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THE COST OF NOT HOLDING BACK THE SEA - PHASE 1
ECONOMIC VULNERABILITY

by

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CONTENTS

FINDINGS[1]

The first step in estimating the cost to the United States of allowing the oceans to rise in response to greenhouse warming against unprotected coastlines is to develop a methodology by which researchers can catalog and measure the current value of real sources of economic wealth that might be threatened. Such measures represent initial, if naive, estimates of the social cost that would be incurred at each site if a decision to forego any protection from rising seas were made. If the sites chosen for application of the methodology are also part of a national sample, the localized estimates that they support can eventually be used to judge the potential cost of a universally applied decision of no protection. They can, in other words, be used to produce a first cut at a measure of economic vulnerability across the United States to greenhouse-induced sea level-rise.

This paper reports on the first steps of a process which will lead to this national estimate. The first three chapters are designed to outline the methodology by which site-specific cost estimates were made for Long Beach Island, New Jersey, and to record the results of its application. In the first, the underlying theory of the measurement is described. There are three areas of focus: the value of threatened structure, the value of threatened property, and, where appropriate, the social value of threatened coastline. The results of applying the theory to Long Beach Island are recorded in Chapter 2, while discussion found in the third chapter tries to put these local results into some perspective.

Broader perspective is drawn in the last two chapters. Chapter 4 begins the extension by describing more fully the sampling methodology by which local estimates of vulnerability can lead to a national estimate. The site selection process and more generally applicable estimation procedures are of particular interest there. A final chapter concludes with an outline of the issues that will have to be confronted if measures of economic vulnerability are to be translated into measures of economic cost. Discounting, uncertainty, growth, depreciation, and frictional adjustment costs will all have to be considered; identifying their precise role in the translation process certainly will be the focus of subsequent research.

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CHAPTER 1

THE THEORY BEHIND MEASURING VULNERABILITY

The cost of not holding back the sea should flow from at least four separate sources: (1) the value of lost structure, (2) the value of lost property, (3) the value of lost social "services" delivered from the existing coastline, and (4) adjustment costs associated with redeploying productive resources once applied to the lost land. The present effort considers only the first three of these sources, postponing any thorough consideration of the frictional costs of redeployment until later.[2] They relate more to immediate measures of vulnerability; the last relate more to adjustments that will be required to translate vulnerability to cost.

Land and structures are, for example, stores of economic wealth; even threatening their loss would likely produce macroeconomic reductions in aggregate demand, the effects of which would extend well beyond the shoreline. The extent of their potential contractionary influence on economic activity and long-term growth is thus another concern which should be investigated when the dimension of likely shoreline loss is more fully understood.[3] Social services provided by coastlines are, similarly, major components of economic and social well-being for which people have demonstrated a significant and immediate willingness to pay. Each of the first threesources of potential cost is, therefore, significant and deserving of individual attention.

THE VALUE OF THREATENED STRUCTURE

The precise notion employed to compute the economic value of threatened structure is that people will abandon a structure when the land upon which it sits is covered by water during mean spring high tide. In fact, the inundation scenarios upon which the vulnerability calculations are based are not sufficiently detailed to apply that notion exactly. The shoreline retreat scenarios provided by Park et al. (this volume) indicate, for each site in the national sample, only the percentages of developed cells (usually 500 meters square) that are flooded when the seas rise 50 cm, 100 cm, and 200 cm through 2100. In practice, therefore, the percentage of structure currently located in each cell and deemed abandoned with each increment of sea level rise must be taken to be the percentage of that cell that is flooded.

More precisely, the current value of structure located within any specific cell can be estimated from tax records or housing and business census data on the basis of a sample of structures presently located within its boundaries. To be sure, neither tax records nor census data necessarily reflect current market value. A reasonable translation from recorded value to current market value can, however, be accomplished by noting (1) the percentage of market value reported by the assessor's office, and (2) some degree of inflation since the last assessment. The accuracy of the translation can, in addition, be validated by comparing the assessed values of structures now on the market with their quoted prices. Moving to an estimate of the value of threatened structure within that cell can then be accomplished using the percentages indicated by the inundation scenarios. If, for example, a 50-cm sea level rise is expected to put x% of the region under water by the year 2075, then it can be assumed that x% of the estimated value of the structure located

[2]See Chapter 5 for a brief discussion of the anticipated role of adjustment cost in the process which translates economic vulnerability to economic cost. Adequate treatment of frictional adjustment costs will involve more sophisticated intertemporal modeling.

