach for placing a value on time cost." (As noted above, they recommend an alternative approach by asking a contingent valuation question in the TCM survey instead of asking income and reducing it, but in the absence of a new survey this is not possible.) Based on these published reports (and taking a conservative approach), I recommend adjusting the reported hourly wages by multiplying them by a factor of 0.60. Thus, I have recalculated the value per beach visit based on the spreadsheet, "Solana Beach Survey" using income values at 0.60. The result is that the value of a beach visit falls from $21.15 to $12.69, with a corresponding value per square foot of $3.61. These results are presented in Table 1 (see column 3).

2. The Income Estimates Should Be Net of Taxes

An additional consideration in this regard is that the value of time—what matters to individuals—is their disposable income (i.e., net of taxes). Thus, traditional approaches to estimate the value of time to individuals should use the adjusted wage, net of all taxes. This is addressed in McConnell and Strand's (1981) paper, in which they model this explicitly using a proportional tax, "t." According to McConnell and Strand (p. 154), the reason why before-tax income is most frequently used is because it is "the most frequent measure available from surveys." However, in order to make a more realistic estimate, these figures should be estimated using an estimated disposable income. I have made an estimation for this using (a) the standard deduction for 2009 from the IRS (2009 Tax Rate Schedules from IRS) and (b) assuming that each survey respondent is a head of household. This option was chosen as a middle-ground option, since the assumption of married, filing jointly would be associated with a higher rate, whereas single or married and filing separately would be associated with a lower rate. These could be re-estimated rather easily if one were to make different assumptions. Based on these assumptions, the mean value for beach visits—without the adjustment for the corner solution problem mentioned above is \$19.51, corresponding to a value per square foot of \$5.55 (Table 1). Next, I have estimated the value including both the corner solution and disposable income adjustments (see column 5 of Table 1). The values become \$11.71/visit and \$3.33/square foot.

3. Another PMC Mathematical Mistake

As is now well known, PMC made numerous mathematical errors in its original report dated March 2010. These errors were supposedly fixed and the revised report was published in July 2010. However, there is at least one more mathematical error that escaped noticed. Upon closer inspection of the June 2, 2010 memo and the Excel spreadsheet "Solana Beach Survey" we received from the City, there is also another error made in terms of the income categories. The midpoint for the lowest income category, \$0 - \$20,000, should actually be \$10,000, not \$15,000. This is not a trivial error since that is actually the modal response category with 120 observations out of 474 observations. I have adjusted the "Solana Beach Survey" spreadsheet to correct for this mistake and the new value per visitor falls from \$21.15 to \$20.83 (see column 6 of Table 1). Correcting for all three issues, corner solution adjustment, disposable income adjustment and the median value corrections, the mean value becomes <u>\$11.54/visit and \$3.28/square foot</u> (column 7). I have included median values in Table 1 as well since this is actually more reliable, especially in the presence of outliers. Notice that the median values are \$8.31/visitor and \$2.37/square foot (column 7).

C. Survey Methodology Concerns

In general, there are many opportunities for error when mapping (a) the survey of beachgoers information with (b) the beach enumeration efforts. Two issues in particular are of concern: (i) are the enumerators able to distinguish between adults and children (i.e., can an enumerator tell whether someone wading in the water several yards away is an adolescent or an adult) and (ii) how representative is the sample of beachgoers in the survey of the entire beach-going population that is then enumerated in the beach count.

There are some additional concerns with respect to the timing of the "beach counts." Are these sample beach days representative of the entire year? Are they representative of the different tides? Since the enumerations were actually samples, not census counts for the entire year, they had to make several adjustments. One of these is the percentage of beach visitors missed by counting in that time block (see p. 3-5). It is unclear from the data presented in their Table 3-4 how reliable these estimates are. It would be helpful to have confidence levels determined for each of the intervals. Given the magnitude of these adjustment ratios (e.g., ranging from 2.7 to 20.4) very small changes to these values could have very large consequences.

D. PMC Failed to Fully Consider Heterogeneity of Area Values

In their estimate of the average value of a square foot of beach in Solana Beach, PMC assumed that each square foot of beach is worth the same as any other square foot of beach—in other words, they assumed a uniform valuation throughout the entire Solana Beach area. What this failed assumption implies is:

(i) a square foot of beach in Fletcher Cove is worth the same as a square foot of beach halfway between Fletcher Cove and Tide Beach Park.

(ii) a square foot of beach at the foot of the bluff is worth the same as a square foot of beach half-way between the bluff and the mean high tide mark; and is worth the same as the square foot of beach area right at the mean high tide mark.

This is an oversimplification of reality. Further, there is evidence contained in the PMC study itself, to support this conclusion. It is important to clarify these two different types of value heterogeneity. The first, articulated in point (i) above, is what I will refer to as "north-south" heterogeneity. This is the difference in valuation that occurs as one moves up and down (generally north and south) along the entire length of beach included in the survey. The second, articulated in point (ii) above, is what I will refer to as "east-west" heterogeneity.

1. North-South Heterogeneity

Since PMC has divided the entire beach survey area into 35 segments, it is possible to estimate the north-south value heterogeneity, at least by segment (though there would also be variation within each segment which we are not able to estimate given the limitations of the survey methodology). The first step of this process has already been completed by PMC (see PMC study, Appendix 1). We can extend this analysis to estimate an average value per square foot by segment. Before proceeding further, however, it bears mentioning here that it appears PMC has made yet another error. They indicate that the total number of adult visitors in their enumeration survey is 101,415, based on their Table 3-5 (adding totals for adult visitors). However, when I summed the actual numbers in their table for adults, I found a much lower total, 100,143. My totals were 63,106 for adult Beach visitors, 10,591 for Wading/Swimming and 26,446 for Surfing. While the Beach and Surfing values are close enough (off by only one) to suggest rounding errors, the difference for Wading/Swimming is 1,270 (11,861 – 10,591). It is not clear whether the total is (in)correct or the specific values for each segment are (in)correct. The values in their Table 3-9 are different but also do not add up to 101,415. For the purposes of this analysis, I have used the values that were in their Table 3-9, though using 1,305 for segment 9, instead of 1,035.2.

These results are presented in Table 2 (and assuming the value per visit is $11.54, since this is the best estimate given the appropriate adjustments to the $21.15 value I made above and assuming the TCM methodology). The last two columns of Table 2 are derived from calculations based on the PMC results. Since acreage was already included in their Appendix, I have merely divided the value for each segment by the acreage and then converted this to square feet in the last column. It is clear from the last column that north-south heterogeneity exists when comparing segments of beach that were counted.

The ratio of average segment valuation to the global mean value ($3.28/sq. ft.) is provided in Table 3. Results presented here suggest that the average value per square foot is more than twice the global mean in segments (15, 20, 16 and 21) and less than one-third the global mean in four segments (10, 24, 11, 12). Since two of the top four segments (Fletcher Cove, segments 15 and 16) include public land, it stands to reason that private individual landowners are being disproportionately and unfairly charged. A fairer assessment process would involve charging different fees based on the segment over which the property is located. For example, if the overall average rate is determined to be $3.28/sq. ft. and a property owner lives in Segment 7 (a ratio of 1.19 in Table 3), then s/he would be assessed a loss-in-recreational-use fee at a rate of $3.28*1.19 = $3.90/sq. ft. On the other hand, if the property owner lives in Segment 24 (a ratio of 0.25), then s/he would be assessed at a rate of only $0.82/sq. ft.

Why has the PMC chosen to consolidate all 35 segments into one? According to their report, they initially considered combining all 35 segments into 9 zones based on beach density (PMC report, 4-1). They note in their report that Fletcher Cove (notably, a public beach with no potential for accruing private fees from BRDs) is the highest density area and the area just to the north of Fletcher Cove has the lowest density. However, all segments are averaged together for a variety of reasons, principally because of (i) the dynamic nature of the beach and beach use and (ii) uncertainty over the next 72 years, particularly due to "beach nourishment projects being planned thereby impacting the localized beach density" (PMC report, 4-1). In other words, PMC argues that using an unfair approach today is fair in order to avoid the potential for future unfairness.

To illustrate the PMC approach further, imagine a group of three couples that go out to dinner together. One couple orders a light dinner combination (e.g., soup and salad) while the other two couples order the most expensive seven-course meals on the menu, replete with before, during and after dinner drinks. The first couple is like those property owners who live in segments listed in the bottom of Table 3 (e.g., segments 10, 24, 11 and 12). The second two couples are like those who live in the segments at the top of Table 3 (including the two highest-valued segments which include a public beach). At the end of the dinner, the second two couples suggest that—out of fairness since the first couple may, at some point in the future decide to order a seven-course meal with drinks—they should split the check into three equal parts and each couple pay their "fair share." If the assumption is that (a) meal choice is random over time and (b) this is a repeated event ("game") over time, then this may be a fair solution over time. However, if the meal choice is not random, i.e., the first couple tends to order "light" and the second two couples tend to order the most expensive items on the menu, then the "equal checks" arrangement would favor the second two couples. Extending this to the Solana Beach situation, if beach use is generally stable over time (e.g., that beachgoers tend to congregate at Fletcher Cove—due to ease of access, parking and configuration of beach area—albeit with some variation), then this proposed "equal checks" arrangement is not fair. Second, if this is not a repeated event, but a one-time dinner outing, then the arrangement also favors the second two couples.

In the Solana Beach situation, it is clearly possible that some property owners may build a BRD in 2011 (i.e., with the current configuration of beach use) and others will build in 2021 (i.e., with a potentially different configuration of beach use). In this case, those who live in "light" segments and build in 2011 would be unfairly punished.

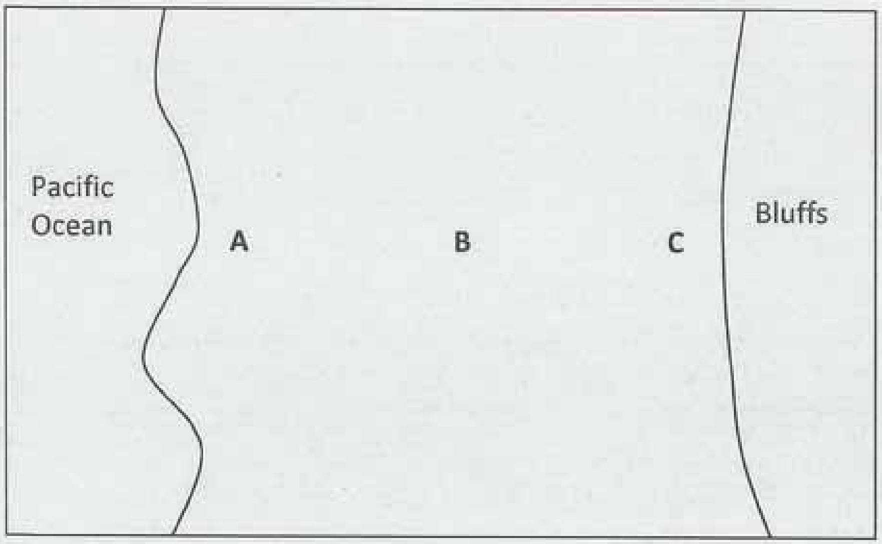
I would argue that since the PMC study has the ability to apply a fair standard today, they should apply it today and if things change in the future, they should adjust the fee assessments accordingly. In other words, the fee could be set up with parameters that could be adjusted in the future to take into account changes in total area. Based on their methodology, this would not be very difficult. There is already indication in the Staff Report (April 14, 2010, p. 6) and draft Land Use Plan that another key factor in this estimation, erosion rates, "shall be reviewed . . . at least every ten (10) years, and more often if warranted by physical circumstances." On p. 4-20, PMC state that "the Draft LCP Land Use Plan provides for updating the variables and/or assumptions used in the fee calculation. . . . It is anticipated that the Land Lease/Recreation Fee will be updated before the end of 2081."

Taking this a step further, even if the PMC did not want to create individual assessments of the Land Lease/Recreation (LLR) fee by individual segments, the question remains why they would lump together the private and public beachfront into one sum? The current methodology takes the sum total of the entire length of Solana Beach beaches, based on the value of total attendance. As such, the private property owners are being assessed a LLR fee based, in large part, on valuations from public land (i.e., Fletcher Cove). (Recall that even though the Fletcher Cove segments—15 and 16—were only two out of 35, they were among the top four highest valuations per square foot. Lumping everyone together is clearly not fair for the private landowners. Rather, it benefits the City of Solana Beach, who paid for the PMC study. At a minimum, I recommend removing segments 15 and 16 from the population counts and the valuation, and re-estimating the LLR.

2. *East-West Heterogeneity*

To understand the notion of east-west heterogeneity, it is perhaps easiest to consider what would happen if the beach were completely empty. A lone visitor to the beach—say he wishes to walk on the beach or sunbathe on a towel and read a book—would have his choice of where to locate (see Figure 1 below). To make things simple, let's say he could walk/lie down in one of three areas—A. Right next to the water's edge, B. Half-way between the toe of the bluff and the water's edge or C. Right next to the toe of the bluff. Since we assume that the visitor does not wish to get wet while walking or lying down, he would prefer to locate either at "B" or "C." If the beach were actually very crowded, then he may actually locate at "A" but as a last resort. In other words, he has a strong preference for "B" or "C." However, if he knows that there are episodic bluff collapses in Southern California that have killed beachgoers, then he may have a preference for "B" or "A." Again, if the beach were crowded (or he were unaware of the danger), then he may choose to locate at "C," but only as a last resort. Put differently, the value of the beach is not the same from shoreline to bluff. It should be noted that swimmers, waders and surfers would not have any need to spend time at "C" so its value is even lower when considering other users.

Figure 1.1 Diagram for East-West Location Choice on Beach



I have already expressed the need to measure this in a memo to Leslea Meyerhoff, Tina Christiansen and Dino Serafini dated November 17, 2008, in which I stated, " . . . one suggestion I raised during the meeting was to create smaller spatial designation, for example, to subdivide each of the 36 zones to include subsections ('horizontal areas') of beach. . . ." The issue is that it is important to create, as it were, "east-west" (perhaps a better descriptor than "horizontal") sub-segments in order to estimate this heterogeneity of value. Apparently, this was either deemed unnecessary or cost-prohibitive. However, this is potentially a very important omission, since the value of the beach for which bluff retention device (BRD) owners are being charged, namely at the toe of the bluff, has the lowest value. Instead, residents are being charged the same amount for the first foot of beach near the bluff as the last one away from the bluff. While the value of the last foot is adjusted for inflation and discounted back to the present value the reference value (e.g., \$3.28 per square foot) is the same. Clearly, this creates an upward bias on the LLR fee that BRD owners are expected to pay. To support this point further, the fact that there is any positive benefit derived from providing BRDs is proof enough that the value of beach at the toe of the bluff is worth less than area which is a safe distance away. In the example provided in the PMC study (pp. 5-11, 12) they conclude "the total benefit due to avoidance of injury or death over the 72 year period (including the initial failure cycle) is calculated at $97,900. . ."

In sum, there is an important remaining piece of the study that should be conducted if BRD owners are to be charged fairly. Alternatively, reasonable allowances (i.e., estimates) should be made to compensate for this heterogeneity of value. The fact that the PMC study does find a positive potential public benefit from BRDs in terms of improved safety to beachgoers should be evidence enough of the potential heterogeneity of east-west beach valuation.

There is some additional information in the study that should be considered that is related to the issue of heterogeneity of value, namely, the reported beach-going activities. There are three basic areas or activities that were included in the enumeration part of the survey, as presented in PMC survey Table 3-5: "beach," "wading or swimming," and "surfing." If one were to consider the impact of losing sand on the beach directly in front of a bluff, clearly these three groups would be impacted differently. It is logical to assume that those who were actually "on the beach" would be impacted the most, while waders and swimmers would be impacted somewhat less and surfers would be impacted the least. According to a report by David Skelly, the primary surf breaks in Solana Beach are reef breaks, which ware relatively unaffected by sand levels. Thus, to the extent that waves for surfing in Solana Beach are created by reefs, as opposed to rising sand, the effect of eroding beaches on surfing may actually be close to zero. The LLR fee should be recalculated using a differential weighting that considers the actual impact on activity (i.e., lower weighting for less-impacted activities).

E. PMC failed to Adequately Adjust for Offsets

While the estimates of value as stated above are now much more in line with what the actual LLR fee should be, there is an additional, important consideration which reduces the fees even further. According to the PMC report, the Draft LCP Land Use Plan for Solana Beach indicates that offsets may be applied as long as the net benefit to the public (netting out the private benefit to property owners) is positive. This is to ensure that the private individuals are compensated for benefits they provide to the public that exceed their private benefit from building BRDs. There are several points that need to be addressed here. First, the private benefit should be net of the cost of the BRD. To demonstrate why, consider a case where ***A*** purchases a new car which he values at $20,000 (derived from the benefits of commuting to work, transporting children to school, transportation for shopping, vacations, etc.) . . . but it cost ***A*** $20,000 to purchase the car. ***A***'s net benefit is actually $0. Similarly, in the case of BRD installation, say BRD owner, ***B***'s home equity rises by $100,000 after installing a BRD, but the BRD cost ***B*** $100,000 to install. Just as with ***A***, ***B***'s net private benefit is $0. This is not to suggest that all net private benefits from BRDs will be $0, but they should be considered net of the costs. I believe this may not be clearly articulated in the PMC report.

One clear public benefit from BRDs is that, by stabilizing the lower part of the bluff, they can reduce the risk of injury or death to beachgoers due to a reduction in the probability of a bluff collapse. However, given the stated "episodic nature" of the bluff collapses in the report, it is important to use as broad of a framework as possible. To illustrate why, let's assume the collapses occurred in a predictable manner—in the first month of every decade (for a rate of 0.10/year). Using a timeframe of January 1, 1991 – December 31, 1999 would result in zero bluff collapses over a nine-year period (a rate of 0.0/year)—a rate that is way too low. Using a timeframe of January 1, 1990 – December 31, 2000 would include two bluff collapses over an 11-year period (a rate of 0.182/year)—a number that is too high. Doubling this second timeframe to a 22-year period, i.e., from January 1, 1990 – December 31, 2011, would include three bluff collapses over a 22-year period (a rate of 0.136/year)—a rate that is closer to the true rate of 0.10. Extending the same period another 10 years to December 31, 2021 would result in a rate of 4/32, or 0.125. Clearly, the estimated rate is approaching the actual rate asymptotically as the timeframe increases.

The timeframe chosen in the PMC report is from 1990 to 2009 and includes Encinitas and Solana Beach coastlines. On p. 5-4, the PMC report indicates that from "1990 (to) 2009 there were approximately 126 documented bluff failures along the Encinitas and Solana Beach coastlines, about 6.6 failures per year. One of these failures resulted in a fatality for a mortality rate per documented failure of 1/126 = 0.008." However, there are actually five reported fatalities if two minor adjustments to the framework are considered: (a) the timeframe is extended back to 1995 and (b) the geographic range is extended to include Carlsbad to the Scripps Institute of Oceanography. While there would likely be additional bluff failures as well, it is not clear whether this would be a five-fold increase. Even if the mortality rate doubles to 0.016, the expected loss would also double. It is very important—in terms of improving accuracy of the estimated rate—to recalculate the mortality rates based on the recommended extensions of time and distance.

F. Present Discounted Value

The Land Lease / Recreation (LLR) fee is based on the theory that the installation of a bluff retention device (BRD) on a public beach causes a loss of recreational use over a period of time. Since (at least partial) payment is required in the first period, there is a need to consider present value of the stream of payments over the entire timeframe. Simply stated, present value is the amount this future stream of payments is worth today. This arises because of the time value of money, namely, that individuals are not indifferent between $1 received today and the same $1 payment to be received, say, 71 years hence. Individuals value the $1 payment to be received in the future less than they do the same $1 payment today. This is due to impatience, risk, inflation, opportunity cost, etc. Thus, in order to adjust the value of $1 to be received in the future back to the present value, we would need to discount that value. This will be discussed in more detail below.

1. Inflator

It is reasonable to assume that the value of a square foot of beach (e,g, that theoretically lost due to erection of a BRD) would increase over time and then be discounted back to the present value. Typical calculations of this kind generally consider both an inflator and a discount factor. The PMC study does not discuss inflators—only a net discount rate. To measure the inflator for the spreadsheet, it is reasonable to assume that the average increase in lease values will approximate the average increase in inflation over long periods of time.

There are several ways to estimate future inflation. The best method is to rely on what financial investors, collectively through their investment decisions, indicate is the expected inflation by calculating the yield spread between (traditional) 30-year Treasury bonds and 30-year Treasury Inflation Protected Securities (TIPS). Since the latter are inflation protected, the difference should reflect what bond investors, collectively, expect the average inflation rate to be over the next 30 years. Further, since the 30-year Treasury Bond is the longest-term available, it is the best instrument to estimate the value for the next 72 years. In Table 4, I have included the values for the past seven months. The average difference is 2.37%, suggesting that the expected inflation has been 2.37% this year. This spread should be examined periodically (e.g., every five years) to update these values.

G. Discount Rate

The PMC study uses a 2% discount rate for their (simplified) example instead of inflating today's value of the beach and then discounting the cash flow stream to the present. Since their example is for illustrative purposes only, it is important to determine what discount rate should actually be applied since this will greatly affect the LLR fees that are actually paid. The discount rate for individual legal entities (e.g., corporations, cities, etc.) includes the riskless rate plus a risk factor. One standard way to determine this with a corporation is to calculate the weighted average cost of capital (WACC). However, this case is somewhat unique since there is not a specific corporate entity, per se, involved in the discounting.

One approach is to assume that the appropriate discount rate is what the "cost of capital" is for the State of California. The bond ratings for the State as of June, 2010 are: A- (Fitch); A1 (Moody's) and A- (Standard and Poor's), according to Bill Lockyer, California State Treasurer (http://www.treasurer.ca.gov/bonds/index.asp , accessed on June 12, 2010).

According to FMS Bonds, Inc., the yield rate for tax-free municipal bonds as of 6/12/10 for "A" rated bonds with a 30-year term (national) is **5.50%** (http://www.fmsbonds.com/Market_Yields/index.asp?source=google&kw=bond%20rates&9gtype=search&9gkw=bond%20rates&9gad=3962304893.1&9gag=359470339&gclid=COzw1ImrzqECFSP6agodBH9GHQ Web accessed on 6/12/10). However, it is important to note that this is a tax-free bond rate to investors, so investors (lenders) are willing to accept a lower interest rate for comparable risk. In other words, this should be considered a lower bound on the actual discount rate. Investors (lenders) would be indifferent between a tax-free rate of 5.50% and a taxable rate of **7.86%** for a 30% marginal tax rate; **6.86%** for a marginal tax rate of 20%.

According to Yahoo! Finance Bond Center, California 30-year bond yields ranged from 0.000% to 8.202%. For example, California Infrastructure and Economic Recovery Bonds, which were rated "AA" and due May 15, 2049, had a yield of **6.163%** as of May 12, 2010.

According to the Federal Reserve H.15 data for "State and local bonds" with a 20-year maturity, the yield as of 6/10/2010 was **4.37%**, though, again, these will include tax-free municipal bonds and the classic yield curves suggest that a longer-term interest rate would be perhaps 50 to 200 basis points (100 basis points = 1%) higher. The value had fallen to **3.84%** by September 30.

In sum, there is likely to be considerable debate about what would be an appropriate discount rate for a 72-year time horizon. Based on information presented here, I would argue a reasonable range of discount rate values would fall **between 6.0 and 8.0 percent**.

2. Application of the Land Lease/Recreation Fee

The LUP for Solana Beach is actually quite clear about how the LLR fee is supposed to be calculated. First, the City is to determine the appropriate fee for the BRD. To calculate this, the City is to use the LLR in effect at the time (for example, $3.28/square feet), and multiply this by the area (alleged to be) affected by the BRD over time. The second step is to determine how the fee is to be paid—either as a lump sum or one-third down, with amortized payments over the remaining years.

There are some apparent inconsistencies in the application of the Land Lease/Recreation (LLR) Fee in the PMC study (section 4) and the examples provided therein. First, there is no inflator. As noted above, the standard approach to Table 4-3, for example, would be to include an inflator and a discount rate in the table. Based on information provided above, an appropriate inflator is approximately 2.5% (0.025). Then the appropriate discount rate should be used. Based on information provided above, I recommend a value of 7.0% (.070). Also, the value per square foot should be adjusted downward based on the recommendations found herein. I am happy to assist the City and PMC by providing a set of spreadsheets that would properly consider these factors and that would outline the payments under the 1/3 down option.

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Appendix

Table 1. Estimated Value for a Beach Visit and Value per Square Foot under Different Assumptions

	Column 1	Column 2	Column 3	Column 4	Column 5	Column 6	Column 7
	Original Estimation in PMC Report	Based on Revised July 2010 Corrections	Corner Solution Correction: Column 2 adjusted for 0.6 times Wage	Disposable Income Adjustment	Corner Solution and Disposable Income	Median Income Adjustment for $15,000 values	Corner Solution, Disp Inc and Median Inc
Mean Value per Visit	$19.83	$21.15	$12.69	$19.51	$11.71	$20.83	$11.54
Variance		$440.90	$158.73	$385.76	$138.88	$443.69	$139.56
Median Value per Visit		$14.65	$8.79	$14.01	$8.40	$14.47	$8.31
Mean Value per Square Foot	$4.80	$6.02	$3.61	$5.55	$3.33	$5.93	$3.28
Median Value per Square Foot		$4.17	$2.50	$3.99	$2.39	$4.12	$2.37

Table 2 Value Per Square Foot, by Segment

CIC Segments	Photo Points	Acres	Adults**	Ave Value/ Adult Visitor Day	Total Value based on Ave Value/ Adult Visitor Day	Value/ Acre	Value/ Sq. Ft.
4	4-5	0.31	5709	$11.54	$65,882	$212,522	$4.88
5	5-6 (Tide Park)	0.38	4797	$11.54	$55,357	$145,677	$3.34
6	6-7	0.07	1436	$11.54	$16,571	$236,735	$5.43
7	7-8	0.06	882	$11.54	$10,178	$169,638	$3.89
8	8-9	0.04	800	$11.54	$9,232	$230,800	$5.30
9	9-10	0.18	963	$11.54	$11,113	$61,739	$1.42
10	10-11	0.15	539	$11.54	$6,220	$41,467	$0.95
11	11-12	0.45	734	$11.54	$8,470	$18,823	$0.43
12	12-13	0.21	228	$11.54	$2,631	$12,529	$0.29
13	13-14	0.55	3654	$11.54	$42,167	$76,668	$1.76
15	15-16 (Fletcher Cove North)	0.4	12856	$11.54	$148,358	$370,896	$8.51
16	16-17 (Fletcher Cove South)	0.43	11356	$11.54	$131,048	$304,763	$7.00
17	17-18	0.15	1959	$11.54	$22,607	$150,712	$3.46
18	18-19	0.11	2186	$11.54	$25,226	$229,331	$5.26
19	19-20	0.1	1158	$11.54	$13,363	$133,633	$3.07
20	20-21	0.01	278	$11.54	$3,208	$320,812	$7.36
21	21-22	0.03	783	$11.54	$9,036	$301,194	$6.91
22	22-23	0.09	946	$11.54	$10,917	$121,298	$2.78
23	23-24	0.07	1207	$11.54	$13,929	$198,983	$4.57
24	24-25	0.32	979	$11.54	$11,298	$35,305	$0.81
25	25-26	0.17	2104	$11.54	$24,280	$142,824	$3.28
26	26-27	0.55	3214	$11.54	$37,090	$67,436	$1.55
27	27-28	0.2	3067	$11.54	$35,393	$176,966	$4.06
28	28-29	0.2	3001	$11.54	$34,632	$173,158	$3.98
29	29-30	0.14	2790	$11.54	$32,197	$229,976	$5.28
30	30-31	0.24	2969	$11.54	$34,262	$142,759	$3.28
31	31-32	0.22	3247	$11.54	$37,470	$170,320	$3.91
32	32-33	0.24	3475	$11.54	$40,102	$167,090	$3.84
33	33-34	0.22	2431	$11.54	$28,054	$127,517	$2.93
34	34-35	0.12	1974	$11.54	$22,780	$189,833	$4.36
35	35-36	0.24	1386	$11.54	$15,994	$66,644	$1.53
36	36-37	0.58	2774	$11.54	$32,012	$55,193	$1.27
37	37-38	0.25	4536	$11.54	$52,345	$209,382	$4.81
38	38-39	0.57	9691	$11.54	$111,834	$196,200	$4.50
39	39-40	0.13	1304	$11.54	$15,048	$115,755	$2.66
Total		**8.18**	**101,413**		**$1,170,306**		

Note: Based on PMC Report, Table 3-5 and 3-9; ** Including estimated no. of adults on beach, wading and surfing

Table 3 Ranking of Segments by Ratio of Segment Value to Global Mean Value per Square Foot by Segment

CIC Segments*	Description	Value/Sq. Ft.	Ratio of Segment Value to Global Mean Value of $3.28
15	15-16 (Fletcher Cove North)	$8.51	2.60
20	20-21	$7.36	2.25
16	16-17 (Fletcher Cove South)	$7.00	2.13
21	21-22	$6.91	2.11
6	6-7	$5.43	1.66
8	8-9	$5.30	1.62
29	29-30	$5.28	1.61
18	18-19	$5.26	1.61
4	4-5	$4.88	1.49
37	37-38	$4.81	1.47
23	23-24	$4.57	1.39
38	38-39	$4.50	1.37
34	34-35	$4.36	1.33
27	27-28	$4.06	1.24
28	28-29	$3.98	1.21
31	31-32	$3.91	1.19
7	7-8	$3.89	1.19
32	32-33	$3.84	1.17
17	17-18	$3.46	1.05
5	5-6 (Tide Park)	$3.34	1.02
25	25-26	$3.28	1.00
30	30-31	$3.28	1.00
19	19-20	$3.07	0.94
33	33-34	$2.93	0.89
22	22-23	$2.78	0.85
39	39-40	$2.66	0.81
13	13-14	$1.76	0.54
26	26-27	$1.55	0.47
35	35-36	$1.53	0.47
9	9-10	$1.42	0.43
36	36-37	$1.27	0.39
10	10-11	$0.95	0.29
24	24-25	$0.81	0.25
11	11-12	$0.43	0.13
12	12-13	$0.29	0.09

Table 4. Expected Inflation based on Spread between 30-Year Treasury Bonds and Treasury Inflation Protected Securities (TIPS)

Month in 2010	30-Year Bond Yield	30-Year Inflation-Indexed Security Yield	Difference
February	4.62	2.16	2.46
March	4.64	2.15	2.49
April	4.69	2.05	2.64
May	4.29	1.83	2.46
June	4.13	1.77	2.36
July	3.99	1.87	2.12
August	3.80	1.76	2.04
Mean	**4.31**	**1.94**	**2.37**

Source:
http://www.federalreserve.gov/releases/h15/update/

September 27, 2010

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2010: Dual Excellence Award (Annual award presented to one or two SBA faculty members at USD: for excellence in research and teaching) ($10,000)

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2009: Outstanding Preceptor Award (September) for "Superior performance in teaching and advising" ($1,000)

2009: Mortar Board, Faculty Appreciation Dinner [also in 2007]

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2007: Professor of the Year Award (Gamma Phi Beta sorority) (December).

2007: Outstanding Undergraduate Business Educator Award (SBA), (May) ($5,000).

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2004: Dyson Faculty Award for Excellence in Research for 2003, College of Business, University of West Florida ($1,500).

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RESEARCH

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Conroy, Stephen J. (2009). Lecture Handouts Packet for Managerial Economics (ECON 373), 2nd Edition. University of San Diego Book Store mimeo, 244 pages.

Conroy, Stephen J. (2009). *Lecture Handouts Packet for Principles of Microeconomics, 6th Edition*. University of San Diego Book Store mimeo, 240 pages.

Conroy, Stephen J. (2008). *Lecture Handouts Packet for Principles of Macroeconomics, 15th Edition*. University of San Diego Book Store mimeo, 234 pages.

Published Quotes/References to Published Work:

Pena, Joseph, "Will health care reform impact the economy? Depends who you ask" San Diego News Network, March 31, 2010, available at: http://www.sdnn.com/sandiego/2010-03-31/business-real-estate/how-will-health-care-reform-impact-the-economy-depends-who-you-ask#ixzz0jtICNPpF
http://www.sdnn.com/sandiego/2010-03-31/business-real-estate/how-will-health-care-reform-impact-the-economy-depends-who-you-ask

Zimmermann, Carol, "Downturn brings call to extend unemployment benefits," *The Tidings* (Weekly Newspaper of the Los Angeles Archdiocese), November 21, 2008.

Lazarus, David, "For Insensitivity, Wachovia Refuses To Be Outdone," *Los Angeles Times*, Business Section, October 9, 2008.

Calbrath, Dean, "As Stimulus Checks Arrive, So Do Higher Food, Gas Costs," *San Diego Union-Tribune*, May 25, 2008.

Calbreath, Dean, "Soaring Gas, Food Prices May Blunt Goal of Rebate," *San Diego Union-Tribune*, April 30, 2008, A1.

Barker, M.B. and Maggie Klos, "L.I.F.E. Week Opens Capital Punishment Forum," *The Vista*, May 10, 2007.

Roca, Adriana, "Financiamiento de empresas a partidos politicos no es etico," *Peru21*, January 22, 2006.

Lerner, Gabriel, "Treinta mil desamparados latinos viven en las calles de Los Angeles," *La Opinion*, September 4, 2004.

Crane, Charlotte, "The Rich are Still Getting Richer, While the Rest of Us . . .," *Pensacola News Journal*, April 4, 2004, Money Section, 1B.

Blair, Kimberly, "Bay Area Consumers Upbeat," *Pensacola News Journal*, March 3, 2004, Money Section, 10C.

La Opinion, "Desamparados Latinos," January 4, 2004.

Caputo, Anton, "Consumers Have Faith in Economy," *Pensacola News Journal*, December 31, 2003, Money Section, 8C.

Macias, Jorge Luis, "Estudian Formas de Ayudar a los Desamparados Latinos: Las Personas Sin Hogar de Este Grupo Etnico Reciben Menos Asistencia," *La Opinion*, December 23, 2003, 3A.

Crane, Charlotte, "Attitudes on Ethics Change with the Times," *Pensacola News Journal*, July 6, 2003, Money Section, 1C.

Crann Good, Alice, "Dow Jones: One Big Crybaby," *The Independent Florida Sun*, July 26, 2002, p. 19.

Cooper, Louis, "Santa Rosa's Homeless Population on Rise," *Pensacola News Journal*, December 10, 2001, pp. 1C and 4C.

Research Grants and Contracts:

2008: Burnham-Moores Center for Real Estate Small Faculty Grant, for "Hedonic Pricing Estimation for Housing in San Diego County."

2001-2002: University of West Florida 2001/2002 Faculty Small Grant Award, for "Testing for Significant Differences in Learning with Interactive and Complete Power Point Lecture Notes," February, 2002 ($2,000). Result: Academic Proceedings Publication.

2000-2001: University of West Florida 2000/2001 Faculty Small Grant Award, for "A Comparison of the Perception of Business Ethics," March, 2001 ($2,000). Result: 2 Journal Publications.

2000: University of West Florida University Summer Research Award, for "Intergenerational Exchanges: The Role of Altruism in Giving," April, 2000 ($6,000).

2000: "Analysis of Economic Activity in Downtown Pensacola" Research Award with Rick Harper of the Haas Center for Business Research and Economic Development, from the Pensacola Downtown Improvement Board, January - June 2000 ($2500). Result: Published Monograph.

1999-2000: University of West Florida 1999/2000 Faculty Small Grant Award for "Intergenerational Exchanges: The Role of Altruism in Giving," March, 2000 ($2,000).

1998-1999: National Institute on Aging Postdoctoral Research Training Grant (No. T32-AG00037), July 1998 - August 1999 (Approximately $17,000)

1995-1998: National Institute on Aging Research Traineeship (No. T32- AG00037) August 1995 - June 1998 (Approximately $24,000 in stipends, plus tuition remission)

Professional Television and Radio Appearances:

KPBS (PBS affiliate for San Diego), Interview with Tom Fudge for "Economists Give Health Care Reform Mixed Reviews," available at http://www.kpbs.org/news/2010/mar/30/economists-give-health-care-reform-mixed-reviews/ , March 30, 2010.

KUSI Television, "Economic experts discuss health care reform in San Diego," (news clip of comments made during presentation) http://www.kusi.com/home/89568352.html

San Diego Union-Tribune "Op-Ed Talk," by Bernie Jones, Editor of the San Diego Union-Tribune Editorial Pages, on SignonRadio.com (http://www.signonradio.com/programs/op-ed-talk/), October 23, 2008. (Discussion about my Op-Ed piece in the San Diego U-T.)

WEAR (ABC affiliate for Pensacola), Interview about rising gasoline prices, May 18, 2004.

WSRE (PBS affiliate for Pensacola) "AWARE: Financial Empowerment Program," (Appeared as a panelist), April 27, 2001.

WEAR (ABC affiliate for Pensacola), Interview about Downtown Improvement Board Study, September, 2000.

Academic Presentations and Panels:

"Analysis of Non-profit and For-profit Microfinance Institutions" (with Kenneth Downey), 37th Annual Meeting of the Academy of Economics and Finance, Houston, TX, February 11, 2010.

"Beyond Grey Pinstripes: Can Business Really Incorporate Service Learning?" (with Chris Nayve), 10th Annual Continuums of Service Conference, Seattle, WA, April 18, 2009.

"Using Oaxaca Estimation to Estimate the Coastal Premium for Residential Housing in San Diego County," (with Jonathan Sandy), 36th Annual Meeting of the Academy of Economics and Finance, Pensacola, FL, February 2009.

"Using Immersion Experiences and Community Service Learning to Promote the Principles of Catholic Social Teaching in an Economics Course," Business Education at Catholic Universities: Exploring the Role of Mission-Driven Business Schools, Notre Dame, IN, June 12, 2008.

"The Role of Norms in Inter-Sibling Negotiations for Care of Aging Parents over Time," (with Merril Silverstein and Daphna Gans), 60th Annual Scientific Meeting of the Gerontological Society of America, San Francisco, CA, November 19, 2007

"An Estimation of the Coastal Premium for Residential Housing Prices in San Diego County," (with Jennifer Milosch), 82nd Annual Conference of the Western Economic Association International, Seattle, WA, July 3, 2007.

"Ethical Cycles and Trends: Implications for Research Methodologies," (with Tisha Emerson), 34th Annual Meeting of the Academy of Economics and Finance, Jacksonville, FL, February 2007.

"Intergenerational Transfers Across Families: The Role of Moral Capital," (with Merril Silverstein), 33rd Annual Meeting of the Academy of Economics and Finance, Houston, TX, February, 2006.

"Commitment to Caregiving: Intergenerational Sources of Filial Obligation to Older Parents," (with Merril Silverstein and Daphna Gans), 58th Annual Scientific Meeting of the Gerontological Society of America, Orlando, FL, November 2005.

"The Union Impact on Earnings: The Recent Evidence," (with Javed Ashraf), 31st Annual Meeting of the Academy of Economics and Finance, Biloxi, MS, February, 2004.

"An Economic Analysis of Urban Infill Development Strategies: The Case of Charleston, South Carolina," (with Joslynn Jones), 31st Annual Meeting of the Academy of Economics and Finance, Biloxi, MS, February, 2004.

"The Socioeconomic Conditions of the US-Mexican Border Region: A Study of Juarez and El Paso," (with Benjamin Schultz), 30th Annual Meeting of the Academy of Economics and Finance, Pensacola, FL, February 2003.

"Testing for Significant Differences in Learning with Complete and Incomplete PowerPoint Lecture Notes," 29th Annual Meeting of the Academy of Economics and Finance, Pensacola, FL, February, 2002.

"Analyzing School Quality in Florida: The Role of Parental Involvement in Student Achievement," 71st Annual Conference for the Southern Economic Association, Tampa, FL, November 17 – 19, 2001.

"Consumption and Income Choices of Homeless Persons in Los Angeles," 28th Annual Meeting of the Academy of Economics and Finance, Biloxi, MS, February, 2001.

"Economic Development and Homelessness: Is Homelessness A Developing Country Phenomenon?" 27th Annual Meeting of the Academy of Economics and Finance, Nashville, TN, February 9 - 12, 2000.

"Reciprocity in Parent-Child Relations Over the Life Course," 61st Annual National Conference on Family Relations, Irvine, CA, November 13, 1999.

Professional Presentations and Panels:

"Health Care & Public Finance" (Panelist), Panel sponsored by Economics Council for USD students regarding the Health Care legislation, budget deficits and federal government stimulus, Manchester Auditorium, March 30, 2010. (Local television and radio coverage.)

"Economic Stimulus Package—Professor Panel Discussion" (Panelist), Panel sponsored by Economics Council, for USD students regarding the economic stimulus package and current U.S. financial crisis, Manchester Auditorium, March 24, 2009.

"Incorporating CST into the Curriculum: Two Examples from Economics," presented to USD faculty, November 22, 2008.

"Economics of Our Next President" (Panelist), Panel for local business community of San Diego sponsored by TGG Capital, presented in Kroc Institute of Peace and Justice Theater, October 7, 2008.

"Financial Crisis" Panel (Moderator), Panel presented to USD School of Business students, faculty, staff and news media (approximately 150 in attendance), October 1, 2008

"Community Service Learning in the School of Business: Two Examples from Economics," for Community Service Learning Workshop for USD Faculty, May 13, 2008.

"Costs and Benefits of Immigration," part of a panel on immigration for LIFE Week at USD, April 8, 2008.

"Cost Benefit Analysis Model of Cheating Behavior," presentation made to USD students as part of an Academic Dishonesty Panel, April 2, 2008.

"Catholic Social Teaching: A Pedagogical Example for Economics 101 with a Comment about Graduate Education," presentation made to the USD New Faculty Series, October 18, 2007.

"CST: A Pedagogical Example for ECON 101," presentation made to the USD New Faculty Series, Catholic Identity, Kroc Institute for Peace and Justice, October 17, 2006.

"Promoting Trade, Investment, and Development in the Border Region," (panel moderator), sponsored by the USD Trans Border Institute, Kroc Institute for Peace and Justice, October 6, 2006.

"Off-Campus Survey Results: Presentation for USD Town Hall Meeting," sponsored by the Catholic Social Thought Committee, Soloman Hall, September 21, 2006.

"Catholic Social Teaching: A Pedagogical Example for Economics 101," part of the Luncheon Colloquium: Catholic Social Thought—A Sequel, sponsored by the USD Faculty and Curriculum Development Program 2006, March 23, 2006.

"The Role of Catholic Social Teaching in a Business Education," Presentation to the Board of Trustees, University of San Diego, February 24, 2006.

"Cambiando Actitudes Eticas: Los Escandalos Enron e ImClone," Presentation (in Spanish) at la Universidad San Ignacio de Loyola; Lima, Peru, January 18, 2006.

"Catholic Social Teaching," Presentation to faculty and staff at USD, March, 2005.

"Conroy's Three Rules for Urban Economic Development," Economic Development Panel: West Florida Leadership Academy, Pensacola, Florida, March 5, 2004

"Lessons from Enron: What do the Latest Research Findings Tell Us?" University of West Florida's Leisure Learning Series for Older Adults, September 30, 2003.

"Research Strategies: How to Do Research . . . Conroy's List of 10," University of West Florida's Center for University Teaching and Learning's New Faculty Series, *The Compleat Professor*, March 22, 2002.

"Reciprocity and Parent-Child Relations Over the Life Course: Why Do Adult Children Support Their Parents," University of West Florida's Leisure Learning Series for Older Adults, February 8, 2002.

"Parking Issues Facing Downtown," Downtown Improvement Board of Pensacola Panel Presentation, 2001.

"Taking Initiative," University of West Florida's Center for University Teaching and Learning's New Faculty Orientation Series, February 2, 2001.

"Analysis of Economic Activity in Downtown Pensacola: Pensacola Downtown Improvement Board Project, Presentation of Findings," Pensacola, Florida, September, 2000.

EXPERT WITNESS AND CONSULTING

Baker v. Major League Baseball
Provided deposition testimony on behalf of the plaintiff. Prepared expert report estimating the loss of earnings. [April, 2010 – Present] [Deposed on August 4, 2010].

Beach and Bluff Conservancy (BBC)
Prepared expert reports to be presented to consultants for the City of Solana Beach. Made presentations and provided expert testimony to City of Solana Beach workshops. [April, 2010 – Present; August – November 2008]

Joseph Steinberg v. California Coastal Commission
Prepared an expert report on behalf of Plaintiff. Evaluation of estimated loss in recreational value from the proposed construction of a coastal bluff seawall. [October 2006]

Surfsong Condominium Association, Inc. v. California Coastal Commission
Prepared an expert report on behalf of Plaintiff. Evaluation of estimated loss in recreational value from the proposed construction of a coastal bluff seawall. [July 2006]

Las Brisas Condominium Association, Inc. v. California Coastal Commission
Superior Court of the State of California for the County of San Diego,(Case No. GIC 858210, 2006)
Prepared an expert report on behalf of Plaintiff. Evaluation of estimated loss in recreational value from the proposed construction of a coastal bluff seawall. [February 2006]

Telefonica Moviles, S.A.C.
Supervised and assisted graduate MBA students with analysis on a project based in Lima, Peru, to assess the costs and benefits of a proposed capital expenditure project within the company. (University of San Diego.) [January 2006]

LarcoMar, S.A
Supervised graduate MBA students on a project to create a strategic plan for the management team of a large "destination" mall overlooking the Pacific Ocean in Lima, Peru. The student team identified key issues and provided an implementation strategy for the client. (University of San Diego.) [January 2006]

Nina Pollack v. Experian, et. al.
Superior Court of the State of California for the County of Los Angeles (Case No. BC 308919, 2005). Used demographic life tables to estimate economic loss to Pollack due to alleged wrongful termination. (Analysis Group, Inc.) [March 2005]

Howard Group, Inc., Destin Florida
Conducted an economic impact analysis to estimate the impact of Silver Sands Factory Outlets on Northwest Florida economy. [December 2001].

Downtown Improvement Board, Pensacola, FL

Follow up of September 2000 report with short paper summarizing the issue of parking in downtown area. (Haas Center for Business Research and Economic Development.) [Aril 2001]

Downtown Improvement Board, Pensacola, FL
Used survey of downtown business establishments to (a) identify baseline economic data and (2) conduct a critical needs assessment of the area. (Haas Center for Business Research and Economic Development.) [September 2000].

UNIVERSITY COURSES TAUGHT

At the University of San Diego:
ECON 101 Principles of Microeconomics (Preceptorial in Fall) (F 2005 - F 2009)
ECON 102 Principles of Macroeconomics (F 2004, S 2005, F 2005, S 2006, F2006, S 2008, S 2010)
ECON 335 Economic Development of Latin America (F 2009)
ECON 373 Managerial Economics (S 2006, S 2007, S 2008, S 2009, S 2010)
GSBA 509 Managerial Economics and Decision Making (MBA Program) (S 2005, Su 2005, Su 2006, F 2007, F 2008, S 2009, Su 2010)
GSBA 594 Microfinance and Wealth Creation (MBA Program) (with EGADE Business School, ITESM, Campus Guadalajara) (Su 2008, Su 2010)
GSBA 597 International Business Practicum (Lima, Peru, with Universidad San Ignacio de Loyola, January 2006; Rio de Janeiro, Brazil with COPPEAD Business School, UFRJ, January 2009)

SERVICE

Professional Service and Affiliations:

Editorial Review Board:
Journal of Economics and Finance Education, from the Academy of Economics and Finance (6/02 – Present).

Journal Reviewer:
Journal of Business Ethics (2006, 2009, 2010), *Management Research Review* (2009), *Journal of Economics and Finance Education* (2002 – 2006, 2009, 2010), *Perspectives on Economic Education Research* (2005, 2006, 2007, 2008), *Journal of International Consumer Marketing: Special Issue on Cross-Cultural Issues in International Consumer Marketing* (2008); *Journal of Business Ethics: Special Edition on Teaching Business Ethics* (2004, 2005), *Contemporary Economic Policy* (2000, 2002), *Journal of Markets and Morality* (2002).

Conference Session Chair/Moderator:
Business Education at Catholic Universities Conference: "Teaching Economics at a Catholic University" (2008)
Academy of Economics and Finance: "Ethical Issues in Business, Economics and Finance" (2007)
Academy of Economics and Finance: "Examining Concepts with Undergraduates" (2002)
Southern Economic Association: "Topics in Health Economics Part 3" (2001)

Conference Session Discussant:
Academy of Economics and Finance (2000, 2002, 2004, 2006, 2007)
Southern Economics Association (2001)

Professional Membership in:
American Economic Association (since 1993)
Western Economic Association International (since 1994)
Gerontological Society of America (1998 - 2004)
Academy of Economics and Finance (since 1999)

Service to the University, College and Department:

University of San Diego:

Committees and Task Forces:
University Level:
Catholic Social Thought and Culture Advising Council (USD) (10/08 – Present)
Faculty Oversight Committee for Trans Border Institute USD (12/07 – Present)
Center for Educational Excellence (CEE) Advisory Committee (9/08 – 5/10)
Catholic Social Thought and Culture Director Search Committee (12/09 – 4/10)
Association of Catholic Colleges and Universities (ACCU) Conference ("Transcending Borders") Planning Committee (6/09 – 1/10)
Catholic Social Teaching Transition Committee (Co-Chair) USD, (5/07 – 4/08)
Catholic Social Teaching Strategic Directions Initiatives Task Force, Co-Chair (9/05 – 5/07)
Catholic Social Teaching Task Force (1/05 – 4/08)
Discover San Diego: Coordinated Trips to Mission San Diego (9/06; 9/07); Chicano Park: (8/09)
Catholic Social Teaching Task Force Off-Campus Resources Subcommittee Chair (10/05 – 5/06)
Program Developers Committee (Center for Learning and Teaching) (9/05 – 4/08)

SBA Level:
Microfinance Project (Chair), (4/08 – Present)
Teaching Excellence Committee, (Chair, SBA (9/08 – 5/09); Member 5/09 – 5/10)
Faculty Search Committee for Economics (12/07 – 2/08)
Preceptor for ECON 101 (F 2005- F 2009)

Honors Theses Supervised:
Kenneth Downey, 2009 (An Analysis of Microfinance Gross Yields: Impact of Profit, Women and Portfolios in Microfinance)
Matthew Thelen, 2008 (Price Elasticity of Professional Sporting Tickets as they Approach Perishability)
James Nelson, 2008 (The Effects of Demographic Disruptions on the Chinese Economy)
Jennifer Milosch, 2007 (Housing Prices in San Diego County)

Doctoral Dissertation Committees:
Jan Taylor Morris, 2008 – 2009 (The Relationship of In-Charge Auditors' Perceptions of Authentic Leadership and Organizational Ethical Climate within Certified Public Accounting Firms and the In-charge Auditors' Dysfunctional Audit Behaviors)

Service to the Community:

San Diego Microfinance Alliance (Committee Member: S 2009 – Present)
Instructor for "Microfinance 101" at Point Loma Nazarene University (October 6, 2009)
Panel Moderator for San Diego Microfinance Summit (May, 2009) and Panelist (May 2010)
Assistant Soccer Coach, Rancho Bernardo Youth Soccer Association (Sp 2006, F 2006, F 2007, S 2008)
Lector at St. Michael's Catholic Church, Poway, CA (Su 2005 – 10/08)

DECLARATION OF RYAN C. BOSWORTH, PhD

In the matter of the City of Solana Beach Draft Land Lease / Recreation Fee Study

I, Ryan C. Bosworth, declare as follows:

1. I am an Assistant Professor in the Department of Applied Economics at Utah State University in Logan, Utah. Prior to my position at Utah State University, I was an Assistant Professor in the Department of Public Administration at North Carolina State University, in Raleigh, North Carolina from 2006-2010. I received my PhD in Economics from the University of Oregon in 2006. I also hold Master's and Bachelor's degrees in Economics from Utah State University.

2. I have taught both graduate and undergraduate courses in statistics, econometrics, environmental policy, public policy analysis, and mathematical economics. Additionally, I have conducted and published research related to survey design, human health benefits of environmental policy, education policy, and business valuation in the *Journal of Environmental Economics and Management*, *Medical Decision Making*, *Economics of Education Review*, the *Journal of Education Finance*, and *Business Valuation Review*. A full version of my CV, including a complete list of my publications and the courses I have taught, is attached hereto.

3. I have examined the report City of Solana Beach, Draft Land Lease / Recreation Fee Study - Revised July 2010 and the supporting documents available on the City's website prepared by CIC Research, Inc. and PMC pertaining to the construction of Bluff Retention Devices (hereafter "BRDs") in the area of Solana Beach, California. In particular, I have reviewed the methods and analyses employed by the report authors in conducting surveys of beach visitors in order to estimate the value of beach area which may be affected by the existence of BRDs.

4. Based on my review of the survey methods, I have several concerns about the validity and accuracy of any conclusions based on these survey results, as discussed below.

- The PMC report fails to adequately explain how the actual counts of beach visitors were "expanded" into total annual estimates. The report states that "the proportion of visitors missed was derived by examining the respondents' arrival time and estimated departure time and determining what proportion would not have been in the area during the counting time period on average." However, it is not clear which arrival and departure times are examined (i.e., Are weekends compared only to weekends or to all days?). The report appears to suggest an implicit assumption that the time distribution of arrivals is the same for all days.

- Potentially useful information is either disregarded or not considered in the PMC report. For example, environmental factors such as number of daylight hours, weather and tide are likely to affect the number of visitors to a beach. The PMC report uses only information from sampled times and days to impute expected visitors for non-sampled times and days. While it is not clear whether incorporation of such information would increase or decrease the estimated number of visitors, the reliability of these estimates would be improved by accounting for this readily available information.

- The survey captures only one year. To the extent that the number of beach visitors varies from year to year due to economic conditions, weather, and other conditions, the survey may over or under represent the actual number of beach visitors.

- It appears that PMC did not attempt to deal with the well-known "multiple destination problem" in time/travel cost models. For example, if a person visits the beach from out-of-town in conjunction with a visit to his sister who lives nearby the beach, the travel cost method will incorrectly attribute all the time and travel cost to the beach visit itself. The beach survey does not attempt to gather multiple destination information.

- PMC has not correctly applied the travel cost method to estimate the value of Solana Beach. A properly estimated travel cost model would use a statistical modeling technique (such as regression analysis) to estimate the relationship between the number of beach visits per unit of time and the price (travel cost) per trip. Instead, the PMC report merely calculates an "average value per visitor day [...] based on distance traveled, mode of transportation, and annual individual salary." (p. 3-8 PMC report).

- A properly estimated travel cost model should also account for the presence of, and travel cost to, substitute options such as other nearby beaches. The key mistake in the PMC study is that the value of a day of recreation at Solana Beach is not the same thing as the value of Solana Beach because visitors to Solana Beach have numerous substitute destinations including the adjacent beaches in Del Mar and Encinitas, not to mention numerous parks and other attractions that San Diego has to offer. This mistake would substantially bias the result in the form of an artificially high value for Solana Beach. The PMC study acknowledges that travel cost models have problems accounting for substitutes (pg. 2-2 PMC study), but the real problem is that PMC has misapplied the travel cost method. The empirical academic literature on this subject suggests that a random-utility model approach, which accounts for substitution possibilities more appropriately, could be used to address this issue. Even if a random-utility model is not used, travel cost models, properly estimated, can be modified to account for substitute sites. PMC does not estimate a model that can account for these substitution possibilities. Clearly, PMC's failure to account for substitution possibilities substantially biased the result in the form of an artificially high value for Solana Beach.

- Assigning a single value per-square-foot to each square foot of beach, as done in the PMC study, is problematic in the context of survey data. Given that not all areas of a beach are likely to be utilized equally, it follows that certain areas of the beach are more valuable (per square foot), especially considering that the area under the bluffs is dangerous and less utilized. A proper surveying methodology would account for the distribution of beach visitors across the various segments of the beach, and ensure that sufficient sampling is done to account for heterogeneity in beach area quality. By failing to address this heterogeneity of value, PMC undoubtedly overvalued the portions of the beach that are most impacted by BRDs, as it is this area of the beach that is subject to the danger of bluff collapse and receives less visitation.

- Using an actuarial approach to valuing the safety benefits of BRDs ignores the fact that the risk of death or injury can be mitigated by individuals staying away from the bluffs. This likely underestimated the public benefits of BRDs because it failed to adequately address the safety benefits. Even individuals who would not be at risk of death or injury because of their behavioral response to the danger would benefit from the presence of the BRD due to increased beach usability and decreased stress. A random utility approach that allowed individuals to express a value for the improved safety and increased usability of the beach could capture this benefit.

- The PMC study appears to have made an arbitrary decision to base their estimate of the risk of death on data only from Solana and Encinitas beaches. PMC reports that in this coastline only 1 fatality has occurred between 1990 and 2009. However, a total of 5 fatalities have occurred from bluff collapse in the surrounding areas between South Carlsbad State Beach and the northerly end of Torrey Pines State Beach, a distance of approximately 12 miles that contains 10 miles of seacliffs similar to those found in Solana Beach. Failure to incorporate these relevant events into the estimate of the probability of death may have the effect of seriously underestimating the true public safety benefits of the BRDs.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 29th day of September 2010, in the city of Logan, Utah.

By: Ryan C Bosworth

Dr. Ryan C. Bosworth, PhD

RYAN C BOSWORTH

CURRICULUM VITAE
October 2010

Work:
Department of Applied Economics
Utah State University
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ryan_bosworth@usu.edu

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1058 E 420 S
Smithfield UT 84335
453.363.4661
801.549.7315 (cell)
ryan.bosworth@gmail.com

EDUCATION

Ph.D., Economics, University of Oregon, 2006

Dissertation Title: *Demand for Public Health Policies*
Committee: Trudy Ann Cameron (Chair)
William T. Harbaugh
Robin McKnight
Paul Slovic (Psychology)

M.S., Economics, Utah State University, 2001

Thesis Title: *Economies of Scale in Wyoming Public Education*

B.S., Economics, Utah State University, 2000

PROFESSIONAL EXPERIENCE

Assistant Professor (2010-present)
Department of Applied Economics
Utah State University

Assistant Professor (2006-2010)
School of Public and International Affairs
North Carolina State University

Instructor (2002-2006)
Department of Economics
University of Oregon

RESEARCH AREAS

Health/Environmental Economics
Education Economics
Applied Micro-Econometrics

TEACHING EXPERIENCE

Mathematical Economics
Econometrics
Public Policy Analysis
Benefit-Cost Analysis
Environmental Policy Analysis
Political Economy
Principles of Microeconomics
International Economics
Labor Economics
Managerial Economics

AWARDS, HONORS, AND FELLOWSHIPS

RESEARCH

Joseph L. Fisher Dissertation Fellowship
Resources for the Future, 2005-2006

Kleinsorge Fellowship
Department of Economics, University of Oregon, 2001-2002, Summer 2005

J.W. Pope Faculty Summer Grant
School of Public and International Affairs, North Carolina State University, 2008

TEACHING

Robins Awards Finalist: Graduate Teaching Assistant of the Year
Utah State University, 2001

Graduate Teaching Fellowship
Department of Economics, University of Oregon, (2001-2006)

RESEARCH PAPERS

"Cheap Talk and Trichotomous Choice Experiments" with Laura Taylor

"Health Attitudes and Rates of Time Preference", with Trudy Ann Cameron and J.R. DeShazo

"Willingness to Pay for Public Health Policies to Treat Illness" Under Revision, with Trudy Ann Cameron and J.R. DeShazo

"Class Size, Classroom Heterogeneity, and the Distribution of Student Achievement" Revision requested from *Education Economics*

"An Empirical Basis for Allocating Enterprise and Personal Goodwill" *Business Valuation Review*, 29 (1), July 2010, with Tyler J. Bowles

"Is an Ounce of Prevention Worth a Pound of Cure? Comparing Demand for Public Prevention and Treatment Policies" *Medical Decision Making*, 30 (4), July 2010, pp E40-E56 with Trudy Ann Cameron and J.R. DeShazo

"Demand for environmental policies to improve health: Evaluating community-level policy scenarios" *Journal of Environmental Economics and Management*, 57 (3) 2009 pp 293-308 with Trudy Ann Cameron and J.R. DeShazo.

"Educational Production and Teacher Preferences" *Economics of Education Review* 26 (4, August 2007): 487-500, with Frank Caliendo.

"Scale Economies in Public Education: Evidence from School Level Data" *Journal of Education Finance* 28 (2, Fall 2002):285-99, with Tyler J. Bowles.

WORK IN PROGRESS

"Ability Sorting and Class Size Differences in Urban and Rural Elementary Schools"

"Sales Price, Revenue, Ownership Structure, and Firm Size" with Tyler J. Bowles

"Environmental Health Policies: Risk Attitudes, Socio-Demographics, and Fairness" with Trudy Ann Cameron and J.R. DeShazo

CONFERENCES AND PRESENTATIONS

2009

Southern Economic Association, San Antonio TX (Presentation, Discussant)
Utah State University, Logan UT (Presentation)
Center for Environmental and Resource Economic Policy, North Carolina State University, Raleigh NC (Presentation)
Annual Meetings of the American Academy of Economic and Financial Experts, Las Vegas, NV (Co-Author)

2008

ARNOVA 37, Philadelphia PA (Co-Author, Poster presentation)

Association of Public Policy Analysis and Management Annual Meetings, Los Angeles CA (Co-Author)

2007

Triangle Resource and Environmental Economics Workshop, Raleigh NC (Presentation, Session Chair)

13th International Symposium on Society & Resource Management Park City UT (Presentation)

2006

Southern Economic Association, Charleston SC (Presentation, Discussant, Session Chair)

RTI International, Raleigh NC (Presentation)

Camp Resources, Wilmington NC (Presentation)

W1133 Meetings, San Antonio TX (Presentation)

University of Montana, Department of Economics, Missoula MT (Presentation)

University of Maryland-Baltimore County, Department of Economics, Baltimore MD (Presentation)

U.S. EPA, Washington DC (Presentation)

Virginia Tech, Blacksburg VA (Presentation)

North Carolina State University, School of Public and International Affairs, Raleigh NC (Presentation)

2005

Oregon Ad Hoc Workshop in Environmental and Resource Economics. Willamette University, Salem OR (Presentation)

8th Occasional California Workshop on Environmental and Resource Economics. Santa Barbara, CA (Presentation)

Utah State University, Economics Department, Logan, UT (Presentation)

2001-2004

Camp Resources, Wilmington, NC (Presentation) (2004)

Utah State University, Economics Department, Logan, UT (Presentation) (2004)

Western Agricultural Economics Association Annual Meetings, Logan, UT (Presentation) (2001)

40th Annual Meeting of the Western Regional Science Association, Palm Springs, CA (Presentation) (2001)

EXTENTION ACTIVITIES

Industrial Extension Service of North Carolina State University: Economic Impact Study (Consultant)

Wake County Public Schools Evaluation and Research Department: Training in Benefit-Cost Analysis and Cost-Effectiveness Analysis

Wake County Public School Evaluation and Research Department: Statistical and Cost Effectiveness Analysis of the Helping Hands program

PROFESSIONAL ACTIVITIES

AFFILIATE:	*Center for Environmental and Resource Economic Policy* (CEnREP)
MEMBER:	*American Economic Association* *Association of Environmental and Resource Economists* *Southern Economic Association*
REFEREE:	*Journal of Policy Analysis and Management, Economics of Education Review, Journal of Environmental Economics and Management, Journal of Environment and Development, Education Economics, Journal of Educational Administration and Policy Studies, Medical Decision Making*

Assessment of the statistical methodology for annual beach visitor count and surveys: City of Solana Beach Land Lease/Recreation Fee Study

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Executive summary: The statistical methods applied to estimate the annual number of adult beach visitors in the PMC Land Lease/Recreation Fee Study is assessed. This study relies on two surveys: 1) beach count survey: a count of beach visitors on 88 randomly selected days during the study period and randomly selected times within each of those days and 2) beach visitor survey: an interview of 563 beach visitors during the study period used in part to adjust the beach count survey for undercounting. The primary statistical concerns about the validity and accuracy in the estimated annual number of adult beach visitors inferred from these surveys may be summarized as follows:

1. *Sample size*:
   - The samples selected in each survey are not representative of either the population of beach days occurring during the study period nor the beach visitor population leading to a potential bias/inaccuracy in the annual adult beach visitor count estimate.
   - The samples sizes are too small to draw reasonably precise estimates of the annual number of adult beach visitors.
2. *Sampling plan*: The number of beach visitors varies by tide condition, weather, month/season, time of day, and location. The surveys do not account for these factors leading to imprecise and biased estimates of annual adult beach visitor counts if not completely unreliable inferences.
3. *Precision*: The annual adult beach visitor count is estimated with error inherent within the survey sampling mechanisms, the undercount adjustment, and data collection/measurement. A quantification of this uncertainty is not provided nor considered in the report and, due to the deficiencies in the sampling plan, may be excessive.

Summary of statistical methodology used in the Land Lease/Recreation Fee Study

We first briefly detail our understanding of the methods used and surveys performed to estimate the annual number of beach visitors within the City of Solana Beach region under consideration. The City of Solana Beach retained the company PMC, with CIC Research as a sub-consultant, to perform the study. We thus throughout refer to PMC as the acting party in our assessment of the statistical methodology and any reference to a beach under consideration pertains to the study region in the City of Solana Beach. Two surveys are used for obtaining the annual number of beach visitors: a beach count in which a surveyor walks the beach and counts the number of beach attendees and a beach visitor survey where a surveyor interviews select beach visitors to estimate the value a person places on the beach and related activities. Throughout, we will refer to these two data sets as the "beach count survey" and the "beach visitor survey".

In order to estimate the annual number of beach visitors to the City of Solana Beach region under study, PMC randomly selected 88 days during the period July 2008-July 2009, with an aim of sampling 7 days per month including 5 week days and 2 weekend days. The exact distribution of days sampled by month appears in Table 1

Month	# days sampled	# weekend days sampled	# Fridays sampled
July*	10	3	2
August	8	2	1
September	7	2	1
October	7	2	1
November	7	2	1
December	7	2	1
January	7	2	1
February	7	2	1
March	7	2	1
April	7	2	1
May	7	2	1
June	7	2	1

Table 1: Number of days sampled in PMC beach count survey with delineation of the number of weekend days and Fridays within each month.
* includes both July 2008 (3 days) and 2009 (7 days).

The surveyor randomly chose a time to walk the beach on the given day and randomly selected either the northernmost or southernmost entrance to the beach at which to start. The surveyor counted the number of beach attendees in each of 35 sections of the beach, walking all segments and performing the count in about 30-60 minutes. This beach count survey is then used to determine the typical number of beach visitors per day and extrapolated out to an average annual number of beach visitors (multiplying the average number per day by 365).

The study report recognizes that such a scheme produces an underestimated count of beach visitors, each data point being merely a snapshot of beach attendees during a short window during a given day. PMC thus relies on the beach visitor survey, also performed as part of the study, to quantify the amount of underestimation and correct the beach visitor counts accordingly. This beach visitor survey has a primary purpose of estimating the value a visitor places on the beach. The survey includes interviews of 563 beach attendees, interviewed on randomly selected days and times within a day throughout the year of study. Of particular note, the data includes the time an individual came to the beach, at what segment they entered, and a guess of the time they will leave the beach that day. This data is used to correct the beach count survey data for underestimation by dividing a day into six time intervals: 6-8 am, 8-10 am, 10 am - 12 pm, 12-2 pm, 2-4 pm, and a grouping of early morning 5-6 am and evening 4-8 pm, and determining the percentage of the 563 survey subjects that were at the beach at the midpoint of each interval (namely, 7 am, 9 am, 11 am, 1 pm, 3 pm, and 5 pm).

In all, the statistical approach to estimating the average number of beach visitors entails three parts: 1) beach count survey on 88 study days, 2) beach visitor survey from 563 beach visitor interviews, and 3) averaging and adjustment to obtain final estimate of the annual average number of beach visitors. We critique each part in turn, beginning with item (3), the averaging and adjustment routine.

Re-analysis of beach count and beach visitor surveys

The method for estimating the average annual number of beach visitors suffers from three deficiencies which may, in part, be corrected using the survey data collected.

1. *Average by month rather than by day:* The estimated average annual beach visitor count is computed by extrapolating the expected number of daily beach visitors. However, the sampling is stratified by month, presumably to account for seasonal (and monthly) variations in beach attendance. Consequently, a calculation of the average number of monthly visitors then extrapolated out to an annual count is more appropriate.

2. *Finer time intervals within which to adjust for undercount:* The average annual beach visitor count is driven by the adjustment for unaccounted beach visitors during the counting process. The division of a day into two-hour time intervals for this adjustment is seemingly arbitrary and perhaps undesirable given that the counts are performed in a beach walk requiring typically less than an hour. In particular, individuals at the beach during the early and late hours (e.g., 7 am, 8 am, 4 pm) may be weighted too heavily in the adjustment leading to an overcount. The affect of choice of time intervals is largest during hours with lightest activity at the beach as the difference between an empty beach and a handful of people can lead to adjustments differing by an order of magnitude. For example, in the PMC study, an individual arriving in the very early morning hours, say before 7 am to an empty beach will represent the same number of people (adjustment factor) as an individual arriving close to 8 am. As we show in the analysis below, this leads to an overcount. However, during busy beach hours from 10 am - 2 pm, choice of time interval has little affect on the adjustment due to the large counts already present. We thus retain the PMC study categorization during these hours. We are not able to divide the early and late hour (5-7 am and 5-8 pm category) further into hourly intervals as there are too few data points, in both the beach count survey and beach visitor survey, to provide reasonable estimates of the undercount adjustment and subsequently a daily estimate of number of beach visitors. Overall, a careful consideration of appropriate intervals, prior to sampling and with a sampling design that covers each, is required. For this re-analysis based on the existing survey data, we propose dividing time into hourly intervals during low volume periods (early morning, late afternoon) and two-hour intervals during high volume periods (10 am - 2 pm), see Table 2.

3. *Estimate of precision:* There are numerous sources for error in this study, none of which are accounted for in presenting a "point" estimate for the annual number of beach visitors. Typically in the report of statistical analyses, a confidence interval is provided to quantify uncertainty or precision in any estimates presented. This study utilizes data from two surveys for estimating the annual number of beach visitors, one being the beach count survey, a random sampling of 88 days for the count, and the second being a beach visitor survey of 563 beach visitors and their arrival/departure time to/from the beach. Each survey consists of a sample from the population and thus is subject to variation merely through the process of estimating beach visitor counts from the given subset of the beach visitor population. We may quantify the uncertainty presented by the estimates from the beach count survey via the study and data from that survey, details of that calculation provided in the appendix. However, an estimate of precision incorporating error from the beach visitor survey, used to adjust for the undercount from the beach count survey, is a significant, if not impossible,

Time interval	% beach visitors not accounted for	Capture %	Adjustment ratio
7:00 am - 7:59 am	92.0%	8.0%	12.511
8:00 am - 8:59 am	82.4%	17.6%	5.687
9:00 am - 9:59 am	76.0%	24.0%	4.170
10:00 am - 12:00 pm	62.0%	38.0%	2.631
12:00 pm - 2:00 pm	62.7%	37.3%	2.681
2:00 pm - 2:59 pm	68.7%	37.3%	3.199
3:00 pm - 3:59 pm	73.5%	26.5%	3.779
4:00 pm - 4:59 pm	84.7%	15.3%	6.547
5:00 am - 7:00 am and 5:00 pm - 8:00 pm	96.3%	3.7%	26.810

Table 2: Adjustment for missing beach visitors during count based on hourly intervals rather than two-hour intervals as used in the PMC study. Format follows that of Table 3-4 in the PMC report.

challenge. As the application of this latter beach visitor survey presents numerous problems in general, we discuss these matters later and do not address this source of imprecision here. We emphasize then that the analyses presented here are then an underestimate of the precision (narrower confidence intervals) incorporating only one source of error, that from the beach count survey, and not the uncertainty induced by the beach visitor survey.

We re-analyzed the PMC data to address the three items mentioned above, presenting the estimated number of annual adult beach visitors from an estimated average monthly count, adjusted according to the factors in Table 2. The result is an estimate of 92,999 adult visitors in the year (with 95% confidence interval 77,983 to 115,968 adult visitors), as compared to 101,415 adult visitors presented in the PMC report. Again note that the interval range overestimates the precision in our estimate (interval too narrow) since we are accounting for only one of the major sources of variation, that of randomly sampling 88 days of the year from which to obtain the beach visitor counts. The interval does not account for variability presented by the beach visitor survey also used in the estimation process. Given the error inherent in that study, discussed below, we expect the confidence interval to be substantially wider (interval estimate far more imprecise). Nonetheless, note that though many of the adjustment factors actually increase relative to the PMC study, an overcount results from grouping the early morning hours (6- 8 am) and late afternoon and evening hours (2-4 pm and 4-8 pm) together. Given that the surveys are not designed to correctly sample time intervals through the day, either those put forth by PMC nor those of Table 2, this overcount is in fact most likely severely understated by this analysis.

We additionally estimated the number of "non-beach days", days during the study period where we would expect no beach visitors, based on minimum and maximum daily temperature, daily precipitation, maximum and minimum wind speed, and daily average wind speed during the morning hours. From this data, it is estimated that during the study period, 37 days during the study period would be defined as a "non-beach day" or close to 10% of the 396 days under consideration (see appendix for details on this calculation). The PMC study estimated 2 days out of 88 with no beach visitors. Adjusting the beach count for 37 non-beach days over the study period results in an estimate of 82,724 adult visitors. This is merely an illustration of the importance of correctly representing the proportion of non-beach days, either with zero beach visitors or very few visitors, in the survey sample.

Appropriate sampling frames

The PMC report correctly identifies the estimate of annual beach visitors from the beach count survey as an undercount and thus uses the beach visitor survey to quantify the undercount. Such an approach aims to estimate how many beach attendees each beach visitor counted represents. For example, according to Table 2, an individual counted on a beach walk at 8:00 am represents 5.687 people for the entire day. The PMC study makes two crucial assumptions in coming to this adjustment: 1) the beach count survey does not miss nor double-count any beach visitors and 2) the adjustment using the beach visitor survey does not vary through the year. Both assumptions address the sampling plan for both the beach count survey and the beach visitor survey. We shall address each in turn beginning with the latter beach visitor survey.

Survey of beach visitors

This survey is performed on randomly selected days throughout the year and times within the year. The survey suffers from a number of drawbacks towards estimating the undercount adjustment from the beach count survey.

- The number of beach visitors will vary by time of day, tide condition, weather, and month/season (in violation of the second assumption mentioned above). A random sample of days throughout the year and time periods in a day within which to perform the survey may lead to severe imprecision and bias in estimated adjustments, a bias most likely in the direction of an overcount. This expected overcount is due to an undersampling of times of light activity on the beach and thus imprecise and most likely unnecessarily large adjustment factors (individuals at the beach during these times seeming to represent more daily beach visitors than they actually do in the estimation process).

- Related to the previous bullet, the odds of a beach visitor entering the survey depends on the number of people on the beach at that time (which changes by time of day, season, and weather) and the beach area (which changes by tide condition). Such inclusion probabilities must be considered in the survey design and accounted for in the average annual beach count computations otherwise estimates will be biased, most likely as severe overcount. Again, this expected overcount is due to the consequence of undersampling visitors who were at the beach during hours of light activity and thus overinflating their weight (adjustment factor) in the estimation process.

- Uncertainty presented by sampling a mere 583 subjects out of the tens of thousands of beach visitors annually must be incorporated into any presentation of average annual beach counts, via say a confidence interval. Furthermore, such a small sample size will lead to imprecise estimates from which yearly fee rates can not be accurately (or fairly) computed.

- The survey data suffers from potential "recall" bias/measurement error in that subjects provide their best guess of arrival to the beach and asked to make a guess as to when they will leave the beach, both of which may not be accurate.

- The mechanism for choosing subjects to survey is unclear and most likely is not random. In particular, though the day and time at which the surveyor goes to the beach is chosen randomly from the study period, the process for selecting interviewees for the study from visitors at the beach during that time and accounting for non-responders (those refusing to do an interview) is not presented.

One solution to the first three bulleted problems is to collect a sample stratified by tide condition/time of day, weather condition, and month with an appropriately large sample size (number of surveys) randomly collected within each strata to overcome any biases and imprecision due to variation in count over such differing daily/seasonal conditions. Furthermore, the number of people present at the beach when the survey is performed should be recorded and estimates of count precision presented in any reports.

Beach count survey

This survey is performed on randomly selected times within a randomly selected days throughout the year, with the caveat that at least seven days per month including two weekend days are sampled. The survey suffers from a number of drawbacks towards estimating the annual number of beach visitors.

- The sampling plan is in fact stratified by month and days within a week. Such a plan aids in reducing imprecision in the annual beach count estimate as a consequence of tide condition and weather due to the coverage of sampling days during each season and varying times throughout a day. However, a sampling plan which directly stratifies the sampling period by weather and tide condition will be more successful at such a task, rather than leaving sampling of such conditions to chance according to a random sample over month and time of day. For example, proportionally low number of "non-beach days", where poor weather conditions lead to small numbers of, if not zero, beach visitors, suggests a plan in which winter months are oversampled may be appropriate.

- We must assume surveyors do not miss nor double-count any beach visitors during their count. This assumption is reasonable presuming proper training of surveyors. However during the 30-60 minute surveyor walk of the beach, across the 35 defined segments, visitors arriving in a segment after the surveyor performed the count or leaving before the surveyor reaches that segment will be missed. A sample stratified by segment and perhaps tide condition/time of day may overcome such imprecision in the count.

- Every month, exactly one Friday is sampled. Such an event is highly unlikely under the purported random selection of days within a month on which the counts are drawn. If a stratification by days is performed, for example to ensure each day of the week is sampled once per month, such a scheme should be clearly delineated. In fact, since beach counts do probably vary by day-of-the-week, such a sampling plan may be desirable.

- As show in Table 1, the survey seems to oversample the busiest beach months of the year with 10 July days and 8 August days sampled, as compared to 7 days during each of the lighter months (e.g., January and February). Furthermore, it is unclear why days from both July 2008 and July 2009 were sampled. A preferable sampling frame is perhaps a 12 month, rather than 13 month, period say August 1, 2008 to July 31, 2009.

- Only one count was performed during the evening hours, on 9/12/2008 from 4:25 pm to 5:39 pm. Thus estimates of say visitors coming to the beach to experience the sunset is not correctly captured in this survey. A stratified sampling plan ensuring appropriate sampling during this time interval in each season seems a necessity.

Target population

The PMC survey draws inferences only towards the annual number of beach visitors during the period under study, July 2008-July 2009. Given changing weather and beach conditions from year to year, applying such counts as estimates of the number of beach visitors in future (or past) years is suspect. A solution is to perform a multi-year study spanning a sufficient time period to capture year-to-year variation, particularly in weather conditions (hot and cold spells, rainfall, climatic conditions such as El Nino/La Nina events, dry spells and wild fires, etc.).

Sample sizes

As mentioned, the beach count survey aims to estimate the number of annual beach visitors from 88 days randomly sampled throughout the study period, with restrictions on the number of days per month and number of weekend days chosen. The beach visitor survey includes interviews of 563 visitors collected throughout the study period, in part, to adjust the beach visitor count from the beach count survey for undercounting. These sample sizes are quite small for obtaining representative samples given the variability in beach visitors and capture rate in the presence of changing weather conditions, tide conditions, and seasonal variation. We illustrate this deficiency via an example within the context of the survey presented and then discuss caveats which actually will lead to even larger required sample sizes.

We first consider the beach count survey. For point of illustration, we assume that the adjustments of the beach counts from the beach visitor survey are exact, no uncertainty encountered as a result of that data collection. We may thus use the re-analysis of the PMC data performed earlier to consider the number of days of counting required to attain a given level of precision in the beach visitor count. In particular, the width of the confidence interval on beach visitor count quantifies our uncertainty in the estimated average annual beach visitor count: the longer the interval (larger the width) the more uncertain we are in that estimated average. Figure 1 displays the half-width of the confidence interval, better known as the margin of error, as a function of the number of days sampled. For the given data set, the half-width is 15,016 people, in some sense the amount we may be off (with 95% confidence) from the truth relative to the average count of 92,999 annual adult visitors. As the number of days sampled increases, this margin of error, and consequently our precision in the average count estimate, will decrease/improve. We may determine how many days must be sampled to achieve a given precision by specifying a desired half-width. For example, if we desire precision (margin of error) within 8,000 people, we would require about 350 days of sampling.

Again, Figure 1 is an illustration of sample size required, not taking into account the uncertainty inherent in the adjustment factors from the beach visitor survey nor the necessary stratification we propose for weather condition, tide condition, month/season, and time of day. These factors in fact would increase the number of days or at least times of day on which counts should be performed. But Figure 1 suggests that 88 days of sampling is too few and in fact if a precision on the order of a half-width less than 10,000 people is required, at least twice as many days need be sampled. If a precision on the order of a half-width of 5,000 people is required, which may be desirable, stratification by time of day need be performed with sampling every day of the year surveyed.

We next consider the beach visitor survey. The base problem is that of estimating the capture percentage, namely the percentage of visitors on the beach during a given time period, by sampling a subgroup of the tens-of-thousands visitors to the beach in the study period. This capture percentage is then used to compute the adjustment factor for correcting the beach count survey for undercounting. Table 3 presents the number of surveys that need to be collected for each of

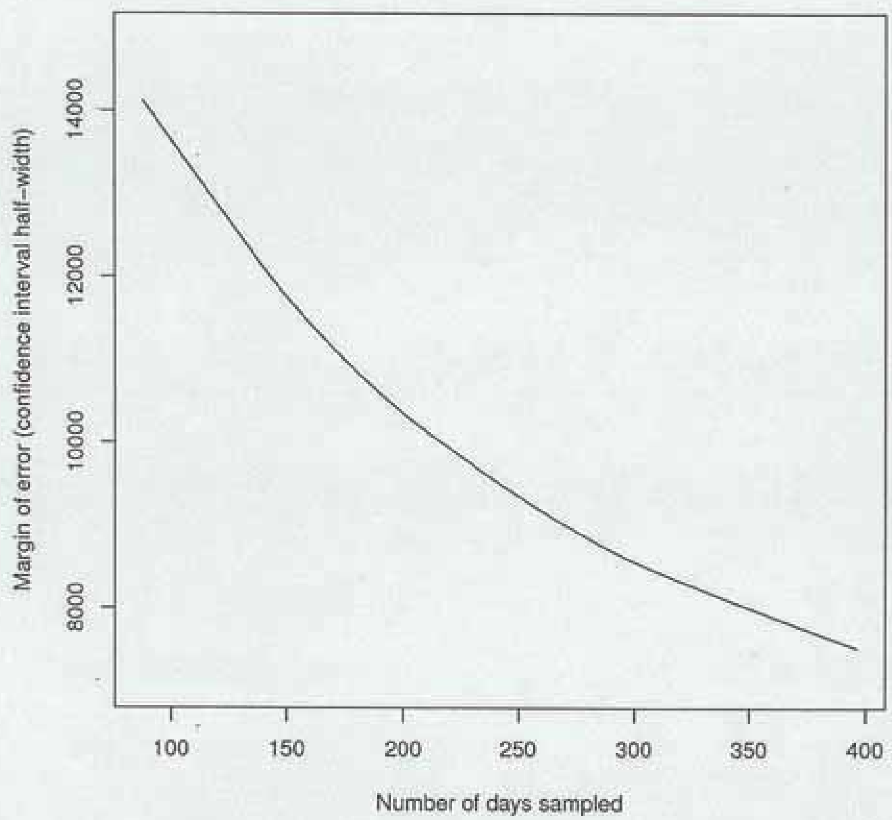

Figure 1: Half-width of 95% confidence interval on average annual adult beach visitors against number of days sampled. The PMC study counted beach visitors on 88 days through the period of study.

Time interval	# interviews
6:00 am - 7:59 am	1313
8:00 am - 9:59 am	240
10:00 am - 11:59 am	113
12:00 pm - 1:59 pm	118
2:00 pm - 3:59 pm	159
5:00 am - 5:59 am and 4:00 pm - 7:59 pm	693
Total	2636

Table 3: Number of interviews required in the beach visitor survey by time interval. These time intervals are taken from Table 3-4 of the PMC report being the intervals used for computation of capture percentage and corresponding adjustment factors.

the time intervals considered in the PMC analysis (Table 3-4 of the Land Lease/Recreation Fee Study report). The PMC analysis performed 563 interviews. Table 3 shows that not only are more than four times that number required to attain a desired level of precision (margin of error), but in order to capture an expected low percent capture during the early morning and late evening hours, significantly larger samples sizes are needed.

As in the computations of Figure 1, the sample size computations in Table 3 assume no uncertainty entered into the sampling process from weather conditions, tide conditions, season, nor time of day. Again, once our proposed stratification on these variables is performed, the requisite sample size for the survey, which must interview a given number of beach visitors for each stratum to obtain an adjustment factor to a given level of precision, will be substantially higher.

The appendix presents details for the procedures used to create Figure 1 and Table 3.

Appendix A: Bootstrap estimate of precision

A parametric bootstrap procedure was used in order to provide a measure of precision for the annual number of adult beach visitors. The bootstrap is a routine which allows one to accurately estimate uncertainty in a given estimation procedure via a simulation process based on the data collected. For our purposes, we need to quantity variation from the estimated annual number of adult beach visitors over repeated surveys if such surveys were performed. The parametric bootstrap for performing such a task is as follows:

1. Regress the adjusted daily beach counts against month and type of day (a categorization of weekend, Friday, and M-R was deemed best) giving a model

$$count_i = \beta_0 + \beta_M month_i + \beta_D day_i + e_i$$

   with random errors e_i independently and identically distributed according to a normal distribution with mean 0 and standard deviation σ, $i = 1, \ldots, 88$.

2. Obtain regression coefficient and standard error estimates from (1), namely $\hat{\beta}_0$, $\hat{\beta}_M$, $\hat{\beta}_D$, and $\hat{\sigma}$.

3. Simulate B new data sets of 88 days each via the regression model in (1) using the estimates from (2).

4. Estimate the number of annual adult beach visitors using the adjustment process outlined in the PMC report, though using the intervals recommended by Table 2, for each of the B data sets from (4).

5. Report bootstrap estimates being the average number of annual adult beach visitors and 2.5th and 97.5th quantiles (for a 95% confidence interval) from the simulated values in (5).

For the analyses herein, $B = 1000$ and a square-root transformation is performed on the adjusted counts in the model of step (1) to avoid violations of random, normally distributed errors.

Appendix B: Sample size calculations

Two sample size calculations are performed: the first to estimate an appropriate number of days to sample in the beach count survey and the second to estimate the number of interviews to perform in the beach visitor survey.

The bootstrap procedure outlined in Appendix A may be used to obtain address the first calculation. In particular, we simulate data sets with n days, ranging from 88 (the number of days in the PMC beach count survey) to 396 (the number of days in the study period July 1, 2008 to July 31, 2009). Again, for each n we simulate $B = 1000$ bootstrap data sets and compute a bootstrap confidence interval as in step (5) in Appendix A. From this confidence interval, we may compute the margin of error, being the half-width of the confidence interval. Figure 1 is then a smoothed (using a LOESS smooth) relationship of these margin of errors against number of days. We may thus choose an appropriate number of days for a desired margin of error. As mentioned in the report, this calculation focuses solely on simulating a beach count survey, with annual beach count numbers adjusted according to the factors in Table 2. Consequently, we are underestimating the precision, assuming these factors are exact.

The second sample size calculation may be performed by envisioning the beach visitor survey as a means of estimating a binomial proportion, namely the capture percentage for each of time intervals in Table 3-4 of the PMC report. A standard sample size calculation may be computed for each time interval as

$$n \geq (1.282/ME)^2 \hat{p}(1-\hat{p})$$

where $\hat{p}$ is an expected capture percentage (we used the values in Table 3-4 of the PMC report) and we desire inferences to a prescribed margin of error (we chose ME = 0.0098 which represented a 20% difference from the observed capture percentages) and confidence level (we assumed a conservative 90%). The results from this formulation are presented in Table 3.

Appendix C: "Non-beach days"

To determine if the PMC sample reasonably represents/covers non-beach days occurring through the study period, namely days in which there are zero or very few beach visitors, we obtained data of maximum and minimum temperature, precipitation, maximum wind speed, minimum wind speed, and average wind speed from 8 am - noon for each day during the study period July 1, 2008 to July 31, 2009. The latter average wind speed was used under the assumption that potential visitors may choose to go to the beach depending on the strength of the wind during the morning hours on a given day. To predict the number of non-beach days over the study period, we regressed the number of daily adult beach visitors obtained in the PMC study against these weather variables for the 88 days in that study, using a log-transformation of the count data to avoid any violations in regression model assumptions. We then predicted the number of daily adult beach visitors for each day during the study period from this fitted model and counted the number of days in which a 95% prediction interval covered values less than one (visitor). Thirty-seven days out of 396 (approximately 10%) achieved this criterion, compared to the 2 out of 88 days (approximately 3%) with a recorded zero beach visitors in the PMC study. The annual number of adult beach visitors is then recalculated, via the adjustment factor proposed in Table 2, assuming the predicted distribution of non-beach days in each month, resulting in the estimate of 82,724. The quantification of precision in this estimate is not presented in part due to the difficulty in producing such a measure over this complicated multi-stage process but also in light of the goal of merely illustrating the potential for overcount in the PMC study from an undersampling of non-beach days.

Note: R code for performing all computations are available upon request.

Solana Beach Study Beach Counts

PN: 2567

28-Sep-10

Date	Day	Duration (hours)	Time Range		Total Count	Adult Count	Avg Adult Count Per Half-Hour	Time Block	Adj Factor	Tide Range (MLLW)		Weather Conditions: Max Temp	Min Temp	Precip (inches)	Weather Station Location	Wind Speed @ SIO Pier (m/s)	Notes by Solana Beach Observers
										2008							
25-Jul-08	Fri	1.93	11:30 AM	1:26 PM	193	142	37	11	2.662	3.16	4.60	74	63	0	Solana Beach	1.0	
27-Jul-08	Sun	1.33	9:55 AM	11:15 AM	238	191	72	9	4.554	2.50	2.51	74	66	0	Solana Beach	1.2	
30-Jul-08	Wed	1.13	1:00 PM	2:08 PM	260	192	85	13	2.741	2.28	1.98	74	65	0	Solana Beach	1.6	
4-Aug-08	Mon	1.40	1:55 PM	3:19 PM	387	282	101	13	2.741	4.93	3.11	75	69	0	Solana Beach	1.1	
7-Aug-08	Thu	1.33	10:35 AM	11:55 AM	199	142	53	11	2.662	3.06	3.96	78	69	0	Solana Beach	2.7	
13-Aug-08	Wed	0.75	1:10 PM	1:55 PM	118	69	46	13	2.741	2.53	2.45	74	65	0	Solana Beach	1.9	Overcast
16-Aug-08	Sat	0.73	3:15 PM	3:59 PM	623	512	351	15	3.339	1.64	1.65	77	68	0	Solana Beach	1.5	
19-Aug-08	Tue	0.58	3:25 PM	4:00 PM	226	154	133	15	3.339	2.24	1.72	66	68	0	Solana Beach	1.2	
22-Aug-08	Fri	1.25	3:35 PM	4:50 PM	286	219	88	15	3.339	4.62	3.52	73	67	0	Sea World	2.5	
24-Aug-08	Sun	0.83	12:00 PM	12:50 PM	202	147	89	13	2.741	3.73	4.21	74	65	0	Solana Beach	2.9	
25-Aug-08	Mon	0.75	12:00 PM	12:45 PM	69	51	34	13	2.741	3.07	3.35	78	68	0	Solana Beach	1.2	
										Labor Day - 1 Sep							
6-Sep-08	Sat	1.00	11:00 AM	12:00 PM	110	83	42	11	2.662	3.96	4.33	76	66	0	Solana Beach	no data	
8-Sep-08	Mon	0.92	1:00 PM	1:55 PM	67	63	34	13	2.741	3.64	3.89	75	67	0	Solana Beach	no data	*Collapse @ 12th Pt
11-Sep-08	Thu	0.75	1:00 PM	1:45 PM	28	25	17	13	2.741	2.27	2.19	71	66	0	Solana Beach	no data	
17-Sep-08	Wed	0.70	3:45 PM	4:27 PM	55	49	35	15	3.339	0.92	0.35	73	65	0	Solana Beach	1.2	
21-Sep-08	Sun	1.23	4:25 PM	5:39 PM	185	152	62	17	3.339	4.59	3.51	73	63	0	Solana Beach	3.3	
26-Sep-08	Fri	0.72	2:00 PM	2:43 PM	59	48	33	15	3.339	1.05	1.12	74	65	0	Solana Beach	0.9	
30-Sep-08	Tue	0.73	4:00 PM	4:44 PM	66	55	38	17	11.245	0.22	0.05	74	63	0	Solana Beach	0.6	
6-Oct-08	Mon	1.03	3:45 PM	4:47 PM	38	34	16	15	3.339	4.10	3.70	75	62	0	Solana Beach	0.4	

Solana Beach Study Beach Counts

PN: 2567

28-Sep-10

Date	Day	Duration (hours)	Time Range		Total Count	Adult Count	Avg Adult Count Per Half-Hour	Time Block	Adj Factor	Tide Range (MLLW)		Weather Conditions: Max Temp	Min Temp	Precip (inches)	Weather Station Location	Wind Speed @ SIO Pier (m/s)	Notes by Solana Beach Observers
										2008							
11-Oct-08	Sat	0.75	2:00 PM	2:45 PM	57	45	30	15	3.339	1.21	1.40	66	57	0	Solana Beach	8.6	
15-Oct-08	Wed	0.78	3:55 PM	4:42 PM	124	93	59	15	3.339	-0.64	-0.75	77	57	0	Solana Beach	0.7	
19-Oct-08	Sun	1.00	4:00 PM	5:00 PM	126	105	53	17	11.245	3.58	2.37	65	59	0	Solana Beach	0.5	
24-Oct-08	Fri	0.68	11:40 AM	12:21 PM	88	74	54	11	2.662	1.89	1.42	73	59	0	Solana Beach	0.6	

28-Oct-08	Tue	0.63	3:45 PM	4:23 PM	55	54	43	15	3.339	-0.36	-0.31	70	57	0	Solana Beach	0.2	
30-Oct-08	Thu	0.72	3:45 PM	4:28 PM	22	17	12	15	3.339	0.24	-0.16	70	54	0	Solana Beach	1.8	
7-Nov-08	Fri	0.65	1:00 PM	1:39 PM	55	48	37	13	2.741	2.74	3.04	73	52	0	Sea World	1.4	
10-Nov-08	Mon	0.67	9:05 AM	9:45 AM	14	14	11	9	4.554	4.05	3.14	67	54	0	Solana Beach	4.8	
12-Nov-08	Wed	0.65	2:20 PM	2:59 PM	48	41	32	15	3.339	-1.19	-1.18	69	52	0	Solana Beach	1.8	
18-Nov-08	Tue	0.67	11:00 AM	11:40 AM	7	7	5	11	2.662	4.69	4.99	70	57	0	Solana Beach	0.3	
20-Nov-08	Thu	0.75	1:00 PM	1:45 PM	17	15	10	13	2.741	3.19	3.61	65	51	0	Solana Beach	1.4	Cold
23-Nov-08	Sun	0.75	7:00 AM	7:45 AM	18	16	11	7	20.407	5.53	5.07	67	56	0	Solana Beach	2.4	
29-Nov-08	Sat	0.50	10:30 AM	11:00 AM	50	50	50	11	2.662	5.38	4.97	66	52	0	Solana Beach	0.8	
4-Dec-08	Thu	0.75	3:00 PM	3:45 PM	16	16	11	15	3.339	3.38	2.89	66	56	0	Solana Beach	4	Overcast/Cool
9-Dec-08	Tue	0.63	1:00 PM	1:38 PM	18	17	13	13	2.741	-0.48	-0.39	74	50	0	Solana Beach	3.6	Sunny/Breezy/Cool
12-Dec-08	Fri	0.63	3:00 PM	3:38 PM	47	38	30	15	3.339	-1.86	-1.88	64	50	0	Oceanside Marina	3.9	
17-Dec-08	Wed	0.58	7:15 AM	7:50 AM	1	1	1	7	20.407	2.32	2.54	53	49	1.61	Solana Beach	1.8	Rain/Cold/Windy
20-Dec-08	Sat	0.75	9:45 AM	10:30 AM	39	32	21	9	4.554	1.52	1.29	61	43	0	Solana Beach	4.6	Clear/Cold
21-Dec-08	Sun	0.83	11:45 AM	12:35 PM	60	45	27	11	2.662	0.66	0.68	61	44	0	Solana Beach	4.0	

Solana Beach Study Beach Counts

PN: 2567

28-Sep-10

Date	Day	Duration (hours)	Time Range		Total Count	Adult Count	Avg Adult Count Per Half-Hour	Time Block	Adj Factor	Tide Range (MLLW)		Weather Conditions			Weather Station Location	Wind Speed @ SIO Pier (m/s)	Notes by Solana Beach Observers
												Max Temp	Min Temp	Precip (inches)			
2009																	
29-Dec-08	Mon	0.58	10:45 AM	11:20 AM	6	6	5	11	2.662	5.39	4.91	62	45	0	Solana Beach	0.2	
9-Jan-09	Fri	0.50	1:00 PM	1:30 PM	17	17	17	13	2.741	-0.09	-1.45	60	51	0	Solana Beach	0.8	Clear/Sunny Breezy/Cool
12-Jan-09	Mon	0.58	11:20 AM	11:55 AM	18	9	8	11	2.662	5.64	4.75	75	56	0	Solana Beach	3.1	Clear/Windy/Santa Ana Warm
15-Jan-09	Thu	0.67	8:50 AM	9:30 AM	1	1	1	9	4.554	2.79	3.35	66	55	0	Solana Beach	0.7	Clear/Cool
17-Jan-09	Sat	0.83	10:30 AM	11:20 AM	207	188	113	11	2.662	1.76	2.08	67	50	0	Solana Beach	0.8	Clear/Warm
20-Jan-09	Tue	0.60	12:46 PM	1:22 PM	79	73	61	13	2.741	0.17	0.25	67	57	0	Solana Beach	0.8	Cloudy/Cool
25-Jan-09	Sun	0.58	1:00 PM	1:35 PM	60	54	46	13	2.741	0.87	0.16	61	49	0.08	Solana Beach	5.8	Partly Cloudy/Cool
28-Jan-09	Wed	0.50	7:20 AM	7:50 AM	0	0	0	7	20.407	3.92	4.39	62	42	0	Solana Beach	4.1	Clear/Cold
3-Feb-09	Tue	0.62	9:28 AM	10:05 AM	21	18	15	9	4.554	0.80	0.63	67	52	0	Solana Beach	0.7	Clear
8-Feb-09	Sun	0.58	12:40 PM	1:15 PM	77	64	55	13	2.741	0.18	-0.68	60	49	0.2	Solana Beach	3.4	Sunny-Partly Cloudy/Breezy/Cool
12-Feb-09	Thu	0.58	2:40 PM	3:15 PM	7	6	5	15	3.339	1.62	0.98	59	48	0	Solana Beach	5.1	Clear-Cloudy/Windy/Cold
16-Feb-09	Mon	0.50	10:30 AM	11:00 AM	0	0	0	11	2.662	1.11	1.20	57	47	0.53	Solana Beach	3.4	Rain & Cold
18-Feb-09	Wed	0.67	11:40 AM	12:20 PM	28	23	17	11	2.662	0.38	0.30	61	44	0	Solana Beach	3.5	Clear/Sunny/Windy/Cold

21-Feb-09	Sat	0.58	10:15 AM	10:50 AM	81	81	69	11	2.662	2.76	1.98	64	49	0	Solana Beach	0.6	
27-Feb-09	Fri	0.58	7:00 AM	7:35 AM	6	6	5	7	20.407	2.27	2.88	64	50	0	Solana Beach	3.1	Cloudy/Cold
5-Mar-09	Thu	0.55	11:02 AM	11:35 AM	40	38	35	11	2.662	-0.30	-0.36	60	Missing	0	Solana Beach	5.8	Clear/Cool
10-Mar-09	Tue	0.62	2:45 PM	3:22 PM	49	45	36	15	3.339	-0.32	-0.73	61	47	0	Solana Beach	1.9	Clear/Sunny/Cool
15-Mar-09	Sun	0.65	7:00 AM	7:39 AM	5	5	4	7	20.407	0.34	0.42	61	54	0	Solana Beach	1.3	Cloudy/Cold/Breezy
18-Mar-09	Wed	0.62	11:03 AM	11:40 AM	33	24	19	11	2.662	0.74	0.73	61	51	0	Solana Beach	0.1	Foggy - Sunny
21-Mar-09	Sat	0.58	1:00 PM	1:35 PM	66	57	49	13	2.741	0.08	-0.05	63	55	0	Solana Beach	0.8	Sunny/Breezy/Cool

Solana Beach Study Beach Counts

PN: 2567

28-Sep-10

Date	Day	Duration (hours)	Time Range		Total Count	Adult Count	Avg Adult Count Per Half-Hour	Time Block	Adj Factor	Tide Range (MLLW)		Weather Conditions: Max Temp	Weather Conditions: Min Temp	Weather Conditions: Precip (inches)	Weather Station Location	Wind Speed @ SIO Pier (m/s)	Notes by Solana Beach Observers
2009																	
27-Mar-09	Fri	0.58	3:03 PM	3:38 PM	139	121	104	15	3.339	0.96	0.65	66	52	0	Solana Beach	2.7	Clear/Sunny/Warm/Cool/Breezy
30-Mar-09	Mon	0.50	8:30 AM	9:00 AM	10	9	9	9	4.554	0.32	0.70	65	52	0	Solana Beach	3.6	Cloudy/Cool
3-Apr-09	Fri	0.53	12:20 PM	12:52 PM	26	25	23	13	2.741	-0.39	-0.25	57	48	0	Solana Beach	4.2	
8-Apr-09	Wed	0.52	2:42 PM	3:13 PM	80	61	59	15	3.339	0.22	0.12	68	57	0	Del Mar Fire Station	4.3	
11-Apr-09	Sat	0.50	8:00 AM	8:30 AM	1	1	1	9	4.554	1.23	1.78	67	48	0.10	Del Mar Fire Station	6.7	Cloudy/Cold
13-Apr-09	Mon	0.50	2:35 PM	3:05 PM	25	23	23	15	3.339	2.73	2.59	65	51	0	Solana Beach	0.5	Light Overcast/Warm
16-Apr-09	Thu	0.58	10:40 AM	11:15 AM	68	63	54	11	2.662	0.62	0.73	57	48	0	Solana Beach	2.3	Sunny/Cold/?
21-Apr-09	Tu	0.50	7:00 AM	7:30 AM	13	13	13	7	20.407	4.10	4.20	79	55	0	Del Mar Fire Station	0.7	
26-Apr-09	Sun	0.50	12:00 PM	12:30 PM	40	33	33	13	2.741	3.62	3.43	64	48	0	Del Mar Fire Station	3.6	
5-May-09	Tue	0.60	12:31 PM	1:07 PM	55	50	42	13	2.741	0.73	0.49	71	40	0	Del Mar Fire Station	1.5	Sunny/Clear/Warm
8-May-09	Fri	0.58	12:35 PM	1:10 PM	20	19	16	13	2.741	2.64	2.19	68	57	0	Oceanside Marina	2.7	Overcast/Cool/Breezy
11-May-09	Mon	0.58	10:25 AM	11:00 AM	10	10	9	11	2.662	2.60	2.93	66	59	0	Solana Beach	2.1	Light Overcast/Sunny/Warm/Cool Breeze
14-May-09	Thu	0.57	6:51 AM	7:25 AM	30	30	26	7	20.407	0.35	0.19	67	57	0	Solana Beach	no data	Clear/Cool
20-May-09	Wed	0.50	12:30 PM	1:00 PM	39	35	35	13	2.741	1.09	1.10	73	61	0	Del Mar Fire Station	no data	
24-May-09	Sun	1.08	2:20 PM	3:25 PM	429	292	135	15	3.339	1.86	1.64	73	58	0	Del Mar Fire Station	no data	*(Memorial Day Weekend)
Memorial Day - 25 May																	
30-May-09	Sat	0.55	8:50 AM	9:23 AM	20	16	15	9	4.554	-0.09	-0.19	67	60	0.01	Del Mar Fire Station	no data	
2-Jun-09	Tue	0.62	10:40 AM	11:17 AM	40	32	26	11	2.662	1.47	1.20	74	61	0	Del Mar Fire Station	no data	Sunny/Warm
7-Jun-09	Sun	0.62	3:11 PM	3:48 PM	335	273	221	15	3.339	2.13	2.19	68	59	0	Solana Beach	no data	Sunny/Warm *(Fiesta Del Sol)
12-Jun-09	Fri	0.57	6:52 AM	7:26 AM	26	25	22	7	20.407	-0.02	-0.03	67	61	0	Solana Beach	no data	Cloudy/Cool

Solana Beach Study Beach Counts

PN: 2567

28-Sep-10

Avg Adult

Weather Conditions

Wind Speed

Date	Day	Duration	Time Range		Total Count	Adult Count	Avg Adult Count Per Half-Hour	Time Block	Adj Factor	Tide Range (MLLW)		Max Temp	Min Temp	Precip (inches)	Weather Station Location	Wind Speed @ SIO Pier (m/s)	Notes by Solana Beach Observers
2009																	
17-Jun-09	Wed	0.50	10:48 AM	11:18 AM	67	54	54	11	2.662	1.54	1.58	69	64	0	Solana Beach	no data	Overcast/Warm
20-Jun-09	Sat	0.67	12:28 PM	1:08 PM	37	35	26	13	2.741	2.1	1.93	67	63	Trace	Solana Beach	no data	Overcast/Heavy Mist
25-Jun-09	Thu	0.58	8:04 AM	8:39 AM	25	25	21	9	4.554	-0.37	0.31	69	63	0	Solana Beach	no data	Overcast
29-Jun-09	Mon	0.65	8:34 AM	9:13 AM	43	41	32	9	4.554	1.1	0.96	68	62	0	Solana Beach	no data	Overcast
3-Jul-09	Fri	0.72	11:30 AM	12:13 PM	189	132	92	11	2.662	2.67	2.43	70	61	0	Solana Beach	no data	Overcast
Independence Day - 4 Jul																	
8-Jul-09	*Wed*	*0.57*	*6:10 AM*	*6:44 AM*	23	23	20	7	20.407	-0.28	0.12	66	59	0	Solana Beach	no data	
12-Jul-09	Sun	0.60	7:54 AM	8:30 AM	46	42	35	7	20.407	0.66	0.99	80	62	0	Del Mar Fire Station	no data	
14-Jul-09	Tue	0.73	10:01 AM	10:45 AM	114	78	53	11	2.662	1.97	2.45	78	66	0	Del Mar Fire Station	no data	
18-Jul-09	Sat	0.92	12:30 PM	1:25 PM	471	347	189	13	2.741	2.37	2.6	72	64	0	Solana Beach	no data	
20-Jul-09	Mon	0.67	12:45 PM	1:25 PM	311	197	148	13	2.741	2.4	2.06	79	66	0	Del Mar Fire Station	no data	
23-Jul-09	*Thu*	*3.72*	*5:06 AM*	*8:49 AM*	*58*	*58*	*8*	9	4.554	-1.46	2.52	74	67	0	Sea World	no data	

23-Jul-09 Assumed time of survey to be "AM"

Indicates weekend date

Max Temp 62° or below

Time Blocks Used:

Time Block	Adj Factor
7	20.407
9	4.554
11	2.662
13	2.741
15	3.339
17	11.245

CURRICULUM VITAE

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Employment

Professor, Department of Mathematics and Statistics
San Diego State University — 2009 to present

Founding Director and Graduate Advisor
Computational Statistics PhD Concentration — 2007 to present

Associate Professor, Department of Mathematics and Statistics
San Diego State University — 2004 to 2009

Coordinator, Division of Statistics, Department of Mathematics and Statistics
San Diego State University — 2005 to 2006

Assistant Professor, Department of Mathematics and Statistics
San Diego State University — 2002 to 2004

Assistant Professor, Department of Statistics,
University of California, Davis — 1996 to 2002

Visiting Scientist, Geophysical Statistics Project,
National Center of Atmospheric Research — 1996 to 1997

Affiliate group memberships:

SDSU/UC San Diego Bioinformatics & Medical Informatics Graduate Program	2008 to present
SDSU/UC Davis Joint Doctoral Program in Ecology	2000 to present
SDSU/Claremont Graduate University Joint Doctoral Program in Computational Science	2002 to present
UC Davis Epidemiology Graduate Group	1997 to 2002
UC Davis Center for Health Services Research in Primary Care	1997 to 2002
UC Davis Biostatistics Affinity Group	1996 to 2002

Education **Cornell University**
Ph.D. in Statistics, August 1996
Thesis: Optimizing Convergence Rates and Variances in Gibbs Sampling Schemes
Advisor: Professor George Casella
Major in Mathematical and Environmental Statistics
Minors in Epidemiology and Biometrics
Phi Kappa Phi, May 1993

M.S. in Statistics, January 1994
Thesis: Convergence of Posterior Odds

State University of New York at Binghamton
B. S. in Mathematics with honors, May 1991
GPA: 4.0 Phi Beta Kappa, May 1990
Tropical Ecology - Caribbean, Galapagos Islands, Amazon, January 1989, 1990

Extramural Funding

Co-PI, National Science Foundation, "Modeling and Validation for Cross-Platform Comparison of Microarray Data and Development of a Platform Independent Database for Biomedical Hypothesis Generation and Testing" $777,585, 2010-2013, submitted

Co-PI, National Science Foundation, S-STEM program, "Bioinformatics Statistical Informatics Track" $589,034 2010-2015

Principal Investigator, National Institutes of Health–National Eye Institute, "Measuring and Predicting Visual Field Progression with Longitudinal-Survival CART" $430,199 2009-2011

Co-Investigator, National Institutes of Health, R03CA117292, "Error in Diet Assessment: Impact on Diet-Cancer Trials" $152,219 2006-2008

Principal Investigator, Fulbright scholarship, "Computational Environmetrics/Biometrics for Environmental Studies and Public Health Policy," Zhejiang University, Hangzhou, China, 2007

Principal Investigator, National Science Foundation DMS-0329380, focused research group collaborative proposal, "Statistical Analysis of Uncertainty in Climate Change" $55,423 2002-2006

Principal investigator, National Science Foundation INT-0328581, "Bayesian Inventory Management under Censored Demand" $18,560 2001-2006

Principal investigator, Lawrence Livermore National Laboratory/Department of Energy, "Stochastic Engine/Deep Injection Initiative: Markov chain Monte Carlo sampling of solutions to inverse problems" $56,549 2001-2003

Principal investigator, National Science Foundation DMS-0079430, Scientific Computing Research Environments for the Math Sci $182,981 2000-2003

Principal investigator, National Science Foundation and Environmental Protection Agency DMS-9978321, "Probabilistic Modeling and Computational Methods in Environmental Statistics" $99,600 1999-2001

Principal investigator, four grants:
NSF, ONR, NIH, NSA "Sixth North American Meetings of New Researchers in Statistics and Probability," $55,000 in total 2002-2003

Intramural Funding

University of California, Davis (UCD) Faculty Research Grant, "Optimal Markov Chain Monte Carlo Samplers" 2001 - 2002

Principal investigator, UCD Faculty Research Grant, "Improved Monte Carlo Markov Chain Sampling Schemes" Summer 1997

Principal investigator, UCD Junior Faculty Research Fellowship, "Improved Monte Carlo Markov Chain Sampling Schemes" Summer 1996

Principal investigator, UCD Undergraduate Instructional Improvement Program (UIIP) Grant, "Interactive Computer-based Presentations in the Introductory Statistics Classroom" 2000-2001

Principal investigator, UCD UIIP Grant, "Incorporating Matlab into Undergraduate Statistical Computing Courses" 1998-1999

Principal investigator, UCD UIIP Grant, "Statistical Computing via a Web-Based System" 1997-1998

Honors and Awards

Fellow, American Statistical Association 2010

Outstanding Faculty Member, SDSU College of Sciences 2009-2010

Fulbright Scholarship to Zhejiang University, Hangzhou, China Spring 2007

Fellowship recipient for the Third, Fourth, and Fifth IMS New Researchers Conferences Summers 1997, 1999, 2001

Office of Naval Research Graduate Fellow August 1991 to January 1995

NIH Environmental Statistics training grant student August 1991 to July 1996

National Center for Atmospheric Research colloquium on statistics and climate modeling fellowship recipient July 1994

Recipient of Cornell University Graduate School Award January 1994

Excellence in Mathematics Award, SUNY Binghamton May 1991

Guardian Life Insurance Award November 1991

SUNY Foundation Scholarship for Academic Excellence November 1989

Valedictorian, Valley Stream South High School May 1987

Professional Experience

Editor, *Journal of Computational and Graphical Statistics* 2010-present

Editor-Elect, *Journal of Computational and Graphical Statistics* 2009

Member, Committee on Publications, American Statistical Assoc 2010-present

Member, American Statistical Association *Journal of Computational and Graphical Statistics* Management Committee 2009-present

Assoc Editor, *Journal of Computational and Graphical Statistics* 1998-2009

External reviewer, Zhejiang University School of Medicine, doctoral dissertation of Jin Mingjuan Summer 2007

External reviewer, Zhejiang University School of Medicine, thesis papers of Huang Xianhong and Jin Mingjuan Spring 2007

Statistical adviser, Zhejiang University Foreign Medical Student program, first-year laboratory practicals 2007

Vice President of Academic Affairs, San Diego Chapter of the American Statistical Association 2003-2005

Continuing Education Officer, Section on Statistics in the Environment, American Statistical Association 2003-2005

Program chair and organizer, ASA Statistical Careers Day 2003-2005

Expert reviewer for the National Research Council Board on Atmospheric Sciences and Climate report on climate change 2005

ETS Faculty Consultant for AP exam in Statistics 2001-2005

Session organizer and chair, Joint Statistics Meetings, Minnesota August 2005

Program committee, Conference on "Computational Environmetrics," Chicago, Illinois 2003-2004

External expert reviewer, Lawrence Livermore National Laboratory program review panel April 2001, August 2003

Program chair and organizer, IMS New Researchers Conference 2001-2004

Member, IMS new researchers committee 1999-2003

Webmaster for the IMS New Researchers Conferences, 1999 and 2001 organization committee 1999-2003

Member, IMS Nominations Committee 2002-2004

Member, WNAR Nominations Committee 2002-2004

Member, WNAR Biometrics Regional Advisory board 1998-2001

Nominated to run for Sec/Treas of ASA Computing Section Fall 2000

AP Statistics exam survey and reviews for ETS Fall 1999

Remote organizer and member of the organizing committee for the IMS New Researchers Conference at Johns Hopkins University, received *Certificate of Appreciation* for efforts August, 1999

Session organizer and chair, Joint Statistics Meetings, NY, NY August 2002

Session chair, Joint Statistics Meetings, Baltimore August 1999

Session chair, Western North American Region of the Biometrics Society annual meeting, San Diego June 1998

Session chair, section for Physical Engineering and Sciences at the Joint Statistical Meetings, Anaheim August 1997

Member: Institute of Mathematical Statistics, American Statistical Association, International Biometrics Society, International Society for Bayesian Analysis, Society for American Baseball Research

Reviewed papers for *American Statistician*, *Biometrika*, *Journal of Climate*, *Journal of Computational and Graphical Statistics*, *Journal of Quantitative Analysis in Sports*, *Journal of Statistical Planning and Inference*, *Journal of the American Statistical Association*, *Statistics and Computing*, *Statistical Modeling*, and *Statistical Science*

Reviewed grant proposals for the *National Science Foundation*

Significant University service at SDSU

Director and Graduate adviser, Computational Statistics PhD Concentration, 2007-present

Member, Committee for Academic Review of the SDSU Department of Information and Decision Systems, 2008-2009

Chair, Applied Statistics faculty search committee, 2007-2008

Division of Statistics Coordinator, Department of Mathematics and Statistics, 2005-2006

Technical administrator, SDSU site licenses for SPlus and CIS, 2004-present

Elected Member, Department of Mathematics and Statistics Retention, Tenure, and Promotion Committee, 2004-2006, 2007-2008

Member, Department of Mathematics and Statistics Executive Committee, 2005-2006

Member, College of Sciences Research Committee, 2004-2006

Member, Department of Math/Stat Chair search committee, 2005-2006

Member, Biostatistics faculty search committee, 2005-2006

Member, Applied Statistics faculty search committee, 2005-2006

Chair, Department of Math/Stat, Computer Equipment and Operations, 2004-2005, 2009-present

Person-in-charge, Statistics Division organization of Fall 2005 class schedule and teaching assignments, Spring 2005

Member, SDSU Phi Beta Kappa Committee on Members in Course, 2002-2005

Chair, ad hoc committee to develop BS with emphasis in statistical computing, 2002-2003

Visiting Researcher

Zhejiang University, China, Dept of Epi and Biostat	Winter-Summer 2007
Bilkent University, Turkey, Department of Industrial Engineering	Spring 2000
Cornell University Department of Statistics	Summer 1999
Cornell and Ohio State Universities Departments of Statistics	Spring 1998

Academia Sinica, Taiwan R. O. C. Winter 1994-1995

Centre de Recherche en Economie et Statistique, Paris, France September 1994

Naval Health Research Center, San Diego, CA Summer 1992

Invited speaker at Universities and research centers

UCLA Deparment of Biostatistics, January 2010

University of Maryland Department of Mathematics, December 2009

CSU Calpoly San Luis Obispo Dept of Stat, May 2008

SDSU Mathematics Literary Group, September 2007

Zhejiang Medical Academy, Department of Public Health Hangzhou, China, June 2007

Shanghai Jiaotong University, Department of Mathematics, Shanghai, China, June 2007

Northwest University, Department of Environmental Science and Geography, Xi'an, China, May 2007

Zhejiang University School of Medicine, Hangzhou, China, May 2007

Zhejiang University Department of Epidemiology and Biostatistics, Hangzhou, China, March 2007

UC Santa Cruz Department of Statistics, February 2006

UC San Diego Division of Biostatistics, January 2006

UC Irvine Department of Statistics, November 2005

SDSU Computational Sciences Colloquium, March 2005

Portland State U Department of Mathematics and Statistics, February 2005

UC Riverside Department of Statistics, November 2004

UCLA Department of Biostatistics, November 2003

SDSU Department of Mathematics and Statistics, November, 2003

SDSU Ecology and Evolutionary Biology Seminar, February 2003

UCSD Division of Biostatistics, November 2002

Claremont Graduate University Comp Science Workshop, October 2002

SDSU Department of Mathematics and Statistics, February 2002

Pomona College Department of Mathematics, February 2002

SFSU Department of Mathematics, February 2002

CSUF Department of Mathematics, February 2002

CSULB Department of Mathematics, February 2002

Bilkent University, Turkey, Department of Industrial Engineering, June, 2000

Purdue University, Department of Statistics, May, 2000

Iowa State University, Department of Statistics, October, 1999

Geophysical Statistics Project, NCAR, Boulder, CO, June, 1999

UCDMC Center for Health Research in Primary Care, March, 1999

UC Davis Division of Statistics, October, 1998

Boston University, Mathematics Department, September, 1998

Ohio State University Statistics Seminar, April, 1998

Cornell University Statistics Seminar, April, 1998

UCD Atmospheric Science Group, October, 1997

UC Davis, Division of Statistics, October, 1997

Neyman Seminar, UC Berkeley, Department of Statistics, September, 1997

University of Colorado, Boulder Mathematics Seminar, March, 1997

Colorado State University Statistics Symposium, February, 1997

University of Colorado Health Sciences Center, February, 1997

UC Davis, Division of Statistics, October 1996

Invited talks at conferences and workshops

IMS Annual Meeting, Gottenburg, Sweden, August 2010

KSEA US-Korea Conference on Science, Technology, and Entrepreneurship, San Diego, California, August 2008

American Mathematical Society, San Diego, California, January 2008

University of Washington/NOAA Fisheries workshop, June 2003

IMS New Researchers Conference, Davis, CA, July 2003

Joint Statistical Meetings, New York, New York, August 2002

EPA/NSF Meeting on Environmental Statistics, September, 2001

Joint Statistical Meetings, Atlanta, August, 2001

IMS New Researchers Conference, Atlanta, August, 2001

Sacramento Statistical Society Annual Meetings, April, 2001

International Society for Bayesian Analysis Conference, Hersonissos, Crete, June 2000

Workshop for hierarchical modeling in Environmental Statistics, Ohio State University, May 2000

IMS New Researchers Conference, Baltimore, August, 1999

WNAR/IMS Annual Meeting, Seattle, June 1999

Invited Poster Session, Joint Statistical Meetings, August, 1997

IMS New Researchers Conference, July, 1997

IMS Asian and Pacific Regional Meeting, July, 1997

National Center for Atmospheric Research, Boulder, CO, January, 1997

Contributed talks at conferences

WNAR/IMS Annual Meeting, Seattle, June 1999

Joint Statistical Meetings, Dallas, August 1998

WNAR/IMS Annual Meeting, San Diego, June 1998

Significant Statistical Consulting

Shaban Demirel, Devers Eye Institute, Portland Oregon, "Psychophysics in Glaucoma Study" 2008 - present

Loki Natarajan, Department of Preventive Medicine, UCSD, "Diet assessment in the Women's Healthy Eating and Living study" 2005 - present

Toshi Hayashi, Cancer Detection Service and Sue Lindsay, San Diego State University Graduate School of Public Health, "Clinical Services Quality Assurance Project" 1999 - present

John Keltner, Dept of Opthalmology, UCDMC, "Ocular Hypertensive Treatment Study" 2002 - 2007

Kathleen Yost, Healthcare Research Institute, Evanston Illinois, "Quality of life assessment in the Women's Healthy Eating and Living study" 2004-2005

Paul Hagerman, Dept of Biological Chemistry, UCDMC, "Neurological Phenotype on FMR1 Premutation Carriers" 2002 - 2004

Clara Eder, University of San Diego, "ProKids Golf Academy quality of service study" 2002 - 2004

Randi Hagerman, MIND Institute, UCDMC, "Study of fragile-X syndrome" 2001 - 2004

Barth Wilsey, Anesthesiology and Pain Management, UCDMC, "Risk factors for morbidity from chest wall trauma" 2000-2003

California Department of Corrections, "Evaluation of the Preventing Parolee Crime Program" 1999 - 2003

Jane Yuen, UCDMC, "Effect of Simvastatin on Hemodialysis Access Failure" 1997 - 1999

Richard Katzberg, UCDMC, "Comparison of X-Ray film and MRI for spinal injury diagnoses" 1996 - 1998

Richard Kravitz, Center for Health Services Research in Primary Care, Vision Project 1997 - 1998

Peer Reviewed Publications

(underlined names denote graduate students I worked with on the paper)

1. Levine, R. A., Fan, J., Ohman, P. A., Demirel, S. Frailty Modeling via the Empirical Bayes Hastings Sampler. Submitted to *Biostatistics*.