[3]Real estate markets are assumed to be efficient, so the economic value of public goods and services which are also threatened by inundation is capitalized in the values of land and structure. No separate accounting of public goods and services is therefore necessary. No notion of critical mass is employed, as a result, so some early vulnerability estimates for regions which will essentially disappear may be too low; they will capture the total loss of the value of public activity only when the last piece of property is lost even though, in fact, public activity probably stopped years earlier.

in that region is lost by 2075. Adding across all threatened cells can finally produce a site-specific cost estimate of potential structure loss.

One sampling procedure upon which the estimation process can rest looks at strips of land running inland from the shoreline past an inland point at which (1) property and structure are no longer threatened by sea level rise, and (2) property values no longer reflect surplus location rent derived from proximity with the shore. Series of real estate valuations along these strips should be sufficient to support aggregate potential cost estimates subject, of course, to some sampling error. Sampling error could be avoided completely if the inundation scenarios were more detailed and if tax records were digitized, but neither of these conditions is met in reality. Resulting estimates must rely, instead, on the efficient operation of real estate markets to keep the sampling errors low; a small number of strips in each sample should, in fact, be sufficient to keep the t-statistics around sample means of (e.g.) structure values, in excess of 10.

The technicalities of sampling aside, a procedure which uses current value as a measure of potential future cost can be- criticized for several reasons. For one thing, the sites being studied will surely enjoy economic growth over the next half century or so. Current value misses that growth entirely. For another, structure prices tend to inflate more, quickly than the general Consumer Price Index. Estimates based on current value might, therefore, be conservative to the degree that they ignore either or both of these phenomena.

On the other hand, using current value sidesteps both the vagaries- of social discounting and the potential that threatened structures will be allowed to fall into disrepair when it becomes known that they may be under water in the foreseeable future. Inasmuch as the cost of not holding back the sea will be compared with the cost of protection on a year-to-year (or decade-to-decade) basis as various future scenarios unfold, however, the problems created by not discounting are not necessarily as severe as they might at first appear. They may involve discounting over a decade's time, for example, and not over a half-century. Moreover, it may turn out that the growth and relative inflation trends just noted proceed over the long term at a rate which roughly offsets the effect of discounting on the real value of threatened structure. Current value and present value would then match over the long term if not over decades.

The issue of not maintaining structure is also one of timing. For example, if the owner of a $200,000 structure that will be inundated in the year 2050 were to ignore its physical upkeep over the 25-year period from the year 2025 to 2050, then the owner would suffer a smaller loss in 2050 than he would otherwise. How much smaller? The present value, in 2050, of the money that he did not spend maintaining the property since the year 2025 net of the reduced rent that he received as the property deteriorated. If, however, it were known that the structure were going to be abandoned in 2050, then the market value of that - structure would begin to decline well before 2050. An accurate accounting of the economic loss might therefore also start recording this decline in value years ahead of the 202S collapse, thereby moving the loss forward and increasing its current present value. Which effect would dominate is, at this point, anybody's guess; but it is certainly an issue which warrants further consideration.

All of these intertemporal issues will be considered, when vulnerability measures are adjusted to reflect cost, with an eye toward keeping track of precisely "Who knows what and when?" Discounting must, for example, be considered to the extent that decisions to protect ponder investment at some time certain in anticipation of avoiding,loss sometime in the future. Its implications will be clear, however, only in the context of modeling, which also allows for economic growth, depreciation, market expectations, and uncertainty. For the moment, it must be emphasized that only current value estimates are provided here.

THE VALUE OF THREATENED PROPERTY

The same sampling procedure outlined'above can also be used to produce estimates of the current value of lost property which are subject to, virtually the same set of concerns. To the degree that current values miss the effects of higher relative inflation, they likely to be too low. To the degree that they are not discounted, they are likely to be too high. Market value erosion might also be expected; it would be based on the same rational response to anticipated inundation, and it would happen automatically through the operation of the marketplace. In fact, the only caveat that no longer applies is the analog to an owner's ability to run down a structure. The value of the land upon which something might be built cannot be significantly diminished by neglect. It maybecome unsightly, but the marketplace will continue to acknowledge its intrinsic value derived from location andother relatively unalterable characteristics.

There is, however, one additional wrinkle that must be considered -- exactly what piece of property islost when the sea rises? For structures, the answer to this question is simple; the structure that is abandoned is the one that is lost. For property, though, loss of a shoreline lot means that the next lot is now a shoreline lot. Economic loss should, therefore, be measured at some interior point.