2. Levine, R. A., Fan, J., Su, X-G., Nunn, M. E. Bayesian Multivariate Survival Trees for Tooth Prognosis. Submitted to *Computational Statistics and Data Analysis*.

3. Natarajan, L., Pu, M., Fan, J., Levine, R. A., Patterson, R. E., Thomson, C. A., Rock, C. L., Pierce, J. P. Measurement Error of Dietary Self-report in Intervention Trials. To appear in *American Journal of Epidemiology*.

4. Brown, G., Levine, R. A., Tikare, V. and Olevsky, E. (2010). Meso-scale Monte Carlo Sintering with Anisotropic Grain Growth. *Advances in Sintering Science and Technology*, 101-111.

5. Brown, G., Levine, R. A., Shaikh, A., and Olevsky, E. (2009). Three-dimensional Solar Cell Finite Element Sintering Simulation. *Journal of the American Ceramic Society* 82, 1450-1455.

6. Demirel, S., Fortune, B., Fan, J., Levine, R. A., Torres, R., Nguyen, H., Mansberger, S. L., Gardiner, S. K., Cioffi, G. A., and Johnson, C. A. (2009). Predicting progressive glaucomatous optic neuropathy using baseline standard automated perimetry data. *Investigative Ophthalmology and Vision Science* 50, 674-680.

7. Levine, R. A. and Casella, G. (2008). Comment: On Random Scan Gibbs Samplers. *Statistical Science* 23, 192-195.

8. Fan, J., Ghurye, S., and Levine, R. A. (2008). Lundberg Process Lifetime Distributions with Aging. *Journal of Probability and Statistical Science* 6, 13-24.

9. Levine, R. A. and Bhattacharya, D. (2007). Bayesian Estimation and Prior Selection for the AR(1) Model Using Asymmetric Loss Functions. *Journal of Applied Statistical Science* 15, 295-304.

10. Fan, J. and Levine, R. A. (2007). To amnio or not to amnio: that is the decision for Bayes. *Chance* 20, 26-32.

11. Berk, E., Gürler, Ü., and Levine, R. A. (2007). Bayesian demand updating in the lost sales newsvendor problem: A two-moment approximation. *European Journal of Operation Research* 182, 256-281.

12. Keltner, J.L., Johnson, C.A., Cello, K.E., Bandermann, S.E., Fan, J.J., Levine, R.A., Kass, M.A., and Gordon, M.O. (2007). Visual Field Quality Control in the Ocular Hypertension Treatment Study (OHTS). *Journal of Glaucoma* 16, 665-669.

13. Mathur, J., Bizzoco, R. W., Ellis, D. G., Lipson, D. A., Poole, A., Levine, R. A., and Kelley, S. T. (2007). Effects of abiotic factors on the phylogenetic diversity of bacterial communities in acidic thermal springs. *Applied and Environmental Microbiology* 73, 2612-2623.

14. Levine, R. A. and Casella, G. (2006). Optimizing Random Scan Gibbs Samplers. *Journal of Multivariate Analysis* 97, 2071-2100.

15. Fan, J., Su, X-G., Levine, R. A., Nunn, M., and LeBlanc, M. (2006). Assigning Tooth Prognosis by Multivariate Survival Trees. *Journal of the American Statistical Association* 101, 959-967.

16. Levine, R. A., Demirel, S., Fan, J., Keltner, J. L., Johnson, C. A., Kass, M. A. Asymmetries and Visual Field Summaries as Predictors of Glaucoma in the Ocular Hypertension Treatment Study. (2006). *Investigative Ophthalmology and Vision Science* 47, 3896-3903.

17. Keltner, J. L., Johnson, C. A., Anderson, D. R., Levine, R. A., Fan, J., Cello, K. E., Quigley, H. A., Budenz, D., L., Parish, R. K., Kass, M. A., Gordon, M. O. (2006). The Association Between Glaucomatous Visual Fields and Optic Nerve Head Features in the Ocular Hypertension Treatment Study. *Ophthalmology* 113, 1603-1612.

18. Layton, D. F. and Levine, R. A. (2005). Bayesian Approaches to Modeling Stated Preference Data. *Applications of Simulation Methods in Environmental and Resource Economics* edited by R. Scarba and A. A. Alberini. Springer, New York, Chapter 10.

19. Levine, R. A. and Bhattacharya, D. (2005). On Asymptotically Efficient Sequential Tests for Autoregressive Times Series with a Unit Root. *Journal of Probability and Statistical Science* 3, 213-228.

20. Keltner, J. L., Johnson, C. A., Levine, R. A., Fan, J., Cello, K. E., Kass, M. A., and Gordon, M. O. (2005). Normal Visual Field Tests Following Glaucomatous Visual Field Endpoints in The OHTS. *Archives of Ophthalmology* 123, 1201-1206.

21. Levine, R. A. (2005). A Note on Markov Chain Monte Carlo Sweep Strategies. *Journal of Statistical Computation and Simulation* 75, 253-262.

22. Levine, R. A., Yu, Z., Hanley, W. G., Nitao, J. J. (2005). Implementing Componentwise Hastings Samplers. *Computational Statistics and Data Analysis* 2, 363-389.

23. Levine, R. A., Yu, Z., Hanley, W. G., Nitao, J. J. (2005). Implementing the Random Scan Gibbs Sampler. *Computational Statistics* 20, 177-196.

24. Drake, C. and Levine, R. A. (2005). Sensitivity, Specificity, and other Diagnostic Measures with Multiple Sites per Unit. *Contemporary Clinical Trials* 26, 252-259.

25. Yost, K., Haan, M., Levine, R. A., and Gold, R. (2005). Comparing SF-36 scores across three groups of women with different health profiles. *Quality of Life Research* 14, 1251-1261.

26. Levine, R. A. and Fan, J. (2004). An Automated (Markov Chain) Monte Carlo EM Algorithm. *Journal of Statistical Computation and Simulation* 74, 349-359.

27. Jacquemont, S., Hagerman, R. J., Leehey, M., Hall, D. A., Levine, R. A., Brunberg, J. A., Zhang, L., Jardini, T., Gane, L. W., Harris, S. E., Herman, K., Grigsby, J., Greco, C., Berry-Kravis, E., Tassone, F., Hagerman, P. J. (2004). Penetrance of the Fragile-X Associated Tremor/ataxia Syndrome (FXTAS) in a Premutation Carrier

Population: Initial Results from a California Family-based Study. *Journal of the American Medical Association* 291, 460-469.

28. Marchetti, M., Moyle, P., Levine, R. A. (2004). Alien fishes in California watersheds: characteristics of successful and failed invaders. *Ecological Applications* 14, 587-596.

29. Marchetti, M., Moyle, P., Levine, R. A. (2004). Invasive species profiling? Exploring the Characteristics of Non-native Fishes Across Invasion Stages in California. *Freshwater Biology* 49, 646-661.

30. Layton, D. F. and Levine, R. A. (2003). How Much Does the Far Future Matter? A Hierarchical Bayesian Analysis of the Public's Willingness to Mitigate Ecological Impacts of Climate Change. *Journal of the American Statistical Association* 98, 533-544.

31. Levine, R. A. and Casella, G. (2003). Implementing Matching Priors for Frequentist Inferences. *Biometrika* 90, 127-137.

32. Lin, C-D., Levine, R. A. (2003). Mega Deal? A Relative Performance Analysis for Major League Baseball Players. *Economics, Management, and Optimization in Sports*, edited by P. M. Pardalos, S. Butenko, and J. Gil-Lafuente, pages 163-184. Springer, New York.

33. Jacquemont, S., Hagerman, R. J., Leehey, M., Grigsby, J., Zhang, L., Brunberg, J. A., Greco, C., Des Portes, V., Jardini, R., Levine, R. A., Berry-Kravis, E., Brown, W. T., Schaeffer, S., Kissel, J., Tassone, F., Hagerman, P. J. (2003). Fragile X Premutation Tremor/Ataxia Syndrome: Molecular, Clinical, and Neuroimaging Correlates. *American Journal of Human Genetics* 72 (4), 869-878.

34. Levine, R. A. and Casella, G. (2001). Implementations of the Monte Carlo EM Algorithm. *Journal of Computational and Graphical Statistics* 10, 422-439.

35. Berk, E., Gürler, Ü., and Levine, R. A. (2001). The Newsboy Problem with Bayesian Updating of the Demand Distribution and Censored Observations. *Bayesian Methods with Applications to Science, Policy, and Official Statistics, Selected Papers from ISBA 2000: The Sixth World Meeting of the International Society for Bayesian Analysis*, 21-30.

36. Watnik, M. and Levine, R. A. (2001). NFL Y2K PCA. *Journal of Statistics Education* Volume 9(3).

37. Levine, R. A. (2001). Discussion of "The Art of Data Augmentation" by D. A. van Dyk and X. Meng. *Journal of Computational and Graphical Statistics* 10, 51-59.

38. Berliner, L. M., Levine, R. A., and Shea, D. (2000). Bayesian Assessment of Climate Change. *Journal of Climate* 13, 3805-3820.

39. Fan, J., Ghurye, S. G., and Levine, R. A. (2000). Multi-component Lifetime Distribution in the Presence of Aging. *Journal of Applied Probability* 37, 521-533.

40. Yuen, J. Y., Levine, R. A., Mantadilok, V., and Kaysen, G. A. (2000). C-Reactive Protein Predicts All-Cause and Cardiovascular Mortality in Hemodialysis Patients. *American Journal of Kidney Diseases* 35, 469-476.

41. Levine, R. A. and Berliner, L. M. (1999). Statistical Principles for Climate Change Studies. *Journal of Climate* 12, 564-574.

42. Katzberg, R. W., Benedetti, C., Drake, C., Ivanovic, M., Levine, R. A., Beatty, C., Nemzek, W., McFall, R., Ontell, F., and Bishop, D. (1999). Prospective Magnetic Resonance Imaging Assessment of Acute Cervical Spine Injuries in a Level I Trauma Center. *Radiology* 213, 203-212.

43. Briggs, W. M. and Levine R. A. (1997). Wavelets and Field Forecast Verification. *Monthly Weather Review* 125 (6), 1329-1341.

44. Levine, R. A. and Ohman, P. (1997). Repeated Challenge Studies: A Comparison of Union-Intersection Testing with Linear Modeling. *Psychometrika* 62, 435-455.

45. Levine, R. A. and Casella, G. (1996). Convergence of Posterior Odds. *Journal of Statistical Planning and Inference* 55, 331-344.

46. Garland, F. C., Garland, C. F., Doyle, E. J., Levine, R., Balazs, L. L., Pugh, W. M., Gorham, E. D. (1996). Carpal Tunnel Syndrome and Occupation in U.S. Navy Enlisted Personnel. *Archives of Environmental Health*, 51 (5), 395-407.

Book Reviews and Editorials

1. Levine, R. A. (2000). Review of the book "Statistical Methods in the Atmospheric Sciences" by D. Wilks. *Journal of the American Statistical Association* 95, 344-345.

2. Levine, R. A. and Fan, J. (2000). Review of the book "Practical Statistics by Example Using Microsoft Excel." *American Statistician* 54, 151-153.

Limited Distribution

1. Wilson, J. L. and Levine, R. A. NFL Player Rating Systems: An Investigation of the Passer Rating and Proposal for a Rusher Rating. Under revision for *Journal of Quantitative Analysis in Sports.*

2. Lin, C-D., Levine, R. A., and Davis, J. The General Manager as a Sabrmetrician: Quantitative Decision-making for Designing a Winning (and Profitable) Team. Under revision for *Journal of Quantitative Analyses in Sports.*

3. Kushnarev, B., Brown, G., Levine, R. A., Olevsky, E. A., Tikare, V. (2006). Virtual Reality of Sintering: Implementation of Multiple Scale Models. *Advances in Powder Metallurgy and Particulate Materials* Volume 1, Part 1.

4. Aines, R., Nitao, J., Newmark, R., Carle, S., Ramirez, A., Harris, D., Johnson, J., Johnson, V., Ermak, D. Sugiyama, G., Hanley, W., Sengupta, S., Daily, W., Glaser, R., Dyer, K., Fogg, G., Zhang, Y., Yu, Z, Levine, R. (2002). The Stochastic Engine Initiative: Improving prediction of behavior in geologic environments we cannot directly observe. Technical Report, Lawrence Livermore National Laboratory, UCRL-ID-148221.

5. Lin, J., Saito, N., Levine, R. A. (2001). Edgeworth Approximations of the Kullback-Leibler Distance Towards Problems in Image Analysis. Technical report, Department of Mathematics, University of California, Davis.

6. Lin, J., Saito, N., and Levine, R. A. (2000). An Iterative Nonlinear Gaussianization Algorithm for Resampling Dependent Components. *Proc. 2nd International Workshop on Independent Component Analysis and Blind Signal Separation.* IEEE, Helsinki, Finland, 245-250.

7. Fan, J., Ghurye, S. G., and Levine, R. A. (1999). Polya-Lundberg Process Lifetime Distributions. *Proceedings of the American Statistical Association Joint Statistical Meetings, Biometrics Section*, Baltimore, MD.

8. Drake, C. and Levine, R. A. (1998). Identifying Risk Factors Under Informative Loss to Follow Up. *Proceedings of the American Statistical Association Joint Statistical Meetings, Biometrics Section*, Dallas, TX.

9. Briggs, W. M. and Levine, R. A. (1998). Comparison of forecasts using the bootstrap. *14th Conf. on Probability and Statistics in the Atmospheric Sciences*, Phoenix, AZ, Amer. Meteor. Soc., 1-4.

10. Briggs, W. M. and Levine, R. A. (1996). Wavelets and image comparison: new approaches to field forecast verification. *13th Conf. on Probability and Statistics in the Atmospheric Sciences*, San Francisco, CA, Amer. Meteor. Soc., 274-277.

Advising

Ph.D. students

Daniel Herrlin, Computational Sciences with Concentration in Statistics JDP
Jeffrey Ledahl, Computational Sciences with Concentration in Statistics JDP
Jonathan Wilson, jointly advised with Kristin Duncan, Compstat JDP
Gordon Brown, jointly advised with Eugene Olevsky, Computational Sci JDP
Jen-Jen Chang (Lin), 2000, "Simulation and Synthesis of High-Dimensional Data and Related Issues." Current position: Associate Professor, Ming-Chuan University, Taipei, Taiwan

M.S. students

Jane Friedman, expected graduation Summer 2010
Vince Dayes, 2010; currently independent statistical consultant
Courtney Worman, 2009; currently statistician at Amylin Pharm.
Selwyn Au, 2006; currently statistician auto insurance industry
Doug Wilkins, 2006; currently statistician at Visa
Karen Campbell, 2006; currently PhD student in SDSU Compsci JDP
Ian Fellows, 2006; currently PhD student at UCLA Biostat
Mark LaTurner, 2005; currently statistician at Naval Health Research Center
Evan Stanelle, 2004; currently CEO of BigHat Finance
Adriana López, 2003; currently statistician at MD Anderson Cancer Center
Zhaoxia Yu, 2002; currently Asst Prof, UCI Dept Stats
Heather LeGrand, 2002; currently manager at Market Metrix
Jun Song, 2002; currently unknown
Gabriel Chandler, 2001; currently Asst. Prof. Conn. College
Holly Liu, 2000; currently PhD economist at KPMG accounting firm
Clara Kim, 2000; currently PhD researcher at U Pennsylvania
Brian Moyers, 2000; currently software engineer at Oracle Corp.

Barbara Okihiro, 1999; currently coordinator at Jennings & Assoc Comm.

Ph.D. dissertation committees: 12 students
Advancement to candidacy (doctoral) exam committees: 33 students
Masters thesis/exam committees: 45 students
Committees in Departments of Biology, Ecology, Math/Stat, Music, and Public Health

Teaching

(* indicates I developed and introduced the course)
SDSU: Elementary Statistics (STAT 13), Applied Probability (STAT 550), Statistical Computing (STAT 580*); Advanced Mathematical Statistics (STAT 670A, B), Statistical Computing (STAT 671); Monte Carlo Statistical Methods (STAT 701*)
UC Davis: Elementary statistics (STA 13); Introduction to Biostatistics (STA 100); Statistical Computing (STA 141); PhD Applied Statistics (STA 232 A, B*); Statistics for Ecological Systems (ECL/STA 298*); Davis Honors Challenge projects (HNR 190X)

Interests

SDSU Wind Symphony and Clarinet choir	2002 to present
Davis Klezmer Orchestra, clarinetist	2000 to 2002
UCD Symphony Orchestra, Principal clarinet	1996 to 2002
UCD Clarinet Choir and Wind Symphony	1999 to 2002
Yolo County Concert Band, Principal clarinet	2000 to 2002
Sacramento State University Clarinet Choir, Principal clarinet	Fall 1996

Hobbies include fantasy baseball/football, softball, swimming, swing, ballroom, and Latin dancing, and the Lindy-hop.

SANDAG's SAND COST SCHEDULE FOR THE RBSP II PROJECT SCHEDULED FOR APRIL 2012

Construction Costs

ITEM NO.	ITEM DESCRIPTION	Assumed Borrow Site RBSP I	RBSP I Final QT. in CY	UNIT COST	TOTAL	Assumed Borrow Site RBSP II	RBSP II Proposed QT in CY	UNIT COST	TOTAL
Construction Costs									
1	Mobilization & Demobilization			$2,500,000	$2,500,000			$2,500,000	$2,500,000
2	Oceanside Beach	SO7	420,000	$7.01	$2,943,365	SO6	420,000	$11.35	$4,767,000
3	N. Carlsbad	SO5	225,000	$9.01	$2,026,713	SO6	225,000	$10.33	$2,323,421
4	S. Carlsbad	SO7	160,000	$5.54	$886,943	SO5	158,000	$11.41	$1,802,741
5	Batiquitos	SO7	118,000	$5.04	$595,107	SO5	118,000	$10.23	$1,207,247
6	Leucadia Beach	SO7	130,000	$5.33	$692,777	SO5	117,000	$9.80	$1,146,862
7	Moonlight Beach	SO7	103,000	$5.58	$574,649	SO5	105,000	$9.00	$944,841
8	Cardiff Beach	SO6	104,000	$4.72	$491,206	SO5	101,000	$7.77	$784,372
9	Fletcher Cove	SO5	140,000	$5.96	$833,968	SO5	146,000	$7.66	$1,118,198
10	Del Mar	SO5	180,000	$5.29	$952,218	SO5	183,000	$6.80	$0
11	Torrey Pines	SO5	240,000	$5.79	$1,389,651	SO5	245,000	$7.44	$1,822,800
12	Mission Beach	MB1	150,000	$5.26	$788,642	MB1	151,000	$6.76	$0
13	Imperial Beach	MB1	120,000	$9.36	$1,123,026	MB1	120,000	$12.03	$1,443,890
	Total amount of sand:		2,090,000	Subtotal:	$13,298,265		2,089,000	Subtotal:	$17,361,372
14	Construction Contingency			10%	$1,579,826				$1,579,826
15	Construction Management			7%	$1,105,878				$1,105,878
16	Construction Survey or Inspection			3%	$473,948				$473,948
	TOTAL CONSTRUCTION COSTS:				$ 18,957,918				$ 23,021,024

Letter F

Donna Snider

From: Leslea Meyerhoff [lmeyerhoff@cosb.org]
Sent: Monday, October 04, 2010 10:40 AM
To: Donna Snider
Subject: FW: Corrected Report Available - Public Review extended through 10.4.10 - Solana Beach Draft Land Lease & Recreation Fee Report
Attachments: draft_land_lease_comments_TomCook.pdf

Hi Donna - Please see attached comments letter.

Leslea

From: tom cook [tcook@mpl.ucsd.edu]
Sent: Monday, October 04, 2010 10:01 AM
To: Leslea Meyerhoff
Subject: Re: Corrected Report Available - Public Review extended through 10.4.10 - Solana Beach Draft Land Lease & Recreation Fee Report

HI Please see the attached comments, which replace my previously submitted comments.
Thanks,
Tom Cook
San Diego

On Wed, Aug 4, 2010 at 3:26 PM, Leslea Meyerhoff <lmeyerhoff@cosb.org> wrote:
> Hello - The City of Solana Beach has prepared a revised Land Lease/Recreation Fee Study which contains corrections and changes to the original report. The corrections and changes to the report are shown in redline/strikeout to facilitate and streamline public review. The City has extended the public review and comment period on the draft report for an additional 60 days. The extended public comment period will end on October 4, 2010.
>
> The report is available online at
> http://www.ci.solana-beach.ca.us/newsmanager/templates/?a=70&z=1
>
> Leslea Meyerhoff, AICP
> City of Solana Beach

Comments on Solana Beach Draft Land Lease & Recreation Fee Report
Tom Cook
tcook@mpl.ucsd.edu
Comment 1

It is my opinion that the beach user count sampling for the Draft Land Lease & Recreation Fee Report undercounts surfers. Surfers tend to come and go at different times during the day, as changing wind and tide conditions influences a surfer's decision to surf. Additionally, the characteristic of the waves (swell height, direction and period) greatly influence where to surf. For instance on a large long period NW groundswell, most surfers will go to Table Tops, however the spot doesn't break during a small short period NW windswell. Obviously, the designers of the survey know this, and have chosen to vary the times of their surveys.

However, my issue with the sampling of beach counts goes beyond the above statements. I have compiled data from local wave buoys provided by Scripps Institution of Oceanography, which show that typically the dates of the surveys do not always capture the bigger wave events. I have included timeseries plots (Figures 1a-m) of the wave height from the Torrey Pines buoy, and overlaid the survey dates (red lines). These show that very few of the surveys occurred during peak wave conditions. This leads to the surfer and big-wave-observer population from being under sampled.

To illustrate this point, the mean and maximum wave height over the year that the surveys were conducted were found to be 1m and 4.2m respectively. Next, the buoy wave data is subset to only include data during the surveys, and the mean and maximum wave heights were found to be 1m and 2.8m respectively. This clearly shows that the surveys captured mean conditions sufficiently (wave height means are the same), but did not capture the larger wave events (maximum wave heights differ). Furthermore, 61% of the Solana Beach surveys were taken when wave height was less than 1 meter.

The surfer count data from the Solana Beach surveys is also compared to an independent count provided by SurfShot.com, an internet surf report that compiles surf conditions for many surf spots in San Diego County. The SurfShot counting methodology has many differences to the one conducted for the Land Lease & Recreation Fee report, which implies that the counts can not be directly compared. For instance, the SurfShot.com Solana Beach report does not refer to one specific spot, but rather a group of spots (Fletcher Cove, Table Tops, Cherry Hill) and the report typically refers to the best spot for that day. Additionally, the SurfShot.com count is taken around dawn.

In order to allow some qualitative comparison, the Solana Beach survey surfer counts are taken as a sum at each of the survey locations, and subsequently averaged over the number of survey locations. This allowed a reduction of Solana Beach survey surfer counts, and allowed some qualitative comparison to the SurfShot.com count which is recorded at one location. The SurfShot.com count, Solana Beach surfer count, and wave height data are matched in time, so that for each Solana Beach survey there is a corresponding value of wave height and SurfShot.com surfer count.

The time matched data are compared using scatter plots and linear regression techniques. Linear regression is a technique for establishing the relationship between two variables, and is related to a measure of correlation between the two variables called the correlation coefficient (called R). When R=0, there is no correlation between the variables, and when R=1 there is perfect correlation. For the purposes of this analysis, it is assumed that there will be some amount of correlation between buoy wave height and the number of surfers in the water. A perfect correlation is not assumed, as often, the wave height readings are highest during stormy conditions, which may not be the best for surfing.

First, the two counting methods are compared as a check for consistency. There is little to no correlation of the SurfShot.com counts to the survey counts (Figure 2), and the correlation coefficient R=0.14 indicates a very slight correlation. This is expected, as the methodologies of counting differ between the Solana Beach survey and SurfShot.com. There is no correlation between the Solana Beach surfer count data and the wave heights from SIO wave buoys (Figure 3). The correlation coefficient between the Solana Beach surfer count and wave height has a value of R=0.02, which is indicative of uncorrelated data. The correlation between the SurfShot.com counts and the wave height (Figure 4) is slightly positive (R=0.21), and a there is a general trend showing an increase of surfers with increased wave height.

I feel that the evidence I've provided shows that the Solana Beach survey surfer count has been underestimated. First, the Solana Beach surveys were not taken during peak wave conditions, therefore missing surfers and observations taking advantage of the larger waves. Second, while it is not possible for a direct comparison between the independent SurfShot.com surfer count and the Solana Beach survey surfer count, the Solana Beach survey surfer counts do not vary with wave height as the SurfShot.com surfer counts do.

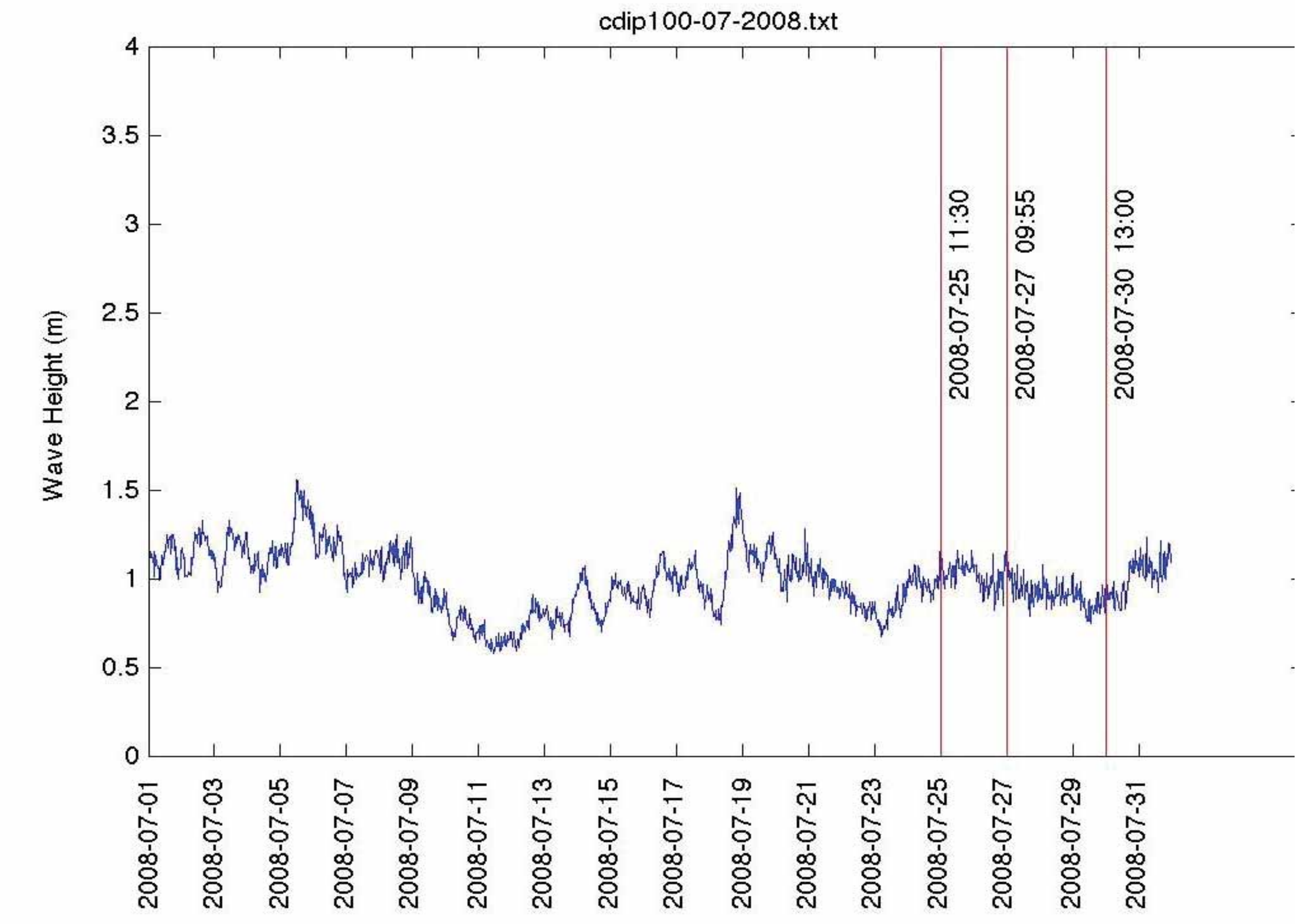
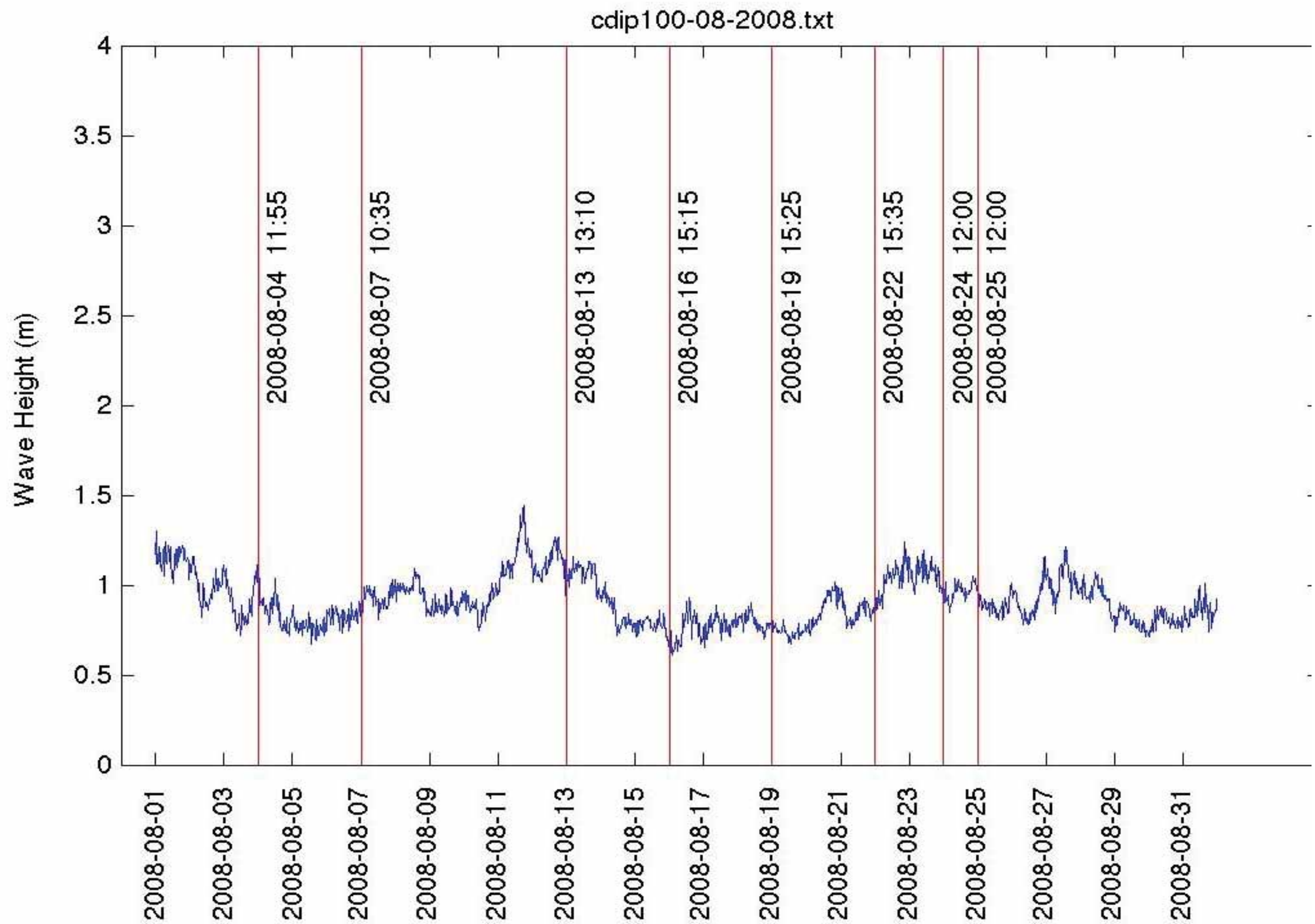


Figure 1 a) Wave height (meters) from Torrey Pines Scripps Institution of Oceanography CDIP buoy (blue line), survey dates (red line) during July 2008. Figures to follow are the same, but for dates b) August 2008, c) September 2008, d) October 2008, e) November 2008, f) December 2008, g) January 2009, h) February 2009, I) March 2009, j) April 2009, k) May 2009, l) June 2009, m) July 2009.

b)


cdip100-08-2008.txt
Wave Height (m)
0
0.5
1
1.5
2
2.5
3
3.5
4
2008-08-04 11:55
2008-08-07 10:35
2008-08-13 13:10
2008-08-16 15:15
2008-08-19 15:25
2008-08-22 15:35
2008-08-24 12:00
2008-08-25 12:00
2008-08-01
2008-08-03
2008-08-05
2008-08-07
2008-08-09
2008-08-11
2008-08-13
2008-08-15
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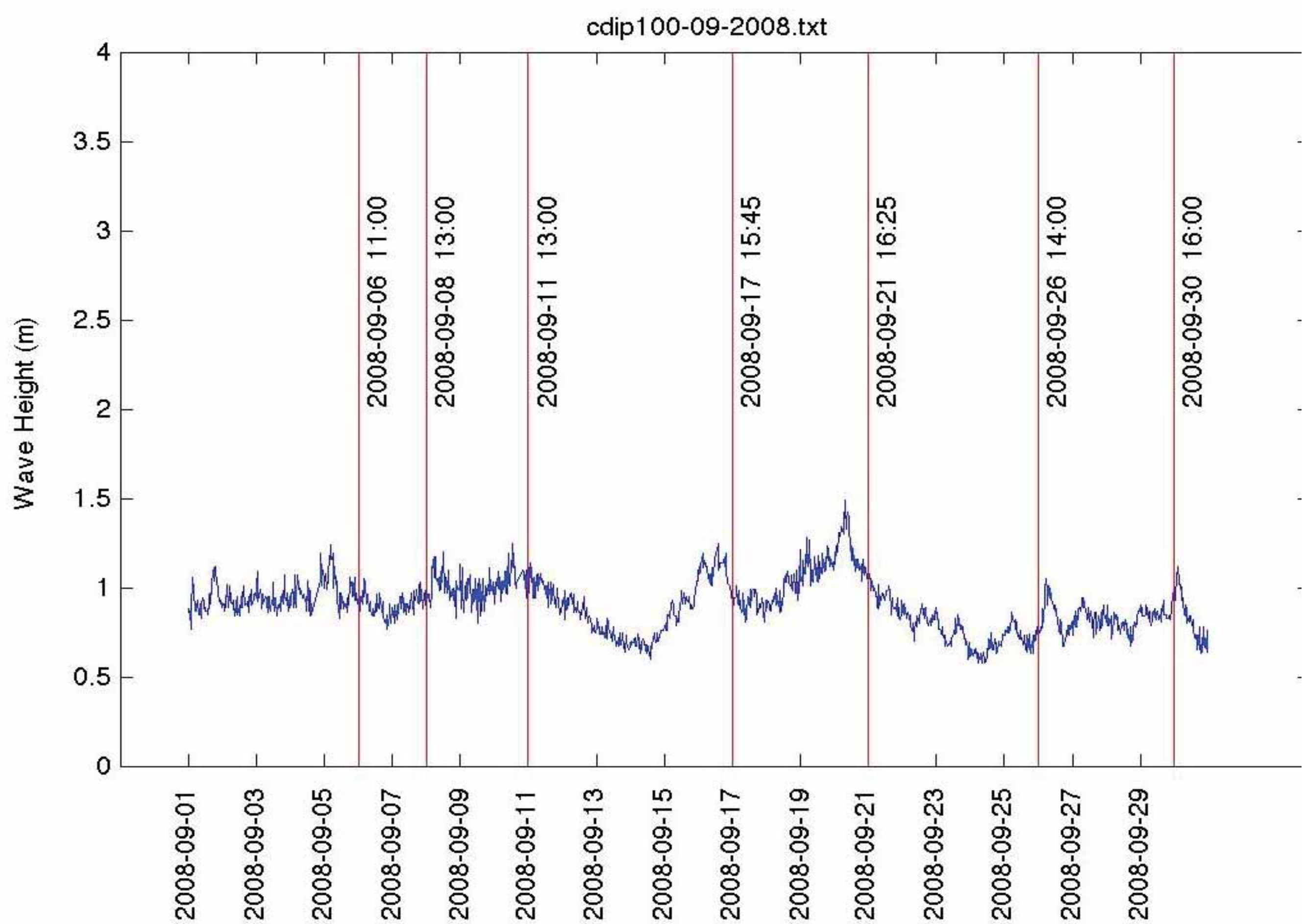
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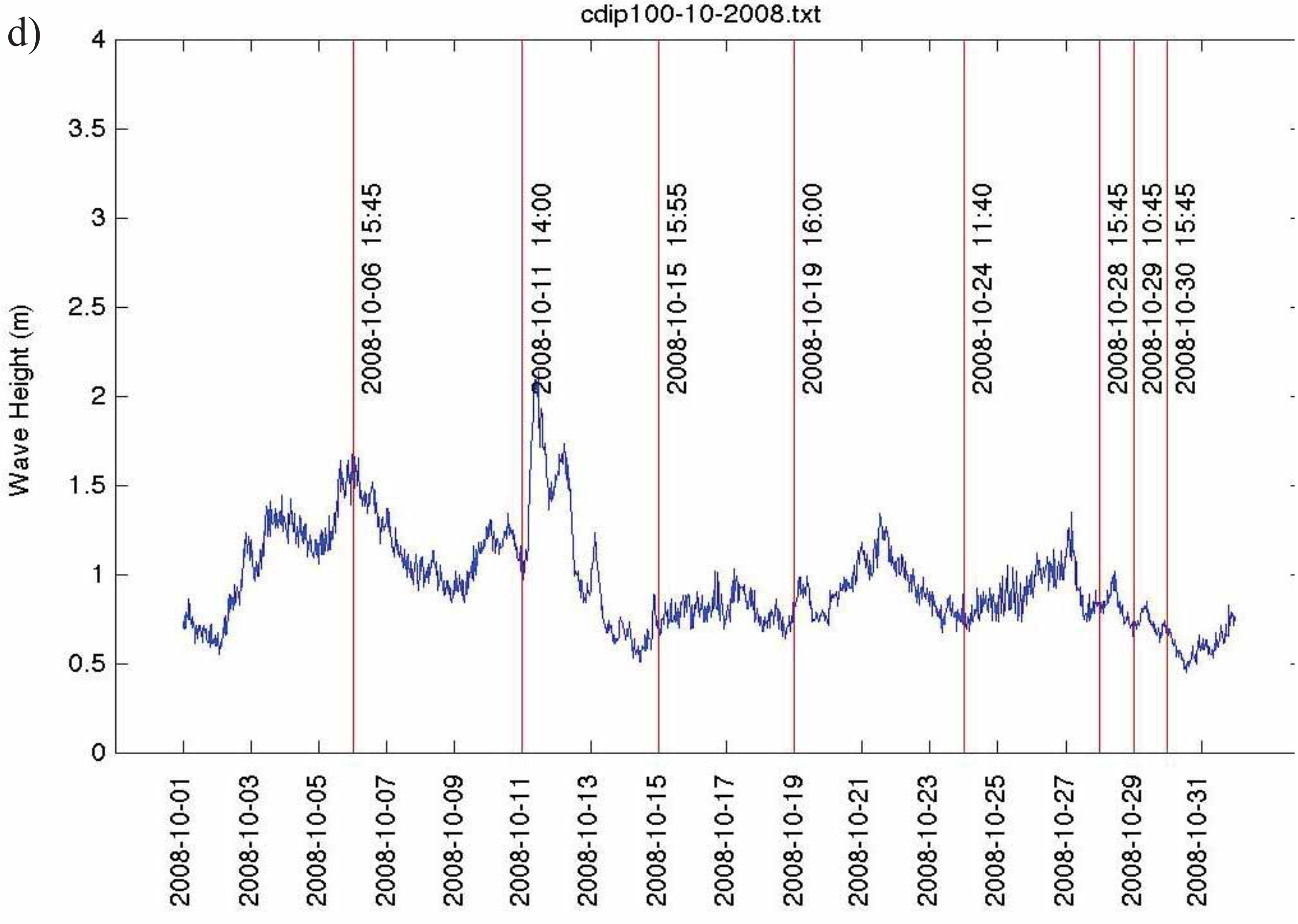
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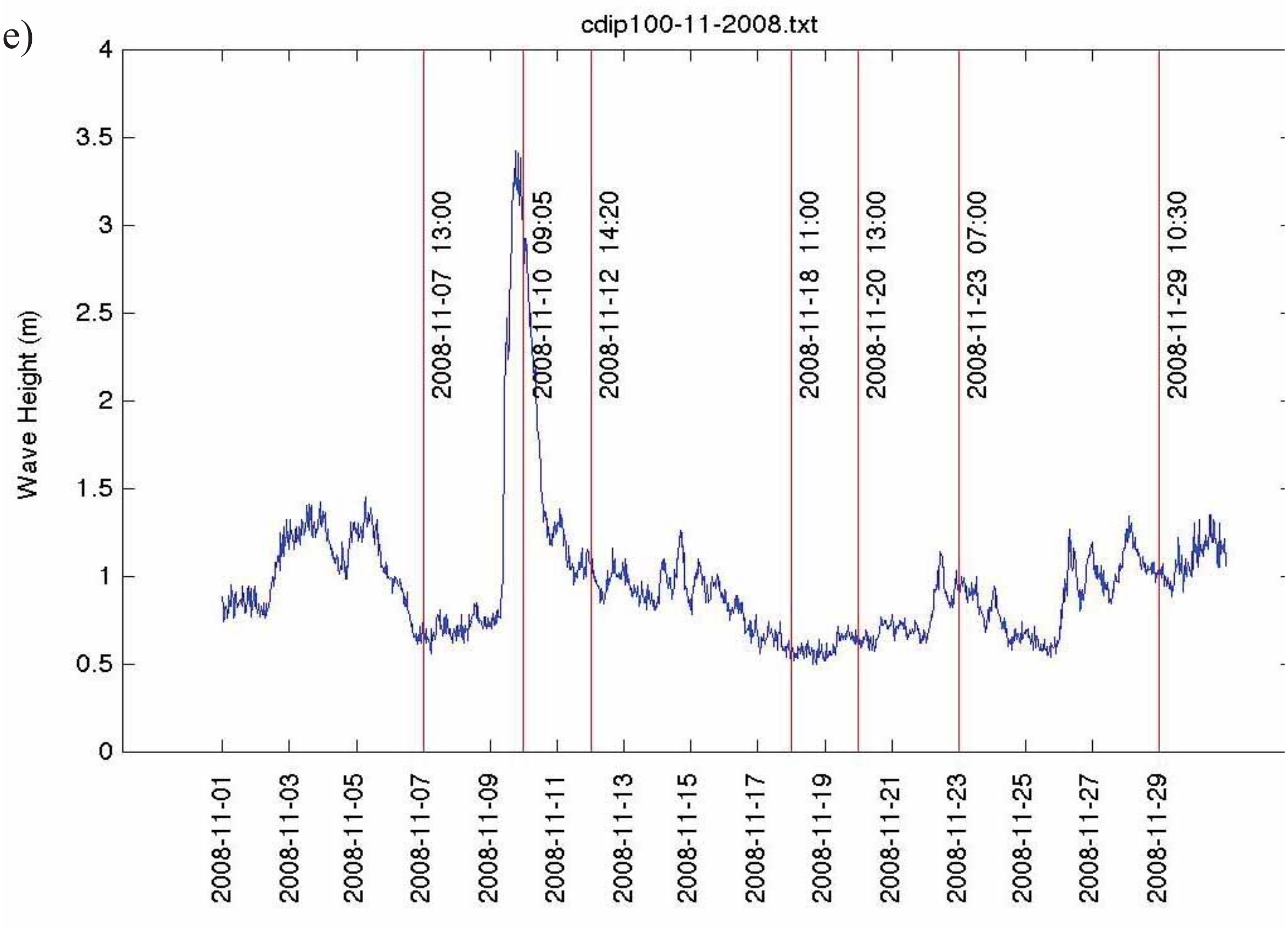
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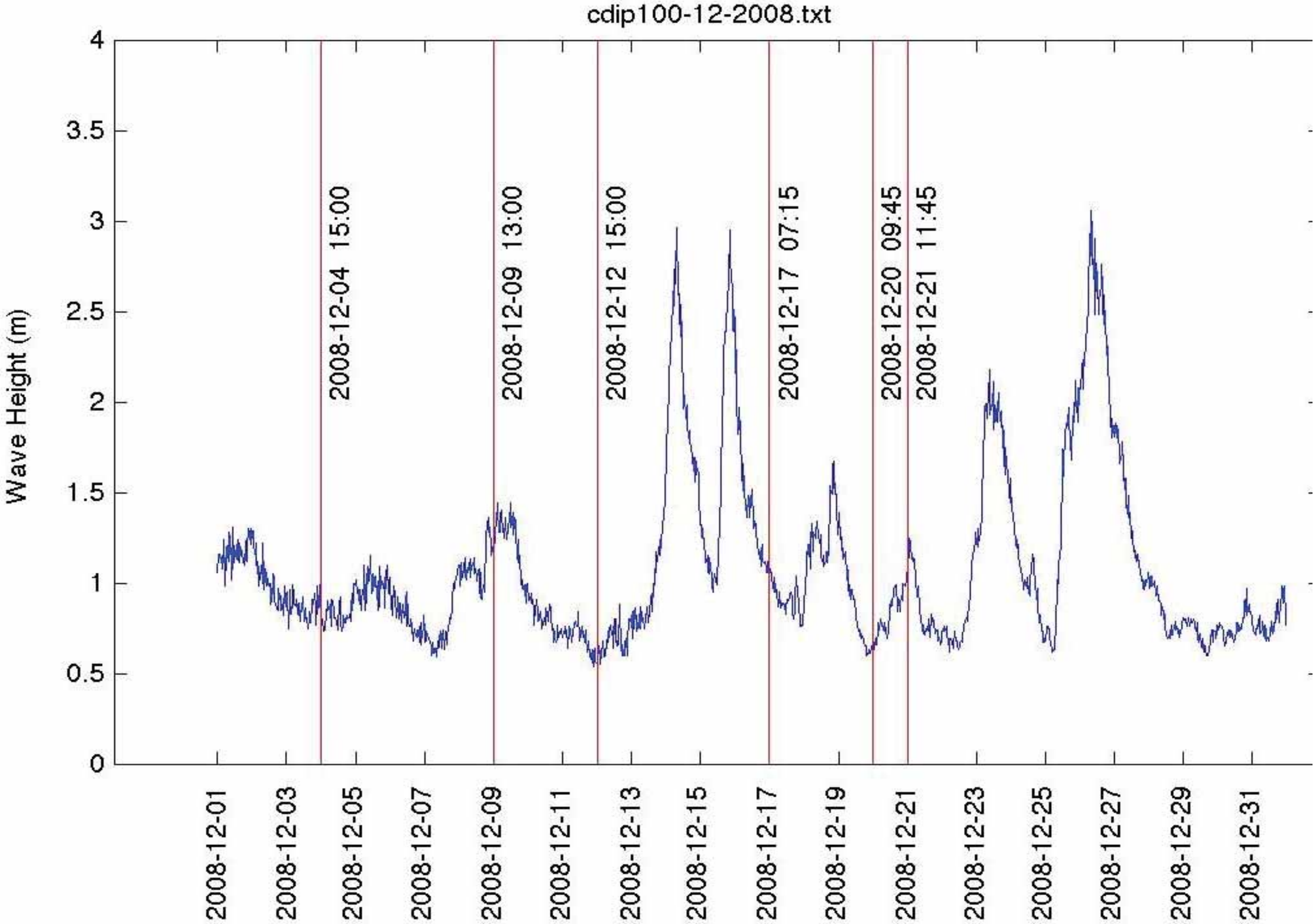
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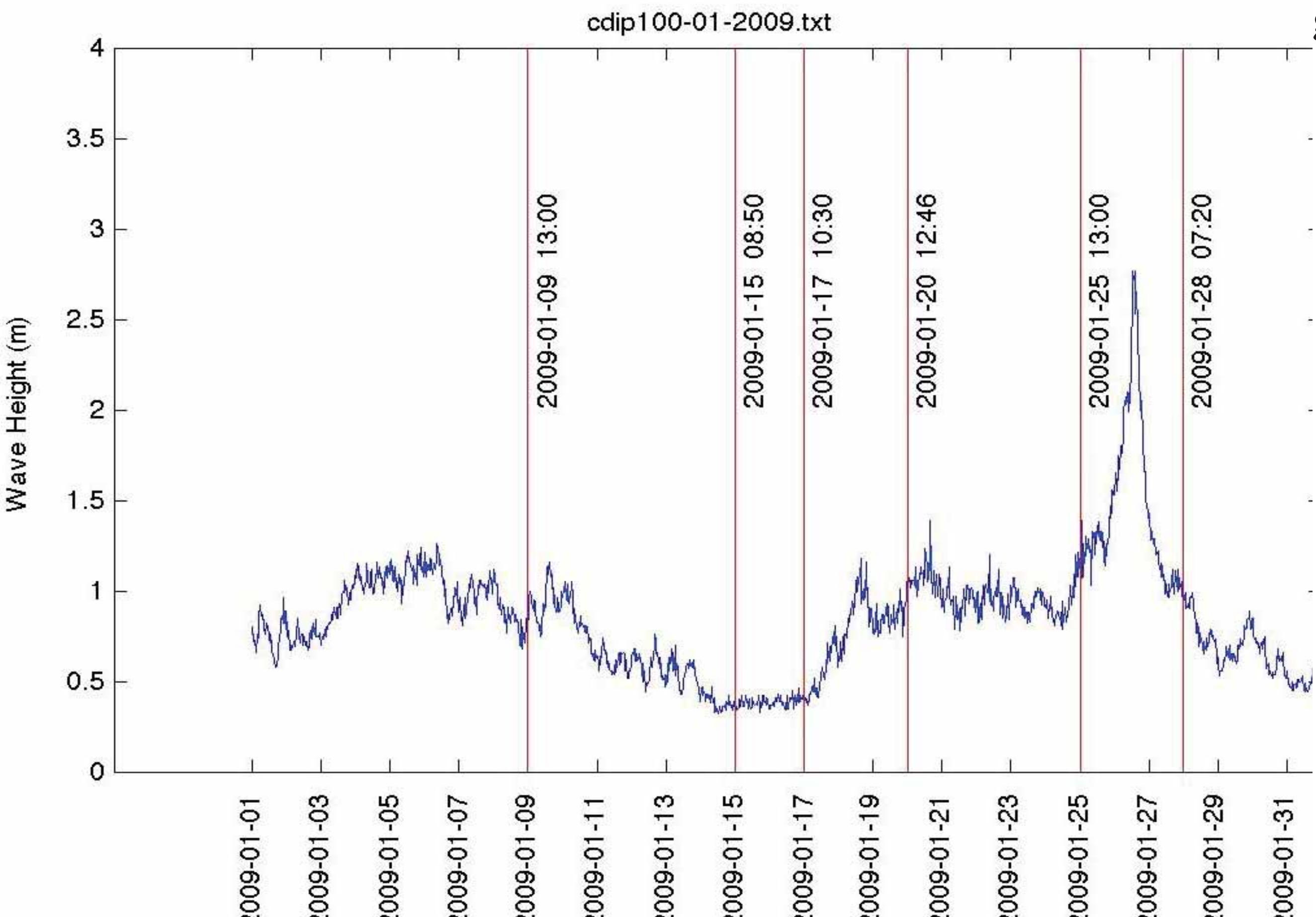
g)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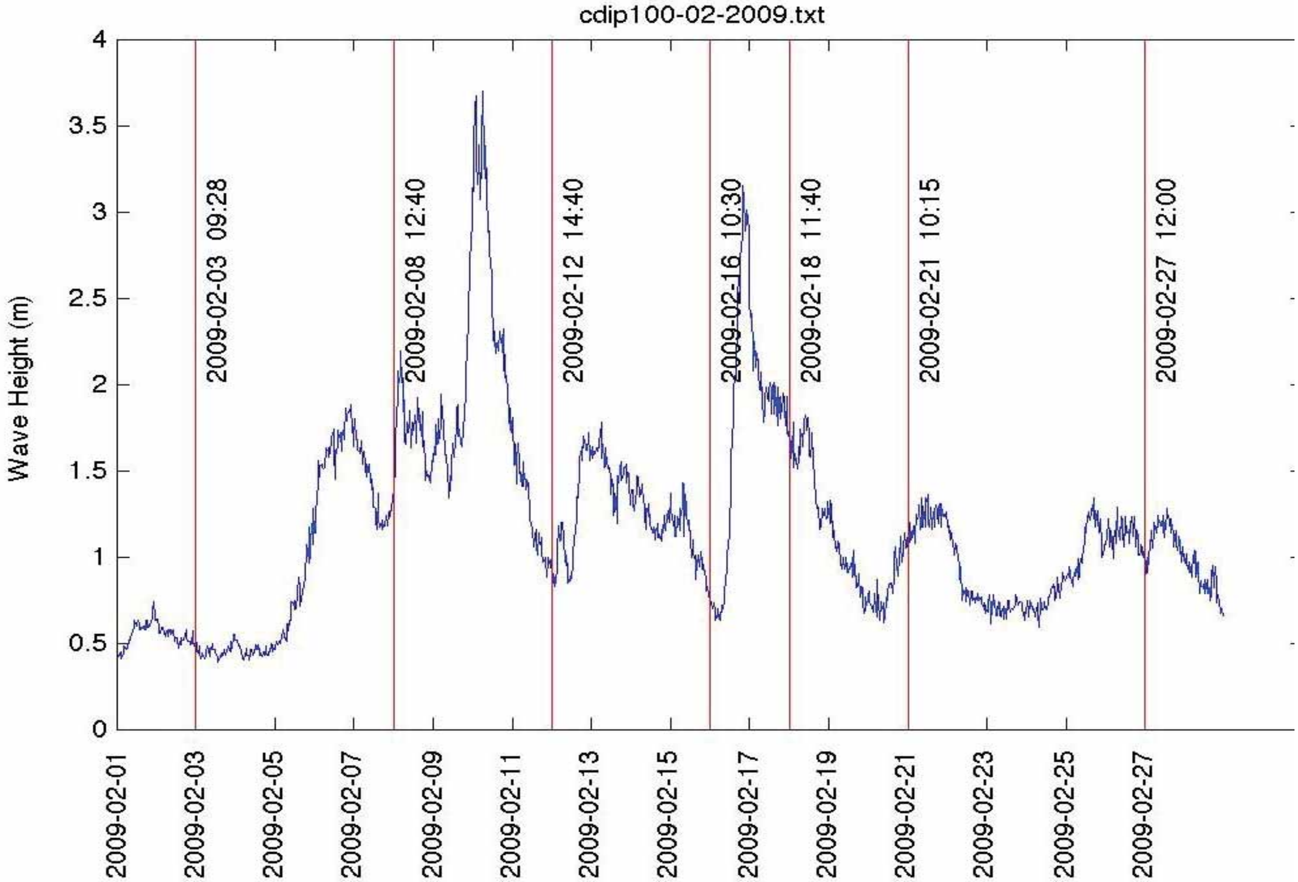
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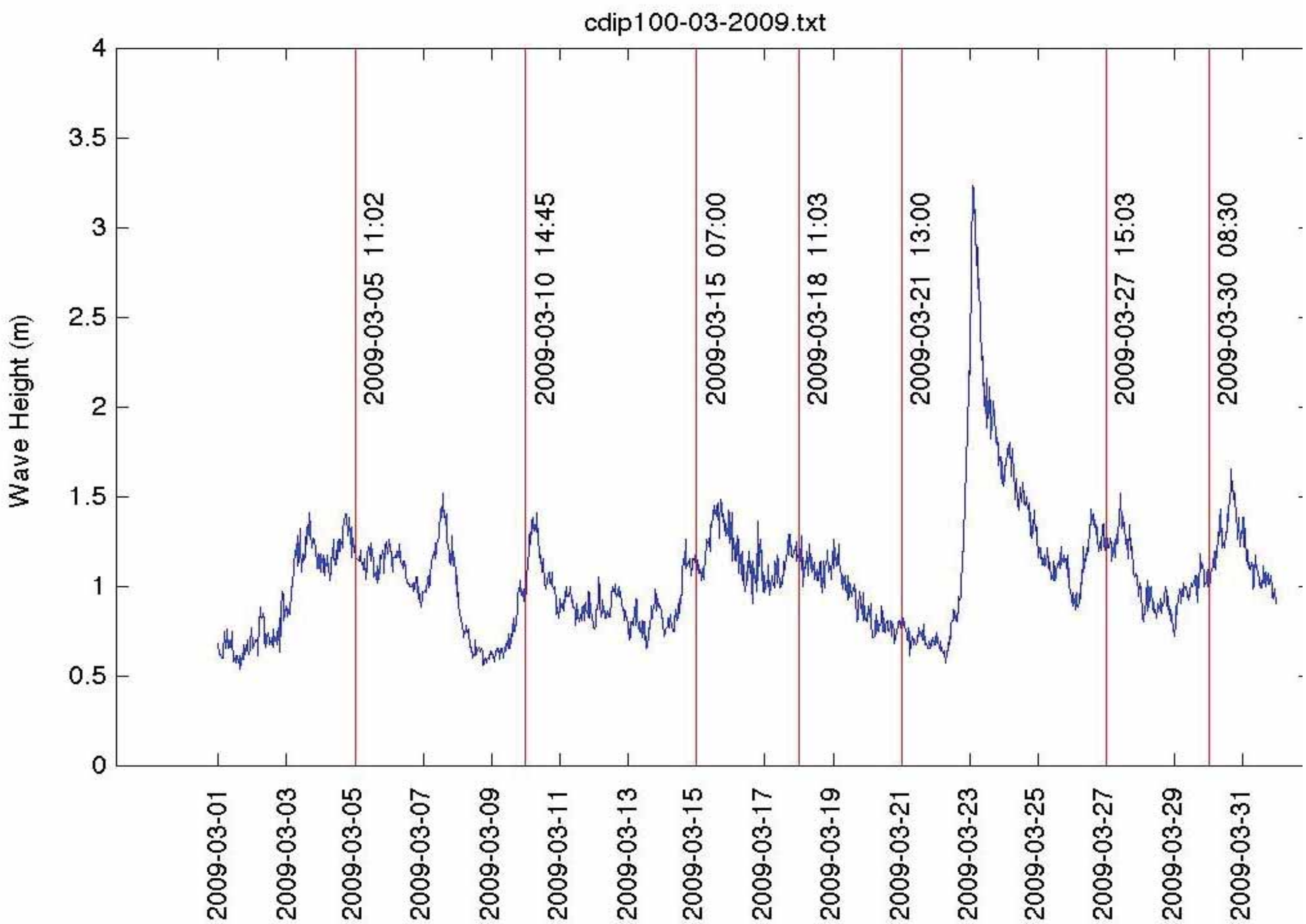
h)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i)

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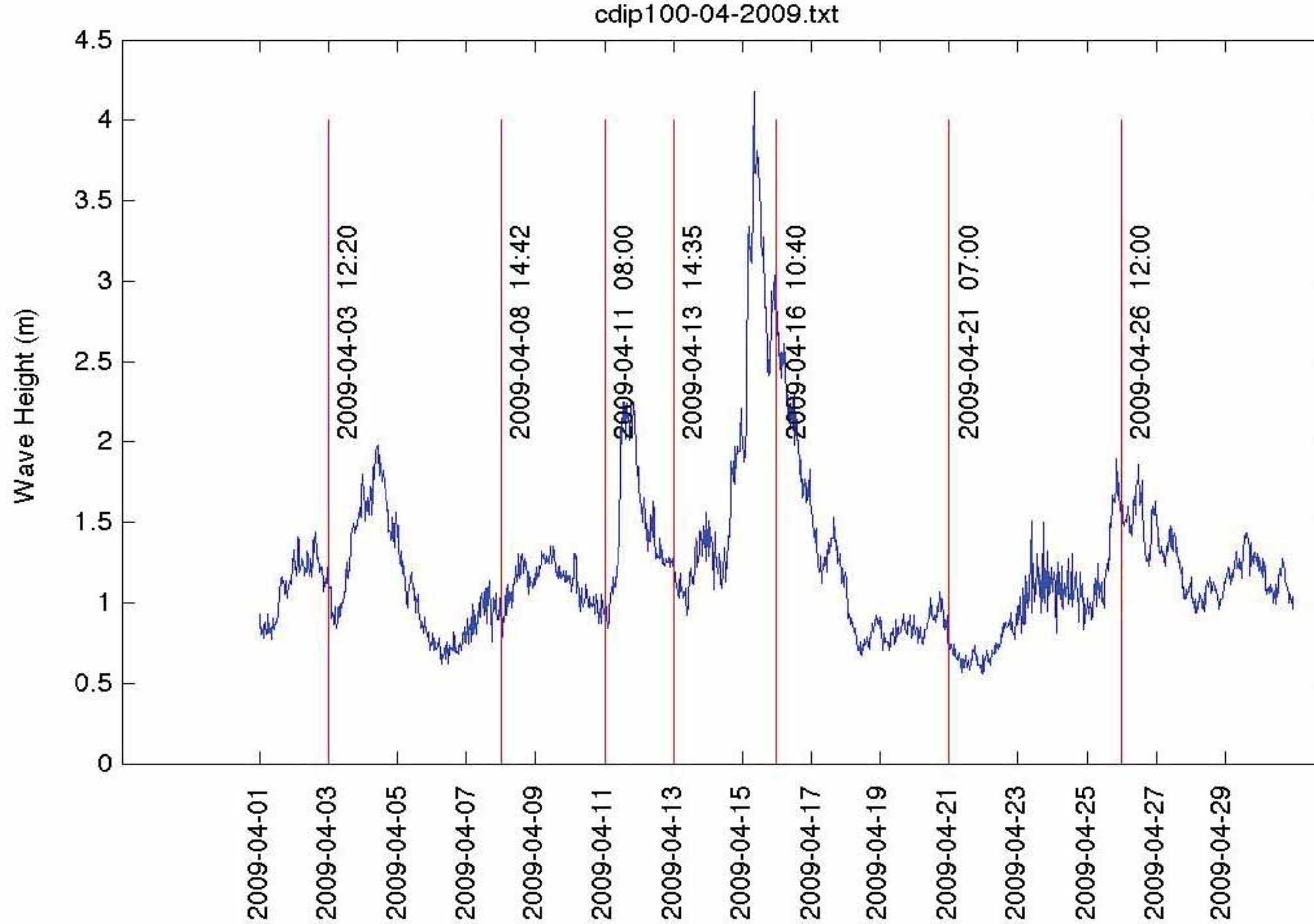
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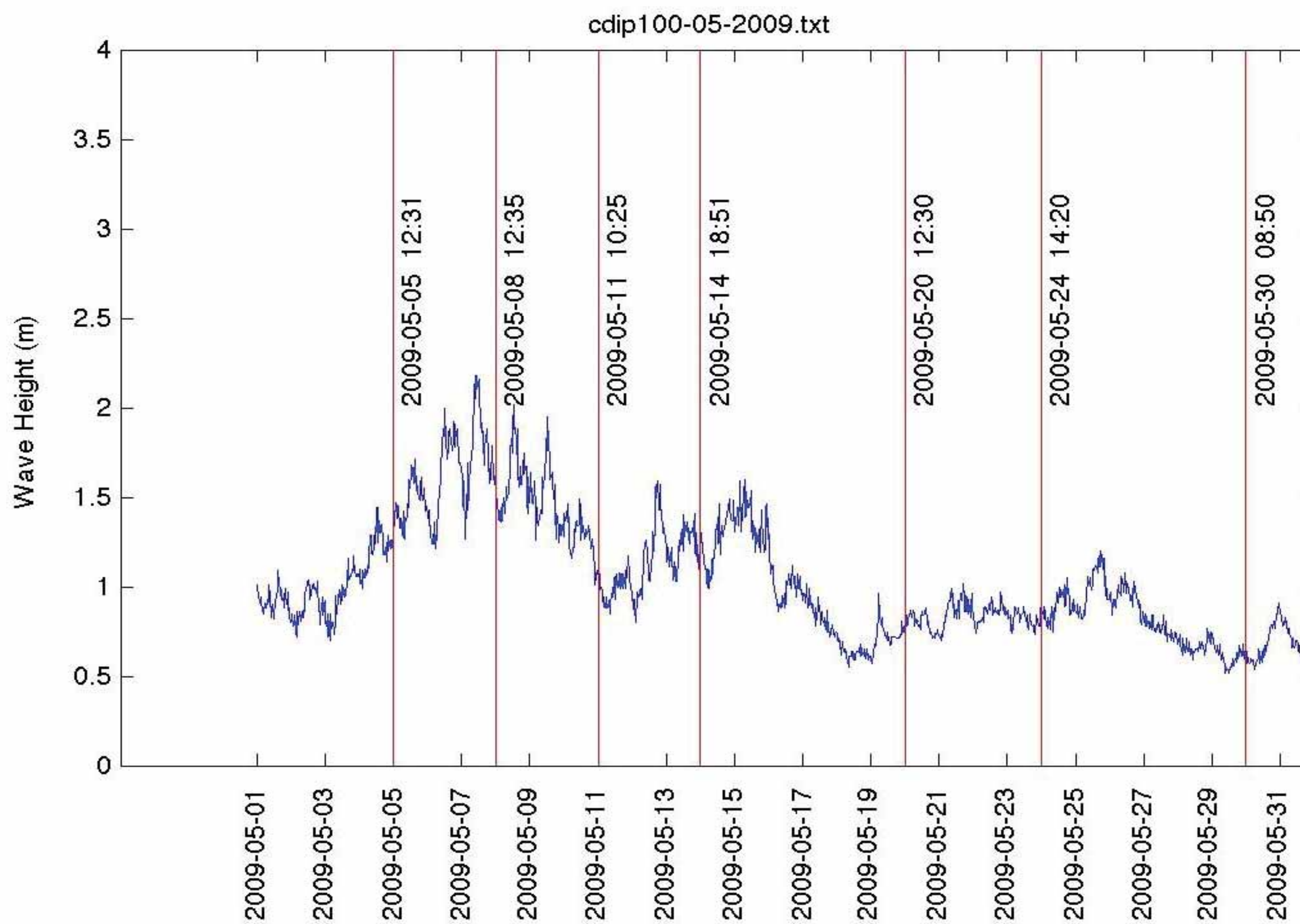
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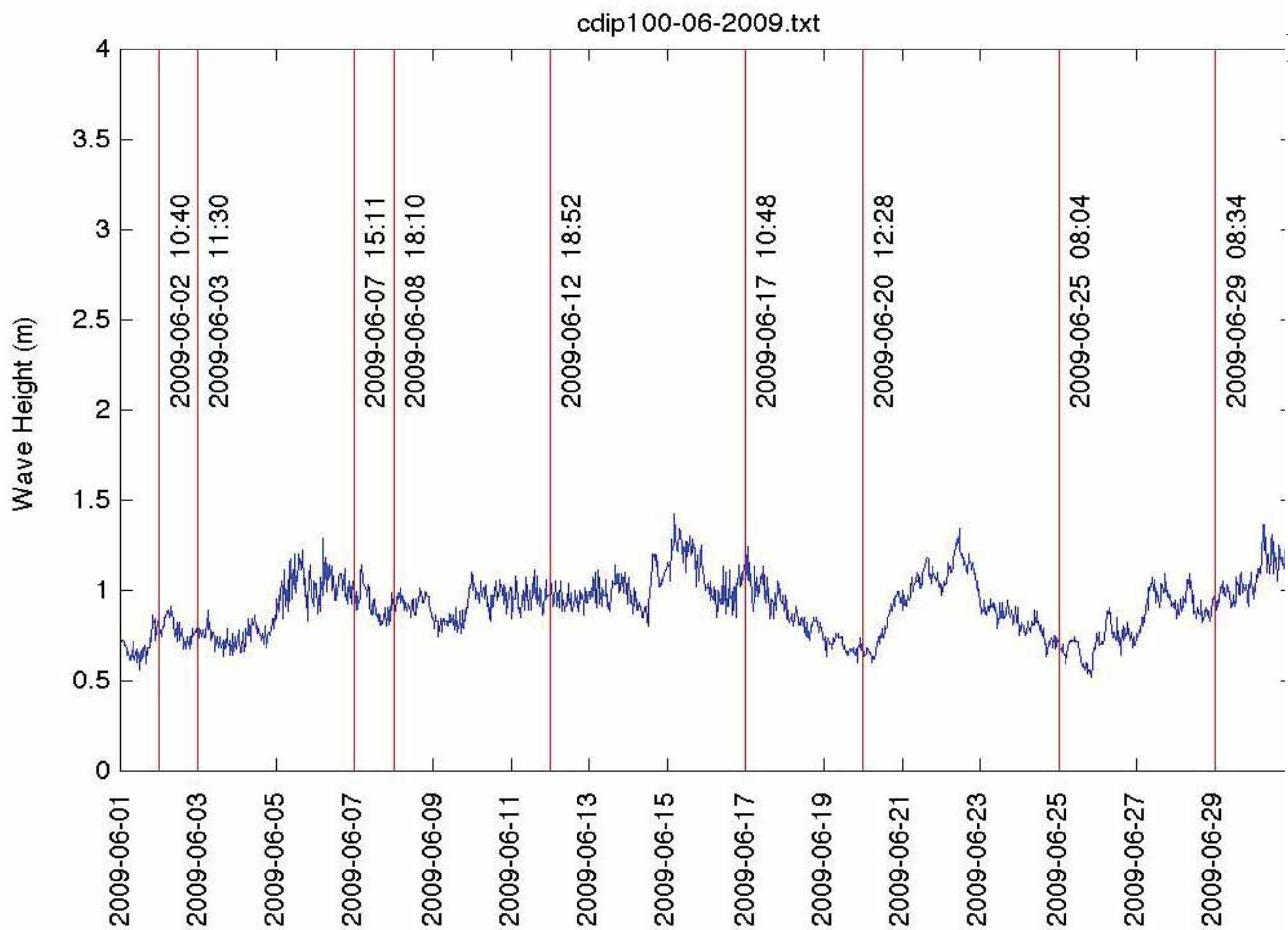
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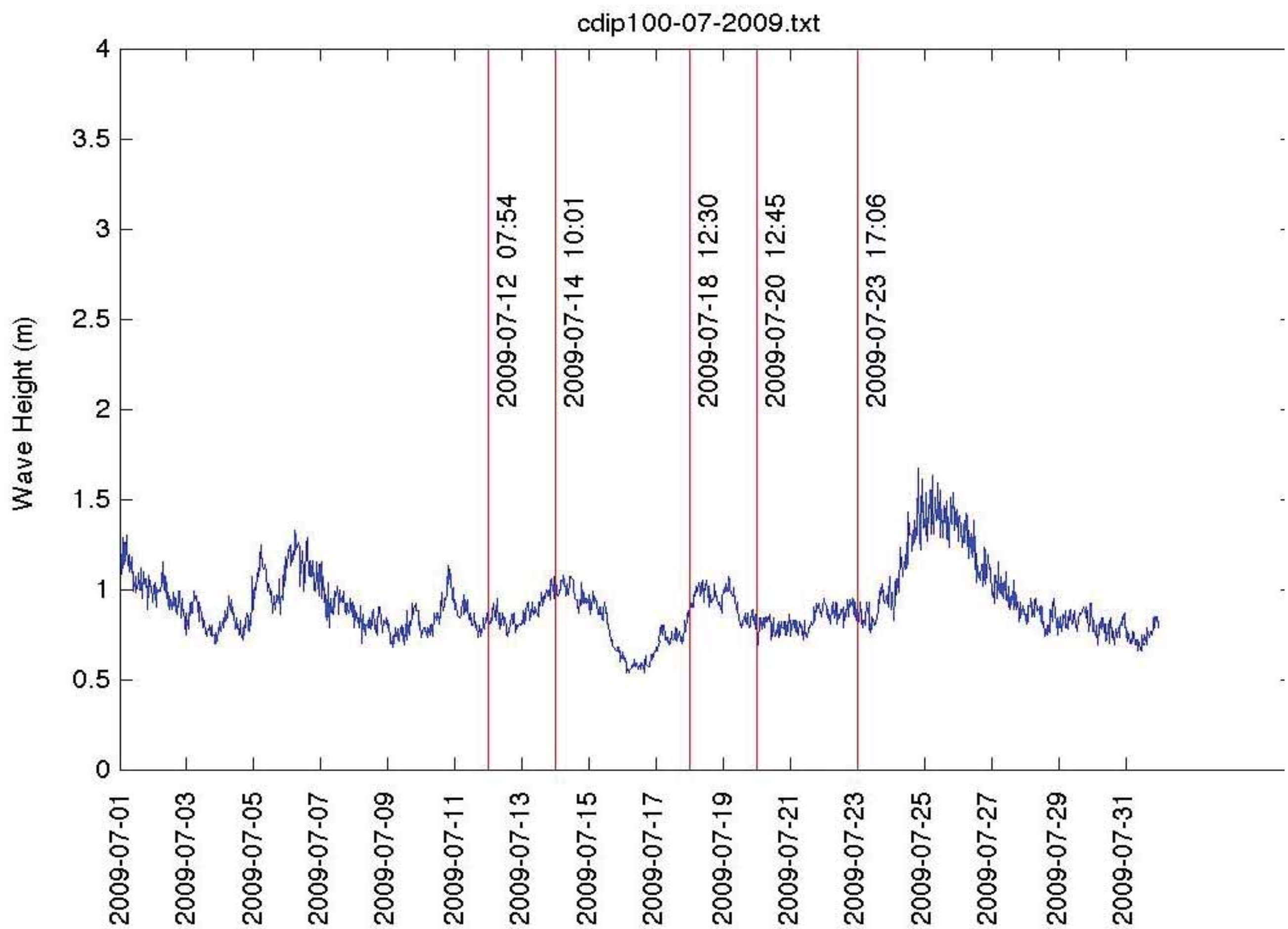
m)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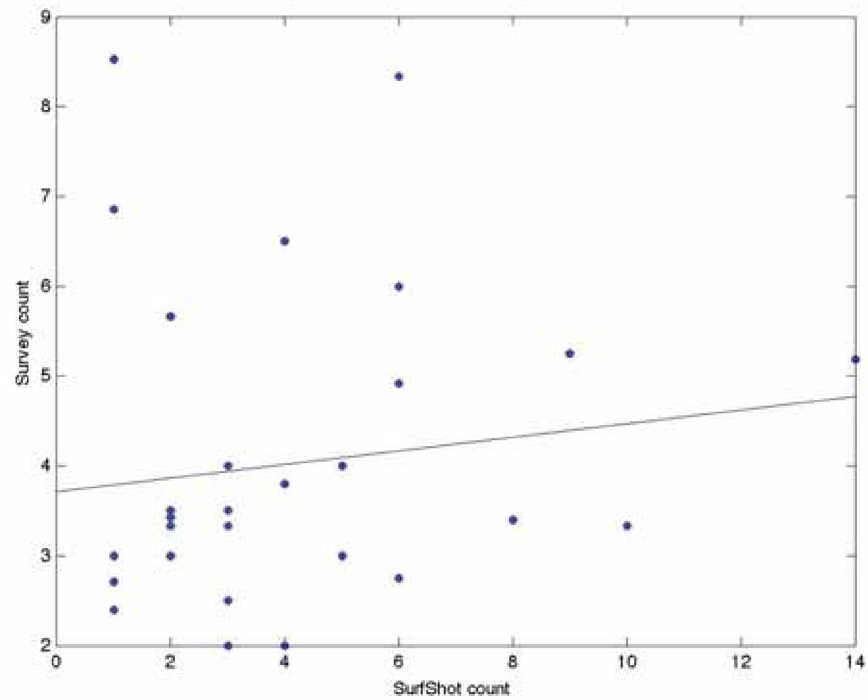

Figure 2. Scatter plot of SurfShot.com surfer count (X axis) vs Solana Beach Survey average surfer count (Y axis). Correlation coefficient R=0.14.

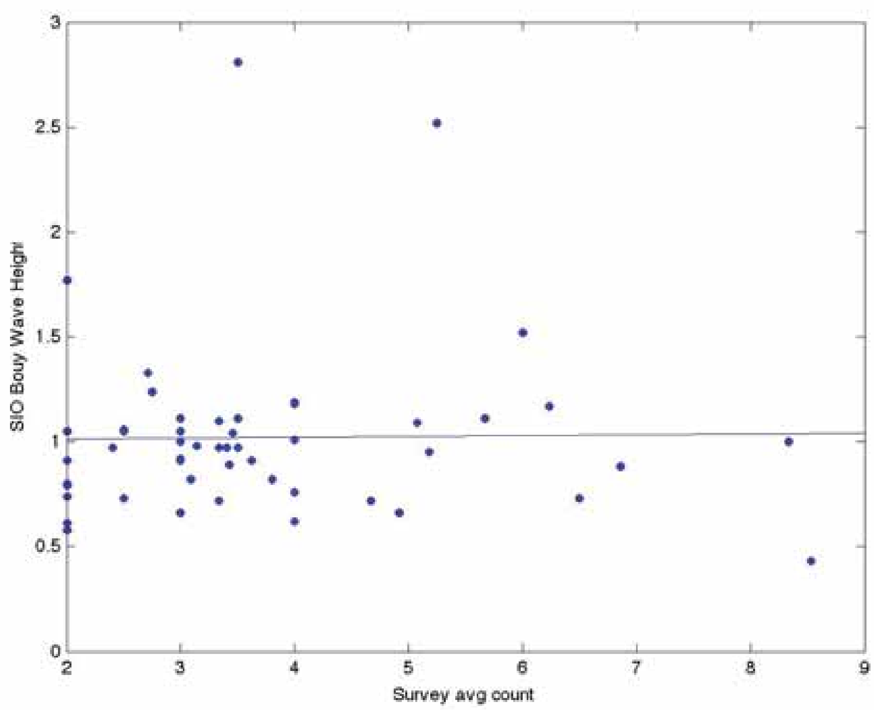

Figure 3. Scatter plot of Solana Beach Survey average surfer count (X Axis) vs SIO buoy wave height (m) (Y axis). Correlation coefficient R=0.02.

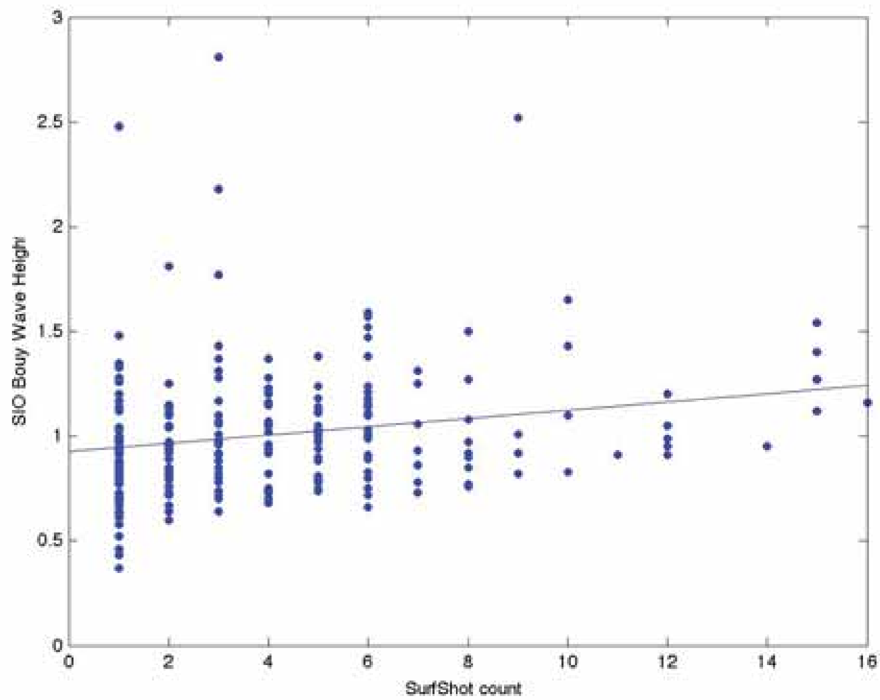

Figure 4. Scatter plot of SurfShot.com surfer count (X Axis) vs SIO buoy wave height (m) (Y axis). Correlation coefficient R=0.21.

Letter G

Donna Snider

From: Leslea Meyerhoff [lmeyerhoff@cosb.org]
Sent: Monday, October 04, 2010 10:53 AM
To: Donna Snider
Subject: FW: Surfrider Foundation San Diego County Chapter Review of Draft Land Lease & Recreation Fee Report

ANother comment for your files.

Leslea

____
From: Jim Jaffee [jmjaffee@roadrunner.com]
Sent: Monday, October 04, 2010 8:29 AM
To: Leslea Meyerhoff; Tina Christiansen; David Ott
Cc: Gordon Hanson; cnelsen
Subject: RE: Surfrider Foundation San Diego County Chapter Review of Draft Land Lease & Recreation Fee Report

At 04:58 PM 7/13/2010, Leslea Meyerhoff wrote:

Dear Leslea,

We want to state on the record that we stand by our comments as submitted on July 13 and do not believe the revised report changes our requested revisions to the report.

Jim

>Hi Jim - We have received your comments. Thank you.
>
>The City is in the process of issuing a revised/corrected report and
>will be extending the public review and comment period for an
>additional length of time to allow all interested parties an adequate
>time to review the revised/corrected report.
>
>We will let you know as soon as this report has been posted on the
>City's website for public review.
>
>Thank you.
>
>Leslea Meyerhoff
>____
>From: jmjaffee@roadrunner.com [jmjaffee@roadrunner.com]
>Sent: Tuesday, July 13, 2010 7:44 AM
>To: Tina Christiansen; Leslea Meyerhoff; David Ott
>Cc: Gordon Hanson; cnelsen
>Subject: Surfrider Foundation San Diego County Chapter Review of Draft
>Land Lease & Recreation Fee Report
>
>Dear Tina, Dave and Leslea,
>
>Please find attached our review of the "Draft Land Lease & Recreation
>Fee Report". This review includes 3 parts:
>
>SurfriderSummaryCommentsLandLeaseFeeStudy7102010.pdf
>- A summary document of our review by Jim Jaffee and Dr. Gordon Hanson

>with review by Chad Nelsen.
>SurfriderFoundationCommentMatrix7-10-2010.pdf - A detailed comments
>matrix with reference to specific issues and section of the "Draft Land
>Lease & Recreation Fee Report" by Jim Jaffee and Dr. Gordon Hanson with
>review by Chad Nelsen.
>CIC_report_evaluation_v5.pdf - A peer review of the “A Study of the
>Economic Value of Public Beach Land in Solana Beach” by CIC Research,
>Inc. performed under contract by Dr. Ken Baerenklau, Associate
>Professor of Environmental Economics & Policy, University of California
>- Riverside
>
>Please incorporate these in the record.
>
>Regards
>
>Jim Jaffee

Review of
"A Study of the Economic Value of Public Beach Land in Solana Beach"
by CIC Research, Inc.

Prepared for The Surfrider Foundation

by

Dr. Ken Baerenklau
Associate Professor of Environmental Economics & Policy
University of California – Riverside
ken.baerenklau@ucr.edu

Executive Summary

The Solana Beach valuation study by CIC Research has produced a dataset that is useful for estimating the recreation value of Solana Beach to beach visitors. However the methodology used by CIC for estimating that value is flawed and inconsistent with economic theory and accepted practice. This review addresses the main shortcomings of that methodology and provides a defensible estimate of the recreation value of Solana Beach that is consistent with theory and standard practice. The estimated recreation value for adult visitors is found to be between $1 and $3 million per year, and most likely in the lower half of that range.

1. Summary of the CIC Report

CIC Research, Inc, conducted two surveys of visitors to Solana Beach from July 2008 to July 2009. The purpose of these surveys was to collect data to estimate the annual recreation value of the beach. Results were presented in a report titled "A Study of the Economic Value of Public Beach Land in Solana Beach." A correction and clarifications to this report were issued by CIC Research in a memo dated June 2, 2010.

The "beach count" survey counted the number of people on the beach at various times of the day and on various days throughout the year. A stratified sampling method was used to ensure that weekends and weekdays are proportionately represented in the dataset. These counts are used to estimate the total number of annual visitors to the beach.

The "beachgoer survey" collected information about individual visitors. Such "intercept surveys" are common in the field of natural resource economics. The beachgoer survey is fairly standard and includes questions about visitation frequency; mode of transportation to the beach; number of companions; distance traveled to get to the beach; home ZIP code; employment status; occupation; age; education level; and personal income. Some of this information (i.e., mode of transportation; distance traveled; personal income) is used to determine the cost incurred to visit the beach by each surveyed individual. This "travel cost" includes both out-of-pocket expenses (e.g., gas and depreciation for a private car; fees for public transportation) and the opportunity cost of time spent traveling (i.e., the value of an individual's time).

CIC estimates that 86,276 adults visited the beach during 2008-09, and that the average travel cost per adult was $24.15. CIC multiplies these numbers to get an estimated annual recreation value of $2.08 million for the beach.

2. Comments on the CIC Report

The beach count and beachgoer surveys provide data that is useful for estimating the recreation value of the beach. Both surveys appear to be reasonably well-conducted and generally consistent with accepted practice. However the analysis of the data is not consistent with accepted practice. Therefore this review will focus on the analysis and will present alternative estimates for the recreation value of the beach that are consistent with standard practice.

Calculation of Travel Costs

A spreadsheet containing the survey data and CIC's original (uncorrected) travel cost calculations is posted on the City's website (http://solana-beach.hdso.net/docs/PL_BeachStudySurvey.xls). The column "tcost" contains travel costs calculated using the methodology in the CIC report and "altcost" contains travel costs calculated using a similar method that also incorporates wage data published by the U.S. Department of Labor.

Attempts to reproduce CIC's original calculations using the original method were not successful: CIC's average values are $20.82 for "tcost" and $19.83 for "altcost"; replication efforts produced average values of $21.02 and $20.03, respectively. Some calculated values for individual observations are the same but others are not, and there is no obvious pattern to explain the differences. However an attempt to reproduce the corrected average "altcost" figure of $24.15 using the corrected method was successful. A spreadsheet containing corrected calculations has not been made available as of this time so line-by-line comparisons cannot be made, but this analysis proceeds under the assumption that the replicated "altcost" values are the same for each observation.

The CIC travel cost methodology is reasonable, but economists continue to debate how to value an individual's time in a recreation context. CIC assumes the value of travel time is equal to 100% of the hourly wage rate implied by the annual personal income level reported by each respondent. This approach is simple and intuitive and has been used by some researchers; however it assumes that if an individual were not traveling to the beach, s/he would choose to work and would be compensated for the extra time spent working at 100% of the wage rate. Clearly this may not be the case (e.g., for salaried workers), and many people might choose another leisure activity rather than working if they were not traveling to the beach. A highly cited study by Cesario[1] refers to empirical data suggesting that the value of time for U.S. recreation activities is around 1/3 of the wage rate. Many researchers have adopted this convention, although it also is somewhat arbitrary. A more recent study by Calfee and Winston[2] estimates that the value of travel time is around 19% of the wage rate. An overview by Small[3] finds that the value varies from 20% to 100% across different urban areas, and concludes that 50% is a reasonable value to use. [4] In the absence of any specific information about the value of time for the respondents in a given dataset, it is common practice to conduct a sensitivity analysis using different approaches.

The CIC methodology also does not account for the possibility that adults traveling to the beach together by car may have shared travel expenses. It is common practice to account for this in travel cost analyses.

Finally, the approach used by CIC to identify and control for "outliers" in the estimated travel costs is inadequate. Definitions of an outlier vary, but intuitively an outlier is an observation that differs substantially from the majority of observations. The corrected values for "altcost" contain six estimates over $100 and several more over $50. Travel costs in this range are plausible for individuals who drove significant distances to visit the beach. However, as noted by CIC, three of these estimates are over $400 and one of these is nearly $800. CIC identifies these as "outliers" and uses a method called Winsorizing to reduce these values to "acceptable" levels and retain the observations in the dataset. However, there are two problems with this approach. First, if extreme high values are to be reduced for no other reason than they are high, then extreme low values also should be increased for no other reason than they are low. Second, the appearance of a high (or low) travel cost, by itself, does not indicate that an observation is an outlier (e.g., a particularly wealthy individual may have driven a great distance to the beach); therefore this approach to arbitrarily identifying and "correcting" outliers is questionable.

An alternative approach is to determine *why* very high and low travel costs appear and, if justified, to omit suspicious observations from the dataset. Inspection of the dataset reveals that the three individuals identified by CIC apparently walked or skateboarded 12 miles each way to visit the beach. The CIC methodology assumes ½ hour per mile for this mode of transportation. Multiplying by the high incomes reported by these individuals produces the high travel costs. There are actually a total of five individuals in the dataset who reported walking/skateboarding 12 miles each way to visit the beach. Using the

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1 Cesario, F.J., 1976. "Value of Time in Recreation Benefit Studies." *Land Economics*, 52(1): 32-41.

2 Calfee, J. and C. Winston, 1998. "The Value of Automobile Travel Time: Implications for Congestion Policy." *Journal of Public Economics* 69: 83-102.

3 Small, K. 1992. Urban Transportation Economics. Harwood: Philadelphia, PA.

4 Some practitioners have argued that the value of leisure time could be greater than the wage rate because individuals typically demand overtime pay for working when they normally would not, but this approach has found very limited empirical support. On the contrary, largely because people frequently interpret "income" to mean "gross pay," whereas the value of time should be measured as "take home pay," and because intuition suggests that individuals are likely more averse to work time than to travel time for leisure activities, implying that they must be compensated more to work an extra hour than to drive an extra hour to a recreation activity, a consensus had developed in the profession that 100% of the wage rate is an upper limit.

corrected CIC methodology, their travel costs are: $793, $519, $410, $202 and $86. These observations can be considered outliers that might unduly influence subsequent calculations. Although this approach is still arbitrary, it is preferable because it omits nonsensical observations but retains others with relatively high travel costs if there is no reason to suspect their legitimacy (i.e., several observations with travel costs greater than $86 were retained).[5]

To address these issues, recreation value estimates are presented later in this review using four different sets of estimated travel costs: 1) replicated "altcost" with five outliers removed; 2) replicated "altcost" with five outliers removed and 1/2 of the wage rate as the value of time; 3) replicated "altcost" with five outliers removed and 1/3 of the wage rate as the value of time; 4) replicated "altcost" with five outliers removed, 1/3 of the wage rate as the value of time, and out-of-pocket expenses shared equally among companions for individuals who drove to the beach.[6]

Definition of Economic Value

The CIC report assumes that the value of a beach visit is equal to the travel cost incurred to visit the beach. This is inconsistent with economic theory and the published literature on recreation valuation.[7] According to both theory and common practice, an appropriate measure of the value of a beach visit is "consumer surplus."

Economists use demand curves to represent value (see figure 1 in Appendix A). The value of each unit of a good ($/unit) is plotted on the vertical axis and the number of units consumed is plotted on the horizontal axis. In the standard case this produces a downward sloping demand curve: the first unit of consumption is the most highly valued; additional units have lesser value. The price that must be paid to obtain each unit of the good also can be displayed on this same graph, as a horizontal line at the appropriate level. Units with values greater than the price will be demanded (because the reward from consumption—the value—exceeds the sacrifice that must be made in order to consume—the price); units with values less than the price will not be demanded. Therefore the graph defines the quantity demand as the point where the demand curve intersects the price line. It also defines the gross value of consumption as the area under the demand curve between 0 units and the quantity demanded; and the net value as the difference between this area and the consumers' cost of consumption. In figure 1, the net value is area A, the consumers' cost of consumption is area B, and the gross value is areas A plus B. Economists refer to the gross value as "willingness to pay" and the net value as "consumer surplus." Consumer surplus is a legitimate and commonly used measure of economic value because it quantifies the loss experienced by consumers if access to the good is denied.

---

[5] A similar inspection of very low travel costs did not reveal any suspicious observations.

[6] Although the "tcost" methodology is more standard, the "altcost" methodology is reasonable and is adopted here in order to make these estimates more comparable with those in the CIC report. Using "tcost" instead of "altcost" tends to increase the value estimates from these models by 2-3%.

[7] See, for example: Parsons, G.R., 2003. "The Travel Cost Model." Chapter 9 in A Primer on Nonmarket Valuation, Champ, Boyle, and Brown, Eds. Kluwer: Dordrecht.

This same theory applies to both market goods (e.g., gasoline) and non-market goods (e.g., beach visits). Estimating demand curves for non-market goods is more difficult in part because the price paid per unit must be estimated for each consumer; it cannot be readily observed in a market. In recreation demand studies, the travel cost is used to represent the price.[8] Therefore, assuming it is appropriate to apply the average value of "altcost" to all beach visits, the CIC report has estimated the total *cost* incurred by visitors to Solana Beach (area B in figure 1); not the recreation *value* of the beach to those visitors (area A).

3. Alternative Approach: Modeling Demand for Beach Visits

The beachgoer survey data can be used to estimate a demand curve for beach visits, and from this the recreation value of the beach can be derived. Economists have developed different statistical frameworks to estimate demand curves. The goal is to construct a mathematical equation that expresses demand as a function of observable attributes that might reasonably influence demand, including the price of the good. For datasets like this one—with one recreation site and with demand expressed as integer values (here, the number of trips taken in the past month)—"count data" models typically are used. A commonly used variety is the Poisson model, which is widely available in commercial software packages.[9]

For this application, a reasonable specification for the demand function is:

Quantity of beach visits demanded during the previous month = a function of…

- *The season of the year (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec)*
- *Respondent's age (taken as the midpoint of the reported range)*
- *Respondent's gender*
- *Respondent's estimated travel cost*
- *Respondent's income (taken as the midpoint of the reported range)*

Seasons might be otherwise defined to be more consistent with the school calendar (i.e., summer = Jun-Aug), but this would result in only one observation during the spring due to the sampling schedule used by CIC. The above seasonal definitions are generally consistent with typical weather patterns for Solana Beach.

Education level often is included as an explanatory variable in demand estimation, but a large number of observations would need to be omitted in order to use this variable due to missing values in the dataset. The above specification strikes a balance between including explanatory variables and retaining a large dataset for the statistical analysis.

---

[8] This idea originally was suggested by Harold Hotelling in a 1949 letter to the U.S. Department of the Interior: "An Economic Study of the Monetary Valuation of Recreation in the National Parks."

[9] The term "Poisson" refers to the name of the statistical distribution used in the model. Technical details and properties of the Poisson model can be found in any graduate-level econometrics textbook. For an environmental application, see pp. 164-169 in: Haab, T.C. and K.E. McConnell, 2002. Valuing Environmental and Natural Resources. Edward Elgar: Cheltenham.

Travel cost and income are included by necessity, both to derive trip value and to ensure that the demand framework is consistent with economic theory.

Before the Poisson demand model can be estimated, observations with missing values and outliers must be removed from the dataset. This leaves 325 observations for the analysis. The remaining observations must be weighted to control for apparent over-sampling of summer and fall visitors and under-sampling of winter and spring visitors in the dataset. For example, according to the beach count survey, 53.8% of adults visited during the summer; but 60.9% of respondents in the beachgoer survey visited during the summer. Therefore summer visitors are over-represented in the dataset and must be down-weighted appropriately; otherwise these observations will have too much influence on the estimation. Similar logic applies to the other seasons.[10]

4. Alternative Estimation Results and Value Calculations

The Poisson model is estimated using the commercially available software package NLOGIT version 3.0, developed by Dr. Bill Greene of New York University. The model has the convenient property that the average consumer surplus derived from a single visit is equal to the negative reciprocal of the coefficient estimate on the travel cost variable. Multiplying by the estimated total number of adult visitors from the beach count survey (86,276) gives an estimate of the annual recreation value of the beach. Key results for each model specification are provided below; detailed model output from NLOGIT is reproduced in Appendix B.

Model 1: replicated "altcost" with five outliers removed.

Average consumer surplus per trip: -1/-0.03225582 = $31.00
Annual recreation value of the beach: $31.00 × 86,276 = $2.67 million

Model 2: replicated "altcost" with five outliers removed and 1/2 of the wage rate as the value of time.

Average consumer surplus per visit: -1/-0.06366289 = $15.71
Annual recreation value of the beach: $15.71 × 86,276 = $1.36 million

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[10] An example helps explain these weights. Suppose that a population is 50% male and 50% female, and that a ballot measure is supported by 80% of men but only 40% of women. Overall, then, the ballot measure is supported by 60% of the population. Suppose that a random sample of the population has generated the following information: out of 100 residents, 24 men support it and 6 do not; 28 women support it and 42 do not. Even though the gender-specific support rates are accurate in the sample (i.e., 80% of men and 40% of women in the sample support the measure), the ballot measure is supported by only (24+28)/100 = 52% of sample respondents because women have been over-sampled. Weighting the number of male supporters by (0.5/0.3) and the number of female supporters by (0.5/0.7), each the ratio of the population gender proportion to the sample gender proportion, gives the corrected sample estimate of the population average: (24×0.5/0.3 + 28×0.5/0.7)/100 = 60%.

Model 3: replicated "altcost" with five outliers removed and 1/3 of the wage rate as the value of time.

Average consumer surplus per visit: -1/-0.08545229 = \$11.70
Annual recreation value of the beach: \$11.70 × 86,276 = \$1.01 million

Model 4: replicated "altcost" with five outliers removed, 1/3 of the wage rate as the value of time, and equally shared out-of-pocket expenses for respondents who drove.

Average consumer surplus per visit: -1/-0.08100019 = \$12.35
Annual recreation value of the beach: \$12.35 × 86,276 = \$1.07 million

Separate Seasonal Estimations

Noting that the majority of beach visits occur in the summer, it is plausible that the demand function for summer visits is markedly different from that for non-summer visits. Modeling summer visits separately from non-summer visits allows for this possibility and also permits summer visits to be valued differently from non-summer visits. Results for this approach are summarized below.

Model 1: similar to Model 1 but with separate estimations for summer and non-summer trips.*

Average consumer surplus per summer trip: \$42.29
Average consumer surplus per non-summer trip: \$22.96
Summer recreation value of the beach (46,463 visitors): \$1.97 million
Non-summer recreation value of the beach (39,813 visitors): \$0.91 million
Annual recreation value of the beach: \$2.88 million

Model 2: similar to Model 2 but with separate estimations for summer and non-summer trips.*

Average consumer surplus per summer trip: \$18.81
Average consumer surplus per non-summer trip: \$12.96
Summer recreation value of the beach (46,463 visitors): \$0.87 million
Non-summer recreation value of the beach (39,813 visitors): \$0.52 million
Annual recreation value of the beach: \$1.39 million

Model 3: similar to Model 3 but with separate estimations for summer and non-summer trips.*

Average consumer surplus per summer trip: \$13.21
Average consumer surplus per non-summer trip: \$10.17
Summer recreation value of the beach (46,463 visitors): \$0.61 million
Non-summer recreation value of the beach (39,813 visitors): \$0.41 million
Annual recreation value of the beach: \$1.02 million

Model 4: similar to Model 4 but with separate estimations for summer and non-summer trips.*

Average consumer surplus per summer trip: $15.11
Average consumer surplus per non-summer trip: $10.20
Summer recreation value of the beach (46,463 visitors): $0.70 million
Non-summer recreation value of the beach (39,813 visitors): $0.41 million
Annual recreation value of the beach: $1.11 million

Summary of Results

Although Model 4* is arguably the most consistent with accepted practice, it is clear from this analysis that the estimated recreation value of the beach is highly dependent on assumptions about the value of travel time, and that this value could be greater than 1/3 of the wage rate. One can conclude from this analysis that a defensible estimate of the annual recreation value of the beach for adult visitors is between $1 and $3 million and probably in the lower half of this range.

5. Caveats for this Analysis

This analysis remedies the key shortcomings of the CIC report but does not address other important issues. These include:

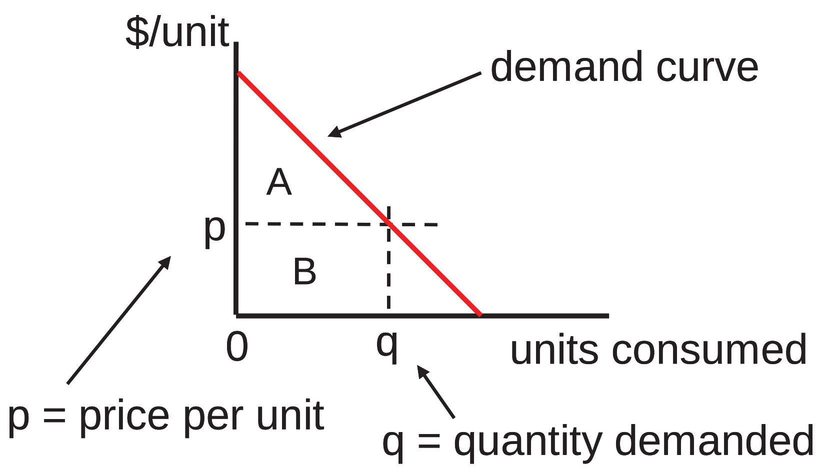
- The dataset only enables estimation of the *recreation* value of the beach *for beach visitors*. It does not inform the value of the beach as a revenue generating asset for local businesses or the City. It also does not inform other non-market components of beach value such as non-use (existence, option, bequest) value and amenity value.
- The dataset cannot be used to address the fact that some beach visits may be part of multi-purpose trips to the Solana Beach area (e.g., visiting friends, shopping, dining, golfing). Neglecting to account for multi-purpose trips, particularly those with a primary purpose other than visiting the beach, tends to bias the estimated recreation value upward.
- The dataset cannot be used to account for substitute recreation sites and activities that might be chosen as alternatives to a Solana Beach visit. Neglecting to account for substitutes also tends to bias the estimated recreation value upward.
- The dataset cannot be used to distinguish between weekday and weekend trips, which may have different values. If weekend trips are more highly valued and more common, neglecting to account for this will bias the estimated recreation value downward.
- Beach visitation currently could be impacted by seawall-induced erosion. To the extent this is happening, neglecting to account for it will bias estimated recreation values downward. The dataset potentially could be used to address this issue, although supplemental data might be needed.
- Neither this analysis nor the CIC report accounts for the possibility that respondents may choose their residential locations based, in part, on their preferences for outdoor recreation. Neglecting to account for beach users who deliberately choose to live close to the beach because they have strong preferences for beach recreation

will bias the estimated recreation value downward. The dataset potentially could be used to address this issue, but doing so would require substantial additional work.

- Neither this analysis nor the CIC report accounts for potentially different impacts of beach loss on different types of beach users. The dataset might be used to address this issue.
- Travel time costs could be further refined, for example, by treating unemployed and employed respondents differently. The dataset could be used to address this issue.
- Neither this analysis nor the CIC report accounts for visits by children. Including children is problematic because it is even more difficult to place an appropriate value on their time. However that value should be positive but less than the value of an adult's time. Therefore the information in this analysis could be used to estimate an upper bound on the recreation value of the beach for children.

Appendix A

Figure 1: A standard demand curve.



Appendix B

Model 1: replicated "altcost" with five outliers removed.

```
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Model estimated: Jun 07, 2010 at 05:16:05PM.|
| Dependent variable               TRIPS1     |
| Weighting variable             ADULT_WT     |
| Number of observations              325     |
| Iterations completed                  7     |
| Log likelihood function       -1615.371     |
| Restricted log likelihood     -1909.570     |
| Chi squared                    588.3973     |
| Degrees of freedom                    7     |
| Prob[ChiSqd > value] =         .0000000     |
| LEFT  Truncated data, at Y =  0.            |
| Chi- squared =  2563.05159  RsqP=   .1210   |
| G  - squared =  2142.44759  RsqD=   .2026   |
| Overdispersion tests: g=mu(i)  :  4.100     |
| Overdispersion tests: g=mu(i)^2:  2.848     |
| Robust (sandwich) estimator used for VC     |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.20841936	.21009331	10.512	.0000	
SPRING	-.16511455	.18952311	-.871	.3836	.15635179
SUMMER	.14308625	.15011080	.953	.3405	.58957655
FALL	.08351890	.19576464	.427	.6696	.14006515
AGE_MID	.01066151	.00319487	3.337	.0008	39.5944625
SEX_M1	.01124376	.10296274	.109	.9130	.57003257
ALTCOST2	-.03225582	.00596868	-5.404	.0000	20.1929915
INC_000	.00049082	.00144886	.339	.7348	56.1726384

Model 2: replicated "altcost" with five outliers removed and 1/2 of the wage rate as the value of time.

```
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Model estimated: Jun 07, 2010 at 05:19:17PM.|
| Dependent variable              TRIPS1      |
| Weighting variable            ADULT_WT      |
| Number of observations             325      |
| Iterations completed                 8      |
| Log likelihood function      -1478.075      |
| Restricted log likelihood    -1909.570      |
| Chi squared                   862.9890      |
| Degrees of freedom                   7      |
| Prob[ChiSqd > value] =        .0000000      |
| LEFT  Truncated data, at Y =  0.            |
| Chi- squared =  2265.65033  RsqP=   .2230   |
| G  - squared =  1874.66129  RsqD=   .3023   |
| Overdispersion tests: g=mu(i)  :  4.110     |
| Overdispersion tests: g=mu(i)^2:  2.764     |
| Robust (sandwich) estimator used for VC     |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.34947894	.19062050	12.325	.0000	
SPRING	-.17460856	.18064658	-.967	.3338	.15635179
SUMMER	.12122418	.14149030	.857	.3916	.58957655
FALL	.08186590	.18151916	.451	.6520	.14006515
AGE_MID	.00991578	.00294505	3.367	.0008	39.5944625
SEX_M1	.05229353	.09792016	.534	.5933	.57003257
ALTCOST4	-.06366289	.00939724	-6.775	.0000	13.5992645
INC_000	.00035534	.00146937	.242	.8089	56.1726384

Model 3: replicated "altcost" with five outliers removed and 1/3 of the wage rate as the value of time.

```
+--------------------------------------------+
| Poisson Regression                         |
| Maximum Likelihood Estimates               |
| Model estimated: Jun 07, 2010 at 05:20:56PM.|
| Dependent variable               TRIPS1    |
| Weighting variable             ADULT_WT    |
| Number of observations              325    |
| Iterations completed                  8    |
| Log likelihood function       -1399.995    |
| Restricted log likelihood     -1909.570    |
| Chi squared                    1019.149    |
| Degrees of freedom                    7    |
| Prob[ChiSqd > value] =         .0000000    |
| LEFT  Truncated data, at Y =  0.           |
| Chi- squared =  2090.03763  RsqP=   .2832  |
| G  - squared =  1718.11972  RsqD=   .3605  |
| Overdispersion tests: g=mu(i)  :  4.583    |
| Overdispersion tests: g=mu(i)^2:  2.978    |
| Robust (sandwich) estimator used for VC    |
+--------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.42006833	.17825417	13.577	.0000	
SPRING	-.17661642	.17506227	-1.009	.3130	.15635179
SUMMER	.11018288	.13628649	.808	.4188	.58957655
FALL	.08584336	.17277348	.497	.6193	.14006515
AGE_MID	.00937837	.00279710	3.353	.0008	39.5944625
SEX_M1	.07448887	.09481751	.786	.4321	.57003257
ALTCOST5	-.08545229	.01218899	-7.011	.0000	11.4013555
INC_000	.117878D-04	.00146833	.008	.9936	56.1726384

Model 4: replicated "altcost" with five outliers removed, 1/3 of the wage rate as the value of time, and equally shared out-of-pocket expenses for respondents who drove.