To see this more precisely, consult Figure 1; a hypothetical property value gradient for one-eighth acre lots is displayed there. Note that values start at $100,000 on the shoreline and eventually stabilize at $50,000 some SOO feet from the shoreline. Were the sea to rise so that the first lot were lost, then the second lot would become a shoreline lot and assume the $100,000 value originally attributed to the first. The value of the third lot would climb to $90,000, and so on. The community would, in effect, lose the economic value of an interior lot located initially more than 500 feet from the shoreline. The true economic loss would be the equivalent of a $50,000 lot instead of the shoreline $100,000 lot; there would be a distributional effect, to be sure, but the net social loss would be $SO,000. Where appropriate and accessible, this sort of accounting procedure can be applied in the property value loss calculations. The strip sampling method is, in fact, specifically designed to provide enough information to support its application. Note, as well, that the interior valuation process works from all directions for an island. The value of an interior plot of land can, as a result, rise, at least for a while. Proper sampling design for an island therefore involves looking at strips that run its entire length or width.

THE SOCIAL VALUE OF THREATENED COASTLINE

The final source of potential economic loss from sea level rise can be traced to the social value of the coastline that may be lost. Beaches are recreational areas, for example, which are generally available for use at the price of a beach badge; estimation of even their recreational value is therefore extremely difficult. The literature, building on work by Clawson (1966), suggests using transportation cost to construct at least a partial measure of value. More specifically, if using the beach is essentially free except for the cost of getting there and getting home, then the prices that families (e.g.) pay to use the beach are simply equal to the expenses that they incur simply getting to the beach and getting back home. Use surveys can then be employed to construct a demand curve for beach services by matching these prices with quantities demanded (people living various distances from the beach pay different prices to enjoy its services). The contribution of the beach to general social welfare can then be taken to be the usual consumer surplus area under this demand curve.

There are, of course, an array of other benefits generated by our coastlines which are not captured by this travel cost measure, and the problem of estimating the cost of losing a coastline region is one of measuring the value of all of these benefits. One approach that showed some promise in moving toward a more general measure was developed by Knetsch (1964) and David (1968). They both noted that property values increase with proximity to a recreation area like a beach. Since these increases reflect, quite simply, a willingness to pay for the general amenities provided by a beach, e.g., Knetsch and David argued that the sum of these increases could be employed as a measure of the value of that beach. As the beach disappears, then, the economic cost might be estimated by keeping track of the losses in proximity-generated surplus economic rents.

There are, however, several difficulties in applying the Knetsch-David notion directly. Some of the amenity, and thus some of the slope in a property value gradient, comes from views of the ocean that please residents with or without a beach. Attributing the entire slope to the beach proximity would therefore produce an overestimate of beach value. On the other hand, there are many people who do not live near the beach but who nonetheless use the beach. Using a property value gradient exclusively would miss the value of the beach services that they enjoy, and would thus produce an under-estimate of beach value. Finally, there is considerable storm protection value provided to inland property by a beach and its associated dune structure which is captured by neither transportation cost surveys nor property value