```
+---------------------------------------------+
| Poisson Regression                          |
| Maximum Likelihood Estimates                |
| Model estimated: Jun 07, 2010 at 05:22:16PM.|
| Dependent variable                TRIPS1    |
| Weighting variable               ADULT_WT   |
| Number of observations                325   |
| Iterations completed                    7   |
| Log likelihood function       -1612.978     |
| Restricted log likelihood     -1909.570     |
| Chi squared                    593.1832     |
| Degrees of freedom                      7   |
| Prob[ChiSqd > value] =         .0000000     |
| LEFT  Truncated data, at Y =  0.            |
| Chi- squared =  2583.07761  RsqP=   .1141   |
| G  - squared =  2119.33940  RsqD=   .2112   |
| Overdispersion tests: g=mu(i)  :  5.208     |
| Overdispersion tests: g=mu(i)^2:  3.492     |
| Robust (sandwich) estimator used for VC     |
+---------------------------------------------+
```

Variable	Coefficient	Standard Error	b/St.Er.	P[|Z|>z]	Mean of X
Constant	2.16061436	.20417437	10.582	.0000	
SPRING	-.16348665	.19302259	-.847	.3970	.15635179
SUMMER	.17975554	.15467974	1.162	.2452	.58957655
FALL	.16869673	.19625521	.860	.3900	.14006515
AGE_MID	.01109796	.00313529	3.540	.0004	39.5944625
SEX_M1	.05792394	.10166342	.570	.5688	.57003257
ALTCOST6	-.08100019	.01729944	-4.682	.0000	8.02641691
INC_000	-.00022354	.00152737	-.146	.8836	56.1726384

Letter G-1

Jim Jaffee
738 Seabright Lane
Solana Beach, CA 92075
July 10, 2010

Ms. Tina Christiansen, AIA, Community Development Director
City of Solana Beach,
635 South Highway 101
Solana Beach, CA, 92075

Dear Tina:

These comments are in response to the:

1) "Draft Land Lease & Recreation Fee Report", dated March 2010.
2) A memorandum provided by Leslea Meyerhoff from Donna Snider of PMC with the subject: Re: Solana Beach Land Lease/Recreation Fee, dated June 2, 2010.
3) Material from the City website with supporting data for Beach Counts and Beach Survey contained in the :
    a. Beach Study Survey (pdf)
    b. Beach Study Survey (excel)
    c. Beach Study Beach Counts (pdf)
    d. Beach Study Beach Counts (excel)

1. Summary

The data collected by CIC and published by PMC provides a framework that could lead to a fair assessment of Land Lease and Recreation Value of beaches impounded or blocked from formation by seawalls and other such structures in Solana Beach if corrections were made to account for several factors identified in review of the aforementioned documents.

The Surfrider Foundation asked Professor Kenneth Baerenklau to examine the analysis of beach value conducted by CIC Research. Dr. Baerenklau is an Associate Professor of Environmental Economics and Policy (and Associate Dean of the Graduate Division) at UC Riverside. He has published extensively in academic journals and is an expert on the economic valuation of environmental resources. Surfrider requested that Dr. Baerenklau examine the methodology that CIC used to collect data on beach attendance and to estimate the recreational value of the beach along the coastline of Solana Beach. Dr. Baerenklau‟s review of CIC‟s report revealed three flaws in their analysis (in addition to several statistical discrepancies). First, CIC erred in how they estimated the value of beach visits. CIC used standard methods to estimate the travel cost that beach users

Comment 1

incurred in visiting the beach but then engaged in the non-standard practice of equating this cost with the value that users attach to their visit. CIC‟s approach to beach valuation violates best practice in the environmental economics profession for it ignores the value the beach users derive from visiting the beach above and beyond their travel cost. Using

Comment 2

Comment 3

CIC"s data, Dr. Baerenklau applied best-practice methods in beach valuation, which account for the full value of a beach visit. This correction increases the estimated recreational value of the beach by 32% (from $2.08m to $2.67m). Second, CIC did not allow for the possibility that the demand for using the beach is stronger in the summer, when most beach visits occur. In his analysis, Dr. Baerenklau allowed for seasonal differences in the demand for beach use, which raised the recreational value of the beach by a further 10% (from $2.67m to $2.88m). Third, CIC did not explain how individual leisure time should be valued. In estimating the travel cost each visitor incurred in going to the beach, CIC applied the standard practice of using an individual"s hourly wage rate to value his or her time cost. However, CIC then followed the non-standard practice of valuing an individual"s leisure time at 100% of his or her wage rate. Such an approach may overstate the value of a beach visit, as had individuals not gone to the beach they may not have been able to work for their full market wage. In truth, the value that individuals place on their leisure time may be less than 100% of their hourly income. Thus, two of CIC"s errors lead to an underestimate of the recreational value of the beach and one leads to an overestimate. Dr. Baerenklau"s report is attached to this summary.

In addition to Dr. Baerenklau"s review, Surfrider Foundation volunteers, aided by Environmental Director Chad Nelsen[1], extensively reviewed the report and we believe that corrections are possible within the scope of the present framework outlined by CIC and PMC.

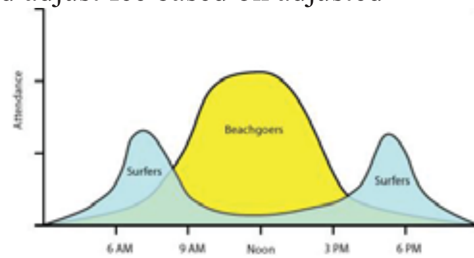
Table 1 provides a summary of the corrections and approaches to correct for them. Note there are numerous factors that would impact the value and attendance as well as offset credits.

Table 1 Summary of Required Corrections

Comment 4

#	Issue	Correction
1	Underestimated Impact of Special uses	Obtain value of Special uses such as Junior Lifeguard Program, Triathlons, Surf Contests and others and add the attendance to the beach counts and associated spending to the beach value. The estimated fees from the Junior Lifeguard program based on 600 participants over 2.5 sessions at $325 yields approximately $162,500 in fees alone. Junior Lifeguard Revenue in the 09/10 Budget is listed as $123,000. (See Comment Matrix #11)

[1] Chad Nelsen is the Environmental Director at the Surfrider Foundation and is also pursuing his doctorate at UCLA on surf economics in the interdisciplinary Environmental Science and Engineering (ESE) program.

Comment 5	2	Underestimated Beach Attendance due to under sampling surfers and morning intensive uses. Beach attendance was under sampled in morning hours when surfers are most likely to use the beach.	Scale beach attendance with a more appropriate estimate and adjust fee based on adjusted attendance.  A graphical representation of typical surfing and beach going attendance patterns over a day for many places in the world. From http://surfeconomics.blogspot.com/2009/02/intercepting-surfers.html (See Comment Matrix # 18)
Comment 6	3	Lack of use of consumer surplus in determining value	Add a demand curve formulation from acquired data to determine the surplus. The demand curve will yield the willingness to pay of beach visitors. (See Dr. Baerenklau‟s Report and Comments Matrix #23)
Comment 7	4	Beach Area Calculation is not correct.	The Land Lease Area should be enlarged in the first years to account for episodic erosion consistent with the LUP requirement. This is also consistent with the Sand Mitigation Fee area = Retreat Rate * Width of Seawall * Design Life of Seawall. The Land Lease Recreation Fee should be scaled by the enlarged area to account for episodic erosion. (See Section 3 Lease Area Correction and Comments Matrix #1 through 4)
Comment 8	5	The erosion rate is not reflective of the latest science and observations.	The erosion rate should be adjusted upward to be consistent with the Army Corps data and for required sea level rise planning. The land lease area and fee should be adjusted by the scaled erosion rate. (See Comments Matrix # 7 and 8)
Comment 9	6	Safety benefits to property owners were calculated over a larger study area than beach attendance and surveys.	The area for the attendance, surveys and preferences should be similarly scaled or the area for safety benefit study reduced for consistency. (See Comments Matrix #5)
Comment 10	7	The impact of already constructed seawalls blocking access to segments of the beach was not considered in the study.	This impact could be determined by scaling beach attendance and value in areas such as Fletcher Cover which is not impacted by a seawall and applying it to other areas impacted by seawalls. Alternatively, the study site could be extended as was done for the safety issue to find alternative sites. (See Comments Matrix # 12 and 17)

Comment 11	8	The benefits of seawalls in safety to property owners were not considered as an offset.	The LUP requires that benefits to property owners offset any public benefit. Safety benefits to residents of private property being protected from bluffs collapsing beneath them and for workers or visitors on their property must be added to offsets. (See Comments Matrix # 16)
Comment 12	9	Children were not counted in the study beach value. Attendance and economic impact of child visits are completely omitted from the study.	Attendance of beach by children has a value and must be added in the study. An example willingness to pay metric is the price of a Junior Lifeguard day which is approximately $16 per day. Alternatively, a percentage of adult value could be considered. (See Comments Matrix # 28)
Comment 13	10	Aesthetics which is recognized as unmitigated impact in the MEIR was not considered in fee valuation.	An impact offset associated with aesthetics could be determined by extending the study site as was done for the safety issue to an area similar to Solana Beach that does not have shoreline armoring. A factor for attendance preference based on aesthetics may be determined from the alternative beach site. (See Comments Matrix # 13)
Comment 14	11	Surfing and other uses that are particular to the study site were not valued.	See if data collected at Solana Beach from surfers can be used with the model used to value the waves at Mavericks. "The Value of a Wave, An Analysis of the Mavericks Region and An Analysis of the Mavericks Wave from an Ecotourism Perspective", from http://savethewaves.org (See Comments Matrix #28)
Comment 15	12	Value of resident preferences to live near the beach not accurately reflected in Travel Cost method. These who pay extra to live near the beach and not use cars are penalized in travel costs.	Consider assigning a preference value to those living in walking distance. (See Comments Matrix # 27)
Comment 16	13	Detailed Comments Matrix	Additional Issues are included in the Comments Matrix Attached to this Summary Document. All of the issues identified in the Comments Matrix should be included in the response to public comments.

Comment 17

2. Corrections for Recreation and Land Value

Corrections can be made by scaling attendance, lease area and adding requisite valuation for additionally identified components in our review.

The study assumes the annual value of the recreational beach area is:

Equation 1 Beach Value Equation from PMC Report

$$Value = AdultAttendance \times RecreationValueAdultDay$$

A corrected equation for value would include factors for children‟s attendance at the beach, special uses of the beach including Junior Lifeguards and surf contests, consumer surplus, attendance under-sampling of surfers in morning hours, attendance under-sampling of Junior Lifeguards and valuing surfing as a specific use.

Equation 2 Corrected Value Equation for recreational beach use adds ability to account for surfing preference, children attending the beach, and value of Junior Lifeguards, Special Uses and Aesthetics

$$\begin{aligned} CorrectedValue \\ = &\Big(\big(AdultAttendance_{Beach*} + AdultAttendance_{Wading}\ *\big) \\ &\times RecreationSurplusAdultDay\Big) + AdultAttendance_{Surfing*} \\ &\times\ RecreationSurplusAdultDay_{Surfing} \\ &+ \Big(\big(ChildAttendance_{Beach*} + ChildAttendance_{Wading*}\big) \\ &\times RecreationSurplusChildDay\Big) + ChildAttendance_{Surfing*} \\ &\times\ RecreatioSurplusChildDay_{Surfing} + Value_{JrGuards} \\ &+ Value_{SpecialUse} + Value_{Aesthetics} \end{aligned}$$

In the *CorrectedValue* Equation, an asterisk „*‟, represents a corrected attendance value to account for issues identified in Table 1 and in Dr. Baerenklau‟s review, such as potential under-sampling of surfers and Junior Lifeguards. The attendance values are separated into components so that a value can be assigned to surfing.

The *CorrectedValue* Equation contains value components for the Junior Guard Program, Special uses and Aesthetics.

Comment 18

3. Lease Area Correction

The lease area can also be corrected by increasing the area of the first year land lease to account for episodic erosion. The erosion is then similarly scaled over the entire lease interval. The model for erosion used in Section 5 and illustrated in Figures 5-5, 5-6 and 5-7 of the report are appropriate to account for episodic erosion.

Figure 1 shows a comparison of calculated lease area per year in the report with a model for episodic erosion. The model for episodic erosion is based on simplified model of 8.2ft of erosion occurring every 21 years consistent with the probabilistic models proposed in Section 5 of the report. Note that in the first year, the Land Lease Area is 2.4ft, which assumes 0.4ft/yr of erosion plus a wall thickness of 2 ft. In sharp contrast, the model for episodic erosion has a first year Land Lease Area of 10.2ft, which includes 2 ft of wall thickness and 8.2ft to account for a 70% probability of failure consistent with Section 5 of the PMC report.

The LUP calls for accounting for episodic erosion. Thus a correction must be made to the Land Lease Area to account for episodic erosion given the huge discrepancy in area shown in Figure 1.

The model for episodic erosion shown in Figure 1was used to account for safety offsets in the PMC report yet was ignored for the Land Lease Area.

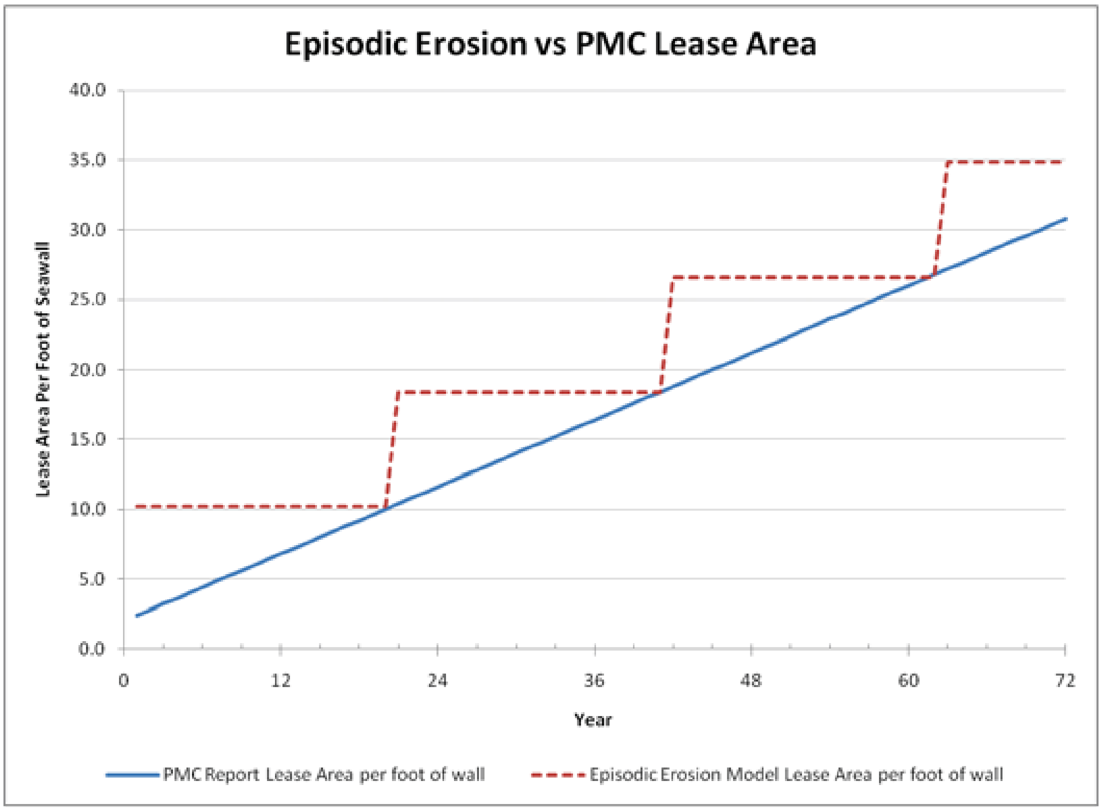


Figure 1 Comparison of PMC's calculated lease area in the report with a model for episodic erosion

4. Clarifications Required

In order to make the report more reproducible and defensible, certain clarifications must be provided as outlined in Table 2.

Table 2 Required Clarifications

Comment 19

#	**Issue**	Clarification
1	Scaling attendance not clear	The methodology used to scale attendance especially for early morning visitors such as surfers is not adequately exemplified. It is not clear if surfers were interviewed for arrival time by sampling in the early morning hours

			in sufficient quantity to get a valid estimate of attendance and appropriate scaling. (See Comments Matrix # 18)
Comment 20	2	Junior Lifeguard Sample Days not easy to deduce from data	Given that the Junior Lifeguard Program begins the first Monday after school is finished and ends 10 weeks later it is likely that beach counts should have sampled the program in full attendance at one time over this interval. From the data provided on the City Website, there does not appear to be a summer day sampled where attendance matches expected attendance at a Junior Lifeguard Day where approximately 100 children should be on the beach daily with accompanying support staff. (See Comment Matrix #26)
Comment 21	3	City Position on Sea Level rise and erosion rates	The City Should Clarify its position on Sea Level Rise. The City has requested that the 22nd DAA include Sea level rise estimates in the Fairgrounds DEIR. The same standard of review should likely apply in the present study in determining erosion rates. (See Comments Matrix # 8)

Any clarifications that lead to further adjustments in attendance or erosion rate can easily be adapted in the framework provided by PMC and including the corrections mentioned in Sections 1 to 3 of this document.

5. Conclusion

In conclusion, Surfrider Foundation contracted Dr. Baerenklau to perform a peer review of the CIC Report. Dr. Baerenklau‟s found that CIC‟s approach to beach valuation violates best practice in the environmental economics profession for it ignores the value the beach users derive from visiting the beach above and beyond their travel cost. Review of the PMC Report and CIC Report by Surfrider Foundation found that additional factors would limit the value PMC and CIC derived for the beach lost to seawalls. These factors are outlined in the attached Comment Matrix and in Table 1. Among the important factors requiring corrections are the attendance of surfers in early morning hours, value of children‟s beach visits, value of the Junior Lifeguard Program and other Special Uses, Corrections to arrive at a fair value are proposed in Section 2, ***Corrections for Recreation and Land Value*** and in ***Equation 2 Corrected Value Equation for recreational beach use adds ability to account for surfing preference, children attending the beach, and value of Junior Lifeguards, Special Uses and Aesthetics***.

The PMC report also fails to properly calculate the Land Lease Area to account for episodic erosion as required by LUP Policy 4.80 B.1. In Section 3 Lease Area Correction, we propose a model from within PMC‟s Report to account for episodic erosion in correcting the Land Lease Area in the first year.

Sincerely,

Jim Jaffee - Advisor to the San Diego County Chapter of the Surfrider Foundation
Dr. Gordon Hanson - Volunteer San Diego County Chapter of the Surfrider Foundation

Attachments:

1) San Diego Chapter of the Surfrider Foundation CalBeach Advocates Comment Matrix Solana Beach Land Lease Recreation Fee Study
2) Review of "A Study of the Economic Value of Public Beach Land in Solana Beach" by CIC Research, Inc. Prepared for The Surfrider Foundation by Dr. Ken Baerenklau. Associate Professor of Environmental Economics & Policy University of California – Riverside ken.baerenklau@ucr.edu

#	Comment	Section	Notes
1	33% of fee is due up front and should include 33% of the erosion due to episodic event being prevented. The calculations in the report do not charge 33% up front.	Executive Summary 1-3	LUP requires in 4.80 B.1 that "...an initial payment equal to thirty three percent (33%) of the total amount of the Land Lease/Recreation Fee shall be paid to the City when the building permit is issued, as mitigation for episodic events, which might have occurred if the Bluff Retention Device had not prevented erosion of the bluff from occurring."
2	The Land Lease Area is not calculated correctly. The first year area is 2.4ft times the length of the wall. The area is the total area through 2081 times the erosion rate and should account for episodic erosion.	Table 4-2 and 4-3	LUP Definitions: "Land Lease Area shall equal the area on the public beach measured in square feet from the seaward face of the Bluff Retention Device to the line at the base of the theoretical plane to which the bluff would have eroded if no Bluff Retention Device existed from the date of completion of the Bluff Retention Device through December 31, 2081, assuming the Erosion Rate, limited by the seaward fee simple property line of the subject Bluff Property." The area is the total area over the 2081 time period.
3	Episodic erosion was used to consider safety offset but not Land Lease Areas. On page 5-8, it is noted a 7 foot average notch depth is what is observed in Terra Costa data. On Fig 5-5, it is predicted a 100% chance of failure of an existing 7ft notch occurs within 3 years. On page 5-11, it is clearly shown for safety calculations that episodic events on the order of 8.2ft would occur every 21 years and initially. All this assumes 0.4ft/yr erosion.	Page 5-8 to 5-11	Inconsistent application of episodic erosion. Used for safety calculations, but not for lease area. Lease area at year 3 is 1.2ft and 2 additional feet for the wall thickness. This is well short of the 8.2 ft factor and also well short of 33% of the erosion assumed in the LUP. Episodic erosion must be accounted for in the lease area payment for the first years.
4	The Fee study mentions the section of the Draft LUP but clearly omits mention of the 33% episodic erosion factor.	page 2-2	Quote from Section 4.80B omits: "For new Substantial Infills and Coastal Structures, an initial payment equal to thirty three percent (33%) of the total amount of the Land Lease/Recreation Fee shall be paid to the City when the building permit is issued, as mitigation for episodic events, which might have occurred if the Bluff Retention Device had not prevented erosion of the bluff from occurring. The remaining sixty seven percent (67%) of the Land Lease/Recreation Fee shall be amortized over the remaining yearly periods ending December 31, 2081, prorated and paid annually."

5	For calculations of safety the study area was extended to Batiquitos Lagoon. "Therefore, in order to obtain failure-fatality data upon which to base an average fatality loss analysis it is necessary to extend the analysis beyond Solana Beach to include Encinitas where both failures and fatalities (one)have occurred."	Page 5-4	Extending the study area is not consistent with other portions of the study. Factors affecting beach attendance such as the narrowing of the beach by the presence of existing seawalls along Solana Beach were not considered and compared to other areas without Seawalls outside the study area. Additionally, preference of beach users in attending beaches outside the study area was not considered. The study area was extended to Batiquitos Lagoon for safety factors. No similar extension of the study area was made to account for the impact of CPS on beach attendance or preferences. Either the safety study area be reduced or preference data from study area extension should be applied to the beach attendance and preferences.
6	It is unclear why 126 failures were used in safety calculations given that the referenced study "Statistical Simulation for Coastal Bluff Failure Induced by Storm Waves" mentions 193 failures between 1990's and 2004.	Page 5-4	As noted, the referenced study contains a list of 193 failures limited to the study period ending in 2004. Additional failures likely occurred after 2004. Why were the failures truncated to 126? Why were additional failures after 2004 not considered? There have been no deaths between 2004 and 2010. Why was this data not included.
7	Latest Erosion Rate data not considered in study.	CalBeach Advocates 11/6/2008 Comment Letter to City	CalBeach Advocates supplied detailed comments to the fee study on November 6, 2008. These comments are still not adequately addressed in the draft report. “The LUP and the City continue to neglect information in the ACOE DEIS which estimates bluff retreat rates of 0.4-1.2 ft/yr and between 1.67 and 1.9ft/yr when accounting for sea level rise. Present mitigation fees from the LUP assume a retreat rate of 0.4ft/yr. This is new information that is ignored. This information was presented in study authored by both the Army Corps of engineers and using Walter Crampton, a representative Geotechnical Engineer for many property owners.” he City should apply the same standard to calculate erosion rates of coastal bluffs.

8	Sea Level Rise not factored in erosion rate. "The DEIR lacks a discussion of potential impacts, impact conclusions and mitigation measures for the project site associated with projected sea level rise. This is a statutory requirement of all projects under CEQA and is critically important for a project which contains elements that are planned for below-grade adjacent to a flood plain and coastal lagoon areas. The lack of analysis and failure to identify these significant impacts of sea level rise on the project site and failure to include specific mitigation, triggers a requirement for recirculation of a revised the DEIR pursuant to CEQA § 15088.5(a) (1)." and "The DEIR also fails to provide sufficient information concerning discussion of impacts to sea level rise given Governor Arnold Schwarzenegger's Executive Order (EO) S-13-08 issued by the State on November 14, 2008 (see Attachment #2). This Executive Order provides guidance to state agencies, like the 22nd DAA, for how to plan for sea level rise in designated coastal and floodplain areas. Provide data supporting this issue, then revise and recirculate the DEIR."	City Letter (Section F) and Comments Matrix (Item #46) on Del Mar Fairgrounds DEIR dated Feb. 1, 2010	The City submitted detailed comments on the Fairgrounds EIR that included state guidance on Sea Level Rise as a consideration for development in the floodplains. Sea level rise scenarios from current guidance are 16 inches in 2050 and 55 inches in 2100. The City should apply the same standard of review with respect to sea level rise to calculate erosion rates of coastal bluffs.
9	Erosion rate estimate from MEIR and Group Delta multiplies shore platform slope times sea level rise estimate.	MEIR and references	Historical sea level rise 0.64 ft/century *60:1 slope = 40 ft/century erosion or 0.4 ft/yr. Sea Level rise of 16 inches until 2050 yields an erosion rate estimate of 1.33ft/40 years *60:1 slope= 2ft/yr. Sea Level rise of 55 inches until 2100 yields an erosion rate estimate of 4.58ft/90 years *60:1 slope= 3.06ft/yr. A readjustment of the erosion rate and an associated scaling of the Land Lease Area and Fee must be added to the calculations.
10	Item 9 of CalBeach Advocates 11/6/2008 comments still not addressed: "9) It is unclear how the present survey instrument will value recreational and other uses of the ocean itself by surfers, swimmers, divers, boaters, fisherman, paddleboarders and others. The study must address the value of these uses."	CalBeach Advocates 11/6/2008 Comment Letter to City	Given that surfing was the primary use of beach users according to the survey instrument, additional value should be determined for such use.

11	Item 11 of CalBeach Advocates comments still not addressed: "11) It is unclear how the study will value the Junior Lifeguard Program, surfing contests, triathlons and other such events and programs. The study must consider these."	CalBeach Advocates 11/6/2008 Comment Letter to City	It costs $325 to send a child to the beach for the 20 day Solana Beach Junior Lifeguard Program. There are approximately 600 participants over 2.5 sessions. The total value of fees alone is estimated at $160,000. Junior Lifeguard Revenue in the 09/10 Budget is listed as $123,000. There are several session over the 10 weeks of the summer program. Additionally, the Junior Lifeguard Program creates jobs in the City and spending in the City. There are also likely grants that the City receives and savings in teaching youth beach safety. Triathlons and other special events such as the Beach Blanket Bingo Surf Contest and others must also be considered. The benefit of special uses should be added to the beach valuation. If the beach were to be lost to seawalls, the revenue from these beach dependent uses would be lost.
12	Item 14 of CalBeach Advocates comments still not addressed: "14) The study of beach attendance in process neglects the impact of CPS's that have already been constructed. Since the City has allowed construction of CPS's to occur with only deposits for mitigation, the impact of these structures is already being felt on the beach. This impact may have already led to a narrowing of the beach. This effect may decrease the public's willingness to attend the beach. This should be factored into the analysis portion of the study or with additional survey instruments. The Random Utility or Contingent Value models are better suited to address this other of the concerns mentioned."	CalBeach Advocates 11/6/2008 Comment Letter to City	Not only was the original request ignored, but the study chose to extend the study area for the purposes of determining safety factors. As noted in Comment 5 above, the study area was extended to Batiquitos Lagoon for safety factors. No similar extension of the study area was made to account for the impact of CPS on beach attendance or preferences. Either the safety study area be reduced or preference data from study area extension should be applied to the beach attendance and preferences.

13	Item 19a of CalBeach Advocates comments still not addressed. This concern, in part, was also raised by Mayor Nichols at the time: " 19)There are negative impacts that should be a negative to any offset credit consideration at the public hearing. A negative means that it would deduct from an offset credit and would be equivalent to an additional fee if it was assessed. Alternatively, these additional negative credits could be considered as additional permit fees on a case by case basis. A list of suggested negative offset credits for consideration follows. a) Aesthetics – This is an unmitigated impact in the MEIR. The complete armoring of the upper and lower bluffs will render the ocean and view from Table Tops reef for both surfers and Tide Pooler's, obsolete. The study must consider aesthetics."	CalBeach Advocates 11/6/2008 Comment Letter to City Draft Report 5-1	Page 5-1 of the study clearly states negative offsets were neglected. Negative offsets should be included as a separate component of the fee.
14	Item 19c-e of CalBeach Advocates comments still not addressed. This concern, in part, was also raised by Mayor Nichols at the time: " 19)c) Erosion of the Tidal Terrace – This impact was clearly identified in the MEIR. The erosion of the tidal terrace could increase the need for additional sand in the system, have adverse impacts on wave breaking and surf breaks among other impacts. The Land Lease and Sand Mitigation Fees do not consider these. d) Reflection - This impact was clearly identified in the MEIR. The erosion of the tidal terrace could increase the need for additional sand in the system, have adverse impacts on wave breaking and surf breaks among other impacts. The Land Lease and Sand Mitigation Fees do not consider these. e) Surf breaks – Impacts from seawalls on surf breaks was neglected in the MEIR and DEIS from the ACOE. The Land Lease and Sand Mitigation Fees do not consider such impacts in their formulation.	CalBeach Advocates 11/6/2008 Comment Letter to City Draft Report 5-1	Page 5-1 of the study clearly states negative offsets were neglected. Negative offsets should be included as a separate component of the fee.

15	Item 19f of CalBeach Advocates comments still not addressed. This concern, in part, was also raised by Mayor Nichols at the time: " 19) f) Costs of all the studies that are required to assess and administer the shoreline programs including the fee study itself, staff overhead, inventory of surf breaks, the design costs incurred by the city for Preferred Bluff Retention Solution and other required elements in the LUP.	CalBeach Advocates 11/6/2008 Comment Letter to City Draft Report 5-1	It is important to recover on a cost basis all fees associated with granted permits and applying mitigation. Otherwise these funds will be taken from the general fund or be subtracted from the lease fees thus detracting from the actual mitigation.
16	Offset credit public safety – The benefit in protecting life on private property was neglected in assigning a value to the private property owner. It is far more likely that an injury would occur from the top of the bluff than at the bottom without the construction of the seawall.	Draft Report Section 5	An offset can only be applied to the extent the public benefit exceeds the private benefit, this must be accounted for. CalBeach Advocates letter of 11/6/2008 noted case of injuries in the study site associated with seawall construction and people falling from the top of the bluff. A private benefit in safety protection to property owners including residents and workers should be added to the offset calculation
17	We strongly disagree with this statement. "The number of visitors within a beach area reveals the preference of on beach area over another. The more crowded a beach area, the more it is valued and this approach inherently captures the heterogeneity of beach area such as quality, amenities and surf conditions.	Executive summary pp 1-1 to 1-2	While it may be true for the subject site in its present condition, it does not factor the environmental degradation we note caused by the presence of seawalls and compare those to unaffected beaches out of the study site or even within the site. Beach attendance is very likely impacted by the presence of seawalls. These seawalls were allowed to be constructed pending mitigation determined by this study. The impact of their presence is a factor. As an example, a narrow beach close to an access may prevent access along the shoreline to other zones. Further exemplifying this, the notch fill directly adjacent and north of Fletcher Cove was built in approximately 2002. Such obstruction to beach access likely limited the attendance on these beaches. An estimate of preference should be used to correct attendance figures and preferences

18	It is unclear if the beach count estimates are adequate to sample surfers and other beach users who are likely to arrive and depart in hours that were not rigorously sampled.	Table 3-4 and supporting material	Table 3-4 shows that 94% of beach visitors between 6:00am and 7:59am and 79.2% of beach visitors between 8:00am and 9:59am were estimated to be missed in counting in that time block. There is a very small number of counts made during those hours. These hours are the most likely times surfers and possibly fisherman, triatheletes and others visit the beach. Given that surfing was already identified as the highest type of beach visitor purpose, this is likely a significant undercounting. It also would have undersampled those surfers that are likely to have 9-5 jobs for salary data. More detailed Explanation of scaling attendance should be added to the report and the beach estimates for specific uses such as surfing in undersampled times must be corrected.
19	The total beach area is estimated to be 8.18 acres. Using an erosion rate of 0.4ft/yr per the Draft LUP, we lose 5.09 acres relative to the 8.18 acres of existing beach over the study period.	Page 4-13 Table 4-1	The lease area is trapped behind the seawall and is significant relative to the beach especially considering sea level rise. With sea level rise scenarios per S-13-08 guidance, we may lose 20.4 acres in the 2050 scenario over the 75 years and 35 acres with the 2100 scenario of sea level rise. Both of these assume linear modeling.
20	The NPV value of 2% is nowhere in the report justified. Also, fees are not adjusted for inflation for future payments.	Page 4-17 Table 4-3	An explanation of the discount rate and the lack of inflation should be added to the report and the report corrected as needed.

21	CalBeach and others have repeatedly objected to the use of Public Land for private use. We find it ironic that the City would object to the use of Public trust land in the fairgrounds for private use yet sell out its own vested Public Ownership rights to private property owners for seawalls. "The Proposed Project is one of region-wide, and arguably state-wide, significance in both its scope and magnitude. The changes contemplated by the 22nd DAA in its draft 2008 Master Plan document (dated October 2009) represent a presumptuous departure from the historical uses of the site, and may also exceed those allowed on property held in trust for the people of California by the State of California. The DEIR fails to address how the construction of a condo-hotel, as proposed in the Master Plan, is consistent with the Public Trust Doctrine. The California Coastal Commission and the State Lands Commission have formally objected to the selling of public trust lands for private residential use, as proposed in the Master Plan. (See attached memo from Coastal Commission and "A Public Trust Synopsis" prepared by the States Land Commission or refer to the agencies comment letters in response to the NOP). The DEIR needs to be revised and recirculated to address the conflict of the proposed condo-hotel with the public access policies of the Coastal Act, Article X, section 3 and Article X, section 4 of the California Constitution, and subsequent case law on the Public Trust Doctrine." (see Attachment #1), "Public Trust Policy" from the California State Lands Commission for reference."	Page 15 of City Comment Matrix #45 to Del Mar Fairgounds EIR	The City does an excellent job in its comments to the 22nd DAA regarding Chapter 3 policies of the Coastal Act and Article X, Section 4 of the Constitution with respect to a private use on Public Trust Lands. The same discretion should be applied to the question of seawalls. Seawalls are a private use on Public Trust Lands.

22	Charging for 0.4ft/yr for the area of lease fee in the first year is inconsistent with sand mitigation fees.	Table 4-2 and 4-3	The Sand Mitigation Fee adopted by the Coastal Commission and agreed upon by the property owners assesses the fee for lost sand. The fee is calculated per "Report on In-Lieu Fee Beach Sand Mitigation Program: San Diego County". The formula for area lost to erosion is Aw = The area of beach lost due to long-term erosion is equal to the long-term average annual erosion rate (R) times the number of years that the back beach or bluff will be fixed (L) times the width of the property that will be protected (W) rate (ft./yr.). Aw = R x L x W. For example if a 50ft wide seawall were built, with an assumed erosion rate of 0.4ft/yr and design life of the wall of 22 years, then the area of sand lost is 0.4*22*50=440ft. Note that the above formula is also included in the June 2009 DraftLUP in Appendix A.
23	The Solana Beach valuation study by CIC Research has produced a dataset that is useful for estimating the recreation value of Solana Beach to beach visitors. However the methodology used by CIC for estimating that value is flawed and inconsistent with economic theory and accepted practice.	See appended report	Details in “A Study of the Economic Value of Public Beach Land in Solana Beach” by CIC Research, Inc. Prepared for The Surfrider Foundation by Dr. Ken Baerenklau, Associate Professor of Environmental Economics & Policy, University of California – Riverside. "The CIC report assumes that the value of a beach visit is equal to the travel cost incurred to visit the beach. This is inconsistent with economic theory and the published literature on recreation valuation. According to both theory and common practice, an appropriate measure of the value of a beach visit is “consumer surplus.”"
24	Several Points in the Beach Study Survey summary spreadsheet appear incorrect	See Beach Study Survey Spreadsheet on City website	ID 651 lists the time as 4 and ID 710 lists the time as 105. In addition some points appear to have arrival times after the survey time.
25	Data from July 4 holiday weekend does not appear to be included in the survey spreadsheet Beach Study Beach Counts.	Count Spreadsheet Available on the City Website Beach Study Beach Counts	Detailed data showing exact beach counts in a viable format should be provided especially for holiday weekends.

26	It does not appear that significant beach count sampling was perfromed during times of the Junior Lifeguard Program	Count Spreadsheet Available on the City Website Beach Study Beach Counts, Table 3-1	Review of the data in this spreadsheet does not appear consistent with attendance figures of the Junior Lifeguard Program. Data in the summer weekdays during hours of operation of the Junior Lifeguard Program should be vetted against expected Junior Lifeguard attendance. Attendance for example in the first junior lifeguard session is likely at the 100 limit imposed by the City given that it is typically sold out. Per the City website: "The maximum enrollment for each session is 100 students unless otherwise authorized by the City and Marine Safety Captain." There are 2 sessions per day with 100 children each therefore 200 children should be expected for a beach day. No data points in the count appear to have 200 children at the Cherry Hill locations.
27	Value of resident preferences to live near the beach not accurately reflected in Travel Cost method. Those who pay extra to live near the beach and not use cars are penalized in travel costs.	None	Assign a preference value to those living in walking distance.
28	Visits by children were not considered in beach valuation	Sections 2 and 3 and Table 3-9	Determine a value for children visits based on beach visits and value using either a percentage of adult value or a metric such as the Junior Lifeguard Fees.
29	Surfing and other uses that are particular to the study site were not valued.	Throughout	See if data collected at Solana Beach from surfers can be used with the model used to value the waves at Mavericks. “The Value of a Wave, An Analysis of the Mavericks Region and An Analysis of the Mavericks Wave from an Ecotourism Perspective”, from http://savethewaves.org

Letter H

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October 4, 2010

RECEIVED
OCT 04 2010
Planning-Comm Dev Dept
City of Solana Beach

David Ott, City Manager
City of Solana Beach
635 S. Highway 101
Solana Beach, CA 92075

Re: Comments to the Draft Land Lease/Recreation Fee Study

Dear Mr. Ott:

This firm represents Mr. Joseph Steinberg, the owner of the single-family residence located at 645 Circle Drive West, Solana Beach, California. This correspondence shall constitute Mr. Steinberg's comments to the Draft Land Lease/Recreation Fee Study – Revised July 2010 and also to the Land Use Plan for the draft Solana Beach Local Coastal Program, currently pending certification before the California Coastal Commission. Please distribute this letter and its attachments to the members of the City Council and PMC, and please incorporate them into the City's administrative record.

I. Summary of Comments

The beach in Solana Beach is in horrible condition – striped of sand, inaccessible at many times of the day, dangerous and unsightly – due not to the construction of seawalls, but to the cumulative permitted and unpermitted development and mining activities undertaken by all citizens and the government throughout San Diego County. This intensive, largely unregulated and unchecked development of coastal zone, starting in the 1950s and accelerating due to continued population growth and commercial activity, has irreversibly disrupted the fluvial and other natural processes that once sustained our wide and sandy beaches, and has caused the present need for seawalls.

High Tide in Solana Beach

Comment 1

Despite the fact that seawalls are needed due to the cumulative impacts of each and every citizen and our local, state and federal governments, bluff top property owners are alone singled out for payment of mitigation fees. No one other than bluff top property owners has been required to pay a beach mitigation fee even as their developments cause far more damage to the beach than seawalls ever will. Various people and organizations have spread irresponsible and blatantly false information that seawalls caused the current condition of the beach. The truth is that seawalls are a response to, not the cause of, the current condition of the beach, and are only needed because the beach has been ruined.

For this reason, it makes no sense and lacks any legal validity to charge bluff top homeowners a so-called Land Lease/Recreation ("LL/R") fee in any amount. If anything, the public that now demands this potentially huge and unreasonable fee, should be reimbursing bluff top property owners for the expenses they incur defending their properties from the beach erosion that the public caused.

Comment 2

Alternatively, if the beach in Solana Beach is really worth $6.02 per square foot per year, as theorized by PMC's flawed study, then the public should be paying that amount to the bluff top homeowner because the seawall the homeowner builds transforms at least 25 feet of dangerous, unusable beach area into a place that is once-again safe for family recreation.

The irony of the LL/R fee is that it is justified on the theory that seawalls occupy space that would otherwise be useable for public recreation. This is obviously not true; seawalls greatly increase safety on the beach and enhance recreational opportunities. In the last 15 years alone, there have been hundreds of bluff collapses with fatal consequences on 5 occasions. As a quintessential Southern California beach community, do we really believe it appropriate to invite tourists to our shores, when falling bluff material could crush their children at any time and without warning? It would be one thing if the beach was wide, and the danger zone perhaps avoidable. But the beach is extremely narrow most of the time, and beachgoers are forced into the danger zone if they wish to remain dry. It is simply irresponsible to invite people to such a place, and simultaneously dissuade bluff top homeowners from building protective seawalls by charging them outrageous and illegal mitigation fees.

Comment 3

The LL/R fee is neither fair nor legal. Despite the fact that the public and the government have wrought utter devastation on the beach environment, no one other than bluff top property owners who build seawalls have been required to pay mitigation. This is true despite the facts that seawalls provide huge public benefits. Even ignoring the public benefits, any negative impacts of seawalls are negligible in comparison to the impacts of mankind's "overdevelopment" of the coastal zone.

Comment 4

II. The Public Caused the Need for Seawalls; Now It Demands a Huge Fee

Blufftop property owners did not cause the conditions that now require seawalls to protect beachgoer safety and property. These conditions are the result of the cumulative impacts of intensive overdevelopment throughout the Southern California coastal zone. [See, Exhibit A, SANDAG (May 2010) *San Diego Regional Beach Sand Project, Fact Sheet*; Exhibit B, Crampton (2002) A Different Perspective on the Concept of Planned Retreat; Exhibit C, Patsch & Griggs (2006), *Littoral Cells, Sand Budgets, and Beaches: Understanding California's Shoreline*, pages 23 – 25]. Sadly, our beaches were once so wide, stable and healthy, they were once even used as reliable travel ways; now our modern travel ways (e.g., freeways, railroads, and surface streets) have not just replaced, but have played a large part in the destruction of their natural predecessor.

> **Why beach nourishment?**
> **The region's beaches have been steadily eroding for the past 20 years. Sand that once flowed down rivers to preserve our beaches is no longer making that trip because of the development throughout the region, and water supply and flood control projects needed to support that development.**
>
> Excerpt From SANDAG Fact Sheet

> "Traditionally, slope degradation in the Solana Beach area as a result of seaward assault has been negligible. Prior to 1940, local bluffs enjoyed the protection of wide sandy beaches which typically extended 100 – 250 feet. The broad beaches commonly served as major travelways along the coast prior 1900. The beaches were sustained by a persistent southward drift of river generated sediments which provided a continuous source of sand for beach nourishment. Since 1940 the works of man have impacted local beach properties." [Exhibit D, Vinje (1995), *Geotechnical Investigation of Bluff Conditions and Stability at Solana Beach & Tennis Club*, page 6].

This historically unprecedented disruption of natural processes has had the unintended, yet catastrophic, consequence of ruining our once beautiful and wide sandy beaches and exposing ocean bluffs to constant wave attack. This wave attack leads to catastrophic bluff collapse and with it significant risks to public safety, public property, and private property. As a direct consequence of these man-made conditions, seawalls are now needed in Solana Beach to protect public safety, public property, and private property. Because the public at large created the very need for these horribly expensive edifices, it is unreasonable and unfair for that same public, through its governmental agencies, to complain that these seawalls occupy space otherwise available to them for recreation, and to demand a fee for theorized impacts to "lost recreation," especially when the beach in this area is not safe for recreation in the first place. [See, Exhibit E, Crampton Letter dated 10.14.10].

In Southern California, just the damning of rivers alone, not to mention the numerous other anthropogenic reductions to sand inputs, has reduced the volume of sand reaching the beaches by 47%. For the Oceanside littoral cell, in which resides the City of Solana Beach, the reduction is measured at 54%. [See, Exhibit C, pages 23 – 4].

Littoral Cell		Rivers (dams)
Oceanside	Reduction yd^3/yr	154,000
	Percent reduction	54%

To emphasize how human interference in these normal processes impacts coastal environments, it is useful to compare these two below images.

Undisturbed Coastal Watershed

The above satellite image shows an undisturbed coastal environment where sand freely flows from upland hillsides down into streams and rivers that in turn carry the sand to the beach, forming a healthy, stable and wide sandy coastal environment, including a huge sand dune in the right-hand bottom corner. In this picture, the beach remains in a natural state of equilibrium.

Solana Beach, California: An Irreversibly Disturbed Coastal Watershed

This image, on the other hand, shows modern day Solana Beach where all the hillsides are covered with rooftops, driveways, roads, and manicured lawns, and the estuaries on either side of the City are blocked by multiple transportation corridors, a racetrack and huge asphalt parking lots. Moreover, this photograph only depicts a portion of the problem because it does not reveal the entire watershed, most all of which has been completely developed with homes, buildings, roads, dams, etc. This development, not seawalls, irrevocably changed the equilibrium, has denuded our once-sandy beaches and ruined the natural environment despite its ideal position between 2 saltwater estuaries that traditionally delivered huge volumes of sand to Solana Beach.

To add insult to injury, no one, other than bluff top property owners – who are now building and maintaining seawalls in response to the public's massive and irreversible interference with coastal processes – have been required to pay any form of mitigation fees for the comparatively minor impacts of seawalls. Compared to the devastation wrought on the beach environment by the cumulative and unmitigated impacts of the myriad dams, flood control projects, roads, rooftops, parking lots, transportation corridors, man-made harbors, jetties, and every

Boulder Weighs at Least 1 Ton

beautifully manicured lawn, the impacts of seawalls on coastal processes are negligible.[1]

Nevertheless, it is bluff top property owners alone who are blamed for impacts to the beach and charged outrageous fees. To our knowledge, no other person or entity has been charged beach impact fees of any sort, no matter how much damage their projects caused to the beach environment. This unequal treatment is unfair and we submit violates the equal protection and due process clauses of the U.S. and California constitutions.

Comment 5

III. The Passive Erosion Theory Would Be Irrelevant *But For* Human Intervention

The stated purpose of LL/R fee is to compensate the public for the installation of seawalls on beach areas that are theoretically available for recreation *but for* the presence of a seawall. First and foremost, the area of the beach that is or may be impacted by a seawall is *NOT* available for recreation. Recreation (i.e., an activity done for enjoyment) should not, by definition, carry a high risk of certain death or injury. The subject beach area is *NOT* therefore available for real recreation because it is excessively dangerous. The Torrey sandstone that comprises the lower half of the bluffs weighs the same as concrete, somewhere between 3,000 and 4, 000 pounds per cubic yard. Over the last 15 years, 5 people, ordinary people enjoying an afternoon at the beach, have been killed by falling bluff material just in the 10 mile stretch between north Torrey Pines Park and South Carlsbad. Many others have been killed or injured at many other locations throughout California where tall ocean bluffs line the beach.

Regardless of whether the "impacted" beach area really is available for public recreation, the proposed fee is unfair because most of the fee stems from the theory that seawalls cause passive erosion. However, the root cause of passive erosion (to the extent it actually occurs and assuming *arguendo* that a retreating cliff would reveal additional *useable* beach) is not the seawall. The root cause of passive erosion is the public's interference with normal coastal processes that have reduced Solana Beach to its perennially eroded and eroding state. But for

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[1] In addition to these more commonly understood causes of beach erosion, substantial additional beach erosion has undoubtedly resulted from various legislative measures (e.g., the Clean Water Act, watershed protection measures, erosion control requirements, etc.) that are intended to address upland environmental concerns, but have the unintended consequence of removing beach sediments from upland water sources, and thereby further decreasing normal fluvial inputs to the coastal environment. What this all points to is a pervasive societal problem, that should not be disproportionately placed on the shoulders of bluff top property owners.

this unnatural condition, seawalls would not cause passive erosion because passive erosion can only occur only on actively eroding, sand-depleted beaches. Passive erosion, by definition, does not occur on stable beaches that receive sufficient sand supply.

As discussed above, the beach in Solana Beach is actively eroding only as a result of human interference with natural sediment delivery systems. In other words, *but for* the public's interference with normal coastal processes, seawalls would not cause passive erosion in Solana Beach, and the amount of the land lease recreation fee would be limited to the footprint area of the seawall. For most single-family homes, this area is about 100 square feet, and even using PMC's incorrect and exorbitant estimation that each square foot of beach is worth $6.02 per foot, the fee would be a tolerable (although still invalid) $602 per year.

IV. The Fee Justification is Tautological

The component of the fee that is based on the theory of passive erosion is further problematic because it assumes that the beach will continue to erode throughout the life of the seawall permit and it fails to account for the fact that the fee charged will be used for beach replenishment that will slow down or even completely abate beach erosion. Thus, the justification for the fee is based on circular logic: a fee is charged to halt erosion, but it is calculated on the theory that erosion will continue forever.

As described above, once the beach stops eroding, passive erosion ceases to occur. Nevertheless, despite the fact that the sand mitigation fee, the land lease recreation fee, SANDAG projects (e.g., RBSP I and II), and the potential Army Corps project could replenish the beach and halt passive erosion, the fee study assumes that passive erosion will occur forever, and the lion's share of the fee charged is based on the theory that the beach erosion will continue indefinitely and without regard for the fact that the fee is intended to halt beach erosion with sand replenishment efforts. [See, Exhibit F, SANDAG, (2010) *Scoping Flyer for RBSP II*; Exhibit G, U.S. Army Corp of Engineers, *Encinitas – Solana Beach Feasibility Study*,

Comment 6

powerpoint]. The City cannot simultaneously charge a fee to replenish the beach and stop erosion while charging a fee that is based on continual erosion. Such a justification is tautological, and cannot be recognized as valid.

Comment 7

V. Seawalls Increase Net Useable Beach; There Should be No Fee

A. Area Occupied by Seawalls, Plus 25 feet Seaward, is Not Available for Recreation

Given the severely eroded beach conditions in Solana Beach, the area occupied by seawalls is not safe and not available for recreation. As stated above, there have been 5 deaths in 15 years on just a 10-mile stretch of beaches, all geologically similar to the Solana Beach coastline, between north Torrey Pines and south Carlsbad, and several very close calls. For example, on October 1, 1999, just south of Fletcher Cove in front of Las Brisas condominiums, a surfer's wetsuit was buried by a large bluff collapse in the very location where that very surfer had, moments before, been standing. [See, Exhibit H, Crampton (2003) *What Shoreline Are We Leaving For Our Children?*]. Also, please take a moment to watch the North County Times video entitled *Cliff Collapse Kills Las Vegas Man* found at http://videos.nctimes.com/p/video?id=2098563. This sad story explains how falling bluff material killed a Frisbee-playing tourist in front of his family. One of the notable points from this video is that the volume of material, while certainly fatal, looks relatively small and incapable of causing such a horrific result.

How Close Should Your Children Play?

Once a seawall is erected, however, the risk of death from falling bluff material is greatly diminished, if not eliminated (or reduced to an acceptably low level). In point of fact, to our knowledge, there has not been a single upper or lower bluff collapse, let alone a death or injury, on any beach where the bluffs are protected by seawalls. Meanwhile, unprotected bluffs between Torrey Pines and Carlsbad have killed 5 people in just the last 15 years, and according to the PMC study, there have been 126 bluff collapses in Solana Beach alone. The zone of danger is not just limited to the base of the bluff. The zone of danger extends at least 25 feet seaward from the base of the bluff, if not more. The poor woman who was killed near Moonlight Beach was reportedly sitting on the beach 40 feet seaward of the base of the bluff. (Exhibit E).

The danger of the bluffs, and the 25-foot zone of danger below them, is expressly and undeniably recognized by all governmental agencies, including the City of Solana Beach, as evidenced by the fact that these agencies erect numerous warning signs at nearly every beach entrance and on the face of many bluffs themselves, place public safety messages on their websites, and train lifeguards to proactively direct people away from areas near the bluffs. Whatever the form may be, these warnings sternly advise beachgoers that the bluffs are actively failing and to stay away from the bluff area. The City's website has a whole section devoted to bluff safety and the dangers of getting stuck on the beach by high tides. The bluff failures section includes a WARNING sign that emphasizes the need to "*stay away from the bluffs!*" It also advises beach patrons that bluff failures are a "year-round hazard" and that "lifeguards … recommend that all beach patrons stay as far away from the bluffs as possible." The City's own website includes these warnings in photographic, graphic and textual form.

Danger Zone At Least 25 Feet

BLUFF FAILURES:

Falling bluffs are a natural occurrence within the aquatic environment and a product of high surf, fragile sandstone, and erosion. Bluff failures are not only a summer time occurrence, but a year-round hazard. Although public awareness and education help prevent failure related accidents, it is impossible to predict or prevent a failure. Lifeguards use a proactive approach and recommend that all beach patrons stay as far away from the bluffs as possible, especially from actively failing areas.

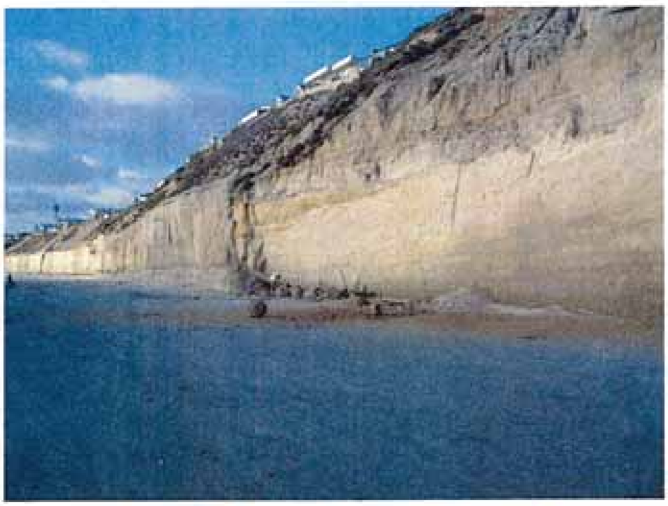
Bluff Failures Section on City's Website

What these statistics, government warning signs, and government actions warning beach visitors away from the bluffs tell you is that the area occupied by seawalls is not available for recreation, completely eviscerating the justification for charging bluff top property owners a LL/R fee. The simple, unavoidable truth is that seawalls do *NOT* occupy beach space that is otherwise available for recreation, and there is no valid justification for charging the fee proposed in the Draft Study, or set forth in the City's LUP.

Comment 8

B. Seawalls INCREASE Useable Beach Area

Not only do seawalls *not* occupy useable beach area, they actually transform dangerous beach areas into areas that are once-again safe for family recreation. Properly engineered and constructed, like the walls in Solana Beach, seawalls drastically reduce, if not completely eliminate, the risk of sudden and unexpected bluff collapse, and with it the risk of death or serious injury. Public and private liability associated with claims arising from bodily injury to beachgoers is also substantially reduced. With a seawall in place, the risk of lower bluff collapse is eliminated, and because lower bluff failure is the precursor to an upper bluff failure, the risk of sudden bluff collapse is also essentially zero. To our knowledge, there has never been a bluff collapse, upper or lower, when a seawall is present. Accordingly, instead of demonizing those who have no choice but to build seawalls and charging them outrageous and unjustified fees, seawalls should properly be viewed as providing a substantial public benefit because they eliminate the 25-foot plus danger zone that now exists on our beaches. Seawalls also protect public infrastructure and preserve the tax base.



Note: Bluff Failure Stopped at Seawall

According to the PMC study, the beach in Solana Beach is on average only 50 feet wide. Without a seawall, at least half of that width is too dangerous to use. With a seawall, ALL of that space is safe to use. This is to say, in Solana Beach, seawalls double the width of ***useable*** beach. Yet, somehow, this huge safety benefit is completely ignored or trivialized, and the very same public that created the need for seawalls in the first place now seeks to charge bluff top property owners outrageous fees to protect themselves from the public's malfeasance.

Comment 9

C. Thc Govcrnmcnt Should Reimburse Bluff Property Owners for Seawall Expenses

For all the reasons set forth above, not only is there no valid justification for imposing a lost recreation fee, the Government should reimburse bluff property owners for all seawall expenses because the public is the legal cause of the need for these walls. To illustrate, in February 1991, following a lengthy trial, judgment was entered against the County of San Diego and in favor of Mr. Steinberg wherein the Court determined the County of San Diego to be the legal cause of the major bluff collapse and resultant need for the seawall constructed in front of Mr. Steinberg's home. The County of San Diego ultimately was ordered to reimburse Mr. Steinberg not just for his seawall related expenses, but also for all of his attorney's fees.

Mr. Steinberg, along with all other Solana Beach bluff top property owners, finds himself in the same situation today: the public has caused the need for seawalls and should therefore pay for the hard and soft expenses associated therewith, including attorney's fees. To make matters worse, however, not only is the government making it extremely difficult to build seawalls through an impossible permitting regimen and many hidden expenses, it is also demanding huge mitigation fees that many people cannot afford.

If the government is not going to reimburse bluff top homeowners for their seawall-related expenses, it should perhaps compensate them for the public benefits that these seawalls provide. According to PMC, the value of the beach in Solana Beach is $6.02 per square foot per year. The average seawall, at 2.4 feet thick and 50 feet long, potentially occupies 120 square feet of public beach. However, since the seawall eliminates the 25-foot danger zone, it results in a net increase in useable beach area of 1,130 square feet [i.e., (50 x 25) – (50 x 2.4)]. Using the PMC number for the value of the beach per square foot, the public receives a benefit at the expense of the bluff top property owner in the amount of $6,802.60 annually (i.e., 1,130 x $6.02), in addition to the protection of public infrastructure and the preservation of the tax base.

Comment 10

VI. The Sand Mitigation Fee Already Includes the LL/R Fee

Another reason why the PMC report should be rejected and the LUP revised, is that the theorized impacts to be mitigated by the LL/R fee are already included in the sand mitigation fee formula. The Coastal Commission report, attached hereto as Exhibit I, makes it completely clear that the sand mitigation fee formula used by the Coastal Commission includes the impacts to public recreation. Therefore, the LL/R fee is completely redundant. Also, it begs the question of why the City would try to impose the LL/R when the sand mitigation fee already includes a component for this mitigation.

VII. The Fee May Not Be Imposed as a Matter of Law

Comment 11

A. There is No Legal Right to Impose Any Fee

As stated by the United States Supreme Court in Nollan v. California Coastal Commission (1987) 483 U.S. 825, the power to impose a permit condition derives from the power to deny the permit. If the government has no discretion to deny the permit, it cannot impose mitigation fees unless such fees are specifically authorized by statute. Here, the government lacks the power to deny the permit and, therefore, lacks the power to impose mitigation fees.

Public Resources Code §30235 imposes a mandatory duty on the government to grant a seawall permit as long as an existing structure or the beach is in danger from erosion or when the seawall is needed to serve coastal dependent uses. The only condition that may be imposed on the mandatory seawall permit is the one set forth in §30235, a requirement that the device be "designed to eliminate or mitigate adverse impacts on local shoreline sand supply." Therefore, since denying the permit would constitute a taking, and since the only condition that may be validly imposed is the design requirement quoted above, the imposition of the mitigation fees proposed by PMC would also constitute a taking and may not be validly imposed.

To be sure, because public interference with coastal processes created the need for the seawall in the first place, the public should now be estopped from demanding a fee to compensate for the theorized impacts to public space. Charging impact fees for a seawall that would not now be necessary *but for* the public's interruption of natural sand movement, is unfair and illogical, and as stated herein, illegal.

Comment 12

B. Mitigation Fees Must Be Proportional to the Impact

In Nollan, the U.S. Supreme Court held that permit conditions, such as a condition for the dedication of a public easement, must have a nexus, or a logical link, to the alleged impact. In Ehrlich v. City of Culver City (1996) 12 Cal.4th 854, the California Supreme Court held that the nexus requirement also applied to mitigation fees. However, a state agency does not satisfy the nexus requirement by making conclusory statements that the project type generally causes impacts. Instead, the state agency must make specific findings, supported by substantial evidence that the identified impacts actually exist with respect to that particular project. Once the actual impact is substantiated, the state agency must then identify how the fee will be used to mitigate for that specific, well-documented impact. Without such substantial evidence, a claimed nexus between the impact and fee is not legally defensible. Surfside Colony, Ltd. v. California Coastal Commission (1991) 26 Cal.App.3d 1260, 1272 [Absence of "site specific" evidence fatal to Coastal Commission's claimed justification for easement on private property.] "[A] 'close connection' entails evidence more 'substantial' than general studies which . . . may not even apply to the case at hand. *Substantial evidence must be reasonable in nature, credible, and of solid value."* Id. at 1270 [emphasis added].

In Dolan v. City of Tigard (1994) 512 U.S. 374, the U.S. Supreme Court held that in addition to having a nexus with projected impacts, a permit condition must also be sufficiently connected in nature and extent, or "roughly proportional" to the documented impact. While "[n]o precise mathematical calculation is required," the government "must make some sort of individualized determination that the [condition] is related both in nature and extent to the impact of the proposed development." Id., at 391. "Moreover, that determination could not be based on general or conclusory findings that the fee is reasonably related to the impact; rather the [government] has to make 'some effort to quantify' the relationship between fee and impact." Ocean Harbor House v. California Coastal Commission (2008) 163 Cal.App.4th 215, 237.

Comment 13

D. PMC's Fee is Not Proportional to the Impact

Seawalls are claimed to cause two primary impacts. One claimed impact is that they impound sand that would otherwise make its way to the public as the beach eroded. This erosion, which has been accelerated by the public's interference with coastal processes, is a mostly minor, and temporary, impact. It is temporary because the sand behind the wall will only be impounded as long as the wall remains in place. Under the Solana Beach LUP, a seawall permit might last until 2081, but at this point in time the Coastal Commission permits are only for 20 years. So this impact needs to be considered temporary. In addition, the experts agree "the impact of armoring on the sand supply is minor. Every known study agrees on this point.... The question is not whether this source is relatively small, but how small." [See, Exhibit J, Flick and Elwany, (2006), *Analysis of Beach Sand Contribution From Coastal Bluffs at Solana Beach, CA*).

The second claimed impact is that seawalls occupy an area of public beach, increased by the effects of so-called passive erosion that is otherwise available for public recreation. Ignoring the facts that seawalls actually increase the area of useable beach and that passive erosion occurs only because the public and the government have disrupted natural sand delivery systems, there is a better way to measure this impact than the one set forth in the LUP and then estimated by PMC. Instead of using an esoteric and questionable economic model to determine the "value" of the beach in the area occupied by seawalls, the City should simply look at the cost of replacing the impacted beach area with modern sand replenishment techniques. The cost of a cubic yard of sand is not an unknown; it is $7.66 [See, Exhibit J, SANDAG's Sand Costs for RBSP II (2010)]. If you simply multiply this sand cost by the amount of sand that is needed to replace the beach that is allegedly occupied by a seawall, you have your fee – no mental acrobatics needed – and you are imposing a fee that is more proportional to the alleged impact.

Comment 14

E. PMC's Fee Cannot Apply To Existing Seawalls

Independent of PMC's failure to establish the requisite nexus between the proposed fee and the asserted impact, to the extent there is any express or implied attempt or consideration of the application of the fee to a property owner such as Mr. Steinberg, respectfully we submit such an act would amount to unconstitutional *ex post facto* legislation. Mr. Steinberg's existing seawall was constructed in the late 1980's while his litigation against the County of San Diego was pending. Every aspect of the design, permitting and construction was done with the express approval and consent of local and State regulatory agencies. Pursuant to a lengthy and arduous application process, Mr. Steinberg was required to address very similar issues to those raised by the PMC's new fee. At no time was his construction or permitting of his seawall ever conditioned upon his payment of any type of mitigation fee related to any alleged negative impact his seawall would have upon beach erosion.

As Mr. Steinberg has at all times complied with the established regulatory procedures and constructed a seawall on his property within the framework of California law, an future effort by the City to impose any new fees relative to Mr. Steinberg's longstanding permitted seawall violates the *ex post facto* clause of the United States Constitution. "In the words of the United

States Supreme Court, 'the 'principle that the legal effect of conduct should ordinarily be assessed under the law that existed when the conduct took place has timeless and universal appeal.'" Myers v. Philip Morris Companies, Inc. (2002) 28 Cal.4th 828, 840-841 (citing Landgraf v. USI Film Products (1994) 511 U.S. 244, 265.

The Supreme Court has explained the operative principal thusly:

> In a free, dynamic society, creativity in both commercial and artistic endeavors is fostered by a rule of law that gives people confidence about the legal consequences of their actions. It is therefore not surprising that the antiretroactivity principle finds expression in several provisions of our Constitution. The *Ex Post Facto* Clause flatly prohibits retroactive application of penal legislation. . . . The Fifth Amendment's Takings Clause[, and] [t]he Due Process Clause also protect[] the interests in fair notice and repose that may be compromised by retroactive legislation; a justification sufficient to validate a statute's *prospective* application under the [Due Process] Clause 'may not suffice' to warrant its *retroactive* application.

Landgraf, supra, 511 U.S. at 265-266.

Mr. Steinberg constructed his seawall over (20) years ago in accordance with the then-existing legal framework established by the State and County. Having received the necessary approval and consent of these bodies, Mr. Steinberg proceeded with construction of the seawall on his property, confident in the propriety of his actions, and lacking any forewarning that the City would someday attempt to hold him liable for some fees associated with building that very seawall under a new and oppressive fee regime. Mr. Steinberg was and is entitled to act "with confidence about the legal consequences of [his] actions" when he built the seawall on his property.

Consequently, while the City may in theory levy some type of "mitigation" fee prospectively on any property owner who builds a *new* seawall (provided the City is able to develop substantial evidence supporting its expressed position), any attempt to retroactively charge property owners with existing seawalls such as Mr. Steinberg would violate vested constitutional rights.

VII. Conclusion

For all the reasons stated herein, Mr. Steinberg respectfully asks the City to disregard the PMC study and to also remove the so-called Land Lease/Recreation Fee from its LUP. The LL/R fee is illegal and illogical, and should not be imposed on anyone. The evidence is clear that seawalls are needed only because the public and the government ruined the beach. Moreover, the Coastal Commission's sand mitigation fee formula already includes mitigation for the false theory that seawalls occupy space that is otherwise available for public recreation.

Notably missing from this letter is any analysis of PMC's economic study that that led it to conclude that a square foot of beach in Solana Beach is worth $6.02 per year. We understand that the BBC is submitting a critique of that study. Although we think such a critique is unnecessary – not because we agree with the report, but because we believe the fee is illegal in the first place – we incorporate herein by reference the BBC letter and its attachments.

Very truly yours,

Robert D. Shoecraft
Shoecraft ♦ Burton, LLP

RDS/rs
cc. Mr. Joseph S. Steinberg

EXHIBIT A

SAN DIEGO REGIONAL BEACH SAND PROJECT
FACT SHEET

Restoring a priceless resource

Sun, sand, and surf are images San Diegans and people around the world think of when they hear names like Oceanside, Carlsbad, Moonlight Beach, Fletcher Cove, Torrey Pines, and Imperial Beach. But the image quickly fades when residents and visitors alike discover that sand is missing from many of the region's beaches.

RBSP I photos for Imperial Beach before, after, and March 2010

That's one of the reasons why residents and community leaders from coastal areas and inland neighborhoods are again making a concerted effort to place sand onto the critically eroded beaches along the region's shoreline.

In 2001, the SANDAG Regional Beach Sand Project (RBSP I) dredged 2.1 million cubic yards of clean, beach quality sand from offshore and placed it on 12 eroded beaches from Imperial Beach to Oceanside.

In spring 2012, the Regional Beach Sand Project II (RBSP II) will widen beaches by adding millions of cubic yards of clean sand to eroded shorelines. It is the second major public works effort being coordinated by local governments, working together through SANDAG.

Why beach nourishment?

The region's beaches have been steadily eroding for the past 20 years. Sand that once flowed down rivers to preserve our beaches is no longer making that trip because of the development throughout the region, and water supply and flood control projects needed to support that development.

Oceanside at present

Some beaches are stripped of sand and during the next few decades, most of our beaches will be too narrow to enjoy unless positive action is taken, starting now.

The RBSP II will benefit the region's environment and economy and, most all, its overall quality of life. As the beaches continue to erode and become increasingly narrow, recreational opportunities are restricted. A unique and highly valued environment disappears. The important visitor industry component of the local, state, and national economies is constrained. In addition, private and public development and infrastructure are subject to increased damage from storms.

There are choices when it comes to protecting and restoring the region's coastline. Should we enhance the shoreline by restoring and maintaining wide sandy beaches, or armor it with heavy duty steel, rock, and concrete seawalls, or sacrifice it to the destructive forces of storm waves, flooding, and erosion?

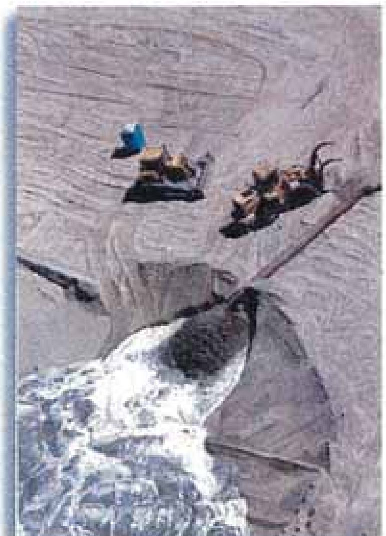
The RBSP II is based upon the conclusion that beach sand restoration is the best

(Continued on reverse)

SANDAG

401 B Street, Suite 800
San Diego, CA 92101
(619) 699-1900
Fax (619) 699-1905
www.sandag.org

Beachgoers enjoying RBSP I final product



Bulldozers and sand at Batiquitos RBSP I

Source:
Great Lakes Dredging and Dock Company

strategy to pursue. Putting sand onto the region's beaches will provide environmental, economic, and recreational benefits for its residents and visitors.

But what happens to the sand after it is placed, won't it continue to erode? The answer is yes, the sand will eventually spread out over the region's entire 60-mile coastline. The San Diego coastline loses sand to various places including offshore to deeper water and inside the harbors and lagoons. These losses are not adequately offset by input from rivers, bluffs, and nourishment. So the losses exceed the gains each year and the sand volume is decreasing. The good news is that beach width gains from the 2001 RBSP I sustained for about four years on average and volumes sustained for about six years. And, as of 2008, there still appeared to be RBSP I sand in the system and this material will serve as a foundation for the RBSP II.

How are beaches restored?

The RBSP II will place sand on many of the region's beaches most likely from large deposits of sand located in 30 to 100 feet of water found within two miles of the shoreline.

Dredging sand from nearshore sources and pumping it to beaches is a technology that has proven reliable and effective all over the world. The nearshore sand sources must be tested to prove they will provide a quality source of material for the region's beaches that is compatible, such as similar size, texture, and color. The most cost-effective, highest-quality, and environmentally-suitable sources of sand will be used.

Beach building technology must be adapted to the specific geological and environmental challenges presented by our shoreline. The RBSP II takes into consideration all of the unique features of our region's coastline and will avoid sensitive reef habitats in the nearshore and make every effort to minimize impacts to our coastal environment.

What's next?

SANDAG wants your input! SANDAG is currently in the environmental phase of the project. The project's Environmental Impact Report (EIR) is being prepared for public review in winter 2010.

If you would like more details about the RBSP II, receive the EIR, or provide input please contact SANDAG at (619) 699-0640, beachsand@sandag.org, or visit www.sandag.org/shoreline.

EXHIBIT B

A Different Perspective on the Concept of Planned Retreat

Walter F. Crampton[1]

ABSTRACT

Reflect back for a moment, 20 years ago, when virtually no seawalls existed in San Diego's North County. Man's urbanization of the upland watershed essentially severed the principal source of sand to this county's beaches, causing a sand deficit and triggering accelerated coastal erosion. Seawalls were constructed in response to this loss of sand and removal of those seawalls will not bring the sand back. In the ensuing 20 years, the only thing that has occurred is additional urbanization within the upland watershed and the more effective severing of any upcoast sediment supply. It is important to emphasize that the beaches in San Diego's North County did not disappear because seawalls were built. The opposite is true: seawalls are needed because the beaches disappeared.

In recent years, the environmental community is now blaming seawalls for all of San Diego County's shoreline problems. Environmental groups are now stating, "Seawalls and other types of shoreline armoring deprive the beach of sand and can narrow it until the beach is inaccessible ." Proponents of the recently authored Assembly Bill 2943, intended to limit future seawall construction in California, propose that "this amendment will close loopholes in the Coastal Act that have allowed reckless armoring of the California coast. With increased population and shoreline erosion, Californians need an improved policy on coastal erosion."

There is a fundamental flaw in this logic. However, this environmental plea to the masses has definite curb appeal. Those that would propose that we do nothing and return to nature to let the "shoreline heal itself" essentially guarantees a vision for the California shoreline of planned neglect, unplanned retreat, devastation of coastal property values, and a serious trashing of the state's $15 billion coastal recreational resource.

In many areas of Southern California, there is today little to no sandy beach, essentially eliminating lateral access and significantly degrading the recreational experience that all Californians and the millions of beach-going visitors at one time enjoyed. Although the environmental community would argue to the contrary, in the absence of a proactive plan, and assuming no future seawalls and no future significant beach renourishment projects on the immediate horizon, there will continue to be a total absence of any sand beach, and there will never be any lateral access along much of this state's coastline, nor any recreational beach to enjoy. Moreover, coastal

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erosion will continue unabated, with Southern California's coastal bluffs releasing sediment at a rate that is several orders of magnitude less than the available sediment transport capacity that the waves have to carry the sediment away. What this means is that, even as erosion continues and sea cliffs collapse and the upper bluffs retreat, eventually undermining structures, there will never be any sand on the beach. The unfortunate reality is that the healthy, recreational resource envisioned by the environmental coalition, i.e., the wide sandy beach, which would provide greater recreational opportunities resulting in increased beach use and economic benefits to the State of California, is only possible with artificial beach replenishment, not the elimination of seawalls.

CALIFORNIA'S BEACHES

California's beaches define our quality of life, and they generate over $15 billion annually in tax revenue. California's beaches are its most popular recreational destination, with over 550 million visitors in 1995, 85 percent of whom were non-coastal residents (State of California, 2002). To quote from the state's January 2002 Beach Restoration Study, "the state's beaches provide California with an enriched quality of life, worldwide recognition, and unparalleled tourist opportunities for economic enhancement."

Fig. 1. San Diego's Mission Beach

Figure 1 shows San Diego's Mission Beach. Undeniably San Diego County's most popular recreation beach, a beach that was stabilized in 1950 by the construction of the Mission Bay Entrance Jetty and the subsequent placement of over a million cubic yards of sand associated with the dredging of Mission Bay.

COASTAL HAZARDS, IMPACTS & RETREAT

This conference session addresses the hazards, impacts, and retreat of this state's coastline, and this paper focuses on the erosion of San Diego County's coastal bluffs and the sandy beaches that at one time fronted many of these coastal bluffs.

One of the hazards affecting Southern California's coastal bluffs is those relatively infrequent large waves often associated with El Niño storms.

In the absence of a healthy sand beach, these large waves impact our coastal bluffs, and these coastal hazards quickly start to impact the quality of life for those living atop those coastal bluffs, as well as the beach-going public that recreate on these beaches.

The real hazard, however, adversely impacting a significant portion of Southern California's coastline is the many people that now live in this state's coastal watershed. Over 80 percent of Southern California's residents live on the west side of the coastal range, with all of this urban development clearly impacting the sediment supply to this state's beaches.

It has been said that seawalls deprive the beaches of sand. The facts prove otherwise. There is no question that San Diego's North County beaches' loss of sand is the result of extensive urbanization of the coastal watershed, the construction of dams and flood control facilities, the relatively effective elimination of sediment production within the watershed, and the extensive mining of the alluvial sands from the lower reaches of the county's rivers, all of which has effectively severed the natural supply of historical sediment to the littoral zone. These conflicting societal interests, presumably for the benefit of the citizens of Southern California, have proven to be to the detriment of Southern California's coastal resources.

Although dam construction in San Diego County has effectively severed over 60 percent of the County's 3,849-square-mile watershed (Nordstrom and Inman, 1973) from the littoral zone, more troublesome is man's exhaustive sand mining activities in the lower reaches of Southern California's major rivers to enable the many construction activities that we as a state embrace. In the 52-mile-long Oceanside Littoral Cell today, there is a 30 million cubic yard sand deficit. Yet, in the last 60 years, sand mining alone in San Diego County, almost exclusively downstream of the county's dams and reservoirs, has removed over 100 million cubic yards of beach quality sand originally destined for the county's beaches.

There has been much discussion of the cumulative impacts of seawall construction. But what of the cumulative impacts of development within the upland watershed? The wholesale elimination of littoral sands reaching much of Southern California's beaches has had a significant cumulative environmental impact on this coastal resource.

The environmental community continues to blame seawalls for all of this state's shoreline problems. However, the facts would indicate otherwise. California, and Southern California in particular, has been one of the most studied coastal environments in the world. The U.S. Army Corps of Engineers' Coast of California Storm and Tidal Waves Study Reports probably represent one of the most comprehensive compendiums of coastal knowledge in any area, and countless other studies of the California coastline, from the universities and from the private sector, provide a wealth of additional knowledge.

The State of California Department of Boating and Waterways and the State Coastal Conservancy published, in January 2002, the California Beach Restoration Study, which provides an excellent summary of the state of the California coastline and what the State considers necessary to restore the quality of this immensely valuable natural resource.

Table 8.4 Sediment Inputs to the Oceanside and Santa Barbara Littoral Cells

Oceanside Littoral Cell			
Inputs	**Natural (cy/yr)**	**Actual (cy/yr)**	**Reduction (cy/yr)**
Rivers	286,500 44.7%	132,500 27.9%	154,500 53.8%
Bluff Erosion	67,300 10.5%	54,900 11.6%	12,400 18.4%
Gullies/Terraces	287,000 44.8%	287,000 60.6%	0 0.0%
Total Littoral Input	641,500 100.0%	475,100 100.0%	166,400 26.7%
Santa Barbara Littoral Cell			
Inputs	**Natural (cy/yr)**	**Actual (cy/yr)**	**Reduction (cy/yr)**
Rivers	3,642,773 99.6%	2,167,000 99.5%	1,475,773 40.5%
Bluff Erosion	14,028 0.4%	11,312 0.5%	2,716 19.3%
Total Littoral Input	3,656,801 100.0%	2,178,312 100.0%	1,478,489 40.4%

Fig. 2. Table 8.4 from California Beach Restoration Study

Figure 2, reproduced from the California Beach Restoration Study (2002), lists the sediment inputs to the Oceanside and Santa Barbara Littoral Cells. Focus on the Oceanside Littoral Cell for a moment, where under natural conditions, total littoral transport into the system averaged 641,500 cubic yards per year. Today, within the Oceanside Littoral Cell, about 7 miles of this 52-mile coastline has been armored, admittedly removing some potential source material from this littoral cell. However, this reduction in source material from 7 miles of coastal armoring amounts to a little over 12,000 cubic yards per year, or less than two percent of the natural sediment supply.

In the Santa Barbara Littoral Cell, about 11 miles of the 144-mile-long coastline has now been armored, but this impact is even significantly less, with a reduction of only 2,700 cubic yards compared to a natural total littoral input of over 3½ million cubic yards. To quote from the California Beach Restoration Study, "what is clear from Table 8.4 is that bluff erosion plays an insignificant role as a source of sand for the Santa Barbara Littoral Cell." One must also conclude that seawalls have an insignificant impact on the Oceanside Littoral Cell. This is clearly in contrast to the story that the environmental community is pushing to the public.

One of the truly significant impacts of urbanization of the upland watershed is only obliquely mentioned in the State's Beach Restoration Study, and that is, the true significance of sand mining, and particularly within San Diego County, where there has been over 100 million cubic yards of sand mined in San Diego County in the last 60 years, all of which was originally destined for San Diego County beaches. And yet, in the Oceanside Littoral Cell, in the last 60 years and assuming natural conditions, there would only have been 38,500,000 cubic yards of sand delivered to the beach during this same period.

In other words, 60 years of sand mining has removed 155 years of natural sediment supply from the littoral system. Bottom line, today, we have few sandy beaches in San Diego's North County, and the bluff-top property owners did not contribute to the sand deficit problem that exists along the North County shoreline today. Moreover, forbidding coastal protection projects or, for that matter, by removing all of the existing seawalls in San Diego's North County, will not have any measurable impact on this littoral sand deficit. We have proven it is not the seawalls that are the culprit.

AN ANALYTICAL APPROACH

Coastal erosion can be mathematically described as being a function of both the wave energy, f_w and the strength of the sea cliff, or the rock resistance, f_r. In its simplest expression, predictive cliff-erosion models take the following form (Sunamura, 1997):

$$dx / dt \; \alpha \; \ln (f_w / f_r)$$

What this simply says is that for a given wave energy, the stronger the rock resistance, the less erosion that occurs. Of particular interest, however, is the fact that a minimum or critical wave energy capable of causing erosion exists, below which, for a given rock lithology, no erosion would occur. This is important, as it explains why highly erosion-resistant rock sea cliffs often do not have sandy beaches and relatively deep water at the base of the sea cliff.

Fig. 3. Sunset Cliffs on the Point Loma Peninsula

Figure 3 is looking down the Point Loma Peninsula in San Diego. Note the deep water adjacent to the cliffs. The sea floor fronting this Cretaceous-age (80 million years old) sea cliff is around elevation -5 feet MSL and, as a result, considerable wave energy assails the coastline. The rock is so hard that, to initiate any erosion and retreat of the coastline, deeper water is required, and hence more wave energy, to compensate for the stronger rock strength. With deeper water, there is obviously no lateral access along the base of the sea cliff and of course no sand beach.

Fig. 4. Encinitas Sea Cliffs in San Diego's North County

In San Diego's North County, where the sea cliffs are of Eocene age (45 million years old), and the rock strength (unconfined compressive strength) is several hundred psi, more rapid marine erosion occurs, particularly when the protective sand beach is absent. Figure 4 shows the sea cliff in Encinitas, in northern San Diego. The actual mechanism of erosion is the formation of a notch, the collapse of the overhang, and progressive failures of the upper bluff.

The elevation of the bedrock at the base of the sea cliff and underlying the transient sand beach is near sea level in Encinitas. Also of importance is that, 25 to 30 years ago, San Diego's North County had healthy sand beaches, essentially 12 to 13 feet higher than the bedrock shore platform. Today, in the absence of this protective sand beach, there is increased erosion. However, the erosion rate, with these Eocene sediments, although somewhat weaker than those along Point Loma, is still so slow that these coastal bluffs are still releasing sediment at a rate that is several orders of magnitude less than the available sediment transport capacity that the waves have to carry the sediment away.

What this means is that, even as accelerated erosion continues in San Diego's North County, and as sea cliffs collapse and the upper bluffs retreat, eventually undermining bluff-top structures, there will never be any sand on the beach. Although the environmental community would argue to the contrary, in the absence of a proactive plan, and assuming no future seawalls, and no future significant beach renourishment projects on the immediate horizon, and even assuming we remove every seawall in San Diego's North County, there will continue to be a pervasive absence of any sand beach.

The unfortunate reality is that the healthy, recreational resource envisioned by the environmental coalition, i.e., the wide sandy beach, which would provide greater recreational opportunities resulting in increased beach use and economic benefits to the State of California, can only occur with artificial beach replenishment, not the elimination of seawalls.

PUBLIC SAFETY

While the beach can be a dangerous place, all of the coastal-related dangers with the single exception of bluff instability, have existed along San Diego's North County beaches in the past. These potential "natural" dangers are presumably familiar to the beach-going public. Since people are now often forced to walk along the beach immediately adjacent to the bluff, there is a much greater risk from a bluff failure injuring or killing them on the beach. The stability of portions of San Diego's North County coastline has degraded in recent years, creating a new, previously non-existent danger to the beach-going public. This danger presents the very real possibility of a bluff collapse injuring or killing someone on the beach.

It is unreasonable to assume that the beach-going public possesses the same level of recognition regarding the potential for a bluff collapse injuring them then from a rip current carrying them out to sea. It is fair to assume that the majority of the beach-going public has at least some familiarity with the dangers of waves, rip currents, cold water, and the many other natural hazards that exist along ocean shorelines. However, it is also fair to say that the vast majority of the beach-going public has little knowledge of the potential risks associated with a bluff collapse along the landward edge of the beach.

Coastal bluffs do not back most of the beaches along the U.S. East and Gulf coasts. Therefore, many visitors to our beaches probably have no idea that the bluffs present any danger to them. Even in Southern California, many of the more popular beaches, including Santa Monica, Newport, and Mission Beach, are similarly not backed by coastal bluffs. Moreover, most coastal bluffs are reasonably stable, including the majority of those within Point Loma and La Jolla. It is only those that are actively eroding, most notably in San Diego's North County, and where the upper bluff face has not had a chance to equilibrate, that the biggest risk to the beach-going public exists. This risk is relatively new to San Diego, and atypical of most recreational beach areas throughout the country.

THE URBAN COASTLINE

As an urban society living within the coastal watershed, we have not been kind to this state's coastline. Twenty-five years ago, when there were virtually no seawalls along the California coast, man's urbanization of the coastal watershed stopped the supply of sand, causing accelerated coastal erosion and a desire by many to protect their properties. Again, Southern California's beaches did not disappear because seawalls were built. Seawalls were needed because the beaches disappeared. The facts bear this out, and simply eliminating seawalls will not even begin to fix the problem.

As a society, we must all come to grips with the real hazards and impacts affecting our coastal resource. Only then can we work together to improve the quality of this resource. The coastline along much of Southern California is totally developed, and this must be considered in future coastal land use policies. As a society, we are primarily responsible for the loss of this resource and we must consider renourishing these coastal areas that would clearly benefit from this effort. In San Diego's North County, 25 years ago, we had healthy, albeit relatively narrow, beaches, with the elevation of the back beach typically around +12 feet. In the last two decades, competing societal interests have caused the loss of this ribbon of sand that many have come to enjoy. Its loss, however, has also significantly increased the erosive wave energy, f_w, acting on our coastal bluffs, and the cumulative impacts of this 12 to 13 foot [12 foot back beach elevation, minus the bedrock shore platform elevation] loss of sand is an order of magnitude more severe than the impact of passive erosion from a seawall. With beach renourishment, in the absence of sufficient sand to preclude its loss from say a 100-year storm, seawalls can protect the coastal bluffs that back the beach.

There may also be locations along even an urban coastline where certain bluff-top properties could be purchased in a given location, where the engineering and environmental constraints dictated that removal and planned retreat made more economic sense than beach renourishment or the construction of seawalls. With everyone working together and armed with the facts, and giving reasonable consideration to property rights and the impacts that we as a society have created to the detriment of our coastlines, we can truly improve the quality of the coastal experience for everyone that visits the California coastline.

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EXHIBIT C

LITTORAL CELLS, SAND BUDGETS, AND BEACHES: UNDERSTANDING CALIFORNIA'S SHORELINE

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OCTOBER 2006
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CALIFORNIA DEPARTMENT OF BOATING AND WATERWAYS
CALIFORNIA COASTAL SEDIMENT MANAGEMENT WORKGROUP

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Table of Contents

EXECUTIVE SUMMARY

The coastline of California can be divided into a set of distinct, essentially self-contained littoral cells or beach compartments. These compartments are geographically limited and consist of a series of sand sources (such as rivers, streams and eroding coastal bluffs) that provide sand to the shoreline; sand sinks (such as coastal dunes and submarine canyons) where sand is lost from the shoreline; and longshore transport or littoral drift that moves sand along the shoreline. Sediment within each cell includes the sand on the exposed or dry beach as well as the finer-grained sediment that lies just offshore.

Beach sand moves on and offshore seasonally in response to changing wave energy, and also moves alongshore, driven by waves that usually approach the beach at some angle. Most beach sand along the coast of California is transported from north to south as a result of the dominant waves approaching the shoreline from the northwest, although alongshore transport to the north occurs in some locations and at certain times of the year in response to waves from the south. Average annual rates of littoral drift typically range from about 100,000 to 1,000,000 yds^3/yr along the California coast.

Sand budgets have been developed for many of California's littoral cells by calculating or estimating the amount of sand added annually from each source or lost to each sink, and by documenting the volume of sand moving alongshore as littoral drift by using harbor dredging records as proxies. It is the balance between the volumes of sand entering and leaving a littoral cell over the long-term that govern the long-term width of the beaches within the cell. Where sand supplies have been reduced through the construction of dams or debris basins in coastal watersheds, through armoring the seacliffs, by mining sand or restricting littoral transport through large coastal engineering structures, the beaches may temporarily or permanently narrow.

The impacts of human activities on the amount of sand supplied to California's beaches have been well documented. While there is a public perception that Southern California beaches have narrowed in recent years, fueled at least in part by the stormy 20-year El Niño dominated period that extended from 1978 to 1998 and severely eroded many beaches, long-term changes in beach width are still being studied.

Beach nourishment or beach restoration is the placement of sand on the shoreline with the intent of widening a beach that is naturally narrow or where the natural supply of sand has been significantly reduced through human activities. Nourished shorelines provide a number of benefits including increased area for recreation, increased revenue from tourism, habitat improvement for shore dependent species, greater protection of the coastline from coastal storms, reduced need for armor, and increased public access.

To date, opportunistic beach fill has provided the majority of sand historically used for beach nourishment in California. Over 130 million yds^3 of sand were added to the beaches of southern California between 1930 and 1993 as a by-product of several large coastal construction projects and from the dredging of existing harbors and new marinas. As a result, the beaches of Santa Monica Bay and the Silver Strand, for example, are much wider than they were under natural conditions. Although the amount of sand provided by these projects has dropped sharply, the use of sand retention structures, such as groins or offshore breakwaters, has been effective in stabilizing the sand and maintaining wider beaches at many locations.

Beach nourishment has emerged as an option in recent years for portions of the southern California coastline (northern San Diego County and portions of Santa Barbara and Ventura counties, for example) where beaches are narrow and back beach or cliff top development is being threatened. While nourishment may appear to be an attractive alternative to coastal armoring or retreat, there are a number of issues or considerations that need to be carefully considered and addressed. These include the source and method of obtaining appropriate sand, costs and impacts of removing and transporting large volumes of sand to the site, financial responsibility for the initial project and subsequent re-nourishment, the potential impacts of sand placement, and the lifespan of the nourished sand. Due to the high littoral drift rates that characterize most of the California coast, sand added to a beach that is narrow to begin with cannot be expected to remain at that location for any extended period of time. Sand retention systems have been used effectively at a number of sites in California, however, as a way to significantly extend the lifespan of a beach nourishment project.

Chapter 1

Introduction

People have been interested in beaches and coastal processes for many years. Researchers have observed that beach width can change significantly over a range of time periods, from hours and days to years and decades. Long-term erosion or narrowing of any California beach is of concern to coastal managers as well as the general public.

In an effort to better understand the processes that change beaches, scientists use the concept of sand budgets to identify and quantify, to the degree possible, additions and losses of sand that influence beach width. By the 1960's, researchers recognized that the coastline of California could be separated into distinct, essentially self-contained regions or cells that were geographically limited. For example, beach sand in the Santa Barbara area originated from the watersheds and the coastline in the Santa Barbara area, and beach sand in San Diego or Santa Cruz originated in those geographic areas.

Coastal geologists and engineers termed these essentially self-contained coastal units littoral cells. These cells are geographically bounded by specific physical features that act as barriers to sediment movement, and contain additional features that either provide or remove sand from the cell. Understanding this setting allows researchers to focus on the major elements influencing specific beach or shoreline areas. This report discusses the physical process (littoral drift) that moves sand from one location to another within littoral cells. Littoral cell boundaries, features within the cell that supply sand to the beaches (sources), or remove sand from beaches (sinks) are also explained.

The methods used to develop sand budgets are first illustrated and then summarized for California's major littoral cells. Information is provided on how development associated with California's urbanizing society has altered the sand budgets of many of California's littoral cells, generally by decreasing the input of sand into the cell. This report concludes with a discussion of how the state is attempting to replace the sand lost through human activities (dam removal and beach nourishment) and the issues raised by such restoration activities.

The California Coastal Sediment Management Workgroup (CSMW), a taskforce of state and federal agencies seeking to resolve coastal sediment management issues, and the University of California at Santa Cruz, have developed this report as part of their public outreach and education effort associated with the CSMW's Sediment Master Plan, or SMP. A more detailed report on specific sand budgets for California's major littoral cells has been completed and is a complement to and resource for this more general discussion (Patsch and Griggs, 2006). Funding for both studies was provided by the California Resources Agency as part of a Coastal Impact Assistance Program grant for the SMP. The document was prepared with significant input from CSMW members, but does not necessarily represent the official position of member agencies.

CHAPTER 2

AN OVERVIEW OF LITTORAL CELLS AND LITTORAL DRIFT

WHAT IS LITTORAL DRIFT?

Researchers have learned that sand is in constant motion along California's coastline, and only resides "temporarily" on an individual beach. An alongshore or littoral current is developed parallel to the coast as the result of waves breaking at an angle to the shoreline. This current and the turbulence of the breaking waves, which serves to suspend the sand, are the essential factors involved in moving sand along the shoreline. As waves approach the beach at an angle, the up-rush of water, or swash, moves sand at an angle onto the shoreface. The backwash of water rushes down the shoreface perpendicular to the shoreline or a slight downcoast angle, thus creating a zigzag movement of sand (Figure 2.1). This zigzag motion effectively results in a current parallel to the shoreline. Littoral drift refers to the movement of entrained sand grains in the direction of the longshore current.

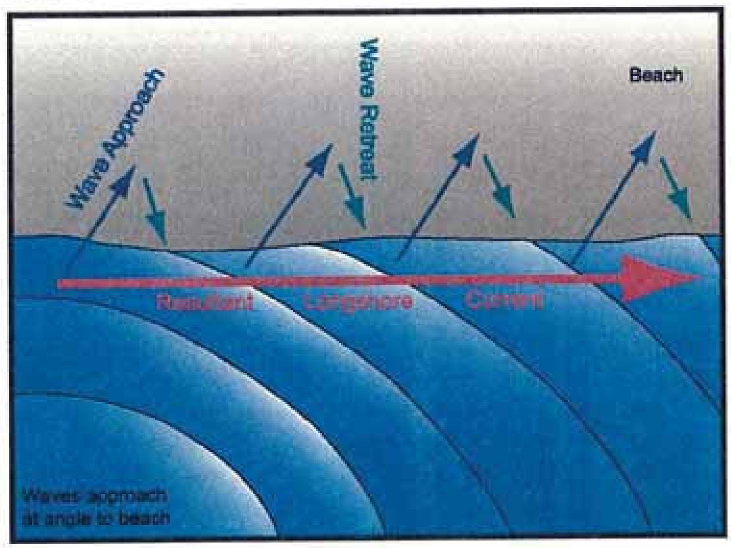

Figure 2.1: Development of longshore current as a result of waves approaching the beach at an angle. Littoral drift refers to the net movement of sand grains in the directions of the longshore current.

Littoral drift can be thought of as a river of sand moving parallel to the shore, moving sand from one coastal location to the next and so on until the sand is eventually lost to the littoral system. Littoral drift or transport in California can occur alongshore in two directions, upcoast or downcoast, dependent on the dominant angle of wave approach (Figure 2.2). Along the California coast, southward transport is generally referred to as downcoast and northward transport is considered upcoast. If waves approach perpendicular to the shoreline, there will be no net longshore movement of sand grains, no littoral current, and thus no littoral drift. Longshore transport for a reach of coast will typically include both upcoast and downcoast transport, often varying seasonally.

Gross littoral drift is the total volume of sand transported both up and downcoast, while net littoral drift is the difference between the two volumes. In other words, along a particular segment of coastline, there may be 200,000 yds^3 of sand transported in a southerly or downcoast direction each year, and 50,000 yds^3 transported in a northerly or upcoast direction. The gross littoral drift would be 200,000 + 50,000 or 250,000 yds^3, whereas the net drift would be 200,000 – 50,000 or 150,000 yds^3 downcoast.

For most of California, from Cape Mendocino south to San Diego, waves from the northwest have the greatest influence on littoral drift, and thus, a southward net littoral drift of sand dominates

Figure 2.2: Net littoral drift directions in California

(Figure 2.2). The more energetic winter waves generally approach from the northwest direction, driving littoral drift southward or southeastward along the beaches. There are also areas such as southern Monterey Bay, and Oceanside, where longshore transport to the north may take place. During El Niño winters, waves generally come from the west or southwest and the predominance of southward transport is reduced. Transport may be to the northwest, or upcoast, in most of southern California during the summer months when southern swell dominates.

Coastal engineering structures designed to widen or stabilize beaches, such as groins, the construction of harbor entrance jetties and breakwaters, and also the stability or lifespan of beach nourishment projects, are all closely tied to littoral drift direction and rate. Interrupting or disrupting the littoral drift or "river of sand", in addition to the benefits of retaining sand and widening beaches, can have serious consequences to the downdrift shorelines, including increased beach or cliff erosion and, in the case of a harbor entrance, costly dredging. Erosion of downdrift properties may necessitate the emplacement of additional coastal armoring, which extends the disruptions to the shoreline farther downcoast.

WHAT CONSTITUTES BEACH SAND?

Whereas it is common practice to refer to most beach sediment as "sand", grain sizes on beaches in California range from very-fine grained sand to cobbles as a result of differences in the wave energy, and the material available to any particular beach. Geologists and engineers classify sediment by size (e.g. silt, sand, pebbles) because different size materials behave very differently and sediment of different sizes is stable on different beaches. The Wentworth scale is one of the classification schemes most commonly used and it groups sediment by grain diameter (millimeters) based on powers of two (Krumbein, 1936). According to this scale, sand is defined as all particles between 0.0625 mm and 2 mm in diameter, although sand is further broken down into fine-grained, medium-grained, etc. (Table 2.1). The phi scale was introduced as an alternate measure of sediment size based on the powers of two from the Wentworth scale and is commonly used in the coastal geology community. It is important to note that larger phi sizes correspond to smaller grain sizes (Table 2.1).

Wentworth Scale Size Description	Phi Units Φ	Grain Diameter (mm)
Boulder	-8	256
Cobble	-6	64
Pebble	-2	4
Granule	-1	2
Very Coarse Sand	0	1
Coarse Sand	1	0.5
Medium Sand	2	0.25
Fine Sand	3	0.125
Very Fine Sand	4	0.0625
Silt	8	0.004
Clay	12	0.00024

Table 2.1: Wentworth scale of sediment size classification–Note that larger Phi sizes indicate smaller grain size

LITTORAL CUT-OFF DIAMETER

Very fine-grained sand, ranging from 0.0625 to 0.125 mm in diameter (4ø to 3ø), typically doesn't remain on the exposed (dry) portions of most California beaches due to the high-energy wave environment. An investigation of littoral transport processes and beach sand in northern Monterey Bay (Hicks, 1985), discovered that there is a littoral cut-off diameter, or a grain-size diameter, characteristic of any particular segment of coast. The cut-off diameter serves as a functional grain size boundary in that very little material finer-grained than this diameter actually remains on the exposed beach. The cut-off diameter along any particular beach or stretch of coast is primarily a function of wave energy at that location.

Studies along the coast of northern Santa Cruz County, which is a relatively high-energy, exposed coast, determined a littoral cut-off diameter of ~0.18 mm (2.5ø) for this stretch of coast, with very little finer sand remaining on the exposed beaches. In southern California, where much of the coast is protected from strong wave action by the sheltering effect of the Channel Islands, the littoral cut-off diameter is smaller, typically around 0.125mm (3ø). When estimating or calculating inputs to a sand budget or planning a beach nourishment project, it is important to consider the littoral cut-off diameter. Sand placed on the beach or entering a littoral cell that is finer than the littoral cut-off diameter will not remain on the dry beach.

THE BEACH PROFILE

The exposed (dry) beach is the visual portion of a profile of sediment that extends from the back of the beach to some depth (commonly referred to as "closure depth") representing the point beyond which it is believed that there is little net seasonal movement of sand on- and offshore. The grain size distribution varies along this profile perpendicular to the shoreline, and the overall distribution of size can be represented by an "envelope" of grain sizes. The coarsest materials within this envelope reside on the beach itself; successively finer-grained materials are present further offshore along the profile. Materials within the nearshore are an important part of the beach and related system. . Sediment smaller than the cut-off diameter may move into the nearshore and help support the beach profile. It may also move alongshore as littoral drift.

We do not currently have the historical information needed to quantify changes in nearshore sand volumes. This report focuses on the changes and processes affecting beach sands, which provides an adequate surrogate for the total volume of sediment moving alongshore as littoral drift.

LITTORAL CELLS

The California coast can be divided into a number of individual segments within which littoral sediment transport is bounded or contained. These essentially self-contained segments have often been referred to as beach compartments (Figure 2.3; Inman and Frautschy, 1966) or littoral cells.

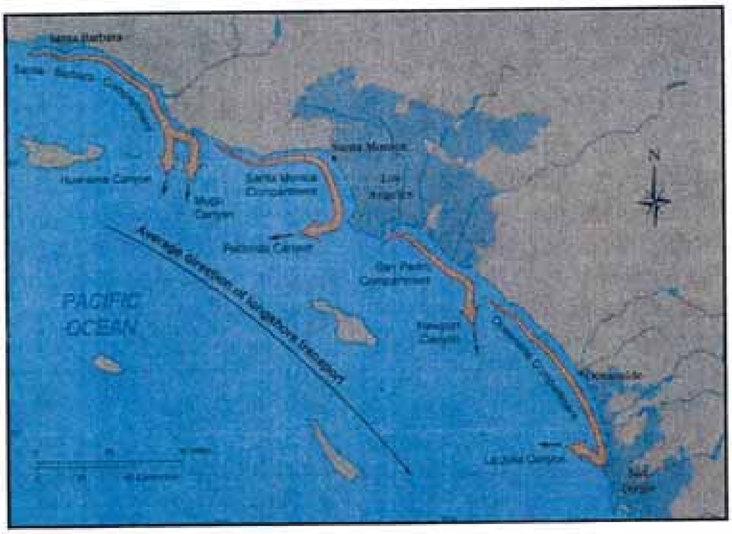

Figure 2.3: Littoral cells in southern California

Each cell has its own source(s) of sand, littoral drift, and ultimately, a sink or sinks where sand is lost permanently from the littoral cell (Figure 2.4). Sediment within a littoral cell consists of sand on the exposed or dry beach as well as the finer grained materials residing in and moving through the adjacent nearshore environment. Typical sources and sinks are described in detail in Chapter 3. The littoral cell concept has been perhaps the most important discovery in the field of coastal and beach processes in the last 50 years. It has enormous value in understanding coastal processes, sand input, output, storage and transport, and provides an extremely valuable and useful framework for assessing any human intrusions into the coastal zone.

The upcoast boundary of a littoral cell is typically a rocky headland, littoral barrier or sink such that littoral drift into the cell from the adjacent upcoast compartment is restricted or minimal. Sand enters the littoral cell primarily from streams and rivers draining to the shoreline and from bluff erosion, and is transported alongshore by littoral drift. Ultimately, sand is lost from the compartment offshore into the head of a submarine canyon or beyond the reach of longshore transport, onshore into coastal dunes, or in some cases, to sand mining.

CROSS-SHORE TRANSPORT

During large storm events, sand may be either transported offshore or onshore from the seafloor seaward of the surf zone. Thus the nearshore area may be either a source or sink for beach sand. However,

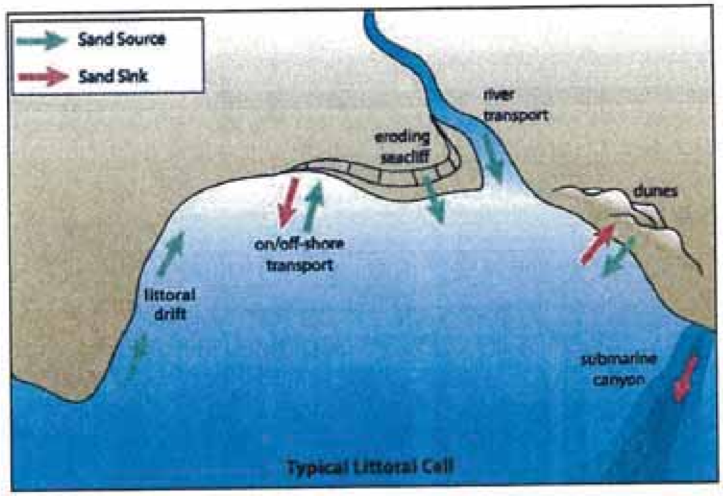

Figure 2.4: Sources and sinks in a typical littoral cell in California

for most littoral cells we simply don't have adequate information to quantify this cross-shore transport and, therefore, the importance of the sand in the nearshore area to littoral sand budgets is poorly understood.

LIMITATIONS TO THE LITTORAL CELL CONCEPT

Ideally, each littoral cell exists as a distinct entity with little or no transport of sediment between cells. It is believed that many headlands form nearly total barriers to littoral drift, but under particular conditions, such as during large storms, significant sand may be suspended and carried around points or across the heads of submarine canyons onto the beaches of adjacent cells. Fine-grained materials being transported in suspension behave differently than sand moving along the surface of the beach or nearshore zone, and the littoral cell boundary concept does not apply to these materials.

Nevertheless, while boundaries have been delineated for California's major littoral cells (Figure 2.5; also see Chapter 4), there are still uncertainties and information gaps on these often well-studied cells: Where are the actual boundaries of each littoral cell? Does significant sand transport take place around or across these "boundaries"? What is the dominant littoral drift direction throughout each cell? These are a few of the questions that remain partially unanswered.

The application of a budget to understand changes in and processes affecting beach sand is a useful tool in coastal land use management and coastal engineering. It is an essential step in understanding sand routing along the coast. One of the first sediment budgets for a littoral cell was created in the region from Pismo Beach to Santa Barbara, estimating each sand input and output along this portion of the central coast of California (Bowen and Inman, 1966). This budget has proven to be a valuable template for subsequent studies.

Our historic lack of understanding of littoral cells and their importance, or the failure to incorporate this type of information early on in the decision-making process in large watershed or coastal engineering projects has resulted in costly problems to society. For example, ongoing harbor entrance channel dredging is required where these projects were constructed in the middle or downcoast ends of littoral cells with high drift rates (Griggs, 1986). The reduction of sand delivery to beaches due to impoundment of sediment behind dams in coastal watersheds has contributed to cliff and beach erosion and the loss of recreational benefits. An improved qualitative and quantitative understanding of littoral cells and sand budgets can help us to resolve existing coastal sediment problems and also inform future planning so as to avoid the mistakes of the past.

Figure 2.5. California's littoral cells (Habel and Armstrong, 1978)

SEASONAL AND DECADAL MOVEMENT OF SAND WITHIN A LITTORAL CELL

The shoreline within a littoral cell is dynamic, changing with the rhythms of the tides, seasons, and long-term climatic shifts, including fluctuations of sea-level. Beaches respond with great sensitivity to the forces acting on them, primarily wind and waves. Waves provide the energy to move sand both on- and offshore as well as alongshore. The beach is a deposit of well-sorted material that appears to be stable, but in reality, the beach and sand in the nearshore are in constant motion on-, off-, and alongshore. This motion occurs underwater and on both short term (individual waves) and long-term (seasonal and decadal) time scales.

As sea level changes with tidal cycles, so does the width of the exposed beach. In addition to daily variations, long-term fluctuations in sea level occur over hundreds and thousand of years as a result of global climate change. Sea level has been rising for about 18,000 years, and it is assumed by virtually all coastal and climate scientists that it will continue to rise into the foreseeable future. Over the past century, sea level has risen relative to the coastline in southern California by about 8 inches (20 cm), and at San Francisco by about 9 inches (23 cm).

Beach widths in California also change on a seasonal scale, due to changes in weather, storm intensity, and wave climate (Figures 2.6 and 2.7). Seasonal beach erosion is typically a recoverable process; beach width narrows each winter and generally widens the following summer. In the winter, the coast experiences an increase in storms and wave energy. The increased wave energy tends to erode the beach, and moves sand into the nearshore where it is stored in sand bars. These sand bars tend to reduce the wave energy hitting the shoreline because the waves will break farther offshore (over the bars), losing some of their energy before reaching the shoreline. As the winter storms pass and the wave intensity is reduced, the smaller, less energetic spring and summer waves begin to dominate. These smaller waves rebuild the beach with the sand moved offshore during the winter storms. Figure 2.7 shows a beach in central California (A) during the summer when smaller waves have moved sand onshore to build a wide beach, and (B) in winter when large storm waves have narrowed the beach by moving sand onto offshore bars.

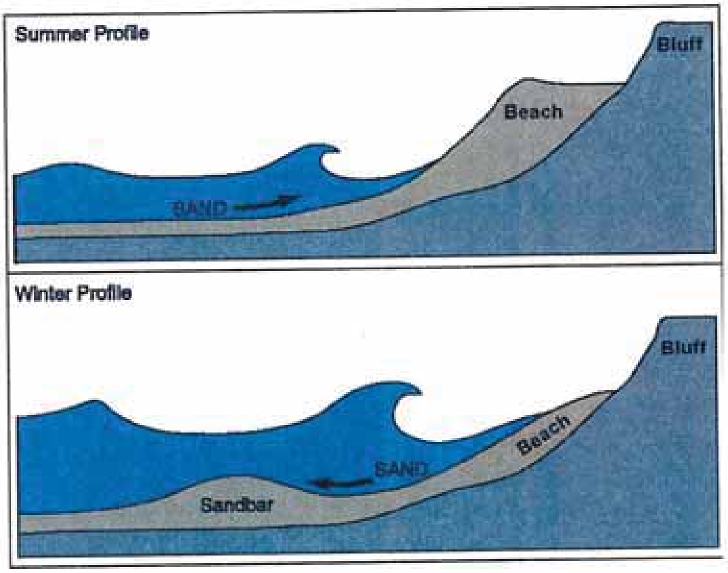

Figure 2.6: Summer profile (also known as the swell profile) results from waves wit low heights, and long periods and wavelengths. The beach is characterized by a stee foreshore and a broad berm (a terrace formed by wave action along the backshore o a beach). The winter beach profile (also known as the storm profile) is a response t higher waves, shorter wave periods, and shorter wavelengths. Waves become erosiv and cut away at the berm, transporting sand onto offshore bars where it is stored unti the following summer.

Over years and decades, beaches can erode (narrow), advanc (widen), or remain in equilibrium, as a result of available sand with in a littoral cell. When sand supply is reduced through the construc tion of dams or altered by large coastal engineering structures suc as breakwaters or jetties, affected beaches can experience perma nent erosion or take years or decades to re-establish equilibrium This loss of sand and beach width may be recoverable, however, i the sand supply is restored.

Large-scale ocean warming episodes related to El Niño occur in th Pacific Ocean when mean sea level in California can be elevated by u to 15 cm or more for several months to a year. El Niño winters are als characterized by more frequent and vigorous storms over the Pacific and severe beach erosion can result when large waves approachin from the west or southwest arrive simultaneously with very hig tides. Research on changing climate conditions has identified period sometimes lasting several decades, when El Niño events are muc more severe than those occurring during La Niña periods (characte ized by cooler temperatures, decreased storm intensity and rainfall such as the period from the mid-1940's to 1978. Although the tim ing of these decadal-scale changes are not predictable, cycles of mor frequent El Niño events have been recognized when increased stor intensity and duration result in increased beach loss and cliff erosio The most recent cycle of intense El Niño events began in 1978. Wi ter storms of 1982-1983 and 1997-1998, in particular, caused seve beach erosion along California's shoreline and significant damage t oceanfront structures and coastal infrastructure.

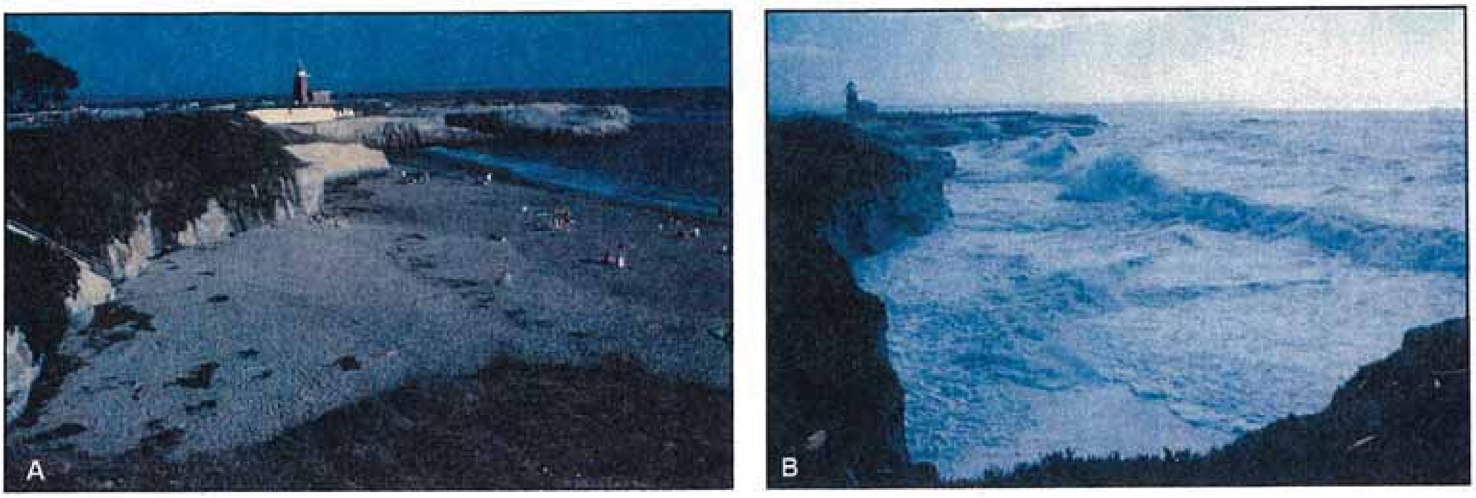

Figure 2.7: Seasonal beach changes
A. Wide, summer beach at Its Beach in Santa Cruz (October 1997) B. Narrow winter beach at Its Beach in Santa Cruz (February 1998)

CHAPTER 3

ELEMENTS INVOLVED IN DEVELOPING SAND BUDGETS FOR LITTORAL CELLS