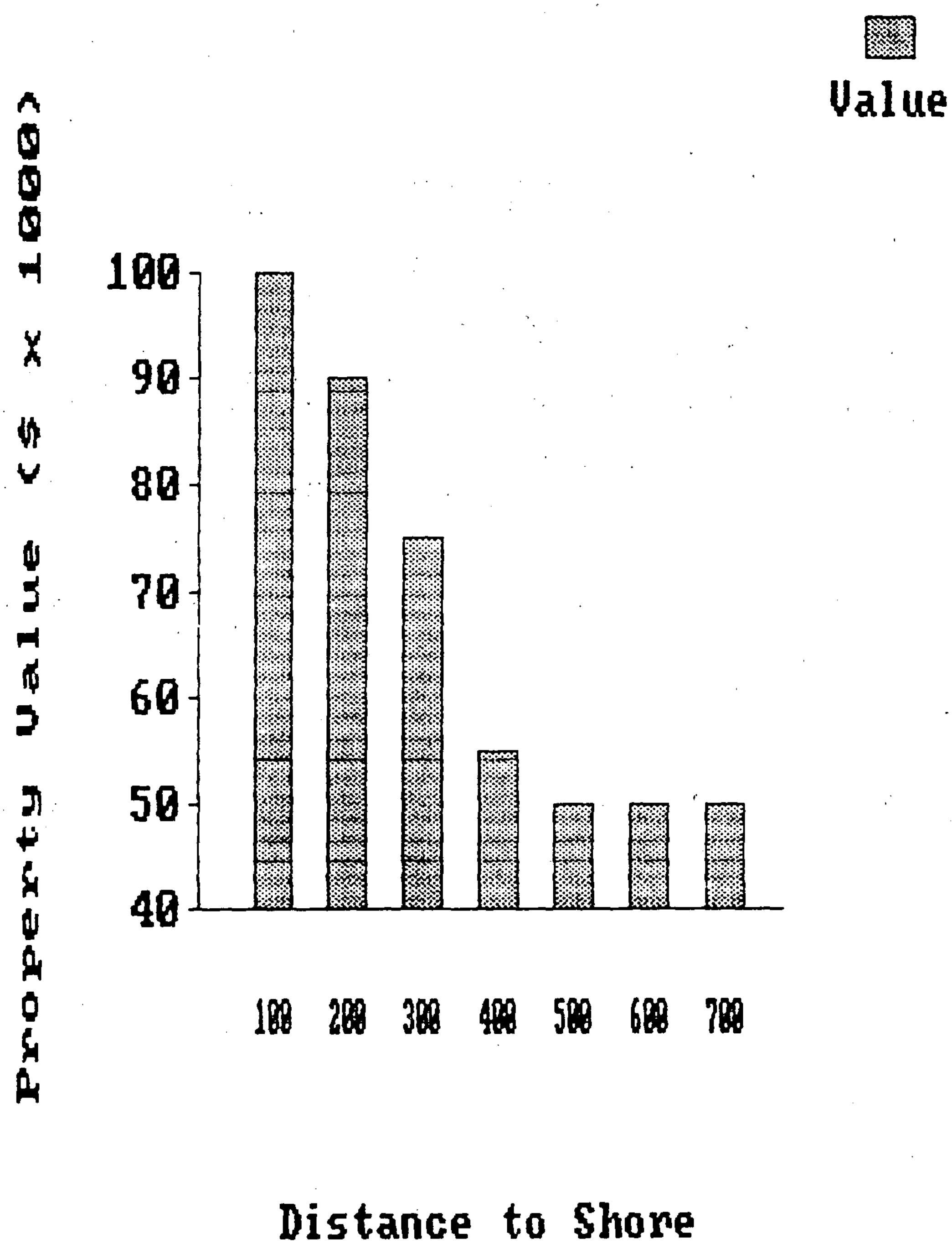


Figure 1. Distance to shore.

gradients. Still, a rough Knetsch-David style estimate can provide context – an order of magnitude guess against which to judge more careful estimates derived in other ways.

The alternative procedure employed here attempts to account for all of the sources of value to the degree actually recognized by shoreline communities by judging beach value from community behavior when beaches are threatened. As a matter of law, in some places like Texas (Texas Open Beach Act), and of practice, in other places like New Jersey and North Carolina, a structure located along a beachfront must be abandoned and/or torn down when the land upon which it sits is inundated during the mean spring high tide. This allows the beach and presumably its dune to migrate inland, albeit at the expense of the property owner whose structure was in the way, but. to the good of the inland community. By revealed preference, therefore, the social value of a beach must be at least as high as the value of beachfront structures which would be abandoned if the beach were to erode. It is, in other words, reasonable to assume that a beachfront structure is sacrificed to preserve the social value of coastline whenever a sea level rise scenario brings the water within a certain minimum distance of its foundation. Titus and Greene (this volume) submit that that minimum width is 40 feet.

Refer again to Figure 1 to see how this procedure might work operationally. Suppose, for the sake of argument, that $200,000 structures were located on each lot and that there were a 40-foot beach on the ocean side of the first lot. Recall that the lots are all 100 feet long moving away from the water. Now let the ocean rise, eroding 100 feet of beach and dune. What has been the cost? Any structure on the first lot is now within 40 feet of the ocean. To maintain the minimum beach width, therefore, that structure must be abandoned and perhaps torn down; the loss, attributable to the social value of the beach, is thus at least $200,000 derived from the lost structure. What about the property? An additional $25,000, representing half of the property value of an interior lot, has been lost, as well, because half of the first lot is gone.[4] Should this loss be added to the property loss accounting outlined in the previous subsection, or should it be attributed to the beach value accounting just noted? Ultimately, the answer to this question does not matter as long as it is not added in both places. Total vulnerability is, after all, the sum of the losses attributed to structure, coastline, and property. To emphasize the importance of preserving the social services provided by coastline, though, the accounting procedure adopted here attributes all property and structure loss associated with maintaining a coastline to the value of preserving that coastline.