Beach sand is in a constant state of flux, moving on-, off- and alongshore under the influence of waves and currents. Sand is transported to beaches from a variety of sources, including rivers, seacliffs or dunes, updrift beaches and possibly offshore sources (Figure 2.4). Sand generally remains at a given location on a beach for only a short time before it is entrained and moved on as littoral drift. When the removal of sand (output) exceeds that being transported in (input), beach erosion or narrowing results. Conversely, beach widening results when sand input exceeds output, or when some barrier to littoral transport (a groin or jetty for example) is constructed that leads to sand storage (output is reduced). Beaches are said to be in equilibrium when sand inputs are approximately equal to sand outputs.

A sand budget is an attempt to quantify changes in the on-shore sand volume along a stretch of coast by applying the principle of conservation of mass. In order to develop a sand budget, estimates must be made of the primary sand sources (input) and sand losses (output) for a stretch of shoreline. Balancing or creating a sand budget for a reach of coast is similar to balancing a checkbook. Sand sources such as river inputs, seacliff or dune erosion, longshore transport from upcoast areas, beach nourishment and onshore transport from the nearshore can be thought of as deposits (inputs) into the account (Figure 2.4). Sand sinks (e.g., submarine canyons, dune growth, longshore transport out of an area, offshore transport and sand mining) represent outputs from the system or debits to the account (Figure 2.4). The difference between the total volume of sand provided by all sand sources and the volume lost to all sinks within a particular littoral cell will equal the change in sand volume or storage within that compartment and provide insight on the stability of the beach or particular stretch of coast (Table 3.1).

Sources of Sand	**Sinks for Sand**	**Balance**
Longshore Transport In	Longshore Transport Out	Accretion
River Inputs	Offshore Transport	Erosion
Seacliff or Bluff Erosion	Dune Growth	Equilibrium
Gully Erosion	Sand Mining	
Onshore Transport	Submarine Canyons	
Dune Erosion		
Beach Nourishment		

Table 3.1: Sources and sinks of sand and the resulting balance in the development of a sand budget.

A sand budget can be developed to represent short-term conditions, such as seasonal or yearly changes. However, when planning a large engineering, restoration or nourishment project or other alteration to the coast, it is best to construct a long-term sand budget that includes historic and present conditions. Many assumptions and errors involved in the data analysis and interpretation of a sand budget can be reduced when a budget spans a greater length of time and averages out year-to-year variations in the components.

It is the balance between sand sources and sinks within each littoral cell that govern the long-term width of beaches within a beach compartment. If there is a significant reduction in the amount of sand reaching a particular stretch of coast, the beach should gradually erode or narrow. Conversely, if there is an increase of sand in a particular area, the beach should advance seaward, or widen.

COMPONENTS OF A SAND BUDGET

The main challenge in developing a sand budget is quantitatively assessing all sources and sinks to a reasonable degree of accuracy. A thorough literature search should be performed to find the most up-to-date information on each component. Along the California coast, most of the naturally supplied beach sand comes from river and stream runoff with a lesser amount derived from the erosion of coastal cliffs and bluffs. Sand is lost from littoral cells predominantly to submarine canyons, to sand dunes to a lesser extent, and perhaps to offshore transport during extreme storm events. Sand mining directly from the beach historically was a major loss for some littoral cells, but most of this has now been eliminated.

Sand contributions from seacliff erosion, rivers, and dunes as well as other components of the budget, have been or can be quantified or calculated with some effort for many of the state's littoral cells (Patsch and Griggs, 2006; Patsch, 2005). The volume of materials dredged from harbors within the littoral cell can serve as a surrogate (or check point) for the volume of littoral drift at a specific location. The following sections give more specific information on the difficulties and limitations involved in calculating or estimating contributions and losses for a sand budget.

River Inputs (Source): Rivers contribute the majority of sand to most beaches in California. Physical and chemical weathering slowly breaks down the rocks from coastal mountains into smaller fragments. The broken-down boulders, cobbles, gravel, sand, silt and clay move into mountain streams and creeks through rainfall, runoff, and slope failures, and the sediments are sorted and transported downstream into larger streams or rivers. As sediments travel down stream, they break down and become smaller. Large cobbles and boulders are often left upstream because the river does not have enough energy to transport them downstream. Sediment is transported in streams either as suspended load (the finer-grained sediment which makes it look muddy), or as bedload (the coarser material that is transported along the bed of the stream). Most of the suspended load consists of clay and silt, except during high discharge events when significant volumes of sand can be transported in suspension and delivered to the shoreline. Although the total amount of sediment carried as bedload is much less than that carried in suspension, most of the bedload is sand and will contribute directly to the littoral sand budget.

Eventually, the smaller cobbles, sand, silt and clay will reach the shoreline. The finer silt and clay particles are too small to settle and remain on the beach, and consequently are carried offshore by coastal and offshore currents, and eventually deposited on the seafloor nearby or perhaps many miles away. Offshore mudbelts are fairly common, where much of the fine-grained sediment eventually ends up. Most sand-sized material will remain on the beach, and gradually be moved alongshore by littoral drift, thereby feeding downcoast beaches. The finer-grained sand may, however, move into the nearshore zone and also be transported alongshore.

Sand contributions for the majority of the coastal rivers and streams in California have been determined using daily measured values of water discharge, or probabilities of discharge events, to develop "sediment-rating curves". These curves show the relationship between the volume of water discharge and sand loads for individual streams.

Sediment rating curves can be used to estimate the annual sediment yield from individual rivers and streams. Using these curves, average sand loads (sediment sufficiently coarse to remain on the beach) have been calculated for most of the rivers and streams in California (Willis and Griggs, 2003; Slagel, 2005). Under historical or natural conditions about 13-14.5 million yds^3 of sand was being delivered annually to the coast of California from 37 major rivers and streams. This volume has been reduced about 23% statewide through impoundment behind dams, such that, on average, about 10,000,000 yds^3 of sand is presently delivered to the coast each year.

The methodology used in these two studies is believed to be the most reliable approach currently available for determining sand contributions to the shoreline from rivers; however it is not without error. Some gauging stations are often well upstream from the mouth of the river; thus, sediment loads may differ significantly between the gauging station and the shoreline due to deposition or erosion that may occur along the stream channel or flood plain between the gauging station and the river mouth.

Sediment delivery by rivers to California's littoral cells is extremely episodic. Most sediment discharged by any particular stream typically occurs during several days of high flow each year. Additionally, sediment discharge during a single year of extreme flood conditions may overshadow or exceed decades of low or normal flow. For example, the Eel River transported 57 million tons of suspended sediment on December 23, 1964, representing 18% of the total sediment discharged by the river during the previous ten years. This one-day discharge is greater than the total average annual suspended sediment discharge for all rivers draining into the entire California coastline. On some streams, however, little or no sediment discharge data may exist for the flood or large discharge events that transport the greatest volumes of sediment. As a result, rating curves may not adequately predict sand transport from water discharge records during the high discharge events. Data or calculations for sediment impounded behind dams can help fill such gaps or deficiencies in sediment discharge records (Slagel, 2005).

Fluvial sediment discharge has also been shown to vary widely from El Niño to La Niña periods (Inman and Jenkins, 1999), such that the length of historic streamflow record from any particular gage may or may not be representative of long-term conditions. In Southern California, mean annual stream flow during wet El Niño periods exceeded that during the dry periods by a factor of about three, while the mean annual suspended sediment flux during the wet periods exceeded the sediment transported during dry periods by a factor of about five (Inman and Jenkins, 1999).

At their best, data on fluvial sand discharge are believed accurate to within about 30% to 50% (Willis and Griggs, 2003). Yet, the amount of sand transported and delivered to the shoreline by streams is an extremely important component of all sand budgets for California.

Reductions to Fluvial Inputs: Damming of rivers or streams reduces sediment delivery to the coast by both trapping sand in the reservoirs and reducing peak flows that transport the greatest amount of sediment. Most of California's large dams, under good management, have reservoir capacities sufficient to absorb all incoming water during a normal winter, releasing low flows to downstream areas during the spring and summer months. The magnitude and frequency of peak flows are therefore reduced, decreasing the river's ability to transport material downstream (Figure 3.1). Dams act as complete barriers to bedload and trap most of the suspended sediment load except during large flood events when flows overtop the dam or pass through the spillway. The average trapping efficiency (the amou of suspended sediment trapped by the dam) for most coastal dams in California is about 84% (Brune, 1953; Willis and Griggs, 2003).

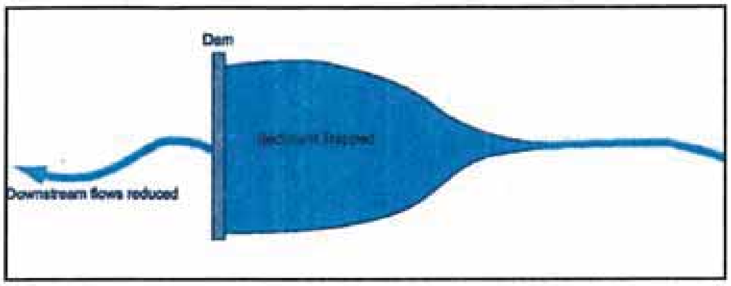

Figure 3.1: Dams trap sediment, preventing it from moving downstream to the shoreline, in addition to reducing the river's flow volume and thus its ability to transport sediment.

Recent work by Willis and Griggs (2003) and Slagel (2005) indicate that the present day delivery of sand to the shoreline has been reduced to about 10 – 11 million yds^3/year, or approximately a 23-25% reduction from natural conditions, due to the more than 500 dams on California's coastal streams. Approximately 3 million yds^3 of sand is trapped each year and a total of about 163 million cubic yds^3 of sand has now been deposited behind dams on the state's 21 major rivers (Slagel, 2005). The great majority of this reduction is concentrated in southern California (Tables 4.1 and 4.2; These two tables list only the amounts of sand provided to California's ten major littoral cells under natural and present-day conditions, and do not include all of the state's major coastal rivers and dams analyzed by Slagel [2005] and Willis and Griggs [2003])

Sand mining in Northern California coastal watersheds and along stream channels has removed an estimated 9 million yds^3 (11 million tons) of sand and gravel annually on average, and similar operations in Southern California have removed about 41.5 million yds^3 (55.8 million tons) annually on average (Magoon and Lent, 2005). It is unclear how much of this sand and gravel would naturally be delivered to the coast by rivers, but sand mining may play a major role in the reduction of sand delivery by rivers to the shoreline.

If sand supply from rivers is continually reduced through impoundment behind dams, as well as through sand and gravel mining from stream beds, then beaches should eventually be deprived of a significant portion of their predominant sand source. Over decadal time scales, beaches should, therefore, narrow or erode, assuming no change in littoral transport rates (Figure 3.2). Littoral drift rates are a function of the amount of wave energy, the angle of wave approach, and the sand available for transport. More wave energy and a greater angle of wave approach will generate larger littoral drift rates.

Seacliff erosion (Source): Seventy-two percent of California's 1,100-mile coast consists of seacliffs or coastal bluffs, which, when eroded, may contribute sand to California's beaches. Coastal cliffs that consist of materials such as sandstone or granite that break down into sand-sized grains will contribute directly to the beaches. Fine-grained rocks that consist of silt and clay (shales or mudstones), on the other hand, will not contribute significantly to beaches.

The geology of the seacliffs along the coast of California varies widely alongshore and, therefore, the amount of sand contained in the cliffs or bluffs also varies from place to place. Typically, where the coastal cliffs consist of uplifted marine terraces, there is

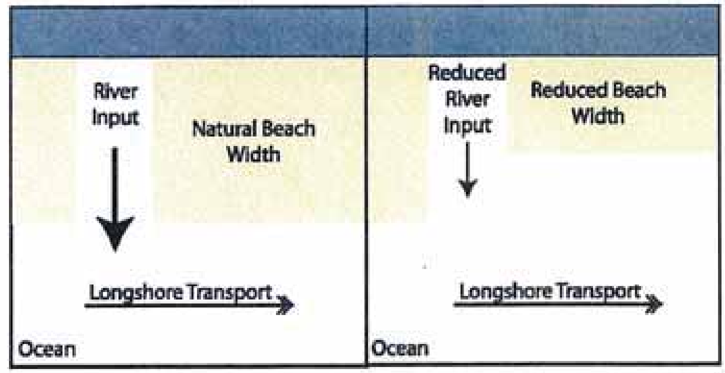

Figure 3.2 illustrates beach narrowing expected from a reduced sand supply. A simplified littoral cell is presented with a single river as the only sand source, thus ignoring sand contributions from cliffs and other budget components. If the amount of sand delivered by the river is reduced, and the littoral drift remains the same, then the downdrift beach volume or width should decrease over time.

an underlying, more resistant bedrock unit and an overlying sandy deposit, consisting predominantly of relict beach sand. Each unit will have its own particular sand content. In order to make qualitative assessments or quantitative measurements of the contribution of coastal cliff retreat to beaches, it is necessary to divide the coast into manageable segments somewhat uniform in morphology and rock type. Estimates of sand contributions from individual segments can then be combined to arrive at a total contribution of beach sand over a larger area, such as an individual littoral cell.

The annual production of sand coarse enough to remain on the beach resulting from seacliff erosion (Qs) along a segment of coastline is the product of: 1- the cross-sectional area of seacliff (Area = alongshore cliff length x cliff height); 2- the average annual rate of cliff retreat, and; 3- the percentage of material larger than the littoral cutoff diameter (Figure 3.3):

$$Qs\ (ft^3/yr) = Lc*E*(Hb*Sb + Tt*St)$$

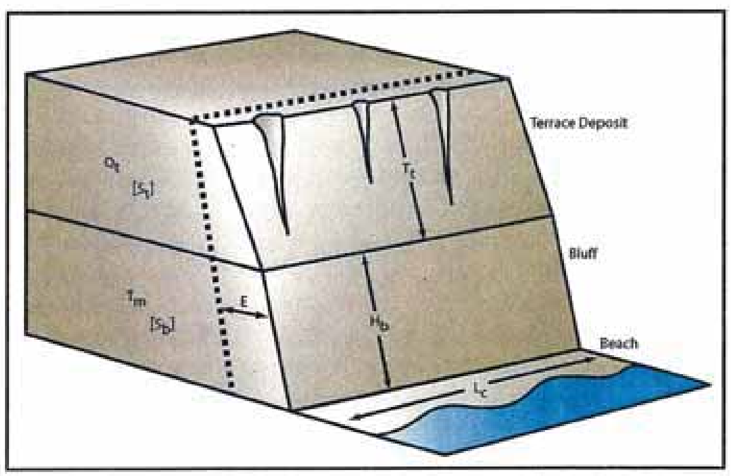

Figure 3.3: Seacliff showing the components involved in calculating sand contribution: Lc is the alongshore length of the cliff (ft); E is erosion rate (ft/yr); Hb is bedrock height (ft); Sb is percentage of sand size material larger than the cutoff diameter in bedrock; Tt is thickness of the terrace deposit (ft); and St is percentage of sand larger than the cutoff diameter in the terrace deposit. Tm (Tertiary Marine) represents geology of the bedrock, and Qt (Quaternary Terrace) represents geology of the capping terrace deposit.

The methodology for determining sand contributions from seacliff erosion is simpler than the process used to determine river contributions of sand. However, these calculations still have a high degree of uncertainty. The most difficult element of this methodology to constrain is the long-term seacliff erosion rates due to the high spatial variability and episodic nature of cliff or bluff failure. Seacliff erosion rates are typically determined by precisely comparing the position of the cliff edge over time on historical stereo aerial photographs (Griggs, Patsch and Savoy, 2005).

On a state-wide basis, contributions to beach sand from seacliff erosion tend to be much less than those from streams. However, such contributions may be very important locally where very sandy cliffs are rapidly eroding and there are no large streams (Runyan and Griggs, 2003). For example, while bluff erosion contributes less than one percent of the sand to the Santa Barbara littoral cell, bluff erosion is believed to contribute about 31% and 60% of the sand to the Laguna and Mission Bay littoral cells, respectively. Also, recent research in the Oceanside littoral cell, utilizing composition of sand in the bluffs and beaches, as well as very precise LIDAR (a very precise, laser-based, topography measuring system) measurements of coastal bluff retreat (over a relatively short 6-year period) concluded that bluffs may contribute 50% or more of the sand to beaches in this littoral cell.

Beach Nourishment (Source): Beach nourishment is used to describe sand artificially added to a beach and/or the adjacent nearshore that would not have otherwise been provided to the littoral cell. It is a way to artificially widen otherwise narrow or eroding beaches, and has occurred more frequently in southern California than in other region of the state. Historically, sand placed on the beach or just offshore has come from a variety of sources, including: dredging of coastal harbors, lagoons, bays, estuaries or river channels; coastal construction projects where dune or other excavated sand is placed on the beach; and, dredging of offshore areas. Most beach nourishment projects have served dual purposes, i.e., the primary purpose was to create a marina, clear a river channel for flood control, restore a coastal wetland or excavate a construction site, and the secondary purpose of the project was to nourish or widen the beach.

When developing a littoral budget, sand excavated from offshore, coastal or inland sources is considered to be an additional source of sand to the littoral cell, and thus labeled as nourishment. Harbor entrance bypassing operations or channel maintenance dredging do not represent new sources of sand, because they are simply moving the sand to a new location within the same cell, and so are not considered nourishment.

Cross-shore exchange (Source/Sink): Quantifying the potential movement of sand between beaches and the nearshore and offshore areas is the most challenging and poorly evaluated sand budget element. Cross-shore transport can result in either a net gain or loss for the beach. A comparison of sediment composition (e.g., distinct minerals contained in the sand) between beach, nearshore and shelf sand is often used as evidence for a net onshore or offshore transport; however, the similarity in composition only indicates that an exchange has taken place. It rarely indicates direction of transport or volumes of sand moved, which are necessary for development of a sand budget.

Whether or not sand is moved on- or offshore is controlled by factors such as wave energy and tidal range, bottom slope and the grain size of the sand. In order to thoroughly evaluate this component it would be necessary to have data on the precise thickness or depth of beach-sized sand over large offshore areas and to know how this has changed over time. With the large shelf areas typically involved, a small increase in the thickness of the sediment veneer over an extensive area can produce a large volume of sand in storage. We simply don't have these data, and it would require long-term studies to determine how the distribution of sand changes over time. In developing sand budgets, it is often assumed that net cross-shore exchange of sand is zero, such that the volumes of sand transported on- and offshore are balanced, unless sediment data are available on a particular area of interest. In other cases, however, unaccounted for losses are usually ascribed to offshore transport.

Offshore dredge disposal: There are several littoral cells where large volumes of beach size sand that have been dredged from harbors or channel entrances have been or continue to be transported offshore for disposal, thus removing this material permanently from the littoral system. Offshore disposal can, therefore, be a significant littoral sand sink.

Close to a million cubic yards of sand on average is dredged from the Humboldt Bay entrance channel every year and transported to EPA's Humboldt Open Ocean Disposal Site (HOODS; Tom Kendall, USACE). Sediment lost to the littoral cell from dredging and offshore disposal was also a major issue in San Diego. About two million cubic yards of sediment was scheduled for dredging as part of the deepening of San Diego Bay for larger U.S. Navy vessels. This sediment was originally intended for the SANDAG nourishment project, but was disposed of offshore due to ordinance found in the dredge spoils from the bay. These are very large volumes of potential beach sand that are being removed more-or-less permanently from the littoral system for different reasons. This is an issue that merits further investigation in order to document how extensive these losses are, where they are taking place, and what options exist for possible utilization of these materials in the adjacent littoral cells.

Dune Growth/Recession (Sink/Source): Sand dunes occur adjacent to and inland from beaches at many locations along the coast of California. Dunes are created where ample fine-grained sand is available with a persistent onshore wind and a low-lying area landward of the beach where the sand can accumulate. Typically, if the shoreline is backed by seacliffs, dunes can't accumulate or migrate and thus will not grow to any significant size. In many areas of California, such as the area north of Humboldt Bay, Golden Gate Park in San Francisco, southern Monterey Bay, The Pismo Beach area, and areas along Santa Monica Bay, wind-blown sand has created large dune complexes.

Dunes commonly represent sand permanently lost from littoral cell budgets, constituting a significant sink to a cell. For example, it has been estimated that an average of 200,000 yd^3/yr of wind-blown sand is permanently lost from the beaches along the 35-mile coastline from Pismo Beach to Point Arguello (Bowen and Inman, 1966; Figure 3.4). On the other hand, in areas such as the Southern Monterey Bay littoral cell, dune erosion and recession play an important role as a sand source to the littoral budget. While uncommon, sand may be blown onto the beach from a coastal dune area (representing a source).

Dune migration, growth and erosion (or deflation) can be measured from aerial photographs or in the field and converted into sand volumes. Dune growth and deflation illustrate the need to introduce a time element into sand budgets. One major storm can erode the portion of dunes closest to the ocean (i.e., the foredune), which were previously considered a sink, returning the sand to the beach. However, many studies have concluded that this type of foredune erosion may occur for only a few days during a major storm event and is followed by a prolonged period (from years to decades) of foredune growth.

Figure 3.4: Pismo Dunes in San Luis Obispo County. Copyright © 2002 Kenneth & Gabrielle Adelman California Coastal Records Project, www.Californiacoastline.org.

Losses into Submarine Canyons (Sink): Submarine canyons that extend close to shore (e.g., Mugu, Redondo, Newport and Monterey submarine canyons) (Figure 3.5) serve as effective barriers to littoral drift and terminate most littoral cells in California. These canyons are the largest permanent sink for sand in California. Sand accumulates at the heads of these submarine canyons and, through underwater sand flows or turbidity currents, is funneled away from the shoreline and deposited in deep offshore basins.

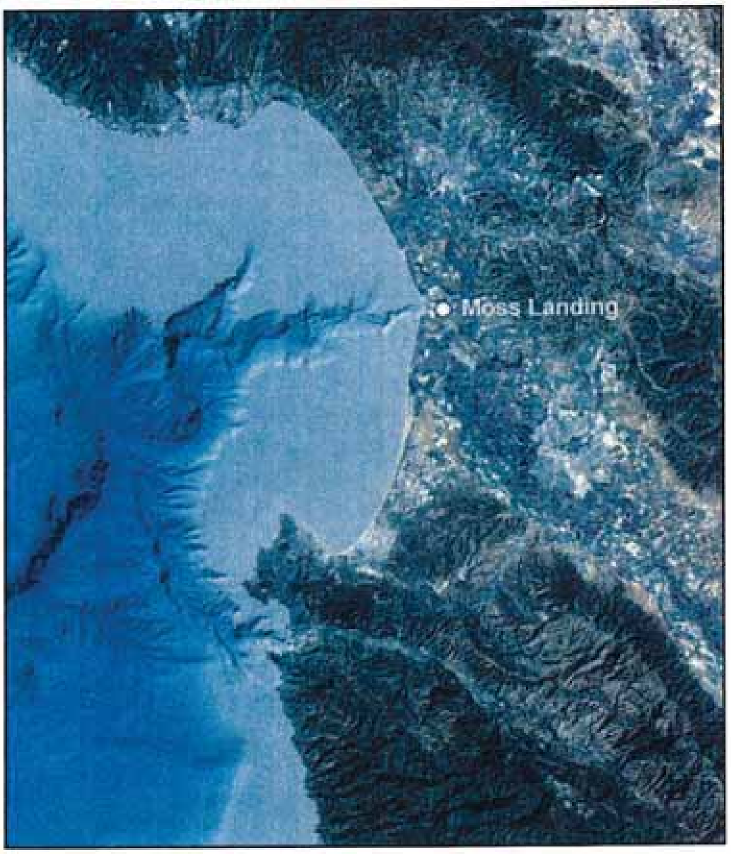

Figure 3.5: Monterey Submarine Canyon

It is believed that an average of over a million cubic yards of sand is annually transported down into Mugu Submarine Canyon, thus terminating the littoral drift within the Santa Barbara littoral cell. Monterey Submarine Canyon (Figure 3.5), located in the center of Monterey Bay, is one of the world's largest submarine canyons and is over 6,000 feet deep. An average of at least 300,000 yds^3 of sand is annually lost down this canyon. As part of sand budget calculations, after all sand sources and other sinks are first accounted for, any remaining sand in the budget is assumed to be directed into a submarine canyon, where one exists and reaches close enough to the shoreline to trap littoral drift, and is permanently lost to the littoral cell.

Sand Mining (Sink): Sand and gravel removed from riverbeds, beaches, dunes and nearshore areas for construction and/or commercial purposes, represents a significant permanent sink for some of California's littoral cells. Sand mining along the beaches of California and Oregon began in the late 1800s when there seemed to be an overabundance of sand and no obvious impacts from mining. Overall in northern California, (i.e., from the Oregon border to the Russian River), about 8 million yds^3 (11 million tons) of sand and gravel are removed each year from the coastal streambeds (Magoon and Lent, 2005). In southern California, the annual total is nearly 41.5 million yds^3 (56 million tons), primarily in the greater Los Angeles and San Diego areas.

Beach or streambed sand mining has historically been a large sink for beach sand in some specific locations; however the volumes removed are difficult to quantify for the purposes of a sand budget. Due to the proprietary (and therefore publicly unavailable) nature of sand mining operations, gathering information on specific mining practices for a given river or beach within a littoral cell may not be possible. Information on mining should be included in long-term sand budgets when available. While there are still extensive sand and gravel mining operations along many streambeds in California, direct removal of sand from the beach along the coast of California was mostly terminated by the early 1990's. However, mining of the back beach still occurs at some sites (e.g., near Marina in southern Monterey Bay) (Figure 3.6).

Figure 3.6: Sand is still mined directly from the back beach in the Marina area of southern Monterey Bay (2005). Copyright © 2005 Kenneth and Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org.

LITTORAL DRIFT CHECK POINTS

Direct measurement of the volume of sand moving as littoral drift would confirm estimated sand inputs from streams and bluffs; however, such direct measurement is unfortunately not feasible. However, California's four large ports and 21 small craft harbors (Figure 3.7) can serve as constraints, or check points, on this volume when developing sand budgets. Half of the littoral cells in California (10 of the 20 cells) contain at least one harbor that effectively traps the littoral drift. These coastal sand traps, however, are very different from dams and reservoirs, which keep sand from ever entering the littoral system.

Much of the sand moving along the coast as littoral drift is caught in either harbor entrances or designed trapping areas, dredged, and, with few exceptions, placed downdrift. The configuration and

Figure 3.7: California's harbors and location by county.

geometry of some harbors (e.g., Ventura and Channel Islands; Figure 3.8) were designed to trap littoral drift before it enters the harbor's navigation channel. Sand resides in these sediment traps until it is dredged, typically once or twice a year. Other harbors (e.g., Humboldt Bay, Oceanside, and Santa Cruz harbors) were not designed with a specific sediment trapping area. Thus, once the sand residing upcoast of the first jetty reaches the jetty tip, littoral drift travels around the jetty and accumulates in the harbor entrance channel, often forming a sandbar. While some littoral drift may naturally bypass the entrance channel, especially at those harbors designed without a specific trapping area, harbor dredging records are the most dependable numbers currently available for estimating long-term annual gross and, occasionally, net littoral drift rates.

For purposes of sand budget calculations, there must be enough sand being added to the littoral cell to balance the average dredged volume. Some littoral cells have more than one harbor, and thus multiple check points for quantifying the cell's littoral drift. These cells provide optimum conditions for developing reliable sand budgets.

Inherent errors do exist when using harbor entrance dredging volumes to estimate littoral drift as checkpoints in the development of

Figure 3.8: Ventura Harbor: maintenance dredging in 1972. Copyright © Kenneth and Gabrielle Adelman, California Coastal Records Project www.Californiacoastline.org

littoral cell sand budgets, however. Errors involved in estimating dredging volumes include, but are not limited to, the type of equipment used to dredge, and the time frame of sand removal and placement. There can also be uncertainties involved in the pre-dredge conditions and the method used to determine the reported volume of sand dredged from a location.

Other uncertainties include: 1–harbors, (e.g., Oceanside) where detailed studies indicate that littoral drift reverses seasonally, such that sand can be dredged twice, and; 2- significant natural bypassing of sand beyond the dredging area can also occur (e.g., again at Oceanside, where sand appears to have been transported offshore and formed a permanent bar) (Dolan, Castens, et al., 1987; Seymour and Castel, 1985).

It is believed, however, that the margin of error involved in estimating dredged sand volumes is still significantly lower than the error associated with quantifying the annual volumes of most sand sources and sinks within littoral cells (such as the sand contribution from streams and cliff erosion and sand lost to submarine canyons). For most harbors, entrances or trapping areas form nearly complete littoral drift traps. Where long-term data exist, which tend to average out year to year fluctuations, harbor dredging records provide rational check points for littoral cell sand budgets.

CHAPTER 4

SAND BUDGETS FOR CALIFORNIA'S MAJOR LITTORAL CELLS AND CHANGES IN SAND SUPPLY

The beaches of southern California are intensively used recreational areas that generate billions of dollars of direct revenue annually. Wide, sandy beaches, used by people playing volleyball, sunbathing, swimming, jogging and surfing, are the quintessential image of southern California. Wide, sandy beaches, however, were not always the natural condition. Many of these beaches have been artificially created and maintained through human intervention, including placement of massive amounts of sand and the construction of groins, jetties and breakwaters (Flick, 1993). The rate at which sand was added to these beaches, however, has diminished over the past 30 years, fueling the public's perception of erosion and the narrowing of the beaches. Sand sources for most of the littoral cells in southern California are minimal to begin with, and have been reduced further through stream channel sand mining and the damming of rivers, and, to a lesser extent, armoring of seacliffs and reduction in beach nourishment projects.

Sand is naturally supplied to the beaches of California's littoral cells from a combination of river discharge, seacliff erosion, and dune deflation or erosion. In addition, sand has been added to the beaches historically through various beach nourishment projects. These elements are included as inputs for the sand budgets presented in this summary for the major littoral cells in California. The cells described include (Figure 2.5) Eureka, Santa Cruz, Southern Monterey Bay, Santa Barbara, Santa Monica, San Pedro, Laguna, Oceanside, Mission Bay, and Silver Strand littoral cells.

Table 4.1 summarizes selected major littoral cells and the relative importance of individual sand sources to the total sand supplied to the cells. These data were developed for and derived from the more detailed companion study which quantified sand budgets for these littoral cells (Patsch and Griggs, 2006). Under present-day (i.e., dams in place) conditions (excluding beach nourishment), and based on all data published to date, fluvial inputs constitute about 87% of the sand entering California's major littoral cells and 90% of the sand provided to southern California beaches (from Santa Barbara to the Mexico border). Seacliff erosion contributes 5% of the sand to the major littoral cells statewide, and about 10% of the sand reaching the beaches in southern California. Dune recession statewide accounts for 8% of the sand in the statewide analysis but is 0% in southern California

When beach nourishment is taken into account as a contributing source of sand, the relative importance of rivers, bluffs, and dune erosion statewide drops to 72%, 4% and 7% respectively in California's major littoral cells, with beach nourishment accounting for the remaining 17% of the sand input. In southern California, beach nourishment represents 31% of the sand supplied to the beaches, thus reducing the importance of river and bluff inputs to 62% and 7% respectively.

Table 4.2 is a summary of the anthropogenic reductions to the sand supplied to the major littoral cells in California and to southern California from armoring of seacliffs and damming of rivers. In addition, these reductions are contrasted against the sand supplied through beach nourishment, and a net balance associated with these anthropogenic changes is shown. The greatest reduction in sediment supplied to southern California results from the damming of rivers. Such damming has reduced the apparent volume of sand

Littoral Cell	All Sand Volumes in yd3/yr	Rivers	Bluff Erosion	Dunes	Beach Nourishment	Total Sand Supply
Eureka	Total "Actual" sand contribution	2,301,000	0	175,000	0	2,476,000
	% of Budget	93%	0%	7%	0%	100%
Santa Cruz	Total "Actual" sand contribution	190,000	33,000	0	0	223,000
	% of Budget	85%	15%	0%	0%	100%
Southern Monterey Bay	Total "Actual" sand contribution	489,000	0	353,000	0	842,000
	% of Budget	58%	0%	42%	0%	100%
Santa Barbara	Total "Actual" sand contribution	2,167,000	11,000	0	0	2,178,000
	% of Budget	99%	1%	0%	0%	100%
Santa Monica	Total "Actual" sand contribution	70,000	148,000	0	526,000	744,000
	% of Budget	9%	20%	0%	71%	100%
San Pedro	Total "Actual" sand contribution	278,000	2,000	0	400,000	680,000
	% of Budget	41%	0%	0%	59%	100%
Laguna	Total "Actual" sand contribution	18,000	8,000	0	1,000	27,000
	% of Budget	66%	31%	0%	4%	100%
Oceanside	Total "Actual" sand contribution	133,000	55,000	0	111,000	299,000
	% of Budget	23%	9%	0%	19%	51%*
Mission Bay	Total "Actual"sand contribution	7,000	77,000	0	44,000	128,000
	% of Budget	5%	60%	0%	35%	100%
Silver Strand	Total "Actual"sand contribution	42,000	0	0	256,000	298,000
	% of Budget	14%	0%	0%	86%	100%
Total	Total "Actual" sand contribution	5,695,000	335,000	528,000	1,338,000	7,896,000
	% of Budget	72%	4%	7%	17%	100%
Southern CA Total: (Santa Barbara cell to Mexico)	Total "Actual" sand contribution	2,715,000	301,000	0	1,338,000	4,354,000
	% of Budget	62%	7%	0%	31%	100%
Total: Without Beach Nourishment	All	87%	5%	8%	N/A	6,558,000
	Southern CA	90%	10%	0%	N/A	3,016,000

Table 4.1: Summary of the average annual (post-damming and seacliff armoring) sand contributions from rivers, seacliff erosion, dune recession, and beach nourishment to the major littoral cells in California. * Gully erosion and terrace degradation accounts for the remaining 49% of the sand in the Oceanside littoral cell. This category is not accounted for in this table. Nourishment data is for the period 1930–1993. (For data sources see Patsch and Griggs, 2006)

reaching the beaches within the state's major littoral cells and to southern California cells by about 43% and 47%, respectively. The reduction in southern California equates to nearly 2.4 million yds^3 of sand annually (Willis and Griggs, 2003). Seacliff armoring has reduced the sand supplied to the major littoral cells and southern California's beaches by 11% and 10%, respectively. The southern California reduction is about 35,000 yds^3 annually, still less than 7% of the total sand input to all of these littoral cells.

Littoral Cell		Rivers (dams)	Bluff Erosion (armor)	Total Reduction	Beach Nourishment	Balance (nourishment-reductions)
Eureka	Reduction yd^3/yr	N/A	N/A	N/A	0	N/A
	Percent Reduction	N/A	N/A	N/A		
Santa Cruz	Reduction yd^3/yr	6,000	8,000	14,000	0	-14,000
	Percent reduction	3%	20%	6%		
Southern Monterey Bay	Reduction yd^3/yr	237,000	N/A	237,000	0	-237,000
	Percent reduction	33%	N/A	33%		
Santa Barbara	Reduction yd^3/yr	1,476,000	3,000	1,479,000	0	-1,479,000
	Percent reduction	41%	19%	40%		
Santa Monica	Reduction yd^3/yr	29,000	2,000	31,000	526,000	495,000
	Percent reduction	30%	1%	13%		
San Pedro	Reduction yd^3/yr	532,000	0	532,000	400,000	-132,000
	Percent reduction	66%	0%	66%		
Laguna	Reduction yd^3/yr	0	1,000	1,000	1,000	0
	Percent reduction	0%	13%	4%		
Oceanside	Reduction yd^3/yr	154,000	12,000	166,000	111,000	-55,000
	Percent reduction	54%	18%	47%		
Mission Bay	Reduction yd^3/yr	65,000	17,000	82,000	44,000	-38,000
	Percent reduction	91%	18%	50%		
Silver Strand	Reduction yd^3/yr	41,000	0	41,000	256,000	215,000
	Percent reduction	49%	0%	49%		
Total	Reduction yd^3/yr	2,540,000	43,000	2,583,000	1,338,000	-1,245,000
	Percent reduction	43%	11%	39%		
Southern CA Total	Reduction yd^3/yr	2,297,000	35,000	2,332,000	1,338,000	-994,000
	Percent reduction	47%	10%	44%		

Table 4.2: Summary of the anthropogenic reductions to the sand supplied to the major littoral cells in California and to southern California, due to seacliff armoring and the damming of rivers. In addition, sand supplied to the cells through beach nourishment is shown for the period 1930–1993. Note: sand bypassing at harbor entrances is not included in the nourishment volume.

CHAPTER 5

DISCUSSION OF BEACH NOURISHMENT IN CALIFORNIA

Beach nourishment or beach restoration is the placement of sand on the shoreline with the intent of widening beaches that are naturally narrow or where the natural supply of sand has been significantly reduced through human activities. Although there are several different approaches to beach nourishment, procedures are generally distinguished by methods of fill placement, design strategies, and fill densities (Finkl, et. Al. 2006; NRC, 1995; Dean, 2002). Types of nourishment according to the method of fill emplacement include the following (Figure 5.1; Finkl, et. al. 2006)):

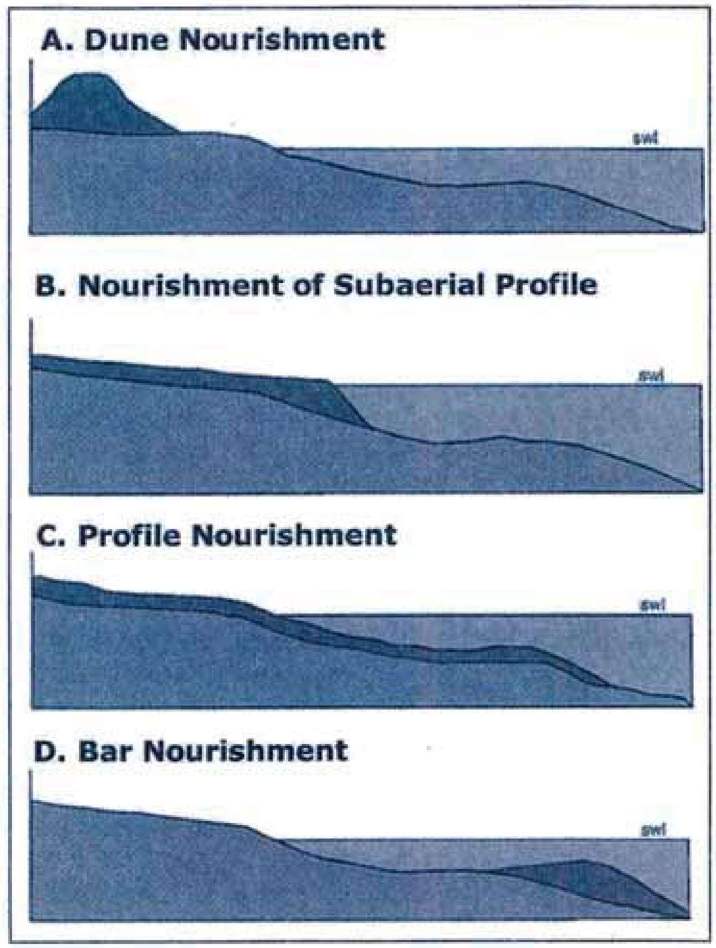

Figure 5.1. Methods of beach nourishment defined on the basis of where the fill materials are placed (from Finkl, Benedet and Campbell, 2006).

(a) Dune nourishment: sand is placed in a dune system behind the beach.

(b) Nourishment of subaerial beach: sand is placed onshore to build a wider and higher berm above mean water level, with some sand entering the water at a preliminary steep angle.

(c) Profile nourishment: sand is distributed across the entire beach and nearshore profile.

(d) Bar or nearshore nourishment: sediments are placed offshore to form an artificial feeder bar.

Nourished shorelines provide two primary benefits: increased area for recreation and greater protection of the coastline against coastal storms. Other potential benefits include, but are not limited to, increased tourism revenues, increased public access, reduced need for hard protective structures, higher property values, enhanced public safety and restored or expanded wildlife habitats.

Beach nourishment in California has been concentrated primarily in the southern part of the state. Flick (1993) summarized the history of beach nourishment in southern California and determined that over 130 million yds^3 of sand was added to those beaches between 1930 and 1993. About half of this amount was divided evenly between the Santa Monica and the Silver Strand littoral cells where the beaches widened significantly in response to this nourishment. Wiegel (1994) prepared a very thorough evaluation of ocean beach nourishment along the entire USA Pacific Coast; however, the report is mostly about Southern California because of the numerous beach nourishment projects that have taken place there.

What is clear is that there are major differences between the tectonic, geomorphic, oceanographic, climatic, and wave conditions along the Pacific Coast as compared to the Atlantic and Gulf Coasts. In addition to these inherent geological and oceanographic differences, there is a pronounced difference in the practice of beach nourishment (Finkl, et. al., 2006). Large nourishment projects using sand from offshore are common along the Atlantic and Gulf Coasts, but beneficial or opportunistic sediment (from coastal construction, channel maintenance and bypass operations) predominate on the West Coast (Herron, 1987; Flick, 1993; Wiegel, 1994).

The California Beach Restoration Study (2002) is a comprehensive assessment of California's beaches and their economic benefits, beach nourishment and restoration, as well as an evaluation of the major sources of sand to the state's beaches and how these have been impacted by human activity (http://www.dbw.ca.gov/beachreport.htm). The report concludes that continued loss of many public beaches could be substantially reduced by beach nourishment.

Opportunistic beach nourishment, which has provided the majority of sand historically used for beach nourishment in southern California, occurs when beach-compatible sand from a harbor development or expansion project, excavation for a large coastal construction project (e.g., El Segundo Power Plant or Hyperion Sewage Treatment Plant construction) or other construction or maintenance project is placed on nearby beaches. In other words, such sand is a byproduct of some construction or maintenance project that was not undertaken with beach replenishment or nourishment as a specific goal, but rather as an added benefit.

In addition to opportunistic beach nourishment there are other projects (the largest example being the 2001 SANDAG project in San Diego County) where sand has been delivered to the coastline with the sole purpose of widening the existing beaches. Sand may come from either terrestrial (stream channels or dunes, for example) or offshore sources (the inner shelf).

Beach nourishment, unless it takes place where there is a headland or other natural barrier to littoral transport, or unless it is accompanied by some structure or mechanism of holding the sand in place (e.g., groins), may not provide a long-term solution to narrow beaches or beach erosion in California, simply because the high to very high littoral drift rates that characterize most of California's shoreline will tend to move any additional sand added to the shoreline alongshore.

In the absence of any major reductions in littoral sand supply (due to either large-scale climatic fluctuations or human activities), beaches over the long-term will tend to approach some equilibrium size or width; e.g. a summer width that will vary about some mean from year to year. This width is a function of a) the available littoral sand, b) the location of barriers or obstructions to littoral transport (Everts and Eldon, 2000; Everts, 2002) c) the coastline orientation, and d) and littoral drift direction and rate, which is related to the amount of wave energy incident on the beach and the angle of wave approach.

In northern Monterey Bay, for example, because of the direction of dominant wave approach and the coastline orientation, those shorelines oriented northwest-southeast, or east-west (and where littoral transport barriers exist), such as the Santa Cruz Main Beach, Seabright Beach, or the inner portion of Monterey Bay, have wide well-developed beaches (A. Figure 5.2). In contrast, where the coastline is oriented essentially north-south (from Lighthouse Point to Cowell's Beach (B. Figure 5.2) and the Opal Cliffs shoreline between Pleasure Point and New Brighton Beach, for example), and where no significant littoral drift barriers exist, beaches are narrow to nonexistent because littoral drift moves the sand along this stretch of coast rapidly without any retention.

Figure 5.2. The coastline of northern Monterey Bay at Santa Cruz illustrating how the orientation of the coastline determines whether or not a beach forms. Where the shoreline is oriented essentially east-west and littoral barrier exist (A), wide stable beaches have formed. Where the coastline is oriented essentially north-south and there is no barrier, beaches rarely form (B). North is up in the photograph.

FACTORS AFFECTING THE LONGEVITY OF A BEACH NOURISHMENT PROJECT

It has often been assumed that the important parameters in the durability or longevity of a beach nourishment or replenishment project include the alongshore length of the nourishment project, the density or volume of fill placed, grain size compatibility with the native beach, the use of sand retention structures such as groins in conjunction with sand placement, and storm activity following nourishment. Those nourishment projects that had the greatest alongshore dimensions have been shown to last longer than shorter beach fills.

Fill Density: Density of the fill refers to the volume of sand per unit length of shoreline. The longevity of a nourishment project has often been assumed in the past to be directly related to fill density, with greater fill densities yielding longer life spans. In California, the initial fill densities range from 20,000 cubic yards per mile to 2,128,000 cubic yards per mile.

Grain Size: Grain size compatibility between the native beach and the fill material is also perceived to be an important factor in the longevity or durability of a nourished beach. Beach fill must be compatible with the grain sizes of the native sand (as coarse as or coarser than the native sand) such that the waves will not immediately carry the sand offshore. If the fill sand is to remain on the dry or exposed beach under prevailing wave conditions at the particular site, it must be larger than the littoral cut-off diameter.

Sand Retention Structures: Coastal structures aimed at retaining sand, such as groins or detached offshore breakwaters, have been successful in extending the life span of nourishment projects. For example, groins throughout the Santa Monica littoral cell and groins placed on beaches in Capitola, Ventura, Redondo Beach and Newport Beach have all been successful at stabilizing beach fill projects. However, if there is not enough sand in the system to begin with, groins will not be effective, as was the case at Imperial Beach where a series of groins has not been adequate to combat erosion. Groins will continue to trap littoral drift in the years following a beach nourishment project, thus maintaining the updrift beach. Groins must be considered on a regional scale, however. While beaches updrift of groins will be stabilized or widened, beaches downdrift of a groin may experience erosion once their sand supply is cut-off. A series of groins along the shoreline of interest in conjunction with beach nourishment may be an effective way to address downdrift beach erosion.

Offshore breakwaters have been widely used in Europe and in a few locations in the United States to stabilize or widen beaches by reducing wave energy and littoral drift in the lee of the breakwater. These offshore structures can be either slightly submerged, at sea level, or slightly above sea level. The offshore breakwater at Venice is a good example of the effects of such a structure in California, where the beach landward of the breakwater significantly widened (Figure 5.3). The Santa Barbara breakwater was completed in 1929 as a detached offshore structure. Although the purpose of the breakwater was to provide a protected anchorage for boats, accretion of littoral sand in the lee of the structure by the fall of 1929 had become so serious that the breakwater was extended to the beach at Pt. Castillo, a distance of about 600 feet. This was followed by rapid deposition of sand on the west or up-coast side of the structure (Griggs, Patsch and Savoy, 2005).

Detached offshore breakwaters can effectively reduce wave energy at the shoreline, thereby widening or stabilizing otherwise narrow or eroding beaches. They are not without their impacts, however: high construction costs, navigation hazards for vessels, dangers for recreational coastal water users, as well as a reduction in sand transport to down coast beaches are all important considerations.

Storm Intensity: The life span of beach nourishment projects has been correlated with storm intensity to which a fill is exposed. Large or extreme storms, such as those that have occurred during El Niño years, have caused increased beach erosion, whether nourished or not. Sand removed from the beaches during these large storm events is often deposited on offshore bars where it is stored until the smaller waves associated with the summer months carry the sand back to the beach. During conditions of elevated sea levels and very large waves, sand may be transported offshore into deep enough water where summer waves cannot move the sand back onshore. Longshore transport may also increase with the larger storm waves, thus reducing the residence time of the sand on a nourished beach.

During the strong 1997-98 El Niño, however, monthly beach surveys collected along 22 miles of Santa Cruz County coastline showed that although the beaches experienced extreme erosion during the winter months, by the end of the summer of 1998 all but one beach had returned to their original pre- El Niño widths (Brown, 1998).

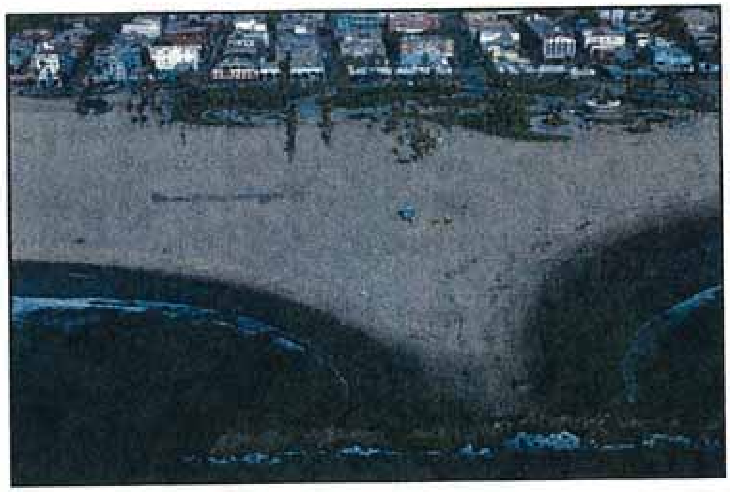

Figure 5.3. Offshore breakwater at Venice where beach has widened in protected area behind breakwater (2004). Photo © Kenneth and Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org

ISSUES INVOLVED WITH BEACH NOURISHMENT

While beach nourishment appears to be an attractive alternative to either armoring the coastline with seawalls, riprap or revetments, or to relocating threatened structures inland, as with any large construction project, there are a number of issues or considerations that need to be carefully evaluated and addressed. In California, littoral cells span large stretches of the coastline, from 10 miles to over 100 miles in length, and, in most locations, experience high net littoral drift rates (from 150,000 yd^3/yr to over 1 million yd^3/yr). As a result, the life span or longevity of sand placed on a particular beach may be short (less than a single winter, in some cases) due to the prevailing winter waves transporting the sand alongshore as littoral drift. Properly constructed and filled retention structures (groins, for example) can help increase the longevity of beach fill.

In addition, potential considerations associated with beach nourishment in California include costs, financial responsibility for the initial project and subsequent re-nourishment, the source and method for obtaining sand, transportation of large quantities of sand to the nourishment site, and the potential smothering or temporary loss of marine life or habitats when placing the sand.

The availability of large quantities of beach compatible sand is a significant issue that has not been completely explored. Sand exists offshore in large volumes but it may not always be beach compatible. In addition, there are environmental and habitat issues that need to be evaluated and possibly mitigated. Some offshore areas are protected, such as the 400 miles of coastline included within the Monterey Bay National Marine Sanctuary, and for which dredging sand from the seafloor is a complex issue with a long list of environmental concerns and probable opposition.

While consideration is being given to removing sediment from behind dams essentially completely filled (e.g., Matilija Dam on the Ventura River and Rindge Dam on Malibu Creek) and placing such sediment on the beach, there is not yet any agreed upon approach for accomplishing this objective. Dam removal followed by natural fluvial transport, trucking, and slurry pipelines have all been studied and each has their costs and impacts. Even though this sediment would have been delivered to the shoreline by these streams under pre-dam natural conditions, accomplishing the same "natural process" today is far more complex. The release of all of the impounded sediment would overwhelm any downstream habitats that are now being protected. In addition, the current USEPA guidelines do not normally allow any sediment to be placed on beaches when the amount of fines (silt and clay) is over 20% (the so-called 80:20 guideline, or acceptable sediment for beach nourishment must consist of at least 80% sand and no more than 20% silt and clay). Unfortunately, the sediment transported by streams and trapped behind dams doesn't follow this 80:20 guideline and contains far more than 20% silt and clay. As a result, most sediment impounded in reservoirs might not be acceptable to the EPA for beach nourishment under such criteria, even though these same streams naturally discharge such sediment every winter to the shoreline, where waves and coastal currents sort out all of this material. The USEPA has and is working with project proponents to identify appropriate conditions that allow the use of sediments with a fine-grained content greater than 20% to be used for beach restoration purposes. These conditions are described in CSMW's Sand Compatibility and Opportunistic Use Program (SCOUP) report. (http://www.dbw.ca.gov/csmw/csmwhome.htm).

If inland sources of beach compatible sand can be located, approved, and transported to the coastline, there are additional challenges of getting the material onto the beach and spreading it out in a timely manner. A 200,000-yds^3 beach nourishment project, for example, would require 20,000 10-yds^3 dump trucks.

In California, obtaining sand from an inland source to place on the beach is far more costly than sand from offshore sources, primarily due to significantly higher removal and transport costs. Inland sources provided by trucking would also have environmental impacts associated with the quarrying, transport, and placement of the sand. Estimates in the Monterey Bay area for truck delivered beach-quality sand in 2004 were around \$21/yd^3. The offshore area in this location is a National Marine Sanctuary such that dredging sand from the seafloor is not acceptable under existing policies. The estimated cost associated with delivering ~240,000 yd^3 of sand (to build a beach ~3,000 feet long and 100 feet wide) from an inland source from a recent proposal for a nourishment project in southern Monterey Bay would be ~\$5.5 million dollars (~\$23/yd^3) (O'Connor and Flick, 2002).

It is also important to look objectively at the logistics of a nourishment project of this scale. Placing 240,000 yd^3 of sand on the beach would require 24,000 10-yd^3 dump truck loads of sand. If a dump truck could deliver a load of sand to the beach and dump it every 10 minutes, 48 truckloads could be dumped in an 8-hour day. Keeping this process going 7 days a week could deliver 1440 truckloads or 14,400 yd^3 each month. At this rate, it would take over 16 months to complete this nourishment project. There are also issues of delivering sand in the winter months when high wave conditions might make truck traffic on the beach difficult; placing sand in the winter-months would also reduce the lifespan of the nourished sand. However, beaches are used the most during the summer months. While none of these are overwhelming obstacles, beach nourishment from inland sources by truck is not a simple or straightforward process. Smaller-scale maintenance projects would take proportionally less time to deliver smaller amounts of sand, and while more logistically feasible, don't have the impacts of larger projects.

Beach nourishment projects using terrestrial or inland sources of sand can be very expensive undertakings and any such project will probably have to be re-nourished on a regular basis unless the sand is retained. The limitations and costs associated with beach nourishment and re-nourishment must be balanced by the ultimate benefits of the project, including the recreational, environmental, and economic value of widening a beach, in addition to the back-beach protection offered to development by a wider beach.

NOURISHMENT HISTORY OF INDIVIDUAL LITTORAL CELLS

In California, beach nourishment (not including harbor bypassing) has historically provided on average ~1.3 million yd^3 annually to the beaches in southern California (Point Conception to the international border), representing 31% of the overall sand budgets in the area (Table 4.1). Large quantities of sand excavated during major coastal construction projects, such as the excavation associated with the Hyperion Sewage Treatment Facility (17.1 million yd^3 from 1938-1990) and Marina del Rey (~10 million yd^3 from 1960-1963) in the Santa Monica littoral cell, as well as the dredging of San Diego Bay (34 million yd^3 between 1941-1985) have provided millions of cubic yards of sand to the beaches of southern California (see comprehensive summary articles by Flick, 1993 and Wiegel, 1994 for detailed discussion of southern California beach nourishment projects.). Between 1942 and 1992 about 100 million yd^3 of material were placed on the beaches with approximately half of the sand derived from harbor or marina projects (Flick, 1993).

Santa Monica Littoral Cell: In the Santa Monica littoral cell, over 29 million yd^3 of sand has been placed on the beaches since 1938 for projects where the primary objective was not specifically beach nourishment. As a result, the shoreline in many areas of Santa Monica Bay advanced seaward from 150 to 500 feet from its earlier natural position. Although the majority of beach fill was placed prior to 1970, beaches in this area are still wider than their natural pre-nourished state, due, in large part, to the construction of retention structures to hold the sand in place. Currently, there are 5 breakwaters, 3 jetties and 19 groins along the nearly 19 miles of shoreline from Topanga Canyon to Malaga Cove, effectively retaining the sand before it is lost into Redondo Submarine Canyon. Sand retention structures have been very effective at maintaining the wide artificial beaches in the Santa Monica littoral cell because of the nearly unidirectional longshore transport to the southeast.

San Pedro Littoral Cell: In the San Pedro littoral cell, federal, state and local governments fund ongoing beach nourishment at Sunset Beach (just downcoast of Seal Beach) to maintain a wide enough beach to meet the recreational needs of the area and to mitigate for the erosion caused by the construction of the Anaheim jetties. The area is nourished with ~390,000 yd^3 of sand annually. Herron (1980) stated that 22,000,000 yd^3 of sand from harbor and river projects have been placed on the 15 miles of public beaches of the San Pedro littoral cell.

Oceanside Littoral Cell: Nearly 11.9 million yds^3 of sand were placed on the beaches of the Oceanside Cell between 1943 and 1993 (Flick, 1993). This represents an annual average rate of about 250,000 yd^3. Most of this sand has come from the dredging of Agua Hedionda Lagoon and Oceanside Harbor which each contributed about 4 million yd^3 in 1954 and 1961, respectively. About 1,300,000 million yd^3 were trucked from the San Luis Rey River bed to the Oceanside beaches in 1982. Two smaller projects, construction of the San Onofre Nuclear Power Plant and nourishment of Doheny Beach, each generated about 1,300,000 million yd^3.

Mission Bay Littoral Cell: The beaches in the Mission Bay littoral cell have also benefited from large construction projects along the coastline. Nearly 4 million cubic yards of sand dredged from Mission Bay to create the aquatic park and small craft harbor were placed on the beaches to create wider recreational areas. The upcoast jetty at

Mission Bay now holds the southern portion of Mission Beach in place. A concrete seawall about 13 feet above mean sea level backs the Mission Beach area but was overtopped during both the 1982-83 El Niño and the unusual storm of January 1988 (Flick, 2005).

Silver Strand Littoral Cell: The Silver Strand littoral cell is somewhat unique in the region in having an overall net littoral transport from south to north. The nearly 35 million yds³ of sand placed on its beaches since 1940 represents the most highly altered stretch of beach in southern California (Flick, 1993). Much of this volume, about 26 million yds³, was excavated from the massive expansion of naval facilities in San Diego Bay just after WWII. Prior to this effort, the Silver Strand had been a relatively narrow sand spit separating San Diego Bay from the ocean, which was occasionally overwashed by storm waves.

THE SAN DIEGO ASSOCIATION OF GOVERNMENTS (SANDAG) BEACH NOURISHMENT PROJECT

The most recent large-scale, non-opportunistic beach nourishment project in California with the sole purpose of widening the beaches was completed in San Diego County in 2001. Approximately 2-million yds³ of sand were dredged from six offshore sites and placed on 12 beaches in northern San Diego County at a total cost of $12.25 million dollars or $5.83/yd³ (Figure 5.4). This project was coordinated by local governments working together through SANDAG and was funded by $16 million in state and federal funds and about $1.5 million from the region's coastal cities. It was seen as an initial step in overcoming what has been perceived as a severe sand deficit on the region's beaches.

A total of six miles of beaches were nourished from Oceanside on the north to Imperial Beach on the south (Figures 5.4 & 5.5). Eighty-five percent of the sand went to the beaches of the Oceanside Littoral Cell. A comprehensive regional beach-profiling program had been in place since the 1983 El Niño event, which provided a baseline for monitoring the results or status of many of the individual nourished sites. Sixty-two beach profile lines were surveyed, typically in the fall and in the spring. Seventeen of these profile lines either already existed or were established at the individual beach nourishment sites (Coastal Frontiers, 2005).

While it is difficult to completely evaluate and summarize the vast amount of beach survey data that have been collected in this report, it is important to try and extract some overall measures of performance or behavior following the nourishment if we are to derive any useful conclusions from this large project.

At 14 of the 17 nourishment sites surveyed, the beach width (determined by the mean sea level shoreline position) narrowed significantly between the fall of 2001 (immediately following sand placement) and the fall of 2002. While the surveyed beaches showed initial increases in width of 25 to over 100 feet from the nourishment, most of these beaches narrowed 20 to 60 feet during the first year following sand emplacement. Twelve of the 17 sites showed further decreases in width over year two, and 13 of these sites continued to decrease in width in the 3rd year. Three of the beaches in the Oceanside Cell showed modest width increases (6 to 15 feet) in the first year following nourishment, but in the two following years all declined in width.

A very detailed study of the Torrey Pines State Beach fill project was carried out as part of the post-nourishment monitoring (Seymour, et al. 2005). This fill was 1600 feet long and included about 330,000 yds³ of sand, one of the larger fills. Rather than being constructed as a sloping fill, the upper surface was level and terminated in a near-vertical scarp about 6 feet high. Profiles 65 feet apart were collected bi-weekly along 1.8 miles (9500 feet) of beach and extended

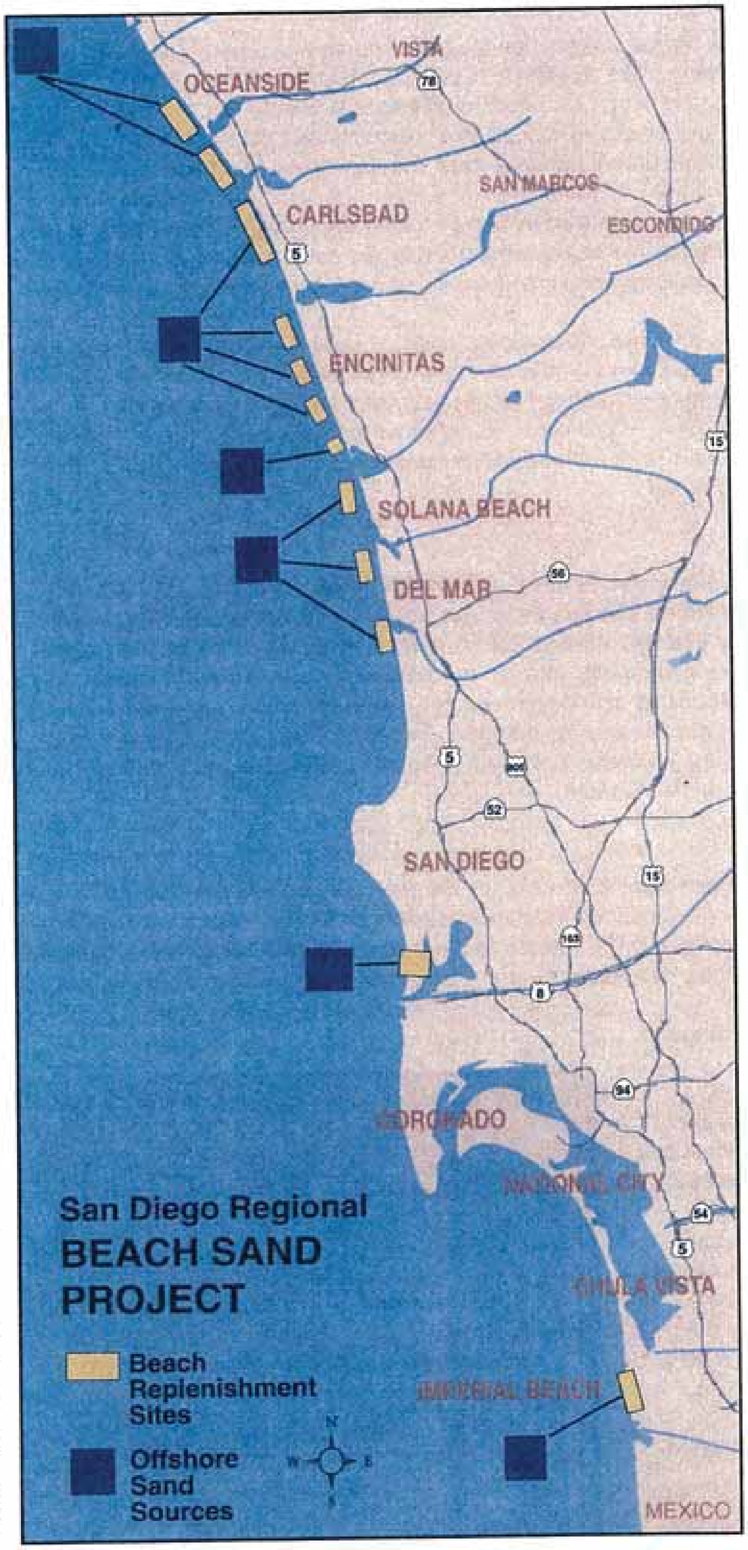

Figure 5.4. Offshore sand sources and nourishment sites for the 2001 SANDAG 2,000,000 yds³ beach nourishment project.

offshore to a depth of 26 feet. The temporal and spatial resolution provided by this surveying program, in combination with offshore wave measurements, provided an exceptional database for documenting the relationship between wave conditions and the behavior of a beach fill (Seymour, et. al., 2005).

The fill was completed near the end of April, 2001 (Figure 5.6). Wave

Figure 5.5: Beach nourishment at South Carlsbad State Beach. In July 2001. 150,000 yds^3 of sand were placed on this beach in a fill that was 2000 feet long, 180 feet wide and up to + 12 feet msl.

conditions during the summer and fall were mild, with significant wave heights (the average of the highest 1/3 of the waves) generally less than 3 feet except for a few incidents of waves as high as 5 feet. The front scarp of the fill remained intact and there were only modest losses at the ends of the fill.

At noon on Thanksgiving Day, November 22, 2001, significant wave heights reached nearly 10 feet and remained in the range of 9 to 10.5 feet for seven hours. The fill was overtopped and began to erode quickly. By daylight on November 23, the fill had been almost completely eroded to the riprap at the back of the beach (Seymour, et al., 2005). The fill was stable for approximately 7 months of low wave energy conditions, but was removed within a day when the first large waves of the winter arrived.

Some overall conclusions can be drawn from the four years of published beach surveys in the nourished areas (Coastal Frontiers, 2005). The performance of the individual beach fills varied considerably. At some sites, such as Del Mar, Moonlight, and South Carlsbad, the gains in the shorezone (defined as the subaerial or exposed portion of the beach as well as the nearshore sand out to the seasonal depth of closure) that occurred during placement of fill were short-lived. At other sites, such as Mission Beach and Oceanside, the gains in the shorezone persisted through the time of the Fall 2004 survey. In many cases, dispersal of the fill was accompanied by shorezone volume gains on the downdrift beaches. Both the grain size of the sand and the volume of the fill were important factors in how long nourished sand

Figure 5.6. Aerial view of the Torrey Pines beach fill project (from Seymour, et.al., 2005).

remained on the beach. For the smaller fills, erosion or losses from the ends of the fills were significant. One very small nourishment site in the Oceanside cell (Fletcher Cove) received a small volume of very-fined grained sand and it was removed very quickly.

Nearly all of the sand added to the beaches in the SANDAG project tended to move both offshore and also alongshore with the arrival of winter waves although much of this has persisted just offshore in the shorezone. This sand does provide some benefits including dispersing some of storm wave energy and flattening the beach profile. However, most of the general public expects to see a wider exposed beach as the benefit of a beach nourishment project. It is important to understand for the SANDAG project or any nourishment plan or proposal, that most beaches have some normal or equilibrium width, as discussed earlier. Without either regular or repeated nourishment or the construction of a retention structure, such as a groin, to stabilize or hold a beach fill, there is no reason why in an area of significant longshore transport and moderate to large winter wave conditions that the sand should stay on the exposed beach for any extended period of time. The considerations that need to be weighed prior to any beach nourishment project are whether the benefits of littoral cell or shorezone sand increases, and the potentially short-term or temporary beach width increases resulting from beach nourishment are worth the initial investment and continuing costs.

CHAPTER 6

CONCLUSIONS

Before large-scale human influence or interference, the majority of beaches in southern California were relatively narrow. Large coastal construction projects, the creation and expansion of harbors and marinas, and other coastal works found a convenient and cost-effective disposal site for excavated material on the beaches in southern California, thus creating the wide sandy beaches that people have come to expect in this region, particularly along the beaches of the Santa Monica littoral cell and the Silver Strand cell. The majority of sand was placed before the mid-1960's, however. Since then, the rates of nourishment have dropped sharply. In many cases, sand retention structures such as groins, built in conjunction with the placement of beach-fill, have been successful in stabilizing the sand and maintaining wider beaches. Carefully designed retention structures have been shown to extend the life of beach nourishment projects and should be considered when planning beach restoration projects in the future. A single episode of beach nourishment, however, will not provide a permanent solution to areas with naturally narrow beaches or to problems associated with beach erosion. Any potential California beach nourishment program should be viewed as a long-term and ongoing process.

When assessing the success or failure of a nourishment project, one must look beyond the individual beach where the nourishment took place and examine the regional effects throughout the entire littoral cell. Often the nourished site serves as a feeder beach, providing sand to be transported by littoral drift to "feed" or nourish the downdrift beaches.Where littoral drift rates have been documented they are typically in the range of about a mile-per-year (Bruun, 1954; Wiegel, 1964; Griggs and Johnson, 1976), although this will depend upon the wave energy, the orientation of the shoreline, and the angle of the dominant wave approach. Depending on the potential littoral drift in an area, as well as the coastline configuration and barriers to littoral transport, nourishment projects may or may not have a fairly short residence time on a particular beach. However, if well planned on a regional scale, the placed sand should feed the downdrift beaches until ultimately ending up in a submarine canyon, offshore, or retained behind a coastal engineering structure.

Because of California's high littoral drift rates, the emplacement of a well-designed, properly constructed and filled retention structure is also a very important consideration in the success or longevity of any beach fill or nourishment project. Groins and offshore breakwaters have been used successfully in a number of locations in California to widen or stabilize beaches (Ventura, Santa Monica and Newport Beach, for example). Retention structures can make the difference in the long-term success of a beach nourishment project. It is recommended that all existing retention structures and their effectiveness and impacts be evaluated so as to learn from past experiences and improve on their use in the future by mitigating any potential negative impacts.

When engineering a beach nourishment project in California, it is important to consider such elements as grain size compatibility, fill density, or the volume of sand per unit length, possible sand retention structures and the effects on down drift beaches, the rate and direction of littoral drift, and wave climate (including storm duration and intensity).

Harbor maintenance and large construction projects along the coast may be excellent sources of opportunistic beach nourishment. There are many difficulties associated with nourishing the beach with sand taken from an inland or terrestrial source including the 80:20 rule, cost, financial responsibility of the project, the source and method for obtaining sand, transporting large quantities of sand to the nourishment site, and the potential for covering over marine life or habitats when placing the sand. Offshore sand sources also have their limitations and impacts including costs, location of compatible sand offshore, permit issues such as environmental impacts associated with disturbing the seafloor habitat, transporting and placing large quantities of sand (Figure 5.5) increased turbidity, etc.

The limitations and costs associated with beach nourishment must be balanced by the ultimate benefits of the project including public safety and access, expanded wildlife habitat and foraging areas, the economic and aesthetic value of widening a beach, in addition to the back-beach or coastal protection offered by a wider beach.

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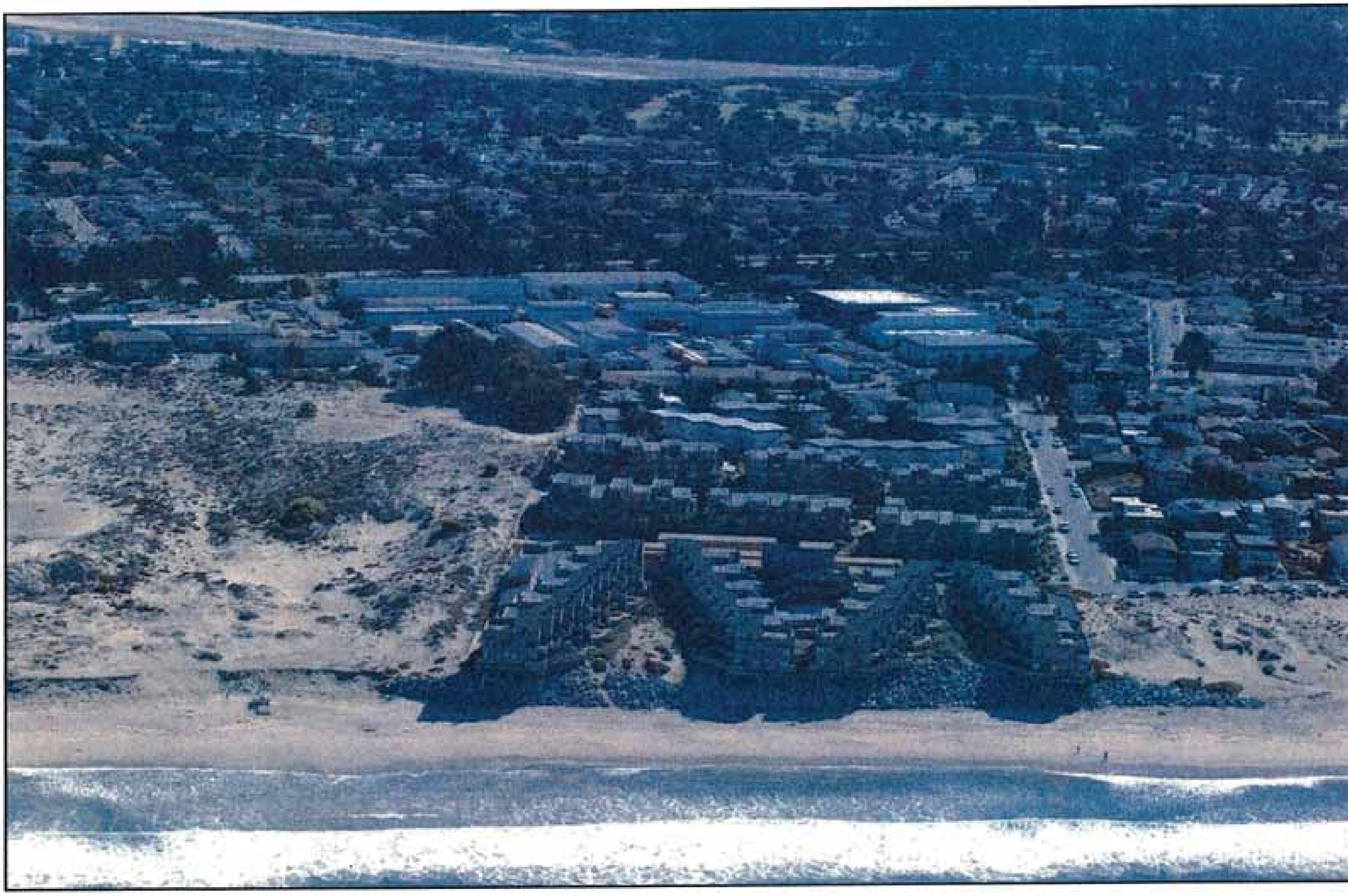


Dune erosion threatens the Ocean Harbor House apartment complex on Del Monte Beach, Monterey CA (October 2005). Copyright © 2005 Kenneth and Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org.

Very wide beach at Venice Beach, CA (October 2002). Copyright © 2005 Kenneth and Gabrielle Adelman, California Coastal Records Project, www.Californiacoastline.org.

EXHIBIT D

GEOTECHNICAL INVESTIGATION OF BLUFF CONDITIONS AND STABILITY
SOLANA BEACH & TENNIS CLUB
447 SOUTH SIERRA AVENUE
SOLANA BEACH, CALIFORNIA

APRIL 3, 1995

PREPARED FOR:

SOLANA BEACH & TENNIS CLUB, HOA
ATTN: C. J. SAUNDERS
447 SOUTH SIERRA AVENUE
SOLANA BEACH, CALIFORNIA 92075

JOB #95-140-P

VINJE & MIDDLETON ENGINEERING, INC.

2450 Vineyard Avenue, #102
Escondido, California 92029-1229

Phone (619) 743-1214
Fax (619) 739-0343

Job #95-140-P

April 3, 1995

Solana Beach & Tennis Club, HOA
Attn: C. J. Saunders
447 South Sierra Avenue
Solana Beach, California 92075

Geotechnical Investigation of Bluff Conditions and Stability at Solana Beach Tennis Club, 447 South Sierra Avenue Solana Beach, CA

Pursuant to your request, Vinje & Middleton Engineering, Inc. has completed the attached geotechnical investigation of bluff conditions and stability at the above referenced site.

The following report summarizes the results of our field investigation, laboratory analyses and conclusions, and provides recommendations for enhancing bluff stability and improving site geotechnical conditions. In our opinion, improvements to enhance bluff stability and site conditions are feasible from a geotechnical engineering standpoint provided the recommendations presented in this report are incorporated into the final improvement plans and implemented at the project site.

Thank you for choosing Vinje & Middleton Engineering, Inc. If you have any questions concerning this report, please do not hesitate to call us. Reference to our Job #95-140-P will help to expedite our response to your inquiries.

We appreciate this opportunity to be of service to you.

VINJE & MIDDLETON ENGINEERING, INC.

REGISTERED PROFESSIONAL ENGINEER
RALPH MALCOLM VINJE
No. 863
Exp. 12-31-97
GEOTECHNICAL
STATE OF CALIFORNIA

Ralph M. Vinje
GE #863

RMV/kmh

1. Cave 1 - Spring sapping and erosion from wave abrasion of thin siltstone/claystone bed. Resulting cave is 1-13 feet deep at an estimated height of three feet.

2. Cave 2 - Spring sapping and erosion from wave abrasion of thicker section of siltstone/claystone. Resulting cave is 10 feet deep (maximum) at an estimated height of nine feet.

3. Cave 3 - A failed section of fractured rock. Resulting cave is 4.5 feet deep and approximately 11 feet high.

4. Cave 4 - A smaller feature controlled by shear/fracture surfaces. Resulting cave is approximately 10 feet deep and in excess of seven feet high.

5. Cave 5 - A large cave resulting from erosion along a series of near vertical shears/fractures. Cave is approximately 24 feet deep and four to seven feet (approximately) high.

Photographs of each of the five caves are attached with this report as Figures 1-5. A typical view of project bluffs and geotechnical conditions is attached as Figure 6.

E. **Regional Processes:** Beach development in Solana Beach typically includes multi-story dwelling structures located near over-steepened sea cliffs which descend in excess of 50 feet onto the lower beach. The stability of sea cliffs is critical to the continued security of dwelling structures. Continuous assault from the sea, chiefly in the form of wind, rain, and wave activity, represents a threat to bluff terrain which could translate to significant losses.

Traditionally, slope degradation in the Solana Beach area as a result of seaward assault has been negligible. Prior to 1940, local bluffs enjoyed the protection of wide sandy beaches which typically extended 100-250 feet. The broad beaches commonly served as major travelways along the coast prior to 1900. The beaches were sustained by a persistent southward drift of river generated sediments which provided a continuous source of sand for beach nourishment. Since 1940 the works of man have impacted local beach properties. A boat basin constructed at Camp Pendleton during World War II interrupted normal beach nourishment and greatly diminished the size of Oceanside beaches. Similar obstructions to the south including groin fields and jetties have had the same effect on local beaches exposing them to wave attack resulting in historically high levels of bluff degradation.

EXHIBIT E

TerraCosta
Consulting Group
Geotechnical Engineering
Coastal Engineering
Maritime Engineering

Project No. 2567
October 4, 2010

Mr. Joseph Steinberg
c/o Robert Shoecraft
Shoecraft Burton LLP
1230 Columbia Street, Suite 1140
San Diego, CA 92101

RE: DRAFT LAND LEASE/RECREATION FEE STUDY – REVISED JULY 2010

Dear Mr. Shoecraft:

TerraCosta Consulting Group, Inc. (TCG) is pleased to answer your specific questions with respect to PMC's March 2010 City of Solana Beach Draft Land Lease/Recreation Fee Study.

1. We agree that a "danger zone" extends at least 25 feet seaward from the base of the bluff. There is considerable evidence to support this conclusion. The Torrey Sandstone that comprises the first 35 feet of the Solana Beach sea cliffs weighs somewhere between 3,000 and 4,000 pounds per cubic yard. On many occasions, I have seen this material on the beach in excess of 25 feet from the base of the bluff. I have also seen even more photographs of such conditions.

2. This danger zone area should not be considered safe for recreation, as bluffs can, and do, fail at any time without warning. The woman who was killed near Moonlight Beach was reportedly sitting, with her back to the bluff, some 40 feet from the base of the bluff.

3. Passive erosion, occasioned by a seawall, can only occur on actively eroding beaches. The beach in Solana Beach is such a beach; however, its current condition is the result of development throughout the upland watershed and the blockage of longshore transport by jetties and man-made harbors, which have reduced fluvial sediments to the beach by more than 54 percent. The limited sand that does make it to the beach is no match for the transport capacity of the Pacific Ocean and is rapidly transported to our own local sink, the La Jolla Submarine

Canyon. In my opinion, if Southern California, or even just San Diego County, happened to remain in its natural state prior to urbanization of the upland watershed, the beach in Solana Beach would be relatively stable, and seawalls would not only not cause passive erosion but they would be largely unnecessary in the first place.

We appreciate the opportunity to be of service and trust this information meets your needs. If you have any questions or require additional information, please give us a call.

Very truly yours,

TERRACOSTA CONSULTING GROUP, INC.

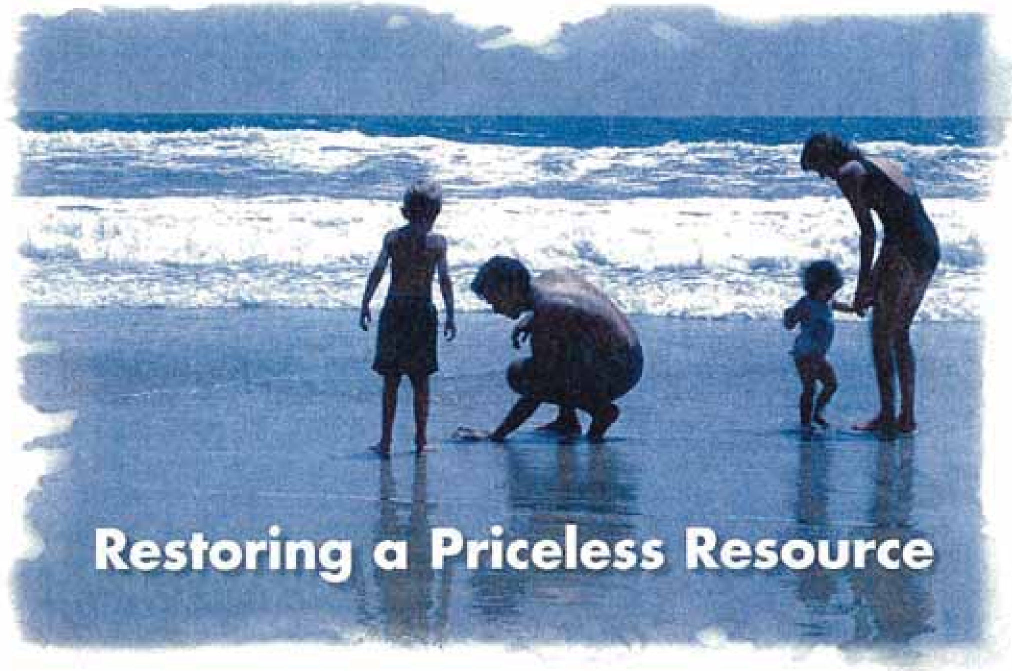
David B. Nevius

David B. Nevius, Project Engineer
R.C.E. 65015, R.G.E. 2789
for Walter F. Crampton, Principal Engineer
R.C.E. 23792, R.G.E. 245

WFC/jg

EXHIBIT F

The Regional Beach Sand Project



The Regional Beach Sand Project II (RBSP II) will widen beaches by adding millions of cubic yards of clean sand to many of the region's eroded beaches. This public works effort is being coordinated by local governments, working together through SANDAG.

SANDAG wants to hear from you! Come learn about the project and provide your input during the scoping period, which will run from May 21, 2010, through June 21, 2010.

Please join us at one of three public scoping meetings scheduled in June 2010.

Thursday, June 3, 2010
12:30 - 2 p.m.
Shoreline Preservation Working Group Meeting
SANDAG
401 B Street, 7th Floor
(Conference Room 7)
San Diego, CA 92101

Thursday, June 3, 2010
6 - 7:30 p.m.
Encinitas City Hall,
Poinsettia Room
505 S. Vulcan Avenue
Encinitas, CA 92024

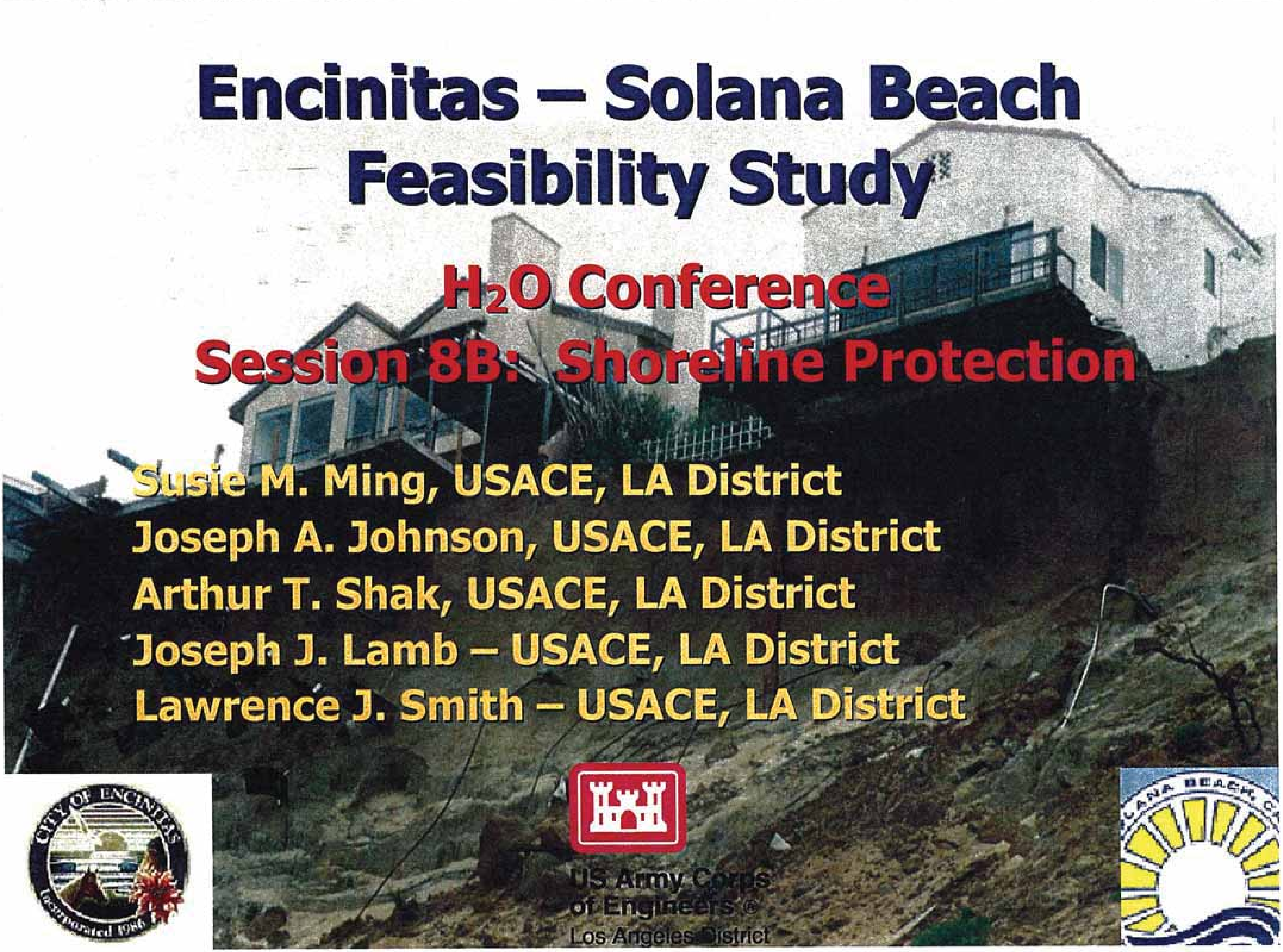
Tuesday, June 8, 2010
6 - 7:30 p.m.
Dempsey Holder Safety Center
950 Ocean Lane
Imperial Beach, CA 91932

If you would like to know more details about the RBSP II, receive the Environmental Impact Report, or provide input of any kind please contact SANDAG at (619) 699-0640, beachsand@sandag.org, or visit www.sandag.org/shoreline.

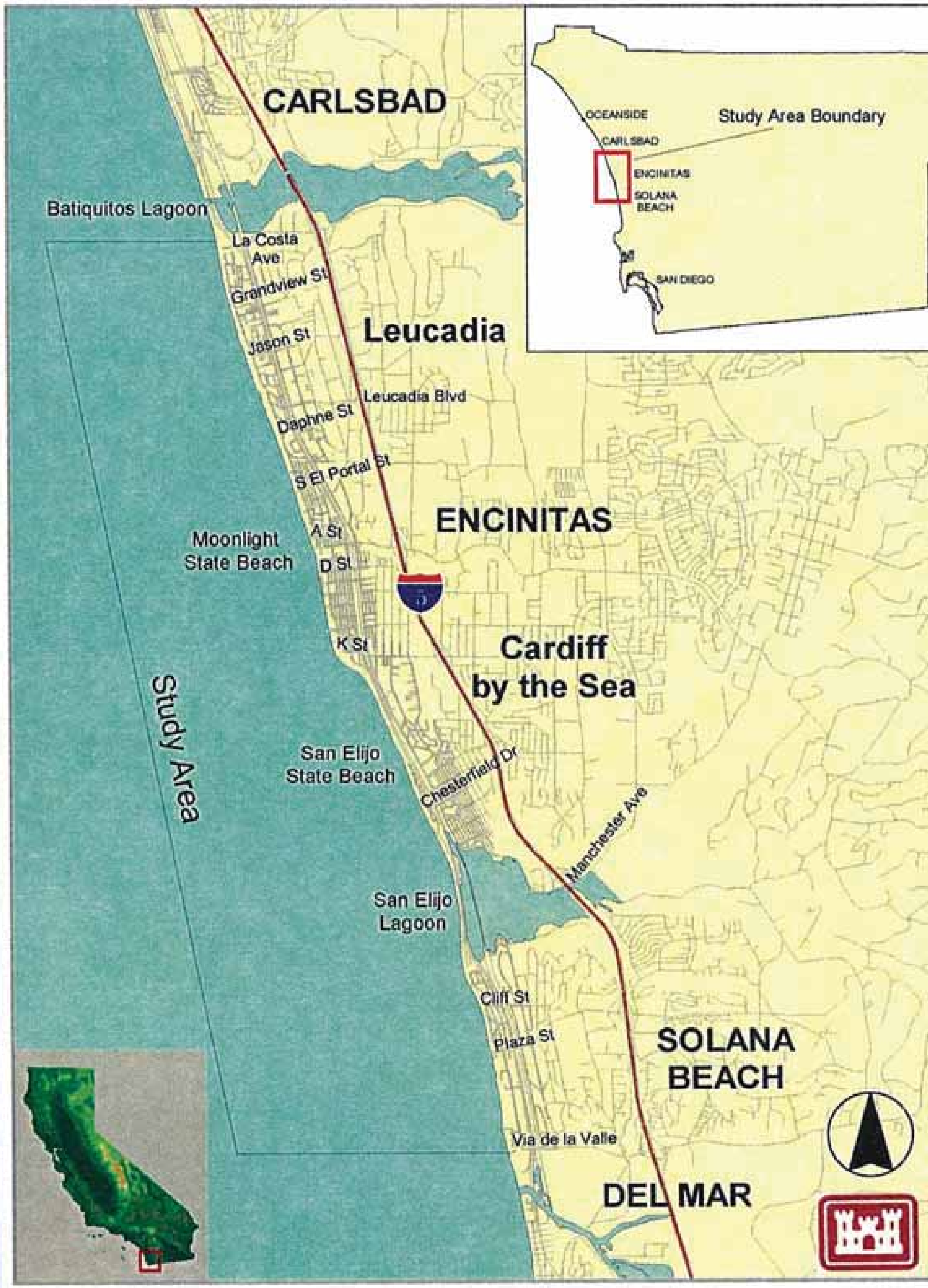
SANDAG

In compliance with the Americans with Disabilities Act (ADA), SANDAG will accommodate persons who require assistance in order to participate in the scoping meetings listed above. If such assistance is required, please contact SANDAG at ((619) 699-0640 at least 72 hours in advance of the meeting. To request materials in an alternative format, please call (619) 699-0640, (619) 699-1904 (TTY), or fax (619) 699-1905.

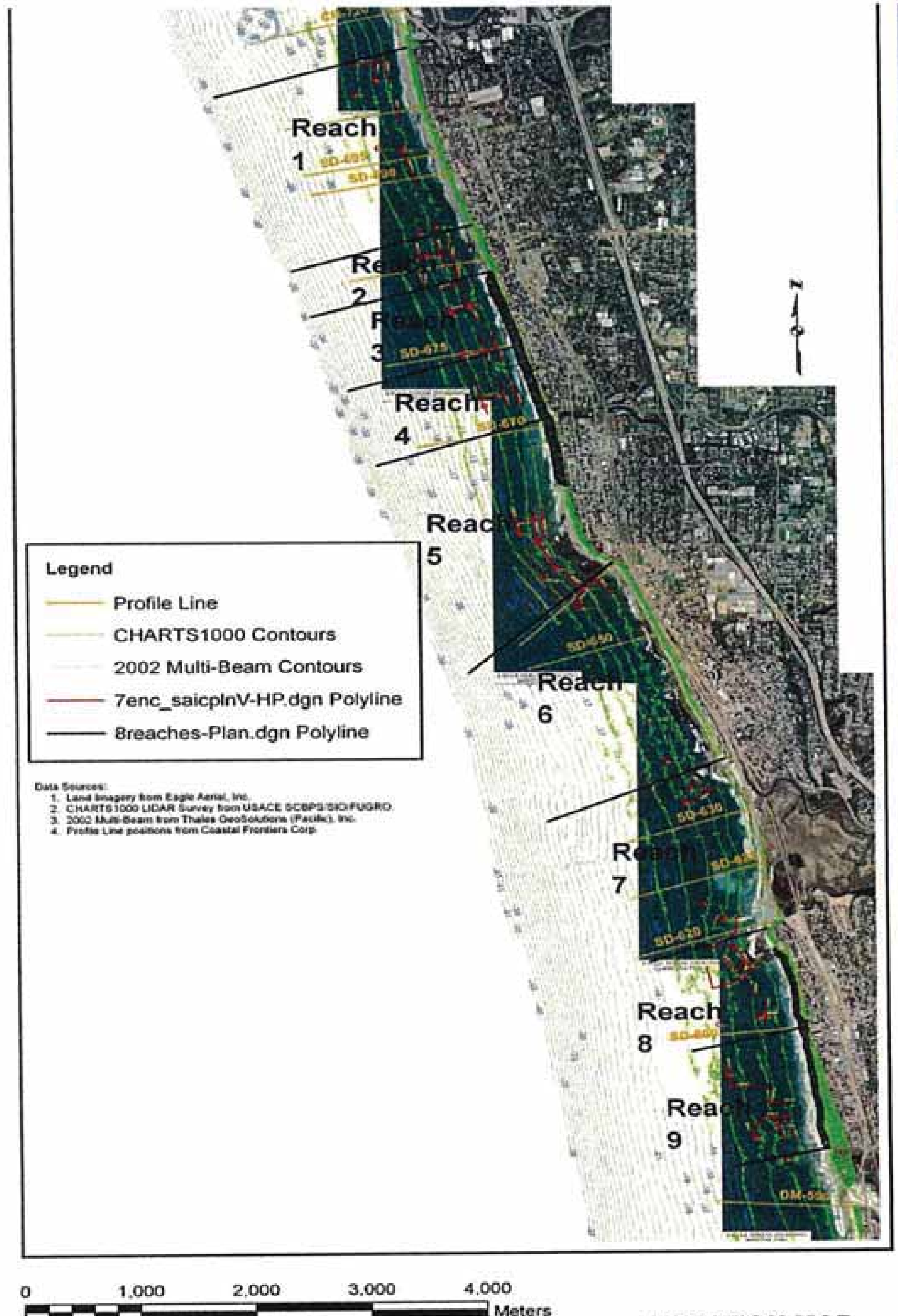
EXHIBIT G


Encinitas – Solana Beach
Feasibility Study
H_2O Conference
Session 8B: Shoreline Protection
Susie M. Ming, USACE, LA District
Joseph A. Johnson, USACE, LA District
Arthur T. Shak, USACE, LA District
Joseph J. Lamb – USACE, LA District
Lawrence J. Smith – USACE, LA District
US Army Corps
of Engineers ®
Los Angeles District
CITY OF ENCINITAS
Incorporated 1986
SOLANA BEACH

Study Area


CARLSBAD
Batiquitos Lagoon
La Costa Ave
Grandview St
Jason St
Leucadia
Leucadia Blvd
Daphne St
S El Portal St
ENCINITAS
A St
Moonlight State Beach
D St
5
K St
Cardiff by the Sea
Study Area
San Elijo State Beach
Chesterfield Dr
Manchester Ave
San Elijo Lagoon
Cliff St
Plaza St
SOLANA BEACH
Via de la Valle
DEL MAR
OCEANSIDE
Study Area Boundary
CARLSBAD
ENCINITAS
SOLANA BEACH
SAN DIEGO

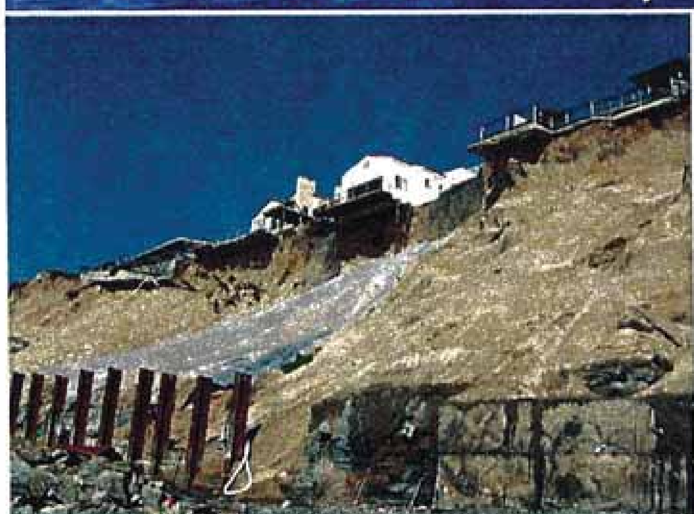
Study Reaches

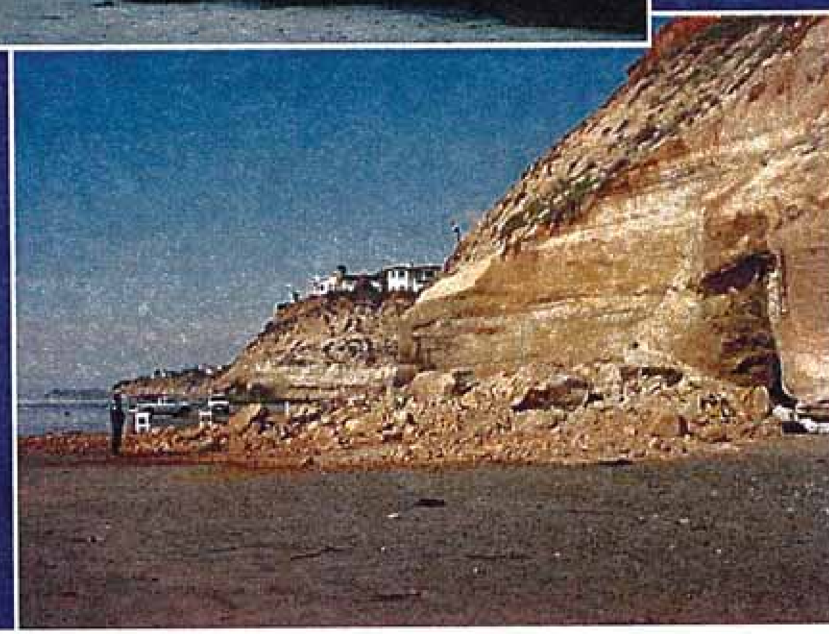


LOCATION MAP

Problem Summary

- Lack of Sediment Supply
- Loss of Protective Beach
- Wave attack at toe of bluff
- Toe notch formation
- Large Bluff Failures
- Present over-steepened Bluff face





Patchwork of Shore Protection Devices

Planning Objectives

- Reduce storm damage potential within the study area.
- Improve Public Safety along the beach.
- Preserve the environmental resources within the study area.
- Enhance Recreational Opportunities within the study area.

Planning Constraints

- No adverse impacts to the aesthetics along the shoreline.
- Maintain Public Access to the beach.
- Preserve the recreational opportunities within the study area.
- Preserve the environmental resources within the study area.

Plan Formulation – Initial Screening of Alternatives

- No Action
- Managed Retreat
- Breakwaters
- Groins
- Revetment
- Seawall
- Beach Nourishment
- Bluff base notch fills

Final Alternative Array

- Alternative 1- Beach Nourishment
- Alternative 2- Beach Nourishment with Notch Fills
- Alternative 3- Seawalls

Recommended Plan

Segment One - Encinitas

- 2.4 km Notch Fill
- Initial placement of 628,000 cubic meters
- Initial berm width is 60 meters.
- Beach will be renourished every 5 years with 262,000 cubic meters

Alongshore Extent of Beach Fill in Segment 1

Figure 6-4

Recommended Plan - Estimated Costs

Total Costs	$30,142,000
Annual Costs	-$1,772,000
Annual Benefits	+$2,582,000
Net Annual Benefits	**$809,000**
Benefit / Cost Ratio	**1.46**

Significant Comments on Recommended NED Plan*

- Potential impacts to:
  - environmental resources, i.e., surfgrass and reefs
  - surfing impacts

* Public Release of Draft Feasibility Report and DEIS/EIR in August/September 2005

As a result.........

- Coastal Engineering Analysis (USACE)
  - Provided profiles showing predicted sand burial at depths based on historical and bathymetry of the Recommend Plan
- Coastal Reef Habitat investigations (SAIC)
  - Provided representative characterization and mapping of biological habitat quality of nearshore reefs.
  - Reef heights and biological indicator species (surfgrass, giant kelp, feather boa kelp, sea palm, and sea fans).
- Development of Environmental Impact Methodology and Assessment EIR/EIS Team (Everest/Anchor/Chambers/USACE)
  - Impacts of sand burial determined by overlaying the predicated sand thickness on the representative underwater transects.
- Coordination with Resource Agencies
- FSCA Amendment for increase in project costs
- 105 Day Plan

105 Day Plan

- To determine environmental impacts, coastal analysis of SANDAG project, identify additional economic benefits, and review plan formulation.
- Determine additional work effort needed to complete feasibility study.
- Coordinated work effort between Los Angeles District Staff, PCX Staff, Local Sponsors, and Resource Agencies (Project Team).

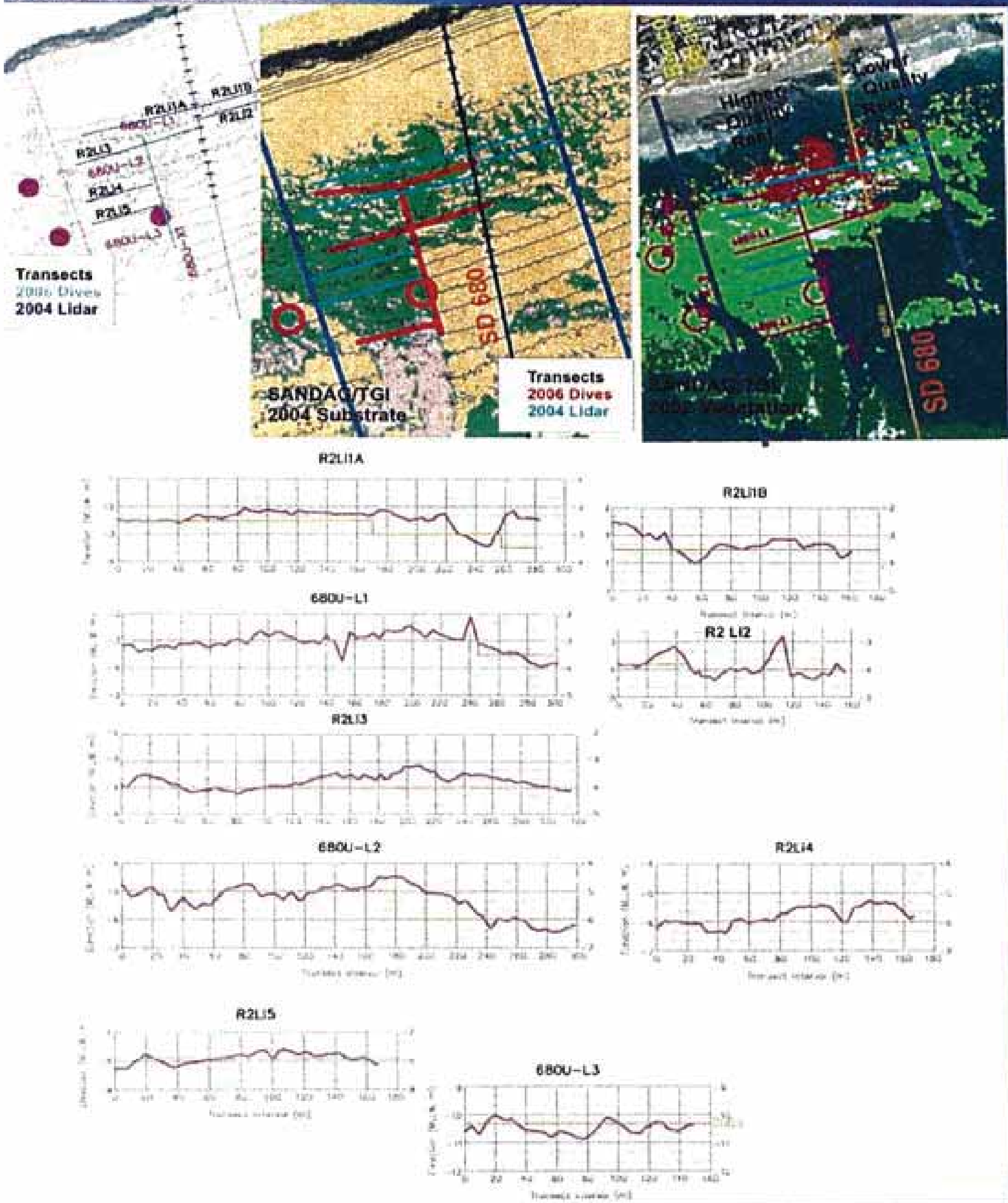
National Planning Center of Expertise (PCX) for Coastal Storm Damage Reduction

- North Atlantic Division (NAD)
- Provide planning services for coastal storm damage reduction needs, interacting with project delivery teams
- Develop, maintain and apply the best and most appropriate national and regional expertise and science and engineering technology to the planning of coastal storm damage reduction projects

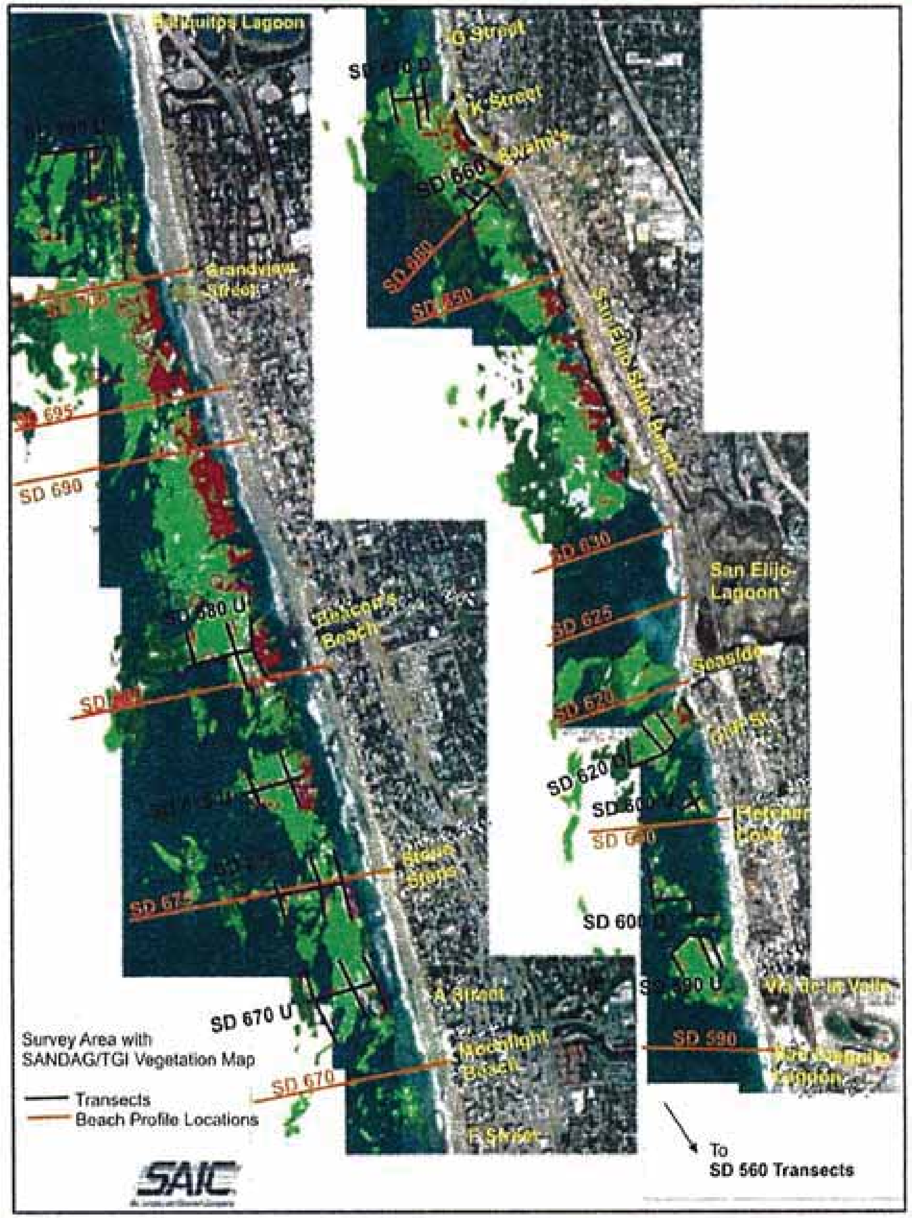
Methodology for Estimating and Contrasting Impacts to Nearshore Reefs

- Establish a representative set of reef locations to support the impact analysis.
- Match appropriate sand thickness predictions to representative reef locations.
- Apply predictions of sand thickness increases to selected reef locations to identify potential impacts.
- Quantify total potential impact acreage to nearshore reefs based on a scaling-up the impact percentages at representative locations.
- Compare and contrast biological resource impact estimates associated with sand thickness predictions for two sand volume and placement scenarios (Hybrid plan, SANDAG-volume) with the 2001 San Diego Regional Beach Sand Project.

Example Draft Data and Analysis

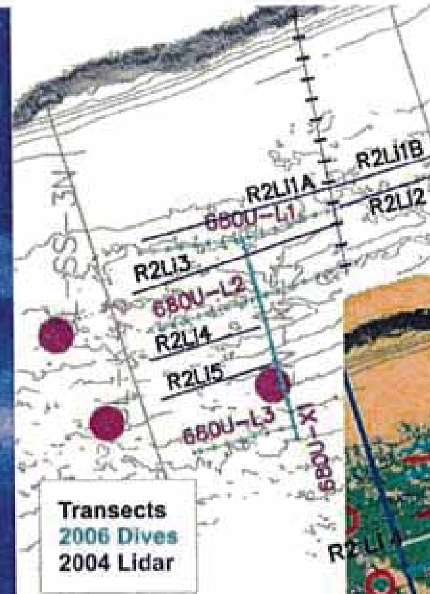


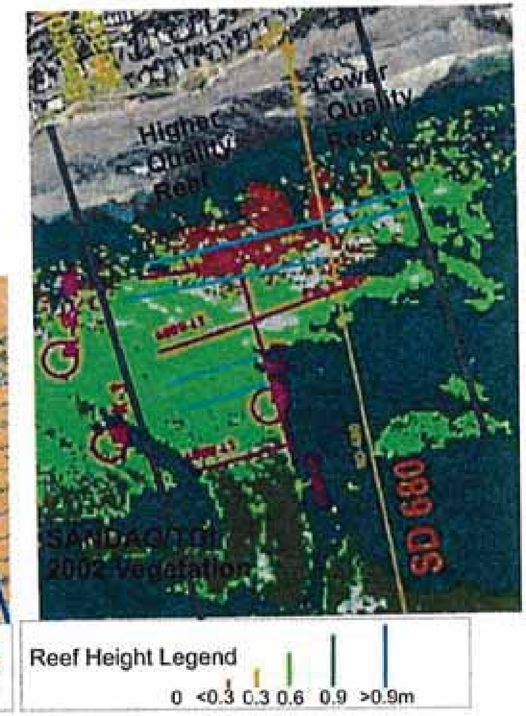
Example of transect elevation profiles for Reach 2

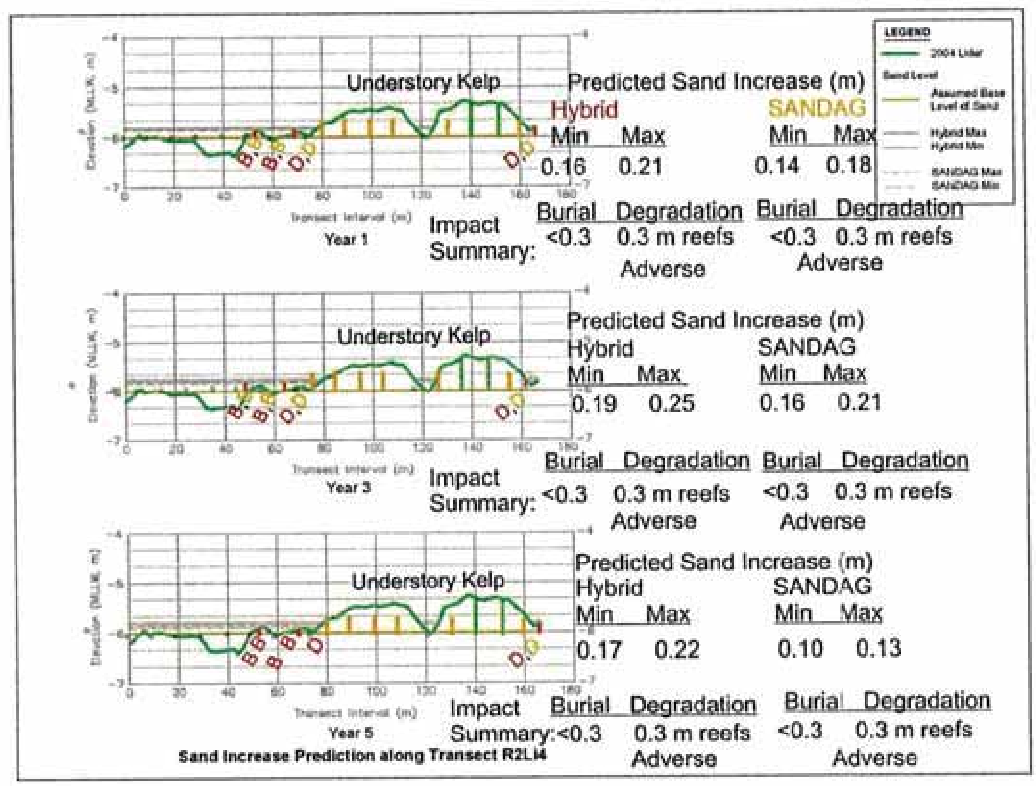


Locations of 2006 Dive Transects

Example of Impact Assessment Worksheet







105 Day Plan Completed Activities

- Numerous collaborative meetings with Project Team.
- Additional coastal analysis of SANDAG plan.
- Environmental Analysis of hybrid and SANDAG plans 90% complete (October 25th).
- Review of Economic benefits analysis.
- Review of Project assumptions.
- Developed methods matrix.
- Draft Cost Estimate and Schedule.

Initial Findings of Collaborative 105 Day Plan

- Initial analysis of environmental impacts are lower than originally predicted based on revised methodology.
- Additional and updated economic benefits were identified.
- Identified a range of shore protection measures needed to analyze in order to determine NED plan.
- PCX staff reviewed information and provided memorandums (with recommendations) from 3 collaborative meetings.
  - Reformulation of Plan and Additional Benefits
  - Independent Technical Review and External Peer Review
- Based on revised preliminary environmental analysis and additional benefit categories, there is the potential for a federal project.

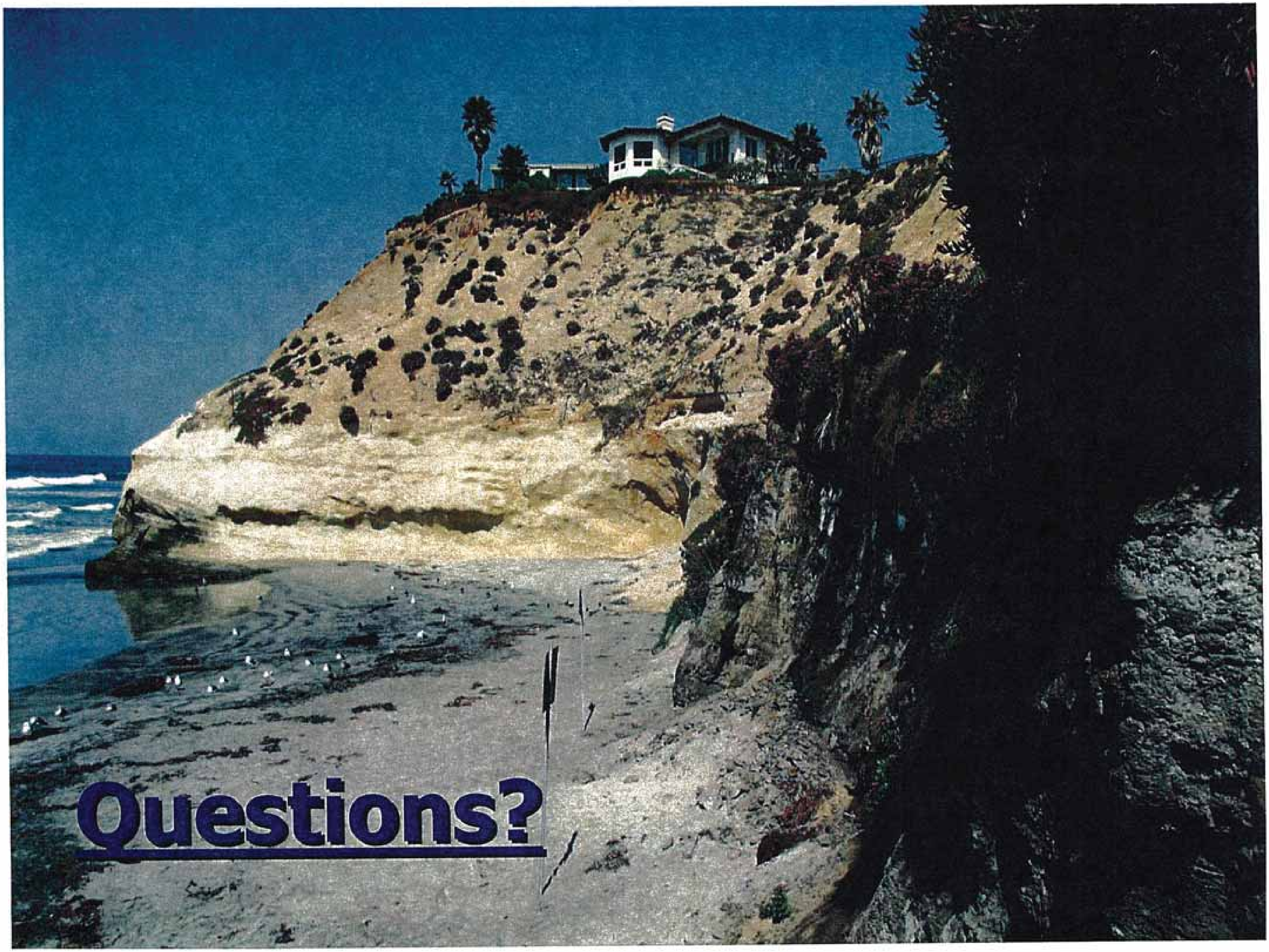
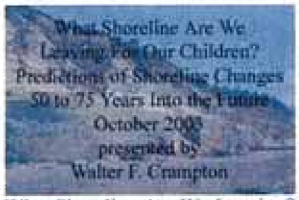

Questions?

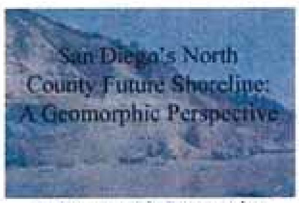
EXHIBIT H

What Shoreline Are We Leaving For Our Children?
Predictions of Shoreline Changes 50 to 75 Years Into the Future
Presented by Walter F. Crampton
HEADWATERS TO OCEANS CONFERENCE
October 2003



What Shoreline Are We Leaving?

California's beaches define our quality of life, and they generate over $15 billion annually in tax revenue. This state's beaches are California's most popular recreational destination, with over 550 million visitors in 1995, 85 percent of whom were non-coastal residents. To quote from the state's 2002 Beach Restoration Study, "the state's beaches provide California with an enriched quality of life, worldwide recognition, and unparalleled tourist opportunities for economic enhancement." The study also discusses the serious amount of erosion now affecting the majority of this state's beaches and the need to preserve and enhance this coastal resource.



A Geomorphic Perspective

In this morning's session, "What Shoreline Are We Leaving For Our Children?", Lesley asked me to look into my crystal ball and predict what we might expect to see in 50 to 75 years along San Diego's North County shoreline, a coastal area I've studied extensively for over a decade and although I will give a geomorphic perspective, I believe the future of our shoreline, to a large degree, depends on the political actions that will likely take place in the next few years, fueled by a very polarized debate on whether or not this state should embrace planned retreat; a subject that is today before the Solana Beach City Council and, to a lesser extent, has been considered at the State level in certain versions of Wiggins' Assembly Bill 2943 and more recently Hannabeth Jackson's Assembly Bill 947, and something that is even discussed in the Draft California Beach Restoration Study.

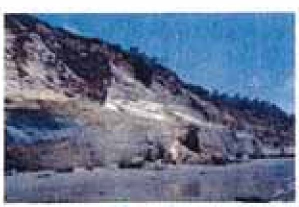


Photo 01

This is in Solana Beach, just south of Fletcher Cove, where a gradually enlarging basal notch in the sea cliff collapsed, undermining the upper terrace deposits, triggering a massive failure that occurred in April last year; four years after the 1997-98 El Niño storm season. The important thing to remember today, and into the future, is that unlike previous storm seasons when the summer beach would return, San Diego's North County has experienced a wholesale loss of its previously-persistent sand beach, allowing waves to assail the coastal bluffs on a daily basis, enlarging these basal notches, eventually triggering these massive failures. Thanks in part to the efforts of Mr. Jaffee, our next speaker, along with other Surfrider members who have strongly opposed any structural measures, small preemptive notch infills that would have precluded this failure, are no longer being allowed, and a serious political rift has now formed between what I'll refer to as the environmental coalition, which is primarily headed by the Surfrider Foundation, and the private bluff-top property owners in San Diego's North County. I have made 50 copies of two editorials published in two San Diego County newspapers in the last two weeks, to give you a little flavor of the differing positions on this debate.

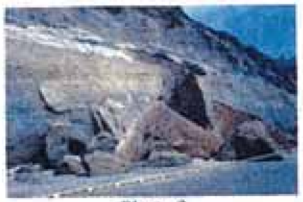


Photo 2

This is a close-up of last April's failure, which illustrates some of the safety issues that I will discuss later, along with the problems of ongoing stability of the coastal bluff.

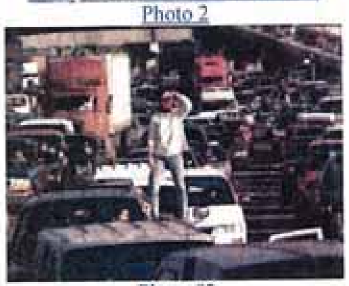


Photo 03

As the State's 2002 study so nicely summarized, the root problem affecting Southern California's coastline is the many people that now live in our coastal watershed. Over 80 percent of Southern California's residents live on the west side of the coastal range, with all of this urban development essentially severing the sediment supply to the State's beaches.

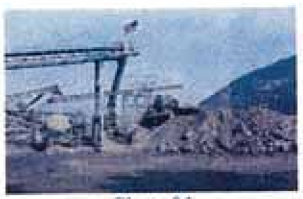


Photo 04

Although only briefly mentioned in the State's 2002 study, extensive sand mining activities in the lower reaches of most of Southern California's major rivers have further ensured the loss of this coastal resource. In the Oceanside Littoral Cell today, there is a 30 million cubic yard sand deficit. Yet, in the last 60 years, sand mining alone in San Diego County, almost exclusively downstream of the county's dams and reservoirs, has removed over 100 million cubic yards of beach quality sand originally destined for the beach. In other words, 60 years of sand mining has removed over 150 years of natural sediment supply from the littoral system, effectively ensuring that we cannot simply go back to the status quo, and, in the absence of significant beach nourishment projects, there will be no recreational resource whether or not seawalls are built to protect bluff-top improvements.

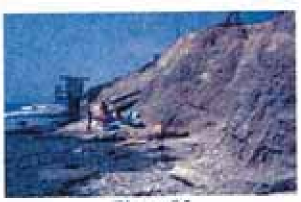


Photo 05

This is San Elijo State Beach, a few miles north of Solana Beach, during an extreme low tide exposing the bedrock shore platform, entirely denuded of its one-time healthy sand beach. The lifeguard tower in the background is about 11 feet above the bedrock surface, where 20 years ago the sand beach was at the base of this tower platform and extended several hundred feet offshore.

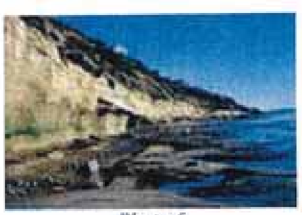


Photo 6

This photograph, taken in Solana Beach in December 1997 prior to any of their recent coastal bluff failures, nicely illustrates the problem and is a good starting point for our look into the future. Again, this was taken during the extreme tidal low, looking south at a totally sand-barren bedrock shore platform with the platform-seacliff junction elevation around -1 foot, MSL. This photo also nicely shows the geology of San Diego's North County, consisting of a lower Eocene-age, 47-million-year-old, cliff-forming unit overlain by a relatively young 120,000-year-old terrace deposit. The geologic contact at this location, and throughout most of San Diego's North County, is around +25 feet, MSL, and in Solana Beach, the top of the coastal bluff is around +80 feet. Twenty years ago, when a stable back beach existed, as I said before, the elevation was around +12 or roughly at the location of this overhang.

Photo 7

This is a close-up with Dave Skelly in the photo for scale. And with a healthy back beach around +12, this entire sea cliff would be fully protected. However, in the absence of a sand beach, this sea cliff is now subjected to wave activity and cobble abrasion on a daily basis.

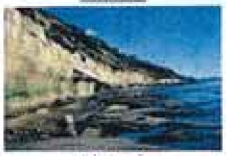


Photo 8

I've shown this photo again for perspective in 1997, with the following photo taken from the same location in 1989.

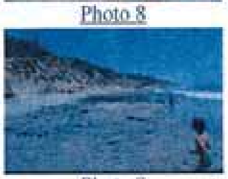


Photo 9

This photo, taken six years after the 1982-83 El Niño storm season has a completely recovered beach profile, with the pre-El Niño storms creating a significant offshore bar, which helped to protect this shoreline from the 1982-83 storms.

COE Fig C1-29

If we examine beach profiles from the Corps of Engineers, and this is again in Solana Beach, one of the first things we see is an offshore slope of about 1 in 60, and this winter low tide bar often shows up typically about 150 to 200 meters offshore, then further offshore we occasionally see Inman's winter bar berm function, where sand from the summer profile is displaced to its winter profile. It is the presence of these winter bars that trip the larger offshore waves, reducing wave energy into the scoured beach profile. In the absence of these nearshore bars, Solana Beach experienced significantly increased coastal erosion during the 1997-98 El Niño storm season, and in the absence of beach nourishment, this problem will only become worse in the future. Note also that this beach profile has a vertical exaggeration of about 25 to 1 to illustrate these offshore features.

Summer Profile

I have included this barely discernible typical summer profile sketch plotted with no vertical exaggeration to make an important point. First, this profile shows the 1 on 60 offshore slope, with the point of closure about 2700 feet offshore where we encounter the -40-foot contour. This plot would be representative of the typical historical summer profile where we had +12 back beach. But most important, this profile, with a relatively flat foreshore, provides a very different perspective than the typical, very exaggerated, vertical scaled profile. This very gentle bedrock shore platform encourages the accumulation of even minor amounts of transient sand against the base of the coastal bluff.

Figure 1

Looking more closely at the coastal bluff face (and this is one of our surveyed sites in Solana Beach), we again have the Eocene cliff-forming Torrey Sandstone and the younger overlying Bay Point Formation. It is of interest to note that this geologic contact was formed during a high still stand, when sea level was 20 feet higher than it is today and the relic sea cliff would be off to the right of this picture, actually in Solana Beach around Cedros Avenue a few thousand feet to the east, and as sea level receded, a sand beach formed, with this 10-foot clean sand zone overlain by slightly more cemented terrace deposits. Also shown in this sketch is what I'll refer to as the historic stable summer back beach around +12, and the more contemporary transient beach sand shingle beach that fairly frequently scours, leaving the underlying relatively flat shore platform.


Figure 2

In the absence of a stabilizing notch infill to preclude its collapse, the overhang along this section of shoreline did fail in April 2001, exposing these clean sands and destabilizing the upper bluff.

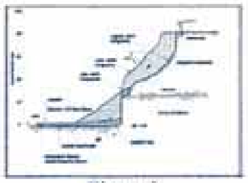


Figure 3

A subsequent failure occurred in August 2001, with a series of multi-yard additional failures occurring up and through October 2002, when work started on the construction of a seawall. This figure is also important in that it illustrates the fairly fragile condition of these coastal bluffs, which, when undermined by the collapse of the basal notch in April 2001, set into motion a period of significant upper-bluff instability with multiple failures occurring over a period of years until the new slope equilibrates.

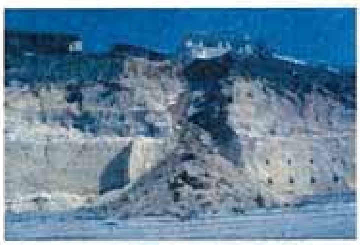


Photo 10

This is a photograph immediately after the failure. You can see the basal clean sand layer contributing to this upper-bluff instability. I think the most important point here is that most of these failures occur on warm, sunny afternoons as moisture in the soil slowly dries out, reducing its capillary tension, which helps hold the slope together. In other words, many of these upper-slope failures occur in the absence of wave activity and usually in the afternoon, often when people have access to the beach below. And of course, in the absence of a very wide sandy beach, people are close to the bluff and at significant risk.

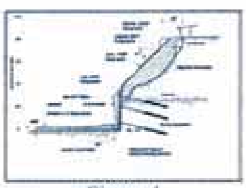


Figure 4

A seawall was eventually approved and constructed in late 2002. However, by this time, about 5 feet of marine erosion resulted in about 20 feet of sea-cliff retreat and the loss of a portion of this bluff-top residence.


Photo 11

Although I am a coastal engineer and design seawalls, I am not a strong advocate of seawalls. Moreover, I can promise you that no homeowner wants to spend $300,000 to $500,000 for a seawall. It is simply his last option. I think everyone in this room will agree that healthy sand beaches, in addition to being a multi-billion-dollar recreational resource, protect our coastal bluffs and those private properties atop the coastal bluffs. However, with the loss of our sand beaches, we see accelerated coastal erosion and we find ourselves in a complex philosophical dilemma. The seawall represents the last line of defense when insufficient sand is available to protect the coastal bluffs, much less provide a recreational resource. This seawall is 35-feet high and attempts to replicate the vertical sea cliff, with a reconstructed sloping stable upper bluff that looks reasonably natural. More to the point, however, it stabilizes the upper bluff, essentially eliminating the potential for future upper-bluff failures above the wall. And although the seawall debate pits sand beaches against seawalls, I can promise you that even in the total absence of seawalls within the 52-mile-long Oceanside Littoral Cell, it was man's urbanization of the upland watershed and the resulting wholesale loss of sand that necessitated the seawalls. And if you remove every seawall within the

Oceanside Littoral Cell, you will not even begin to replace the sand lost through upland urbanization. It is important to realize that these beaches did not disappear because seawalls were built. The opposite is true. Seawalls were needed because the beach disappeared.

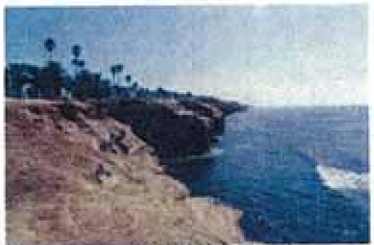


Photo 12

This is an important concept, which I would like to illustrate with this photo looking down the Point Loma Peninsula in San Diego. As you can see, this is a different geologic unit. Actually, it's Cretaceous in age, about 80 million years old, but it's much stronger than the Eocene sediments that comprise the sea cliffs of San Diego's North County. Note also in this photo that there is deep water adjacent to the cliffs. The sea floor in this area is around elevation -5 feet, and as a result, much more wave energy can come into the coastline, but the rock is so hard that to initiate any erosion and retreat of the coastline, you need deeper water and the potential for more wave energy to compensate for the stronger rock. As you can imagine, there is no lateral access along the base of the sea cliff along the Point Loma Peninsula, simply because the rock is so strong that it can sustain the deeper water and the increased wave energy for its equilibrium condition.

Photo 13

This photo is of the sea cliff in Encinitas, just north of Solana Beach, and it nicely illustrates the actual mechanism of erosion where a basal notch occurs and the overhang collapses, causing a progressive failure of the upper bluff. What's important here is that, in the absence of upland sediment feeding the Oceanside Littoral Cell, we lose our sand beach. Again, this photograph was taken at low tide. But even the Eocene-age sea cliff possesses sufficient erosion resistance so as to release coastal bluff sediments at such a slow rate that the available littoral transport capacity of Southern California's wave environment simply sweeps these sands out of the system. Planned retreat cannot and will not measurably replace the 13 to 14 feet of sand lost solely due to the urbanization of the upland watershed.

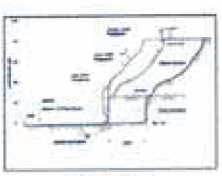


Figure 5

Mr. Jaffee is going to speak about passive erosion. A subject that he and many in the Surfrider Foundation are truly passionate about. I would like to present a different perspective on this subject, and I will again use my same example and assume for a moment that the seawall was not constructed and we had a conservative erosion rate of half a foot a year, which in 75 years would be 37½ feet. Now to begin with, this erosion can only occur in the absence of the sand beach, allowing the wave energy to get to the coastal bluff. And at this point I must add that, if we experience 37½ feet of erosion over the next 75 years, it means that all of us in this room have failed to nourish our North County beaches - something that is truly unfortunate. So back to our example, in the absence of a seawall over the next 75 years, with no sand beach, the coastal bluff will continue to retreat through a series of slope failures, continuing to maintain a very dangerous condition for the beach-going public over the next 75 years.

The presence of the seawall, again in the absence of any additional beach renourishment projects, would still have no sand beach in front of the seawall and the 37½ feet of erosion that did not occur because of the presence of the seawall is, in fact, the passive erosion.

In the absence of the seawall, 75 years into the future, what precisely have we gained? The shore platform will advance its profile landward 37½ feet. The downwearing of the platform is more or less equal to the backwearing divided by the platform slope. In essence, the profile just moves to the east. We've lost the bluff-top improvements. For the past 75 years, we've been exposed to ongoing bluff failures. Many people have likely been hurt or worse. And we have done absolutely nothing to improve the quality of this coastal resource that the State of California strongly believes that we should, today, preserve and enhance.


Figure 6

Let's go back for a moment and reexamine the seawall that exists. But let's now renourish our beach as the State is recommending, and the Army Corps of Engineers is considering, and the Solana Beach bluff-top property owners have already proposed to initiate as part of a privately funded Geologic Hazard Abatement District. We now have our previously historic back beach at +12 again. Instead of a 50- to 60-foot-wide historically-persistent back beach, now we have a 200-foot-wide beach, as recommended by the Corps of Engineers to stop further marine erosion. And we recapture our $15 billion tourist economy.

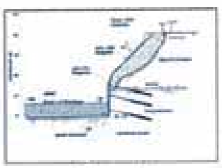


Figure 7

So on the one hand, we have 37½ feet of erosion, with the ill-conceived concept of planned retreat, loss of bluff-top improvements in a totally urbanized coastal community, a high likelihood of many injuries, and possibly death, and no improvement of the coastal resource.

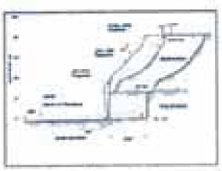


Figure 6

On the other hand, we have a seawall that some people dislike, a stable upper bluff, and, if the State, the Corp of Engineers, and private sector all come together to support beach renourishment, we'll have a 200-foot-wide recreational stable back beach near elevation +12. And remember, if the Corps participates in this project, they are committed to providing about a 200-foot-wide stable back beach for the next 50 years.

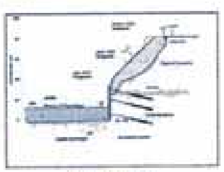


Figure 7

I am sure that Mr. Jaffee is now infuriated with this presentation, so in fairness to the Surfrider Foundation, let's for a moment assume no sand beach in front of the seawall. We have now experienced 37½ feet of passive erosion or erosion that we did not have. This equates to a lowering of the shore platform of about 6/10 foot. Let's call it a foot. Let's maybe add a half a foot for sea level rise. So that over the course of 75 years, in the total absence of any beach nourishment projects, we see a deepening of the water surface in front of the seawall of about a foot and a half. Undeniably, this is a problem. This is the result of passive erosion. But it is still an order of magnitude less than the loss of the historically persistent, stable back beach due to the urbanization of the upland watershed. There is a lot that's been said about cumulative impacts of seawalls, but what of the cumulative impact of the urbanization of the upland watershed?

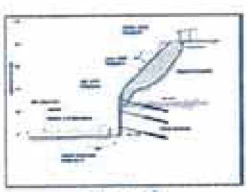


Figure 8

What shoreline are we leaving for our children? And particularly in San Diego's North County? I don't know the answer to that question. What I do know is that in the last five years, the small coastal city of Solana Beach has experienced almost 40 separate and significant coastal bluff failures, which to date have destabilized about 45 percent of the city's 1.4-mile-long coastline. This is typical of the progressive coastal bluff failures that have occurred in Solana Beach, with the light blue representing the extent of failures in June 1998, the pink shading representing the growth in coastal bluff failures through June 2000, and the magenta carrying us through September 2001. I can say that in the absence of any beach nourishment projects the remaining 55 percent of this city's coastline will also eventually fail, destabilizing the entire city coastline, with ongoing failures continuing until some change in the existing geomorphic environment occurs. I can also tell you that regardless of what certain environmental groups would say, in the absence of beach nourishment, and if we removed every seawall within the Oceanside Littoral Cell, we will not substantially change the existing sediment-starved shoreline condition, a condition that the State of California believes should be rectified if we are to preserve this State's $15 billion annual tourist economy.

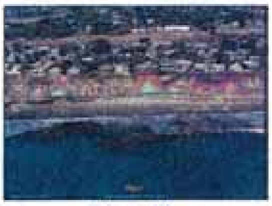


Photo 14

I can also say that the construction of properly designed seawalls will also arrest marine erosion and stabilize the upper currently-unstable younger terrace deposits, and specifically those that have been undermined. I can tell you that when combined with beach nourishment projects, and particularly the project that the Corps of Engineers is contemplating, we will at least, for the next 50 years, have a minimum 200-foot-wide stable recreational sand beach that, for the next 50 years, will protect the remaining 55 percent of the Solana Beach coastline that has not yet failed, without the need for seawalls. And this sand beach would provide an incredible recreational resource. I can tell you that in the absence of the beach nourishment, we would experience something like 37 to 38 feet of passive erosion; we would see a gradual deepening at the base of the seawalls, and we would do a grave disservice to this coastal community. Although personally I think it pales compared to what implementing planned retreat would do for this coastal community.


Photo 15

In wrapping up my presentation, I would like to address public safety. While the beach can be a dangerous place, all of the coastal-related dangers with the single exception of bluff instability, have existed along San Diego's North County beaches in the past. These potential "natural" dangers are presumably familiar to the beach-going public. Since people are now often forced to walk along the beach immediately adjacent to the bluff, there is a much greater risk from a bluff failure injuring or killing them on the beach. It is unreasonable to assume that the beach-going public possesses the same level of recognition regarding the potential for a bluff collapse injuring them then from a rip current carrying them out to sea. It is fair to assume that the majority of the beach-going public has at least some familiarity with the dangers of waves, rip currents, cold water, and the many other natural hazards that exist along ocean shorelines.

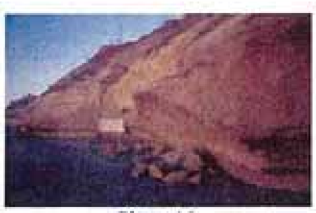


Photo 16

However, it is also fair to say that the vast majority of the beach-going public has little knowledge of the potential risks associated with a bluff collapse along the landward edge of the beach.

Coastal bluffs do not back most of the beaches along the U.S. East and Gulf coasts. Therefore, many visitors to our beaches probably have no idea that the bluffs present any danger to them. Even in Southern California, many of the more popular beaches, including Santa Monica, Newport, and Mission Beach, are similarly not backed by coastal bluffs. Moreover, most coastal bluffs are reasonably stable, including the majority of those within Point Loma and La Jolla. It is only those that are actively eroding, most notably in San Diego's North County, and where the upper bluff face has not had a chance to equilibrate, that the biggest risk to the beach-going public exists. This risk is relatively new to San Diego, and atypical of most recreational beach areas throughout the country.

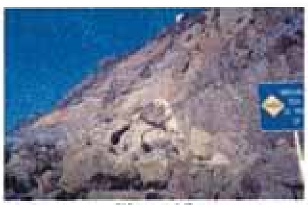


Photo 17

On October 1, 1999, on a sunny Friday afternoon, a surfer got out of the water, took off his wetsuit, and set it down on the beach about 40 feet from this bluff. Luckily, he walked back down to the beach. Moments later, in the total absence of any waves, several hundred cubic yards of this bluff collapsed, burying his wetsuit and frankly scaring him out of his wits. If a surfer, knowledgeable of the local conditions, was surprised by such a failure, how could a family visiting from, say Phoenix, be expected to recognize the potential danger of a bluff collapse that could injure or kill someone in their family?

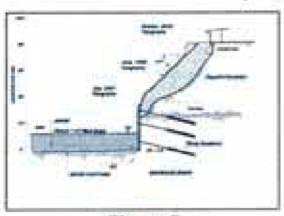


Figure 7

In closing, and responding specifically to the Surfrider Foundation's proposal for planned retreat, which includes removing all coastal structures in 75 years - - let's for a moment assume that some level of a recreational beach exists at the base of the sea cliff - - the moment we remove the seawalls, we again destabilize the upper bluffs, and then immediately set into motion an avalanche of upper-bluff failures, with the attendant life safety threat and which this city would not have experienced for the past 75 years. Thank you.

EXHIBIT I

State of California

California Coastal Commission
San Diego District

MEMORANDUM

TO: Commissioners

DATE: March 15, 1994

FROM: Staff

FILE NO: 6-93-85

SUBJECT: Mitigation for Impacts of Seawalls on Sand Supply - Recommended Condition and Finding

STAFF NOTES:

At the November 18, 1993 Commission hearing, the Commission approved three permit applications for seawalls with a condition requiring the applicants to mitigate for the impacts of the shoreline protective devices on sand supply and public beach access by paying a fee, in-lieu of providing sand to the beach. The fees are to be deposited into an account with the purpose of establishing a beach sand replenishment fund to aid in the restoration of beaches within San Diego County. Since the San Diego Association of Governments (SANDAG) is currently developing a plan to implement the Shoreline Preservation Strategy adopted in July 1993, it has been identified as the logical entity to help administer the fund. This would be done by coordinating with representatives from the local jurisdictions where the fees are derived, and identifying to the Executive Director, sand replenishment projects which would benefit either those jurisdictions directly, or benefit the littoral cell in which they are located.

The Commission's approval of the seawall projects with this condition followed much testimony regarding the appropriateness of staff's proposed methodology used to derive the fee, and also suggestions that the local governments should be the entities to establish such a fund, through tax assessment or other means, to reach the community as a whole and not just the bluff top property owners. The Executive Director indicated at the time that the beach sand replenishment fund could be replaced in the future, should a broader-based program be established by the City, that also addresses the impacts of shoreline protective devices on local shoreline sand supply and beach access.

Since the Commission action in November, a meeting was held by the SANDAG Shoreline Erosion Committee which had previously agreed to administer the fund through a Memorandum of Agreement with the Coastal Commission, and to provide assistance, through its review and comments, on the methodology being prepared. Comments on the proposed methodology and fund were given by interested parties at that meeting. Additionally, the proposed methodology has been reviewed by Dr. Craig Everts, Coastal Engineer with the firm of Moffatt and Nichol, as well as other technical experts and interested parties.

In response to the above-mentioned comments, the recommended condition language and the proposed methodology have been modified by staff. Also, to address the importance of approving the proposed seawall with a condition which mitigates the impacts of armoring the shoreline on local sand supply, but also to acknowledge the fact that the City of Encinitas is currently in the process of developing a Geologic Hazared Abatement District which should address mitigation for those impacts, staff is also recommending condition language which requires the applicant to pay the fee after a six month period, if an alternative to compliance with the condition is not developed and approved by the Commission through an amendment to this coastal development permit within that time frame.

Staff recommends the following condition and finding be adopted for Coastal Development Permit #6-93-85 Auerbach et al:

2. Mitigation for Impacts to Sand Supply. Prior to issuance of the coastal development permit, each applicant shall provide evidence, in a form and content acceptable to the Executive Director, that a fee of no less than $1,643.00 and no more than $17,393.00 (402 Neptune Avenue); $1,635.00 and no more than $17,270.00 (396 Neptune Avenue); $1,643.00 and no more than $17,393.00 (378 Neptune Avenue); $1,643.00 and no more than $17,393.00 (370 Neptune Avenue); $1,665.00 and no more than $17,870.00 (354 Neptune Avenue); and, $1,620.00 and no more than $16,920.00 (312 Neptune Avenue) has been deposited in an interest bearing account designated by the Executive Director, in-lieu of providing sand to replace the sand and beach area that would be lost due to the impacts of the proposed protective structure. The methodology used to determine the appropriate mitigation fee for the subject site(s) shall be that described in the memo titled "Mitigation for Impacts of Seawalls on Sand Supply" dated March 15, 1994, prepared for coastal development permit #6-93-85. The California Coastal Commission shall be named as trustee of this account, with all interest earned payable to the account for the purposes stated below.

The purpose of the account shall be to establish a beach sand replenishment fund to aid SANDAG, or a Commission-approved alternate entity, in the restoration of the beaches within San Diego County. The funds shall solely be used to implement projects which provide sand to the region's beaches, not to fund operations, maintenance or planning studies. The funds shall be released only upon approval of an appropriate project by the Executive Director of the Coastal Commission. The funds shall be released as provided for in a memorandum of agreement (MOA) between SANDAG, or a Commission-approved alternate entity, and the Commission, setting forth terms and conditions to assure that the in-lieu fee will be expended in the manner intended by the Commission. In the event SANDAG does not enter into a MOA with the Commission within 1 year from deposition of the initial fee, the Commission can appoint an alternative entity to administer the fund.

Recommended finding and proposed methodology:

In approving the proposed seawall, the Commission must find that a need for the project has been documented consistent with Chapter 3 policies, and that the proposed alternative is the least damaging to the environment. Additionally, Section 30235 of the Coastal Act requires that construction of seawalls which "alter natural shoreline processes" shall be permitted to protect existing structures when "designed to eliminate or mitigate adverse impacts on local shoreline sand supply". The natural shoreline processes referenced in Section 30235, such as the formation and retention of sandy beaches, may be altered by the construction of a seawall, since bluff retreat is one of the many ways that beach quality material is added to the shoreline. This retreat is a natural process resulting from many different factors such as undercutting by wave action of the toe of the bluff causing bluff collapse, saturation of the bluff soil from ground water causing the bluff face to slough off and natural bluff deterioration. When a seawall is constructed on the beach at the toe of the bluff, the seawall directly impedes these natural processes. While the seawall may be necessary to protect development located on the bluff top, the seawall has adverse impacts on shoreline processes and on public access to, and use of, the beach.

The San Diego Association of Governments (SANDAG) has adopted the Shoreline Preservation Strategy for the San Diego region and is currently working on techniques toward its implementation. The Strategy considers a full range of shoreline management tactics, but emphasizes beach replenishment to preserve and enhance the environmental quality, recreational capacity, and property protection benefits of the region's shoreline. As identified in the Strategy, while shoreline protective devices result in immediate protection for the endangered property, they also result in long-term adverse impacts on the beach seaward of the wall or revetment.

The construction of a seawall along a shoreline backed by coastal bluffs, such as in Encinitas, can have several quantifiable impacts on shoreline processes and beach access, as well as numerous, less quantifiable effects which have been discussed elsewhere in current literature on seawalls. Three of the quantifiable impacts from such structures are:

1. The seawall will halt natural bluff retreat, preventing a portion of the bluff material from becoming part of the sand supply;

2. The seawall will halt the landward migration of the beach and nearshore profiles, preventing the formation of beach that would otherwise be available for public use over time, if the seawall were not constructed;

3. The seawall will physically occupy area, by its encroachment seaward of the toe of the bluff, that would otherwise be available for recreational use.

The above is graphically depicted on attached Figures 1 - 6. Figures 1 - 5 depict the current and future bluff conditions as discussed above. Figure 6 depicts the losses to beach that will occur as a result of the armoring.

Shoreline protective devices, such as that proposed, fix the inland extent of the beach. Therefore, when additional erosion occurs seaward of the wall, it is at the expense of beaches or recreational areas owned or utilized by the general public. "Seawalls inhibit erosion that naturally occurs and sustains the beach. The two most important aspects of beach behavior are changes in beach width and changes in the position of the beach. On narrow, natural beaches, the retreat of the back of the beach, and hence the beach itself, is the most important element in sustaining the width of the beach over a long time period. Narrow beaches, typical of most of the California coast, do not provide enough sacrificial sand during storms to provide protection against scour caused by breaking waves at the backbeach line. This is the reason the back boundary of our beaches retreats during some storms. Armoring in the form of a seawall fixes the backbeach line and interrupts this natural process. A beach with a fixed landward boundary is not maintained on a recessional coast because the beach can no longer retreat." (ref. Memo by Dr. Everts dated 3/14/94 re: Review of CCC Methodology for Quantifying Impacts to Sand Supply from Bluff Armoring).

Seawalls also trap bluff material which would otherwise become part of the local sand supply, thus reducing the sand supply for the affected beach and surrounding areas. Accordingly, in its review of such projects under Section 30235 and the access policies of the Coastal Act, the Commission must assess both the need to protect property and the need to mitigate adverse effects on beach access and shoreline sand supply.

Funding from a variety of sources will be required to implement the beach replenishment and maintenance programs identified in the SANDAG Strategy. In this particular case, SANDAG has agreed to administer a program which would identify projects which may be appropriate for support from the beach sand replenishment fund, through input from the Shoreline Erosion Committee which is made up of representatives from all the coastal jurisdictions in San Diego County. The Shoreline Erosion Committee is currently monitoring several large scale projects, both in and out of the coastal zone, they term "opportunistic sand projects", that will generate large quantities of beach quality material suitable for replenishing the region's beaches. The purpose of the account is to aid in the restoration of the beaches within San Diego County. One means to do this would be to provide funds necessary to get such "opportunistic" sources of sand to the shoreline.

The applicants are being required to pay a fee, in-lieu of depositing the sand on the beach, because the benefit/cost ratio of such an approach would be too low. The larger projects can take advantage of the economies of scale and result in quantities of sand at appropriate locations to benefit both the local jurisdiction where the fees were derived, and the entire littoral cell in which it is located. The funds will be used only to implement projects which benefit the area where the fee was derived, and provide sand to the region's beaches, not to fund operations, maintenance or planning studies.

Such a fund will aid in the long-term goal of increasing the sand supply and thereby reduce the need for additional armoring of the shoreline in the future. The fund also will insure available sandy beach for recreational uses.

Several of the comments received at the Shoreline Erosion Committee meeting, addressing the proposed methodology to determine an appropriate mitigation fee, suggested the fee would be requiring the blufftop property owners to compensate for the fact that dams, breakwaters and other upcoast structures have resulted in less sand on the beach, and, thus, greater erosion potential. However, the methodology, as proposed, is not attempting to address any impacts to shoreline processes other than those directly attributable to the proposed seawall on the subject properties. The methodology provides a means to quantify the sand and beach area that would be available for public use, but for the seawall.

Special Condition #2 requires the applicant to deposit an in-lieu fee to fund beach sand replenishment projects as mitigation for impacts of the proposed shoreline protective device on beach sand supply and shoreline processes. The following is the methodology to be used by the applicant to develop the in-lieu fee which will provide mitigation for the quantifiable effects of the proposed project on this segment of the Encinitas shoreline. The methodology estimates the total quantity of sand necessary to replace : a) the reduction in beach quality material contributed from the seacliff over the life of the armoring; b) the reduction in beach width which will occur when the landward migration of the beach profile is stopped, over the life of the structure; and c) the reduction in beach area which will occur from the seaward encroachment of the seawall. The methodology uses site specific information provided by the applicant as well as estimates, derived from region-specific criteria, of both of the loss of beach material and beach area which could occur over the life the structure, and of the cost to purchase an equivalent amount of beach quality material and to deliver this material to beaches in the project vicinity.

The following is a description of the methodology. The calculations which utilize values that are applicable to the subject sites, and were used as the basis for calculating the estimated range of the mitigation fee, are attached as Exhibit 4 to this report.

Fee = (Volume of sand for mitigation) x (unit cost to buy and deliver sand)

$M = V_t \times C$

where	M =	Mitigation Fee
	V_t =	Total volume of sand required to replace losses due to the structure, through reduction in material from the bluff, reduction in nearshore area and loss of available beach area (cubic yards). Derived from calculations provided below.

$C =$ Cost, per cubic yard of sand, of purchasing and transporting beach quality material to the project vicinity ($ per cubic yard). Derived from the average of three written estimates from sand supply companies within the project vicinity that would be capable of transporting beach quality material to the subject beach, and placing it on the beach or in the near shore area.

$$V_t = V_b + V_w + V_e$$

where $V_b =$ Volume of beach material that would have been supplied to the beach if natural erosion continued, based on the long-term regional bluff retreat rate, design life of the structure, percent of beach quality material in the bluff, and bluff geometry (cubic yards). This is equivalent to the long-term reduction in the supply of bluff material to the beach resulting from the structure.

$V_w =$ Volume of sand necessary to replace the beach area that would have been created by the natural landward migration of the beach profile without the seawall, based on the long-term regional bluff retreat rate, and beach and nearshore profiles (cubic yards)

$V_e =$ Volume of sand necessary to replace to area of beach lost due to encroachment by the seawall; based on the seawall design and beach and nearshore profiles (cubic yards)

$$V_b = (S \times W \times L/27) \times [(R\ h_s) + (h_u/2 \times (R + (R_{cu} - R_{cs})))]$$

where $R =$ Long-term regional bluff retreat rate (ft./yr.), based on historic erosion, erosion trends, aerial photographs, land surveys, or other accepted techniques. For the Encinitas area, this regional retreat has been estimated to be 0.2 ft./year. This value may be used without further documentation. Alternative retreat rates must be documented by the applicant and should be the same as the predicted retreat rate used to estimate the need for shoreline armoring.

$L =$ Design life of armoring without maintenance (yr.) If maintenance is proposed and extends the life of the seawall beyond the intial estimated design life, a revised fee shall be determined through the coastal development permit process.

W = Width of property to be armored (ft.)

h = Total height of armored bluff (ft.)

S = Fraction of beach quality material in the bluff material, based on analysis of bluff material to be provided by the applicant

h_s = Height of the seawall from the base to the top (ft)

h_u = Height of the unprotected upper bluff, from the top of the seawall to the crest of the bluff (ft)

R_{cu} = Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming no seawall were installed (ft/yr). This value can be assumed to be the same as R unless the applicant provides site specific geotechnical information supporting a different value.

R_{cs} = Predicted rate of retreat of the crest of the bluff, during the period that the seawall would be in place, assuming the seawall has been installed (ft/yr). THis value will be assumed to be zero unless the applicant provides site specific geotechnical information supporting a different value.

NOTE: For conditions where the upper bluff retreat will closely follow the lower bluff, this volume will approach a volume of material equal to the height of the total bluff, the width of the property and a thickness equal to the total bluff retreat that would have occurred if the seawall had not been constructed. For conditions where the upper bluff has retreated significantly and would not be expected to retreat further during the time that the seawall is in place, this volume would approach the volume of material immediately behind the seawall, with a thickness equal to the total bluff retreat that would have occurred if the seawall had not been constructed.

$\mathbf{V_W = R \times L \times v \times W}$

where **R** = Long-term regional bluff retreat rate (ft./yr.), based on historic erosion, erosion trends, aerial photographs, land surveys, or other accepted techniques. For the Encinitas area, this regional retreat has been estimated to be 0.2 ft./year. This value may be used without further documentation. Alternative retreat rates must be documented by the applicant and should be the same as the predicted retreat rate used to estimate the need for shoreline armoring.

L = Design life of armoring without maintenance (yr.) If maintenance is proposed and extends the life of the seawall beyond the intial estimated design life, a revised fee shall be determined through the coastal development permit process.

v = Volume of material required, per unit width of beach, to replace or reestablish one foot of beach seaward of the seawall; based on the vertical distance from the top of the beach berm to the seaward limit of reversible sediment movement (cubic yards/ft of width and and ft. of retreat). The value of v is often taken to be 1 cubic yard per square foot of beach. In the report, Oceanside Littoral Cell Preliminary Sediment Budget Report" (December 1987, part of the Coast of California Storm and Tide Wave Study, Document #87-4), a value for v of 0.9 cubic yards/square foot was suggested. If a vertical distance of 40 feet is used for the range of reversible sediment movement, v would have a value of 1.5 cubic yards/square foot (40 feet x 1 foot x 1 foot / 27 cubic feet per cubic yard). These different approaches yield a range of values for v from 0.9 to 1.5 cubic yards per square foot. The value for v would be valid for a region, and would not vary from one property to the adjoining one. Until further technical information is available for a more exact value of v, any value within the range of 0.9 to 1.5 cubic yards per square foot could be used by the applicant without additional documentation. Values below or above this range would require additional technical support.

W = Width of property to be armored (ft.)

$V_e = E \times W \times v$

where E = Encroachment by seawall, measured from the toe of the bluff or back beach (ft.)

W = Width of property to be armored (ft.)

v = Volume of material required, per unit width of beach, to replace or reestablish one foot of beach seaward of the seawall, as described above;

The applicant shall be responsible for documenting the appropriate values which shall be used to determine the amount of the mitigation fee to be deposited, prior to issuance of the permit. With implementation of this condition, mitigation for impacts on shoreline process and sand supply resulting from the proposed development is provided, consistent with Section 30235 of the Coastal Act.

(9300A)

BLUFFS AT PRESENT
WITHOUT A SEAWALL

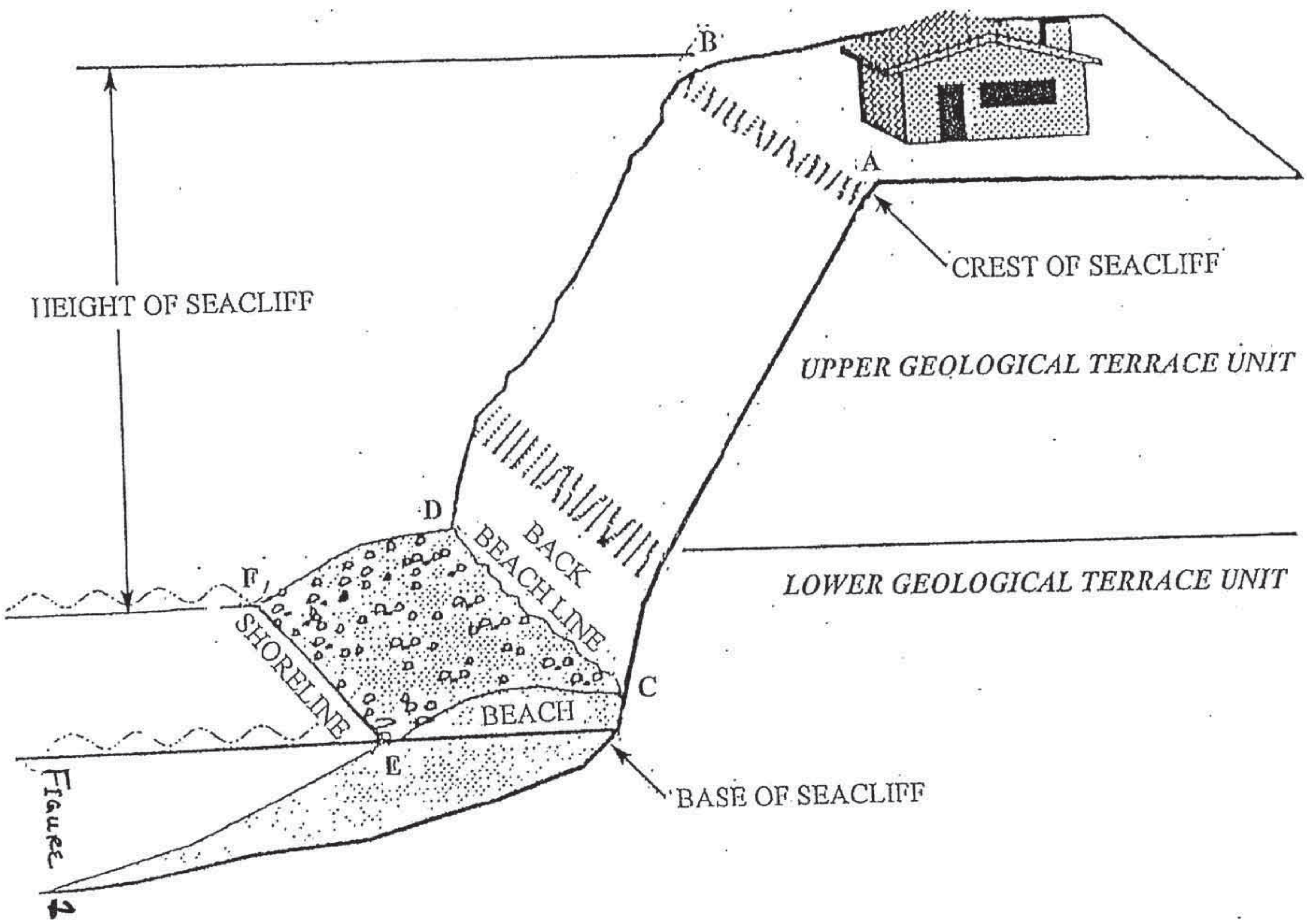


FIGURE 2

BLUFFS AT PRESENT
WITH A SEAWALL

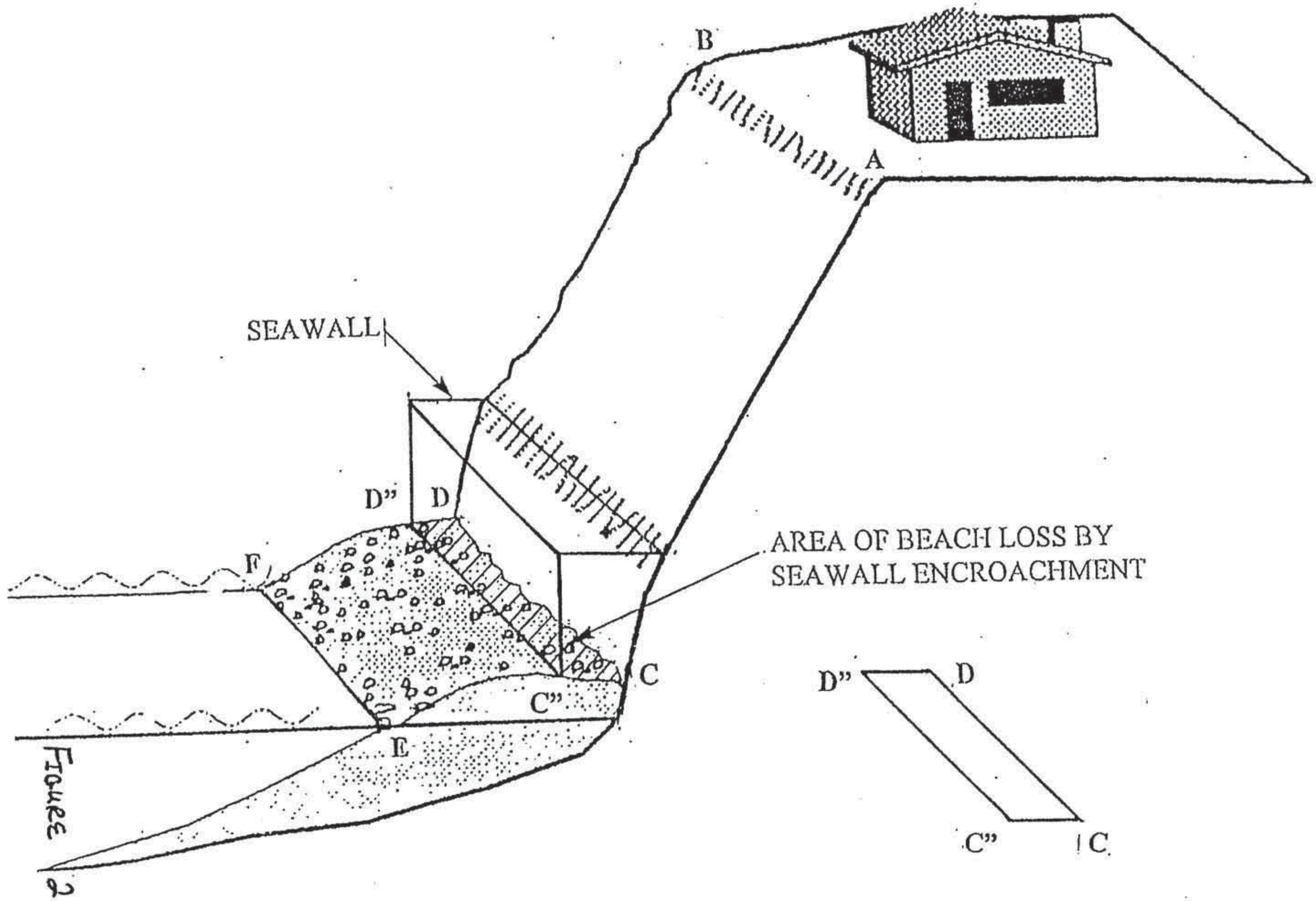


FIGURE 2

BLUFFS IN THE FUTURE
WITHOUT A SEAWALL

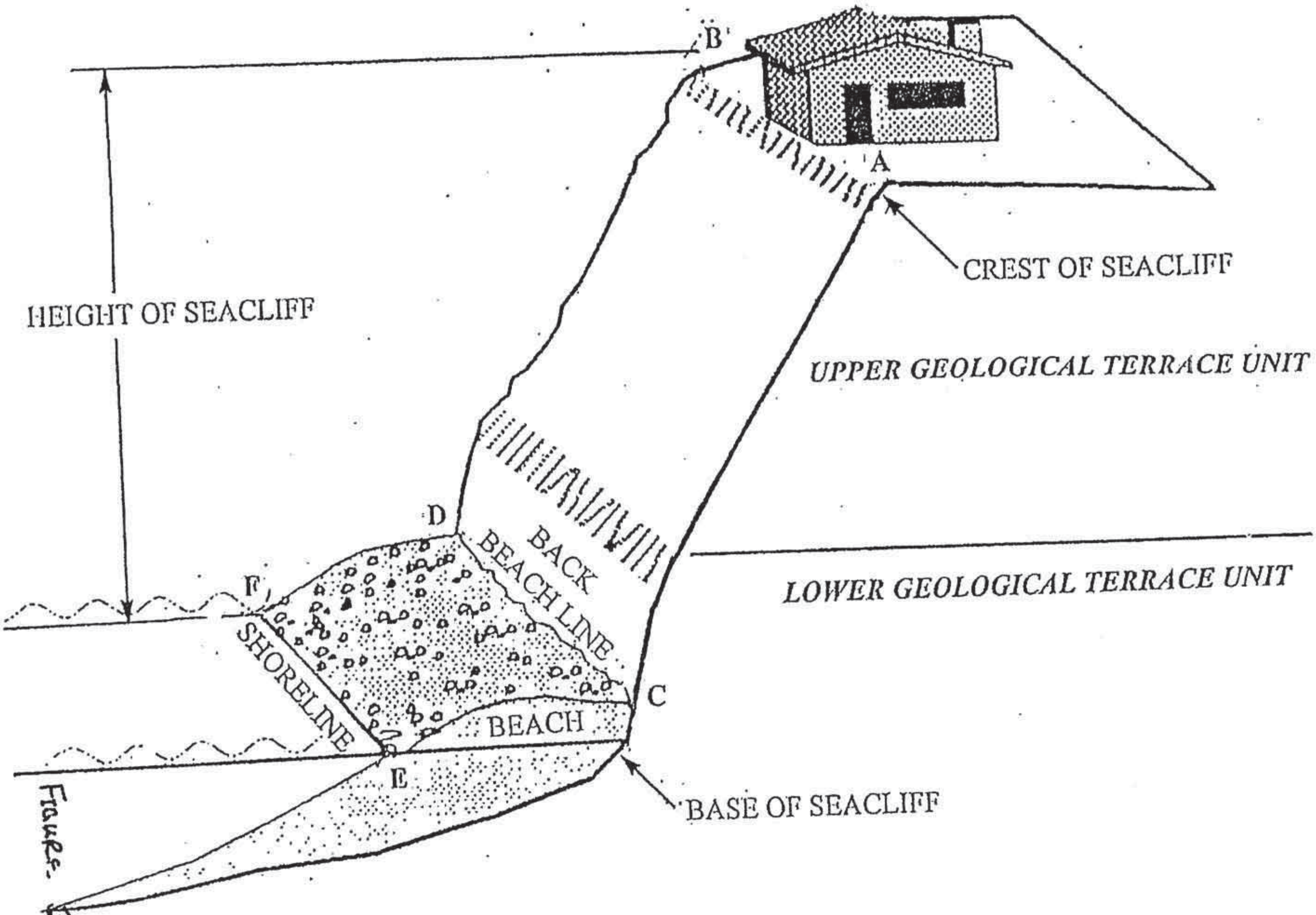


FIGURE 3

BLUFF CHANGES IN THE FUTURE
WITHOUT A SEAWALL

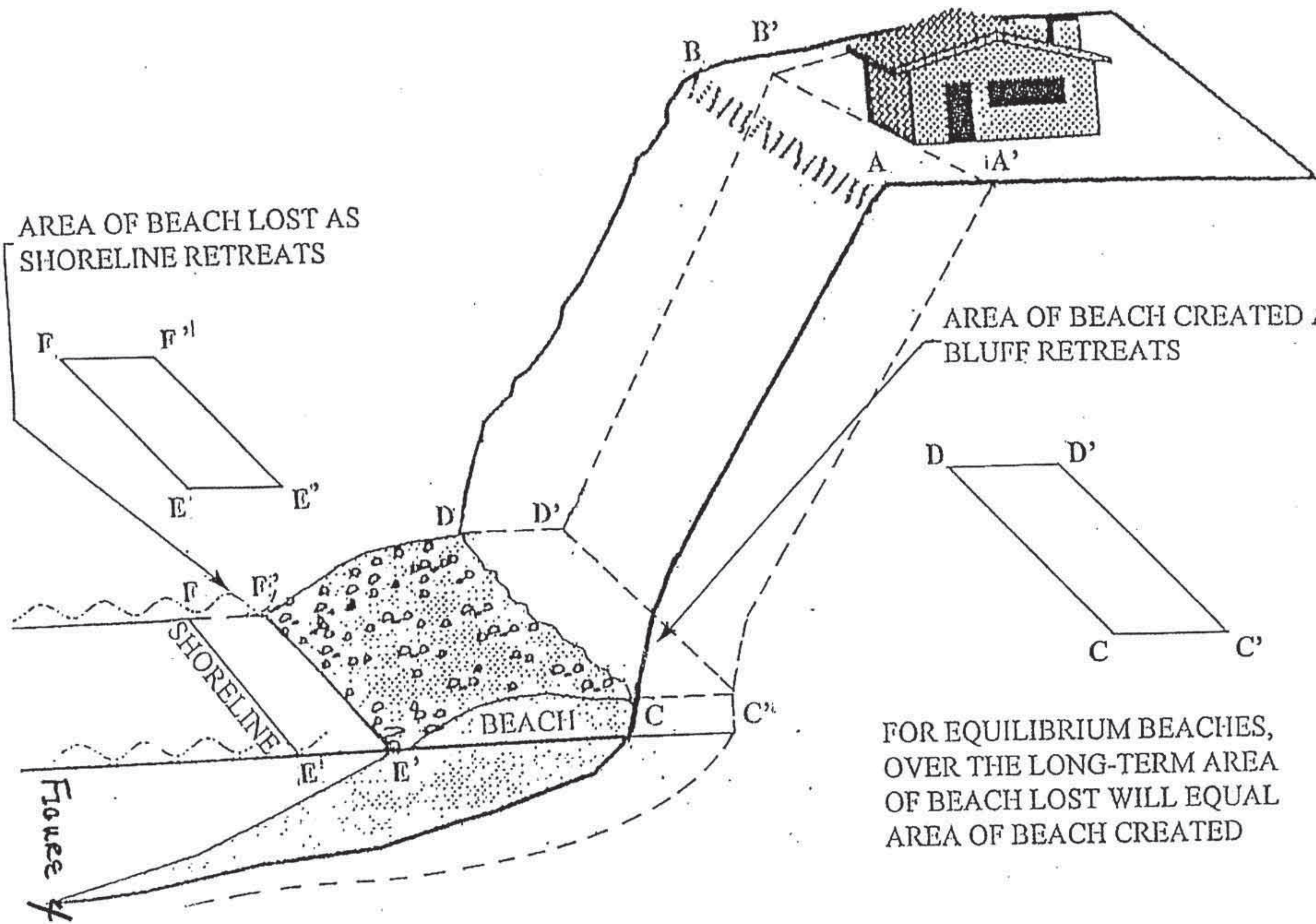


FIGURE 4

BLUFF CHANGES IN THE FUTURE WITHOUT A SEAWALL

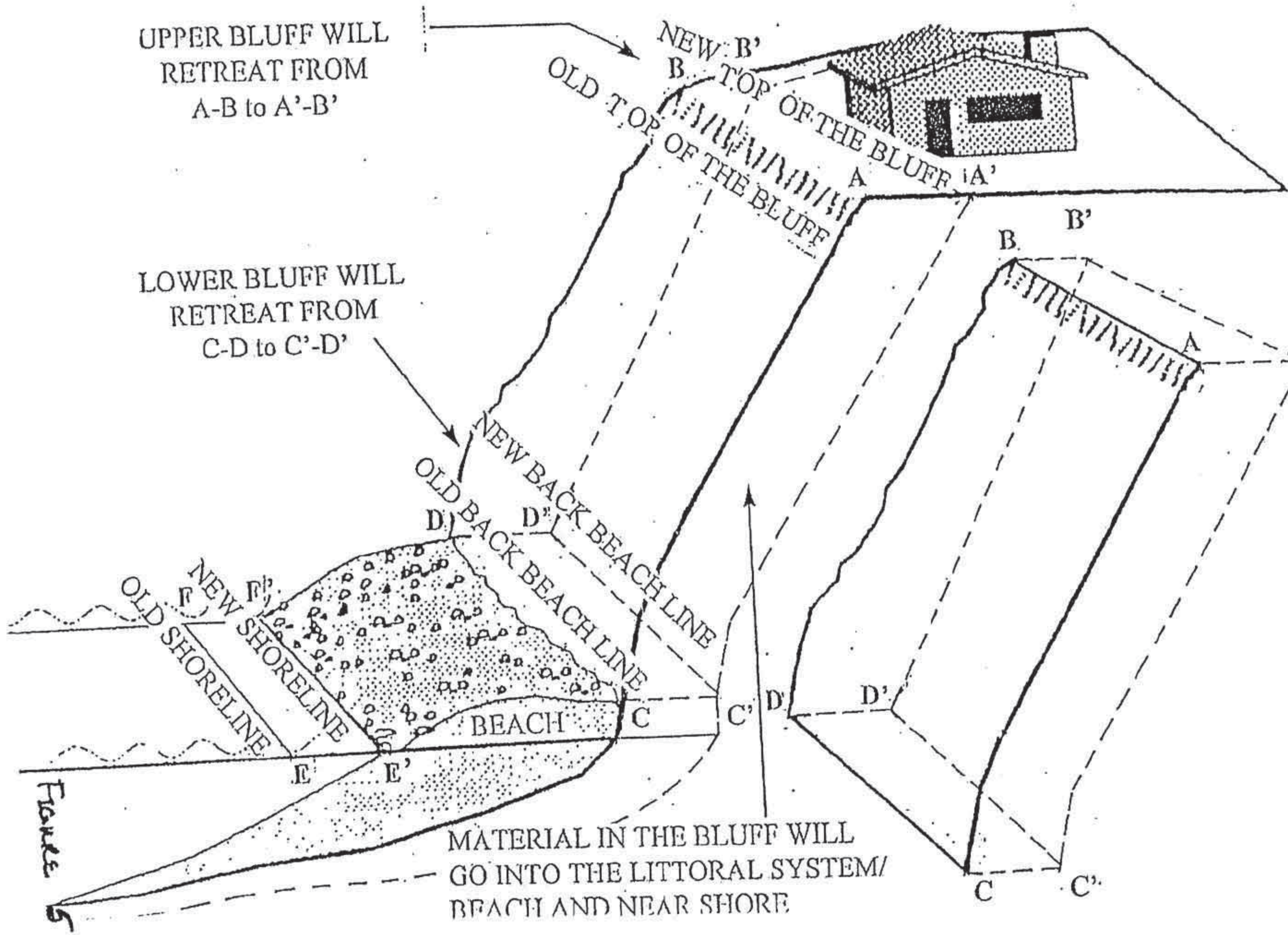


FIGURE 5

BLUFFS IN THE FUTURE
WITH A SEAWALL

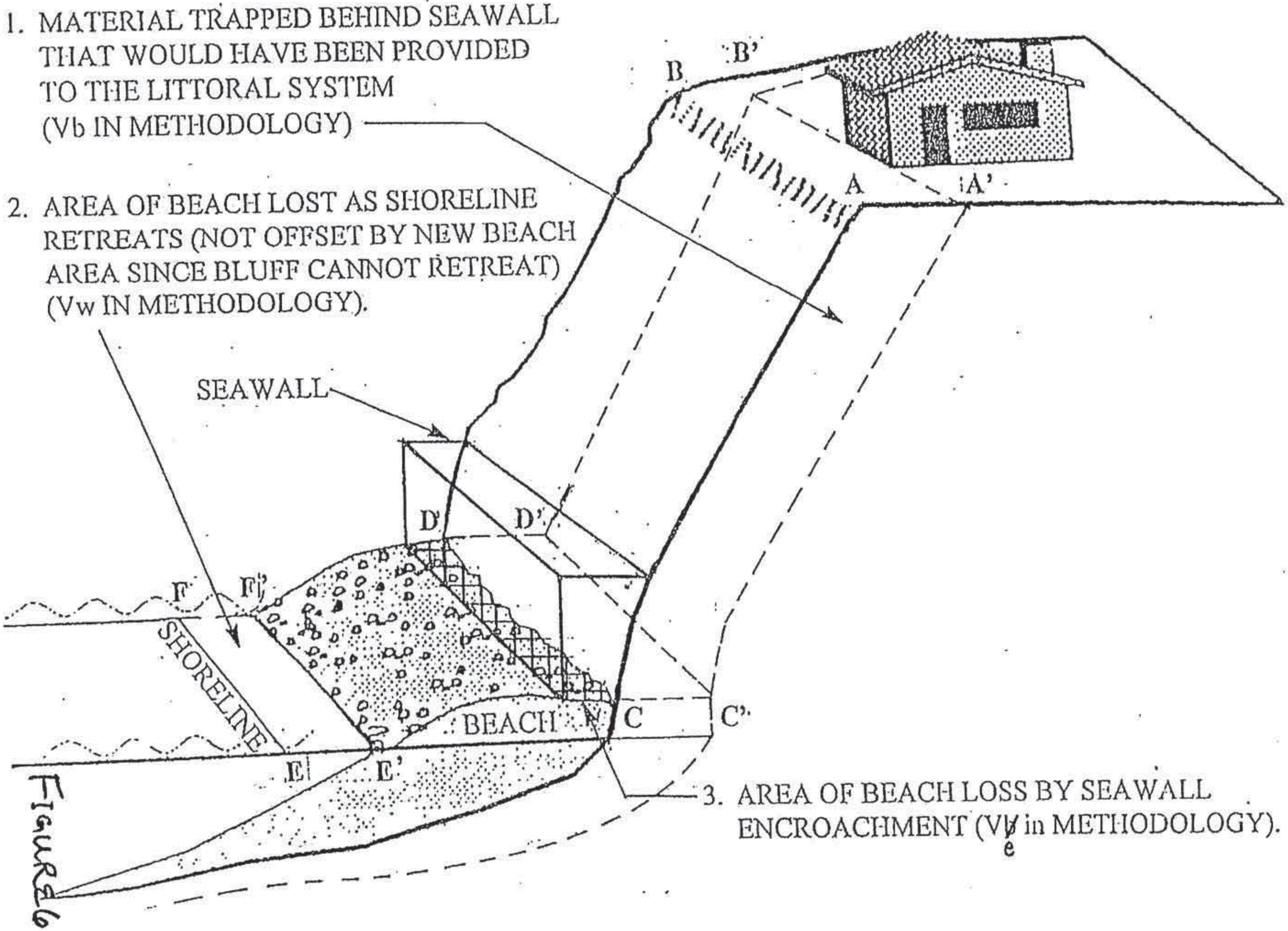


FIGURE 6

EXHIBIT J

ANALYSIS OF BEACH SAND CONTRIBUTION FROM COASTAL BLUFFS AT SOLANA BEACH, CA

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31 July 2006
CE Reference No. 06-12

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Cover Photo: TerraCosta Consulting Group photo of a cliff failure at 371 Pacific Avenue, Solana Beach, CA taken 7 November 2002. Used by permission.

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Summary

The recent study by Young and Ashford (2006) is the first to measure changes in cliff face position over a broad area in the Oceanside Littoral Cell using LIDAR overflight data, albeit over a climatically dry period. However, the quantitative results of per unit and total sand volume yield from cliff erosion in Solana Beach are within the range of some previous studies, and therefore provide no new data in the context of the present CEQA process. The finding of higher cliff sand yields relative to river sand contributions cannot be adjusted to long-term conditions nor be easily reconciled with earlier studies.

The study by Haas (2005) determined that the four sources of beach sand in the Oceanside Littoral Cell were the northern sea cliffs, the rivers, dredge spoils, and the southern sea cliffs. Qualitatively, this conclusion agrees with all previous studies[1]. Haas (2005) however, presents no quantitative estimates of total or percentage beach sand yield from cliff erosion or any other source in either Solana Beach or any other part of the Oceanside cell. The study is therefore not helpful to the present CEQA process.

1. Purpose

The purpose of this report is to address the following questions:

1. Is the amount or percentage of sand on the beach coming from the coastal bluffs larger than was previously believed?
2. Do the recently published studies by Young and Ashford (2006) and Haas (2005) constitute "new information of substantial importance" in the context of the CEQA process?

In the context of Question 2, we consider whether these new studies show that there will be any significant coastal effects not considered in the 2002 Draft Master Environmental Impact Report (DMEIR) or the Draft Final Master Environmental Impact Report (DFMEIR), and/or whether any significant effects previously examined will be substantially more severe than shown in the EIR.

2. Approach

In order to answer the questions posed, we have carried out the following tasks:

1. Reviewed and summarized the new studies by Young and Ashford (2006) and Haas (2005);

[1] Except a small number that also consider the offshore inner continental shelf a significant sand source.

2. Reviewed the DMEIR titled "Solana Beach Shoreline and Coastal Bluff Management Strategies;" and,

3. Reviewed numerous other published and unpublished scientific papers and technical reports on the subjects of cliff erosion, sand sources, and sediment budgets in Solana Beach and other parts of the Oceanside Littoral Cell, dating to as early as 1947.

3. Cliff Erosion

The sea cliffs along the San Diego region's coastline are simply the seaward edges of the flat, gently sloping marine terraces locally known as "mesas" that most of the area's urban development is built upon. The terraces were formed by wave abrasion during past relative still-stands of sea level and subsequently uplifted by tectonic forces to form the urban landscape of San Diego (Flick 2005). Cliff face erosion is one form of terrace erosion that also includes gullying from water runoff and horizontal surface weathering from subaerial forces like water or wind.

These terrace erosion processes now provide the dominant source of sand to the beaches of the Oceanside Littoral Cell[2]. However, the vast majority of this sand is derived from the cliffs and gullies in the northern half and from the southern end of the cell. In fact, studies summarized in USACE (1991) suggest that cliff and gully erosion from these areas has been the dominant sand source in the Oceanside cell for a long time. Even if the proportion of cliff sand contribution had been underestimated relative to river and other sources by previous studies, the fact remains that relatively small amounts of beach sand, both in relative and absolute terms, originate from the sea cliffs between Oceanside and Del Mar.

3.1 Processes

Continued cliff erosion from waves and subaerial processes is a natural consequence of the geological setting of the southern California coast. As cliffs erode and gullies form, they free the loosely consolidated or unconsolidated sediments within the cliffs and terraces and deposit them on the beach[3]. This occurs either episodically during large or

[2] The Oceanside cell extends from Dana Point in southern Orange County to La Jolla in central San Diego. Cliff sections in the northern part of the cell from Dana Point through San Clemente are essentially isolated from the beach and contribute little or no sand to it.

[3] The cover photo on this report shows a good example of this process from Solana Beach, where a slide has occurred at the upper bluff face.

small landslides or cave and notch collapses (Kuhn and Shepard 1984, Harker and Flick 1991, USACE 2003), or more subtly through grain-by-grain erosion of the cliff face. As sea level continues to rise in the future, cliff retreat will continue.

The causes and rates of erosion of the unconsolidated alluvial cliff formations of California (and presumably their contribution to beach sand supply), including those around La Jolla, have been studied at least since Shepard and Grant (1947). That study and others (Shepard 1973) describe cliff erosion processes and rates in other parts of the country and the world as well.

The rate of cliff erosion depends on a number of factors, including cliff material strength, wave climate, amount and intensity of rainfall, and the width of the fronting beach (Benumof and Griggs 1999, USACE 1960). Wave climate, rainfall, and beach width all vary from year to year and on time scales of decades in response to large-scale climate variations and the supply of sediments (Inman and Masters 2005). For this reason, it is important to track cliff retreat and the resulting sand yields over long periods of time. Equivalently, the conclusions drawn from relatively short-term studies cannot be taken as necessarily reflecting long-term conditions or averages (USACE 1991, CDBW and SCC 2002).

While the Oceanside Littoral Cell coastline is almost entirely backed by cliffs, the character of these varies greatly from place to place. The important attributes that determine the amount of material each cliff section contributes to the littoral sand budget include its height and length, the erosion rate, and its sand concentration.

The relative long-term contributions from rivers and cliffs in the Oceanside Littoral Cell vary greatly with both location and time due to natural and anthropogenic causes. For example, the sand-rich, erodible terraces of San Onofre and Camp Pendleton between San Mateo Point and Oceanside in the northern parts of the cell as well as the high, sand-rich cliffs at Torrey Pines between Peñasquitos Lagoon and La Jolla Shores in the south, provide high unit rates of cliff and other terrace-derived sand input, and by far the highest amounts of cliff and terrace sand supply to the Oceanside cell over time.

Severe gullying has been documented by Kuhn and Shepard (1984) at San Onofre and Camp Pendleton (Figure 1). Gullying of the terrace and the cliff face and land slides are also important at Torrey Pines (Figure 2). USACE (1988) cites a 1982 land slide at Torrey Pines that was estimated to contain over 1.3 million cubic meters of sedimentary material.

Figure 1. Photo shows massive land slide (left) and large gully at San Onofre State Beach. Photo 8808 California Coastal Records Project (2002).

Figure 2. Photo shows land slide and surface gulling at Torrey Pines, La Jolla. Photo 9476, California Coastal Records Project (2002).

Sand yield from rivers varies over time due to fluctuations in climate, as noted above. It has also decreased by about half in the Oceanside cell during the 20th century because of flood control and water supply dams built on the rivers and streams in the region (USACE 1987, 1988, 1989, 1990, 1991).

3.2 Quantifying Sand Contribution

The factors related to quantifying cliff erosion include, first, the rate of cliff retreat. This simply refers to the rate that the cliff face is eroded or slides away averaged over the height of the cliff at any particular location. Cliff erosion is known to be highly episodic and site-specific, and upper bluff erosion may lag or be partly or completely unrelated to retreat of the lower sections. For these reasons, cliff erosion data has customarily been averaged over a sufficiently long time and large space to be meaningfully annualized and expressed in units of cm (or ft) per year (cm/yr). The second important variable is the cliff height at the location, expressed in m (or ft). The third variable is the sand content of the cliff material, again averaged over the entire elevation at the location and expressed as a fraction between zero and one, or as a percentage[4].

For the sand content fraction to be useful, it is necessary to determine the "littoral cutoff diameter," which represents the smallest sand grain diameter that will remain on the beach for the wave conditions prevailing at that location. Only the cliff sand fraction

[4] Average sand content is the sand fraction in each cliff layer integrated over the cliff height.

larger than the cutoff is counted[5]. As a cliff retreats, the rate of sand supplied to the beach per unit length of cliff along the beach can then be computed as the product of the cliff retreat rate, the cliff height, and the sand fraction. This is then expressed in units of cubic meters per meter per year (m^3/m/yr), or equivalent English units. Finally, the total rate of sand supply from a section of coast (such as Solana Beach) can be calculated by multiplying the unit rate of supply by the length of the coastal segment[6]. This quantity is then expressed as cubic meters per year (m^3/yr), or equivalent English units.

3.3 Wet and Dry Periods

The work by Young and Ashford (2006) used surveys from 1998 and 2004 spanning a "dry" period of relatively little rainfall over southern California. As the study indicates, this is important because the amount of beach sand delivered to the coast by rivers in the region is small during dry periods, and increases dramatically during "wet" periods when storms bring heavy rainfall and subsequent large river runoff. Haas (2005) does not indicate when her sand samples were gathered[7].

In the San Diego region, episodic, often decades-long, dry periods are punctuated with other episodes, lasting a few years to several decades, of wet, stormy weather (Flick, 2004). The years from 1929 to 1944 were relatively wet, while the subsequent three decades through 1975 were relatively dry with little rainfall or coastal erosion[8]. The winters between 1976 and early 1998 were mostly wet with a return to more storminess. This span featured the major rainfall years of 1978 and 1980, the El Niño winters of 1982-83 and 1997-98, and the average but variable weather from 1983 to 1990. From 1998 to the present, it has been relatively dry again.

Both cliff erosion and river discharge-supplied sand contributions to the beach is expected to increase during wet periods, the former from increased wave attack as well as from gullying and surface runoff, and the latter from greatly increased flow. Scores of studies concerning beach and cliff erosion and the sources of sand on the beaches of

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[5] Differences in assumed littoral cutoff diameter, or alternatively, use of the traditional sand-sized cutoff of 0.0625 mm (4 phi) have led to variations in cliff sand yield estimates among various studies.

[6] More precisely, by integrating the unit rate of supply over the segment length to properly account for longshore variations in retreat rate and sand fraction.

[7] Presumably, samples were collected sufficiently after 2001 for the SANDAG Regional Beach Project nourishment sands to have spread, and before the thesis was published in 2005, and therefore during the same dry period.

[8] This period following World War II also happened to coincide with rapid, and in retrospect, often unwise, coastal development along southern California.

southern California have been completed. While listing or reviewing all these is beyond the scope of this report, it is worth noting that virtually every one known to the authors mentions that the two leading natural sources of beach sand are the rivers and cliffs[9].

4. Summary of New Studies

The two new studies by Young and Ashford (2006) and Haas (2005) have raised legitimate questions about whether they provide substantial new scientific evidence that the contribution of beach sand from cliff erosion in the Oceanside Littoral Cell, and especially in the City of Solana Beach, has been significantly underestimated, either in terms of the unit rate of sand supply, the actual annual or long-term total yields, or in relation to other sources of sand, especially the rivers. Young and Ashford (2006) state: "*…the results of this study indicate that seacliff sediment contributions are a significant sediment source of beach sand in the Oceanside Littoral Cell, and the relative annual seacliff beach-sand contribution is likely higher than previous studies indicate.*" Haas (2005) says: "*While river input is not ruled out as a sediment source, our work reveals that sea cliffs are an important source of sediment that cannot be ignored when studying the Oceanside Littoral Cell.*"

These statements beg the questions of what rates or amounts of cliff sand delivery are "significant" and "important" in the context of the sand budget of the Oceanside cell, and what exactly previous studies have indeed indicated. Young and Ashford (2006) present a quantitative analysis that suggests that 67% of the sand in the cell is cliff-derived for the interval between 1998 and 2004. The remaining 33% is found to derive almost equally from gullying and rivers. Haas (2005) presents no quantitative analysis of sand sources, rates, or budgets, concluding only that "*…the erosion of sea cliffs is a sizeable contributor to the sedimentary budget of the Oceanside Littoral Cell.*" In the context of a medium-to-high wave energy littoral system like the Oceanside cell, "significant," "important," and "sizeable" comparisons of sand sources and rates and amounts of delivery are not restricted simply to origin, but also to sand volume inventory and transport rates from processes including seasonal cross-shore transport and longshore transport potential.

[9] Some studies, including Herron (1983), Flick (1993), and Haas (2005), have also come to the correct conclusion that anthropogenic sources of sand, including coastal construction excavation and dedicated beach nourishment projects formed an important third part of the southern California beach sand budget over the past 60 years. Further, USACE (1989) discussed below suggests that about one-third of the sand in the Oceanside cell may actually come from offshore, a possible source not usually considered.

We suggest that in order for an amount of sand to be "significant," it should be comparable in volume to some measure of the total volume in the littoral system. And, in order for a rate of sand delivery to be "important," it should be comparable not only to other sources, but also to the rate at which it can be moved from the source area or removed from the system altogether. In the context of coastal armoring to protect homes and infrastructure in places like Solana Beach and the consequences of the resulting deprivation of sand to the beach, we think an economic perspective is also needed. That is, the cost of simply replacing the sand deprived to the system due to armoring must be compared with the costs associated with not armoring. The California Coastal Commission in-lieu fee mitigation program addresses this concept (CCC 1997).

4.1 Young and Ashford (2006)

This study used two airborne LIDAR[10] topographic surveys flown in April 1998 and April 2004 to determine the horizontal erosion of the cliffs and the erosion of gullies in the Oceanside Littoral Cell over that interval[11]. Young and Ashford (2006) is the first study to use this technology to measure large-scale cliff erosion in the Oceanside cell. This makes it an important contribution that provides the basis for much-needed future monitoring of these important features. The study presents relevant results for eight sections of the Oceanside cell between Dana Point and Torrey Pines[12].

Use of this technology for coastal surveys is about ten years old, and offers a dramatic breakthrough in the ability to accurately measure beach and cliff contours, and therefore successive changes in elevation and cliff face position. When LIDAR technology is mounted on an airplane, large sections of coast can be surveyed in just a few hours. The USGS conducted LIDAR surveys along the west coast, including San Diego, in 1997 and 1998 using NASA instruments[13]. Beginning in 2002, the Southern California Beach Processes Study (SCBPS) at Scripps Institution of Oceanography began flying twice-yearly LIDAR surveys to track large-scale seasonal and interannual beach topography changes. Young and Ashford (2006) used data from this suite of measurements for their cliff erosion analysis.

[10] LIDAR stands for LIght Detection and Ranging and uses laser light in the same way that RADAR uses radio waves to detect surfaces and measure their distance and direction.

[11] The key to determining differences in topography from successive LIDAR surveys is the determination of highly accurate GPS positions for the LIDAR instrument during each survey.

[12] Neither the Dana Point and San Clemente cliffs, nor those in Oceanside were considered further since they are isolated from the shore by development.

[13] NASA developed the technology to track climate-related erosion of the Greenland ice sheet.

Details of the processing of the voluminous LIDAR data, as well as the resulting cliff elevation and volume change calculations and analyses presented by Young and Ashford (2006), are complex. Detailed presentation, analysis, and critique of their methods, accuracy, and possible flaws, if any, are beyond the scope of this report. For these reasons, the results of their study are used as presented for the purposes of this review.

Table 1 summarizes the cliff erosion rates and relevant unit and total sand contributions for each of the coastal sections considered by Young and Ashford (2006). The total sand yield figures (Column 5) exclude gully contributions, and include only sediments large enough to remain on the beach[14].

Table 1. Cliff erosion and sand yield summary from Young and Ashford (2006)

Section	Cliff Retreat Rate*	Cliff Sand Content	Cliff Sand Yield		Cliff Sand Yield	Gully Sand Yield	
	cm/yr	***%***	***$m^3/m/yr$***	***m^3/yr***	***%***	***$m^3/m/yr$***	***m^3/yr***
San Onofre	**13.2**	**71**	**3.6**	**40,500**	**53**	**1.1**	**11,900**
Camp Pendleton	**6.5**	**54**	**0.6**	**2,900**	**4**	**0.8**	**4,100**
Carlsbad	**3.8**	**80**	**0.5**	**3,200**	**4**	**0**	**0**
Leucadia	**5.8**	**80**	**1.2**	**4,700**	**6**	**0**	**0**
Cardiff	**6.2**	**80**	**1.2**	**4,600**	**6**	**0**	**0**
Solana Beach	**12.8**	**75**	**2.2**	**6,200**	**8**	**0**	**0**
Del Mar	**10.8**	**75**	**1.4**	**3,700**	**5**	**0.2**	**500**
Torrey Pines	**4.8**	**42**	**1.7**	**11,100**	**14**	**0.5**	**3,500**
Oceanside Cell	***8.0***		***1.8***	***76,900***	***100***	***0.5***	***20,000***

* Approximate values read from Figure 7 graph in Young and Ashford (2006).

[14] The littoral cutoff diameter ranges between approximately 0.06 to 0.088 mm (4 phi to 3.5 phi), depending on location.

Inspection of Table 1 shows that 71% of the total cliff sand yield during the study period came from San Onofre, Camp Pendleton, and Torrey Pines (lightly shaded rows). The remaining 29% was contributed by the North San Diego County cities between Carlsbad and Del Mar, including 8% from Solana Beach. Solana Beach was found to contribute a unit rate of 2.2 $m^3/m/yr$ of sand to the beach, or a total of 6,200 m^3/yr.

Young and Ashford (2006) concluded that 67% of the sand in the Oceanside cell during the study period came from cliff erosion. That equals a ratio of cliff to river yield of 2 to 1. In order to arrive at this conclusion, Young and Ashford (2006) assumed that the river sand yield between 1998 and 2004 was equal to the dry-year average sand flux for the Oceanside cell reported by Inman and Masters (2005), which is 19,100 m^3/yr. In contrast, estimates of average long-term river yield values for the Oceanside cell range from about 100,000 to over 200,000 m^3/yr, a factor of five to ten times higher (see Section 5.1.3 below).

4.2 Haas (2005)

This study represents an extensive field sampling and laboratory analysis of grain size and mineralogical characteristics of the beach sands in the Oceanside Littoral Cell in order to identify the sediment source regions. The work involved collecting and analyzing over 100 sand samples from the "mean high tide line" along the beach from Dana Point to La Jolla Shores, as well as numerous samples from cliff talus piles and along coastal river courses. The San Luis Rey, Santa Margarita, and San Dieguito rivers were sampled. Curiously, however, results from San Juan Creek, San Mateo Creek, and San Onofre Creek are not presented (or cited).

Haas (2005) details the geological properties of the various cliff and river drainage source regions and explains which minerals or sand grain characteristics are diagnostic for each. For example, rivers are relatively rich in the minerals amphibole and tourmaline. Cliffs are richer in the clear version of quartz grains compared with beach sands and beach nourishment sand derived from offshore, which have relatively higher fractions of frosted quartz, presumably from physical weathering in the surf. From north to south in the Oceanside cell, grain size decreases and the percentage of clear quartz increases, suggesting continuous input of sand from the cliffs.

It is obvious that a huge amount of effort and careful, painstaking work went into this UCSD Master's of Earth Science thesis, and the analysis results are likely to be valuable as a baseline of information in the Oceanside cell. And, as with Young and

Ashford's (2006) study, the results are herein taken as presented, since a detailed evaluation and criticism is beyond the scope of this report.

However, it is emphasized that the Haas (2005) conclusions regarding relative yields from different sand sources are qualitative and not quantitative. The stated purpose of the study "*was to identify the major sediment contributors to the Oceanside Littoral cell with grain size analysis and mineral identification.*" This was done, and "*three major sediment sources were identified, rivers, cliffs, and anthropogenic sources (beach replenishment projects, harbor and lagoon dredging).*" The northern and southern sea cliffs (presumably San Onofre-Camp Pendleton and Torrey Pines, respectively) are specifically identified as being the distinct sea cliff sources of beach sand. Based on the fact that quartz grains in beach sand increase in clarity and angularity as sediments are transported southward and away from the rivers in the central part of the cell, the main conclusion is that "*the erosion of the sea cliffs is a sizeable contributor to the sedimentary budget of the Oceanside Littoral cell.*" However, no definition of "sizeable" is provided.

5. Previous Work

As has been mentioned, scores of studies have considered the cliffs, rivers, beaches, and coastal processes of the Oceanside Littoral Cell. In fact, perhaps because Scripps Institution of Oceanography has been located in La Jolla since about 1900 and a number of its researchers have been interested in coastal processes since the beginning, this coast may be the most studied in the whole world. For example, at least ten sediment budget studies of the Oceanside Littoral Cell had been conducted by the time the U.S. Army Corps of Engineers' Coast of California Storm and Tidal Waves Study (CSTWS) final report was issued (USACE 1991; see Table 9-1 therein).

A number of previous studies are cited and summarized in this section in order to provide background information regarding previous work on beach sand sources. This earlier work can then be compared to the new studies of Young and Ashford (2006) and Haas (2005) to determine what, if any, new results they contain.

5.1 USACE (1991) and DBW and SCC (2002)

Around 1984, the Los Angeles District of the U.S. Army Corps of Engineers began a comprehensive study of the coast dubbed the *Coast of California Storm and Tidal Waves Study* (CCSTWS). The initial and ultimately most intensive efforts were carried out in the San Diego region comprising the three local littoral cells: Oceanside, Mission

Bay, and Silver Strand. Virtually every historical, geological, meteorological, and physical aspect of the coast was studied and reported upon in a large number of CCSTWS publications, culminating in the ten-chapter comprehensive summary, *San Diego Region, "State of the Coast" Report* (USACE 1991). Several contributory efforts sponsored by the CCSTWS that considered cliff erosion and related beach sand yields to the Oceanside cell include USACE (1986, 1987, 1988, and 1990).

USACE (1991) contains extensive discussion of the importance of coastal cliff and bluffland[15] sand contributions to the sand budget of the Oceanside Littoral Cell. The discussion makes several important points. These include the fact that wave-driven cliff erosion increases as the width of the fronting beach decreases (Williams, *et al.* 2004; Benumof and Griggs 1999). Also, the rate of sea level rise has a profound effect on the relative importance of cliff-derived beach sand versus river contributions.

As sea level has risen to its current level, the gradient of coastal rivers has decreased, and this in turn has decreased the rate of river sand delivery, compared with that from terrace erosion, to the point where terrace erosion dominates the littoral sand budget (USACE 1991; Figure 10-2 reproduced in Appendix I). Sediment budget summaries presented in USACE (1991) Figure 10-7 (reproduced in Appendix II) clearly show that the input of sand from cliff and terrace erosion (denoted as Q_b) has exceeded the contribution from rivers (denoted Q_r) from at least 1900 (under "natural" conditions), through the dry period from 1960 to 1978 ("uniform NW wave climate"), and the average but variable weather span from 1983 to 1990 ("variable W wave climate"). Finally, the fact that river yield has been cut by about half because of the construction of flood control and water storage dams is discussed.

5.1.1 Cliff Erosion Rates

Table 2 shows a summary of the cliff and gully sand yield derived from USACE (1991) and presented in a way that is directly comparable to Table 1, which summarizes the results of Young and Ashford (2006). The unit and total cliff sand yields (Columns 4 and 5) in the two studies differ by a factor of about 2.5.

These results suggest that the yield from cliff erosion in the southern part of the Oceanside cell from Carlsbad Canyon to La Jolla may have been underestimated by the USACE studies. In this context, it is noted that none of the CCSTWS studies made any cliff retreat measurements in the urban areas of North San Diego County from Carlsbad

[15] This includes gullying and surface erosion from coastal terraces.

through Del Mar, presumably because it was assumed that these cliffs did not yield much sediment. A much earlier Army Corps of Engineers study of the region (USACE 1960) states:

> *"The principal sources of beach and nearshore material along the San Diego County coastline are the streams which periodically bring large quantities of sand directly to the shore during periods of floods. The sea cliffs of unconsolidated material, which are gradually being eroded by waves, supply some beach material."*

Table 2. Cliff and total sand yield summary from USACE (1991)

Section	Cliff Retreat Rate	Cliff Sand Content	Cliff Sand Yield*		Cliff Sand Yield	Gully Sand Yield^	
	cm/yr	***%***	***$m^3/m/yr$***	***m^3/yr***	***%***	***$m^3/m/yr$***	***m^3/yr***
San Onofre	**6**	**72**	**1.7**	**19,000**	**64**	**16**	**119,000**
Camp Pendleton	**8**	**54**	**0.7**	**4,000**	**13**	**11**	**86,000**
Torrey Pines	**3**	**42**	**1.1**	**7,000**	**23**	**5.8**	**35,000**
Oceanside Cell				***30,000***	***100***		***240,000***

* For consistency, unit and total cliff sand yields (Columns 4 and 5) are based on cliff length values reported by Young and Ashford (2006), which differed somewhat from USACE (1991).

^ Values in USACE (1991) Table 9-6 were adjusted by subtracting cliff yields (Columns 4 and 5).

This conclusion regarding the relatively small cliff contribution was undoubtedly based on the observations also described in USACE (1960):

> *"The field sheets of the 1887 and 1934 surveys were examined and no difference could be found in the location of the bluff lines as shown on the sheets, and it is believed that no serious bluff erosion occurred along this section of the coast between 1887 and 1934. Several longtime residents of Encinitas and Leucadia were interviewed and all stated that to their knowledge there have been no large slides of the bluffs due to erosion or undercutting by wave action."*

Curiously, the 1941 collapse of the cliff at the site of the Self Realization Fellowship (Swamis) in Encinitas, or the 1958 landslide in Cardiff that destroyed part of Highway 101 are not mentioned (Kuhn and Shepard 1984).

Table 3. Cliff erosion and actual sand yield summary from CDBW and SCC (2002)

Section	Cliff Retreat Rate	Cliff Sand Content	Actual Cliff Sand Yield*		Cliff Sand Yield
	cm/yr	*%*	*$m^3/m/yr$*	*m^3/yr*	*%*
Capistrano	**15**	**57.4**	**1.2**	**2,300**	**5**
San Onofre & Pendleton	**15**	**57.4**	**0.6**	**11,900**	**28**
Carlsbad	**15**	**57.4**	**0.6**	**3,200**	**8**
Leucadia	**20**	**57.4**	**1.4**	**4,500**	**11**
Encinitas	**10**	**57.4**	**0.9**	**520**	**1**
Cardiff	**10**	**57.4**	**0.6**	**640**	**2**
Solana Beach	**10**	**57.4**	**0.6**	**1,300**	**3**
Peñasquitos	**12**	**57.4**	**0.7**	**1,400**	**3**
Torrey Pines	**15**	**57.4**	**2.4**	**16,200**	**39**
Oceanside Cell				***41,960***	***100***

* CDBW and SCC (2002) estimated the natural and actual cliff sand yield, the difference being the amount of sand blocked by cliff armoring. The total blocked sand amounted to about 9,500 m^3/yr, about half of which was blocked by development just south of Dana Point at San Juan Capistrano and San Clemente.

In contrast, numerous consulting engineering studies exist that consider cliff erosion rates in these areas in great detail, including, for example, Lee (1983), already mentioned, as well as TerraCosta (2003), which found a rate of cliff sand contribution for Solana Beach of between 1,900 and 11,400 m^3/yr. Higher cliff erosion rates are also corroborated by information contained in CDBW and SCC (2002) that is summarized in Table 3.

While the coastal section designations in Young and Ashford (2006) and CDBW and SCC (2002) are similar, they differ in detail, and are therefore not strictly comparable. However, the general pattern of higher unit and total sand yields from the northern and southern ends of the Oceanside cell are consistent. CDBW and SCC (2002) used a larger LCD and therefore a smaller (57.4%) cliff sand content percentage than Young and Ashford (2006) and USACE (1991) in all segments except Torrey Pines (compare Column 3 in Tables 1, 2, and 3). Adjusting each total sand yield volume entry in Table 1 (Column 5) by the appropriate sand content ratio to make it comparable to each corresponding value in Table 3 results in a reduction of the total Oceanside cell sand volume for the Young and Ashford (2006) study to about 67,500 m^3/yr, which is about 60% larger then the 41,960 m^3/yr found by CDBW and SCC (2002).

5.1.2 Gully Sand Yields

In contrast to the cliff yields, the unit and total sand yield estimates from gullies disagree by factors of 10 or more between Young and Ashford (2006) and USACE (1991). This may perhaps be explained by the observation that very large gullying due to poor drainage control was observed in the 1970s in the San Onofre and Camp Pendleton regions, as mentioned above (Kuhn and Shepard 1984). If these drainage problems were fixed, this would have decreased the gullying contribution in the later surveys. As was also noted, the Young and Ashford (2006) measurements were made during a dry period with little rainfall to cause gully erosion.

On the other hand, inspection of Table 10-7 in USACE (1991) suggests that terrace sand inputs (denoted as Q_b) are consistently at least twice as big during dry periods as during average ones[16]. What exactly this means, if anything, is not known. However, it does suggest that caution should be taken to not overstate the long-term implications of observations made over a relatively short, dry period, such as those presented by Young and Ashford (2006) since dry-period bluff sand yields may overestimate the long-term average.

[16] Compare the Q_b "Input" values between the "Uniform NW wave climate" and "Variable W wave climate" columns for the central, harbor, and southern sections of the Oceanside cell (Appendix II).

5.1.3 River Sand Yields

USACE (1991; Table 9-7 and references therein) shows that the long-term sand yield from rivers under present conditions in the Oceanside cell ranges between about 90,000 and 110,000 m^3/yr, depending on whether low or high published estimates are used. This suggests a relative cliff (excluding gully) to river sand yield ratio of about 30,000 to 100,000, or about 0.3 to 1. Stow and Chang (1987; Table 1) summarize the various river sediment yield estimates in the Oceanside cell up to that time and discuss the complexities associated with making them. They show that estimates for current conditions vary from 122,000 to 198,000 m^3/yr. Flick (1993) made a similar summary and found that values ranged from 112,000 to 203,000 m^3/yr. These estimates suggest a cliff to river ratio possibly as low as 0.15 to 1. These three studies represent a range of values about five to over ten times higher than the average dry-year yield estimate of 19,100 m^3/yr given by Young and Ashford (2006) who found a cliff to river sand yield ratio of about 2 to 1.

CDBW and SCC (2002, Table 7.1) indicate a long-term river sand yield for the Oceanside cell as about 93,000 m^3/yr. This results in a cliff to river sand yield ratio of about 0.45 to 1, the largest value after Young and Ashford (2006), but still a factor of about four smaller.

5.1.4 Sand Inventory and Transport Rates

USACE (1991) also presented information concerning the total amount of sand in the Oceanside littoral system, longshore transport rates, and several sand budget estimates already mentioned. In the reach from Carlsbad Submarine Canyon to Point La Jolla, the inner continental shelf between depths of 1-30 m was estimated to hold 89.6 million cubic meters of sand, or 2,800 m^3/m. Any subaerial sand on the beach face would be in addition to this amount.

Longshore sand transport potential is defined as the rate that wave forces can move sand along the coast, assuming that sand is available. The longshore transport rate varies with the wave height and angle of approach, both of which change with season and on interannual time scales. Many estimates have been made In the Oceanside cell, but long-term averages in the southern part are likely around 600,000 m^3/yr to the south (in winter) and 400,000 m^3/yr to the north (in summer). This amounts to a total gross value of 1 million m^3/yr, with a net rate of 200,000 m^3/yr to the south. There is some evidence that the net transport rate has decreased since about 1978, owing to changes in wave climate, but this probably has not altered the gross transport potential.

Seasonal changes in beach profile configuration are driven by variations in wave height and period between summer and winter. Larger storm waves in winter tend to move sand offshore narrowing the beach, while gentler summer swell moves it back onshore to widen the beach. Typical seasonal cross shore volume transport rates in the Oceanside cell average about 90 m^3/m (Inman *et al.* 1993).

5.2 Harker and Flick (1991) and Flick (2001)

Allen Harker, a resident of Solana Beach, began to observe beach sand level changes and document cliff erosion at the northern end of the city around 1984 as part of a series of school science fair projects. By 1990, he had amassed enough information to make a presentation at a professional conference, which published the results in its proceedings (Harker and Flick 1991).

Measurements of two cliff slides and two cave collapses in his study area between 1986 and 1989 showed that they provided on the order of 1 $m^3/m/yr$ of beach sand. Previous work by Lee (1983) had shown that up to 3 $m^3/m/yr$ of sand had been deposited on the beach by cliff erosion between about 1971 and 1982 in the same general area. The main conclusion drawn by Harker and Flick (1991) was therefore that a range of values between 1 and 3 $m^3/m/yr$ of sand was a plausible estimate of cliff sand yield for this section of Solana Beach.

Extrapolating this range of estimates to the entire length of Solana Beach (2,800 m, as used by Young and Ashford 2006) results in a total annual cliff sand yield of between 2,800-8,400 m^3/yr. Harker and Flick (1991) found 90% sand content in the slides they examined, whereas the actual overall cliff sand content in Solana Beach is about 75%. Adjusting for this difference results in a yield of 2,300-7,000 m^3/yr.

Flick (2001) increased the estimate (and upper limit) of the amount of sand that the sea cliffs at Solana Beach could provide to 0.8 to 5 $m^3/m/yr$ based on plausible ranges of cliff retreat rates[17]. This resulted in a range of total annual cliff sand yield for Solana Beach of between about 2,200-14,000 m^3/yr, and accounts for the 75% sand content.

Inspection of Table 1 shows that the respective unit and total cliff sand yield values of 2.2 $m^3/m/yr$ and 6,200 m^3/yr, found by Young and Ashford (2006) for Solana Beach using a far more sophisticated method, is just below the mid-point of these earlier and far cruder estimates.

[17] The range quoted in Flick (2001) was 1-6 $yd^3/yd/yr$. The new upper limit was based on historical rates of sea level rise and the slope of the shore platform.

5.3 Inman (1952)

Long-time Scripps Institution of Oceanography professor Douglas L. Inman conducted his Ph.D. dissertation research on the nearshore sediments of La Jolla (Inman 1952). The purpose of the investigation was to characterize the areal and seasonal variation in the physical characteristics of the sand on the beach and nearshore shelf near Scripps.

It was found that the spatial distribution of physical properties such as particle size and sorting characteristics was a strong function of depositional environment. Foreshore sands were the best sorted, while sand in the surf zone was considerably coarser and less sorted since the intense wave action removed finer fractions. Offshore sands tended to be fine to very fine and predominantly well sorted. These observations lead to the conclusion that sand characteristics varied most strongly in the cross-shore direction and were essentially "banded" in the longshore direction. It was found that these general properties were modulated seasonally, but not to a degree that overcame the general underlying structure.

Inman (1952) also found that no simple relationship existed between the amount of any particular mineral species and its position on the beach. He found evidence of selective sorting of material on the basis of size, shape, and density, and that the relative importance of these factors changed markedly with time and location, presumably due to variability in wave forcing. He also determined that the hydraulic characteristics of sediment provided a better indicator of areal distribution of sands than size alone.

The study by Inman (1952) raises some questions about the results presented by Haas (2005), especially regarding the effects, if any, of seasonal and cross-shore variations, which were not addressed. Any further evaluation of these points is beyond the scope of this report.

5.4 USACE (1989)

The purpose of the study presented in USACE (1989) was to identify the local beach sand sources and the volumetric contribution of each using Fourier grain shape analysis (FGSA)[18] of fluvial, cliff, beach, and inner shelf samples from the three littoral cells in the San Diego region. Additional detailed fluvial, cliff, and beach sand mineral analyses

[18] FGSA involves detailed spectral decomposition of the silhouette shape of sand grains into circular Fourier harmonics. For example, the simplest, lowest order harmonic shape would be a perfect circle. Any arbitrary shape can in principle be described by the sum of a series of orthogonal circular functions, just as an arbitrary time series can be described as the sum of a Fourier series of sine waves. Smoother shapes therefore contain lower circular frequencies in their shape spectrum, whereas more angular grains contain higher spatial frequencies.

were done on samples collected at about 30 stations along the Oceanside Littoral Cell, from the cliffs, and in all the rivers. Sampling was carried out twice, in April and October 1986, in order to detect any seasonal differences. Mineralogic analysis included thin section heavy mineral identification. However, no samples were collected between Buena Vista Lagoon in Oceanside and San Elijo Lagoon in Encinitas.

The relative percentage contributions of beach sand from the upcoast (northern) shelf and beach, rivers, cliffs, and the downcoast (southern) shelf and beach was tabulated for each of four sub-cells in the Oceanside cell. A summary of the findings is presented in Table 4, which shows the percentage from each source in each of the defined sub-cell sections from the end-of-winter sampling. Several trends stand out. The first is that about half of the sand in each section arrives via longshore transport either from up or downcoast. The second is that river sources are relatively more important north of Oceanside, where San Juan Creek, San Mateo Creek, and the Santa Margarita River provide a substantial percentage of sand on the beach. In contrast, in the southern reach, the cliff contribution percentage is larger relative to the river percentage.

Table 4. Summary of relative beach sand source percentages in sections of the Oceanside Littoral Cell (USACE 1989)

Section	Northern Shelf	Northern Beach	River(s)	Cliff	Southern Beach	Southern Shelf
Capistrano	**8**		**40**		**40**	**12**
San Onofre	**5**	**8**	**39**	**13**		**35**
Oceanside	**28**	**11**	**6**		**46**	**9**
Encinitas	**22**	**41**	**5**	**12**	**8**	**11**

Solana Beach is in the Encinitas sub-cell, stretching from Carlsbad Submarine Canyon to La Jolla Submarine Canyon. It was determined that the northern shelf provided 22% of the sand in this compartment, upcoast beaches 41%, the San Dieguito River 5%, the cliffs 12%, the downcoast beaches 8%, and the southern shelf 11%, with negligible seasonal variation. While no sand volume rates from the various contributing sources are presented, it is interesting to note that the ratio of cliff to river contributions of sand in this compartment is 12% to 5%, or 2.4 to 1. However, of course, both river and cliff sources are overshadowed by the 33% share found to apparently come from offshore.

Overall for the Oceanside cell, the results in USACE (1989) suggest that an average of 35% of the medium grain size beach sand is derived from relic deposits on the inner continental shelf outside the region normally associated with seasonal beach profile changes. This result had not been widely expected, even though the role of the inner shelf in beach sediment budgets has long been uncertain, and remains so. If this result is correct, it means that river and cliff sources of sand may both be relatively less important than was thought.

The results presented in USACE (1989) are less than completely useful since no comprehensive summary of sand source percentages is given for the Oceanside cell as a whole, and even more importantly, no volume rates from the various contributing sources are presented. This makes it impossible to compare such rates to other studies. However, it does serve to show that at least one comprehensive mineralogic analysis was carried out in the Oceanside cell before Haas (2005).

6. Solana Beach Draft Master Environmental Impact Report

The Solana Beach DMEIR (AMEC 2002a) is a comprehensive and well written document that looks at the broad range of issues associated with alternative strategies for managing the city's coastline. Public and agency comments are addressed in detail in the DFMEIR (AMEC 2002b). The effect of seawalls on beaches is summarized in AMEC (2002a, Section 3), where short and long-term effects of seawalls are defined and discussed. Notably, the document recognizes that the serious effects are long term, and these include:

- Loss of Beach Width – due to passive erosion if there is a retreating shoreline;
- Reduction in Sediment Contribution – from impoundment behind seawalls;
- Beach Encroachment – from placement of seawalls on the beach;
- Wave Reflection – not unlike that from the resistant lower cliff face;
- Erosion of Tidal Terrace (shore platform) – from wave action and halting of cliff erosion;
- Discontinuous Protection Effects – from any breaks in seawall protection; and
- End Scour – from terminal flanking at the end of a seawall.

For the purposes of this report, the main questions are related to the reduction in sediment contribution from impoundment behind seawalls constructed to protect development (second bullet above). Based on Flick (2001), the DMEIR (AMEC 2002a) assumed the midrange value of 3.5 $yd^3/yd/yr$ (equivalent to 2.9 $m^3/m/yr$) as the average unit amount of beach sand contributed by cliff erosion in Solana Beach. This results in a total sand yield for the city of about 10,500 yd^3/yr (equivalent to 8,000 m^3/yr), as cited in AMEC (2002b)[19]. Note that this value is almost 30% higher than the 6,200 m^3/yr of sand yield found by Young and Ashford (2006).

7. Answers to Questions Posed

The purpose of this report is to determine whether the new studies of Haas (2005) and Young and Ashford (2006) provide new information that shows any of the following:

1. Is the amount or percentage of sand on the beach coming from the coastal bluffs larger than was previously believed?
2. Do the recently published studies by Young and Ashford (2006) and Haas (2005) constitute "new information of substantial importance" in the context of the CEQA process?

In regard to Question 2, we consider whether these new studies show that there will be any significant coastal effects not considered in the 2002 Draft Master Environmental Impact Report (DMEIR, AMEC 2002a) or Draft Final Master Environmental Impact report (DFMEIR, AMEC 2002b), or that any significant effects previously examined will be substantially more severe than shown in these reports.

7.1 Amount and Percentage of Sand?

Young and Ashford (2006) provide new data that suggests previous comprehensive studies summarized in USACE (1991) may have underestimated by more than a factor of two the unit and total cliff sand contribution to the Oceanside cell (excluding the other terrace sources). Second, if the Young and Ashford (2006) results are representative of long-term values, most previous studies also apparently underestimated the relative importance of the cliff sand contributions in the central part of North San Diego County between Oceanside and La Jolla.

[19] AMEC (2002a) quoted an incorrect total value of 9,000 yd^3/yr based on Flick (2001), which contained the incorrect value of 1.4 miles for the length of Solana Beach. The correct value is 1.7 miles, or 2,800 m as given by Young and Ashford (2006). Use of the correct length gives the higher and correct value of 10,500 yd^3/yr cited in AMEC (2002b).

In fact, the most comprehensive studies cited (USACE 1989, 1991) did not even sample these areas under the (correct) assumption that not much total sand volume was produced there. CDBW and SCC (2002) found substantially higher erosion rates than those in USACE (1991), but lower overall sediment yield rates than Young and Ashford (2006). Nevertheless, other studies including Harker and Flick (1991) and Flick (2001), and those done by consulting engineers, *did* consider these areas in great detail and have found higher rates (Lee 1983, TerraCosta 2003).

Based on the results presented in Young and Ashford (2006), it is evident that the amount of sand found to have been eroded from the cliffs at Solana Beach during their study period is actually smaller than the average amount considered in the DFMEIR (AMEC 2002b). Furthermore, several previous works presented estimated unit and total cliff erosion sand contribution values for Solana Beach that ranged from less than one-half (USACE 1991, CDBW and SCC 2002), to over twice (Harker and Flick 1991, Flick 2001, TerraCosta 2003) the values found by Young and Ashford (2006). Finally, the amounts of sand in question from Solana Beach are very small fractions of other important measures of the littoral sand budget, including the volume per unit length of sand in the littoral system, the longshore transport potential, and the seasonal cross-shore exchange associated with summer and winter beach profiles.

The study by Haas (2005) presents no quantitative information concerning the unit or total sand yield from cliff erosion, saying only that it is "*sizeable*." Therefore, this study is not relevant for the purposes of this report.

For these reasons, the answer to the first part of Question 1 above (with respect to amounts of sand) is "No."

As far as the percentage contribution of cliff sand to the littoral budget in the Oceanside cell is concerned, the Young and Ashford (2006) results suggest that the ratio of cliff sand contribution to river yield is about 2 to 1 during the relatively dry period from 1998 to 2004. Other comprehensive studies of long-term cliff to river sand yield ratios found values ranging from 0.15-0.45 to 1, neglecting gully contributions. When counting gully contributions to the cliff (terrace) sand yield, these studies show long-term cliff to river sand yield ratios in the range of at least 1 to 1, to over 2 to 1.

Young and Ashford (2006) found that about 8% of the total cliff sand in the Oceanside cell came from Solana Beach. This is nearly three times as high as the value of 3% reported by CDBW and SCC (2002), again based on long-term study. All the larger ratios and percentages in Young and Ashford (2006) are a direct result of the higher unit and total cliff sand volume contributions they found relative to all earlier comprehensive long-term studies, and the assumed (low) dry-year river yield value. USACE (1991) shows that terrace sand yields may be at least twice as big during dry periods as during average ones.

This suggests that caution should be taken to not overstate the long-term implications of Young and Ashford (2006), since observations made over a relatively short, dry period, such as those presented may overestimate the long-term average. However, with the information at hand, it is impossible to reconcile the results of Young and Ashford (2006) with those of the earlier studies. Furthermore, it is not known what the results of future or long-term LIDAR surveys will reveal.

Given these facts, we conclude that Young and Ashford (2006) produced highly useful new information suggesting that the relative importance of the cliff sand contribution to the Oceanside cell in general, and from the Solana Beach segment in particular, may have been underestimated. However, there is no way to adjust these dry-year findings to reflect long-term conditions, and no corroborating evidence is available.

For these reasons, the answer to the second part of Question 1 above (with respect to percentages of sand) is "Perhaps."

However, notwithstanding the fact that we at this time do not know the significance of Young and Ashford's (2006) results with respect to percentage cliff sand yield from Solana Beach relative to other sources, especially rivers, it ultimately cannot be very important in the context of the MEIR. Even if the Young and Ashford (2006) results turn out to be representative of long-term cliff erosion conditions at Solana Beach, and it was confirmed that the rivers indeed supplied relatively less sand than previously thought, the fact remains that the total amount of sand produced by these cliffs is relatively small.

Every known study agrees on this point, including Young and Ashford (2006). The question is not whether this source is relatively small, but how small. Ultimately, the issue that the MEIR revolves around concerns the actual amount of sand likely to be deprived from armoring the Solana Beach cliffs. The issue is *not* what environmental impacts cliff armoring at San Onofre, Camp Pendleton, or Torrey Pines would have[20]. The issue is Solana Beach where the impact of armoring on the sand supply is minor and can be mitigated at reasonable cost.

[20] Everyone is likely to agree that this would be a bad idea, given that these locations certainly provide the majority of the terrace erosion derived sand in the Oceanside cell, and probably the major part of all the sand.

7.2 Substantial New Information?

Based on the numerous studies mentioned or reviewed in this report, it is clear that the importance of cliff erosion in southern California has been appreciated for many decades. Furthermore, the contribution of cliff-derived sand to the sand budget of beaches in general and southern California beaches in particular, has also been understood as well as the subject of numerous research efforts.

While Haas (2005) collected a far greater number of samples from the subaerial beaches of the Oceanside cell than previous studies, other work has addressed the same question with more sophisticated analysis (USACE 1989) or provided important information concerning seasonal and aerial variability (Inman 1952) that was apparently not considered by Haas (2005). Furthermore, at least one previous study (USACE 1989) developed some quantitative information concerning the relative importance of cliff sand contributions, while Haas (2005) did not.

For these reasons, we conclude that neither Haas (2005) nor Young and Ashford (2006) provide any new qualitative understanding of these issues. This is in no way intended to minimize the significant technical contribution of Young and Ashford (2006) or the painstaking work of Haas (2005). It is only to suggest that with respect to the CEQA process at Solana Beach, no important new information was produced by these studies. Indeed, we recognize that Young and Ashford's (2006) application of the relatively new LIDAR technology in the Oceanside cell is an important contribution and sets the stage for much better future quantitative understanding of the role of cliff sand contributions to the littoral sand budget.

As stated previously, the DMEIR (AMEC 2002a) appears to cover the relevant coastal processes, while the DFMEIR (AMEC 2002b) addresses public and agency comments. Neither Haas (2005) nor Young and Ashford (2006) raise any substantive coastal processes that are not covered in the MEIR documents. Similarly, neither new study points to any significant coastal effects that will be substantially more severe than what was considered in these reports. In fact, the results of Young and Ashford (2006) suggest that the sand loss due to cliff armoring may in fact be *less* severe than was assumed in the DFMEIR (AMEC 2002b).

For these reasons, we conclude that the answer to the second question posed is "No."

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APPENDIX I - USACE 1991, Figure 10-2

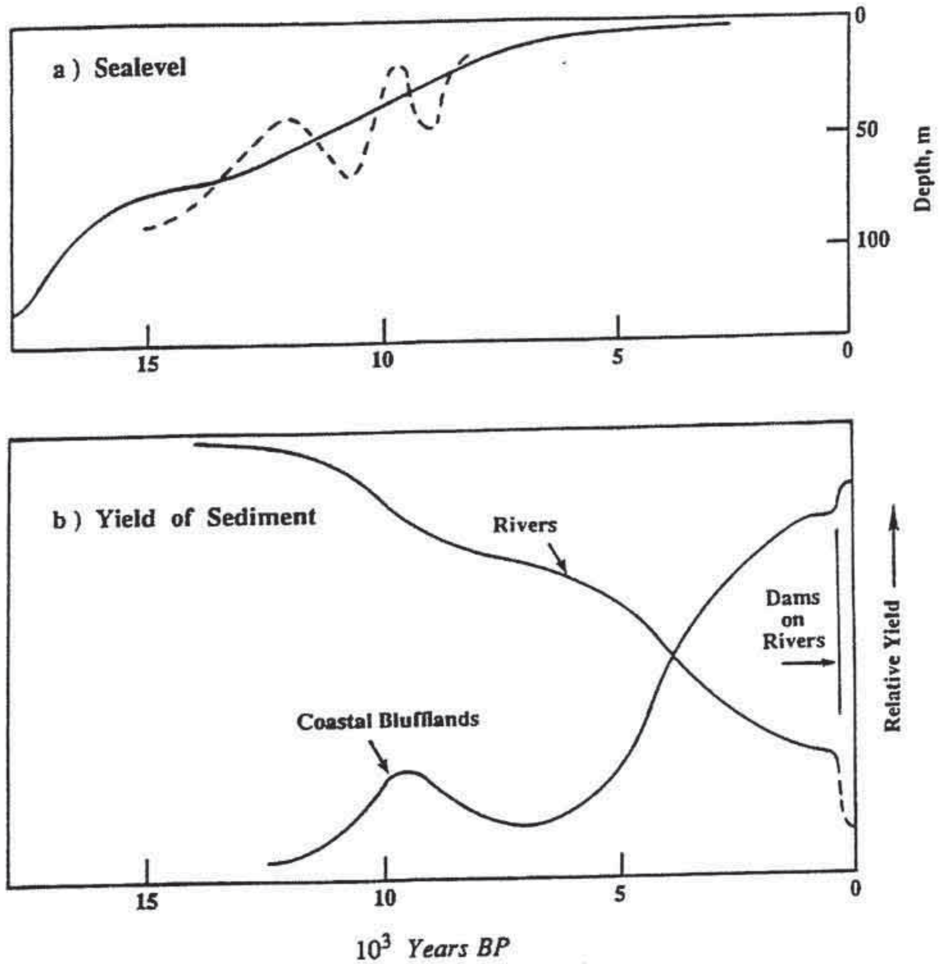


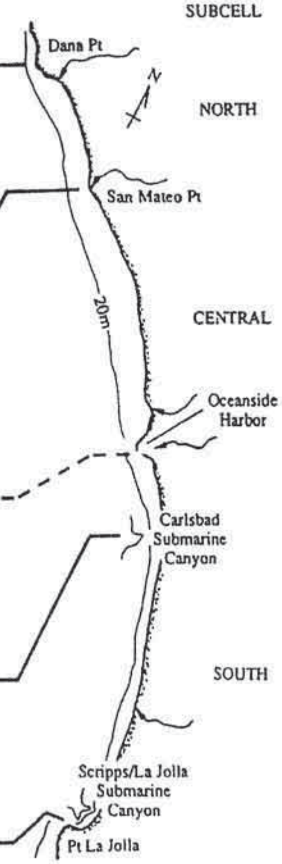
Figure 10-2: Schematic Diagram of the Influence of Sea Level Rise (a) On the Relative Yield of Sediment to the Shore Zone (b) By Rivers and Coastal Blufflands

APPENDIX II - USACE 1991, Figure 10-7

Figure 10-7
Budget of Sediment
Oceanside Littoral Cell

Input or Output		Natural Conditions ca.1900-1938 Input	Output	Uniform NW Wave Climate ca.1960-1978 Input	Output	Variable W Wave Climate ca.1983-1990 Input	Output
Q_l+Q_n	Longshore	0	190	0	190	0	50
Q_r	River	85	0	60	0	60	0
Q_b, Q_o	Bluff, Offshore	170	60	120	60	0	0
Q_a	Nourish	0	0	120	0	0	0
$\partial V'/\partial t$ (10^3 yd^3/yr)		+5		+50		+10	
$\partial X/\partial t$ (ft/yr)		≈ balance		0.7 accretion		≈ balance	
Q_l+Q_n		190	270	190	270	60	70
Q_r		270	0	25	0	0	0
Q_b, Q_o		520	640	370	460	180	0
Q_a		0	0	65	0	30	0
$\partial V'/\partial t$ (10^3 yd^3/yr)				-80		+200	
$\partial X/\partial t$ (ft/yr)				0.6 erosion		1.4 accretion	
				— — — HARBOR	EFFECTS — — —		
$Q_{ld}+Q_{nd}$	Deflection			0	80	0	20
Q_l+Q_n				270	270	70	70
Q_r				40	0	0	0
Q_b, Q_o				160	180	80	0
Q_a				100	0	0	0
$\partial V'/\partial t$ (10^3 yd^3/yr)		+70		+40		+60	
$\partial X/\partial t$ (ft/yr)		0.3 accretion		0.7 accretion		1.0 accretion	
Q_l+Q_n		270	0	270	0	70	0
Q_r		65	0	5	0	0	0
Q_b, Q_o		200	240	200	240	100	0
Q_a, Q_s	Nour., Sub Canyon	0	290	100	290	0	70
$\partial V'/\partial t$ (10^3 yd^3/yr)		+5		+45		+100	
$\partial X/\partial t$ (ft/yr)		≈ balance		0.3 accretion		0.6 accretion	

Episodic Beach Denudation: 1939 Tropical Storm; 1982/83 Cluster Storms



SUBCELL	km	mi
NORTH	14	8.5
CENTRAL	27	16.5
	11	7
SOUTH	32	20
	84	52

EXHIBIT K

SANDAG's SAND COST SCHEDULE FOR THE RBSP II PROJECT SCHEDULED FOR APRIL 2012

Construction Costs

ITEM NO.	ITEM DESCRIPTION	Assumed Borrow Site RBSP I	RBSP I Final QT. in CY	UNIT COST	TOTAL	Assumed Borrow Site RBSP II	RBSP II Proposed QT in CY	UNIT COST	TOTAL
Construction Costs									
1	Mobilization & Demobilization			$2,500,000	$2,500,000			$2,500,000	$2,500,000
2	Oceanside Beach	SO7	420,000	$7.01	$2,943,365	SO6	420,000	$11.35	$4,767,000
3	N. Carlsbad	SO5	225,000	$9.01	$2,026,713	SO6	225,000	$10.33	$2,323,421
4	S. Carlsbad	SO7	160,000	$5.54	$886,943	SO5	158,000	$11.41	$1,802,741
5	Batiquitos	SO7	118,000	$5.04	$595,107	SO5	118,000	$10.23	$1,207,247
6	Leucadia Beach	SO7	130,000	$5.33	$692,777	SO5	117,000	$9.80	$1,146,862
7	Moonlight Beach	SO7	103,000	$5.58	$574,649	SO5	105,000	$9.00	$944,841
8	Cardiff Beach	SO6	104,000	$4.72	$491,206	SO5	101,000	$7.77	$784,372
9	Fletcher Cove	SO5	140,000	$5.96	$833,968	SO5	146,000	$7.66	$1,118,198
10	Del Mar	SO5	180,000	$5.29	$952,218	SO5	183,000	$6.80	$0
11	Torrey Pines	SO5	240,000	$5.79	$1,389,651	SO5	245,000	$7.44	$1,822,800
12	Mission Beach	MB1	150,000	$5.26	$788,642	MB1	151,000	$6.76	$0
13	Imperial Beach	MB1	120,000	$9.36	$1,123,026	MB1	120,000	$12.03	$1,443,890
	Total amount of sand:		2,090,000	Subtotal:	$13,298,265		2,089,000	Subtotal:	$17,361,372
14	Construction Contingency			10%	$1,579,826				$1,579,826
15	Construction Management			7%	$1,105,878				$1,105,878
16	Construction Survey or Inspection			3%	$473,948				$473,948
	TOTAL CONSTRUCTION COSTS:				$ 18,957,918				$ 23,021,024

Letter I

DAVID J. WINKLER
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(619) 733-5105 CELL
(858) 793-1613 HOME

October 4, 2010

Thomas M. Campbell, Mayor
Lesa Heebner, Deputy Mayor
Joe G. Kellejian, Councilmember
David W. Roberts, Councilmember
Mike Nichols, Councilmember
Dave Ott, City Manager

Re: Draft Land Lease/Recreation Fee Study Revised July 2010 ("PMC Study")

Dear Mayor Campbell, Deputy Mayor Heebner, Councilmember Kellejian, Councilmember Roberts, Councilmember Nichols, and City Manager Ott:

Please include in the public record the following comments related to the PMC Study.

Comment 1

<u>Fees Are To Be Measured By Square Foot Of Land Lease Area, Not By Linear Foot Of Bluff Retention Device ("BRD")</u>.

The PMC Study most often references "linear feet" of BRD as the basis for the measurement of the Land Lease/Recreation Fee. The LUP states that the Land Lease/Recreation Fee is to be based upon, "The Land Lease Rate then in effect multiplied by the Land Lease Area" (PMC Study, Page 1-2, Table 1-1 and Policy 4.80.B.1 of the draft Local Coastal Plan ("LCP") Land Use Plan ("LUP")). The Land Lease Rate is correctly, but only occasionally, stated in other parts of the PMC Study to be a dollar amount per square foot of beach area (PMC Study, Page 4-1).

Table 4-2 (PMC Study, Page 4-2) correctly provides for a calculation of Land Lease Area as "The area that would have been available for recreation purposes had erosion been allowed to occur." It is theoretically based upon the actual recreation area lost, not simply the length of the BRD times the erosion rate. All tables and narrative in the PMC Study should be clarified or modified accordingly to reflect area, not linear feet

Comment 2

Longer Survey Period.

Due to variance in the weather and tides, beach attendance should be surveyed over several years, not just one year. One needs only to compare the weather during the Summer of 2009 to the Summer of 2010 to acknowledge a measurable year to year difference in weather. The PMC data for 2008 – 2009 overstates beach use based upon weather. Instead, the data should be averaged over time.

Comment 3

Heterogeneity.

At a public workshop/hearing held in November 2008, testimony was submitted directing PMC to address not just north-south beach use heterogeneity, but also east-west beach use heterogeneity. PMC did divide the length of the beach into north-south segments, but then chose to ignore the data. There was no east-west division of the beach; however, the reasons why people go to the beach was surveyed. This constitutes a general, but imprecise east-west segmentation.

Comment 3

a. North-South Heterogeneity.

Given PMC surveyed 35 north-south segments of beach, it is surprising that these segments were amalgamated, especially given certain segments have considerably more beachgoers (e.g., Fletcher Cove) compared to other areas. The PMC Study states, "The number of visitors within a beach area reveals the preference of one area over another." The more crowded the beach area, the more it is valued (Emphasis added) and this approach (the breakdown into segments) inherently captures the heterogeneity of beach area such as quality, amenities and surf conditions." (PMC Study, Pages 1-1 to 1-2).

Without adequate justification, PMC merges the 35 segments into a single zone based on the "dynamic processes" that ultimately affect beach density (PMC Study, Page 4-1). Dynamic processes are unlikely to materially change the configuration of Fletcher Cove, for example. It has greater east to west depth compared to any other area in Solana Beach, at all times of the year. It also has an adjoining grassy area, playground and parking. At a minimum, the Fletcher Cove segment, which is a statistical outlyer, should be removed from the data since it has a significantly higher density of use when compared to all other areas.

Once the Fletcher Cove segment is removed, the north-south segmentation of beach use should be instated to determine the relative value of each area when calculating any Land Lease/Recreation Fee which may be due.

Comment 4

b. East-West Heterogeneity.

A beachgoer who sits close to the bluff places their life and limb in danger. One only needs to read the signs posted by the Cities of Solana Beach and Del Mar; the State Parks; and other government agencies along the bluffs and beach access points. Five deaths have occurred along North County coastal bluffs in the last 15 years (see Exhibit A).

The LUP specifically provides for east-west heterogeneity to be taken into account in Policy 4.80.B.1. (PMC Study, Page 2-2). This Policy reads as follows: "Any such experts shall evaluate comparable leased beach areas based upon vertical and lateral access, parking, climate, frequency of use, safety, distance from access points, surf quality, water and air temperature, location of area leased, sand quality, time available for use of beach, beach width, tides, ocean conditions, and any other relevant variables."

Logically, the greater the distance from the bluff, the safer the beach area; therefore, greater value should be placed on those distal areas and little to no value placed on beach area which adjoins the bluff toe. PMC did not examine the east-west segmentation of beach use. This variable is particularly important during low tides when beach use is greater. Ignoring this variable is a serious flaw in the analysis. The Land Lease Rate must be adjusted and reduced for east-west beach heterogeneity.

Comment 5

The Land Lease Rate Should Not Consider Surfers and Waders.

The table on PMC Study, Page 3-11, breaks down the $2.1 million total value for use of the beach as follows: $1.3 million for beach use, $250,000 for wading, and $559,000 for surfing. Only the beach area amount should be factored into the Land Lease Rate, not the $2.14 million, which includes the ocean as used in Table 4-1 (PMC Study, Page 4-13). The annual Land Lease Rate per square foot offset for public benefit should be reduced proportionately ($1.3 million/$2.14 million X $6.02/S.F. = $3.74/S.F.).

Table 3-6 (PMC Study, Page 3-7) states that only 24% of the people lie on the beach. The others are engaged in surfing/water sports (26%), walking/running on the beach (22%), swimming/playing in the water (7%), collecting shells/beach combing, etc. (5%), fishing (3%), special events (3%), and picnics (10%). Virtually, all of these uses, but lying on the beach occur away from the toe of the bluff. Based upon this analysis, 24% of the $6.02/S.F. is $1.44/S.F., which is a more appropriate Land Lease Rate.

Both of these significant reductions do not include removal of the Fletcher Cove area, which will cause the Land Lease Rate to decline further.

Comment 6

Mitigation Fee Offsets.

The PMC Study states that an analysis for the offsets of the Land Lease/Recreation Fee and Sand Mitigation Fee is to be taken into account; however, tbere is no consideration of the offset of the Sand Mitigation Fee against the Land Lease/Recreation Fee. A sand mitigation fee is paid to compensate for the sand which the BRD prevents from falling on the beach. The lost sand is replaced. Why should the homeowner also be obligated to pay a Land Lease/Recreation Fee if the replacement sand mitigates the impact?

Due to ongoing sand replenishment programs, it is arguable that the beach width has not changed materially. Therefore, there is minimal, if any loss of usable beach area. The bluff property owner pays twice for the same impact, which is unjustified and unfair.

Furthermore, the bluff property owner mitigates sand loss caused by upland third parties who have deprived the beach of sand. This includes the partial or total damming of rivers and lagoons (Hwy 101 and train tracks); upland sand mining; creation of impermeable surfaces such as streets, roofs, driveways and sidewalks, etc.

It is interesting to note that the most difficult point to pass along the beach between Fletcher Cove and Tide Park is a **natural** out-crop. There is no evidence that the seawalls have a significant impact on beach width, especially with sand replenishment. The loss of all upland sand sources has the greatest impact.

Comment 7

A BRD Increases Useable Beach Area.

Given that the danger zone from the toe of the bluff can extend towards the ocean by as much as 60 feet, the beach area to the west of a BRD is made considerably safer. There appears to be no record of any bluff collapse once a BRD has been built and the bluff has been stabilized. The footprint of the BRD logically has no value due to the lack of use and level of danger where it is situated.

Comment 8

Offsets to the Land Lease/Recreation Fee and Sand Mitigation Fees.

PMC correctly states that there is to be a credit offset to the extent the proven quantified public benefit exceeds the proven quantified private benefit (PMC Study, Page 5-1 and LUP Policy 4.80.B.1.).

The PMC Study provides, "An example offset calculation presented below assumes private benefit is equivalent to the construction cost of the BRD." (PMC Study, Page 5-12. Emphasis added). Later in the paragraph PMC states, "The market would dictate that a minimum value exists for the market value of the bluff property before installation of a BRD that is equivalent to the difference between the full market value and the cost of a BRD." (PMC Study, Page 5-12. Emphasis added). On August 3, 2006, the bluff property at 201 Pacific Avenue sold, which precisely supports this conclusion.

The Bloom/Sloan escrow provided for a $400,000 hold back to pay for a BRD, if it was constructed. This was the anticipated cost of the BRD. Since the BRD was not constructed during the time provided in the escrow, the $400,000 was returned to the buyer. In other words, the value of the BRD was exactly equal to its cost. This was an arms-length transaction and provides strong evidence of the private benefit being equal to the cost of the BRD, resulting in no net benefit to the bluff property owner.

Based upon the PMC language, and the market comparable above, one can reasonably conclude that the cost of the BRD is equivalent to the incremental increase in the value of the property attributable to the BRD. Therefore, there is no net benefit to the bluff property owner. A BRD does not enhance value, it preserves value. PMC states, The BRD "if constructed, would restore the property to that full market value." (PMC Study, Page 5-12).

PMC's failure to acknowledge the cost of the BRD when considering the net increase in value of the property is a material error, which must be corrected. With a zero net private benefit, the public benefit, including the increased level of safety, must reduce the Land Lease Rate proportionately.

Comment 9

Fatality Rates Are Higher.

The PMC Study examined fatalities along the bluffs only in Encinitas and Solana Beach from 1990 to 2009. PMC determined there was one death over this 19 year period (PMC Study, Page 5-4).

Instead, PMC should have examined the number of bluff related deaths from South Carlsbad to North Torrey Pines. Five deaths occurred over 15 years along the bluffs from South Carlsbad to North Torrey Pines. The number of deaths per year, per linear foot of the westerly projection of the bluff is considerably greater than under the sample used by PMC.

The mortality rate must be revised accordingly. PMC should not focus on the number of bluff failures. Instead, the number of deaths over the length of vulnerable linear bluff is what is relevant. This revised calculation will provide a greater offset to the Land Lease Rate. All non-bluff areas should be excluded (lagoon mouths and adjacent low lying areas, e.g., Del Mar Shores, Cardiff south of the campgrounds to north Solana Beach), as should all bluffs with BRDs to the best of my knowledge. There have been no deaths related to bluff failures where BRDs exist.

Comment 10

The Value of a Human Life Must Be Increased By a Cost of Living Adjustment.

The mortality cost factor of a single death of $6.9 million is based on 2004 data from the Environmental Protection Agency (PMC Study, Page 5-4). Since 2004, the cost of living for the San Diego area increased by 15.54% for the period from 2004 to 2010, according to the Bureau of Labor Statistics. The value of each life in the safety analysis should be increased by at least 15.54%, which will also increase the public benefit offset against the Land Lease/Recreation Fee.

<u>Conclusion</u>.

The Land Lease Rate should be reduced significantly or eliminated completely.

The Land Lease/Recreation Fee should be reduced due to:

- the exclusion of the Fletcher Cove segment as an outlier of excessive high beach use compared to all other beach segments;

- failure to account for east-west heterogeneity;

- waders and surfers being removed from the beach area value calculation;

- calculating the fee based upon those lying on the beach only;

- the sand mitigation fee fully paying for the impacts associated with a BRD; and

- bluff property owners not being held responsible for the beach being deprived of sand which was caused by others.

The private benefit of a BRD should be eliminated entirely by subtracting the cost of the BRD. A net zero benefit to the bluff property owner is based upon conclusions drawn by PMC and examination of a recent fair market value transaction. Therefore, the entire public benefit, as discussed and adjusted per the factors above, should further diminish the Land Lease/Recreation Fee.

The public benefit offset is greater than what is stated by PMC due to a greater number of deaths along North County bluffs than what PMC reported per linear foot of affected shoreline; and the value of a life since 2004 must be increased by the cost of living.

Thank you for incorporating these comments and conclusions into the final PMC Study, and revising it accordingly.

Best regards,

David J. Winkler

EXHIBIT A

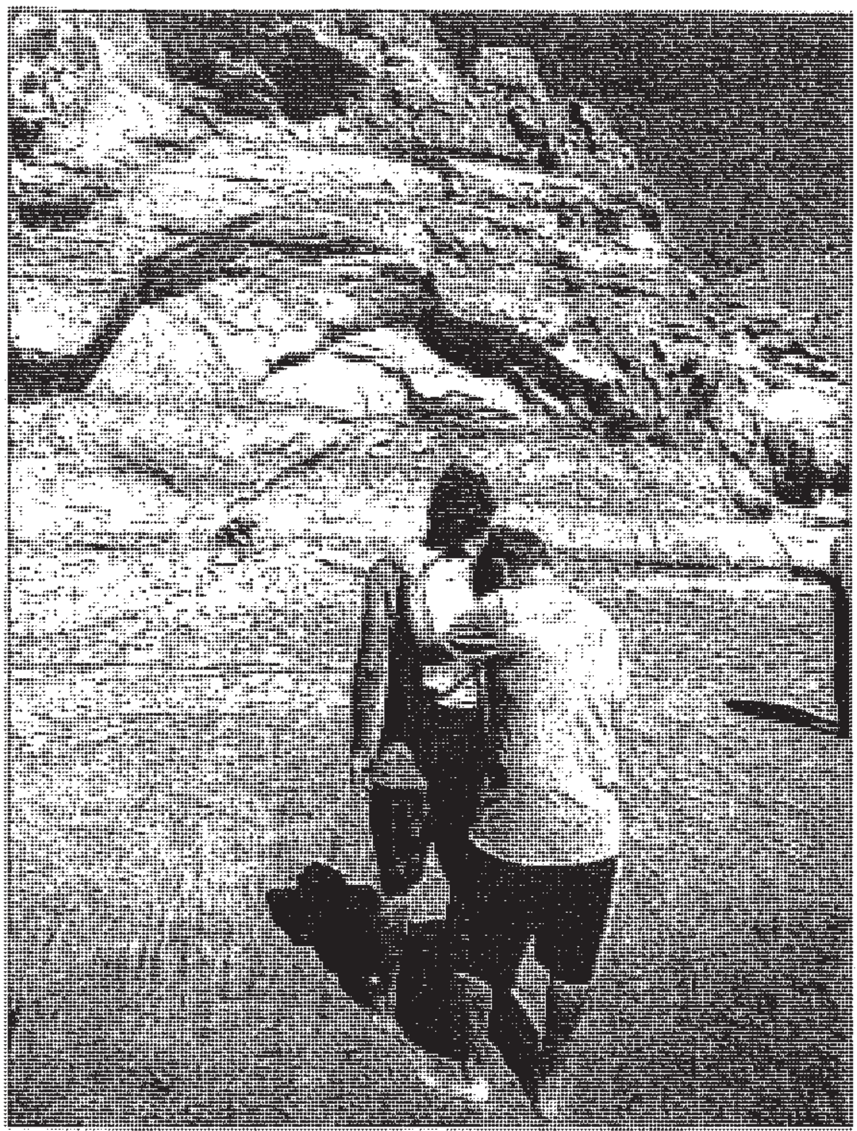
October 4, 2010
David Winkler comments to PMC Study

THURSDAY
August 21, 2008
B
THE SAN DIEGO
UNION-TRIBUNE

OUR REGION

LA JOLLA

Beach-goer dies after cliff collapses



While emergency crews worked at the site of the collapse at Torrey Pines State Beach, the brother (right) and nephew of the victim looked on. Eduardo Contreras / Union-Tribune

Part of Torrey Pines closed for analysis

By Greg Gross
and Kristina Davis
STAFF WRITERS

A popular strip of Torrey Pines State Beach has been temporarily closed after a section of the cliffs gave way yesterday and sent a fatal shower of sand and boulders onto a 57-year-old tourist below.

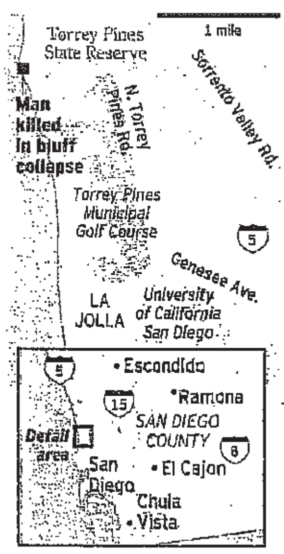
The man, who was visiting from Henderson, Nev., was struck in the head by basketball-size boulders and died shortly after at Scripps Memorial Hospital-La Jolla, authorities said.

His name has not been released.

"He was just spending a day at the beach with his family," said Maurice Luque, spokesman for the San Diego Fire-Rescue Department. "He'd gone to the foot of the cliff to take off his shoes, and a small section of the bluffs just gave way and came down."

The narrow beach area just north of Black's Beach was roped off with caution tape while loose rocks and debris continued to fall late yesterday, said state lifeguard supervisor Jeff Bruck. State geologists were called in to evaluate the stability of that portion of the bluffs. "It's a constant problem," Bruck said. "There's no telling when or where a cliff will let loose."

Authorities don't expect to keep the area permanently closed and hope visitors will heed the many signs already posted that warn of unstable cliffs, including a sign about 30



UNION-TRIBUNE

feet away from the fall site.

"There's only so much you can do," Bruck said.

About three to five cubic yards of debris came down on the man about 1:20 p.m. — about an hour after high tide — near an area known as Flatrock, as the man's brother and nephew played Frisbee on the beach.

The victim's relatives and other beach-goers helped dig him out as state and city lifeguards converged on the scene, said fire department Battalion Chief Daniel Saner.

Emergency crews began performing cardiopulmonary resuscitation while they waited for an all-terrain vehicle to carry him off the beach. He died at a trauma center.

The Torrey Pines area, popu-

Torrey Pines, B3

▶ TORREY PINES

CONTINUED FROM PAGE B1

Collapse occurs about an hour after high tide

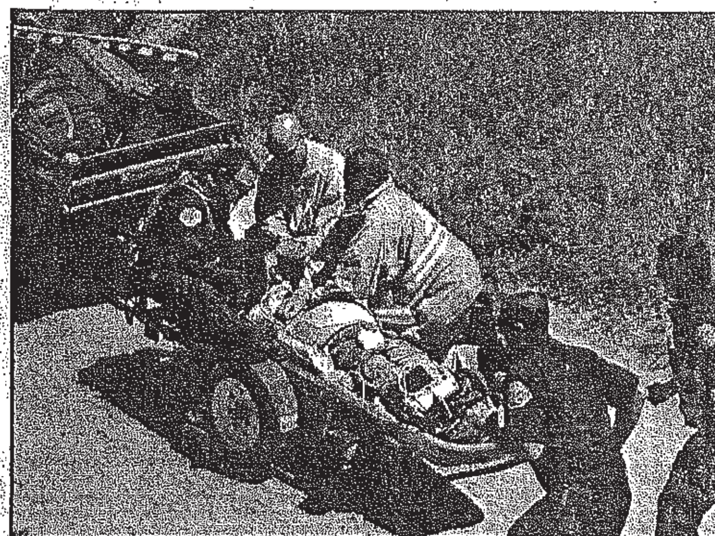
lar with golfers and glider enthusiasts on top of the bluffs and beach-goers below, is notorious for its sandy, unstable cliffs.

"Not a year goes by without a significant collapse of these bluffs," said Patrick Abbott, a geologist with San Diego State University. "Most fall when no one is there. This was at the worst possible time, on a warm summer day when people are playing at the beach. Then an unremarkable event becomes a tragedy."

Abbott said layers of sand began being deposited at the coast about 50 million years ago and hardened into sandstone, compacted by weight and riddled with fractures.

"We have near-vertical sea cliffs 200 to 300 feet high and ocean waves beating at their base. Gravity's always going to win."

Staff writer Pauline Repard contributed to this report.



Emergency crews worked to revive the victim as they took him to an ambulance that transported him to Scripps Memorial Hospital-La Jolla, where he died. *Eduardo Contreras / U-T*

BEACH BLUFF COLLAPSES

- In February, a landscaper was trapped and injured when a retaining wall atop beach bluffs in Encinitas collapsed.
- July 2002: An unidentified man died when the cave he used for shelter at South Carlsbad State Beach collapsed on him.
- Jan. 16, 2000: Rebecca Kowalczyk, 30, was killed when a 110-yard-wide section of an Encinitas bluff she was sitting under just below Neptune Avenue broke loose and fell on her.
- April 27, 1989: Three construction workers were injured after plummeting 50 feet down a Neptune Avenue bluff in Encinitas that they were trying to stabilize.
- Jan. 22, 1995: Two tourists were killed when a beach bluff collapsed on them at Torrey Pines State Reserve, and a 52-year-old Mission Hills man was buried up to his chest and suffered a leg fracture.

Letter J

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FAX 760-454-1886
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October 26, 2010

Tina Christiansen, Community Planning Director
City of Solana Beach
635 S. Highway 101
Solana Beach, CA 92075

Re: BBC and COOSSA Comments to the Draft Land Lease/Recreation Fee Study; Published Economic Papers Referenced in the BBC's October 4th Submittal

Dear Ms. Christiansen:

Enclosed with this letter, please find two copies of the economic studies that were cited in Dr. Stephen Conroy's report, attached as Exhibit A to the BBC letter submitted on October 4, 2010 in response to the draft Land Lease/Recreation Fee Study. The papers submitted are as follows:

Tab	Title	Author
1	The Economic Value of Hiking: Further Consideration of Opportunity Cost of Time in Recreational Demand Models	Jakes F. Casey, Tomislav Vukina and Leon E. Danielson
2	Time and the Recreational Demand Model	Nancy E. Bockstael, Ivar E. Strand, and W. Michael Hanemann
3	Value of Time in Recreation Benefit Studies	Frank J. Cesario
4	Welfare Estimates for Five Scenarios of Water Quality Change in Southern California	Michael Hanemann, Linwood Pendleton, Craig Mohn
5	Valuing Recreation and Amenities at San Diego County Beaches	Daniel K. Lew, Douglas M. Larson
6	Measuring the Cost of Time in Recreation Demand Analysis: An Application to Sportfishing	Kenneth E. McConnell and Ivar Strand
7	A Difficulty with the Travel Cost Method	Alan Randall

We are submitting these to the City as both City Staff and PMC may find them helpful as they review and consider the BBC's comments on the draft Fee Study. Please incorporate these studies into the administrative record for this matter.

Respectfully submitted,

THE AXELSON CORN LAW FIRM

By: ______________________
Jonathan Corn

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ATTORNEYS AT LAW

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October 26, 2010

Tina Christiansen, Community Planning Director
City of Solana Beach
635 S. Highway 101
Solana Beach, CA 92075

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Respectfully submitted,

THE AXELSON CORN LAW FIRM

By: JmCw

Jonathan Corn

The Economic Value of Hiking: Further Considerations of Opportunity Cost of Time in Recreational Demand Models

James F. Casey, Tomislav Vukina and Leon E. Danielson*

Abstract

The paper tests two alternative specifications for the opportunity cost of time in travel cost models. The standard travel cost survey design is enriched to include a contingent valuation type question about peoples' willingness to accept compensation to forgo a precisely defined recreational experience. It is hypothesized that individually revealed value of time more appropriately reflects the opportunity costs of time associated with a particular aspect of recreation than the wage rate which measures the trade-off between work and leisure generally. The results seem to indicate a better overall fit for the models with the elicited value of individual consumer's time than for the models with the more traditional hourly earnings (wage rates). The importance of the correct measurement of the opportunity cost time is illustrated by showing that estimated consumer surpluses based on two different value of time measurements differ significantly.

Key words: *recreation demand, travel cost model, value of time*

Introduction

The optimal allocation of land to alternative uses is that which provides the greatest net benefit or the largest return to the initial investment (Ward and Loomis, 1986). When a certain land use (e.g. preservation) has no market, its value cannot be compared to those for other land uses. Recreational benefits from natural environments are often elusive and difficult to measure. Many of the numerous uses (hiking, sightseeing, boating, fishing) typically are unpriced by the market, except for small access fees or licensing restrictions (Durden and Shogren, 1988).

To quantify some of these benefits, economists have developed non-market valuation techniques. This study uses the travel cost model (TCM) to measure the net benefits of recreational services from the Grandfather Mountain Wilderness Preserve (GMWP) in Linville, North Carolina. The net benefits are measured by the consumer surplus that accrues to hikers at GMWP. The consumer surplus estimate is the dollar value of recreation services (hiking) to an individual hiker. It can also be interpreted as the compensation that would be required to keep the hiker at the same utility level given the closure of the hiking trails.

Central to modeling of demand for recreation has been the problem of how to handle the time people spend in the enjoyment of the recreational activity at a site. Spending more time at a site enhances the benefits of recreational activity, so time becomes an argument in the utility function. But time is also costly and hence should be treated as component of the cost of the trip. Traditionally, in the travel cost literature, time on-site has been exogenously imposed as a constraint and becomes a part of the price. This study uses

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the approach developed by McConnell (1992) where the dual role of on-site time is resolved by specifying the traditional TCM with the appropriate argument for the cost of on-site time, allowing the estimation and interpretation of the demand curve to remain the same.

The main focus of this study is another problem in estimating recreational demand, namely how to measure the opportunity cost of time. The estimates of recreational benefits based on the TCM are known to be highly sensitive to the magnitude of the time cost used[1], and yet there is no broad consensus in the literature to support a proper procedure for valuing time in travel cost studies. The most widely cited approach for placing a value on time cost comes from McConnell and Strand (1981). They argue the opportunity cost of time is some proportion of the individual' s market wage rate, and that it can be empirically estimated from sample data. In their application to sport fishing, this proportion was estimated to be 0.6. The same technique was tested by Smith, DesVousges and McGivney (1983) and the estimates of the opportunity cost of travel time ranged from 80 to -9 times the wage rate depending on the site and the sample, thus seriously undermining the usefulness of the recommended procedure.

An alternative approach employed in this study is based on the assumption that the value of an individual's time can be found by asking that question directly. This approach, proposed earlier by Shaw (1992), suggests the TCM survey design include a contingent valuation type question to elicit the opportunity cost of time. The comparison of the elicited opportunity cost of time with the traditional wage rate approximation is an important part of this paper. The remainder of the paper is structured as follows. The next section discusses the methodology followed by the description of the survey data. In the fourth section, the empirical results are presented. Finally the conclusions and the suggestions for future research are outlined.

Methodology

The objective of the TCM is to estimate a structural demand equation for a recreation site using the participation rate corresponding to varying travel costs. Visitors to a recreation site pay an implicit price, that is, the cost of travelling to and from the site, including time costs (Smith, 1993). The travel-time costs, out-of-pocket expenses, and on-site time costs are used to estimate the price of visiting the recreational area. Thus the TCM helps establish on-site recreation values that can be weighed against the values of commodity outputs (for example, timber, agriculture) from alternative management strategies.

The theory behind the travel cost method comes from traditional demand theory. Demand, as applied to outdoor recreation, is a schedule of volume (visits, user-days) in relation to a price (cost of the experience). If the opportunity for outdoor recreation exists and people are free to choose, many will spend time and money participating in outdoor recreation. Persons who choose to visit outdoor recreation areas presumably weigh the costs of doing so against the costs of other goods and services that may be purchased with the same time and money. It is important to remember that economic analysis deals with physical and other characteristics of goods and services only to the extent that they affect human decisions. The decision to hike is made in ways fundamentally similar to the decisions made about whether to buy a new car or new clothes.

Standard travel cost method assumes that the consumer plans activities for a period of time, typically a season or a year. She chooses x, the number of trips to a specific site. Each trip to the site lasts t hours (days), where t is the time spent on site participating in the recreation activity (hiking). Recreationist is assumed to maximize utility subject to both time and budget constraints. On-site time contributes to utility in its complementary role with the number of trips chosen. It is the combination of t and x that makes up total utility, and increasing t, ceteris paribus, will increase total utility. If $t=0$, then x provides no utility to the consumer. However, on-site time is also part of the cost of a trip. If the consumer spends more time on site, time is taken away from opportunities to work or consume other goods and services. On-site time, then, has a dual role as both a provider of utility and a constraint to the consumer. This dual role complicates the estimation of the recreational demand models.

One of the possible solutions to the problem was provided by McConnell (1992) who demonstrated that the non-linearity of the budget constraint (introduced by endogenous on-site time) does not manifest itself in the demand for trips, but rather in the demand for on-site time. Consequently, one can specify the standard travel cost model with an appropriate argument for the cost of on-site time, and the estimation and interpretation of the demand curve for trips remain the same. In the McConnell's (1992) two-step procedure, the first step is to determine whether the on-site time is endogenous by estimating the demand for on-site time:

$$t = f(p_x, p_t, p, y) \tag{1}$$

where:

$$p_x = c_x + \gamma w; \;\; p_t = c_t + w; \;\; p = c_z + \theta w \tag{2}$$

p_x is the money cost per trip (c_x) plus the product of travel time for each trip (γ) and the opportunity cost of time (w); p_t is the on-site cost per unit of time on site (c_t) plus the opportunity cost of time; and p is the price of Hicksian bundle (c_z) plus the product of time spent on consuming a Hicksian bundle and the individual's opportunity cost of time; and y denotes money income.

If the coefficients of (1) are significantly different from zero, one can conclude that on-site time is endogenous, and proceed with estimating the demand function for trips of the following form:

$$x = f(p_x, p_t, p, y) \tag{3}$$

If the coefficients in (1) are not significantly different from zero, one may conclude that on-site time is exogenous, and proceed with the estimation of another demand function for trips with slightly different specification:

$$x = f(p_x + tp_t, p, y, t) \tag{4}$$

Alternatively, one may simply assume the endogeneity of t and entirely bypass the estimation of the demand function for on-site time (1) and instead directly estimate equation (3). Since equation (1) is not needed for welfare analysis, ignoring it will not bias the coefficients in the demand for x.

The definitions of costs needed to estimate demand functions (1), (3) and (4) are given in expression (2). The total cost for a trip (p_x) consists of the out of pocket expenses and the opportunity cost of travel time obtained by multiplying the travel time with either the wage rate or the individual's revealed value of time. The out-of-pocket expenses are the sum of gas, food, hotel and other expenses such entertainment and souvenirs and hiking fees. Once on the mountain the hikers have nothing to spend their money on, hence p_t in (2) consists only of either the wage rate or the elicited value of individual's time.

A traditional assumption made in most of the early recreation demand literature assumed that the value of an individual's time in a recreation activity is equal to his wage rate or some fraction of this wage rate (see: Cesario, 1976). This result stems from the standard labor supply model which implies that the marginal rate of substitution between labor and leisure equals the wage rate. In a more recent study, Shaw (1992) elaborates instances when this relationship between wage rate and the value of time breaks down and within a travel cost framework suggests an exploration int opportunity cost of time along the lines c contingent valuation method. The suggested approach is empirically tested in our research. The exact wording of the question formulated as the willingness to accept compensation to forgo hiking experience is: *"If someone offered you an opportunity to work overtime instead of visiting Grandfather Mountain, at what hourly rate would they have to pay you for you to accept the offer?"* Notice that the emphasis was placed on the trade-off between work and a particular aspect of leisure, i.e. hiking at the Grandfather Mountain, and should more appropriately reflect costs of time associated with hiking at a particular site than the wage rate, or some arbitrary fraction thereof.

The formulation of the question wh hikers are being asked how much they would n to be compensated if they were working overtim instead of hiking seems appropriate in cases where individuals do not have much discretionary power over work time. The idea reflects institutional obstacles in scheduling activities (see: e.g., Bockstael, Strand and Hanemann, 1987) since it is well known that many jobs are only offered on a conventional 40 hours a week basis and choosing between working and recreating can materialize only at the overtime (more than 40 hours a week) level.

When the recreation site being investigated is part of the larger regional recreation system, such as the case with GMWP, there is a difficult question of deciding which other sites are substitutes whose prices should be included in the site demand equation. The comprehensive approach of including all alternative sites is cumbersome and may require more data than are available. An alternative approach used in designing this survey is to ask each individual what other site that person visits most frequently, and include only that site's price as the relevant substitute price (see: Freeman, 1993, p.454). The total expenditure for a preferred substitute site is the sum of the average expenditure per trip (question 22) and the product of the roundtrip travel time and the value of time. In order to homogenize numerous alternative hiking sites that people selected as their preferred sites, the total expenditures were divided by the times spent on preferred substitute sites. The so constructed total expenditure for a preferred alternative site per unit of time on site serves as an approximation for the total cost (p) of consuming the Hicksian bundle in (2).

Once the demand function in (3) is estimated, the standard interpretation of the area under the Marshallian demand function continues to hold. The welfare cost of a change in p_x from p_x^0 (observed price) to p_x^* (choke price) is given by the area under the demand for trips:

$$CS_x = \int_{p_x^0}^{p_x^*} x(p_x, p_j, p, y)\, dp_x \tag{5}$$

This is the money measure of the value of use of the hiking site, i.e. CS_x compensates the individual for all changes that would occur as a result of a price increase that eliminates (chokes off) the access to the site (McConnell, 1992). The welfare measures critically depend on the individual's cost of time. To explore the impact of various assignments of the opportunity cost of time on welfare measures, two different models are estimated using the calculated wage rate and the revealed opportunity cost of individual hiker's time.

Survey Data

Grandfather Mountain is a privately owned mountain, part of the Blue Ridge Chain in northwestern North Carolina. Grandfather Mountain supports sixteen distinct habitat types for thirteen rare and endangered animals and thirty endangered species of plants. Part of the mountain has been developed as a tourist attraction, but most of the mountain has been preserved in its natural state and is under the permanent protection of The North Carolina Nature Conservancy. The Grandfather Mountain Wilderness Preserve (GMWP) has a thirty-mile network of alpine hiking trails which makes the site a popular hiking destination.

A mail survey was conducted to gain information about hikers at the GMWP. Names and addresses of visitors to the site from October 1993 through June 1994 were obtained from hiking permits. Questionnaires were mailed to 453 households, and 185 of them returned the survey. Households surveyed were those for which legible entrance permit slips collected from several locations that sell permits were available. For 112 survey respondents, hiking at the GMWP was the sole purpose of their visit. For the remaining 73 respondents, the trip to GMWP was part of a larger vacation or business plan. This paper deals only with the single purpose trips. Out of 112 single trip surveys, 80 respondents provided answers about their annual household income (question 20), and 48 of them provided answers about the valuation of their time (question 27)[2]. However, there were only 42 completed surveys with overlapping responses to both income and revealed value of time questions.

Survey questions were designed to obtain information about travel plans, costs associated with travel, quality of experience, substitute hiking areas, and general socio-economic characteristics of the respondents. Since all costs in the survey instrument were reported on the per party basis, the cost figures were divided by the number of persons in the party. A copy of the survey mailed to each hiker is found in the Appendix. Table 1 contains the summary of the relevant survey questions. Fox example, the revealed values of individual hiker's time could be compared with the average hourly earnings obtained by dividing the total annual household pre-tax income with 2,080 hours (260 days x 8 hours a day). For the group of single purpose visitors the average revealed value of individual hiker's time was $46.83 an hour, while the average calculated wage rate equals $26.27 an hour.

Estimation Results

The functional forms for the on-site time demand (eq. 1) and trip demand (eq.3) were selected from among the four most common functional forms: linear, log-linear, semi-log and inverse semi-log. In both wage rate (Model 1) and the revealed value of time model (Model 2), the best results were obtained with the inverse semi-log specification. Estimates of the on-site time model are presented in table 2 with the following notation: p_x is the total cost of trip (monetary costs plus time costs), w is the pre tax hourly earnings, vt is the perceived value of time, p_s is the average total cost related to the most preferred substitute site (trip cost plus travel time cost) per unit of time spent on a most preferred substitute site, and NC is the dummy variable equal to one if the person was aware of the Nature Conservancy's involvement in the GMWP protection, and zero otherwise. The F-statistics are used to test the null hypothesis that all coefficients are simultaneously equal to zero. The null that time is exogenous is rejected at 99% confidence level. The individual parameters from this equation are not needed and therefore their low significance levels cause no problems. The conclusion that on-site time is endogenous implies that equation (3) rather than equation (4) be estimated.

The parameter estimates for the inverse semi-log functional form of the visitation equation (3), their t-statistics and significance levels are summarized in table 3. As one can see income variable is notably absent from the estimation results despite the fact that it was part of the theoretical model specification in (3). The reason for this is its high correlation with the opportunity cost of time variable. Also, as noted by Bockstael, McConnel and Strand (1991), income levels are more likely to distinguish participants in recreational activity from nonparticipants than they are to affect the number of trips a participant takes in a season.

In both wage rate model and the revealed value of time model all estimated coefficient have expected signs. The total cost of trip (p_x) and the opportunity cost of time variables (w and vt respectively) are significant at 5% level. The average total cost related to the most preferred substitute site (p_s) per unit of time spent on a most preferred substitute site is not significant. Poor performance of substitute prices in recreation demand regressions is not unusual even in cases where substitute sites are not aggregated (see, e.g., McConnell, 1992). The dummy variable for hikers' awareness of the Nature Conservancy role in protecting the GMWP acts like a season pass or a proxy for their attitude towards environmental protection. As anticipated, people's awareness of the Nature Conservancy is positively related to the number of hiking trips.

The estimated results seem to suggest that the demand for recreation (hiking trips) is more appropriately specified by using a contingent valuation type of question for the value of time variable rather than by using the more traditional hourly earnings. Model 2 (revealed value of time) outperforms Model 1 (wage rate) in terms of higher adjusted R^2, and the revealed value of time variable is more significant than the wage earnings variable[3].

The central concern of this paper is the impact of various measurements of the opportunity cost of time on the consumer surplus estimates. Given the inverse semi log demand function, using (5) the consumer surplus can be calculated as follows:

$$\begin{aligned} CS_x = {} & \hat{\beta}_0(p_x^* - p_x^0) + \hat{\beta}_1[(p_x^* \log p_x^* - p_x^*) \\ & -(p_x^0 \log p_x^0 - p_x^0)] + \hat{\beta}_2 \log p_i (p_x^* - p_x^0) \\ & + \hat{\beta}_3 \log p_s (p_x^* - p_x^0) + \hat{\beta}_4 NC(p_x^* - p_x^0) \end{aligned} \tag{6}$$

where p^*_x is the choke price (the price when visits go to zero) and superscript zero denotes current (observed) values of other variables. The consumer surplus is evaluated for each of the 42 survey participants for both wage rate and the revealed value of time models. Then, the analysis of variance was performed to test whether trip demand estimates based on different approximations of the opportunity cost of time produce significantly different consumer surplus measurements. The mean of the estimated consumer surplus for the wage rate model (Model 1 in Table 3), equals

Table 1. Descriptive Statistics of Surveyed Hikers at GMWP: Single Purpose Trips Summary

VARIABLES N=42	Mean Value	Standard Deviation	Range
Number of Visits (5)[a,b]	5.64	9.52	1-50
Round-trip Travel Time(10)[c]	4.51	4.03	0.25-24.0
On-Site Time (12)	21.93	17.41	9-96
Total Costs for a Trip (11)[d]	22.10	29.23	4.5-184.5
Revealed Value of Time (27)	46.83	55.63	10-300
Calculated Wage Rate (26)	26.27	13.70	4.81-48.08
Substitute Site Travel Time (20)[e]	4.55	6.39	0.1-40.0
Substitute Site On-Site Time (21)	34.14	30.18	6-156
Substitute Site Total Costs (22)	60.17	125.61	0-800
Nature Conservancy Awareness (28)	43%	-	-

[a] The numbers in parentheses indicate the underlying survey question.
[b] Visits are expressed on an annual basis.
[c] All costs (in dollars) and times (in number of hours) are expressed on a per person per trip basis.
[d] Total costs for the GMWP trip include the admission fees in the amount of $4.50 for a daily pass or $9.00 for an overnight pass.
[e] Round trip travel time to the preferred substitute site was estimated by dividing the roundtrip distance from Question 20 with 50 Mph.

Table 2. Parameter Estimates for the Time-On-Site Equation

Dependent Variable: On-Site Time	Parameter	t-statistic	P-value
Model 1: Hourly Earnings (N=42):			
log p_x	10.016	2.889	0.006
log w	-14.629	-2.409	0.021
log p_s	-3.8309	-1.197	0.239
NC	2.614	0.482	0.633
constant	25.228	1.633	0.111
	Adj.R^2 = 0.1965	F(5,37) = 19.388	0.000
Model 2: Revealed Value of Time (N=42):			
log p_x	6.9383	2.008	0.052
log vt	-6.7427	-1.316	0.196
log p_s	-4.8972	-1.398	0.170
NC	-0.40979	-0.0759	0.940
constant	19.379	1.189	0.242
	Adj. R^2 = 0.1243	F(5,37) = 17.179	0.000

Table 3. Parameter Estimates for the Visitation Equation

Dependent Variable: Visits	Parameter	t-statistic	P-value
Model 1: Hourly Earnings (N=42);			
log p.	-4.3383	-2.273	0.029
log w	6.6025	1.975	0.056
log p.	-1.8613	-1.057	0.298
NC	4.5004	1.508	0.140
constant	5.447	0.6404	0.526
	Adj. $R^2 = 0.1844$	$F(5,37) = 6.278$	0.0003
Model 2: Revealed Value of Time (N=42):			
log p.	-3.8553	-2.134	0.040
log vt	6.6735	2.489	0.017
log p.	-2.1128	-1.153	0.256
NC	5.0403	1.785	0.082
constant	2.438	0.286	0.776
	Adj. $R^2 = 0.1973$	$F(5,37) = 6.498$	0.0002

$1,206.50 per person per year with the standard deviation of $1,532.60. The average consumer surplus for the revealed value of time model (Model 2 in Table 3) is $2,892.80 per person per year with the standard deviation of 5,128.70. Under the null hypothesis of equal means the test statistics has an F distribution with (K-1,N-K) degrees of freedom, where K=2 denotes the number of variables whose means are compared and N=84 is the total number of observations in all series. The F-statistics of 4.17 indicates significantly different consumer surplus estimates between the two models at 5% level of significance[4].

For illustration purposes, we can also calculate the aggregate consumer surplus derived by all hikers on the Grandfather Mountain in one hiking season. The TCM imputes only the recreation value of a site, but does not include many other on and off-site values. The total value of a wilderness preserve would include benefits from watershed protection, educational resources, values of biological diversity and ecological services on local, regional, and global scales. No attempt was made in this study to evaluate any benefits other than recreational (hiking) ones. For 1993/1994 approximately 1,700 permits were sold to hikers. The single purpose travelling parties averaged 2.6 persons per group. Assuming that all trips were single purpose trips (in fact the ratio in our sample was 60% single purpose, 40% multi-purpose trips), the estimated aggregate consumer surplus derived by all participating hikers within one season amounts to $5,332,730 for the wage travel cost model and $12,786,176 for the revealed value of time travel cost model.

Conclusions

The main objective of the paper was to tes alternative specifications for the opportunity cost o time in travel cost models. The standard travel cost survey design was enriched to include a contingent valuation type question about peoples' willingness to accept compensation to forgo a precisely defined recreational experience. Since the emphasis is placed on the trade-off between work and a particular aspect of leisure, i.e. hiking at a specific locality, the revealed value more appropriately reflected opportunity costs of time associated with this particular activity than the wage rate which measures the trade-off between work and leisure generally. The results seem to indicate a better overall fit for the models with the elicited value of individual consumer's time than for the models with the more traditional hourly earnings (wage rates). The importance of the correct measurement of the opportunity cost time has been illustrated by showing that estimated consumer surpluses based on two different value of time measurements differ significantly.

Simplifications made in this study are numerous and opportunities for future research are abundant. First, the analysis was performed with the single purpose trips data only. Dealing with the multi-purpose trips can be extremely complicated especially with regards to extracting the cost shares specifically related to the recreational activity under investigation. Second, an improvement of the survey instrument regarding the treatment of the substitute site may be beneficial. Since the number of preferred substitute hiking sites identified by respondents turned out to be large, effectively preventing the aggregation into some manageable number of localities, specifying only one substitute site may prove to be a superior alternative. However, this approach exposes the practitioner to risk of losing a significant number of observations in cases where respondents had no experience with the specified site. Finally, possibilities for different formulation of contingent valuation question regarding the elicitation of the opportunity cost of time are numerous. Survey design might include willingness to pay question as well as the combination of the willingness to pay and willingness to accept questions by designing different versions of the survey to be given to a different random sample of individuals.

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Appendix:

GRANDFATHER MOUNTAIN SURVEY

HIKER/CAMPER PLEASE FILL OUT ALL QUESTIONS CAREFULLY. YOUR HELP IS GREATLY APPRECIATED AND ALL INFORMATION THAT YOU SUPPLY WILL BE TREATED CONFIDENTIALLY. ANSWER ALL QUESTIONS AND RETURN PROMPTLY.

1) Was the sole purpose for your trip to visit
Grandfather Mtn? (circle one)
YES / NO

IF YES, PROCEED TO QUESTION 5. IF NO, PROCEED TO QUESTION 2.

2) For what other reason(s) did you leave home?

3) How many days were you away from home?

4) What was the round trip distance you travelled on your entire trip?

5) How many times have you visited Grandfather Mountain in the past 12 months?

6) How many trips do you normally make to Grandfather Mountain annually?

7) Composition of your travelling party?
(please check only one category)
Alone ____
Friends ____
Family ____
Friends & Family ____

8) Total # of people in your party? ________

9) For how many people in your party did you cover all expenses? ______

PLEASE ANSWER QUESTIONS 10 AND 11 FOR YOUR ENTIRE TRIP.

10) Total round trip travel time? ________

11) Total round trip expenditures on:
food (at restaurants only) ________
Gas ______
Hotels ______
Souvenirs ______
Entertainment ______
Other (please specify) ______

12) Duration of your stay at Grandfather Mountain?
Days_____ Nights_____

13) Using a school grading scale, with A being the best, C being average and F being the worst, please rate the following attributes of Grandfather Mountain:
Trail system_____
Campsites_____
Scenery and views_____
Wildlife encounters_____
Diversity of plant life _____

14) Using the same scale, how, would you rate your overall hiking/camping experience at Grandfather Mountain?

15) How many other parties did you encounter while hiking/camping at Grandfather Mountain?

too few perfect amount too many (circle one)

IN ORDER TO BETTER UNDERSTAND YOUR OVERALL HIKING EXPERIENCES, WE NEED TO KNOW SOMETHING ABOUT THE OTHER PLACES YOU HIKE.

16) Do you hike other areas?
YES / NO

17) How many times have you hiked other areas in the past 12 months?

18) Aside from Grandfather Mountain, what is your preferred hiking area?

19) How many times have you hiked this preferred site in the past 12 months?

20) How many miles is the round trip drive from your home to this preferred site and back?

21) How long do you typically stay at this site?
Days_____ Nights_____

22) What are your average total expenditures per trip to this preferred site?

23) Using the A to F scale, please rate your overall hiking/camping experience at this preferred site.

IN ORDER TO GAIN COMPLETE INFORMATION ON THE USERS OF GRANDFATHER MOUNTAIN ADDITIONAL INFORMATION IS NEEDED. YOUR ANSWERS ARE COMPLETELY CONFIDENTIAL AND VERY HELPFUL TO OUR STUDY.

24) Your hometown: City_____
State_____ Zip_____

25) Your: Age_____ years
Gender M / F
Occupation _____
Highest level of education completed _____

26) Total pretax household income (circle one)

$1,000 - $10,000
$10,001 - $20,000
$20,001 - $25,000
$25,001 - $30,000
$30,001 - $35,000
$35,001 - $40,000
$40,001 - $45,000
$45,001 - $50,000
$50,001 - $60,000
over $60,000

27) If someone offered you an opportunity to work overtime instead of visiting Grandfather Mountain, at what hourly rate would they have to pay you for you to accept the offer?

28) Before receiving this questionnaire, were you aware of The Nature Conservancy's role in protecting Grandfather Mountain?

YES / NO

THANK YOU FOR TAKING THE TIME TO FILL OUT THIS QUESTIONNAIRE!
ANY COMMENTS OR QUESTIONS?

Endnotes

1. McConnell and Strand (1981) found that the total consumer surplus can be nearly four times as large when time costs are added at one-half the wage rate as when time costs were set at zero.

2. Among those 48 responses to question 27, in three cases the revealed value of time was $1,000 an hour or more. Those were interpreted as protest votes and deleted from the sample.

3. Estimating the revealed value of time trips demand (Model 2) with all 45 available observations instead of only with the 42 overlapping observations also produces more significant opportunity cost of time coefficient than estimating the wage rate trips demand (Model 1) with all 80 available observations.

4. The table value of F distribution for (1, 83) degrees of freedom at 5% critical value is 3.96.

Time and the Recreational Demand Model

Nancy E. Bockstael, Ivar E. Strand, and W. Michael Hanemann

In this paper, a theoretically consistent approach to including time costs in recreational demand models is developed. The demand model is conditional on the recreationist's labor market situation. For individuals at corner solutions in the labor market, utility maximization is subject to two constraints, leading to a demand function with travel costs and travel time as independent variables. With interior solutions in the labor market, time is valued at the wage rate and combined with travel costs to produce one "full cost" variable. In an illustration, welfare measures based on the new model are estimated for a sample of sportfishermen.

Key words: opportunity cost, recreational demand, time costs, travel cost model.

Economists, especially those interested in recreation demand, have long recognized that time spent in consuming a commodity may in some cases be an important determinant of the demand for that commodity. Recreationalists cite time much more than money as the constraining element in their recreation consumption (e.g., U.S. Dep. of Interior). Although the potential importance of time has been discussed at some length in the literature, only recently has the problem of explicitly incorporating time into the behavioral framework of the consumer been addressed.

Even when the treatment of time is critical, a consensus as to a proper approach remains elusive. A number of approaches (e.g., Smith, Desvousges, and McGivney; McConnell and Strand; Cesario and Knetsch) to valuing time are currently in vogue; but no method is dominant, and researchers often improvise. Unfortunately, the benefit estimates associated with changes in public recreation policy are extremely sensitive to these improvisations. Cesario, for example, found that annual benefits from park visits nearly doubled depending on whether time was valued at some function of the wage rate or treated independently in a manner suggested by Cesario and Knetsch. More recently, Bishop and Heberlein presented travel cost estimates of hunting permit values which differed fourfold when time was valued at one-half the median income and when time was omitted altogether from the model.

In applications, researchers have often incorporated travel time in an arbitrary fashion as an adjustment in a demand function or, alternatively, by asking people what they would be willing to pay to reduce travel time. Ad hoc econometric specifications or general willingness-to-pay questions are particularly problematic, however, because time is such a complex concept. Time, like money, is a scarce resource. Anything which uses time as an input consumes a resource for which there are utility-generating alternatives. Because time is an essential input into the production of any commodity which we might call an "activity," time is frequently used as a measure of that activity as well. Thus, while time is formally an input into the production of the commodity, it may also serve as the unit of measure of the output. Hence, direct questioning or poorly conceived econometric estimation may yield confusing results because the distinction between these two concepts is not carefully made.

This paper focuses on time as a scarce re-

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source. Both travel time and on-site time are uses of the scarce resource and must appear in a time constraint to be properly accounted for by the model. The exclusion of either will bias results. The recreational commodity is defined in terms of fixed units of on-site time, and it is assumed that travel does not in itself influence utility levels.

The paper develops a general framework for incorporating time, drawing on recent advances in the labor literature. After discussing the wide range of complex labor constraints which the general model can handle, it is made operational. This task is more difficult than it might appear since the utility-maximizing framework now includes two constraints. The approach developed below not only incorporates a defensible method for treating the value of time but also addresses sample selection bias inherent in recreational survey design and derives exact measures of welfare. Finally, the approach is illustrated with a sample of recreationalists.

Time as a Component of Recreational Demand: A Review

The problems which arise when time is left out of the demand for recreation were first discussed by Clawson and Knetsch. Cesario and Knetsch later argued that the estimation of a demand curve which ignored time costs would overstate the effect of the price change and thus understate the consumer surplus associated with a price increase.

In practical applications, both travel cost and travel time variables have usually been calculated as functions of distance. As a result, including time as a separate variable in the demand function tended to cause multicollinearity. Brown and Nawas, and Gum and Martin responded to the multicollinearity issue by suggesting the use of individual trip observations rather than zonal averages. In contrast, Cesario and Knetsch proposed combining all time costs and travel costs into one cost variable to eliminate the problem of multicollinearity.

Johnson and McConnell were the first to consider the role of time in the context of the recreationalist's utility maximization problem (although others had considered time in other consumer decision problems). In the context of the classical labor–leisure decision, the individual maximizes utility subject to a constraint on both income and time. When work time is not fixed, that is, when it is freely chosen by the individual, then the time constraint can be solved for work time and substituted into the budget constraint. As a result time cost is transformed into a money cost at the implicit wage rate.

However, when individuals are unable to choose the number of hours worked, the direct substitution of the time constraint into the budget constraint is not possible. McConnell suggested that in this case one should still value time in terms of money before incorporating it in the demand function. This is conceptually possible, since at any given solution there would be an amount of money which the individual would be willing to exchange for an extra unit of time so as to keep his utility-level constant. Unfortunately, this rate of trade-off between money and time, unlike the wage rate, is both endogenous and unobservable.

Much of the recent recreation demand literature follows the line of reasoning which relates the opportunity cost of time in some way to the wage rate. McConnell and Strand (see also Cesario; Smith and Kavanaugh; Nichols, Bowes, and Dwyer) demonstrated a methodology for estimating a factor of proportionality between the wage rate and the unit cost of time within the traditional travel cost model. More recently, Smith, Desvousges, and McGivney attempted to modify the traditional recreational demand model so that more general constraints on individual use of time are imposed. They considered two time constraints, one for work/nonrecreational goods and another for recreational goods; the available recreation time could not be traded for work time. The implications for their model suggest that when time and income constraints cannot be reduced to one constraint, the marginal effect of travel and on-site time on recreational demand is related to the wage rate only through an income effect and in the most indirect manner. Unfortunately, their model "does not suggest an empirically feasible approach for treating these time costs" (p. 264). For estimation, these authors confined themselves to a modification of a traditional demand specification which is not necessarily consistent with utility maximization.

Researchers are thus left with considerable confusion about the role of the wage rate in specifying an individual's value of time. But an important body of economic literature, somewhat better developed, has attempted to deal with similar issues. Just as the early literature on the labor–leisure decision provided initial insights into the modeling of time in recreational demand, more recent literature on labor supply behavior provides further refinement.

Labor Supply Literature: A Review

The first generation of labor supply models resembled the traditional recreational demand literature in a number of ways. These models either treated work time as a continuous choice variable allowing a continuous trade-off between income and leisure time at the wage rate or they treated work time as a fixed parameter with individuals being "rationed" with respect to labor supply in a "take-it-or-leave-it" fashion.

While useful in characterizing the general nature of a time allocation problem, first generation labor supply models were criticized on both theoretical and econometric grounds. The second generation of labor supply literature (see for example Ashenfelter, Ham, Burtless and Hausman) generalized the budget line to reflect more realistic assumptions about employment opportunities. As Killingsworth states in his survey, "the budget line may not be a straight line: Its slope may change (for example, the wage a moonlighter gets when he moonlights may differ from the wage he gets at his 'first' job), and it may also have 'holes' (for example, it may not be possible to work between zero and four hours)" (p. 18). This more general view of the problem is useful for recreation demand modeling for it argues that only those individuals who choose to work jobs with flexible work hours (e.g., self-employed professionals and individuals working second jobs or part-time jobs, etc.) can adjust their marginal rates of substitution of goods for leisure to the wage rate. All others can be found at corner solutions where no such equimarginal conditions hold and the wage rate cannot serve as the value of leisure time.

Two further aspects of the second generation labor supply models are noteworthy. The first generation studies estimated functions which were specified in a relatively ad hoc manner, but second generation labor supply functions were derived from direct or indirect utility functions (Heckman, Killingsworth, and MacCurdy; Burtless and Hausman; Wales and Woodland). Such utility-theoretic models have particular appeal for recreational benefit estimation because they allow estimation of exact welfare measures.

Finally, first generation research was concerned either with the discrete work/nonwork decision or with the continuous hours-of-work decision. Second generation empirical studies recognized the potential bias and inefficiency of estimating the two problems independently and employed estimation techniques to correct for this. An analogous problem arises in recreation demand studies; both the discrete participation decision and the continuous demand for recreational trips are important.

A Proposed Recreation Demand Model

The nature of an individual's labor supply decision determines whether his wage rate will yield information about the marginal value of his time. In the recreational literature, researchers have conventionally viewed only two polar cases: either individuals face perfect substitutability between work and leisure time or work time is assumed fixed. Yet, few people have absolutely fixed work time, since part-time secondary jobs are always possible, and only some professions allow free choice of work hours at a constant wage rate. A workable recreation demand model must reflect the implications which labor decisions have on time valuation and allow these decisions to vary over individuals.

In developing a behavioral model that includes time as an input, we begin with a household production model. The individual maximizes utility by choosing a flow of recreational services, x_R, and a vector of other commodities, x_N, each of which may be produced by combining purchased inputs with time.

The technology is assumed to be fixed-proportion so that the x's have fixed time and money costs per unit given by t and p, respectively. For the recreation good, x_R, it implies that a unit of x_R (e.g., a visit) has a constant marginal cost (p_R) and fixed travel and on-site time requirements (t_R). All other commodities are subject to unit money or time costs and the general problem becomes

$$(1) \qquad \max_{x_R, x_N} U(x_R, x_N),$$

subject to

$$E + F(T_w) - p'_R x_R - p'_N x_N = 0, \text{ and}$$
$$T - T_w - t'_R x_R - t'_N x_N = 0,$$

where $U(\ldots)$ is a quasi-concave, twice-differentiable utility function, $E + F(T_w)$ is the sum of the individual's nonwage and wage income, T_w is labor time supplied, and T is the total time available.

In order to characterize an individual's solution to (1), the nature of the labor market constraints must be known. Figure 1 depicts one of many possible labor market scenarios where the individual has the opportunity of taking a primary job (at wage w_p) which requires a fixed work week of forty hours. Depending on the shape of the individual's indifference curve between work and leisure, this individual may choose not to work at all (at B), to work the primary job only (at A), or to work some additional hours at a secondary job which pays $w_s < w_p$ (some point along CA). At an interior solution, such as along line segment AC, the individual adjusts work time such that his marginal rate of substitution between leisure and goods equals his effective (marginal) wage rate. Alternatively, an individual may be at a corner solution of unemployment (point B) or a fixed work week (point A). At both these points no relationship exists between the individual's wage rate and his time valuation.[1]

Strictly speaking, the problem in (1) requires the simultaneous choice of both the x's and the individual position in the labor market (i.e., interior or corner solution). However, modeling the entire labor decision is beyond the scope of most recreation demand studies. Labor market decisions may be affected by individuals' recreational preferences and by the recreational opportunities available. However, the daily and seasonal recreational choices about which we collect data and develop models can reasonably be treated as short-run decisions conditioned on longer-run labor choices. Because changing jobs is costly, labor market adjustments are not made continually. Thus, we consider that recreational choices depend on the type of employment which the individual has chosen. If the individual chooses employment with flexible work hours, then time spent working is endogenous to the model.

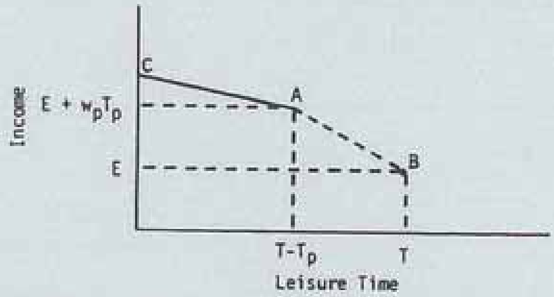

Figure 1. Second generation budget constraints

Let us rewrite the problem in (1) so as to allow treatment of both interior and corner labor market solutions. Define t_F as hours spent working at a job with a fixed work week and t_D as hours of discretionary employment, i.e., hours freely chosen by the individual. The variable w_F is wage associated with t_F, and w_D is the wage received in discretionary employment. Additionally, define $\bar{T}$ as $T - t_F$ or the time available for discretionary activities. Now the time constraint can be expressed as

$$\text{(2a)} \quad T - t_F - t_D - t'_R x_R - t'_N x_N = 0, \text{ or}$$

$$\text{(2b)} \quad \bar{T} - t_D - t'_R x_R - t'_N x_R = 0.$$

Given the distinction between discretionary and nondiscretionary time, it makes sense to define the budget constraint in a general way as well:

$$\text{(3a)} \quad E + w_F t_F + w_D t_D - p'_R x_R - p'_N x_N = 0, \text{ or}$$

$$\text{(3b)} \quad \bar{Y} + w_D t_D - p'_R x_R - p'_N x_N = 0$$

where $\bar{Y}$ is nonwage income and income from nondiscretionary employment.

For any given individual t_D or t_F or both may be zero. Specifically, an individual with $t_D > 0$ will be at an interior solution in the labor market and one with $t_D = 0$ will be at a corner. The lagrangian problem for individuals with $t_D = 0$ can be written as

[1] The wage rate is neither an upper nor a lower bound on the individual's marginal valuation of time when labor time is institutionally restricted. An individual may choose unemployment because he values a marginal leisure hour more than the wage rate. Alternatively, he may value marginal leisure hours less than the wage rate but not be better off accepting a job requiring 40 hours of work per week. An individual at point A in figure 1, for example, may value the marginal leisure hour at more than w_p but choose 40 rather than 0 hours. Alternatively, he may value leisure time at less than w_p but more than a potentially lower wage which could be earned at a secondary job.

$$(4)\quad \max L = U(x_R, x_N) + \lambda(\bar{Y} - p'_R x_R - p'_N x_N) + \mu(\bar{T} - t'_R x_R - t'_N x_N).$$

First-order conditions for these individuals are

(4a)
$$\partial U/\partial x_i - \lambda p_i - \mu t_i = 0 \quad \text{for all } i,$$
$$\bar{Y} - p'_R x_R - p'_N x_N = 0,$$
$$\bar{T} - t'_R x_R - t'_N x_N = 0.$$

Since these individuals cannot marginally adjust work time, the two constraints are not collapsible. Solving (2a) for the demand for x_i yields a demand function of the general form

$$(4b)\qquad x_i = h^C(p_i, t_i, p^0, t^0, \bar{Y}, \bar{T})$$

where p^0 and t^0 are the vectors of money and time costs of all goods other than i.

For individuals at interior solutions in the labor market, at least some component of work time is discretionary, and time can be traded for money at the margin. In this case t_D is endogenous. Because of this, the lagrangian

$$\max L = U(x_R, x_N) + \lambda(\bar{Y} + w_D t_D - p'_R x_R - p'_N x_N) + \mu(\bar{T} - t_D - t'_R x_R - t'_N x_N)$$

can be rewritten as

$$(5)\quad \max L = U(x_R, x_N) + \delta(\bar{Y} + w_D\bar{T} - (p_R + w_D t_R)' x_R - (p_N + w_D t_N)' x_N),$$

where the time constraint has been substituted into the income constraint. This reflects the fact that when (at least a portion of) work time is endogenous, money can be traded for time and time for money at the margin. First-order conditions for the individual at an interior solution are

$$(5a)\quad \partial U/\partial x_i - \delta(p_i + w_D t_i) = 0 \quad \text{for all } i,$$
$$\bar{Y} + w_D\bar{T} - (p_R + w_D t_R)' x_R - (p_N + w_D t_N)' x_N = 0.$$

Solving for the general form of a recreational demand function for an interior solution yields

$$(5b)\quad x_i = h^I(p_i + w_D t_i, p^0 + w_D t^0, \bar{Y} + w_D\bar{T}).$$

Consideration of demand functions (4b) and (5b) suggests that the data requirements for estimation are not overly burdensome. In addition to the usual questions about income and the time and money costs of the recreational activity, one need only ask (*a*) the individual's total work time and (*b*) whether or not he has the discretion to work during recreational time. If he does, his discretionary wage must be elicited.

In problem (5) the recreational demand function is conditioned on the individual having chosen an interior solution in the labor market. The wage rate (w_D) reflects the individual's value of time because work and leisure can be traded at the margin. When this is not the case, as in problem (4), the marginal value of the individual's time in other uses is not equal to the wage rate he faces. This does not imply that the opportunity cost of time is zero for this individual. Rather his opportunity cost is not equal to an observable parameter.

Considerations for Estimating Recreational Benefits

At this point one would like to estimate demand functions such as (4b) and (5b) and relate the estimated parameters to welfare measures. The recent literature in benefit measurement emphasizes the use of "exact" welfare measures. The procedures for integrating back from a Marshallian demand function to utility and expenditure functions are now well established (Hausman, Hanemann), and techniques for approximating compensating variation using numerical methods (when "exact" measures have no closed form solutions) are well developed (e.g., Vartia). However, by formulating the problem above with two constraints (money and time), we open the door to a new set of problems in welfare measurement. It has been demonstrated (Smith) that the utility maximization problem with two linear constraints has two duals, one which minimizes money costs subject to utility and time constraints and the other which minimizes time costs subject to utility and income constraints. Associated with each dual is an expenditure function and a compensated demand. As discussed elsewhere (Bockstael and Strand), compensation can be measured in terms of time or money or any combination of the two.

We can choose the traditional money measure for welfare evaluation, but this does not solve all problems. The conventional wisdom on integrating back to expenditure functions or obtaining exact welfare measures does not apply in the two-constraint case. This means that the procedure of estimating a Marshallian demand function which fits the data well and deriving the associated expenditure function using the parameter estimates is not a feasible alternative at this juncture. If one wants exact measures, one needs to start with the preference structure and explore those demand functions which can be derived from alternative utility functions. One clear difficulty—a symptom of the integrability problem—is that the utility function considered must be a function of at least three goods because it will be maximized with respect to two constraints. It is no longer possible to use the single Hicksian bundle concept. These difficulties are not artificial constructs which follow from the specific formulation of the problem. They characterize any micro decision problem where the individual faces two constraints.

All is not lost, however. An alternative is to start with a plausible utility function and derive the corresponding demand function for the recreational good. An array of such utility functions and demand functions could be explored. Here we select a utility function which is somewhat restrictive in nature but which generates linear demand functions which ease illustration. Nonetheless, the theoretical development in the previous sections and the subsequent general empirical procedures are applicable to any preference function chosen.

Because our empirical illustration has a quality variable involved with the choice of recreational use, the utility function also has quality as an element. This is a straightforward adaption of a quantity/quality model discussed in Hanemann.

The utility function used for illustration has the form,

$$(6) \quad U(x) = \frac{(\gamma_1 + \gamma_2)x_1 + \beta}{(\gamma_1 + \gamma_2)^2} \exp\left[\frac{(\gamma_1 + \gamma_2)(\alpha + \gamma_1 x_2 + \gamma_2 x_3 - x_1 + \gamma_3 q + \epsilon)}{(\gamma_1 + \gamma_2)x_1 + \beta}\right].$$

As is the usual procedure, the parameters α, β, γ_1, γ_2, and γ_3 are assumed common to all individuals for estimation purposes. The random variable, ϵ, reflects the distribution of preferences over the population and is assumed to be distributed normally with mean zero and constant variance, σ^2.

The recreational good is designated as x_1, and q is some quality dimension associated with it. In the two-constraint case, it is useful to partition the set of other goods such that x_2 is a Hicksian bundle of goods with money but no significant time costs. The bundle, x_2, is a numèraire such that the money price of recreation is normalized with respect to p_2. Hicksian bundle x_3 is a bundle of goods with time but no significant money costs and serves as a numèraire such that time prices are normalized with respect to t_3. Thus, the general constraint set is

$$\bar{Y} - p_1 x_1 - p_2 x_2 = 0, \text{ and}$$
$$\bar{T} - t_1 x_1 - t_3 x_3 = 0,$$

where p_2 and t_3 are assumed to be equal to one.

The restrictive form of the utility function chosen has two undesirable properties. For an interior solution, when the two constraints collapse into one, this form implies that either x_2 or x_3 is chosen (but not both). When the two constraints are not collapsible, the functional form implies a constant trade-off between time and money. While restrictive with regard to the Hicksian goods, this utility function does have the advantage of producing easily estimated demand functions for the recreational good.

Solving the system for the optimum value of x_1, and denoting $\beta/(\gamma_1 + \gamma_2)$ as β', yields ordinary recreational demand functions, conditioned on each labor supply decision, of the form

$$(7) \quad x_1 = \alpha + \gamma_1 \bar{Y} + \gamma_2 \bar{T} + \beta' \gamma_1 p_1 + \beta' \gamma_2 t_1 + \gamma_3 q + \epsilon$$

for individuals at corner solutions in the labor market and

$$(8) \quad x_1 = \alpha + \gamma_1(\bar{Y} + w_D \bar{T}) + \beta' \gamma_1 (p_1 + w_D t_1) + \gamma_3 q + \epsilon$$

for individuals at interior solutions in the labor market. Since equations (7) and (8) are linear in the respective variables, they might easily have been specified and estimated as ad hoc demand functions, without reference to utility theory, but the theoretical development provides a basis for interpreting the parameters and understanding the inherent restrictions of the model.

By first substituting demand functions into (6) to obtain the indirect utility function and inverting to obtain the money expenditure function, the compensating variation for each of the above cases can be derived. Compensating variation in money terms is[2]

$$(9)\quad CV_I^Y = \exp[\gamma_1(\bar{p}_1 - p_1^0)]\left(\frac{x_1^0 + \beta'}{\gamma_1}\right) - \frac{\beta'}{\gamma_1}$$

for the interior solution, where (p_1^0, x_1^0) is the initial observed point and $\bar{p}_1$ is the price which drives the individual out of the market for x_1. The money compensating variation for a loss of the recreation good conditioned on a corner solution in the labor market is then

$$(10)\quad CV_C^Y = \exp[\gamma_1(\bar{p}_1 - p_1^0)]\left(\frac{x_2^1 + \beta'}{\gamma_1}\right) - \frac{\beta'}{\gamma_1}.$$

The Empirical Illustration

In this section, a specific application of the model is offered. Parameters of the recreational demand model are estimated for a group of Southern California sportfishermen who fished during 1983. All individuals in the group owned at least one boat and took at least one private boat trip during that year. About one-third of the respondents claimed they could have worked in lieu of fishing and provided information on the wage rate from working. The others were assumed to face fixed work hours and thus were at corner solutions in the labor market. Individuals facing both types of labor market situations, represented by demand equations (4b) and (5b), could be found in the sample.

A more complete description of the questionnaire and data is given elsewhere (i.e., Wegge, Hanemann, and Strand), but the following description of the variables will serve our purposes: x_1 is annual private boat trips in Southern California during 1983; p_1 is the average transportation cost per trip ($/trip); q is the average number of the principal species caught per trip (fish/trip); t_1 is the average round-trip travel time (hours/trip); $\bar{Y}$ is annual household income (in $\$ \times 10^{-3}$); $\bar{T}$ is annual hours of paid vacation plus hours available after work (in hours $\times 10^{-3}$); and w_D is hourly wage for discretionary work time ($/hours).

Following the theoretical development, an individual's demand for trips is given by some systematic function of money and time price, income, discretionary time, and fish catch. The estimation procedure must take account of the different demand functions applicable for people in different labor market situations. Additionally, because the sample contained only recreational participants, a method which corrects for the implied truncation bias (Maddala, p. 165) must be used. One such method (the tobit) assumes the individual's behavior has the following pattern

$$\begin{aligned} x_i &= h_i(\cdot) + \epsilon_i \quad \text{if and only if } h_i(\cdot) + \epsilon_i > 0 \\ x_i &= 0 \quad \text{otherwise,} \end{aligned}$$

where $h_i(\cdot)$ is the systematic portion of the appropriate demand function evaluated for individual i [equation (4b) and (5b)] and ϵ_i is the random disturbance associated with individual i.

Given this model of behavior, the likelihood function for the sample is

$$(11)\quad L = \prod_{j \in M_C} \frac{f(\epsilon_j^C/\sigma)/\sigma}{F(h_j^C(\cdot)/\sigma)} \prod_{j \in M_I} \frac{f(\epsilon_j^I/\sigma)/\sigma}{F(h_j^I(\cdot)/\sigma}.$$

where $f(\cdot)$ and $F(\cdot)$ are the density and cumulative distribution functions of the normal distribution respectively, h^C and h^I denote functions (4b) and (5b), respectively, $\epsilon_j^C = x_j - h_j^C(\cdot)$, and $\epsilon_j^I = x_j - h_j^I(\cdot)$. Finally, M_C is the subset of individuals who are found at corner solutions in the labor market, and M_I is the subset found at interior solutions. Estimates of the parameters of the demand functions in (4b) and (5b) are obtained by maximizing the log-likelihood function in (11).

The estimated parameters are shown in table 1. Although it is difficult to predict signs for the coefficients, the estimates do not contradict a few expectations. One expects increased catch to increase utility and to influence demand positively ($\gamma_3 > 0$). Also, one would normally expect positive income and time effects, especially the time effects given frequent expressions by recreationalists that time is the limiting factor on recreation con-

[2] The compensating variation in terms of time rather than money could also be computed. For individuals at interior solutions the time-compensating variation is given by

$$CV_I^T = \exp[\gamma_1(\bar{p}_1 - p_1^0)]\left[\frac{x_1^0 + \beta'}{\gamma_1 w_D}\right] - \frac{\beta'}{\gamma_1 w_D}.$$

The time compensation for the loss of the recreational good, conditioned on a corner solution in the labor market is given by

$$CV_C^T = \exp[\gamma_1(\bar{p}_1 - p_1^0)]\left[\frac{x_1^0 + \beta'}{\gamma_2}\right] - \frac{\beta'}{\gamma_2}.$$

Table 1. Maximum Likelihood Estimates for Recreation Demand Parameters

Parameters	α	β'	γ_1	γ_2	γ_3	σ
Estimate (t-ratio)	−3.838 (−.743)	−1.019 (−2.563)	.024 (.899)	2.982 (3.715)	.712 (3.208)	15.543 (12.486)

Note: Observations number 391; the log likelihood ratio = 45.23.

sumption. Thus both γ_1 and γ_2 are likely to be positive. If γ_1 and γ_2 are positive, and one expects the coefficient on the travel cost and travel time variables to be negative ($\beta'\gamma_1$, $\beta'\gamma_2 < 0$), then β' should also be negative. All of the above conditions were consistent with the results, although income's effect was statistically insignificant.

Much information of interest can be obtained from estimation of the type of model developed earlier in the paper. On the whole, the recreational decisions modeled here appear very sensitive to time considerations. This is an important result and likely characterizes many related recreational activities. To demonstrate this point, relevant elasticities (calculated at the mean) are reported for both groups of individuals in table 2. For individuals at corner solutions, distinguishable elasticities exist for money price, time price, income, and time. The elasticities of demand with respect to time variables are much larger than those with respect to money variables. Individuals at interior solutions presumably have equated their value of time and money at the margin by adjusting their work hours. For these individuals, elasticities of demand with respect to "full price" ($p + w_Dt$) and "full income" ($\bar{Y} + w_D\bar{T}$) are appropriate. The "full price" elasticities and "full-income" elasticities fall in the range between the money and time price elasticities and the income and time elasticities, respectively, of individuals with fixed work weeks.

Estimates of the welfare losses associated with a hypothetical elimination of the fishing resource are reported in table 3.[3] In the two-constraint case, welfare measures can be assessed either in money or in time compensation. Whether money or time measures are used, compensating and equivalent variations deviate from ordinary surplus by only a few percentage points. The average money compensation varies between \$2,700 and \$4,280 per year. These magnitudes are quite reasonable because the individuals in the data set spend on average \$4,800 in 1983 for fixed items for their boats (items such as insurance, mortgage payments, and slippage fees not included in trip costs and thus not netted out of consumer surplus).

The average money compensation necessary to compensate individuals with flexible work hours for loss of the resource was about \$2,700 per year. The average time compensation for this group was about 160 hours. This result suggests a money-time trade-off of about \$17/hour, which is approximately the mean hourly wage reported for these individuals. By contrast, the average individual with fixed work week would require more income compensation (about \$4,200/year) but

Table 2. Recreational Demand Elasticities for Individuals at Corner Solutions and Interior Solutions in the Labor Market

	Corner Solution Individuals (Fixed Work Week)	Interior Solution Individuals (Flexible Hours)
Money-price elasticity	.01	.
Time-price elasticity	.23	.
"Full price" elasticity	.	.10
Income elasticity	.06	.
Discretionary time elasticity	.77	.
"Full income" elasticity	.	.36

[3] These numbers represent "adjusted" estimates of compensating variation (CV), equivalent variation (EV), and ordinary surplus (OS). The usual procedure for obtaining estimates of CV, EV, and OS has been to substitute econometric estimates of parameters in the formulas (9) and (10) to derive estimates of welfare measures. As Strand and Bockstael show, this procedure in general yields biased estimates of the welfare measures even when the parameter estimates are unbiased. This is because CV, EV, and OS are typically nonlinear functions of the estimated parameters. Based on results of Zellner and Park, Strand and Bockstael demonstrate how consistent estimates of welfare measures can be obtained. The correction formulas are in part functions of the variance of the estimated parameters, which can be approximated by the squared standard errors of the coefficients. They are based on the result of Zellner and Park that if the function of interest is of the form A/B, then the expected value of the function is approximately

$$E(A/B) \simeq \frac{E(A)}{E(B)}\left(1 + \frac{\text{var } B}{E(B)^2}\right).$$

Table 3. Average Welfare Measures Associated with Resource Elimination

	Individuals with Fixed Work Hours	Individuals with Flexible Work Hours
Money measures ($/year):		
Ordinary surplus	4192	2727
Compensating variation	4281	2776
Equivalent variation	4148	2703
Time measures (hours/year):		
Ordinary surplus	68	159
Compensating variation	69	162
Equivalent variation	67	157

less discretionary time compensation (about 68 hours). Thus individuals with fixed work weeks would trade time for money at about $60 per hour, a much higher rate than the individuals with flexible work hours and a much higher rate than the labor market is likely to offer.

These specific results may be sensitive to the restrictions imposed by the choice of utility function, but nonetheless they are consistent with the following theoretical arguments. Individuals with fixed working hours appear to value time much more highly than the wage rate and would be willing to trade work for leisure. However, they have fixed work weeks and probably face all-or-nothing decisions in the labor market (i.e., if they want the job, they must work at least some fixed number of hours). Referring to figure 1, these individuals would like to be at a point between *A* and *B*, but must choose either *A* or *B*. Applications of the general model using more general underlying utility functions could provide more information about the time valuation of people at corner solutions in the labor market.

The numbers in table 3 illustrate an additional point. Had only the money compensation measures been calculated, we would have been tempted to conclude that the group with fixed work hours would be hurt more by the elimination of this resource. However, focusing solely on time compensation, the reverse would appear to be true. Theory offers little guidance here for, as Samuelson recognized in his discussion of rationing coupons, any resource endowment which constrains the individual's consumption can be used as a standard. The ambiguities which arise in such cases are discussed at length in Bockstael and Strand.

Concluding Comments

The major contribution of this work lies in the explicit treatment of recreationalists' labor market situations. For individuals with fixed work hours, the arguments of demand functions and the computation of welfare are different from people whose labor/leisure choice is at an "interior" and whose opportunity cost of time is reflected by the wage rate. Arguments in the demand function for the corner solution include total discretionary time and the hour cost of the trip. An explicit linear model was developed to demonstrate that the general model could be made operational. While the properties of the linear model are somewhat restrictive, the theoretical development is applicable independent of the choice of preference structure. The example provides an illustration and suggests the difficulties encountered when empirical problems involve utility maximization subject to two constraints.

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Value of Time in Recreation Benefit Studies

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INTRODUCTION

The consumers' surplus criterion is gaining widespread acceptance as a way of estimating the primary economic benefits of outdoor recreation sites and facilities. Calculation of the consumers' surplus associated with any recreation site involves measurement of a relevant portion under the demand curve for the services of the site. Since the services provided by the typical public recreation site are not marketed, but are instead offered free of charge or at negligible prices, it is necessary to impute demand curves on the basis of only very limited price-quantity information. A favored method for imputing recreation site demand curves is the so-called Hotelling-Clawson-Knetsch (HCK) approach.[1] Since this method is adequately described elsewhere it need not be described in detail here.[2] It suffices to point out merely that a fundamental problem with application of this method has been the difficulty of capturing effectively the value placed on travel time by consumers of recreation services. Failure to explicitly incorporate this aspect of recreation site usage into the HCK analysis results in the imputation of a demand curve which is biased downward from its "true" position.[3] Consequently, the benefits of the site are estimated conservatively.

The basic problem may be seen by envisioning a simple recreation system with one recreation site and two origins of visitors. The distances to the site from origins 1 and 2 are 5 miles and 15 miles, respectively. The corresponding travel times are 5 minutes and 20 minutes. Assume that the services of the park are offered free of charge. If the variable cost of automobile travel is $0.10 per mile the money costs of a visit to the site from origins 1 and 2 are thus given by $0.50 and $1.50, respectively. Suppose now that the price of a visit is increased to $1.00 per outing. The total money costs of a visit from origins 1 and 2 would then be $1.50 and $2.50, respectively. Assuming that the increase in the park price is viewed by each recreationist in the same way as any other money increase (say, an increase in road tolls) the HCK method assumes that the visit rate from origin 1 would fall to the rate formerly associated with origin 2 (since the money cost to residents of origin 1 after the change is equal to the money cost to residents of origin 2 before the change).

The pitfall in this analysis is that the time cost of the trip is ignored. As the money cost of a visit to a recreation site is increased for each individual, the travel time remains constant. If we take the total cost of a trip to be given by the sum of the money cost and the money equivalent of the time cost, then the

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[1] The terminology follows Cicchetti, et al. [1973]. The HCK method is more popularly known as the "travel-cost technique."

[2] The seminal works are Clawson [1959], Knetsch [1963] and Clawson and Knetsch [1966].

[3] Cesario and Knetsch [1970].

total cost of traveling from visitor origin i to recreation site j is given by:

$$c_{ij} = \alpha d_{ij} + \beta t_{ij} \quad [1]$$

where:
c_{ij} = total cost of travel from i to j
d_{ij} = travel distance from i to j
t_{ij} = travel time from i to j
α = variable cost per unit distance of automobile travel
β = value of a unit of travel time.

In the initial situation above where the price of a visit was equal to zero, we had:

$$c_{2j} = q + 20\,\beta \quad [2]$$

where q is equal to 15α. After the price increase of \$1.00 per visit we have:

$$c_{1j} = q + 5\,\beta \quad [3]$$

which would imply, in the presence of a negative functional relationship between recreation tripmaking and total travel cost, that the two visit rates were not equal. Specifically, the new visit rate from origin 1 would be greater than the old visit rate from origin 2 since $c_{1j} < c_{2j}$.

The obvious problem of including travel-time valuations explicitly in the benefits analysis is that, like recreation consumption itself, time consumption has no market value. That is, whereas the variable cost of automobile travel may be reasonably estimated from market prices for gasoline, oil, tires, etc., the valuation placed on travel time is highly subjective, varying from individual to individual and from situation to situation. Attempts could be made to empirically include the cost of time into the HCK method but the results would probably be disappointing. The fundamental problem is that travel time and travel distance are usually so highly correlated that it is impossible to distinguish empirically between their separate effects. To overcome this problem several researchers incorporated travel-time valuations in HCK analysis in ad hoc and highly arbitrary ways.[4] Although these procedures have resulted in benefit estimates which are higher than those which would have been achieved had travel time been ignored, it is not known to what extent the bias has actually been eliminated.

In recent years the transportation planning literature has reported on several studies of travel-time evaluations in different contexts. Certain generalities are beginning to appear in connection with the study of commuters' travel-time values and these results have implications for recreation benefit studies. These results and implications are discussed in the remainder of this paper. First the theoretical basis for travel-time valuations is discussed; then a brief review of relevant empirical studies is presented; finally an application of the results is described.

THEORETICAL BASIS

At the outset it is important to distinguish between time as a resource and time as a commodity. In the outdoor recreation trip context it is relevant to

[4]Studies by Cesario and Knetsch [1970] and Brown and Hansen [1974] are described in Knetsch [1974]. Cesario, et al. [1970] examined alternative ways of introducing time effects without explicitly placing a monetary value upon a time unit. Mansfield [1969 and 1971] has explicitly introduced travel-time valuations into the formulation and has made some relevant measurements, some of which are reported in Mansfield [1970]. Brown and Nawas [1973] have also published results of attempts to estimate travel-time values.

make the latter interpretation and therefore to be concerned with the value of *saving* time.[5] If time is saved then it can be employed elsewhere.[6] If time is treated as a resource it has scarcity value and the value of time in this interpretation is the value which one attaches to gaining additional units of it. Thus, in this paper the value of time (as a commodity) is the amount one is willing to pay to save time spent traveling. The value of time as a resource (i.e., leisure time per se) is not of special interest, but as we shall see below it provides a lower bound on the value of saving time.

The value of time for an individual in a given situation is conditioned by what activities are being traded off. If the individual is trading off travel time for work time and there is no marginal utility or disutility associated with work or with travel, then there is some basis for valuing travel time at the wage rate. However, it seems farfetched to assume that the recreation tripmaker is trading off time for travel with time for work. It seems much more likely that the tradeoff is between time for travel and time for leisure activities, which we loosely define to be activities conducted during nonwork hours, whether they be in the form of rest, sleep, gardening, outdoor sport, etc. The value of travel time in a recreation tripmaking context thus reflects the value placed on alternative uses of leisure time by the individual, for this is the relevant opportunity cost. If we posit that travel per se carries with it a marginal utility or disutility, then it can be shown that the value of saving travel time will diverge from the value of leisure time.

First, considering leisure time separately and assuming (1) that individuals can in the long run adjust working and leisure hours to suit their preferences, and (2) that different degrees of disutility are associated with different kinds of work, the equilibrium condition for the consumer to maximize utility is given by:[7]

$$\frac{\partial U}{\partial t_\ell} = P\frac{\partial U}{\partial Y} + \frac{\partial U}{\partial t_w} \qquad [4]$$

where U is utility, t_ℓ is leisure time, t_w is work time, P is the money wage, and Y is income. Thus, the marginal utility of leisure is equal to the sum of the marginal utility of money earned by spending the time in work and marginal (dis)-utility of labor. If we divide each side of equation [4] by $(\partial U/\partial Y)$ we get the marginal condition:

$$\frac{(\partial U/t_\ell)}{(\partial U/\partial Y)} = P + \frac{(\partial U/\partial t_w)}{(\partial U/\partial Y)} \qquad [5]$$

Here the marginal rate of substitution between income and leisure is defined as the sum of the money wage rate and the marginal rate of substitution between in-

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[5] See DeSerpa [1971] for a discussion of this point. Throughout the rest of this paper "value of time," "value of travel time" and "value of saving time" are synonymous.

[6] Strictly speaking, time cannot really be saved in the sense of being stored for future use. When a unit of time is saved in one activity it must be used in another as it becomes available. This fact of life presents no unusual problems, but it does lead to the conclusion that the value of time for any individual will undoubtedly fluctuate dramatically over the course of even one day (since certain activities can be carried out only at certain times under certain conditions).

[7] The literature abounds with theoretical results of the nature discussed here. Basically, to get the desired result one minimizes a utility function $U = U(t_w, t_\ell, Y)$ subject to conditions $Y = Pt_w$ and $t_\ell + t_w = t_T$, where t_T is the total time available for work and leisure. Extensions and clarifications of the basic ideas may be found in Collings [1974], DeDonnea [1972], DeSerpa [1971 and 1973], Goodwin [1974], Johnson [1966], Oort [1969] and Tipping [1968].

come and the time spent at work. Inasmuch as it may be supposed that $(\partial U/\partial t_w)$ is negative, it follows from the above that the value of leisure time should be somewhat less than the wage rate, and the difference is determined by the extent of the marginal disutility of labor (about which we can say surprisingly little in a quantitative sense).

Here we have lumped all of leisure together and have ignored explicit recognition of the specific nature of travel itself. Following from the above, a general equilibrium condition would be:

$$T_\ell = T_t + U_t \qquad [6]$$

where T_ℓ is the value of leisure time, T_t is the value of travel time and U_t is the money equivalent of the marginal utility (disutility) of traveling. Thus, for any individual the marginal value of time may be greater than or less than the value of leisure time, depending on whether travel itself confers positive or negative utility upon the individual. In the typical case one might expect that the value of travel time would be greater than the value of leisure time itself.

Although the above results are theoretically interesting, they are not too helpful operationally. That is, the analytics do not yield an objective and unambiguous measure of travel-time valuation in terms of money because the values of the relevant utilities or disutilities are not known. Careful "experimentations" are needed in order to begin to infer what money values might be reasonably placed on time in given situations. It is to this question that we now turn.

EMPIRICAL RESULTS

Transportation planners are interested in travel-time values because (1) time savings are an important and often the dominant source of benefit from transportation projects,[8] and (2) recent emphasis on "disaggregate, behavioral" demand modeling has brought on the need to develop relevant measures of the generalized cost of travel, of which time is a major component.[9] Consequently, it is not surprising to find that considerable efforts have been devoted to gauging travel-time values in different contexts.

The most prevalent frame of reference for the empirical investigations has been the study of choice situations where individuals may be observed in making decisions which involve a tradeoff between money and time—for example, in mode choice, route choice, destination choice, and driving speed choice (although most studies have concentrated on the mode choice decision associated with the commuter's journey to work). For those that actually "trade" time and money, such as might be the case when an individual chooses a fast, expensive mode over a slow, inexpensive mode (or vice versa), an indication of the average value of time may be obtained by observing the number of individuals who make each choice. For example, if the increment of money is given by ΔM and the increment of time is given by ΔT, then those individuals with values of time less than $\Delta M/\Delta T$ will take the slow mode and those with values of time greater than $\Delta M/\Delta T$ will take the fast mode.[10] By observing how people divide up between modes it is then possible to impute by the use of statistical techniques average (but not marginal) values of saving time. Essentially this is the

[8] See Harrison [1974] for more details.

[9] See Transportation Research Board [1973] for more details.

[10] The quantity $\Delta M/\Delta T$ is obviously the "price" of time in this context.

method used in the studies that have been performed to date.[11] The literature devoted to travel-time valuations has been reviewed by others and there is no need to repeat the same material here in detail.[12] Only the principal results, and in some cases the methodologies used to obtain them, are presented.

Beesley [1965] used an ad hoc approach in the study of time-money tradeoffs in urban commuter choices between public transportation modes and between private car and public transport. It was found that travel time is valued at approximately one-third the wage rate for public transit riders, and for higher-income workers the value of time is slightly less than one-half the wage rate. There was some slight evidence to the effect that the value of time is an increasing proportion of income (although due to the size of the sample being considered this latter conclusion can be subject to serious question).

Quarmby [1967] used discriminant analysis in an attempt to explain choices between private car and public transport with respect to a sample of car owners in Leeds. This study tentatively concluded that the average value of time in this context is somewhere between 20 and 25 percent of the wage rate, and that this percentage is virtually constant over all income groups.

Using multiple probit analysis in a study of individuals' mode choice between public and private transport, Lisco [1968] concluded that commuters value their time, on the average, somewhere between 40 to 50 percent of the wage rates. In addition, there was some evidence to the effect that (1) a nonlinear relationship exists between the value of commuters' time and income, and (2) out-of-vehicle time (i.e., time spent waiting or walking) is valued almost three times as much as in-vehicle time. (The above results apply to medium-distance commuting trips in the Chicago area–from suburb to city center–with an average length of about 15 miles.)

Thomas [1968] used logit analysis to study time-money tradeoffs made by private-car commuters in choosing routes to and from work. Commuters in eight different locations in the United States were the focal point of analysis. This study is especially interesting in that two different measures of travel time were used: (1) "objective" measurements were taken with a test vehicle, and (2) "subjective" estimates were solicited directly from commuters. The model based on test vehicle data resulted in an estimate of travel time approximately equal to 40 percent of the wage rate, while the method based on reported data resulted in an estimate equal to approximately 80 percent of the wage rate. A mean value of 60 percent was advocated on the basis of (arbitrary) statistical considerations.

In a study of urban commuters in the United Kingdom, Stopher [1969] found that the value of travel time was somewhere in the range of 20 to 25 percent of the wage rate. In addition, there was some slight (although argumentable) indication that travel time increased less-than-proportionally with income. The methodology used was mutiple logit analysis.

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[11] Using a slightly different tactic, Mohring [1965] estimated travel-time values by assuming that house prices reflected, ceteris paribus, the capitalization of the time and operating costs of commuting. His results conform in general to those discussed here. For example, he estimated that the value of travel time ranged between 22 and 43 percent of earnings.

[12] See Haney [1967], Harrison and Quarmby [1969], McGillivray [1972] and Watson [1974].

Lee and Dalvie [1969] analyzed time-money tradeoffs involved in choices between alternative public transport modes. The data were collected by personal interview techniques and analyzed by regression models. The average value of time over the whole sample of respondents was reported as 30 percent of the wage rate. In addition, some evidence to the effect that (1) travel-time values increase with income, but in decreasing proportion, and (2) travel-time values increase slightly with length of trip was reported.

These early studies were plagued by the usual methodological problems besetting research in any new area of inquiry.[13] Problems of collecting appropriate data and of using the most appropriate statistical techniques are to be expected, and although the research described above can be faulted on these counts, the results are remarkably consistent *considering these difficulties.* Beyond the standard statistical difficulties, however, there are others that need to be dealt with. For example, how does the researcher take into account the typical driver's uncertainty and imperfect knowledge with respect to the relative "costs" of alternative modes, and how do the differences in "intangible" characteristics between modes affect the results (i.e., a violation of "ceteris paribus" conditions)? In a recent paper, Guttman [1975] addressed these issues and found that drivers' uncertainty served to bias (upwards) travel-time valuations on the order of 50 percent or more. Although no numerical results are presented with respect to the second problem, the dangers of not accounting for differences in "comfort and convenience" were made apparent. (It may be that this problem would be minimized if one were to study route choice decisions within the same mode.) There are still other problems and research is continuing in this area. The reader may wish to consult Harrison [1974, Ch. 5–6] for a fuller discussion of the problems and the directions that future research is likely to take.

In summary, subject to certain qualifications, it may be tentatively concluded that on the basis of evidence collected to date the value of time with respect to nonwork travel is between one-fourth and one-half of the wage rate. It is of course necessary to point out that this is an "average" valuation which may not apply strictly to any one individual since the value of time to an individual varies not only with the purpose of the trip, but may also vary with its length, time of day, and other factors.[14] Despite the empirical problems mentioned above, these results must be considered as a major finding; they are too consistent to be ignored. It is clear from these findings that the use of the marginal wage rate for the value of travel-time values in recreation benefit estimation is *inappropriate,* both from the theoretical and practical points of view.

PRACTICAL IMPLICATIONS

In order to examine the extent to which the above findings on travel time valuations can affect results obtained by

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[13] Harrison and Quarmby [1969] discuss many of these problems in detail.

[14] Thus far, the value of time has been positively linked to income. Although value of time may also be expected to depend on these other factors, as of this date there are no firm data upon which to establish these relationships; however, Guttman [1975] has looked at variations over different traffic conditions (peak vs. nonpeak). In lieu of a complete set of data on such variations, it is common to use a "uniform" value for travel time in transportation studies.

traditional HCK analysis, outdoor recreation data pertaining to a set of parks in the northeastern United States were used to generate benefit estimates under three different assumptions:[15]

(i) ignoring travel time;
(ii) using the ad hoc methodology of Cesario and Knetsch;[16]
(iii) valuing travel time in accordance with empirical results described above.

More specifically, travel cost from i to j was taken to be equal to ($0.06 d_{ij}) under assumption (i); ($0.06 $d_{ij}t_{ij}$) under assumption (ii); and ($0.06 $d_{ij} + \beta t_{ij}$) under assumption (iii), where β is the value of travel time. The "average" 1967 variable cost of automobile travel (i.e., $0.06 per mile) was obtained from the American Automobile Association. The value of travel time (i.e., β) for adult recreationists (applied to *all* adults) from a particular county origin was taken to be equal to one-third the average wage rate for that county (as reported in the U.S. Census).[17] Estimates of β ranged from $0.035 to $0.046 per minute.[18] Although, as mentioned previously, individuals value time differently, it was not feasible to disaggregate traveler groups to reflect this phenomenon and the "average" value of travel time was used for all travelers from a given county, with one exception. In recreation tripmaking of the type being considered here, about one-half of the travelers are children under the age of 12 years. It cannot be presumed that the value of a child's time is comparable to that of an adult; certainly the opportunity cost is much less. Thus, the value accorded travel time for children was arbitrarily set at 25 percent of the adult value.[19]

The method of demand curve imputation was the HCK method as modified by Cesario and Knetsch [1976] and Cesario [1975].[20] The basic visitor model from which the estimates are derived is given by:

$$v_{ij} = \theta\, x_i y_j \exp(\gamma c_{ij}) \left[\sum_{k=1}^{M} y_k \exp(\gamma c_{ik})\right]^{\pi} \quad [7]$$

$i = 1,2,\ldots,N$
$j = 1,2,\ldots,M$

where:

v_{ij} = number of visits per unit time from origin (county) i to destination (park) j
x_i = origin characteristics (population)
y_j = destination characteristics (attractiveness)
c_{ij} = generalized cost, as defined in [1]
θ, γ, π = parameters
N = number of origins
M = number of destinations

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[15] The outdoor recreation system has been described elsewhere in Cesario [1971] and Cesario, et al. [1970]. On-site visitor data were secured at a total of 88 recreation sites during the summer of 1967. Data were aggregated by using the county as the origin unit. Virtually all travel takes place by automobile.

[16] Cesario and Knetsch [1970].

[17] A value of one-third the wage rates is arbitrary, and no sensitivity analyses were conducted to examine implications of alternative rates. It is standard in the United Kingdom to use one-fourth the wage rate as the value of time; upon examination of the empirical results it can be seen that values obtained in U.S. studies were generally higher than those for U.K. studies. Hence, the value of one-third was chosen for convenience.

A major issue is whether or not one should entertain equality between the values of time savings for commuters and time savings for outdoor recreation seekers. There are arguments for [Harrison 1974] and against [Cesario and Knetsch 1976] this assumption. At any rate, the data do not permit us to distinguish between these types of trips and the question must remain open for the time being.

[18] Calculations followed the standard procedure of multiplying the average annual wage by 1/3, then dividing this quantity by 2,000 work hours, and then dividing by 60 minutes per hour.

[19] Harrison and Quarmby [1969] suggest that the rate for children be set at one-third the adult rate; this is the convention followed in the U.K. This author believes that the U.K. rate is much too high.

[20] Numerical results differ slightly in these studies because different variables were used in each case.

TABLE 1
BENEFIT COMPARISONS

Recreation Site (State Park)	Annual Benefits ($000's), 1967[a] (i)	(ii)	(iii)
G.W. Childs	25	55	30
Big Pocono	71	117	82
Ralph Stover	86	155	100
Tobyhanna	173	275	202
Prompton Dam	174	291	208
Gouldsboro	185	309	250
French Creek	207	357	280
Worlds End	255	417	334
Promised Land	290	498	382
Hickory Run	474	773	590
Ricketts Glen	515	854	684

[a]assumption (i), travel cost = αd_{ij}, α = \$0.06
assumption (ii), travel cost = $\alpha d_{ij} t_{ij}$, α = \$0.06
assumption (iii), travel cost = $\alpha d_{ij} + \beta t_{ij}$, α = \$0.06,
$0.035 \leqslant \beta \leqslant 0.046$

Parameters were estimated by least squares, and demand curves were imputed in the usual way (i.e., by imposing hypothetical added money costs through the c_{ij} term).

Results of the analysis are given in Table 1. It is seen that the benefit estimates obtained by explicitly considering travel time substantially exceed estimates made when travel time is ignored. And, the method proposed in this paper produced estimates which are substantially lower than those produced by the ad hoc method of Cesario and Knetsch, suggesting that the latter estimates are "too high." The reason for the discrepancy lies in the difference in the tradeoff functions in money and time implicitly considered. The elasticity of visitation with respect to money cost is much greater for the linear tradeoff function than it is for the multiplicative form of the relationship.[21] At any given distance away from a recreation site the product form of the time-cost tradeoff function results in higher visitor estimates than does the linear form of the tradeoff.

In conclusion, explicitly incorporating travel-time valuations in recreation benefit analysis seems vastly superior to excluding them on both theoretical and practical grounds. As further research—especially within the particular context of recreation travel—turns up more refined estimates of travel-time valuations in different circumstances, future studies should make use of them. In the meantime the results presented here should lead to improved estimates.

[21] This result may be seen by assuming visit functions such as $V = f(\alpha DT)^{-\gamma}$ for the multiplicative relationship and $V = f(\alpha D + \beta T)^{-\eta}$ for the linear relationship, where γ and η are parameters, V represents visitors per unit time, D represents travel distance and T represents travel time. Analysis of the same data will result in $|\eta| > |\gamma|$, from which it can be seen that the elasticity of visits with respect to αD is largest for the additive case.

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Welfare Estimates for Five Scenarios of Water Quality Change in Southern California

A Report from the Southern California Beach Valuation Project

Prepared by the Research Team:

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Submitted to

U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration (NOAA),
U.S. Dept. of the Interior: Minerals Management Service,
CA Department of Fish and Game: Office of Spill Prevention and Response (OSPR)
CA State Water Resources Control Board, and
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Introduction

The model of beach choice and activity developed by the Southern California Beach Valuation Project is intended to be the foundation upon which analysts can estimate the potential impact on the economic welfare of beach goers of water quality impairment and beach closures. The model can be used to estimate the loss or gain in consumer surplus that would result from a variety of scenarios that depict water quality and beach closures. In this report, we demonstrate the economic impact of five representative scenarios of beach water quality change. Each scenario examines water quality change or beach closures at a single beach. We examine the welfare impacts of water quality improvement and degradation. We also examine the welfare impact of a beach closure, in this case a closure at Huntington State Beach. We use the model to estimate closures that include a single day closure, a month long closure, and finally a closure that lasts the entire summer.

Three important caveats need to be considered when interpreting the welfare estimates presented below. First, the Beach Valuation Model was estimated separately for six different waves, where each wave models beach goer behavior for a two-month period. This approach accounts for seasonal variation in beach goer behavior and preferences. The results of the Beach Valuation Model, in fact, do indicate that both behavior and preferences differ across seasons. In the first two scenarios that follow, we examine the welfare impacts of water quality changes throughout the entire year. The final three scenarios, the summertime closure of Huntington State Beach, provide estimates for changes that affect one day and one month within the summer wave (July and August) and a three month closure that spans two waves (May/June and July/August). Estimates of welfare change for other waves would differ from those estimates provided below.

Second, an important strength of the Beach Valuation Model is that it accounts for the fact that beach goers have many options when deciding when and where to go to the beach[1]. Beach goers can choose to go to one of the more than fifty major beaches with public access in or near Los Angeles and Orange Counties. They may also choose to participate in activities that include swimming, sand-based activities or shopping. Finally, beach goers may simply choose to go to the beach, but not to swim, if water quality conditions are not suitable. The economic impact of water quality impairment, improvement, or even a closure depends importantly on the degree to which the change in water quality affects all of the beach goers' options. We focus on limited, marginal changes in water quality at beaches in southern California (that is water quality or beach access is impacted at only one beach). Hypothetical or real scenarios that involve water quality change or closure at more than one beach will have increasingly larger welfare impacts. The effects on welfare are non-linear; increasing the spatial extent of the quality change or closure increases the welfare impact at a rate greater than unity (i.e. the change is more than linear).

Finally, the welfare impacts that are estimated by the Beach Valuation model are sensitive to the value placed on travel time -- a large and important component of the total travel cost incurred by the beach goer. In the estimates below, we value travel time at fifty percent of the beach goers' wage rate. Elsewhere in the literature, travel time is valued at only one third of the wage. (In Appendix A, we also provide welfare estimates at zero, thirty-three and one hundred percent wage rate.) Because travel time is only part of the total travel cost, changing the valuation of travel time impacts the welfare estimates in a way that is less than linear, but still substantial.

The Value of a Beach Day

Much of the literature focuses on estimating the value of a recreational day, in our case a beach day. While the concept is widely applied, it is not without some ambiguity. The value of a beach day could bear a variety of meanings. At one end of the continuum of meanings is the value of being able to make a trip to a specific beach rather than not

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[1] Most previous studies have not included these substitution possibilities when modeling the welfare impact of water quality change and beach closure, especially in Southern California.

being able to make a trip to any beach (i.e. the beach goer simply stays home). In reality, many substitution possibilities exist for the beach goer. The other end of the continuum of possible meanings is that the value under consideration represents the value of being able to make a trip to a specific beach rather than not being able to go to that beach while still being able to go to any other beach in the relevant choice set of beaches. Which interpretation of value is the most realistic depends on the particular circumstances at hand. In the Case of the American Trader oil spill at Huntington Beach in 1990, for example, most of the beaches over a long stretch of coastline were affected and the oil spill effectively shut down almost all beach recreation over quite a wide area, at least for a period of time. That would be more consistent with the first definition of the value of a beach day. On many other occasions, however, a closure may affect one or two individual beaches while leaving beach recreation elsewhere virtually unaffected. In that case, the second definition would be more realistic.

Focusing for the moment on the latter concept, the formula for this value is given by:

$$\text{Value of A Beach Day} = \frac{\sum_{i=1}^{n} \frac{CS_0 - CS_{close\ i}}{trips_{0,i}}}{n}$$

where there are n beaches, i represents an individual beach, CS_0 is the baseline consumer surplus enjoyed by all beach goers and $CS_{close\ i,}$ is the CS when beach i is closed but *all other* beaches are open. Our estimate of this value for beach visits in Southern California in the month of July amounts to \$11.17 when one uses a simple (unweighted) arithmetic average across all beaches, and \$11.21 when one takes a weighted average across all beaches using the total number of trips to each beach in the baseline case as the weight.

This value is lower than many of the values for beach visits in Southern California estimated by previous analyses (see Table 1). But those estimates typically involved single-site demand models rather than multi-site demand models and therefore did not account adequately for the inter-site substitution possibilities among the beaches of Southern California which are captured in our Beach Valuation Model.

In the remaining welfare estimates, presented below, we present estimates for the total change in consumer surplus, compared to a baseline, rather than the consumer's surplus per trip. These changes in consumer's surplus are calculated for various beach closure and water quality change scenarios, and the change is summed over all potential beach goers living in the four Southern California counties covered by our study. We also indicate the change in the total number of beach trips taken by beach goers in these counties as a result of the beach impact scenario. These estimates of the total welfare impact are accurate reflections of the non-market economic impact of these scenarios. These total consumer surplus estimates reflect the total benefit or cost of the scenario, which is the figure that is most often required when making assessments about the economic impact of a policy or natural resources damage event.

Table 1: Estimates of the Consumer Surplus Value of Beach Visits in California[2]

	US$(1990)	US$ (2000)
Cabrillo-Long Beach[1]	$8.16	$10.98
Orange County Beaches[2]	$15.00	$20.18
Santa Monica[1]	$18.36	$24.71
Pismo State Beach[3]	$26.20	$35.26
Leo Carillo State Beach[1]	$51.94	$69.91
San Onofre State Beach[3]	$57.31	$77.14
San Diego[3]	$60.79	$81.82

Source: Chapman and Hanemann (2001). The data are extracted from 1) Leeworthy and Wiley (1993) 2) Hanemann (1997) and 3) Leeworthy (1995).

Consumer Surplus/Day	**US$ (2001)**			
Individual Surplus/Day	Carpinteria	Encinitas	San Clemente	Solana Beach
Method 1	$20.48	$18.84	$25.70	$14.58
Method 2	$24.43	$22.17	$30.58	$17.35

Source: Philip King, The Economic Analysis of Beach Spending and the Recreational Benefits of Beaches in the City of San Clemente, 2001. Note: Method 1 - dependent variable is a discrete random variable, CS calculated as the sum of a series of rectangles, each one day wide, touching the demand curve at its upper right corner. Method 2 - CS calculated as the sum of a rectangle for the area under the curve between zero and one, and the definite integral for the area between one and the average number of trips.

[2] From Pendleton (2004).

Estimating the Economic Impact of Beach Water Quality Change in Southern California: Five Scenarios

The Beach Valuation model can estimate the total change in beach goer welfare (consumer surplus) for a change in access to beaches or a change in beach water quality. For the purposes of exposition, we explore the welfare impact on beach goers of five scenarios. The five scenarios are designed to demonstrate the way in which the model estimates improvements in beach water quality, degradation of beach water quality, and beach closures of varying lengths of time. These scenarios are hypothetical. The results of the welfare analyses are summarized in Table 2. Additionally, we provide estimates for the impact that these scenarios would have on the total number of beach visits taken. A discussion of the results follows.

<u>SCENARIO 1: An Improvement In Beach Water Quality</u>

Malibu Surfrider Beach Water Quality Improves by One HTB Letter Grade

In 2000, Malibu Surfrider had a low water quality rating of approximately C (2.13 on a scale of 0 to 4). This hypothetical scenario explores the impact of improving water quality at Malibu, perhaps by reducing sewage effluent inputs into Malibu Creek, so that water quality improves to an average annual grade of B (3.0/4.0). All other sites remain unchanged.

An improvement in water quality at Malibu Surfrider Beach has two major impacts on beach goers. First, the number of trips taken to Surfrider beach increases by 1,538 visits over the course of the year. Most new visits are made by residents of Los Angeles County, the closest county. The second major impact of an improvement in water quality is that annual consumer surplus of beach goers improves by more than $140,000, the majority of these benefits accrue to local residents (i.e. residents of Los Angeles County).

SCENARIO 2: A Degradation of Beach Water Quality

Zuma Beach Water Degrades to an HTB Letter Grade of F

In 2000, Zuma Beach enjoyed a high level of water quality, with an annual HTB grades of A/A+. Zuma Beach also is a popular beach among beach goers. The adjacent beaches also have very high quality ratings of A/A+ and A/A-. This hypothetical scenario explores the potential impact on beach goers that would result if Zuma Beach water quality declined to a grade of F. All other sites remain unchanged.

A dramatic decline in beach water quality at Zuma Beach would have serious consequences for beach goers' welfare. Beach attendance at Zuma Beach would decline by more than 57,000 visitors resulting in a loss of beach goer welfare of over $5.2 million. Most of the welfare and attendance impacts are borne by beach goers from Los Angeles County.

SCENARIOS 3-5: Beach Closures

Huntington State Beach (HSB) Closes for One Day, One Month, and One Summer (June – August)

During 2000, Huntington State Beach (HSB) had numerous days with poor water quality, ranging from a D to an A-; overall the annual average grade for Huntington State Beach was a B-/C+. This is in contrast to the adjacent beach areas, Huntington City Beach and Santa Ana River, which received higher grades (average A-/B+). This hypothetical scenario explores the potential impact that would results from beach closures at Huntington State Beach for three duration lengths: one day in July, one month (July), and one summer season (June, July, and August). All other sites remain unchanged.

First, the model does not allow for temporal substitution. That is, the model assumes site choice decisions are made each day independently of decisions and conditions on other days. As a result, the welfare impact for a one month closure is 31 times the impacts of a one day closure. We estimate that a one day closure at Huntington State Beach, in July, would result in a loss of more than 1,200 beach visits and a welfare loss of over $100,000. A month long closure during July would result in a loss of over 38,000 beach visits and a welfare impact of more than $3.5 million. Huntington State Beach is popular among beach goers from the four southern California counties considered. As a result, the impacts on attendance and beach goer welfare are spread across the four county area. Orange County suffers the greatest impacts, but the economic impacts to beach goers from Los Angeles, San Bernardino, and Riverside Counties are substantial.

A season long beach closure requires that we change water quality during two different waves (remember that a wave consists of a two month period and we allow beach goer preferences to differ among waves). The season long closure consists of the following days of closure: June (30 days), July (31 days), and August (31 days). Such a closure would result in decline in attendance of more than 100,000 visits and a loss in beach goer welfare of over $9 million. Note that the welfare impact is not a simple linear expansion of the value of a daily closure in July because the welfare impacts of a closure in the May/June wave are less than that in July/August.

Table 2 Total Welfare Impacts, Consumer Surplus Change

SCENARIO	Los Angeles	Orange	Riverside	San Bernardino	Total
1. Malibu Improves (C to B)	$132,572	$1,731	$1,816	$4,445	$140,564
2. Zuma Degrades (A to F)	-$4,873,739	-$80,330	-$95,982	-$222,527	-$5,272,578
3. HSB Closes 1 Day	-$44,232	-$48,837	-$10,998	-$11,590	-$115,657
4. HSB Closes 1 Month (July)	-$1,371,198	-$1,513,958	-$340,929	-$359,284	-$3,585,369
5. HSB Closes 1 summer (June, July, and August)	-$3,531,108	-$3,969,551	-$877,816	-$925,711	-$9,304,186

Table 3 Total Change in Trips for All Beach Goers

SCENARIO	COUNTY OF RESIDENCE Los Angeles	Orange	Riverside	San Bernardino	Total
1. Malibu Improves (C to B)	1,450	19	20	49	1,538
2. Zuma Degrades (A to F)	-53,118	-870	-1,054	-2,447	-57,489
3. HSB Closes 1 Day	-478	-523	-120	-127	-1,248
4. HSB Closes 1 Month (July)	-14,821	-16,224	-3,724	-3,930	-38,699
5. HSB Closes 1 summer (June, July, and August)	-38,256	-42,658	-9,605	-10,143	-100,662

It is important to note here that the data provided in Tables 2 and 3 cannot be used to calculate the value of a beach day. Table 2 provides estimates of total welfare gain or loss, by county, for the five scenarios and Table 3 provides estimates of the change in total number of trips taken, also by county. For any one "hypothetical" beach visitor, the welfare impact of a degradation in quality at one of the many beaches in southern California is considerably different than the welfare impact for a beach goer who normally would have gone to the beach in question.[3]

It also is important to note that the welfare estimates given in Table 2 depend importantly on the estimated value of travel time. In the analysis above, we estimate the value of a beach goers' time at fifty percent of their wage rate. Table 4 demonstrates the sensitivity of welfare impacts to different wage rates using the case of Scenario 1 in which the average annual Heal the Bay grade improves from a C to a B. The literature does not provide explicit guidance on the appropriate percentage of wage rate that should be used in the valuation of time. It is important that the analyst understand that estimates of welfare change provided by the beach valuation model reflect a value of time measured at fifty percent of the wage rate; the choice of other time values would change these estimates.

[3] A brief technical memo on the calculation of per trip welfare estimates from random utility models is forthcoming by Michael Hanemann.

Table 4: Sensitivity of Welfare Estimates to Value of Travel Time: Scenario 1 (Malibu Improves from C to B, Los Angeles County Beach Goers Only)

Percent of Wage Rate Used	Welfare Impact (Los Angeles County)
0%	$24,463
33%	$93,603
50%	$132,572
100%	$252,812

Conclusion

Even minor changes in water quality at beaches in Southern California can generate large economic impacts. A day-long closure at Huntington Beach would lead to a loss of recreational welfare well in excess of $100,000. Similarly, a minor improvement in beach water quality at Malibu, from an average grade of C to an average grade of A would generate approximately $140,000 in welfare gains for beach goers. More dramatic changes in beach water quality yield even more substantial welfare impacts. Dramatic declines in water quality at clean beaches, like Zuma Beach, would lead to the loss of millions of dollars in beach goer welfare (in this case more than $5 million); a summer time closure of swimming waters at Huntington State Beach would result in even greater losses (we estimate a loss of over $9 million in beach goer welfare). These values do not include lost expenditures, the subject of another report.

The Southern California Beach Valuation model is a powerful tool that will allow policy makers to explore the potential economic impacts of changes in water quality and beach access in Southern California. Great care has been taken to make sure that the model generates welfare estimates that are the most accurate that can be achieved through current methods of environmental valuation. The welfare model is based on an economic model of site choice that has been designed to accurately reflect beach choices by different types of users and over different seasons. Additionally, the model was estimated using the most comprehensive set of beach characteristics (beach attributes) ever collected for this purpose. Despite our efforts to provide the public with the most accurate welfare estimates of the impacts of water quality changes, we urge the user of the model to check back for improvements and refinements in the model. The field of environmental economics is one that is constantly advancing. We have collected our data in a way that will allow us to refine our model based on these advancements.

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2009 Tax Table

CAUTION *See the instructions for line 44 that begin on page 37 to see if you must use the Tax Table below to figure your tax.*

Example. Mr. and Mrs. Brown are filing a joint return. Their taxable income on Form 1040, line 43, is $25,300. First, they find the $25,300–25,350 taxable income line. Next, they find the column for married filing jointly and read down the column. The amount shown where the taxable income line and filing status column meet is $2,964. This is the tax amount they should enter on Form 1040, line 44.

Sample Table

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
25,200	25,250	3,366	2,949	3,366	3,186
25,250	25,300	3,374	2,956	3,374	3,194
25,300	25,350	3,381	2,964	3,381	3,201
25,350	25,400	3,389	2,971	3,389	3,209

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
0	5	0	0	0	0
5	15	1	1	1	1
15	25	2	2	2	2
25	50	4	4	4	4
50	75	6	6	6	6
75	100	9	9	9	9
100	125	11	11	11	11
125	150	14	14	14	14
150	175	16	16	16	16
175	200	19	19	19	19
200	225	21	21	21	21
225	250	24	24	24	24
250	275	26	26	26	26
275	300	29	29	29	29
300	325	31	31	31	31
325	350	34	34	34	34
350	375	36	36	36	36
375	400	39	39	39	39
400	425	41	41	41	41
425	450	44	44	44	44
450	475	46	46	46	46
475	500	49	49	49	49
500	525	51	51	51	51
525	550	54	54	54	54
550	575	56	56	56	56
575	600	59	59	59	59
600	625	61	61	61	61
625	650	64	64	64	64
650	675	66	66	66	66
675	700	69	69	69	69
700	725	71	71	71	71
725	750	74	74	74	74
750	775	76	76	76	76
775	800	79	79	79	79
800	825	81	81	81	81
825	850	84	84	84	84
850	875	86	86	86	86
875	900	89	89	89	89
900	925	91	91	91	91
925	950	94	94	94	94
950	975	96	96	96	96
975	1,000	99	99	99	99
1,000					
1,000	1,025	101	101	101	101
1,025	1,050	104	104	104	104
1,050	1,075	106	106	106	106
1,075	1,100	109	109	109	109
1,100	1,125	111	111	111	111
1,125	1,150	114	114	114	114
1,150	1,175	116	116	116	116
1,175	1,200	119	119	119	119
1,200	1,225	121	121	121	121
1,225	1,250	124	124	124	124
1,250	1,275	126	126	126	126
1,275	1,300	129	129	129	129
1,300	1,325	131	131	131	131
1,325	1,350	134	134	134	134
1,350	1,375	136	136	136	136
1,375	1,400	139	139	139	139
1,400	1,425	141	141	141	141
1,425	1,450	144	144	144	144
1,450	1,475	146	146	146	146
1,475	1,500	149	149	149	149
1,500	1,525	151	151	151	151
1,525	1,550	154	154	154	154
1,550	1,575	156	156	156	156
1,575	1,600	159	159	159	159
1,600	1,625	161	161	161	161
1,625	1,650	164	164	164	164
1,650	1,675	166	166	166	166
1,675	1,700	169	169	169	169
1,700	1,725	171	171	171	171
1,725	1,750	174	174	174	174
1,750	1,775	176	176	176	176
1,775	1,800	179	179	179	179
1,800	1,825	181	181	181	181
1,825	1,850	184	184	184	184
1,850	1,875	186	186	186	186
1,875	1,900	189	189	189	189
1,900	1,925	191	191	191	191
1,925	1,950	194	194	194	194
1,950	1,975	196	196	196	196
1,975	2,000	199	199	199	199
2,000					
2,000	2,025	201	201	201	201
2,025	2,050	204	204	204	204
2,050	2,075	206	206	206	206
2,075	2,100	209	209	209	209
2,100	2,125	211	211	211	211
2,125	2,150	214	214	214	214
2,150	2,175	216	216	216	216
2,175	2,200	219	219	219	219
2,200	2,225	221	221	221	221
2,225	2,250	224	224	224	224
2,250	2,275	226	226	226	226
2,275	2,300	229	229	229	229
2,300	2,325	231	231	231	231
2,325	2,350	234	234	234	234
2,350	2,375	236	236	236	236
2,375	2,400	239	239	239	239
2,400	2,425	241	241	241	241
2,425	2,450	244	244	244	244
2,450	2,475	246	246	246	246
2,475	2,500	249	249	249	249
2,500	2,525	251	251	251	251
2,525	2,550	254	254	254	254
2,550	2,575	256	256	256	256
2,575	2,600	259	259	259	259
2,600	2,625	261	261	261	261
2,625	2,650	264	264	264	264
2,650	2,675	266	266	266	266
2,675	2,700	269	269	269	269
2,700	2,725	271	271	271	271
2,725	2,750	274	274	274	274
2,750	2,775	276	276	276	276
2,775	2,800	279	279	279	279
2,800	2,825	281	281	281	281
2,825	2,850	284	284	284	284
2,850	2,875	286	286	286	286
2,875	2,900	289	289	289	289
2,900	2,925	291	291	291	291
2,925	2,950	294	294	294	294
2,950	2,975	296	296	296	296
2,975	3,000	299	299	299	299
3,000					
3,000	3,050	303	303	303	303
3,050	3,100	308	308	308	308
3,100	3,150	313	313	313	313
3,150	3,200	318	318	318	318
3,200	3,250	323	323	323	323
3,250	3,300	328	328	328	328
3,300	3,350	333	333	333	333
3,350	3,400	338	338	338	338
3,400	3,450	343	343	343	343
3,450	3,500	348	348	348	348
3,500	3,550	353	353	353	353
3,550	3,600	358	358	358	358
3,600	3,650	363	363	363	363
3,650	3,700	368	368	368	368
3,700	3,750	373	373	373	373
3,750	3,800	378	378	378	378
3,800	3,850	383	383	383	383
3,850	3,900	388	388	388	388
3,900	3,950	393	393	393	393
3,950	4,000	398	398	398	398
4,000					
4,000	4,050	403	403	403	403
4,050	4,100	408	408	408	408
4,100	4,150	413	413	413	413
4,150	4,200	418	418	418	418
4,200	4,250	423	423	423	423
4,250	4,300	428	428	428	428
4,300	4,350	433	433	433	433
4,350	4,400	438	438	438	438
4,400	4,450	443	443	443	443
4,450	4,500	448	448	448	448
4,500	4,550	453	453	453	453
4,550	4,600	458	458	458	458
4,600	4,650	463	463	463	463
4,650	4,700	468	468	468	468
4,700	4,750	473	473	473	473
4,750	4,800	478	478	478	478
4,800	4,850	483	483	483	483
4,850	4,900	488	488	488	488
4,900	4,950	493	493	493	493
4,950	5,000	498	498	498	498

* This column must also be used by a qualifying widow(er).

(Continued on page 78)

2009 Tax Table—*Continued*

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
5,000					
5,000	5,050	503	503	503	503
5,050	5,100	508	508	508	508
5,100	5,150	513	513	513	513
5,150	5,200	518	518	518	518
5,200	5,250	523	523	523	523
5,250	5,300	528	528	528	528
5,300	5,350	533	533	533	533
5,350	5,400	538	538	538	538
5,400	5,450	543	543	543	543
5,450	5,500	548	548	548	548
5,500	5,550	553	553	553	553
5,550	5,600	558	558	558	558
5,600	5,650	563	563	563	563
5,650	5,700	568	568	568	568
5,700	5,750	573	573	573	573
5,750	5,800	578	578	578	578
5,800	5,850	583	583	583	583
5,850	5,900	588	588	588	588
5,900	5,950	593	593	593	593
5,950	6,000	598	598	598	598
6,000					
6,000	6,050	603	603	603	603
6,050	6,100	608	608	608	608
6,100	6,150	613	613	613	613
6,150	6,200	618	618	618	618
6,200	6,250	623	623	623	623
6,250	6,300	628	628	628	628
6,300	6,350	633	633	633	633
6,350	6,400	638	638	638	638
6,400	6,450	643	643	643	643
6,450	6,500	648	648	648	648
6,500	6,550	653	653	653	653
6,550	6,600	658	658	658	658
6,600	6,650	663	663	663	663
6,650	6,700	668	668	668	668
6,700	6,750	673	673	673	673
6,750	6,800	678	678	678	678
6,800	6,850	683	683	683	683
6,850	6,900	688	688	688	688
6,900	6,950	693	693	693	693
6,950	7,000	698	698	698	698
7,000					
7,000	7,050	703	703	703	703
7,050	7,100	708	708	708	708
7,100	7,150	713	713	713	713
7,150	7,200	718	718	718	718
7,200	7,250	723	723	723	723
7,250	7,300	728	728	728	728
7,300	7,350	733	733	733	733
7,350	7,400	738	738	738	738
7,400	7,450	743	743	743	743
7,450	7,500	748	748	748	748
7,500	7,550	753	753	753	753
7,550	7,600	758	758	758	758
7,600	7,650	763	763	763	763
7,650	7,700	768	768	768	768
7,700	7,750	773	773	773	773
7,750	7,800	778	778	778	778
7,800	7,850	783	783	783	783
7,850	7,900	788	788	788	788
7,900	7,950	793	793	793	793
7,950	8,000	798	798	798	798
8,000					
8,000	8,050	803	803	803	803
8,050	8,100	808	808	808	808
8,100	8,150	813	813	813	813
8,150	8,200	818	818	818	818
8,200	8,250	823	823	823	823
8,250	8,300	828	828	828	828
8,300	8,350	833	833	833	833
8,350	8,400	839	838	839	838
8,400	8,450	846	843	846	843
8,450	8,500	854	848	854	848
8,500	8,550	861	853	861	853
8,550	8,600	869	858	869	858
8,600	8,650	876	863	876	863
8,650	8,700	884	868	884	868
8,700	8,750	891	873	891	873
8,750	8,800	899	878	899	878
8,800	8,850	906	883	906	883
8,850	8,900	914	888	914	888
8,900	8,950	921	893	921	893
8,950	9,000	929	898	929	898
9,000					
9,000	9,050	936	903	936	903
9,050	9,100	944	908	944	908
9,100	9,150	951	913	951	913
9,150	9,200	959	918	959	918
9,200	9,250	966	923	966	923
9,250	9,300	974	928	974	928
9,300	9,350	981	933	981	933
9,350	9,400	989	938	989	938
9,400	9,450	996	943	996	943
9,450	9,500	1,004	948	1,004	948
9,500	9,550	1,011	953	1,011	953
9,550	9,600	1,019	958	1,019	958
9,600	9,650	1,026	963	1,026	963
9,650	9,700	1,034	968	1,034	968
9,700	9,750	1,041	973	1,041	973
9,750	9,800	1,049	978	1,049	978
9,800	9,850	1,056	983	1,056	983
9,850	9,900	1,064	988	1,064	988
9,900	9,950	1,071	993	1,071	993
9,950	10,000	1,079	998	1,079	998
10,000					
10,000	10,050	1,086	1,003	1,086	1,003
10,050	10,100	1,094	1,008	1,094	1,008
10,100	10,150	1,101	1,013	1,101	1,013
10,150	10,200	1,109	1,018	1,109	1,018
10,200	10,250	1,116	1,023	1,116	1,023
10,250	10,300	1,124	1,028	1,124	1,028
10,300	10,350	1,131	1,033	1,131	1,033
10,350	10,400	1,139	1,038	1,139	1,038
10,400	10,450	1,146	1,043	1,146	1,043
10,450	10,500	1,154	1,048	1,154	1,048
10,500	10,550	1,161	1,053	1,161	1,053
10,550	10,600	1,169	1,058	1,169	1,058
10,600	10,650	1,176	1,063	1,176	1,063
10,650	10,700	1,184	1,068	1,184	1,068
10,700	10,750	1,191	1,073	1,191	1,073
10,750	10,800	1,199	1,078	1,199	1,078
10,800	10,850	1,206	1,083	1,206	1,083
10,850	10,900	1,214	1,088	1,214	1,088
10,900	10,950	1,221	1,093	1,221	1,093
10,950	11,000	1,229	1,098	1,229	1,098
11,000					
11,000	11,050	1,236	1,103	1,236	1,103
11,050	11,100	1,244	1,108	1,244	1,108
11,100	11,150	1,251	1,113	1,251	1,113
11,150	11,200	1,259	1,118	1,259	1,118
11,200	11,250	1,266	1,123	1,266	1,123
11,250	11,300	1,274	1,128	1,274	1,128
11,300	11,350	1,281	1,133	1,281	1,133
11,350	11,400	1,289	1,138	1,289	1,138
11,400	11,450	1,296	1,143	1,296	1,143
11,450	11,500	1,304	1,148	1,304	1,148
11,500	11,550	1,311	1,153	1,311	1,153
11,550	11,600	1,319	1,158	1,319	1,158
11,600	11,650	1,326	1,163	1,326	1,163
11,650	11,700	1,334	1,168	1,334	1,168
11,700	11,750	1,341	1,173	1,341	1,173
11,750	11,800	1,349	1,178	1,349	1,178
11,800	11,850	1,356	1,183	1,356	1,183
11,850	11,900	1,364	1,188	1,364	1,188
11,900	11,950	1,371	1,193	1,371	1,193
11,950	12,000	1,379	1,198	1,379	1,199
12,000					
12,000	12,050	1,386	1,203	1,386	1,206
12,050	12,100	1,394	1,208	1,394	1,214
12,100	12,150	1,401	1,213	1,401	1,221
12,150	12,200	1,409	1,218	1,409	1,229
12,200	12,250	1,416	1,223	1,416	1,236
12,250	12,300	1,424	1,228	1,424	1,244
12,300	12,350	1,431	1,233	1,431	1,251
12,350	12,400	1,439	1,238	1,439	1,259
12,400	12,450	1,446	1,243	1,446	1,266
12,450	12,500	1,454	1,248	1,454	1,274
12,500	12,550	1,461	1,253	1,461	1,281
12,550	12,600	1,469	1,258	1,469	1,289
12,600	12,650	1,476	1,263	1,476	1,296
12,650	12,700	1,484	1,268	1,484	1,304
12,700	12,750	1,491	1,273	1,491	1,311
12,750	12,800	1,499	1,278	1,499	1,319
12,800	12,850	1,506	1,283	1,506	1,326
12,850	12,900	1,514	1,288	1,514	1,334
12,900	12,950	1,521	1,293	1,521	1,341
12,950	13,000	1,529	1,298	1,529	1,349
13,000					
13,000	13,050	1,536	1,303	1,536	1,356
13,050	13,100	1,544	1,308	1,544	1,364
13,100	13,150	1,551	1,313	1,551	1,371
13,150	13,200	1,559	1,318	1,559	1,379
13,200	13,250	1,566	1,323	1,566	1,386
13,250	13,300	1,574	1,328	1,574	1,394
13,300	13,350	1,581	1,333	1,581	1,401
13,350	13,400	1,589	1,338	1,589	1,409
13,400	13,450	1,596	1,343	1,596	1,416
13,450	13,500	1,604	1,348	1,604	1,424
13,500	13,550	1,611	1,353	1,611	1,431
13,550	13,600	1,619	1,358	1,619	1,439
13,600	13,650	1,626	1,363	1,626	1,446
13,650	13,700	1,634	1,368	1,634	1,454
13,700	13,750	1,641	1,373	1,641	1,461
13,750	13,800	1,649	1,378	1,649	1,469
13,800	13,850	1,656	1,383	1,656	1,476
13,850	13,900	1,664	1,388	1,664	1,484
13,900	13,950	1,671	1,393	1,671	1,491
13,950	14,000	1,679	1,398	1,679	1,499

* This column must also be used by a qualifying widow(er).

(Continued on page 79)

If line 43 (taxable income) is— At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
14,000					
14,000	14,050	1,686	1,403	1,686	1,506
14,050	14,100	1,694	1,408	1,694	1,514
14,100	14,150	1,701	1,413	1,701	1,521
14,150	14,200	1,709	1,418	1,709	1,529
14,200	14,250	1,716	1,423	1,716	1,536
14,250	14,300	1,724	1,428	1,724	1,544
14,300	14,350	1,731	1,433	1,731	1,551
14,350	14,400	1,739	1,438	1,739	1,559
14,400	14,450	1,746	1,443	1,746	1,566
14,450	14,500	1,754	1,448	1,754	1,574
14,500	14,550	1,761	1,453	1,761	1,581
14,550	14,600	1,769	1,458	1,769	1,589
14,600	14,650	1,776	1,463	1,776	1,596
14,650	14,700	1,784	1,468	1,784	1,604
14,700	14,750	1,791	1,473	1,791	1,611
14,750	14,800	1,799	1,478	1,799	1,619
14,800	14,850	1,806	1,483	1,806	1,626
14,850	14,900	1,814	1,488	1,814	1,634
14,900	14,950	1,821	1,493	1,821	1,641
14,950	15,000	1,829	1,498	1,829	1,649
15,000					
15,000	15,050	1,836	1,503	1,836	1,656
15,050	15,100	1,844	1,508	1,844	1,664
15,100	15,150	1,851	1,513	1,851	1,671
15,150	15,200	1,859	1,518	1,859	1,679
15,200	15,250	1,866	1,523	1,866	1,686
15,250	15,300	1,874	1,528	1,874	1,694
15,300	15,350	1,881	1,533	1,881	1,701
15,350	15,400	1,889	1,538	1,889	1,709
15,400	15,450	1,896	1,543	1,896	1,716
15,450	15,500	1,904	1,548	1,904	1,724
15,500	15,550	1,911	1,553	1,911	1,731
15,550	15,600	1,919	1,558	1,919	1,739
15,600	15,650	1,926	1,563	1,926	1,746
15,650	15,700	1,934	1,568	1,934	1,754
15,700	15,750	1,941	1,573	1,941	1,761
15,750	15,800	1,949	1,578	1,949	1,769
15,800	15,850	1,956	1,583	1,956	1,776
15,850	15,900	1,964	1,588	1,964	1,784
15,900	15,950	1,971	1,593	1,971	1,791
15,950	16,000	1,979	1,598	1,979	1,799
16,000					
16,000	16,050	1,986	1,603	1,986	1,806
16,050	16,100	1,994	1,608	1,994	1,814
16,100	16,150	2,001	1,613	2,001	1,821
16,150	16,200	2,009	1,618	2,009	1,829
16,200	16,250	2,016	1,623	2,016	1,836
16,250	16,300	2,024	1,628	2,024	1,844
16,300	16,350	2,031	1,633	2,031	1,851
16,350	16,400	2,039	1,638	2,039	1,859
16,400	16,450	2,046	1,643	2,046	1,866
16,450	16,500	2,054	1,648	2,054	1,874
16,500	16,550	2,061	1,653	2,061	1,881
16,550	16,600	2,069	1,658	2,069	1,889
16,600	16,650	2,076	1,663	2,076	1,896
16,650	16,700	2,084	1,668	2,084	1,904
16,700	16,750	2,091	1,674	2,091	1,911
16,750	16,800	2,099	1,681	2,099	1,919
16,800	16,850	2,106	1,689	2,106	1,926
16,850	16,900	2,114	1,696	2,114	1,934
16,900	16,950	2,121	1,704	2,121	1,941
16,950	17,000	2,129	1,711	2,129	1,949

If line 43 (taxable income) is— At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
17,000					
17,000	17,050	2,136	1,719	2,136	1,956
17,050	17,100	2,144	1,726	2,144	1,964
17,100	17,150	2,151	1,734	2,151	1,971
17,150	17,200	2,159	1,741	2,159	1,979
17,200	17,250	2,166	1,749	2,166	1,986
17,250	17,300	2,174	1,756	2,174	1,994
17,300	17,350	2,181	1,764	2,181	2,001
17,350	17,400	2,189	1,771	2,189	2,009
17,400	17,450	2,196	1,779	2,196	2,016
17,450	17,500	2,204	1,786	2,204	2,024
17,500	17,550	2,211	1,794	2,211	2,031
17,550	17,600	2,219	1,801	2,219	2,039
17,600	17,650	2,226	1,809	2,226	2,046
17,650	17,700	2,234	1,816	2,234	2,054
17,700	17,750	2,241	1,824	2,241	2,061
17,750	17,800	2,249	1,831	2,249	2,069
17,800	17,850	2,256	1,839	2,256	2,076
17,850	17,900	2,264	1,846	2,264	2,084
17,900	17,950	2,271	1,854	2,271	2,091
17,950	18,000	2,279	1,861	2,279	2,099
18,000					
18,000	18,050	2,286	1,869	2,286	2,106
18,050	18,100	2,294	1,876	2,294	2,114
18,100	18,150	2,301	1,884	2,301	2,121
18,150	18,200	2,309	1,891	2,309	2,129
18,200	18,250	2,316	1,899	2,316	2,136
18,250	18,300	2,324	1,906	2,324	2,144
18,300	18,350	2,331	1,914	2,331	2,151
18,350	18,400	2,339	1,921	2,339	2,159
18,400	18,450	2,346	1,929	2,346	2,166
18,450	18,500	2,354	1,936	2,354	2,174
18,500	18,550	2,361	1,944	2,361	2,181
18,550	18,600	2,369	1,951	2,369	2,189
18,600	18,650	2,376	1,959	2,376	2,196
18,650	18,700	2,384	1,966	2,384	2,204
18,700	18,750	2,391	1,974	2,391	2,211
18,750	18,800	2,399	1,981	2,399	2,219
18,800	18,850	2,406	1,989	2,406	2,226
18,850	18,900	2,414	1,996	2,414	2,234
18,900	18,950	2,421	2,004	2,421	2,241
18,950	19,000	2,429	2,011	2,429	2,249
19,000					
19,000	19,050	2,436	2,019	2,436	2,256
19,050	19,100	2,444	2,026	2,444	2,264
19,100	19,150	2,451	2,034	2,451	2,271
19,150	19,200	2,459	2,041	2,459	2,279
19,200	19,250	2,466	2,049	2,466	2,286
19,250	19,300	2,474	2,056	2,474	2,294
19,300	19,350	2,481	2,064	2,481	2,301
19,350	19,400	2,489	2,071	2,489	2,309
19,400	19,450	2,496	2,079	2,496	2,316
19,450	19,500	2,504	2,086	2,504	2,324
19,500	19,550	2,511	2,094	2,511	2,331
19,550	19,600	2,519	2,101	2,519	2,339
19,600	19,650	2,526	2,109	2,526	2,346
19,650	19,700	2,534	2,116	2,534	2,354
19,700	19,750	2,541	2,124	2,541	2,361
19,750	19,800	2,549	2,131	2,549	2,369
19,800	19,850	2,556	2,139	2,556	2,376
19,850	19,900	2,564	2,146	2,564	2,384
19,900	19,950	2,571	2,154	2,571	2,391
19,950	20,000	2,579	2,161	2,579	2,399

If line 43 (taxable income) is— At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
20,000					
20,000	20,050	2,586	2,169	2,586	2,406
20,050	20,100	2,594	2,176	2,594	2,414
20,100	20,150	2,601	2,184	2,601	2,421
20,150	20,200	2,609	2,191	2,609	2,429
20,200	20,250	2,616	2,199	2,616	2,436
20,250	20,300	2,624	2,206	2,624	2,444
20,300	20,350	2,631	2,214	2,631	2,451
20,350	20,400	2,639	2,221	2,639	2,459
20,400	20,450	2,646	2,229	2,646	2,466
20,450	20,500	2,654	2,236	2,654	2,474
20,500	20,550	2,661	2,244	2,661	2,481
20,550	20,600	2,669	2,251	2,669	2,489
20,600	20,650	2,676	2,259	2,676	2,496
20,650	20,700	2,684	2,266	2,684	2,504
20,700	20,750	2,691	2,274	2,691	2,511
20,750	20,800	2,699	2,281	2,699	2,519
20,800	20,850	2,706	2,289	2,706	2,526
20,850	20,900	2,714	2,296	2,714	2,534
20,900	20,950	2,721	2,304	2,721	2,541
20,950	21,000	2,729	2,311	2,729	2,549
21,000					
21,000	21,050	2,736	2,319	2,736	2,556
21,050	21,100	2,744	2,326	2,744	2,564
21,100	21,150	2,751	2,334	2,751	2,571
21,150	21,200	2,759	2,341	2,759	2,579
21,200	21,250	2,766	2,349	2,766	2,586
21,250	21,300	2,774	2,356	2,774	2,594
21,300	21,350	2,781	2,364	2,781	2,601
21,350	21,400	2,789	2,371	2,789	2,609
21,400	21,450	2,796	2,379	2,796	2,616
21,450	21,500	2,804	2,386	2,804	2,624
21,500	21,550	2,811	2,394	2,811	2,631
21,550	21,600	2,819	2,401	2,819	2,639
21,600	21,650	2,826	2,409	2,826	2,646
21,650	21,700	2,834	2,416	2,834	2,654
21,700	21,750	2,841	2,424	2,841	2,661
21,750	21,800	2,849	2,431	2,849	2,669
21,800	21,850	2,856	2,439	2,856	2,676
21,850	21,900	2,864	2,446	2,864	2,684
21,900	21,950	2,871	2,454	2,871	2,691
21,950	22,000	2,879	2,461	2,879	2,699
22,000					
22,000	22,050	2,886	2,469	2,886	2,706
22,050	22,100	2,894	2,476	2,894	2,714
22,100	22,150	2,901	2,484	2,901	2,721
22,150	22,200	2,909	2,491	2,909	2,729
22,200	22,250	2,916	2,499	2,916	2,736
22,250	22,300	2,924	2,506	2,924	2,744
22,300	22,350	2,931	2,514	2,931	2,751
22,350	22,400	2,939	2,521	2,939	2,759
22,400	22,450	2,946	2,529	2,946	2,766
22,450	22,500	2,954	2,536	2,954	2,774
22,500	22,550	2,961	2,544	2,961	2,781
22,550	22,600	2,969	2,551	2,969	2,789
22,600	22,650	2,976	2,559	2,976	2,796
22,650	22,700	2,984	2,566	2,984	2,804
22,700	22,750	2,991	2,574	2,991	2,811
22,750	22,800	2,999	2,581	2,999	2,819
22,800	22,850	3,006	2,589	3,006	2,826
22,850	22,900	3,014	2,596	3,014	2,834
22,900	22,950	3,021	2,604	3,021	2,841
22,950	23,000	3,029	2,611	3,029	2,849

* This column must also be used by a qualifying widow(er).

(Continued on page 80)

2009 Tax Table–*Continued*

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
23,000					
23,000	23,050	3,036	2,619	3,036	2,856
23,050	23,100	3,044	2,626	3,044	2,864
23,100	23,150	3,051	2,634	3,051	2,871
23,150	23,200	3,059	2,641	3,059	2,879
23,200	23,250	3,066	2,649	3,066	2,886
23,250	23,300	3,074	2,656	3,074	2,894
23,300	23,350	3,081	2,664	3,081	2,901
23,350	23,400	3,089	2,671	3,089	2,909
23,400	23,450	3,096	2,679	3,096	2,916
23,450	23,500	3,104	2,686	3,104	2,924
23,500	23,550	3,111	2,694	3,111	2,931
23,550	23,600	3,119	2,701	3,119	2,939
23,600	23,650	3,126	2,709	3,126	2,946
23,650	23,700	3,134	2,716	3,134	2,954
23,700	23,750	3,141	2,724	3,141	2,961
23,750	23,800	3,149	2,731	3,149	2,969
23,800	23,850	3,156	2,739	3,156	2,976
23,850	23,900	3,164	2,746	3,164	2,984
23,900	23,950	3,171	2,754	3,171	2,991
23,950	24,000	3,179	2,761	3,179	2,999
24,000					
24,000	24,050	3,186	2,769	3,186	3,006
24,050	24,100	3,194	2,776	3,194	3,014
24,100	24,150	3,201	2,784	3,201	3,021
24,150	24,200	3,209	2,791	3,209	3,029
24,200	24,250	3,216	2,799	3,216	3,036
24,250	24,300	3,224	2,806	3,224	3,044
24,300	24,350	3,231	2,814	3,231	3,051
24,350	24,400	3,239	2,821	3,239	3,059
24,400	24,450	3,246	2,829	3,246	3,066
24,450	24,500	3,254	2,836	3,254	3,074
24,500	24,550	3,261	2,844	3,261	3,081
24,550	24,600	3,269	2,851	3,269	3,089
24,600	24,650	3,276	2,859	3,276	3,096
24,650	24,700	3,284	2,866	3,284	3,104
24,700	24,750	3,291	2,874	3,291	3,111
24,750	24,800	3,299	2,881	3,299	3,119
24,800	24,850	3,306	2,889	3,306	3,126
24,850	24,900	3,314	2,896	3,314	3,134
24,900	24,950	3,321	2,904	3,321	3,141
24,950	25,000	3,329	2,911	3,329	3,149
25,000					
25,000	25,050	3,336	2,919	3,336	3,156
25,050	25,100	3,344	2,926	3,344	3,164
25,100	25,150	3,351	2,934	3,351	3,171
25,150	25,200	3,359	2,941	3,359	3,179
25,200	25,250	3,366	2,949	3,366	3,186
25,250	25,300	3,374	2,956	3,374	3,194
25,300	25,350	3,381	2,964	3,381	3,201
25,350	25,400	3,389	2,971	3,389	3,209
25,400	25,450	3,396	2,979	3,396	3,216
25,450	25,500	3,404	2,986	3,404	3,224
25,500	25,550	3,411	2,994	3,411	3,231
25,550	25,600	3,419	3,001	3,419	3,239
25,600	25,650	3,426	3,009	3,426	3,246
25,650	25,700	3,434	3,016	3,434	3,254
25,700	25,750	3,441	3,024	3,441	3,261
25,750	25,800	3,449	3,031	3,449	3,269
25,800	25,850	3,456	3,039	3,456	3,276
25,850	25,900	3,464	3,046	3,464	3,284
25,900	25,950	3,471	3,054	3,471	3,291
25,950	26,000	3,479	3,061	3,479	3,299

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
26,000					
26,000	26,050	3,486	3,069	3,486	3,306
26,050	26,100	3,494	3,076	3,494	3,314
26,100	26,150	3,501	3,084	3,501	3,321
26,150	26,200	3,509	3,091	3,509	3,329
26,200	26,250	3,516	3,099	3,516	3,336
26,250	26,300	3,524	3,106	3,524	3,344
26,300	26,350	3,531	3,114	3,531	3,351
26,350	26,400	3,539	3,121	3,539	3,359
26,400	26,450	3,546	3,129	3,546	3,366
26,450	26,500	3,554	3,136	3,554	3,374
26,500	26,550	3,561	3,144	3,561	3,381
26,550	26,600	3,569	3,151	3,569	3,389
26,600	26,650	3,576	3,159	3,576	3,396
26,650	26,700	3,584	3,166	3,584	3,404
26,700	26,750	3,591	3,174	3,591	3,411
26,750	26,800	3,599	3,181	3,599	3,419
26,800	26,850	3,606	3,189	3,606	3,426
26,850	26,900	3,614	3,196	3,614	3,434
26,900	26,950	3,621	3,204	3,621	3,441
26,950	27,000	3,629	3,211	3,629	3,449
27,000					
27,000	27,050	3,636	3,219	3,636	3,456
27,050	27,100	3,644	3,226	3,644	3,464
27,100	27,150	3,651	3,234	3,651	3,471
27,150	27,200	3,659	3,241	3,659	3,479
27,200	27,250	3,666	3,249	3,666	3,486
27,250	27,300	3,674	3,256	3,674	3,494
27,300	27,350	3,681	3,264	3,681	3,501
27,350	27,400	3,689	3,271	3,689	3,509
27,400	27,450	3,696	3,279	3,696	3,516
27,450	27,500	3,704	3,286	3,704	3,524
27,500	27,550	3,711	3,294	3,711	3,531
27,550	27,600	3,719	3,301	3,719	3,539
27,600	27,650	3,726	3,309	3,726	3,546
27,650	27,700	3,734	3,316	3,734	3,554
27,700	27,750	3,741	3,324	3,741	3,561
27,750	27,800	3,749	3,331	3,749	3,569
27,800	27,850	3,756	3,339	3,756	3,576
27,850	27,900	3,764	3,346	3,764	3,584
27,900	27,950	3,771	3,354	3,771	3,591
27,950	28,000	3,779	3,361	3,779	3,599
28,000					
28,000	28,050	3,786	3,369	3,786	3,606
28,050	28,100	3,794	3,376	3,794	3,614
28,100	28,150	3,801	3,384	3,801	3,621
28,150	28,200	3,809	3,391	3,809	3,629
28,200	28,250	3,816	3,399	3,816	3,636
28,250	28,300	3,824	3,406	3,824	3,644
28,300	28,350	3,831	3,414	3,831	3,651
28,350	28,400	3,839	3,421	3,839	3,659
28,400	28,450	3,846	3,429	3,846	3,666
28,450	28,500	3,854	3,436	3,854	3,674
28,500	28,550	3,861	3,444	3,861	3,681
28,550	28,600	3,869	3,451	3,869	3,689
28,600	28,650	3,876	3,459	3,876	3,696
28,650	28,700	3,884	3,466	3,884	3,704
28,700	28,750	3,891	3,474	3,891	3,711
28,750	28,800	3,899	3,481	3,899	3,719
28,800	28,850	3,906	3,489	3,906	3,726
28,850	28,900	3,914	3,496	3,914	3,734
28,900	28,950	3,921	3,504	3,921	3,741
28,950	29,000	3,929	3,511	3,929	3,749

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
29,000					
29,000	29,050	3,936	3,519	3,936	3,756
29,050	29,100	3,944	3,526	3,944	3,764
29,100	29,150	3,951	3,534	3,951	3,771
29,150	29,200	3,959	3,541	3,959	3,779
29,200	29,250	3,966	3,549	3,966	3,786
29,250	29,300	3,974	3,556	3,974	3,794
29,300	29,350	3,981	3,564	3,981	3,801
29,350	29,400	3,989	3,571	3,989	3,809
29,400	29,450	3,996	3,579	3,996	3,816
29,450	29,500	4,004	3,586	4,004	3,824
29,500	29,550	4,011	3,594	4,011	3,831
29,550	29,600	4,019	3,601	4,019	3,839
29,600	29,650	4,026	3,609	4,026	3,846
29,650	29,700	4,034	3,616	4,034	3,854
29,700	29,750	4,041	3,624	4,041	3,861
29,750	29,800	4,049	3,631	4,049	3,869
29,800	29,850	4,056	3,639	4,056	3,876
29,850	29,900	4,064	3,646	4,064	3,884
29,900	29,950	4,071	3,654	4,071	3,891
29,950	30,000	4,079	3,661	4,079	3,899
30,000					
30,000	30,050	4,086	3,669	4,086	3,906
30,050	30,100	4,094	3,676	4,094	3,914
30,100	30,150	4,101	3,684	4,101	3,921
30,150	30,200	4,109	3,691	4,109	3,929
30,200	30,250	4,116	3,699	4,116	3,936
30,250	30,300	4,124	3,706	4,124	3,944
30,300	30,350	4,131	3,714	4,131	3,951
30,350	30,400	4,139	3,721	4,139	3,959
30,400	30,450	4,146	3,729	4,146	3,966
30,450	30,500	4,154	3,736	4,154	3,974
30,500	30,550	4,161	3,744	4,161	3,981
30,550	30,600	4,169	3,751	4,169	3,989
30,600	30,650	4,176	3,759	4,176	3,996
30,650	30,700	4,184	3,766	4,184	4,004
30,700	30,750	4,191	3,774	4,191	4,011
30,750	30,800	4,199	3,781	4,199	4,019
30,800	30,850	4,206	3,789	4,206	4,026
30,850	30,900	4,214	3,796	4,214	4,034
30,900	30,950	4,221	3,804	4,221	4,041
30,950	31,000	4,229	3,811	4,229	4,049
31,000					
31,000	31,050	4,236	3,819	4,236	4,056
31,050	31,100	4,244	3,826	4,244	4,064
31,100	31,150	4,251	3,834	4,251	4,071
31,150	31,200	4,259	3,841	4,259	4,079
31,200	31,250	4,266	3,849	4,266	4,086
31,250	31,300	4,274	3,856	4,274	4,094
31,300	31,350	4,281	3,864	4,281	4,101
31,350	31,400	4,289	3,871	4,289	4,109
31,400	31,450	4,296	3,879	4,296	4,116
31,450	31,500	4,304	3,886	4,304	4,124
31,500	31,550	4,311	3,894	4,311	4,131
31,550	31,600	4,319	3,901	4,319	4,139
31,600	31,650	4,326	3,909	4,326	4,146
31,650	31,700	4,334	3,916	4,334	4,154
31,700	31,750	4,341	3,924	4,341	4,161
31,750	31,800	4,349	3,931	4,349	4,169
31,800	31,850	4,356	3,939	4,356	4,176
31,850	31,900	4,364	3,946	4,364	4,184
31,900	31,950	4,371	3,954	4,371	4,191
31,950	32,000	4,379	3,961	4,379	4,199

* This column must also be used by a qualifying widow(er).

(Continued on page 81)

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
32,000					
32,000	32,050	4,386	3,969	4,386	4,206
32,050	32,100	4,394	3,976	4,394	4,214
32,100	32,150	4,401	3,984	4,401	4,221
32,150	32,200	4,409	3,991	4,409	4,229
32,200	32,250	4,416	3,999	4,416	4,236
32,250	32,300	4,424	4,006	4,424	4,244
32,300	32,350	4,431	4,014	4,431	4,251
32,350	32,400	4,439	4,021	4,439	4,259
32,400	32,450	4,446	4,029	4,446	4,266
32,450	32,500	4,454	4,036	4,454	4,274
32,500	32,550	4,461	4,044	4,461	4,281
32,550	32,600	4,469	4,051	4,469	4,289
32,600	32,650	4,476	4,059	4,476	4,296
32,650	32,700	4,484	4,066	4,484	4,304
32,700	32,750	4,491	4,074	4,491	4,311
32,750	32,800	4,499	4,081	4,499	4,319
32,800	32,850	4,506	4,089	4,506	4,326
32,850	32,900	4,514	4,096	4,514	4,334
32,900	32,950	4,521	4,104	4,521	4,341
32,950	33,000	4,529	4,111	4,529	4,349
33,000					
33,000	33,050	4,536	4,119	4,536	4,356
33,050	33,100	4,544	4,126	4,544	4,364
33,100	33,150	4,551	4,134	4,551	4,371
33,150	33,200	4,559	4,141	4,559	4,379
33,200	33,250	4,566	4,149	4,566	4,386
33,250	33,300	4,574	4,156	4,574	4,394
33,300	33,350	4,581	4,164	4,581	4,401
33,350	33,400	4,589	4,171	4,589	4,409
33,400	33,450	4,596	4,179	4,596	4,416
33,450	33,500	4,604	4,186	4,604	4,424
33,500	33,550	4,611	4,194	4,611	4,431
33,550	33,600	4,619	4,201	4,619	4,439
33,600	33,650	4,626	4,209	4,626	4,446
33,650	33,700	4,634	4,216	4,634	4,454
33,700	33,750	4,641	4,224	4,641	4,461
33,750	33,800	4,649	4,231	4,649	4,469
33,800	33,850	4,656	4,239	4,656	4,476
33,850	33,900	4,664	4,246	4,664	4,484
33,900	33,950	4,671	4,254	4,671	4,491
33,950	34,000	4,681	4,261	4,681	4,499
34,000					
34,000	34,050	4,694	4,269	4,694	4,506
34,050	34,100	4,706	4,276	4,706	4,514
34,100	34,150	4,719	4,284	4,719	4,521
34,150	34,200	4,731	4,291	4,731	4,529
34,200	34,250	4,744	4,299	4,744	4,536
34,250	34,300	4,756	4,306	4,756	4,544
34,300	34,350	4,769	4,314	4,769	4,551
34,350	34,400	4,781	4,321	4,781	4,559
34,400	34,450	4,794	4,329	4,794	4,566
34,450	34,500	4,806	4,336	4,806	4,574
34,500	34,550	4,819	4,344	4,819	4,581
34,550	34,600	4,831	4,351	4,831	4,589
34,600	34,650	4,844	4,359	4,844	4,596
34,650	34,700	4,856	4,366	4,856	4,604
34,700	34,750	4,869	4,374	4,869	4,611
34,750	34,800	4,881	4,381	4,881	4,619
34,800	34,850	4,894	4,389	4,894	4,626
34,850	34,900	4,906	4,396	4,906	4,634
34,900	34,950	4,919	4,404	4,919	4,641
34,950	35,000	4,931	4,411	4,931	4,649
35,000					
35,000	35,050	4,944	4,419	4,944	4,656
35,050	35,100	4,956	4,426	4,956	4,664
35,100	35,150	4,969	4,434	4,969	4,671
35,150	35,200	4,981	4,441	4,981	4,679
35,200	35,250	4,994	4,449	4,994	4,686
35,250	35,300	5,006	4,456	5,006	4,694
35,300	35,350	5,019	4,464	5,019	4,701
35,350	35,400	5,031	4,471	5,031	4,709
35,400	35,450	5,044	4,479	5,044	4,716
35,450	35,500	5,056	4,486	5,056	4,724
35,500	35,550	5,069	4,494	5,069	4,731
35,550	35,600	5,081	4,501	5,081	4,739
35,600	35,650	5,094	4,509	5,094	4,746
35,650	35,700	5,106	4,516	5,106	4,754
35,700	35,750	5,119	4,524	5,119	4,761
35,750	35,800	5,131	4,531	5,131	4,769
35,800	35,850	5,144	4,539	5,144	4,776
35,850	35,900	5,156	4,546	5,156	4,784
35,900	35,950	5,169	4,554	5,169	4,791
35,950	36,000	5,181	4,561	5,181	4,799
36,000					
36,000	36,050	5,194	4,569	5,194	4,806
36,050	36,100	5,206	4,576	5,206	4,814
36,100	36,150	5,219	4,584	5,219	4,821
36,150	36,200	5,231	4,591	5,231	4,829
36,200	36,250	5,244	4,599	5,244	4,836
36,250	36,300	5,256	4,606	5,256	4,844
36,300	36,350	5,269	4,614	5,269	4,851
36,350	36,400	5,281	4,621	5,281	4,859
36,400	36,450	5,294	4,629	5,294	4,866
36,450	36,500	5,306	4,636	5,306	4,874
36,500	36,550	5,319	4,644	5,319	4,881
36,550	36,600	5,331	4,651	5,331	4,889
36,600	36,650	5,344	4,659	5,344	4,896
36,650	36,700	5,356	4,666	5,356	4,904
36,700	36,750	5,369	4,674	5,369	4,911
36,750	36,800	5,381	4,681	5,381	4,919
36,800	36,850	5,394	4,689	5,394	4,926
36,850	36,900	5,406	4,696	5,406	4,934
36,900	36,950	5,419	4,704	5,419	4,941
36,950	37,000	5,431	4,711	5,431	4,949
37,000					
37,000	37,050	5,444	4,719	5,444	4,956
37,050	37,100	5,456	4,726	5,456	4,964
37,100	37,150	5,469	4,734	5,469	4,971
37,150	37,200	5,481	4,741	5,481	4,979
37,200	37,250	5,494	4,749	5,494	4,986
37,250	37,300	5,506	4,756	5,506	4,994
37,300	37,350	5,519	4,764	5,519	5,001
37,350	37,400	5,531	4,771	5,531	5,009
37,400	37,450	5,544	4,779	5,544	5,016
37,450	37,500	5,556	4,786	5,556	5,024
37,500	37,550	5,569	4,794	5,569	5,031
37,550	37,600	5,581	4,801	5,581	5,039
37,600	37,650	5,594	4,809	5,594	5,046
37,650	37,700	5,606	4,816	5,606	5,054
37,700	37,750	5,619	4,824	5,619	5,061
37,750	37,800	5,631	4,831	5,631	5,069
37,800	37,850	5,644	4,839	5,644	5,076
37,850	37,900	5,656	4,846	5,656	5,084
37,900	37,950	5,669	4,854	5,669	5,091
37,950	38,000	5,681	4,861	5,681	5,099
38,000					
38,000	38,050	5,694	4,869	5,694	5,106
38,050	38,100	5,706	4,876	5,706	5,114
38,100	38,150	5,719	4,884	5,719	5,121
38,150	38,200	5,731	4,891	5,731	5,129
38,200	38,250	5,744	4,899	5,744	5,136
38,250	38,300	5,756	4,906	5,756	5,144
38,300	38,350	5,769	4,914	5,769	5,151
38,350	38,400	5,781	4,921	5,781	5,159
38,400	38,450	5,794	4,929	5,794	5,166
38,450	38,500	5,806	4,936	5,806	5,174
38,500	38,550	5,819	4,944	5,819	5,181
38,550	38,600	5,831	4,951	5,831	5,189
38,600	38,650	5,844	4,959	5,844	5,196
38,650	38,700	5,856	4,966	5,856	5,204
38,700	38,750	5,869	4,974	5,869	5,211
38,750	38,800	5,881	4,981	5,881	5,219
38,800	38,850	5,894	4,989	5,894	5,226
38,850	38,900	5,906	4,996	5,906	5,234
38,900	38,950	5,919	5,004	5,919	5,241
38,950	39,000	5,931	5,011	5,931	5,249
39,000					
39,000	39,050	5,944	5,019	5,944	5,256
39,050	39,100	5,956	5,026	5,956	5,264
39,100	39,150	5,969	5,034	5,969	5,271
39,150	39,200	5,981	5,041	5,981	5,279
39,200	39,250	5,994	5,049	5,994	5,286
39,250	39,300	6,006	5,056	6,006	5,294
39,300	39,350	6,019	5,064	6,019	5,301
39,350	39,400	6,031	5,071	6,031	5,309
39,400	39,450	6,044	5,079	6,044	5,316
39,450	39,500	6,056	5,086	6,056	5,324
39,500	39,550	6,069	5,094	6,069	5,331
39,550	39,600	6,081	5,101	6,081	5,339
39,600	39,650	6,094	5,109	6,094	5,346
39,650	39,700	6,106	5,116	6,106	5,354
39,700	39,750	6,119	5,124	6,119	5,361
39,750	39,800	6,131	5,131	6,131	5,369
39,800	39,850	6,144	5,139	6,144	5,376
39,850	39,900	6,156	5,146	6,156	5,384
39,900	39,950	6,169	5,154	6,169	5,391
39,950	40,000	6,181	5,161	6,181	5,399
40,000					
40,000	40,050	6,194	5,169	6,194	5,406
40,050	40,100	6,206	5,176	6,206	5,414
40,100	40,150	6,219	5,184	6,219	5,421
40,150	40,200	6,231	5,191	6,231	5,429
40,200	40,250	6,244	5,199	6,244	5,436
40,250	40,300	6,256	5,206	6,256	5,444
40,300	40,350	6,269	5,214	6,269	5,451
40,350	40,400	6,281	5,221	6,281	5,459
40,400	40,450	6,294	5,229	6,294	5,466
40,450	40,500	6,306	5,236	6,306	5,474
40,500	40,550	6,319	5,244	6,319	5,481
40,550	40,600	6,331	5,251	6,331	5,489
40,600	40,650	6,344	5,259	6,344	5,496
40,650	40,700	6,356	5,266	6,356	5,504
40,700	40,750	6,369	5,274	6,369	5,511
40,750	40,800	6,381	5,281	6,381	5,519
40,800	40,850	6,394	5,289	6,394	5,526
40,850	40,900	6,406	5,296	6,406	5,534
40,900	40,950	6,419	5,304	6,419	5,541
40,950	41,000	6,431	5,311	6,431	5,549

* This column must also be used by a qualifying widow(er).

(Continued on page 82)

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
41,000					
41,000	41,050	6,444	5,319	6,444	5,556
41,050	41,100	6,456	5,326	6,456	5,564
41,100	41,150	6,469	5,334	6,469	5,571
41,150	41,200	6,481	5,341	6,481	5,579
41,200	41,250	6,494	5,349	6,494	5,586
41,250	41,300	6,506	5,356	6,506	5,594
41,300	41,350	6,519	5,364	6,519	5,601
41,350	41,400	6,531	5,371	6,531	5,609
41,400	41,450	6,544	5,379	6,544	5,616
41,450	41,500	6,556	5,386	6,556	5,624
41,500	41,550	6,569	5,394	6,569	5,631
41,550	41,600	6,581	5,401	6,581	5,639
41,600	41,650	6,594	5,409	6,594	5,646
41,650	41,700	6,606	5,416	6,606	5,654
41,700	41,750	6,619	5,424	6,619	5,661
41,750	41,800	6,631	5,431	6,631	5,669
41,800	41,850	6,644	5,439	6,644	5,676
41,850	41,900	6,656	5,446	6,656	5,684
41,900	41,950	6,669	5,454	6,669	5,691
41,950	42,000	6,681	5,461	6,681	5,699
42,000					
42,000	42,050	6,694	5,469	6,694	5,706
42,050	42,100	6,706	5,476	6,706	5,714
42,100	42,150	6,719	5,484	6,719	5,721
42,150	42,200	6,731	5,491	6,731	5,729
42,200	42,250	6,744	5,499	6,744	5,736
42,250	42,300	6,756	5,506	6,756	5,744
42,300	42,350	6,769	5,514	6,769	5,751
42,350	42,400	6,781	5,521	6,781	5,759
42,400	42,450	6,794	5,529	6,794	5,766
42,450	42,500	6,806	5,536	6,806	5,774
42,500	42,550	6,819	5,544	6,819	5,781
42,550	42,600	6,831	5,551	6,831	5,789
42,600	42,650	6,844	5,559	6,844	5,796
42,650	42,700	6,856	5,566	6,856	5,804
42,700	42,750	6,869	5,574	6,869	5,811
42,750	42,800	6,881	5,581	6,881	5,819
42,800	42,850	6,894	5,589	6,894	5,826
42,850	42,900	6,906	5,596	6,906	5,834
42,900	42,950	6,919	5,604	6,919	5,841
42,950	43,000	6,931	5,611	6,931	5,849
43,000					
43,000	43,050	6,944	5,619	6,944	5,856
43,050	43,100	6,956	5,626	6,956	5,864
43,100	43,150	6,969	5,634	6,969	5,871
43,150	43,200	6,981	5,641	6,981	5,879
43,200	43,250	6,994	5,649	6,994	5,886
43,250	43,300	7,006	5,656	7,006	5,894
43,300	43,350	7,019	5,664	7,019	5,901
43,350	43,400	7,031	5,671	7,031	5,909
43,400	43,450	7,044	5,679	7,044	5,916
43,450	43,500	7,056	5,686	7,056	5,924
43,500	43,550	7,069	5,694	7,069	5,931
43,550	43,600	7,081	5,701	7,081	5,939
43,600	43,650	7,094	5,709	7,094	5,946
43,650	43,700	7,106	5,716	7,106	5,954
43,700	43,750	7,119	5,724	7,119	5,961
43,750	43,800	7,131	5,731	7,131	5,969
43,800	43,850	7,144	5,739	7,144	5,976
43,850	43,900	7,156	5,746	7,156	5,984
43,900	43,950	7,169	5,754	7,169	5,991
43,950	44,000	7,181	5,761	7,181	5,999
44,000					
44,000	44,050	7,194	5,769	7,194	6,006
44,050	44,100	7,206	5,776	7,206	6,014
44,100	44,150	7,219	5,784	7,219	6,021
44,150	44,200	7,231	5,791	7,231	6,029
44,200	44,250	7,244	5,799	7,244	6,036
44,250	44,300	7,256	5,806	7,256	6,044
44,300	44,350	7,269	5,814	7,269	6,051
44,350	44,400	7,281	5,821	7,281	6,059
44,400	44,450	7,294	5,829	7,294	6,066
44,450	44,500	7,306	5,836	7,306	6,074
44,500	44,550	7,319	5,844	7,319	6,081
44,550	44,600	7,331	5,851	7,331	6,089
44,600	44,650	7,344	5,859	7,344	6,096
44,650	44,700	7,356	5,866	7,356	6,104
44,700	44,750	7,369	5,874	7,369	6,111
44,750	44,800	7,381	5,881	7,381	6,119
44,800	44,850	7,394	5,889	7,394	6,126
44,850	44,900	7,406	5,896	7,406	6,134
44,900	44,950	7,419	5,904	7,419	6,141
44,950	45,000	7,431	5,911	7,431	6,149
45,000					
45,000	45,050	7,444	5,919	7,444	6,156
45,050	45,100	7,456	5,926	7,456	6,164
45,100	45,150	7,469	5,934	7,469	6,171
45,150	45,200	7,481	5,941	7,481	6,179
45,200	45,250	7,494	5,949	7,494	6,186
45,250	45,300	7,506	5,956	7,506	6,194
45,300	45,350	7,519	5,964	7,519	6,201
45,350	45,400	7,531	5,971	7,531	6,209
45,400	45,450	7,544	5,979	7,544	6,216
45,450	45,500	7,556	5,986	7,556	6,224
45,500	45,550	7,569	5,994	7,569	6,234
45,550	45,600	7,581	6,001	7,581	6,246
45,600	45,650	7,594	6,009	7,594	6,259
45,650	45,700	7,606	6,016	7,606	6,271
45,700	45,750	7,619	6,024	7,619	6,284
45,750	45,800	7,631	6,031	7,631	6,296
45,800	45,850	7,644	6,039	7,644	6,309
45,850	45,900	7,656	6,046	7,656	6,321
45,900	45,950	7,669	6,054	7,669	6,334
45,950	46,000	7,681	6,061	7,681	6,346
46,000					
46,000	46,050	7,694	6,069	7,694	6,359
46,050	46,100	7,706	6,076	7,706	6,371
46,100	46,150	7,719	6,084	7,719	6,384
46,150	46,200	7,731	6,091	7,731	6,396
46,200	46,250	7,744	6,099	7,744	6,409
46,250	46,300	7,756	6,106	7,756	6,421
46,300	46,350	7,769	6,114	7,769	6,434
46,350	46,400	7,781	6,121	7,781	6,446
46,400	46,450	7,794	6,129	7,794	6,459
46,450	46,500	7,806	6,136	7,806	6,471
46,500	46,550	7,819	6,144	7,819	6,484
46,550	46,600	7,831	6,151	7,831	6,496
46,600	46,650	7,844	6,159	7,844	6,509
46,650	46,700	7,856	6,166	7,856	6,521
46,700	46,750	7,869	6,174	7,869	6,534
46,750	46,800	7,881	6,181	7,881	6,546
46,800	46,850	7,894	6,189	7,894	6,559
46,850	46,900	7,906	6,196	7,906	6,571
46,900	46,950	7,919	6,204	7,919	6,584
46,950	47,000	7,931	6,211	7,931	6,596
47,000					
47,000	47,050	7,944	6,219	7,944	6,609
47,050	47,100	7,956	6,226	7,956	6,621
47,100	47,150	7,969	6,234	7,969	6,634
47,150	47,200	7,981	6,241	7,981	6,646
47,200	47,250	7,994	6,249	7,994	6,659
47,250	47,300	8,006	6,256	8,006	6,671
47,300	47,350	8,019	6,264	8,019	6,684
47,350	47,400	8,031	6,271	8,031	6,696
47,400	47,450	8,044	6,279	8,044	6,709
47,450	47,500	8,056	6,286	8,056	6,721
47,500	47,550	8,069	6,294	8,069	6,734
47,550	47,600	8,081	6,301	8,081	6,746
47,600	47,650	8,094	6,309	8,094	6,759
47,650	47,700	8,106	6,316	8,106	6,771
47,700	47,750	8,119	6,324	8,119	6,784
47,750	47,800	8,131	6,331	8,131	6,796
47,800	47,850	8,144	6,339	8,144	6,809
47,850	47,900	8,156	6,346	8,156	6,821
47,900	47,950	8,169	6,354	8,169	6,834
47,950	48,000	8,181	6,361	8,181	6,846
48,000					
48,000	48,050	8,194	6,369	8,194	6,859
48,050	48,100	8,206	6,376	8,206	6,871
48,100	48,150	8,219	6,384	8,219	6,884
48,150	48,200	8,231	6,391	8,231	6,896
48,200	48,250	8,244	6,399	8,244	6,909
48,250	48,300	8,256	6,406	8,256	6,921
48,300	48,350	8,269	6,414	8,269	6,934
48,350	48,400	8,281	6,421	8,281	6,946
48,400	48,450	8,294	6,429	8,294	6,959
48,450	48,500	8,306	6,436	8,306	6,971
48,500	48,550	8,319	6,444	8,319	6,984
48,550	48,600	8,331	6,451	8,331	6,996
48,600	48,650	8,344	6,459	8,344	7,009
48,650	48,700	8,356	6,466	8,356	7,021
48,700	48,750	8,369	6,474	8,369	7,034
48,750	48,800	8,381	6,481	8,381	7,046
48,800	48,850	8,394	6,489	8,394	7,059
48,850	48,900	8,406	6,496	8,406	7,071
48,900	48,950	8,419	6,504	8,419	7,084
48,950	49,000	8,431	6,511	8,431	7,096
49,000					
49,000	49,050	8,444	6,519	8,444	7,109
49,050	49,100	8,456	6,526	8,456	7,121
49,100	49,150	8,469	6,534	8,469	7,134
49,150	49,200	8,481	6,541	8,481	7,146
49,200	49,250	8,494	6,549	8,494	7,159
49,250	49,300	8,506	6,556	8,506	7,171
49,300	49,350	8,519	6,564	8,519	7,184
49,350	49,400	8,531	6,571	8,531	7,196
49,400	49,450	8,544	6,579	8,544	7,209
49,450	49,500	8,556	6,586	8,556	7,221
49,500	49,550	8,569	6,594	8,569	7,234
49,550	49,600	8,581	6,601	8,581	7,246
49,600	49,650	8,594	6,609	8,594	7,259
49,650	49,700	8,606	6,616	8,606	7,271
49,700	49,750	8,619	6,624	8,619	7,284
49,750	49,800	8,631	6,631	8,631	7,296
49,800	49,850	8,644	6,639	8,644	7,309
49,850	49,900	8,656	6,646	8,656	7,321
49,900	49,950	8,669	6,654	8,669	7,334
49,950	50,000	8,681	6,661	8,681	7,346

* This column must also be used by a qualifying widow(er).

(Continued on page 83)

If line 43 (taxable income) is— / And you are— / Your tax is—

50,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
50,000	50,050	8,694	6,669	8,694	7,359
50,050	50,100	8,706	6,676	8,706	7,371
50,100	50,150	8,719	6,684	8,719	7,384
50,150	50,200	8,731	6,691	8,731	7,396
50,200	50,250	8,744	6,699	8,744	7,409
50,250	50,300	8,756	6,706	8,756	7,421
50,300	50,350	8,769	6,714	8,769	7,434
50,350	50,400	8,781	6,721	8,781	7,446
50,400	50,450	8,794	6,729	8,794	7,459
50,450	50,500	8,806	6,736	8,806	7,471
50,500	50,550	8,819	6,744	8,819	7,484
50,550	50,600	8,831	6,751	8,831	7,496
50,600	50,650	8,844	6,759	8,844	7,509
50,650	50,700	8,856	6,766	8,856	7,521
50,700	50,750	8,869	6,774	8,869	7,534
50,750	50,800	8,881	6,781	8,881	7,546
50,800	50,850	8,894	6,789	8,894	7,559
50,850	50,900	8,906	6,796	8,906	7,571
50,900	50,950	8,919	6,804	8,919	7,584
50,950	51,000	8,931	6,811	8,931	7,596

51,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
51,000	51,050	8,944	6,819	8,944	7,609
51,050	51,100	8,956	6,826	8,956	7,621
51,100	51,150	8,969	6,834	8,969	7,634
51,150	51,200	8,981	6,841	8,981	7,646
51,200	51,250	8,994	6,849	8,994	7,659
51,250	51,300	9,006	6,856	9,006	7,671
51,300	51,350	9,019	6,864	9,019	7,684
51,350	51,400	9,031	6,871	9,031	7,696
51,400	51,450	9,044	6,879	9,044	7,709
51,450	51,500	9,056	6,886	9,056	7,721
51,500	51,550	9,069	6,894	9,069	7,734
51,550	51,600	9,081	6,901	9,081	7,746
51,600	51,650	9,094	6,909	9,094	7,759
51,650	51,700	9,106	6,916	9,106	7,771
51,700	51,750	9,119	6,924	9,119	7,784
51,750	51,800	9,131	6,931	9,131	7,796
51,800	51,850	9,144	6,939	9,144	7,809
51,850	51,900	9,156	6,946	9,156	7,821
51,900	51,950	9,169	6,954	9,169	7,834
51,950	52,000	9,181	6,961	9,181	7,846

52,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
52,000	52,050	9,194	6,969	9,194	7,859
52,050	52,100	9,206	6,976	9,206	7,871
52,100	52,150	9,219	6,984	9,219	7,884
52,150	52,200	9,231	6,991	9,231	7,896
52,200	52,250	9,244	6,999	9,244	7,909
52,250	52,300	9,256	7,006	9,256	7,921
52,300	52,350	9,269	7,014	9,269	7,934
52,350	52,400	9,281	7,021	9,281	7,946
52,400	52,450	9,294	7,029	9,294	7,959
52,450	52,500	9,306	7,036	9,306	7,971
52,500	52,550	9,319	7,044	9,319	7,984
52,550	52,600	9,331	7,051	9,331	7,996
52,600	52,650	9,344	7,059	9,344	8,009
52,650	52,700	9,356	7,066	9,356	8,021
52,700	52,750	9,369	7,074	9,369	8,034
52,750	52,800	9,381	7,081	9,381	8,046
52,800	52,850	9,394	7,089	9,394	8,059
52,850	52,900	9,406	7,096	9,406	8,071
52,900	52,950	9,419	7,104	9,419	8,084
52,950	53,000	9,431	7,111	9,431	8,096

53,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
53,000	53,050	9,444	7,119	9,444	8,109
53,050	53,100	9,456	7,126	9,456	8,121
53,100	53,150	9,469	7,134	9,469	8,134
53,150	53,200	9,481	7,141	9,481	8,146
53,200	53,250	9,494	7,149	9,494	8,159
53,250	53,300	9,506	7,156	9,506	8,171
53,300	53,350	9,519	7,164	9,519	8,184
53,350	53,400	9,531	7,171	9,531	8,196
53,400	53,450	9,544	7,179	9,544	8,209
53,450	53,500	9,556	7,186	9,556	8,221
53,500	53,550	9,569	7,194	9,569	8,234
53,550	53,600	9,581	7,201	9,581	8,246
53,600	53,650	9,594	7,209	9,594	8,259
53,650	53,700	9,606	7,216	9,606	8,271
53,700	53,750	9,619	7,224	9,619	8,284
53,750	53,800	9,631	7,231	9,631	8,296
53,800	53,850	9,644	7,239	9,644	8,309
53,850	53,900	9,656	7,246	9,656	8,321
53,900	53,950	9,669	7,254	9,669	8,334
53,950	54,000	9,681	7,261	9,681	8,346

54,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
54,000	54,050	9,694	7,269	9,694	8,359
54,050	54,100	9,706	7,276	9,706	8,371
54,100	54,150	9,719	7,284	9,719	8,384
54,150	54,200	9,731	7,291	9,731	8,396
54,200	54,250	9,744	7,299	9,744	8,409
54,250	54,300	9,756	7,306	9,756	8,421
54,300	54,350	9,769	7,314	9,769	8,434
54,350	54,400	9,781	7,321	9,781	8,446
54,400	54,450	9,794	7,329	9,794	8,459
54,450	54,500	9,806	7,336	9,806	8,471
54,500	54,550	9,819	7,344	9,819	8,484
54,550	54,600	9,831	7,351	9,831	8,496
54,600	54,650	9,844	7,359	9,844	8,509
54,650	54,700	9,856	7,366	9,856	8,521
54,700	54,750	9,869	7,374	9,869	8,534
54,750	54,800	9,881	7,381	9,881	8,546
54,800	54,850	9,894	7,389	9,894	8,559
54,850	54,900	9,906	7,396	9,906	8,571
54,900	54,950	9,919	7,404	9,919	8,584
54,950	55,000	9,931	7,411	9,931	8,596

55,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
55,000	55,050	9,944	7,419	9,944	8,609
55,050	55,100	9,956	7,426	9,956	8,621
55,100	55,150	9,969	7,434	9,969	8,634
55,150	55,200	9,981	7,441	9,981	8,646
55,200	55,250	9,994	7,449	9,994	8,659
55,250	55,300	10,006	7,456	10,006	8,671
55,300	55,350	10,019	7,464	10,019	8,684
55,350	55,400	10,031	7,471	10,031	8,696
55,400	55,450	10,044	7,479	10,044	8,709
55,450	55,500	10,056	7,486	10,056	8,721
55,500	55,550	10,069	7,494	10,069	8,734
55,550	55,600	10,081	7,501	10,081	8,746
55,600	55,650	10,094	7,509	10,094	8,759
55,650	55,700	10,106	7,516	10,106	8,771
55,700	55,750	10,119	7,524	10,119	8,784
55,750	55,800	10,131	7,531	10,131	8,796
55,800	55,850	10,144	7,539	10,144	8,809
55,850	55,900	10,156	7,546	10,156	8,821
55,900	55,950	10,169	7,554	10,169	8,834
55,950	56,000	10,181	7,561	10,181	8,846

56,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
56,000	56,050	10,194	7,569	10,194	8,859
56,050	56,100	10,206	7,576	10,206	8,871
56,100	56,150	10,219	7,584	10,219	8,884
56,150	56,200	10,231	7,591	10,231	8,896
56,200	56,250	10,244	7,599	10,244	8,909
56,250	56,300	10,256	7,606	10,256	8,921
56,300	56,350	10,269	7,614	10,269	8,934
56,350	56,400	10,281	7,621	10,281	8,946
56,400	56,450	10,294	7,629	10,294	8,959
56,450	56,500	10,306	7,636	10,306	8,971
56,500	56,550	10,319	7,644	10,319	8,984
56,550	56,600	10,331	7,651	10,331	8,996
56,600	56,650	10,344	7,659	10,344	9,009
56,650	56,700	10,356	7,666	10,356	9,021
56,700	56,750	10,369	7,674	10,369	9,034
56,750	56,800	10,381	7,681	10,381	9,046
56,800	56,850	10,394	7,689	10,394	9,059
56,850	56,900	10,406	7,696	10,406	9,071
56,900	56,950	10,419	7,704	10,419	9,084
56,950	57,000	10,431	7,711	10,431	9,096

57,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
57,000	57,050	10,444	7,719	10,444	9,109
57,050	57,100	10,456	7,726	10,456	9,121
57,100	57,150	10,469	7,734	10,469	9,134
57,150	57,200	10,481	7,741	10,481	9,146
57,200	57,250	10,494	7,749	10,494	9,159
57,250	57,300	10,506	7,756	10,506	9,171
57,300	57,350	10,519	7,764	10,519	9,184
57,350	57,400	10,531	7,771	10,531	9,196
57,400	57,450	10,544	7,779	10,544	9,209
57,450	57,500	10,556	7,786	10,556	9,221
57,500	57,550	10,569	7,794	10,569	9,234
57,550	57,600	10,581	7,801	10,581	9,246
57,600	57,650	10,594	7,809	10,594	9,259
57,650	57,700	10,606	7,816	10,606	9,271
57,700	57,750	10,619	7,824	10,619	9,284
57,750	57,800	10,631	7,831	10,631	9,296
57,800	57,850	10,644	7,839	10,644	9,309
57,850	57,900	10,656	7,846	10,656	9,321
57,900	57,950	10,669	7,854	10,669	9,334
57,950	58,000	10,681	7,861	10,681	9,346

58,000

At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
58,000	58,050	10,694	7,869	10,694	9,359
58,050	58,100	10,706	7,876	10,706	9,371
58,100	58,150	10,719	7,884	10,719	9,384
58,150	58,200	10,731	7,891	10,731	9,396
58,200	58,250	10,744	7,899	10,744	9,409
58,250	58,300	10,756	7,906	10,756	9,421
58,300	58,350	10,769	7,914	10,769	9,434
58,350	58,400	10,781	7,921	10,781	9,446
58,400	58,450	10,794	7,929	10,794	9,459
58,450	58,500	10,806	7,936	10,806	9,471
58,500	58,550	10,819	7,944	10,819	9,484
58,550	58,600	10,831	7,951	10,831	9,496
58,600	58,650	10,844	7,959	10,844	9,509
58,650	58,700	10,856	7,966	10,856	9,521
58,700	58,750	10,869	7,974	10,869	9,534
58,750	58,800	10,881	7,981	10,881	9,546
58,800	58,850	10,894	7,989	10,894	9,559
58,850	58,900	10,906	7,996	10,906	9,571
58,900	58,950	10,919	8,004	10,919	9,584
58,950	59,000	10,931	8,011	10,931	9,596

* This column must also be used by a qualifying widow(er).

(Continued on page 84)

2009 Tax Table—*Continued*

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
59,000					
59,000	59,050	10,944	8,019	10,944	9,609
59,050	59,100	10,956	8,026	10,956	9,621
59,100	59,150	10,969	8,034	10,969	9,634
59,150	59,200	10,981	8,041	10,981	9,646
59,200	59,250	10,994	8,049	10,994	9,659
59,250	59,300	11,006	8,056	11,006	9,671
59,300	59,350	11,019	8,064	11,019	9,684
59,350	59,400	11,031	8,071	11,031	9,696
59,400	59,450	11,044	8,079	11,044	9,709
59,450	59,500	11,056	8,086	11,056	9,721
59,500	59,550	11,069	8,094	11,069	9,734
59,550	59,600	11,081	8,101	11,081	9,746
59,600	59,650	11,094	8,109	11,094	9,759
59,650	59,700	11,106	8,116	11,106	9,771
59,700	59,750	11,119	8,124	11,119	9,784
59,750	59,800	11,131	8,131	11,131	9,796
59,800	59,850	11,144	8,139	11,144	9,809
59,850	59,900	11,156	8,146	11,156	9,821
59,900	59,950	11,169	8,154	11,169	9,834
59,950	60,000	11,181	8,161	11,181	9,846
60,000					
60,000	60,050	11,194	8,169	11,194	9,859
60,050	60,100	11,206	8,176	11,206	9,871
60,100	60,150	11,219	8,184	11,219	9,884
60,150	60,200	11,231	8,191	11,231	9,896
60,200	60,250	11,244	8,199	11,244	9,909
60,250	60,300	11,256	8,206	11,256	9,921
60,300	60,350	11,269	8,214	11,269	9,934
60,350	60,400	11,281	8,221	11,281	9,946
60,400	60,450	11,294	8,229	11,294	9,959
60,450	60,500	11,306	8,236	11,306	9,971
60,500	60,550	11,319	8,244	11,319	9,984
60,550	60,600	11,331	8,251	11,331	9,996
60,600	60,650	11,344	8,259	11,344	10,009
60,650	60,700	11,356	8,266	11,356	10,021
60,700	60,750	11,369	8,274	11,369	10,034
60,750	60,800	11,381	8,281	11,381	10,046
60,800	60,850	11,394	8,289	11,394	10,059
60,850	60,900	11,406	8,296	11,406	10,071
60,900	60,950	11,419	8,304	11,419	10,084
60,950	61,000	11,431	8,311	11,431	10,096
61,000					
61,000	61,050	11,444	8,319	11,444	10,109
61,050	61,100	11,456	8,326	11,456	10,121
61,100	61,150	11,469	8,334	11,469	10,134
61,150	61,200	11,481	8,341	11,481	10,146
61,200	61,250	11,494	8,349	11,494	10,159
61,250	61,300	11,506	8,356	11,506	10,171
61,300	61,350	11,519	8,364	11,519	10,184
61,350	61,400	11,531	8,371	11,531	10,196
61,400	61,450	11,544	8,379	11,544	10,209
61,450	61,500	11,556	8,386	11,556	10,221
61,500	61,550	11,569	8,394	11,569	10,234
61,550	61,600	11,581	8,401	11,581	10,246
61,600	61,650	11,594	8,409	11,594	10,259
61,650	61,700	11,606	8,416	11,606	10,271
61,700	61,750	11,619	8,424	11,619	10,284
61,750	61,800	11,631	8,431	11,631	10,296
61,800	61,850	11,644	8,439	11,644	10,309
61,850	61,900	11,656	8,446	11,656	10,321
61,900	61,950	11,669	8,454	11,669	10,334
61,950	62,000	11,681	8,461	11,681	10,346

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
62,000					
62,000	62,050	11,694	8,469	11,694	10,359
62,050	62,100	11,706	8,476	11,706	10,371
62,100	62,150	11,719	8,484	11,719	10,384
62,150	62,200	11,731	8,491	11,731	10,396
62,200	62,250	11,744	8,499	11,744	10,409
62,250	62,300	11,756	8,506	11,756	10,421
62,300	62,350	11,769	8,514	11,769	10,434
62,350	62,400	11,781	8,521	11,781	10,446
62,400	62,450	11,794	8,529	11,794	10,459
62,450	62,500	11,806	8,536	11,806	10,471
62,500	62,550	11,819	8,544	11,819	10,484
62,550	62,600	11,831	8,551	11,831	10,496
62,600	62,650	11,844	8,559	11,844	10,509
62,650	62,700	11,856	8,566	11,856	10,521
62,700	62,750	11,869	8,574	11,869	10,534
62,750	62,800	11,881	8,581	11,881	10,546
62,800	62,850	11,894	8,589	11,894	10,559
62,850	62,900	11,906	8,596	11,906	10,571
62,900	62,950	11,919	8,604	11,919	10,584
62,950	63,000	11,931	8,611	11,931	10,596
63,000					
63,000	63,050	11,944	8,619	11,944	10,609
63,050	63,100	11,956	8,626	11,956	10,621
63,100	63,150	11,969	8,634	11,969	10,634
63,150	63,200	11,981	8,641	11,981	10,646
63,200	63,250	11,994	8,649	11,994	10,659
63,250	63,300	12,006	8,656	12,006	10,671
63,300	63,350	12,019	8,664	12,019	10,684
63,350	63,400	12,031	8,671	12,031	10,696
63,400	63,450	12,044	8,679	12,044	10,709
63,450	63,500	12,056	8,686	12,056	10,721
63,500	63,550	12,069	8,694	12,069	10,734
63,550	63,600	12,081	8,701	12,081	10,746
63,600	63,650	12,094	8,709	12,094	10,759
63,650	63,700	12,106	8,716	12,106	10,771
63,700	63,750	12,119	8,724	12,119	10,784
63,750	63,800	12,131	8,731	12,131	10,796
63,800	63,850	12,144	8,739	12,144	10,809
63,850	63,900	12,156	8,746	12,156	10,821
63,900	63,950	12,169	8,754	12,169	10,834
63,950	64,000	12,181	8,761	12,181	10,846
64,000					
64,000	64,050	12,194	8,769	12,194	10,859
64,050	64,100	12,206	8,776	12,206	10,871
64,100	64,150	12,219	8,784	12,219	10,884
64,150	64,200	12,231	8,791	12,231	10,896
64,200	64,250	12,244	8,799	12,244	10,909
64,250	64,300	12,256	8,806	12,256	10,921
64,300	64,350	12,269	8,814	12,269	10,934
64,350	64,400	12,281	8,821	12,281	10,946
64,400	64,450	12,294	8,829	12,294	10,959
64,450	64,500	12,306	8,836	12,306	10,971
64,500	64,550	12,319	8,844	12,319	10,984
64,550	64,600	12,331	8,851	12,331	10,996
64,600	64,650	12,344	8,859	12,344	11,009
64,650	64,700	12,356	8,866	12,356	11,021
64,700	64,750	12,369	8,874	12,369	11,034
64,750	64,800	12,381	8,881	12,381	11,046
64,800	64,850	12,394	8,889	12,394	11,059
64,850	64,900	12,406	8,896	12,406	11,071
64,900	64,950	12,419	8,904	12,419	11,084
64,950	65,000	12,431	8,911	12,431	11,096

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
65,000					
65,000	65,050	12,444	8,919	12,444	11,109
65,050	65,100	12,456	8,926	12,456	11,121
65,100	65,150	12,469	8,934	12,469	11,134
65,150	65,200	12,481	8,941	12,481	11,146
65,200	65,250	12,494	8,949	12,494	11,159
65,250	65,300	12,506	8,956	12,506	11,171
65,300	65,350	12,519	8,964	12,519	11,184
65,350	65,400	12,531	8,971	12,531	11,196
65,400	65,450	12,544	8,979	12,544	11,209
65,450	65,500	12,556	8,986	12,556	11,221
65,500	65,550	12,569	8,994	12,569	11,234
65,550	65,600	12,581	9,001	12,581	11,246
65,600	65,650	12,594	9,009	12,594	11,259
65,650	65,700	12,606	9,016	12,606	11,271
65,700	65,750	12,619	9,024	12,619	11,284
65,750	65,800	12,631	9,031	12,631	11,296
65,800	65,850	12,644	9,039	12,644	11,309
65,850	65,900	12,656	9,046	12,656	11,321
65,900	65,950	12,669	9,054	12,669	11,334
65,950	66,000	12,681	9,061	12,681	11,346
66,000					
66,000	66,050	12,694	9,069	12,694	11,359
66,050	66,100	12,706	9,076	12,706	11,371
66,100	66,150	12,719	9,084	12,719	11,384
66,150	66,200	12,731	9,091	12,731	11,396
66,200	66,250	12,744	9,099	12,744	11,409
66,250	66,300	12,756	9,106	12,756	11,421
66,300	66,350	12,769	9,114	12,769	11,434
66,350	66,400	12,781	9,121	12,781	11,446
66,400	66,450	12,794	9,129	12,794	11,459
66,450	66,500	12,806	9,136	12,806	11,471
66,500	66,550	12,819	9,144	12,819	11,484
66,550	66,600	12,831	9,151	12,831	11,496
66,600	66,650	12,844	9,159	12,844	11,509
66,650	66,700	12,856	9,166	12,856	11,521
66,700	66,750	12,869	9,174	12,869	11,534
66,750	66,800	12,881	9,181	12,881	11,546
66,800	66,850	12,894	9,189	12,894	11,559
66,850	66,900	12,906	9,196	12,906	11,571
66,900	66,950	12,919	9,204	12,919	11,584
66,950	67,000	12,931	9,211	12,931	11,596
67,000					
67,000	67,050	12,944	9,219	12,944	11,609
67,050	67,100	12,956	9,226	12,956	11,621
67,100	67,150	12,969	9,234	12,969	11,634
67,150	67,200	12,981	9,241	12,981	11,646
67,200	67,250	12,994	9,249	12,994	11,659
67,250	67,300	13,006	9,256	13,006	11,671
67,300	67,350	13,019	9,264	13,019	11,684
67,350	67,400	13,031	9,271	13,031	11,696
67,400	67,450	13,044	9,279	13,044	11,709
67,450	67,500	13,056	9,286	13,056	11,721
67,500	67,550	13,069	9,294	13,069	11,734
67,550	67,600	13,081	9,301	13,081	11,746
67,600	67,650	13,094	9,309	13,094	11,759
67,650	67,700	13,106	9,316	13,106	11,771
67,700	67,750	13,119	9,324	13,119	11,784
67,750	67,800	13,131	9,331	13,131	11,796
67,800	67,850	13,144	9,339	13,144	11,809
67,850	67,900	13,156	9,346	13,156	11,821
67,900	67,950	13,169	9,356	13,169	11,834
67,950	68,000	13,181	9,369	13,181	11,846

* This column must also be used by a qualifying widow(er).

(Continued on page 85)

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
68,000					
68,000	68,050	13,194	9,381	13,194	11,859
68,050	68,100	13,206	9,394	13,206	11,871
68,100	68,150	13,219	9,406	13,219	11,884
68,150	68,200	13,231	9,419	13,231	11,896
68,200	68,250	13,244	9,431	13,244	11,909
68,250	68,300	13,256	9,444	13,256	11,921
68,300	68,350	13,269	9,456	13,269	11,934
68,350	68,400	13,281	9,469	13,281	11,946
68,400	68,450	13,294	9,481	13,294	11,959
68,450	68,500	13,306	9,494	13,306	11,971
68,500	68,550	13,319	9,506	13,319	11,984
68,550	68,600	13,331	9,519	13,333	11,996
68,600	68,650	13,344	9,531	13,347	12,009
68,650	68,700	13,356	9,544	13,361	12,021
68,700	68,750	13,369	9,556	13,375	12,034
68,750	68,800	13,381	9,569	13,389	12,046
68,800	68,850	13,394	9,581	13,403	12,059
68,850	68,900	13,406	9,594	13,417	12,071
68,900	68,950	13,419	9,606	13,431	12,084
68,950	69,000	13,431	9,619	13,445	12,096
69,000					
69,000	69,050	13,444	9,631	13,459	12,109
69,050	69,100	13,456	9,644	13,473	12,121
69,100	69,150	13,469	9,656	13,487	12,134
69,150	69,200	13,481	9,669	13,501	12,146
69,200	69,250	13,494	9,681	13,515	12,159
69,250	69,300	13,506	9,694	13,529	12,171
69,300	69,350	13,519	9,706	13,543	12,184
69,350	69,400	13,531	9,719	13,557	12,196
69,400	69,450	13,544	9,731	13,571	12,209
69,450	69,500	13,556	9,744	13,585	12,221
69,500	69,550	13,569	9,756	13,599	12,234
69,550	69,600	13,581	9,769	13,613	12,246
69,600	69,650	13,594	9,781	13,627	12,259
69,650	69,700	13,606	9,794	13,641	12,271
69,700	69,750	13,619	9,806	13,655	12,284
69,750	69,800	13,631	9,819	13,669	12,296
69,800	69,850	13,644	9,831	13,683	12,309
69,850	69,900	13,656	9,844	13,697	12,321
69,900	69,950	13,669	9,856	13,711	12,334
69,950	70,000	13,681	9,869	13,725	12,346
70,000					
70,000	70,050	13,694	9,881	13,739	12,359
70,050	70,100	13,706	9,894	13,753	12,371
70,100	70,150	13,719	9,906	13,767	12,384
70,150	70,200	13,731	9,919	13,781	12,396
70,200	70,250	13,744	9,931	13,795	12,409
70,250	70,300	13,756	9,944	13,809	12,421
70,300	70,350	13,769	9,956	13,823	12,434
70,350	70,400	13,781	9,969	13,837	12,446
70,400	70,450	13,794	9,981	13,851	12,459
70,450	70,500	13,806	9,994	13,865	12,471
70,500	70,550	13,819	10,006	13,879	12,484
70,550	70,600	13,831	10,019	13,893	12,496
70,600	70,650	13,844	10,031	13,907	12,509
70,650	70,700	13,856	10,044	13,921	12,521
70,700	70,750	13,869	10,056	13,935	12,534
70,750	70,800	13,881	10,069	13,949	12,546
70,800	70,850	13,894	10,081	13,963	12,559
70,850	70,900	13,906	10,094	13,977	12,571
70,900	70,950	13,919	10,106	13,991	12,584
70,950	71,000	13,931	10,119	14,005	12,596
71,000					
71,000	71,050	13,944	10,131	14,019	12,609
71,050	71,100	13,956	10,144	14,033	12,621
71,100	71,150	13,969	10,156	14,047	12,634
71,150	71,200	13,981	10,169	14,061	12,646
71,200	71,250	13,994	10,181	14,075	12,659
71,250	71,300	14,006	10,194	14,089	12,671
71,300	71,350	14,019	10,206	14,103	12,684
71,350	71,400	14,031	10,219	14,117	12,696
71,400	71,450	14,044	10,231	14,131	12,709
71,450	71,500	14,056	10,244	14,145	12,721
71,500	71,550	14,069	10,256	14,159	12,734
71,550	71,600	14,081	10,269	14,173	12,746
71,600	71,650	14,094	10,281	14,187	12,759
71,650	71,700	14,106	10,294	14,201	12,771
71,700	71,750	14,119	10,306	14,215	12,784
71,750	71,800	14,131	10,319	14,229	12,796
71,800	71,850	14,144	10,331	14,243	12,809
71,850	71,900	14,156	10,344	14,257	12,821
71,900	71,950	14,169	10,356	14,271	12,834
71,950	72,000	14,181	10,369	14,285	12,846
72,000					
72,000	72,050	14,194	10,381	14,299	12,859
72,050	72,100	14,206	10,394	14,313	12,871
72,100	72,150	14,219	10,406	14,327	12,884
72,150	72,200	14,231	10,419	14,341	12,896
72,200	72,250	14,244	10,431	14,355	12,909
72,250	72,300	14,256	10,444	14,369	12,921
72,300	72,350	14,269	10,456	14,383	12,934
72,350	72,400	14,281	10,469	14,397	12,946
72,400	72,450	14,294	10,481	14,411	12,959
72,450	72,500	14,306	10,494	14,425	12,971
72,500	72,550	14,319	10,506	14,439	12,984
72,550	72,600	14,331	10,519	14,453	12,996
72,600	72,650	14,344	10,531	14,467	13,009
72,650	72,700	14,356	10,544	14,481	13,021
72,700	72,750	14,369	10,556	14,495	13,034
72,750	72,800	14,381	10,569	14,509	13,046
72,800	72,850	14,394	10,581	14,523	13,059
72,850	72,900	14,406	10,594	14,537	13,071
72,900	72,950	14,419	10,606	14,551	13,084
72,950	73,000	14,431	10,619	14,565	13,096
73,000					
73,000	73,050	14,444	10,631	14,579	13,109
73,050	73,100	14,456	10,644	14,593	13,121
73,100	73,150	14,469	10,656	14,607	13,134
73,150	73,200	14,481	10,669	14,621	13,146
73,200	73,250	14,494	10,681	14,635	13,159
73,250	73,300	14,506	10,694	14,649	13,171
73,300	73,350	14,519	10,706	14,663	13,184
73,350	73,400	14,531	10,719	14,677	13,196
73,400	73,450	14,544	10,731	14,691	13,209
73,450	73,500	14,556	10,744	14,705	13,221
73,500	73,550	14,569	10,756	14,719	13,234
73,550	73,600	14,581	10,769	14,733	13,246
73,600	73,650	14,594	10,781	14,747	13,259
73,650	73,700	14,606	10,794	14,761	13,271
73,700	73,750	14,619	10,806	14,775	13,284
73,750	73,800	14,631	10,819	14,789	13,296
73,800	73,850	14,644	10,831	14,803	13,309
73,850	73,900	14,656	10,844	14,817	13,321
73,900	73,950	14,669	10,856	14,831	13,334
73,950	74,000	14,681	10,869	14,845	13,346
74,000					
74,000	74,050	14,694	10,881	14,859	13,359
74,050	74,100	14,706	10,894	14,873	13,371
74,100	74,150	14,719	10,906	14,887	13,384
74,150	74,200	14,731	10,919	14,901	13,396
74,200	74,250	14,744	10,931	14,915	13,409
74,250	74,300	14,756	10,944	14,929	13,421
74,300	74,350	14,769	10,956	14,943	13,434
74,350	74,400	14,781	10,969	14,957	13,446
74,400	74,450	14,794	10,981	14,971	13,459
74,450	74,500	14,806	10,994	14,985	13,471
74,500	74,550	14,819	11,006	14,999	13,484
74,550	74,600	14,831	11,019	15,013	13,496
74,600	74,650	14,844	11,031	15,027	13,509
74,650	74,700	14,856	11,044	15,041	13,521
74,700	74,750	14,869	11,056	15,055	13,534
74,750	74,800	14,881	11,069	15,069	13,546
74,800	74,850	14,894	11,081	15,083	13,559
74,850	74,900	14,906	11,094	15,097	13,571
74,900	74,950	14,919	11,106	15,111	13,584
74,950	75,000	14,931	11,119	15,125	13,596
75,000					
75,000	75,050	14,944	11,131	15,139	13,609
75,050	75,100	14,956	11,144	15,153	13,621
75,100	75,150	14,969	11,156	15,167	13,634
75,150	75,200	14,981	11,169	15,181	13,646
75,200	75,250	14,994	11,181	15,195	13,659
75,250	75,300	15,006	11,194	15,209	13,671
75,300	75,350	15,019	11,206	15,223	13,684
75,350	75,400	15,031	11,219	15,237	13,696
75,400	75,450	15,044	11,231	15,251	13,709
75,450	75,500	15,056	11,244	15,265	13,721
75,500	75,550	15,069	11,256	15,279	13,734
75,550	75,600	15,081	11,269	15,293	13,746
75,600	75,650	15,094	11,281	15,307	13,759
75,650	75,700	15,106	11,294	15,321	13,771
75,700	75,750	15,119	11,306	15,335	13,784
75,750	75,800	15,131	11,319	15,349	13,796
75,800	75,850	15,144	11,331	15,363	13,809
75,850	75,900	15,156	11,344	15,377	13,821
75,900	75,950	15,169	11,356	15,391	13,834
75,950	76,000	15,181	11,369	15,405	13,846
76,000					
76,000	76,050	15,194	11,381	15,419	13,859
76,050	76,100	15,206	11,394	15,433	13,871
76,100	76,150	15,219	11,406	15,447	13,884
76,150	76,200	15,231	11,419	15,461	13,896
76,200	76,250	15,244	11,431	15,475	13,909
76,250	76,300	15,256	11,444	15,489	13,921
76,300	76,350	15,269	11,456	15,503	13,934
76,350	76,400	15,281	11,469	15,517	13,946
76,400	76,450	15,294	11,481	15,531	13,959
76,450	76,500	15,306	11,494	15,545	13,971
76,500	76,550	15,319	11,506	15,559	13,984
76,550	76,600	15,331	11,519	15,573	13,996
76,600	76,650	15,344	11,531	15,587	14,009
76,650	76,700	15,356	11,544	15,601	14,021
76,700	76,750	15,369	11,556	15,615	14,034
76,750	76,800	15,381	11,569	15,629	14,046
76,800	76,850	15,394	11,581	15,643	14,059
76,850	76,900	15,406	11,594	15,657	14,071
76,900	76,950	15,419	11,606	15,671	14,084
76,950	77,000	15,431	11,619	15,685	14,096

* This column must also be used by a qualifying widow(er).

(Continued on page 86)

2009 Tax Table—*Continued*

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
77,000					
77,000	77,050	15,444	11,631	15,699	14,109
77,050	77,100	15,456	11,644	15,713	14,121
77,100	77,150	15,469	11,656	15,727	14,134
77,150	77,200	15,481	11,669	15,741	14,146
77,200	77,250	15,494	11,681	15,755	14,159
77,250	77,300	15,506	11,694	15,769	14,171
77,300	77,350	15,519	11,706	15,783	14,184
77,350	77,400	15,531	11,719	15,797	14,196
77,400	77,450	15,544	11,731	15,811	14,209
77,450	77,500	15,556	11,744	15,825	14,221
77,500	77,550	15,569	11,756	15,839	14,234
77,550	77,600	15,581	11,769	15,853	14,246
77,600	77,650	15,594	11,781	15,867	14,259
77,650	77,700	15,606	11,794	15,881	14,271
77,700	77,750	15,619	11,806	15,895	14,284
77,750	77,800	15,631	11,819	15,909	14,296
77,800	77,850	15,644	11,831	15,923	14,309
77,850	77,900	15,656	11,844	15,937	14,321
77,900	77,950	15,669	11,856	15,951	14,334
77,950	78,000	15,681	11,869	15,965	14,346
78,000					
78,000	78,050	15,694	11,881	15,979	14,359
78,050	78,100	15,706	11,894	15,993	14,371
78,100	78,150	15,719	11,906	16,007	14,384
78,150	78,200	15,731	11,919	16,021	14,396
78,200	78,250	15,744	11,931	16,035	14,409
78,250	78,300	15,756	11,944	16,049	14,421
78,300	78,350	15,769	11,956	16,063	14,434
78,350	78,400	15,781	11,969	16,077	14,446
78,400	78,450	15,794	11,981	16,091	14,459
78,450	78,500	15,806	11,994	16,105	14,471
78,500	78,550	15,819	12,006	16,119	14,484
78,550	78,600	15,831	12,019	16,133	14,496
78,600	78,650	15,844	12,031	16,147	14,509
78,650	78,700	15,856	12,044	16,161	14,521
78,700	78,750	15,869	12,056	16,175	14,534
78,750	78,800	15,881	12,069	16,189	14,546
78,800	78,850	15,894	12,081	16,203	14,559
78,850	78,900	15,906	12,094	16,217	14,571
78,900	78,950	15,919	12,106	16,231	14,584
78,950	79,000	15,931	12,119	16,245	14,596
79,000					
79,000	79,050	15,944	12,131	16,259	14,609
79,050	79,100	15,956	12,144	16,273	14,621
79,100	79,150	15,969	12,156	16,287	14,634
79,150	79,200	15,981	12,169	16,301	14,646
79,200	79,250	15,994	12,181	16,315	14,659
79,250	79,300	16,006	12,194	16,329	14,671
79,300	79,350	16,019	12,206	16,343	14,684
79,350	79,400	16,031	12,219	16,357	14,696
79,400	79,450	16,044	12,231	16,371	14,709
79,450	79,500	16,056	12,244	16,385	14,721
79,500	79,550	16,069	12,256	16,399	14,734
79,550	79,600	16,081	12,269	16,413	14,746
79,600	79,650	16,094	12,281	16,427	14,759
79,650	79,700	16,106	12,294	16,441	14,771
79,700	79,750	16,119	12,306	16,455	14,784
79,750	79,800	16,131	12,319	16,469	14,796
79,800	79,850	16,144	12,331	16,483	14,809
79,850	79,900	16,156	12,344	16,497	14,821
79,900	79,950	16,169	12,356	16,511	14,834
79,950	80,000	16,181	12,369	16,525	14,846

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
80,000					
80,000	80,050	16,194	12,381	16,539	14,859
80,050	80,100	16,206	12,394	16,553	14,871
80,100	80,150	16,219	12,406	16,567	14,884
80,150	80,200	16,231	12,419	16,581	14,896
80,200	80,250	16,244	12,431	16,595	14,909
80,250	80,300	16,256	12,444	16,609	14,921
80,300	80,350	16,269	12,456	16,623	14,934
80,350	80,400	16,281	12,469	16,637	14,946
80,400	80,450	16,294	12,481	16,651	14,959
80,450	80,500	16,306	12,494	16,665	14,971
80,500	80,550	16,319	12,506	16,679	14,984
80,550	80,600	16,331	12,519	16,693	14,996
80,600	80,650	16,344	12,531	16,707	15,009
80,650	80,700	16,356	12,544	16,721	15,021
80,700	80,750	16,369	12,556	16,735	15,034
80,750	80,800	16,381	12,569	16,749	15,046
80,800	80,850	16,394	12,581	16,763	15,059
80,850	80,900	16,406	12,594	16,777	15,071
80,900	80,950	16,419	12,606	16,791	15,084
80,950	81,000	16,431	12,619	16,805	15,096
81,000					
81,000	81,050	16,444	12,631	16,819	15,109
81,050	81,100	16,456	12,644	16,833	15,121
81,100	81,150	16,469	12,656	16,847	15,134
81,150	81,200	16,481	12,669	16,861	15,146
81,200	81,250	16,494	12,681	16,875	15,159
81,250	81,300	16,506	12,694	16,889	15,171
81,300	81,350	16,519	12,706	16,903	15,184
81,350	81,400	16,531	12,719	16,917	15,196
81,400	81,450	16,544	12,731	16,931	15,209
81,450	81,500	16,556	12,744	16,945	15,221
81,500	81,550	16,569	12,756	16,959	15,234
81,550	81,600	16,581	12,769	16,973	15,246
81,600	81,650	16,594	12,781	16,987	15,259
81,650	81,700	16,606	12,794	17,001	15,271
81,700	81,750	16,619	12,806	17,015	15,284
81,750	81,800	16,631	12,819	17,029	15,296
81,800	81,850	16,644	12,831	17,043	15,309
81,850	81,900	16,656	12,844	17,057	15,321
81,900	81,950	16,669	12,856	17,071	15,334
81,950	82,000	16,681	12,869	17,085	15,346
82,000					
82,000	82,050	16,694	12,881	17,099	15,359
82,050	82,100	16,706	12,894	17,113	15,371
82,100	82,150	16,719	12,906	17,127	15,384
82,150	82,200	16,731	12,919	17,141	15,396
82,200	82,250	16,744	12,931	17,155	15,409
82,250	82,300	16,757	12,944	17,169	15,421
82,300	82,350	16,771	12,956	17,183	15,434
82,350	82,400	16,785	12,969	17,197	15,446
82,400	82,450	16,799	12,981	17,211	15,459
82,450	82,500	16,813	12,994	17,225	15,471
82,500	82,550	16,827	13,006	17,239	15,484
82,550	82,600	16,841	13,019	17,253	15,496
82,600	82,650	16,855	13,031	17,267	15,509
82,650	82,700	16,869	13,044	17,281	15,521
82,700	82,750	16,883	13,056	17,295	15,534
82,750	82,800	16,897	13,069	17,309	15,546
82,800	82,850	16,911	13,081	17,323	15,559
82,850	82,900	16,925	13,094	17,337	15,571
82,900	82,950	16,939	13,106	17,351	15,584
82,950	83,000	16,953	13,119	17,365	15,596

If line 43 (taxable income) is— At least	But less than	And you are— Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
83,000					
83,000	83,050	16,967	13,131	17,379	15,609
83,050	83,100	16,981	13,144	17,393	15,621
83,100	83,150	16,995	13,156	17,407	15,634
83,150	83,200	17,009	13,169	17,421	15,646
83,200	83,250	17,023	13,181	17,435	15,659
83,250	83,300	17,037	13,194	17,449	15,671
83,300	83,350	17,051	13,206	17,463	15,684
83,350	83,400	17,065	13,219	17,477	15,696
83,400	83,450	17,079	13,231	17,491	15,709
83,450	83,500	17,093	13,244	17,505	15,721
83,500	83,550	17,107	13,256	17,519	15,734
83,550	83,600	17,121	13,269	17,533	15,746
83,600	83,650	17,135	13,281	17,547	15,759
83,650	83,700	17,149	13,294	17,561	15,771
83,700	83,750	17,163	13,306	17,575	15,784
83,750	83,800	17,177	13,319	17,589	15,796
83,800	83,850	17,191	13,331	17,603	15,809
83,850	83,900	17,205	13,344	17,617	15,821
83,900	83,950	17,219	13,356	17,631	15,834
83,950	84,000	17,233	13,369	17,645	15,846
84,000					
84,000	84,050	17,247	13,381	17,659	15,859
84,050	84,100	17,261	13,394	17,673	15,871
84,100	84,150	17,275	13,406	17,687	15,884
84,150	84,200	17,289	13,419	17,701	15,896
84,200	84,250	17,303	13,431	17,715	15,909
84,250	84,300	17,317	13,444	17,729	15,921
84,300	84,350	17,331	13,456	17,743	15,934
84,350	84,400	17,345	13,469	17,757	15,946
84,400	84,450	17,359	13,481	17,771	15,959
84,450	84,500	17,373	13,494	17,785	15,971
84,500	84,550	17,387	13,506	17,799	15,984
84,550	84,600	17,401	13,519	17,813	15,996
84,600	84,650	17,415	13,531	17,827	16,009
84,650	84,700	17,429	13,544	17,841	16,021
84,700	84,750	17,443	13,556	17,855	16,034
84,750	84,800	17,457	13,569	17,869	16,046
84,800	84,850	17,471	13,581	17,883	16,059
84,850	84,900	17,485	13,594	17,897	16,071
84,900	84,950	17,499	13,606	17,911	16,084
84,950	85,000	17,513	13,619	17,925	16,096
85,000					
85,000	85,050	17,527	13,631	17,939	16,109
85,050	85,100	17,541	13,644	17,953	16,121
85,100	85,150	17,555	13,656	17,967	16,134
85,150	85,200	17,569	13,669	17,981	16,146
85,200	85,250	17,583	13,681	17,995	16,159
85,250	85,300	17,597	13,694	18,009	16,171
85,300	85,350	17,611	13,706	18,023	16,184
85,350	85,400	17,625	13,719	18,037	16,196
85,400	85,450	17,639	13,731	18,051	16,209
85,450	85,500	17,653	13,744	18,065	16,221
85,500	85,550	17,667	13,756	18,079	16,234
85,550	85,600	17,681	13,769	18,093	16,246
85,600	85,650	17,695	13,781	18,107	16,259
85,650	85,700	17,709	13,794	18,121	16,271
85,700	85,750	17,723	13,806	18,135	16,284
85,750	85,800	17,737	13,819	18,149	16,296
85,800	85,850	17,751	13,831	18,163	16,309
85,850	85,900	17,765	13,844	18,177	16,321
85,900	85,950	17,779	13,856	18,191	16,334
85,950	86,000	17,793	13,869	18,205	16,346

* This column must also be used by a qualifying widow(er).

(Continued on page 87)

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
86,000					
86,000	86,050	17,807	13,881	18,219	16,359
86,050	86,100	17,821	13,894	18,233	16,371
86,100	86,150	17,835	13,906	18,247	16,384
86,150	86,200	17,849	13,919	18,261	16,396
86,200	86,250	17,863	13,931	18,275	16,409
86,250	86,300	17,877	13,944	18,289	16,421
86,300	86,350	17,891	13,956	18,303	16,434
86,350	86,400	17,905	13,969	18,317	16,446
86,400	86,450	17,919	13,981	18,331	16,459
86,450	86,500	17,933	13,994	18,345	16,471
86,500	86,550	17,947	14,006	18,359	16,484
86,550	86,600	17,961	14,019	18,373	16,496
86,600	86,650	17,975	14,031	18,387	16,509
86,650	86,700	17,989	14,044	18,401	16,521
86,700	86,750	18,003	14,056	18,415	16,534
86,750	86,800	18,017	14,069	18,429	16,546
86,800	86,850	18,031	14,081	18,443	16,559
86,850	86,900	18,045	14,094	18,457	16,571
86,900	86,950	18,059	14,106	18,471	16,584
86,950	87,000	18,073	14,119	18,485	16,596
87,000					
87,000	87,050	18,087	14,131	18,499	16,609
87,050	87,100	18,101	14,144	18,513	16,621
87,100	87,150	18,115	14,156	18,527	16,634
87,150	87,200	18,129	14,169	18,541	16,646
87,200	87,250	18,143	14,181	18,555	16,659
87,250	87,300	18,157	14,194	18,569	16,671
87,300	87,350	18,171	14,206	18,583	16,684
87,350	87,400	18,185	14,219	18,597	16,696
87,400	87,450	18,199	14,231	18,611	16,709
87,450	87,500	18,213	14,244	18,625	16,721
87,500	87,550	18,227	14,256	18,639	16,734
87,550	87,600	18,241	14,269	18,653	16,746
87,600	87,650	18,255	14,281	18,667	16,759
87,650	87,700	18,269	14,294	18,681	16,771
87,700	87,750	18,283	14,306	18,695	16,784
87,750	87,800	18,297	14,319	18,709	16,796
87,800	87,850	18,311	14,331	18,723	16,809
87,850	87,900	18,325	14,344	18,737	16,821
87,900	87,950	18,339	14,356	18,751	16,834
87,950	88,000	18,353	14,369	18,765	16,846
88,000					
88,000	88,050	18,367	14,381	18,779	16,859
88,050	88,100	18,381	14,394	18,793	16,871
88,100	88,150	18,395	14,406	18,807	16,884
88,150	88,200	18,409	14,419	18,821	16,896
88,200	88,250	18,423	14,431	18,835	16,909
88,250	88,300	18,437	14,444	18,849	16,921
88,300	88,350	18,451	14,456	18,863	16,934
88,350	88,400	18,465	14,469	18,877	16,946
88,400	88,450	18,479	14,481	18,891	16,959
88,450	88,500	18,493	14,494	18,905	16,971
88,500	88,550	18,507	14,506	18,919	16,984
88,550	88,600	18,521	14,519	18,933	16,996
88,600	88,650	18,535	14,531	18,947	17,009
88,650	88,700	18,549	14,544	18,961	17,021
88,700	88,750	18,563	14,556	18,975	17,034
88,750	88,800	18,577	14,569	18,989	17,046
88,800	88,850	18,591	14,581	19,003	17,059
88,850	88,900	18,605	14,594	19,017	17,071
88,900	88,950	18,619	14,606	19,031	17,084
88,950	89,000	18,633	14,619	19,045	17,096

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
89,000					
89,000	89,050	18,647	14,631	19,059	17,109
89,050	89,100	18,661	14,644	19,073	17,121
89,100	89,150	18,675	14,656	19,087	17,134
89,150	89,200	18,689	14,669	19,101	17,146
89,200	89,250	18,703	14,681	19,115	17,159
89,250	89,300	18,717	14,694	19,129	17,171
89,300	89,350	18,731	14,706	19,143	17,184
89,350	89,400	18,745	14,719	19,157	17,196
89,400	89,450	18,759	14,731	19,171	17,209
89,450	89,500	18,773	14,744	19,185	17,221
89,500	89,550	18,787	14,756	19,199	17,234
89,550	89,600	18,801	14,769	19,213	17,246
89,600	89,650	18,815	14,781	19,227	17,259
89,650	89,700	18,829	14,794	19,241	17,271
89,700	89,750	18,843	14,806	19,255	17,284
89,750	89,800	18,857	14,819	19,269	17,296
89,800	89,850	18,871	14,831	19,283	17,309
89,850	89,900	18,885	14,844	19,297	17,321
89,900	89,950	18,899	14,856	19,311	17,334
89,950	90,000	18,913	14,869	19,325	17,346
90,000					
90,000	90,050	18,927	14,881	19,339	17,359
90,050	90,100	18,941	14,894	19,353	17,371
90,100	90,150	18,955	14,906	19,367	17,384
90,150	90,200	18,969	14,919	19,381	17,396
90,200	90,250	18,983	14,931	19,395	17,409
90,250	90,300	18,997	14,944	19,409	17,421
90,300	90,350	19,011	14,956	19,423	17,434
90,350	90,400	19,025	14,969	19,437	17,446
90,400	90,450	19,039	14,981	19,451	17,459
90,450	90,500	19,053	14,994	19,465	17,471
90,500	90,550	19,067	15,006	19,479	17,484
90,550	90,600	19,081	15,019	19,493	17,496
90,600	90,650	19,095	15,031	19,507	17,509
90,650	90,700	19,109	15,044	19,521	17,521
90,700	90,750	19,123	15,056	19,535	17,534
90,750	90,800	19,137	15,069	19,549	17,546
90,800	90,850	19,151	15,081	19,563	17,559
90,850	90,900	19,165	15,094	19,577	17,571
90,900	90,950	19,179	15,106	19,591	17,584
90,950	91,000	19,193	15,119	19,605	17,596
91,000					
91,000	91,050	19,207	15,131	19,619	17,609
91,050	91,100	19,221	15,144	19,633	17,621
91,100	91,150	19,235	15,156	19,647	17,634
91,150	91,200	19,249	15,169	19,661	17,646
91,200	91,250	19,263	15,181	19,675	17,659
91,250	91,300	19,277	15,194	19,689	17,671
91,300	91,350	19,291	15,206	19,703	17,684
91,350	91,400	19,305	15,219	19,717	17,696
91,400	91,450	19,319	15,231	19,731	17,709
91,450	91,500	19,333	15,244	19,745	17,721
91,500	91,550	19,347	15,256	19,759	17,734
91,550	91,600	19,361	15,269	19,773	17,746
91,600	91,650	19,375	15,281	19,787	17,759
91,650	91,700	19,389	15,294	19,801	17,771
91,700	91,750	19,403	15,306	19,815	17,784
91,750	91,800	19,417	15,319	19,829	17,796
91,800	91,850	19,431	15,331	19,843	17,809
91,850	91,900	19,445	15,344	19,857	17,821
91,900	91,950	19,459	15,356	19,871	17,834
91,950	92,000	19,473	15,369	19,885	17,846

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing sepa-rately	Head of a house-hold
		Your tax is—			
92,000					
92,000	92,050	19,487	15,381	19,899	17,859
92,050	92,100	19,501	15,394	19,913	17,871
92,100	92,150	19,515	15,406	19,927	17,884
92,150	92,200	19,529	15,419	19,941	17,896
92,200	92,250	19,543	15,431	19,955	17,909
92,250	92,300	19,557	15,444	19,969	17,921
92,300	92,350	19,571	15,456	19,983	17,934
92,350	92,400	19,585	15,469	19,997	17,946
92,400	92,450	19,599	15,481	20,011	17,959
92,450	92,500	19,613	15,494	20,025	17,971
92,500	92,550	19,627	15,506	20,039	17,984
92,550	92,600	19,641	15,519	20,053	17,996
92,600	92,650	19,655	15,531	20,067	18,009
92,650	92,700	19,669	15,544	20,081	18,021
92,700	92,750	19,683	15,556	20,095	18,034
92,750	92,800	19,697	15,569	20,109	18,046
92,800	92,850	19,711	15,581	20,123	18,059
92,850	92,900	19,725	15,594	20,137	18,071
92,900	92,950	19,739	15,606	20,151	18,084
92,950	93,000	19,753	15,619	20,165	18,096
93,000					
93,000	93,050	19,767	15,631	20,179	18,109
93,050	93,100	19,781	15,644	20,193	18,121
93,100	93,150	19,795	15,656	20,207	18,134
93,150	93,200	19,809	15,669	20,221	18,146
93,200	93,250	19,823	15,681	20,235	18,159
93,250	93,300	19,837	15,694	20,249	18,171
93,300	93,350	19,851	15,706	20,263	18,184
93,350	93,400	19,865	15,719	20,277	18,196
93,400	93,450	19,879	15,731	20,291	18,209
93,450	93,500	19,893	15,744	20,305	18,221
93,500	93,550	19,907	15,756	20,319	18,234
93,550	93,600	19,921	15,769	20,333	18,246
93,600	93,650	19,935	15,781	20,347	18,259
93,650	93,700	19,949	15,794	20,361	18,271
93,700	93,750	19,963	15,806	20,375	18,284
93,750	93,800	19,977	15,819	20,389	18,296
93,800	93,850	19,991	15,831	20,403	18,309
93,850	93,900	20,005	15,844	20,417	18,321
93,900	93,950	20,019	15,856	20,431	18,334
93,950	94,000	20,033	15,869	20,445	18,346
94,000					
94,000	94,050	20,047	15,881	20,459	18,359
94,050	94,100	20,061	15,894	20,473	18,371
94,100	94,150	20,075	15,906	20,487	18,384
94,150	94,200	20,089	15,919	20,501	18,396
94,200	94,250	20,103	15,931	20,515	18,409
94,250	94,300	20,117	15,944	20,529	18,421
94,300	94,350	20,131	15,956	20,543	18,434
94,350	94,400	20,145	15,969	20,557	18,446
94,400	94,450	20,159	15,981	20,571	18,459
94,450	94,500	20,173	15,994	20,585	18,471
94,500	94,550	20,187	16,006	20,599	18,484
94,550	94,600	20,201	16,019	20,613	18,496
94,600	94,650	20,215	16,031	20,627	18,509
94,650	94,700	20,229	16,044	20,641	18,521
94,700	94,750	20,243	16,056	20,655	18,534
94,750	94,800	20,257	16,069	20,669	18,546
94,800	94,850	20,271	16,081	20,683	18,559
94,850	94,900	20,285	16,094	20,697	18,571
94,900	94,950	20,299	16,106	20,711	18,584
94,950	95,000	20,313	16,119	20,725	18,596

* This column must also be used by a qualifying widow(er).

(Continued on page 88)

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
95,000					
95,000	95,050	20,327	16,131	20,739	18,609
95,050	95,100	20,341	16,144	20,753	18,621
95,100	95,150	20,355	16,156	20,767	18,634
95,150	95,200	20,369	16,169	20,781	18,646
95,200	95,250	20,383	16,181	20,795	18,659
95,250	95,300	20,397	16,194	20,809	18,671
95,300	95,350	20,411	16,206	20,823	18,684
95,350	95,400	20,425	16,219	20,837	18,696
95,400	95,450	20,439	16,231	20,851	18,709
95,450	95,500	20,453	16,244	20,865	18,721
95,500	95,550	20,467	16,256	20,879	18,734
95,550	95,600	20,481	16,269	20,893	18,746
95,600	95,650	20,495	16,281	20,907	18,759
95,650	95,700	20,509	16,294	20,921	18,771
95,700	95,750	20,523	16,306	20,935	18,784
95,750	95,800	20,537	16,319	20,949	18,796
95,800	95,850	20,551	16,331	20,963	18,809
95,850	95,900	20,565	16,344	20,977	18,821
95,900	95,950	20,579	16,356	20,991	18,834
95,950	96,000	20,593	16,369	21,005	18,846
96,000					
96,000	96,050	20,607	16,381	21,019	18,859
96,050	96,100	20,621	16,394	21,033	18,871
96,100	96,150	20,635	16,406	21,047	18,884
96,150	96,200	20,649	16,419	21,061	18,896
96,200	96,250	20,663	16,431	21,075	18,909
96,250	96,300	20,677	16,444	21,089	18,921
96,300	96,350	20,691	16,456	21,103	18,934
96,350	96,400	20,705	16,469	21,117	18,946
96,400	96,450	20,719	16,481	21,131	18,959
96,450	96,500	20,733	16,494	21,145	18,971
96,500	96,550	20,747	16,506	21,159	18,984
96,550	96,600	20,761	16,519	21,173	18,996
96,600	96,650	20,775	16,531	21,187	19,009
96,650	96,700	20,789	16,544	21,201	19,021
96,700	96,750	20,803	16,556	21,215	19,034
96,750	96,800	20,817	16,569	21,229	19,046
96,800	96,850	20,831	16,581	21,243	19,059
96,850	96,900	20,845	16,594	21,257	19,071
96,900	96,950	20,859	16,606	21,271	19,084
96,950	97,000	20,873	16,619	21,285	19,096

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
97,000					
97,000	97,050	20,887	16,631	21,299	19,109
97,050	97,100	20,901	16,644	21,313	19,121
97,100	97,150	20,915	16,656	21,327	19,134
97,150	97,200	20,929	16,669	21,341	19,146
97,200	97,250	20,943	16,681	21,355	19,159
97,250	97,300	20,957	16,694	21,369	19,171
97,300	97,350	20,971	16,706	21,383	19,184
97,350	97,400	20,985	16,719	21,397	19,196
97,400	97,450	20,999	16,731	21,411	19,209
97,450	97,500	21,013	16,744	21,425	19,221
97,500	97,550	21,027	16,756	21,439	19,234
97,550	97,600	21,041	16,769	21,453	19,246
97,600	97,650	21,055	16,781	21,467	19,259
97,650	97,700	21,069	16,794	21,481	19,271
97,700	97,750	21,083	16,806	21,495	19,284
97,750	97,800	21,097	16,819	21,509	19,296
97,800	97,850	21,111	16,831	21,523	19,309
97,850	97,900	21,125	16,844	21,537	19,321
97,900	97,950	21,139	16,856	21,551	19,334
97,950	98,000	21,153	16,869	21,565	19,346
98,000					
98,000	98,050	21,167	16,881	21,579	19,359
98,050	98,100	21,181	16,894	21,593	19,371
98,100	98,150	21,195	16,906	21,607	19,384
98,150	98,200	21,209	16,919	21,621	19,396
98,200	98,250	21,223	16,931	21,635	19,409
98,250	98,300	21,237	16,944	21,649	19,421
98,300	98,350	21,251	16,956	21,663	19,434
98,350	98,400	21,265	16,969	21,677	19,446
98,400	98,450	21,279	16,981	21,691	19,459
98,450	98,500	21,293	16,994	21,705	19,471
98,500	98,550	21,307	17,006	21,719	19,484
98,550	98,600	21,321	17,019	21,733	19,496
98,600	98,650	21,335	17,031	21,747	19,509
98,650	98,700	21,349	17,044	21,761	19,521
98,700	98,750	21,363	17,056	21,775	19,534
98,750	98,800	21,377	17,069	21,789	19,546
98,800	98,850	21,391	17,081	21,803	19,559
98,850	98,900	21,405	17,094	21,817	19,571
98,900	98,950	21,419	17,106	21,831	19,584
98,950	99,000	21,433	17,119	21,845	19,596

If line 43 (taxable income) is—		And you are—			
At least	But less than	Single	Married filing jointly *	Married filing separately	Head of a household
		Your tax is—			
99,000					
99,000	99,050	21,447	17,131	21,859	19,609
99,050	99,100	21,461	17,144	21,873	19,621
99,100	99,150	21,475	17,156	21,887	19,634
99,150	99,200	21,489	17,169	21,901	19,646
99,200	99,250	21,503	17,181	21,915	19,659
99,250	99,300	21,517	17,194	21,929	19,671
99,300	99,350	21,531	17,206	21,943	19,684
99,350	99,400	21,545	17,219	21,957	19,696
99,400	99,450	21,559	17,231	21,971	19,709
99,450	99,500	21,573	17,244	21,985	19,721
99,500	99,550	21,587	17,256	21,999	19,734
99,550	99,600	21,601	17,269	22,013	19,746
99,600	99,650	21,615	17,281	22,027	19,759
99,650	99,700	21,629	17,294	22,041	19,771
99,700	99,750	21,643	17,306	22,055	19,784
99,750	99,800	21,657	17,319	22,069	19,796
99,800	99,850	21,671	17,331	22,083	19,809
99,850	99,900	21,685	17,344	22,097	19,821
99,900	99,950	21,699	17,356	22,111	19,834
99,950	100,000	21,713	17,369	22,125	19,846

$100,000 or over — use the Tax Computation Worksheet on page 89

* This column must also be used by a qualifying widow(er)

2009

Tax Rate Schedules

CAUTION

The Tax Rate Schedules are shown so you can see the tax rate that applies to all levels of taxable income. Do not use them to figure your tax. Instead, see the instructions for line 44 that begin on page 37.

Schedule X—If your filing status is **Single**

If your taxable income is: Over—	But not over—	The tax is:	of the amount over—
$0	$8,350	.... 10%	$0
8,350	33,950	$835.00 + 15%	8,350
33,950	82,250	4,675.00 + 25%	33,950
82,250	171,550	16,750.00 + 28%	82,250
171,550	372,950	41,754.00 + 33%	171,550
372,950	....	108,216.00 + 35%	372,950

Schedule Y-1—If your filing status is **Married filing jointly** or **Qualifying widow(er)**

If your taxable income is: Over—	But not over—	The tax is:	of the amount over—
$0	$16,700	.... 10%	$0
16,700	67,900	$1,670.00 + 15%	16,700
67,900	137,050	9,350.00 + 25%	67,900
137,050	208,850	26,637.50 + 28%	137,050
208,850	372,950	46,741.50 + 33%	208,850
372,950	....	100,894.50 + 35%	372,950

Schedule Y-2—If your filing status is **Married filing separately**

If your taxable income is: Over—	But not over—	The tax is:	of the amount over—
$0	$8,350	.... 10%	$0
8,350	33,950	$835.00 + 15%	8,350
33,950	68,525	4,675.00 + 25%	33,950
68,525	104,425	13,318.75 + 28%	68,525
104,425	186,475	23,370.75 + 33%	104,425
186,475	....	50,447.25 + 35%	186,475

Schedule Z—If your filing status is **Head of household**

If your taxable income is: Over—	But not over—	The tax is:	of the amount over—
$0	$11,950	.... 10%	$0
11,950	45,500	$1,195.00 + 15%	11,950
45,500	117,450	6,227.50 + 25%	45,500
117,450	190,200	24,215.00 + 28%	117,450
190,200	372,950	44,585.00 + 33%	190,200
372,950	....	104,892.50 + 35%	372,950

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Valuing Recreation and Amenities at San Diego County Beaches

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Policymakers and analysts concerned with coastal issues often need economic value information to evaluate policies that affect beach recreation. This paper presents economic values associated with beach recreation in San Diego County generated from a recreation demand model that explains a beach user's choice of which beach to visit. These include estimates of the economic values of a beach day, beach closures, and beach amenities.

Keywords beach amenities, coastal recreation, economic value, recreation demand, San Diego

Introduction

Recreation managers and public policy makers often need information on economic values for beach recreation in order to make informed policy decisions. This valuation information is applied in a number of settings, from evaluating beach renourishment projects to land use decisions. One of the most publicized uses is for natural resource damage assessments resulting from oil spills that damage coastal beaches. Recent damage assessments for oil spills, such as the *American Trader* case, have illustrated the importance, yet current paucity, of information on the benefits from coastal recreation (Chapman, Hanemann, & Ruud, 1998).

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The scarcity of economic value information for beach recreation in California is especially evident. In a review of studies providing economic values of beach recreation, Freeman (1995) did not find any studies reporting values for California. In fact, until very recently the only studies reporting values for California beach recreation are two government reports: Leeworthy and Wiley (1993) and Leeworthy, Schruefer, and Wiley (1991).[1] These reports include several estimates of the value of beach recreation generated from surveys conducted by the National Oceanic and Atmospheric Administration (NOAA) for a handful of coastal recreation sites in Oregon, Washington, Southern California, and on the East Coast. Aside from these studies, almost all other studies that estimate the value of beach recreation and coastal water quality improvements are for beaches on the East Coast.[2]

This is surprising given the popularity of beaches in California and their often-publicized problems, such as those in San Diego County. The coastline of San Diego County, the third fastest growing and second most populous county in the state of California, is prized for its world-class beaches and draws millions of visitors to the area each year. Coastal recreationists spend approximately $1.7 billion per year in the coastal beach communities in San Diego County (California Resources Agency, 1997).

At these beaches, like those throughout Southern California, poor water quality is a major concern because of the potential threat it poses to beach recreation. The major contributors to degraded beach water quality are stormwater runoff, sewage spills, lagoon openings, and outflow from the Tijuana River (County of San Diego, 1998, 1999, 2000). Although a major offshore oil spill has not occurred in recent years, they are also a threat to San Diego beach recreation. Depending upon the type and severity of these pollution events, the degradation of water quality can lead to beach closures and an increased risk to beach users of becoming ill. To begin to address the economic impact of beach closures and other actions that may affect beach recreation, economic value information is clearly needed.

To begin to bridge the gap in this information, in this paper we report several economic values related to coastal beach recreation in San Diego County that can help policymakers assess actions and policies affecting beach recreation. These values are generated from an economic model of recreation demand that explains beach users' choices of which beach to visit. Because time costs are often the most important costs (and sometimes the only costs) paid by beach users when visiting the beach, particular attention is given in the model to properly incorporating time costs to ensure accurate measurement of recreation values.

Time Costs and Recreation Demand Models

Time spent traveling to and from the beach is time that could be spent in another productive activity, such as in another leisure activity or at work, and thus represents a real cost that must be accounted for in the price paid by the beach user in going to the beach.[3] These time costs can be translated into money terms by multiplying time units by the shadow value of leisure time (SVLT), which is a measure of the opportunity cost of a unit of time spent in non-work activities.

The appropriate SVLT to use in recreation decision models has been a matter of contention in the literature (McConnell and Strand, 1981; Bockstael, Strand, & Hanemann, 1987; Shaw, 1992). Early attempts to incorporate time costs in recreation demand models used the wage, or a fraction of the wage, as the appropriate opportunity cost of time (e.g., Smith, Desvousges, & McGivney, 1983). Use of the wage rate as the opportunity cost of recreation time is based on the assumption that individuals would trade time spent in recreation, or leisure more generally, for time spent in work (Becker, 1965), which often is not the case. Many researchers also commonly use a SVLT between ¼ and ½ of the wage rate instead of the full wage based on a paper by Cesario (1976).[4] A problem with these wage-based approaches is the fact that many people who engage in recreation are not in the work force. These include students, homemakers, and other unemployed persons. Additionally, some workers have rigid work schedules and thus are unable to trade time for money at the margin. For these individuals, the wage, or a fraction of the wage rate, may not be an accurate reflection of the SVLT. This becomes especially important given that economic values from recreation demand models are sensitive to the choice of SVLT values (e.g., Smith, Desvousges, & McGivney, 1983).

Labor Supply and Time Values

In recent years, economists have recognized that decisions made in the labor market can be used to more accurately measure the SVLT than simple appeals to wage information. Feather and Shaw (1999) showed that a modified version of the labor supply model of Heckman (1974) can be employed to estimate a SVLT for both nonworkers and workers, including those with fixed work schedules. This modified model provides a more accurate measure of the SVLT since it accounts for both nonworkers and constraints on workers who are unable to work flexible hours and hence trade recreation time for work time.

In the Feather–Shaw model, labor market participants can fall into one of four categories: workers with flexible work schedules, non-workers, overemployed workers, and underemployed workers. Flexible schedule workers are able to adjust their work schedules to permit more time for either work or leisure. Nonworkers include students, homemakers, and other unemployed persons. Overemployed and underemployed workers have fixed work weeks, with overemployed individuals working more hours than they would optimally choose and underemployed individuals working fewer.

In the labor supply model, each type of individual is viewed as making a trade-off between the SVLT, which in general depends on hours worked and other demographics, and the market wage, which is a function of labor market conditions and demographics. The SVLT for flexible schedule workers is their wage, since they are able to adjust hours worked to balance the benefits of leisure with the benefit of another hour worked. Those who are unemployed are assumed to have a SVLT that exceeds the wage rate, for if this was not true, the individual would prefer to work.[5] The SVLT of overemployed workers is greater than the wage; since they would prefer more leisure time, its value at the margin is higher. The opposite is true for underemployed workers: their SVLT is less than the wage at the current number of hours worked. These labor market relationships form the basis for probability statements that can be used in maximum likelihood estimation to estimate the SVLT and market wage functions. Predicted SVLT values for the sample can then be obtained from the fitted SVLT function and used in recreation demand models (Feather & Shaw, 1999).

A Model of Beach Site Choice

Beach users' values for recreation and beach characteristics are revealed through their choice of which beach to visit. This decision depends both on the costs (both money and time) of visiting the beach and the features of the beaches that are important to their recreation experience. To model which beach site individuals choose, the popular random utility model is used (McFadden, 1981; Hanemann, 1999; Train, 1998). We define the deterministic conditional indirect utility for the *i*th individual and the *j*th beach site as

$$V_{ij} = V_{ij}(c_{ij}, \mathbf{q}_j) = \theta \cdot c_{ij} + \gamma \cdot \mathbf{q}_j, \tag{1}$$

where θ and γ are parameters to be estimated, c_{ij} is the "full price" of visiting the jth beach by the ith individual, and $\mathbf{q}_j$ is a vector of site attributes for the jth site. This conditional indirect utility function represents an index of the individual's preferences for a specific site. Since recreation is time costly, the full price of a visit to the beach includes both the time and money costs, such that $c_{ij} = p_{ij} + \rho_i \cdot t_{ij}$, where p_{ij} is the monetary costs of visiting beach j by individual i, ρ_i is the SVLT for the ith individual, and t_{ij} is the time required to visit site j by the ith individual.[6]

Adding a disturbance term (ξ_{ij}) to equation (1) provides a full specification for the stochastic conditional indirect utility (V_{ij}^*) that forms the basis for the random utility maximization (RUM) model of recreational choice:

$$V_{ij}^* = V_{ij} + \xi_{ij}. \tag{2}$$

Thus, the choice is analyzed by modeling the probability of observing individual i going to beach j, which equals $\Pr(V_{ij} \geq V_{ik}$, for all $k \neq j)$ and lends itself to econometric estimation. Different assumptions about the distribution of ξ_{ij} lead to different choice models. Assuming ξ_{ij} follows a type I extreme value (TEV) distribution leads to the multinomial logit model (MNL).

Note, however, that the individual's SVLT, denoted by ρ_i, is stochastic from the perspective of the researcher, despite being known to the individual beach user. This results in the probabilities being conditional upon the realized SVLT value for each individual. Thus, to estimate, they must be evaluated over the distribution of SVLT values, resulting in a form of the mixed logit model (Brownstone & Train, 1996; Train, 1998). In this application, the SVLT errors are assumed to be normally distributed. The beach choice model can be estimated using simulated maximum likelihood estimation of the conditional choice probabilities.

Since the SVLT is common to both the labor market model and the recreation demand model, it is possible to use the additional information provided by labor market decisions to estimate the SVLT directly with the recreation site choice decision.[7] This joint modeling of the recreation and labor supply decisions is analogous to models that combine different sources of data from the same individual to model the individual's preferences (e.g., Cameron, 1992; Adamowicz, Louviere, & Williams, 1994). An advantage of this approach is that it explicitly recognizes that the SVLT is observed with error in both the labor market and recreational choice decisions. Lew and Larson (2003) have shown that this joint approach performs better in explaining observed behavior than when the models are estimated separately.

Our model embodies several innovations relative to the literature. First, we specify the form of the SVLT based on results from Larson and Shaikh (2001) and estimate it jointly with the beach choice decision. Previous random utility models have either made an ad hoc assumption about what the SVLT is or introduced estimates of it from elsewhere. The SVLT in our application is both theoretically consistent with a model of consumer choice subject to two constraints, and efficient statistically in that all available information is used in estimating the beach participation and SVLT together.

Data

A telephone-mail-telephone survey was conducted on a sample of randomly chosen households in San Diego County during the period from January 2000 through March 2001. A preliminary phone interview was used to identify beach users who had gone recently or were planning to go to the beach in the near future and recruit them for a detailed follow-up interview on their most recent beach experiences. Of the 607 beach users completing the follow-up interview, 494 provided sufficient information to be used to estimate the economic model. Table 1 provides a summary of several important characteristics of the sample.

The data set contains information on each respondent's most recent trip to one of the San Diego County bay or coastal beaches. The 31 San Diego County beach areas used for the analysis are contained in Table 2, which also shows which beaches respondents visited on their most recent beach visit. Pacific, Mission, and Ocean Beaches, all in the City of San Diego, were the most popular among beach users, with each being visited by over 10 percent of the sample. In contrast, three beaches (Fletcher Cove, Boneyard Beach, and Border Field State Beach) were not visited by anyone in the sample.

Both the distances traveled and the time required to visit each beach were calculated for each individual using geographic information systems (GIS). Across the sample, the mean round-trip travel time for the most recent trip taken was 0.79 hours, or about 47 minutes. The monetary travel costs depended upon the mode of travel taken by beach users and the distance traveled. For beach users who drove to the beach (~85%), the cost per mile for vehicle travel calculated by the Southern California branch of the American Automobile Association of $0.146 was used (Automobile Club of Southern California, 2001).[8] The money costs per mile for nonautomotive modes of travel are assumed to be zero, except for travel by boat (<1%), which is assumed to have the same cost per mile as driving. Those who walk (~12%) or bike (~2%) to the beach are assumed to accrue time costs of travel, but no out-of-pocket expenses. The travel costs were calculated for each beach user and for each beach area.

In addition to economic determinants such as price, conditional indirect utility is assumed to be a function of characteristics of each alternative. The factors likely to affect an individual's choice between beaches include physical characteristics of the beach, amenities available at the beach, and management practices that may limit the individual's activities.

In the survey, respondents were asked to rate eleven factors that may affect the quality of their beach experiences on a scale from 1 to 10, with 1 indicating a factor that is not at all important to their beach experiences and 10 being extremely important to their beach experiences. Table 3 provides a list of the factors respondents were asked to

Table 1
Descriptive statistics for sample of beach users ($N = 494$)

Variable	Units	Mean	Standard deviation	Minimum	Maximum
Income	$/year	$62,698	$41,761	$2,500	$200,000
Average hourly income	$/hour	$18.38	$22.48	$0.00	$291.67
Educational attainment	Years completed	14.91	2.348	3.5	18
Gender	1 = male, 0 = female	0.5101	0.5004	0	1
Household size	Persons	2.8186	1.4305	1	8
Hours	Hours per week worked	32.3239	19.1203	0	100
Age	Years	39.5787	13.3769	18	88

Table 2
San Diego County beach sites and visitation on most recent beach trip

Beach name	Number visiting beach	Percent of sample
San Onofre State–Camp Pendleton Beaches	5	1.01
Oceanside Beaches	46	9.31
Carlsbad Beaches	27	5.47
South Carlsbad State Beach	6	1.21
Ponto Beach	1	0.20
North Encinitas Beaches	6	1.21
Moonlight Beach	10	2.02
Boneyard Beach	0	0.00
Swami's Beach	3	0.61
San Elijo State Beach	7	1.42
Cardiff State Beach	10	2.02
Tide Beach Park	2	0.40
Fletcher Cove Park	0	0.00
Seascape Surf–Del Mar Shores Beaches	14	2.83
Del Mar City Beach	12	2.43
Torrey Pines State Beach	25	5.06
Black's Beach	7	1.42
La Jolla Shores Beach	39	7.89
Scripps Park Beaches	9	1.82
Marine Street Beach	1	0.20
Windansea Beach	4	0.81
Pacific Beach	57	11.54
Mission Beach	73	14.78
Ocean Beach	50	10.12
Coronado Beach	38	7.69
Silver Strand State Beach	8	1.62
Imperial Beach	16	3.24
Border Field State Beach	0	0.00
Mission Bay	11	2.23
San Diego Bay	3	0.61
Sunset Cliffs–Point Loma Beaches	4	0.81

rate and the average ratings across the sample. Clearly, water quality, safety, and availability of parking were major concerns of individuals in the sample.

Thus, the specific factors that were assumed to affect beach recreational site selection were the following:

1. *Water quality indicators*: Two water quality dummy variables were included that reflect sign postings of water quality violations. The first is a dummy variable that takes a value of 1 if, on the day of the individual's visit, there was a posting indicating a beach closure at the beach visited. The second is a lagged variable that takes a value of 1 if there was a beach closure posting in the previous week (7 days). *A priori*, both indicator variables are expected to have a negative effect on conditional indirect utility.
2. *Lifeguard variables*: Two dummy variables indicating the presence or absence of lifeguards on the beach were also used. The first takes a value of 1 if the individual's site visit was to a beach that usually has lifeguards staffed on the beach in lifeguard towers.

Table 3
Ratings of factors affecting beach experiences

Rank	Factor	Mean rating
1	Water quality/cleanliness	8.94
2	Litter (beach cleanliness)	8.74
3	Parking availability	7.71
4	Crime	7.76
5	Quality of showers, restrooms, and other beach facilities	7.81
6	Congestion on the beach	7.43
7	Erosion (sand quality or quantity, cobblestoning)	7.17
8	Availability of showers, restroom, and other beach facilities	7.20
9	Weather	7.09
10	Availability of lifeguards	6.59
11	Surfing and swimming conditions	6.20

The second takes a value of 1 if the visited beach is patrolled by lifeguards in trucks, boats, or other mobile vehicle. Since safety may be a concern to many beachgoers, the expectation is that, *ceteris paribus*, lifeguards patrolling the beach is desirable and has a positive effect on indirect utility and the site choice probabilities.

3. *Beach activity management:* Many beaches in Southern California designate specific areas of the beach (and associated water areas) off-limits to certain activities explicitly by use of posted signs, cones, or flags. Lifeguards strictly enforce these "activity zones" to ensure safety and maintain order. For instance, surfing is generally prohibited in certain areas of the beach to ensure a safe area for waders and swimmers. Since this management of activity areas adds to the safety of beach users, it is likely to have a positive effect on utility and choice probabilities.[9]
4. *Parking availability:* Two dummy variables were used to indicate concerns for availability of parking opportunities, a dummy for free street parking and one for free parking lot availability at each beach. In general, the availability of parking should be a positive attribute of a beach site, particularly since the majority of San Diego beach users drive to the beach.[10]
5. *Physical attributes:* The physical qualities of the beach assumed to affect utility were beach size (length and length squared) and the composition of the beach surface. Length and length-squared variables were included to account for a potentially nonlinear relationship between utility and beach size. A dummy variable for each beach was defined to indicate whether it was subject to cobblestoning, a phenomenon that occurs when a coastal beach loses its source of new sand (e.g., a nearby river mouth), and tidal action denudes the beach of its stock of sand exposing cobblestones and pebbles. This has become a major problem for many North San Diego County beaches because of the closing of several river mouths.[11] *A priori*, the expectation is that cobblestoning has a negative effect on beach visitation.

Respondents were asked questions to determine their labor status for use in modeling their labor market choices. Almost three quarters of the sample were either full- or part-time workers. Together with self-employed workers, about 80 percent of the sample indicated they worked, with the majority being full-time workers. The remaining 99 people, who categorized themselves as temporarily unemployed, students, homemakers, retired, or disabled and unable to work, are nonworkers. With respect to the labor categories used in the empirical labor supply model, over a third (167 or 33.81 percent) of the sample of 494 beach users had flexible work schedules. Almost half of all respondents (228 or 46.15 percent) faced fixed work schedules and were thus classified as either overemployed (95 or 19.23 percent) or underemployed (133 or 26.92 percent).

Results

The joint labor supply-recreation demand model was used to analyze beach users' decisions about which beach to visit on their most recent beach trip.[12] The results from the joint beach choice model are given in Table 4.

All parameter estimates for the conditional indirect utility function are statistically significant except for those associated with water quality and the presence of mobile lifeguard patrols. The fact that the water quality posting variables are not statistically significant is not totally unexpected for several reasons.[13] First, poor water quality may

Table 4
Joint labor supply and beach choice model estimates

Parameter	Estimate[a]	Asymptotic t-value
	Conditional indirect utility function	
Price	**–0.1847**	**–8.9336**
Water quality posting	0.4716	1.3080
Lag water quality posting	–0.3235	–1.1277
On-beach lifeguard	**1.7119**	**5.9291**
Mobile lifeguard	0.2996	1.5635
Activity zones	**0.4465**	**3.4753**
Free lot parking	**0.7980**	**6.1290**
Free street parking	**1.1920**	**2.8325**
Cobblestone	**–0.7857**	**–3.5574**
Length	**0.3315**	**4.2864**
Length squared	**–0.0207**	**–5.1979**
	Shadow value of leisure time function	
Constant	**2.4797**	**9.5596**
Gender	–0.1778	–1.0911
Household size	**–0.4793**	**–2.9836**
Household size squared	**0.0745**	**3.2293**
Standard deviation	**11.7061**	**11.7056**
	Market wage function	
Constant	**–41.8055**	**–3.7361**
Gender	**5.3279**	**4.5181**
Age	**1.9911**	**8.0618**
Age squared	**–0.0233**	**–7.5089**
Education	0.9313	0.6509
Education squared	0.0274	0.5037
Standard deviation	**16.8904**	**18.8517**
Mean log-likelihood	–6.3565	
LRI	0.2745	
Sample size	494	

[a]Parameter estimates in bold are statistically significant at the 5% level of significance.

not be a primary concern for many beachgoers because they do not use the water. Only 129 people (29.11%) reported engaging in some water-based beach activities, while about 60 percent of the sample visited the beach to exercise outside of the water (e.g., walking, running, rollerblading, etc.). It is quite possible that water quality does not affect many beach users' experiences because they do not have contact with the water. Second, lifeguards and other beach authorities conveyed their belief that beach users in the county, particularly surfers, enter the water despite poor water quality conditions and signs prohibiting contact with water.

Although the coefficient associated with the presence of mobile lifeguard patrols was not statistically different from zero, it is positively signed, consistent with our prior. The lack of statistical significance may be indicative of a preference for a less transient lifeguard presence, such as on-beach lifeguard stations.

For the statistically significant variables, the signs and magnitudes conform to expectations. The coefficient on price, which is the negative of the marginal utility of money, is negative, which conforms to theoretical requirements.

The presence of on-beach lifeguards has a positive effect on utility and increases the probability of choosing a beach site. The positive sign on the dummy variable for the presence of activity zones supports the supposition that safety is a concern to beach users since activity zones are implemented to ensure safety. The availability of free parking also positively affects utility, as indicated by the strongly statistically significant positive coefficients on these variables.

Turning to physical site attributes, the negative coefficient on the cobblestone dummy variable suggests that the presence of cobblestoning has a negative impact on utility and therefore diminishes the probability of visiting beaches with this problem, all else being equal. And finally, the size of beaches appears to matter, as the coefficients on the length variables indicate utility increases with the length of a beach at a decreasing rate. For beaches shorter than approximately 8.4 miles long, which includes all San Diego County beach areas except Mission Bay beaches, the results suggest that utility increases with marginal increases in length.

In addition to the parameters of the conditional indirect utility function, the estimates of the parameters of the market wage and SVLT equations are provided in Table 4 below the results for the conditional indirect utility function. Parameter estimates for the market wage function are statistically significant, with the exception of the education variables.[14] The dummy variable representing gender, which equals one for males and zero for females, is positive and statistically different from zero at the 5% significance level. This implies that, all else equal, the market wage is greater for males than females (by over $5), a finding consistent with other empirical studies that have analyzed wage differentials between genders (e.g., Gunderson, 1989). The age and age-squared coefficients are statistically significant and of opposite sign, indicating a concave relationship between age and market wage.

In the SVLT function, the constant and household size coefficients are statistically significant. Household size influences the SVLT, decreasing for households of up to about 3 persons, and increasing with increasing household size for larger households.[15]

Per-Trip Economic Values for Beach Recreation

The estimated model can be used to calculate several types of per-trip economic values related to beach recreation (Small & Rosen, 1981; Hanemann, 1999).[16] Of primary interest is the value of a beach day, which is used in several types of policy analyses. Using the estimated model, the mean (median) value of a beach day across the sample is $28.27 ($30.29). The asymptotic standard error of the mean (median) value of a beach day is \$5.55 (\$6.05), calculated using the bootstrap simulation approach of Krinsky and Robb (1986) with 1000 iterations.

Beach managers and policy makers are also concerned about the influence beach characteristics have on beach user behavior. The empirical results suggest that the presence of poor water quality does not significantly affect beach choice selection, which may not be surprising since most beach use does not involve water contact. In contrast, physical characteristics and amenities of beaches do have a significant effect on behavior. More specifically, free parking opportunities on or near the beach increase the probability that beach users will choose to visit a beach, as does the presence of lifeguards patrolling the beach.

The relative worth of these attributes is indicated by their implicit prices, which reflect the incremental value each of these attributes contribute to the overall value of a beach day.[17] These implicit prices and their standard errors are contained in Table 5.

Signs of the implicit prices for beach attributes (presence or absence of on-beach lifeguards, activity zones, free parking lots, free street parking, and cobblestoning problems) were as expected: all were positive except the marginal price of cobblestoning. The implicit price people would be willing to pay to make sure cobblestoned surfaces are not at any beach is about \$4.25 per trip. Given their large and positive implicit prices, both the availability of lifeguards and free parking appear to be quite valuable to beach users.

Policy analysts are also interested in knowing the economic impacts from beach closures. The lost recreational value associated with an individual beach not being able to be visited when others are available was calculated for each beach user and for each beach.[18] This value can be roughly interpreted as the value of a beach closure and presumes that a single beach becomes unavailable to beach users. The means across the sample are contained in Table 6 and range from \$0 to –\$1.00. Not surprisingly, these values are small in magnitude, reinforcing the fact that there are many high-quality substitute beaches available for beach users in the county. All values are less than or equal to zero to reflect the fact that people are worse off from having sites eliminated from their choice sets.

The beach site associated with the largest lost value when closed is Mission Beach, which is also the beach site visited by the largest number of beach users in the sample. Other beaches that were visited by substantial numbers of beach users, the Oceanside beaches, La Jolla Shores Beach, Ocean Beach, and Pacific Beach, likewise had larger mean values than other beaches in the county.

In contrast, two sites that no one in the sample visited, Boneyard Beach in Encinitas and Border Field State Beach between Imperial Beach and the U.S.–Mexican border, have mean values of –\$0.01 or less. Interestingly, individuals would have to be compensated considerably more (\$0.10 per trip) if the third (and final) site no one in the sample visited, Fletcher Cove Park, was removed from their set of beach choices. This is prob-

Table 5
Implicit prices of beach attributes and characteristics

Attribute	Estimate	Krinsky–Robb standard error
On-beach lifeguard	\$9.27	\$2.06
Activity zones	\$2.42	\$0.73
Free lot parking	\$4.32	\$0.90
Free street parking	\$6.45	\$2.33
Cobblestone	–\$4.25	\$1.40

ably because Fletcher Cove Park, in comparison to Boneyard Beach and Border Field State Beach, is much more accessible and has more amenities on it, and as a result is a better substitute beach site to San Diego beach users than Boneyard and Border Field Beaches are.

On Aggregate Recreation Values

The values reported above are per-trip economic values. Multiplying these individual mean per-trip values by the total number of actual San Diego beach trips taken by County residents yields aggregate values that can be used in policy analyses. Thus, for example, multiplying the total number of beach trips taken to San Diego beaches by County residents on a specific day by the beach closure values in Table 6 provides

Table 6
Mean per-trip lost value from individual San Diego beach site closure

Beach closed	Beach closure value	Krinsky-Robb standard error
San Onofre State Beach/Camp Pendleton	–$0.18	$0.05
Harbor/Oceanside	–$0.74	$0.09
Carlsbad State & City	–$0.20	$0.02
South Carlsbad State Beach	–$0.15	$0.02
Ponto Beach	–$0.06	$0.01
North Encinitas	–$0.04	$0.01
D St. Viewpoint/Moonlight	–$0.31	$0.04
Boneyard Beach	$0.00	$0.00
Swami's Beach	–$0.11	$0.02
San Elijo State Beach	–$0.05	$0.01
Cardiff State Beach	–$0.06	$0.01
Tide Beach Park	–$0.04	$0.01
Fletcher Cove Park	–$0.10	$0.01
Seascape/Del Mar Shores	–$0.23	$0.05
Del Mar City Beach	–$0.28	$0.04
Torrey Pines State Beach	–$0.31	$0.06
Black's Beach	–$0.03	$0.01
La Jolla Shores Beach	–$0.57	$0.06
Scripps Park Beaches	–$0.10	$0.02
Marine Street Beach	–$0.01	$0.01
Windansea Beach	–$0.01	$0.01
Tourmaline/Pacific	–$0.68	$0.07
Mission Beach	–$1.00	$0.13
Ocean Beach	–$0.62	$0.07
Coronado Beach	–$0.44	$0.05
Silver Strand State Beach	–$0.09	$0.03
Imperial Beach	–$0.36	$0.04
Border Field State Beach	–$0.01	$0.00
Mission Bay	–$0.14	$0.04
San Diego Bay	–$0.14	$0.03
Point Loma	–$0.08	$0.02

measures of the aggregate value of beach closures on that day to County residents. Likewise, multiplying the total number of beach trips taken annually by San Diego County residents results in a measure of the total annual recreational value of beaches in the county to its residents.

However, as pointed out by Morey (1994), aggregate economic values calculated in this manner do not account for changes in participation that may occur under changed conditions. That is, the annual aggregate value of a beach closure at a specific beach as calculated above does not take into consideration the possibility that the total number of beach trips taken by county residents resulting from the closure of the beach in question may change as some people decide to forego taking a trip to the beach to do something else. Still, Morey showed that an upper bound measure of aggregate value for a specified time period can be calculated by multiplying the per-trip value by the total number of *current* trips taken, which in this case would be the observed number of trips taken to beaches in the County during the period in question.

Two things further complicate aggregating estimates of beach recreation values. First is the fact that some beach jurisdictions do not keep counts of beach attendance. In San Diego County, attendance is not recorded regularly, if at all, at many beaches. As a result, total trips taken to the beach are generally not known, hindering calculations of aggregate economic values of beach recreation. Second, even when beach counts exist, the proportion of residents versus nonresidents is generally not known.[19] However, by assuming that nonresident visitors have identical beach preferences, this latter difficulty can be circumvented and aggregate values for beach recreation for all users can be calculated.[20]

Policy Implications and Conclusions

Policymakers and analysts concerned with coastal issues often need to evaluate policies, or make decisions about actions, that affect beach recreation. To assess the severity of these impacts, values for beach recreation activities are needed. This study presented the results from a state-of-the-art recreation demand model that generates several types of beach recreation values for San Diego County beaches that are useful in these evaluations. These values are particularly useful because of the scarcity of extant beach valuation information for San Diego coastal recreation.

Because beach users in San Diego have a large set of beaches to choose from, the reduction in the value of a beach day from being precluded from visiting any single beach was relatively small (ranging from $0 to $1, depending upon the beach), though the value of a day at the beach was substantial (about $28 per beach trip). To be useful for policy purposes, beach jurisdictions should keep accurate beach attendance data. Using this beach attendance data, upper bounds on aggregate values for a beach closure, and for beach recreation generally, can be calculated.

Additionally, the paper provided insights into the factors that affect choices between beaches and the value of these factors. Although beach users indicated that water quality was an important factor affecting their beach experience, it did not appear to be a significant determinant of beach choice in the empirical model.[21] In contrast, a number of other factors did have a significant effect on behavior. For instance, several types of beach amenities contributed significantly to the value of a beach day and to attracting beach visitors to specific beaches, including the availability of free parking and lifeguards. Conversely, the results also show that beach users are less likely to visit beaches that suffer from "cobblestoning" than those that do not.

These findings support the basic conclusion of Pendleton (2001) that beach managers wishing to reduce exposure to polluted beaches and other hazards can do so by actively managing beach amenities. As applied here, this means that to discourage visitation at polluted beaches, beach managers can decrease free parking opportunities and hours of a lifeguard presence. This could be a useful strategy for both short-term beach closures and beaches with traditionally troublesome water quality problems. For chronically polluted beaches, putting a hold on sand renourishment projects may also help reduce attendance.

Notes

1. In addition to this research, a study jointly conducted by Professors Michael Hanemann and Michael Ward at UC Berkeley, Professor David Layton at University of Washington, and Professor Linwood Pendleton at the University of Wyoming is examining the value of beach recreation and water quality at Los Angeles and Orange County beaches.

2. These include beaches in Delaware (Parsons, Massey, & Tomasi, 2000), New Jersey (Silberman & Klock, 1988; Leeworthy & Wiley, 1991), Florida (e.g., Bell & Leeworthy, 1990), Rhode Island (McConnell, 1977), and Massachusetts (e.g., Hanemann, 1978).

3. Failure to account for time costs in economic models of recreation behavior has been shown to lead to biased economic values (Cesario & Knetsch, 1970).

4. This practice is often justified as a way to account for the disutility people get from work time.

5. The model assumes that temporarily unemployed individuals are choosing to be unemployed.

6. Although not explicitly shown in (1), a full budget (total monetary value of available time plus money budget) argument is implied, with a coefficient equal to $-\theta$. This is because choice probabilities depend on utility differences and variables in this linear specification that do not vary across choice alternatives cancel out in the probabilities. So long as θ is nonnegative, equation (1) satisfies the usual theoretical restrictions imposed by consumer theory (Lew, 2002).

7. This involves maximizing the sum of the likelihood functions for the separate labor supply and beach choice models under the assumption of independent errors.

8. A reviewer correctly pointed out that assuming a single cost-per mile ignores the differences in operating costs across types of vehicles, and may introduce an errors-in-variables problem with the price parameter. Since vehicle type information was not collected (as is typical for this type of survey), better precision in the measurement of travel costs is unfortunately not possible.

9. For a single choice occasion, the presence or absence of lifeguards is treated as an exogenous characteristic of each beach by beach users, although the supply of lifeguards at individual beaches in San Diego County will depend on past attendance, beach conditions, and temporal considerations, such as the time of year and day of the week.

10. Although the quantity of parking (i.e., congestion) may also be an important determinant of beach recreation choices, no information on parking availability was collected or available.

11. Anecdotal evidence from Solana Beach suggests that long-time visitors to beaches in the area stopped coming because of the replacement of sandy beach surfaces with ones littered by cobblestones.

12. Details of the estimation model can be found in Lew (2002).

13. Although only a seven-day lag water quality posting variable and a water quality posting variable for the day of the beach visit were used, other models were tried with lagged WQ posting variables ranging from one to six days, as well as a lagged variable that indicated whether a posting had occurred on the weekend prior to the beach visit. Additionally, variables to indicate different types of postings also did not yield significant results. All of the models yielded similar results to those reported here.

14. Some preliminary efforts to evaluate the education effect using dummy variables did not improve the specification. Further work on this issue is warranted but goes beyond the scope of the present paper.

15. The partial derivative $\partial SVLT/\partial(\text{household size})$ is greater than 0 for household size > 3.22, suggesting the SVLT decreases for households with fewer than 4 people.

16. These economic values represent exact measures of a beach user's consumer surplus for beach recreation, or the value placed on beach recreation above and beyond the costs actually paid for the experience.

17. These prices are calculated as the ratio of the marginal utility of the attribute divided by the marginal utility of money.

18. The model is capable of calculating the lost recreational value associated with removal of multiple sites as well.

19. Dr. Philip King (via personal correspondence) is studying the proportion of out-of-state versus in-state resident visitors to beaches in California. However, his work does not differentiate San Diego residents from other California residents.

20. Economic values for beach recreation by non-residents are currently unavailable for California beaches, although Bell and Leeworthy (1990) estimated the value of a beach day at Florida beaches to out-of-state visitors at about $50 per day (in 1990 dollars).

21. While these results support the idea that beach users may not have much knowledge about current beach water quality *postings*, sign postings are a way in which people form their water quality perceptions. Other indicators, such as the amount of trash on a beach, or objective water quality measures provided through the media (e.g., the environmental organization, Heal the Bay, provides water quality grades to mass media sources in Southern California), may provide better insights into how water quality may affect choices between beaches. One reviewer notes an additional complication: that some individuals may be more sensitive to water quality concerns than others. Efforts to use alternative water quality variables and assess the role of individual sensitivity to these variables are ongoing, and go well beyond the scope of this paper.

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APPENDIX: Survey Implementation

A random sample of San Diego County households (purchased from Survey Sampling, Inc., a private survey sampling firm) was initially contacted over the phone and screened to determine whether a randomly selected adult from the household had visited a San Diego County beach recently (in the last two weeks) or planned to visit a beach in the county in the next two weeks from the time of the phone interview. This one-month window of time was chosen to improve the respondents' recall about their recent beach experiences. Persons satisfying this requirement were asked whether they would participate in a follow-up interview that collected detailed information on recent beach experiences. Those who agreed were mailed a booklet that contained questions and information to prepare them for the follow-up phone interview.

In total, 3,740 screener interviews were completed, 2,296 refused, and the remaining cases could not be contacted for a variety of reasons (e.g., phone number no longer in service). Given that 83 partial interviews were completed, the total number of individuals successfully contacted was 6,119. Since 3,740 completed the preliminary screening interview to identify qualified beach users, the cooperation rate was 61 percent.

Out of the 3,740 initial interviews completed, 1,105 were qualified beach users, who had visited a San Diego beach or were planning an upcoming trip within the one-month window. Only 8 percent of those initially interviewed were nonusers who had not visited a San Diego County beach or were not planning a future beach visit. Of the qualified beach users, 74 percent agreed to participate in the follow-up interview. Unless completed before then, these individuals were called at least fifteen times (and up to 20 times) at varying times of the day for the follow-up interview after being sent the booklet. A total of 607 follow-up interviews were completed from this group. Of the 428 who did not complete follow-up interviews, there were 83 refusals and 2 partial interviews, and the remainder was not able to be contacted for a variety of reasons (e.g., invalid numbers).

The cooperation rate, defined as the number of completed interviews (607) over the total number of cases successfully contacted (692), is 88 percent. Alternatively, if the cooperation rate is instead defined as the number of completed interviews over the total number of qualified individuals contacted (1,105), the cooperation rate is 55 percent. Using the usable interviews (494) to calculate cooperation rates yields 71 percent and 45 percent, respectively.

Measuring the Cost of Time in Recreation Demand Analysis: An Application to Sportfishing

Kenneth E. McConnell and Ivar Strand

We reckon hours and minutes to be dollars and cents.
—T. C. Haliburton, *The Clockmaster*

Since the work of Cesario and Knetsch, economists have recognized that the opportunity cost of time plays an important role in determining the demand for outdoor recreation. The opportunities one has for spare time are more significant for consumption of time-intensive outdoor recreation activities than for other commodities, especially nondurables. Bishop and Heberlein illustrate "the overwhelming importance of time costs to final [recreational] values. . . . Total consumer surplus is nearly four times as large . . . [when] time costs are added at half the income rate . . . [as when] time costs were set at zero" (p. 21).

Despite the recognition, economists have neither successfully integrated the costs of time with the methods of recreational demand analysis nor reached a consensus on how it should be measured. Brown, Charbonneau, and Hay state, "Finally, the apparently crucial importance of how opportunity cost of time is handled needs further work. While we are convinced it is an appropriate concept, . . . exactly how it should be included and measured . . . remains to be determined" (p. 24). Several approaches have been taken to include it in the travel cost method. One approach (Brown and Nawas, Gum and Martin) suggests that time in transit be considered as a separate independent variable. Another approach (Bishop and Heberlein; Brown, Charbonneau, Hay; Nicols, Bowes, Dwyer; Cesario and Knetsch) measures the cost of time and adds it to other costs. Several approaches have been suggested to measure time costs. One approach is simply to choose an hourly wage, e.g., \$2.00 per hour, or perhaps the minimum wage rate. A more flexible but still ad hoc approach is to use some proportion of the individual's wage rate as the opportunity cost of time (Nichols, Bowes, Dwyer). The proportion is usually taken from independent studies and used to value the travel time. This approach is better than using a constant opportunity cost of time because it allows variation across individuals. It suffers because the choice of the percentage of the wage rate is arbitrary, independent of the sampled population. Cesario has discussed the consequences of ignoring time costs and the differences in values arising from alternative measurement approaches.

In this paper, we argue that the opportunity cost of time is some proportion of the individual's market wage rate or income per hour and that this proportion can be determined from sample data. This method permits the proportion to vary from one study to another, rather than imposing either an arbitrary estimate or one from a sample different from the study's sample.[1]

A Simple Model

The recreationist presumably behaves as if to maximize utility subject to time and budget constraints by choosing trips, denoted r. The original travel cost method (Clawson) used trips per capita (z) as the dependent variable. In this paper, we have chosen to use trips per user (r). But $z = \Pi r$, where Π is the participation rate (proportion of population who participate at least once). Various studies (e.g., Deyak and Smith) have shown that decisions to participate are different from decisions about how frequently to participate. As Brown and Nawas point out, there is loss of information in aggregation. Hence it is more efficient to use r as a dependent variable. However, the method we discuss will work for z or r as the dependent variable.

Let utility be $U(x,r)$, where r is recreation trips and x is a bundle of all other goods. If we introduce a proportionate income tax rate of t, the budget constraint is

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[1] The method as described is similar in spirit to a method described in Commons. This paper, brought to our attention by a reviewer of a version of this paper, describes a method of choosing the proportion for a log-linear demand function by a search method.

$$(1)\qquad [F(w) + E](1 - t) = px + cr,$$

where w is the amount of time worked, $F(w)$ is income earned from w units of work, E is fixed income, t is the income tax rate, p is the price of the composite bundle, and c is out-of-pocket costs per recreational trip. Before-tax income is $F(w) + E$. It is the most frequent measure available from surveys. Suppose the time constraint is given by $T = ar + w$, when T is total time available and a is the amount of travel time per recreational trip.[2] The problem is to maximize

$$(2)\quad U(x,r) - \lambda\{px + cr - (1 - t)[F(T - ar) + E]\}.$$

The first-order condition for r is

$$(3)\qquad \partial U/\partial r = \lambda[c + a(1 - t)F'(w)].$$

Assuming that p does not vary across individuals, we get the demand function for recreation:

$$(4)\qquad r = f[c + a(1 - t)F'(w)].$$

Income is given by $F(w) + E$, while the marginal opportunity cost of time is $(1 - t)F'$. Define average income by $v = [F(w) + E]/w$. Sufficient conditions for the cost of time [measured by $(1 - t)F'$] to equal v are (a) The tax rate, t, is zero; (b) marginal earnings are constant: $F'(w) = F(w)/w$; and (c) nonwork income, E, is zero.

From these, it appears likely that the opportunity cost of time is less than average income. If the income figure is family income where other family members earn income and v = family income/w, the individual's opportunity cost of time will be overstated. The opportunity cost of time will be understated if an individual gets utility from work or if working today is a form of investment which provides higher income in the future.

Suppose the opportunity cost of time is some constant (k) times the average income. Then the demand function is

$$(5)\qquad r_i = f(c_i + ka_iv_i),$$

where $0 < k < 1$ is usually an arbitrarily chosen number and i is an observation index. Instead of choosing k arbitrarily, we let the sample determine k. With a linear form, we have

$$(6)\quad r_i = \beta_0 + \beta_1(c_i + ka_iv_i) + \beta_3Z_i + e_i,$$

where Z_i is a vector of exogenous variables including a wealth or income proxy and e_i is an error term with the classical specification. We can rewrite (6) as

$$(7)\quad r_i = \beta_0 + \beta_1c_i + \beta_2a_iv_i + \beta_3Z_i + e_i.$$

The estimate of k is $\hat{k} = \hat{\beta}_2/\hat{\beta}_1$, where $\hat{\beta}_i$ are the ordinary least squares (OLS) estimates of the parameters of (7). In the following section we show how this method works on a sample of sportfishermen.

An Application to Sportfishing

To test the approach suggested, we use sample data from a 1978 survey of sportfishermen in the Chesapeake Bay region. The complete specification of the equation is

$$(8)\quad r_i = \beta_0 + \beta_1c_i + \beta_2a_iv_i + \beta_3s_i + \beta_4m_i + e_i,$$

when r is the annual sportfishing trips per angler, c is per trip expenses per person, a is the round trip travel time (computed as round trip distance/45 miles per hour), v is average hourly income (annual family income/2080), s is a site variable equaling 1 for residents of Ocean City, Maryland, and 0 otherwise, and m is the length of the angler's boat.

The expected signs and relationships are $\beta_1 < \beta_2 < 0$, $\beta_3 > 0$, $\beta_4 > 0$. The first two inequalities relate to the negative effect of costs, both trip expenses and travel time, on the trips taken per year. Also, $\beta_1 < \beta_2$ implies that the opportunity cost of travel time is less than average income. The site variable (s) attempts to capture variation due to different characteristics of the sites. Since Ocean City, Maryland, was our only resort area, it was given a value of 1 and the other sites given 0. Boat length (m) represents a previous commitment to sportfishing or a wealth proxy. In either case, it should act to increase annual participation.

Fitting equation (8) on the Maryland-Virginia survey gives us

$$(9)\quad r = \underset{}{9.77} - \underset{(3.89)^*}{.0206c} - \underset{(2.00)}{.0126av} + \underset{(2.50)}{.019s} + \underset{(5.06)}{.157m},$$

where $N = 415$, $\bar{R}^2 = .10$, $F(4,411) = 12.8$, and asterisk indicates t-statistics under the null hypothesis of no association. For this equation we have used a subset of observations from the sample.[3] The estimated coefficients agree in sign and magnitude with our prior beliefs. The equation fits reasonably well for cross-sectional observations.

[2] We assume that a is travel time per trip. This approach implies that the opportunity cost of time spent on site is zero. While this is standard practice (Brown and Nawas; Shulstad and Stoevener), it is an unresolved but important issue (McConnell). We do not attempt to deal with the issue in this paper.

[3] The subset of the sample included anglers who made twenty or fewer trips per season. To test whether the groups were different, a Chow test was used. The test statistic [$F(234,412) = 27.3$] permitted rejection at the 99% confidence level of the null hypothesis that the coefficients of the equation (9) were the same for anglers with twenty or fewer trips and anglers with more than twenty trips. We report results only for the twenty or fewer group. The hourly income variable was based on seven annual income categories ($0–$4,999; $5,000–$9,999; $10,000–$14,999; $15,000–$19,999; $20,000–$29,999; $30,000–$49,000; $50,000 and above) with the average of the category range being assigned to respondents in the category. No respondents from the lowest range were used because respondents not wishing to reveal their income often responded by indicating the lowest income class. This exclusion limits the range of v but appeared more appropriate than introducing considerable error and biased data by inclusion. For a detailed description of the survey, see Strand and Yang.

60% ✱

Using equation (9), we can infer that a representation angler values time at about 60% of his hourly income:

(10) $\hat{k} = \hat{\beta}_2/\hat{\beta}_1 = -.0126/-.0206 = .612.$

We expect that k will vary among regions and sites and that this value is applicable only to our sample. However, by estimating it directly from observations on individual behavior we have eliminated the need for ad hoc and arbitrary valuation of the opportunity costs of time.

Properties of $\hat{k}$

As we have observed, variations in k cause considerable variations in estimates of consumers' surplus. Our value of $\hat{k}$ is not the true value but rather the ratio of two random variables; hence, it is a random variable itself. The reliability of the estimate of consumers' surplus depends on the random properties of $\hat{k}$.

We can ascertain something of the underlying probability distribution of $\hat{k}$ from what we know of $\hat{\beta}_2$ and $\hat{\beta}_1$. Under classical assumptions, the distribution of these coefficients is jointly normal. The distribution of the ratio of two $N(0,1)$ variables is a standard form Cauchy (Johnson and Kotz, chap. 16). However, if the variables forming the ratio are jointly dependent, as are $\hat{\beta}_1$ and $\hat{\beta}_2$, then the underlying distribution is more complex (Springer, chap. 4). In both cases, however, the distributions do not have finite moments. Since confidence intervals and significance tests rely on the existence of second moments, neither of the traditional tests is applicable. We can develop some understanding of the dispersion of $\hat{k}$ by Monte Carlo studies of the ratio of jointly normal variates. This procedure offers guidance about the distribution of $\hat{k}$.

Let the joint density function of $\hat{\beta}_1$ and $\hat{\beta}_2$ be given by $f(\hat{\beta}_1,\hat{\beta}_2)$. Then

(11) $$f(\hat{\beta}_1,\hat{\beta}_2) = f_1(\hat{\beta}_1)f_2(\hat{\beta}_2|\hat{\beta}_1),$$

where $f_1(\hat{\beta}_1)$ is the marginal density function of $\hat{\beta}_1$, and $f_2(\hat{\beta}_2|\hat{\beta}_1)$ is the conditional density function of $\hat{\beta}_2$ given $\hat{\beta}_1$. With these conditions, it can be shown that

(12) $$\hat{\beta}_1 \sim N(\beta_1,\sigma_1^2), \text{ and}$$

(13) $$\hat{\beta}_2|\hat{\beta}_1 \sim N[\beta_2 + \rho\sigma_2(\hat{\beta}_1 - \beta_1)\sigma_1^{-1},\sigma_2^2(1-\rho^2)],$$

where ρ is the correlation coefficient of the bivariate normal. With conditions (12) and (13) we can construct two random variables which follow (11) by calculating

(14) $$\tilde{\beta}_1 = \beta_1 + \sigma_1\Theta_1,$$

(15) $$\tilde{\beta}_2 = \beta_2 + \sigma_2[\Theta_2(1-\rho^2)^{\frac{1}{2}} + \Theta_1\rho], \text{ and}$$

(16) $$\tilde{k} = \tilde{\beta}_2/\tilde{\beta}_1,$$

where Θ_i are $N(0,1)$ and independent. We performed experiments by drawing sequential pairs of unit normal random variables, assuming that the true value of β_1, β_2, σ_1, σ_2 and ρ were as estimated in equation (9). The assumed values are $-.0206$, $-.0126$, .0067, .0050, and $-.3781$, respectively.

Several experiments with sample size varying from 50 to 1,000 were conducted (table 1). Each row gives the mean value of $\tilde{k}$, the bias $(\hat{k} - \tilde{k})$, $\tilde{k}$ being the ratio of estimated coefficients, the proportion of estimates greater than zero, and the proportion of estimates in the unit interval. Based on all experiments, there is an estimated probability of .016 that the estimates of $\hat{k}$ will be less than zero. Our experiments also show that 66.7% of the sample ratios fell in the unit interval.

Although these results do not have the theoretical support of formal confidence intervals, they are informative. Despite the possibility of substantial dispersion as $\hat{\beta}_1$ approaches zero, the experiments show remarkable conformity with the distribution of estimates. Though we cannot say $\hat{k}$ is significantly different from zero at the 98.4% level of confidence, it seems reasonable to reject the hypothesis that the ratio is less than or equal to zero.

The alternative to the Monte-Carlo approach is to assume that $\hat{k}$ is asymptotically normal with expected value $E\hat{\beta}_2/E\hat{\beta}_1$ and variance approximated by

(17) $$V(\hat{k}) = (\hat{\beta}_2/\hat{\beta}_1)^2[\hat{\sigma}_1^2/\hat{\beta}_1^2 + \hat{\sigma}_2^2/\hat{\beta}_2^2 - 2\,\mathrm{cov}(\hat{\beta}_1,\hat{\beta}_2)/\hat{\beta}_1\hat{\beta}_2].$$

Using the values of their variables following equation (16), we compute $V(\hat{k}) = .142$. With these assumptions and numbers, we can construct the standard rejection region for the null hypothesis that $k = 0$. For a type 1 error of 10%, the critical region for rejection of the null hypothesis lies beyond .483. Thus, based on this approximation, we would reject the null hypothesis that $k = 0$ because the estimated value of k is .612.

The comparison of the assumption of normality with the Monte-Carlo results indicates the kinds of errors we make by assuming normality. Under the condition that $\hat{k}$ is $N(.612, .142)$, about 80% of observations so distributed will fall in the unit interval, compared with about 67% from the Monte-Carlo results. Thus, this assumption of normality with mean .61 and variance given by (17) leads to underestimating the type 1 error. This difference suggests care in the interpretation of results.

Table 1. Some Properties of $\tilde{k}$ from Sampling Experiments

Sample Size	Mean Value	Bias of $\tilde{k}$	Relative Frequency $\tilde{k} \geq 0$	Relative Frequency $0 \leq \tilde{k} \leq 1$
50	.765	−.154	.984	.672
500	.886	−.247	.983	.662
1,000	.763	−.152	.985	.667

Conclusions

This paper offers a method of estimating the opportunity cost of time in the demand for recreation. It can be used simultaneously with travel cost analysis, requiring only the interviewee's wage rate or income as additional data. It eliminates the need to rely on an exogenous estimate of the opportunity cost of time.

We have applied this technique to linear demand curves, and with linear functions, OLS provides direct estimates of the proportion. The general approach of letting the sample data choose the proportion is applicable to any functional form via the use of maximum likelihood techniques. An advantage of estimating k directly by maximum likelihood methods is that its asymptotic properties are well known.

The opportunity cost of time is determined by an exceedingly complex array of institutional, social, and economic relationships, and yet its value is crucial in the choice of the types and quantities of recreational experiences. Because of its complexity, one must be cautious in explaining it simply, as we have. In particular, while this method has promise, the measurements are not inconsistent with several competing hypotheses. For example, income per hour as time cost may reflect a negative income effect for sportfishing or the effect of income on the willingness to pay to avoid travel. In addition, this simple approach cannot explain why the opportunity cost of time is related to income for individuals working fixed hours.

Although this paper suggests a new direction, there are undoubtedly more advances to be made. For example, this method requires that the ratio of the opportunity cost of time to income per unit of time be constant for all sample observations. A significant improvement would be to let this ratio change as a function of leisure time or occupation.

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A Difficulty with the Travel Cost Method

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ABSTRACT. *Instead of observable prices of recreational visits, travel cost method (TCM) researchers are obliged to substitute researcher-assigned visitation cost estimates. I argue that visitation costs are inherently subjective, but are ordinally measurable so long as the cost increases with distance travelled. It follows that traditional TCM yields only ordinally measurable welfare estimates. The household production function formulation of TCM "resolves" this problem only by imposing severe and untestable analytical restrictions. TCM cannot serve as a stand-alone technique for estimating recreation benefits; rather, it must be calibrated using information generated with fundamentally different methods.* (JEL Q26)

I. INTRODUCTION

The research program to estimate recreation benefits via the travel cost method, TCM (Hotelling 1949; Clawson 1959; Bockstael, McConnell, and Strand 1991), has established an empirically robust result: site visitation and recreation participation rates decrease as the distance to be travelled increases. Assuming that travelling is costly and the cost increases with distance, then it follows that the visitation rate diminishes as the cost of visiting increases. Since the necessary assumption is so obviously plausible, this conclusion seems hard to challenge. Therefore it confirms an essentially economic explanation of recreation choice, a class of behavior that some observers had been tempted to claim lies beyond the reach of standard economic theorizing.

This is an important contribution. But the TCM research program, starting with Hotelling's (1949) initial suggestion, has always had larger ambitions. It seeks to measure the benefits of recreation facilities (e.g., site access); that is, to bring recreation under the scope of standard welfare change measurement theory and procedures.

It is a standard result that if recreation site quality and travel are weak complements, the compensated demand for travel contains all of the information necessary for welfare evaluation of recreation site quality. This result justifies a travel price method (TPM) of recreation benefit estimation. Unfortunately, travel is a nonhomogeneous good, and the demander typically plays a substantial role in its production. Thus, its price is typically unobservable. Instead, TCM depends upon substituting travel cost for the price of travel.

There are a number of persistent difficulties with TCM. I argue that many of these particular difficulties are symptoms of a general problem: travel cost is inherently unobservable. If travel cost is unobservable but is known to be an increasing function of distance travelled, it follows that travel cost is ordinally measurable. In this case, it is shown readily that TCM yields ordinally measurable benefit and welfare change measures. In modern household production formulations of TCM, the cost of travel depends, *inter alia*, on the household's opportunity cost of travel time and its activity production technology, both of which are unobservable. Again, ordinal measurability of welfare estimates is the best that can be expected. Nor do random utility (RUM) models resolve the measurability problem: these models are addressed to other, quite different, issues in the TCM research program.

Researchers using TCM, in its traditional or household production formula-

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tions, report benefit and welfare change measures in money-denominated terms. This is accomplished—despite the inherent unobservability of the cost of travel—by the use of various cost accounting and analytic conventions. These conventions, however, do not resolve the measurability problem: any particular welfare estimate is in part an artifact of the particular conventions selected for imposition.

II. THE TRAVEL PRICE METHOD

Let q be the quality of a specified recreation site, and v be visits to the site. Let p_v be the price of v and $\bar{p}_v$ be its choke price, i.e., a price so high that no v is taken. General weak complementarity (Bradford and Hildebrandt 1977; Maler 1974) holds whenever

$$e(\bar{p}_v, q^0, u^*) = e(\bar{p}_v, q, u^*), \qquad [1]$$

where u is utility; $e(\cdot)$ is expenditure; and the superscripts ^{0} and * denote, respectively, the baseline level and any given level. In words, v and q are weak complements if, when no v is taken, the individual is indifferent to the level of q. Under these conditions, the demand for v contains all of the information about preferences for q that is needed for benefit estimation and welfare change measurement.

To value a household's economic surplus associated with a given level of q^0 (using, e.g., the Hicksian compensating value measure, HC), one needs to estimate

$$\begin{aligned} HC &= e(\bar{p}_v, q^0, u^0) - e(p_v^0, q^0, u^0) \\ &= \int_{p_v^0}^{\bar{p}_v} v(p_v, q^0, u^0) dp_v \\ &= \int_0^{v^0} p_v(v, q^0, u^0) dv - p_v^0 \cdot v^0, \end{aligned} \qquad [2]$$

where $v(\cdot)$ is the Hicksian compensated demand for v, and $p_v(\cdot)$ is the inverse Hicksian compensated demand. General weak complementarity permits welfare evaluation of q^0 by integrating under the compensated demand for v conditioned on q^0. A proposal to change from q^0 to q' may be evaluated by integrating between compensated demands for v conditioned on q^0 and q' respectively.

The travel price method (TPM) of recreation benefit estimation would implement these welfare measures. So long as p_v is absolute-scale measurable (Boadway and Bruce 1984) and third-party observable—as, say, published prices or user-fees would be—these welfare measures have the standard properties of welfare measures (Chipman and Moore 1980). Most important for my purposes, if the compensated demands for v satisfy the standard requirements, HC will be a unique numerical welfare indicator. It will, of course, be conditioned on the prices of other goods, the availability of substitute and complement nonmarketed amenities, demander characteristics, etc., and on the reference level of utility.[1] But, *ceteris paribus*, the welfare measure will be single-valued.

Under the conditions described in this section, a researcher could produce welfare measures having the standard properties for recreation access, using the travel price method, TPM, a particular application of general weak complementarity. Let $p_v(d, \cdot)$ be an increasing function of d, distance to the site, and TPM would be an application of Hotelling's initial insight.

III. THE TRAVEL COST METHOD

Instead of TPM, we observe TCM in general use. Instead of using visit prices that are absolute-scale measurable and third-party observable, TCM practitioners attempt to apply weak complementarity principles using data on travel and access costs.[2] After some thirty years of methodological development and applica-

[1] These additional concerns are routinely included in attempts at detailed empirical estimation based on the simple general idea sketched here.

[2] Not all authors draw attention to this distinction. Two recent review essays provide a contrast. The conceptual development of the travel cost model in Bockstael, McConnell, and Strand (1991) refers only to travel price, p, variables. On the other hand, Anderson and Bishop (1986) base their model on variables identified explicitly as travel cost, TC.

tion of TCM, a number of stubborn methodological problems remain, and there is a considerable literature documenting that welfare estimates generated by TCM are sensitive—sometimes alarmingly so—to the discretionary analytical choices of researchers.

I plan to focus on a particular subset of these problems, those that concern the specification of the costs and opportunity costs of visiting a particular site:

(A) Recreationists vary considerably in their investment in durable equipment useful in travel and recreation. Such equipment may be more or less expensive, and more or less specialized. Allocation of the costs of owning and maintaining vehicles and other durable equipment to any particular trip proceeds, if at all, in arbitrary fashion.

(B) For multi-site recreational trips and multi-purpose trips, cost allocation to specific sites proceeds (if at all) without benefit of any acceptable theoretical basis.

(C) Lodging and subsistence expenditures have a large discretionary component. Should practitioners count all such expenditures as costs of visiting the site?

(D) There is ample empirical evidence that the treatment of substitute sites and/or activities influences the welfare estimates generated with TCM (e.g., Rosenthal 1987). And it is conceptually clear that substitutes should receive proper consideration because they help determine the opportunity costs of selecting the chosen site. However, no nonarbitrary procedure has emerged for delimiting the set of substitutes.

(E) Conventional TCM practice treats the distance from the home to the recreation site, and the cost per mile travelled as exogenously given. However, the disturbing possibility exists that recreational preferences may have influenced the choice of residential location and motor vehicle. In such cases, recreational preferences would influence miles travelled and cost per mile, not just on recreation trips but year-round.

(F) There is general agreement that the opportunity cost of time spent traveling should be counted among the costs of travel. However, the cost of travel time remains an empirical mystery.

Economists are well aware of all these problems. Problems (A)–(C) are problems in the allocation of joint costs, involving joint production of: (A) multiple activities or attributes, both on-site and in-transit; (B) activities and visits to multiple sites; and (C) recreation, lodging, and cuisine experiences. However, as Hof et al. (1985) demonstrate, there exists no unique allocation to individual products of the costs in joint production.

Problem (D), the treatment of substitutes, is a standard problem in neoclassical demand modeling, while problem (E) is a problem in multi-stage budgeting. Standard TCM practice treats recreational choice as the final stage in a multi-stage budgeting process. After the residential location and the motor vehicle(s) have been chosen in previous budgeting stages, the number of trips to a recreational destination is chosen. If, however, this misspecifies the budget allocation process for at least some of the participants, costs are misspecified for those participants and standard aggregation conditions are violated (Deaton and Muellbauer 1980). Problem (F) is the familiar "time cost of travel" problem (e.g., Bockstael, Strand, and Hanemann 1987; Bockstael, McConnell, and Strand 1991).

These problems with TCM have proven rather intractable. Standard TCM practice, despite three decades of research, does not yet incorporate procedures to resolve these difficulties convincingly. Nevertheless, neoclassical economics holds out the hope that these problems may be resolved, one-by-one, with persistent effort by TCM researchers. To the contrary, I argue, they are manifestations of a common problem, one that can be expected to remain intractable. The common problem concerns specifying the "true" costs of participating in recreation at a particular site.

Neoclassical theory posits that cost is determined by technology and factor prices. Assuming that technology and all factor prices are observable, cost is claimed to be "objective." By that, the neoclassicals mean to claim that cost is absolute-scale measurable and third-party observable; in these senses, cost has the properties usually attributed to price. The Austrian school of economics takes a contrary view. Cost is opportunity cost and is therefore subjective. What counts as an opportunity is subjective, as is the sacrifice entailed in choosing one opportunity rather than another. Furthermore, opportunity cost is always *ex ante*; it is the subjective expectation of sacrifice that determines choice.

To clarify what is at issue, consider the empirical estimation of supply. The neoclassical position is that there are two alternative observational bases for supply estimation: one may observe either the response of quantity supplied to price offered, or the relationship between marginal cost and quantity produced. The Austrian position is that only the first-mentioned approach is available. Consider Buchanan's (1969) discussion of the prospects for an all-volunteer military force. He argued that it would be impossible to predict reliably the supply of volunteers by inferring their costs from observations of the wages paid in alternative occupations. Individuals may well have (unobservable) preferences that would influence their subjective opportunity costs of choosing the military line of work. If, however, one could observe the enlistments induced by an array of military wage-offers, one could estimate the supply of military labor.

The Austrians have much the better of the argument (e.g., Buchanan 1969, and Caldwell 1982). In principle, cost *is* subjective, as they claim. The neoclassical concept of cost survives not as a set of principles for understanding the nature of cost, but as a tractable approximation that is serviceable in certain empirical applications. However, there are good reasons to believe that the neoclassical approximation to true subjective costs is rather poor, especially, perhaps, in the case of recreation. For any given trip, those variable factors purchased at observable prices are merely the tip of the iceberg. The household provides its stock of consumer durables (some of which have been accumulated in response to its recreational preferences), its recreational technology, its knowledge of alternative opportunities, its decision-making expertise, and its time. Nature, society, and policy determine q. Some elements of q—e.g., the weather, congestion, and state of maintenance—are *ex ante* uncertain to the household. The household may package its trip with some particular combination of en-route and on-site activities, visits to other attractions, and nonrecreational activities that serve business, work, and/or personal objectives. At every point the household may go "first-class" or "budget," which would produce distinctly different experiences. And all of the decisions that go into the making of the trip are based on the household's own subjective assessments of alternative prospects and their opportunity costs. The idea that third-party observers can define a typical trip and specify its cost is *prima facie* implausible.

The Traditional TCM

Imagine that v, d, x (purchased commodities), and p (their prices) could be observed for household h. If it were possible to vary d while holding the utility level constant, one could estimate $v(d, p, u^0)$, a function relating visits and distance, conditioned on commodity prices and baseline utility. Interpreting d as the "price" of visiting, $v(\cdot)$ is a compensated demand for visits. The household's willingness to pay for site access could be expressed, using the inverse compensated demand, as

$$\tilde{H}\tilde{C}_d = \int_0^{v^0} d(v, p, u^0)dv - d^0 \cdot v^0. \qquad [3]$$

$\tilde{H}\tilde{C}_d$ is denominated in distance units (miles of consumers' surplus—why not?).

The analyst, who prefers dollar-denominated welfare measures but cannot observe p_v, assigns a travel cost $c(d, \cdot)$ increasing in distance and estimates $v(c(d), p, u^0)$ using the same observable variables and rescaling d by the assigned travel cost. The household's willingness to pay for site access, now expressed in dollars, is

$$\hat{H}\hat{C}_c = \int_0^{v^0} c(d)[v, p, u^0]dv - c(d^0) \cdot v^0. \qquad [4]$$

Had the analyst assigned the travel cost $\psi[c(d)]$, where ψ is a monotone increasing transformation, household willingness to pay would be

$$\hat{H}\hat{C}_\psi = \int_0^{v^0} \psi[c(d)][v, p, u^0]dv - \psi[c(d^0)] \cdot v^0. \qquad [5]$$

The situation is illustrated in Figure 1, for the simple case where the visits-distance relationship is $v = a - b \cdot d$ (where a and b are estimated parameters) and c and ψ are scalars. Note that the inverse demands

$$d = \frac{a - v}{b}, c(d) = c\left(\frac{a - v}{b}\right)$$

and

$$\psi[c(d)] = \psi\left[c\left(\frac{a - v}{b}\right)\right]$$

are all consistent with the observation-based visits-distance relationship $v = a - b \cdot d$.

With unobservable travel costs, $c(d)$ and $\psi[c(d)]$ are equally plausible representations of the price of visits, yet the welfare measures $\hat{H}\hat{C}_c$ and $\hat{H}\hat{C}_\psi$ are not equal; one is a monotone increasing transformation of the other. It follows that if travel costs are ordinally measurable—while they are known to be increasing in d, there is no observational basis for determining whether they are $c(d)$ or $\psi[c(d)]$—the welfare estimates generated by traditional TCM are ordinally measurable. Ordinal-scale measures of household welfare change are noncomparable across households and violate the conditions for interhousehold aggregation. TCM analysts, of course, routinely produce

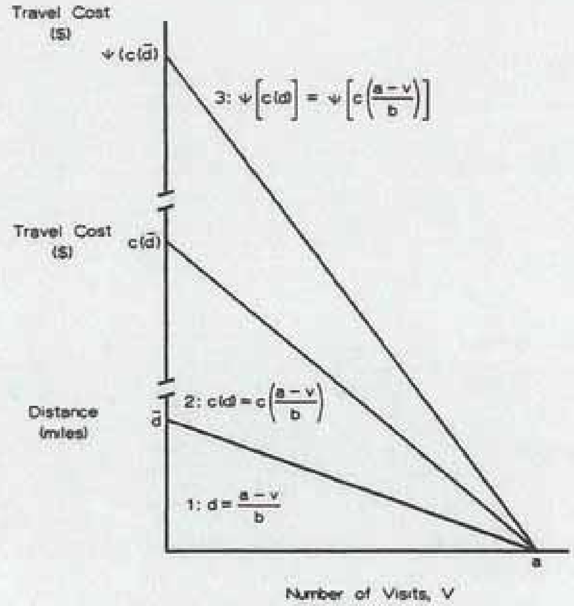

FIGURE 1
Inverse Demand for Visits, with Ordinally Measurable Travel Costs

dollar-dominated aggregate welfare estimates for recreation projects and policies, but when these estimates are based on ordinally measurable travel costs, they are not comparable with welfare change measures for other kinds of projects and policies.

In practice, the TCM analyst proceeds by assigning dollar-denominated costs of participation. Assume that the cost for household h to visit site s can be specified

$$c_{hs} = c_h(d_{hs}, V_h, H_h, Y_h), \qquad [6]$$

where V is vehicle characteristics, H is household characteristics, and Y is some measure of annual household income. Note that [6] is not something to be estimated; we have no independent observation of c_{hs}. Rather, c_{hs} is something to be calculated. The analyst specifies some function for [6], observes d_{hs}, H_h, V_h, and Y_h and calculates c_{hs} in money units. In specifying [6], analysts may use all the economic and cost accounting intuition at their command, but given the third-party nonobservability of c_{hs}, they must ultimately impose some unique but arbitrarily chosen function for [6]. There will exist alternative specifications that are equally defensible, but because we have no independent observation of c_{hs}, we cannot conduct the customary formal and informal tests for misspecification of $c_h(\cdot)$.

The standard response to this situation is to seek, at least, to minimize the contribution of the TCM analysts to the noncomparability of travel cost calculations and welfare estimates. This is accomplished by establishing conventions for calculating travel costs. Those who abide by the same set of conventions impose the same unique function for [6]. The resulting travel costs and welfare estimates remain artifacts of the travel-cost accounting and specification conventions selected for imposition. The underlying subjectivity of travel costs—and the resulting ordinal measurability of TCM welfare measures—is not avoided, just masked.

Does the Household Production Function Formulation Solve the Problem?

Why, exactly, is $c(d)$ nonunique? First, because the budget is not directly observed. Define the budget as $m \equiv px + c(d) \cdot v$; i.e., the budget is equal to expenditures on things purchased plus the costs of visits taken. If it were possible to fix d, v, p, x, and m, $c(d)$ would be unique. But with unobservable $c(d)$, m cannot be fixed. The analyst who assigns the travel cost $c(d)$ to the household is implicitly assuming that the budget is $m_c = px + c(d) \cdot v$, whereas the analyst assigning the travel cost $\psi[c(d)]$ is assuming a budget of $m_\psi = px + \psi[c(d)] \cdot v$. This interpretation is entirely consistent with ordinally measurable travel costs: if m cannot be fixed, there is an indefinitely large number of values for $c(d)$ that are consistent with known d, v, p, and x. Further, this interpretation of m is entirely plausible. The individual's endowment includes a nonmarket component including, but not limited to, access to recreation site s; and analysts assigning different costs (i.e., expenditures) for that nonmarket component would arrive at different accounts of the household's "full" income.

Second, it may be premature to fix v and x independently; some x may be used in "producing" v. Most applications of TCM involve visits in which, at least, motor fuel is consumed. This possibility opens a window of opportunity: the analyst who can observe prices and quantities of purchased commodities used in "producing" a visit knows *something* about $c(d)$. However, the window soon begins to close: unless visits are nothing more than costlessly packaged combinations of commodities, the analyst does not know *everything* about $c(d)$.

The household production model is a reformulation of standard neoclassical consumption theory that addresses these two concerns: that the standard $m = px$ is an incomplete concept of the household's budget, and the immediate sources of utility are not purchased commodities but activities that the household produces from purchased commodities and other inputs. Many TCM analysts have adopted the household production formulation (HPF) of TCM, in the hope that it would resolve persistent problems with traditional TCM.

In the HPF, utility is derived not from purchased commodities (x) directly, but from activities (z). For household h,

$$u_h = u_h(z_h). \qquad [7]$$

Each activity z_j is produced in the household by combining commodities and time t, subject to environmental conditions q and the household's particular activity production technology $z_{hj}(\cdot)$:

$$z_{hj} = z_{hj}(x_{hj}, t_{hj} | q). \qquad [8]$$

Money income constrains the purchase of commodities:

$$y_h = px_h. \qquad [9]$$

Time is constrained at T, and must be allocated between working t_w and activity production:

$$T_h = t_{hw} + \sum_j t_{hj}. \qquad [10]$$

This formulation tells a more appealing story about how households engage in recreation. However, for the task at hand—specifying the costs of recreation—it is not clear that the HPF permits much progress. We can derive an expression for the cost of recreation activity z_j. Let α_{hj} be the implicit cost of time spent producing z_j. Then c_{hj}, the cost to household h of activity z_j, is

$$c_{hj} = c_j[z_{hj}(\cdot), p, \alpha_{hj}|q]. \quad [11]$$

The cost of the recreation activity depends on two things—α_{hj}, the implicit cost of household h's time when spent producing z_j and $z_{hj}(\cdot)$, the household's activity production technology for z_j—that are known subjectively to household h, but substantially if not completely hidden from third-party observers.

The general form of HPF-TCM does not resolve the measurability problems inherent in the standard TCM. Just as with traditional TCM, we can achieve a degree of regularity in HPF-TCM by imposing certain conventions on the analysis. Assume all income is earned by working at the hourly wage w_h, the demand for h's labor is perfectly elastic, and labor contracts are flexible. Then, we can write a single, linear budget constraint:

$$\begin{aligned} \bar{m}_h &= w_h \cdot T_h = w_h \cdot t_w + w_h \cdot \Sigma\, t_j \\ &= px + w_h \cdot \Sigma\, t_j, \end{aligned} \quad [12]$$

where $\bar{m}_h$ is "full income."

Maximizing utility [7] subject to the household's activity production technology [8] and the full income constraint [12], the following first order condition is obtained:

$$\partial u_h/\partial z_{hj} = \lambda\left[\Sigma\, p_i \frac{\partial x_i}{\partial z_{hj}} + w_h \frac{\partial t_j}{\partial z_{hj}}\right], \quad [13]$$

where x_i $(i = 1, \ldots, n)$ is an element of x, and λ is the Lagrangian multiplier. Observe that, unless $\partial x_i/\partial z_{hj}$ and $\partial t_j/\partial z_{hj}$ are constants, $\partial u_h/\partial z_{hj}$ and hence the implicit price of activity z_{hj} are indeterminant. Remember that activity level z_{hj} is jointly determined by inputs of market goods and time, given the household's activity production technology $z_{hj}(\cdot)$.

If we assume that $z_{hj}(\cdot)$ is linear in all x_i and t, the implicit price of z_{hj} is determined. A standard treatment imposes Leontief technology. Then, [8] can be replaced with

$$x_{hij} = a_{hij} z_{hj} \quad [14]$$

and

$$t_{hj} = b_{hj} z_{hj}. \quad [15]$$

The travel cost function [11] becomes

$$c_{hj} = \left(\sum_i p_i \cdot a_{hij} + w \cdot b_{hj}\right) z_j. \quad [16]$$

Finally, assume $a_{hij} = a_{ij}$ and $b_{hj} = b_j$, $\forall h$, and we have

$$c_j = \left(\sum_i p_i \cdot a_{ij} + w \cdot b_j\right) z_j \quad [17]$$

which is quite tractable. If a_{ij} and b_j can be estimated, c_j can be calculated in dollar-denominated terms. This accomplishment is an artifact of the conventions that the analyst imposes. Again, these conventions are nontrivial: flexible labor contracts[3] and identical Leontief activity production technology for all households. Because c_{hj} is not directly observable, these conventions are untestable.

So long as household production technology and the opportunity cost of time are known only subjectively, HPF-TCM welfare measures for site access are ordinally measurable at best, and therefore noncomparable with welfare measures for other kinds of goods and services.

Random Utility Models

Random utility models (RUMs) have been introduced, to deal more explicitly with the choice among substitute recreation sites. Regardless of their merits for that purpose, RUMs neither resolve nor circum-

[3] Bockstael, Strand, and Hanemann (1987) present a model that distinguishes between those recreationists who are able to adjust the number of hours worked and those who cannot.

vent the fundamental issue raised in the present article. For welfare measurement with RUMs, it is essential to specify a vector of visit prices for each site (Bockstael, McConnell, and Strand 1991). In practice, these prices are implicit and unobservable, and costs of travel and site access are substituted.

The Successes of the TCM Research Program

While TPM would generate absolute-scale welfare measures for recreation, it is much harder to make that claim for TCM. If we accept that the costs of travel are subjective to the recreationist household and thus hidden from the analyst, the best we can expect is ordinally measurable welfare estimates from the traditional TCM. More recent developments in TCM, including household production and random utility models, do not resolve this problem. What, then, about the various claims that the TCM research program has generated important successes? Smith's (1993) case that the TCM has worked well is based on three kinds of evidence:

(a) empirical trip demand models consistently support the properties implied by demand theory, e.g., negative own-price effects and elasticity properties consistent with the availability of substitutes;
(b) independent studies obtain roughly consistent demand characteristics and welfare measures for similar types of recreation sites; and
(c) differences in estimates of consumers surplus per unit of use and the price elasticity of demand can be explained by differences in (i) site characteristics and (ii) demand modeling practices.

Interestingly, none of this evidence in any way undermines the basic argument of this article. To the contrary, all of these successes for TCM are entirely consistent with ordinally measurable travel costs and TCM welfare estimates. All that is required for results (a) and (ci) is that own-price be an increasing function of distance, and willingness to travel to a particular site decrease as own-distance and the availability and convenience of substitutes increase. Results (b) and (cii) are consistent with the need to impose conventions in cost-accounting and modeling in order to obtain money-valued cost and welfare measures. Conformity as to conventions used explains consistency in the results of independent studies; differences in conventions explains differences in results.

IV. CONCLUDING COMMENTS

A travel price method, TPM, based on reliable observations of (p_v, v) pairs, would be a strong contender for preferred status among methods of estimating recreation benefits. Preferred status is sometimes claimed for TCM, because it is based on observed v. But observed v is not enough, and observed (d, v) does not substitute adequately for (p_v, v). Frankly, we do not know—and cannot know—what recreational activity costs. With unobservable travel costs, recreation benefits are, at best, ordinally measurable and therefore unique only up to a monotonic transformation.[4]

A degree of standardization is attained, for travel costs and welfare measures, in the traditional TCM by observing particular cost-accounting conventions, and in the household production formulation of TCM by imposing arbitrary and simplistic specifications of household production technology and observing particular accounting or analytical conventions for the household's implicit cost of time. The level of money-valued welfare measures generated by these artifices depends on the particular cost-accounting conventions and the partic-

[4]This problem with TCM applies to other applications of weak complementarity and related methods in which crucial prices are unobservable. Consider the difficulties inherent in Larson's (1993) recent suggestion that nonuse values be estimated from information about nonusers' behavioral responses to changes in amenity levels. These behavioral responses might range from political activism to "just thinking about it;" reliable third-party observation of the costs of such activities is implausible.

ular specification of household production technology invoked. Since travel costs are unobservable, the customary specification tests are inapplicable.

The problem of obtaining valid absolute-valued welfare measures from TCM could conceivably be solved in two ways. One could *adjust the cost-accounting and analytical conventions* until TCM reliably generates welfare measures consistent with some benchmarks established using fundamentally different valuation methods. Alternatively, one could *calibrate the TCM estimates* using welfare information generated by fundamentally different methods.[5] Either way, TCM cannot stand alone.

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[5]Cameron (1992) has some interesting suggestions as to how this might be done. However, her suggested methods, at their present stage of development, rely heavily on restrictive structural assumptions.