[4]Presumably the value of the next lot has increased according to the earlier story.

CHAPTER 2

VULNERABILITY FOR LONG BEACH ISLAND, NEW JERSEY

Estimates of economic vulnerability for Long Beach Island were prepared from a systematic sampling of assessed property and structure values along 25 separate strips of land. Two of the strips were designed to sample from atypical developments on the bay side of the northern part of the island. The remaining 23 were each approximately 200 feet wide, evenly distributed along the 18-mile length of the island and extending from the ocean to the bay; they were designed to sample from the more traditional development pattern of the majority of the island. Table 1 identifies the sample sites.

The general cross-sectional topography of the island, and thus of 23 of the 25 strips, is portrayed in Figure 2. There was some variation in development pattern. The north shows big houses on large lots and located well away from wide beaches; the south shows smaller houses on smaller lots packed up against narrower beaches. Nonetheless, their remarkable consistency made it possible to extrapolate inundation scenarios for each strip into integrated inundation scenarios for the entire island.

Beginning on the bay side, significant inundation will usually begin after a 1-foot rise; there are places where the bulkhead is a bit higher, but rarely could it restrain more than a 3-foot rise. Once begun, inundation will proceed quickly over the virtually flat area located between the bay and Long Beach Boulevard. On the ocean side of the Boulevard, the rate of inundation will slow as elevations rise more quickly, but it will by no means stop until the island is completely underwater. Ten feet above mean high tide is the usual maximum altitude of developed property at the base of the ocean-side protecting dunes.

Turning now to the ocean side, 100 feet of beach is lost on Long Beach Island for every 1 foot of sea level rise (Weggel et. al., this volume). Since the beach is less than 50 feet wide in some spots, particularly on the south end of the island with houses build up the inland sides to the tops of the dunes, maintaining the beach for social value will involve some economic loss even with a 6-inch rise. The cost accelerates until, at about 4 feet of sea level rise, nearly 75% of the $2 billion value of the island is lost.

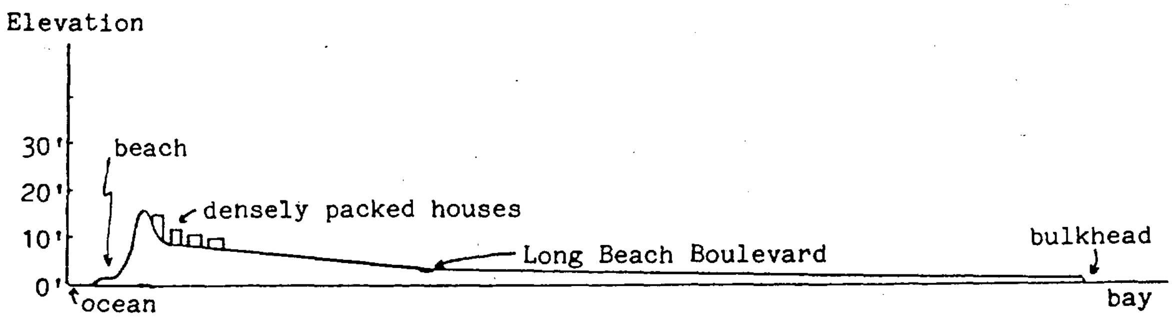
With inundation boundaries defined along each strip of the sample (and, by interpolation, along the entire length of the island) for 6-inch, 1-foot, 18-inch, 2-foot, Moot, 4-foot, and 6-foot sea level rise scenarios, it remained only to estimate the property, structure, and beach values threatened by each step of the process according to the procedure outlined in Chapter 1. Estimates for both property and structure, normalized per eight-acre lots, were produced directly from recent tax maps and a complete grand list for each level of inundation within each sampling strip. A comparison between asking price and assessed value for properties currently listed in the real estate market revealed a close match; no disparities of more than 10% were discovered, and no consistent bias in either direction was noted. Moving from these sampling estimates to property, structure, and beach value estimates for the entire island was finally accomplished by extrapolation, taking note of both the area inundated by each increment of sea level rise within the sample sites and the likely area inundated by each increment between sample strips.

Table 2 records the results of this entire process; it shows cumulative vulnerability estimates for the entire island for increment of sea level rise. Sampling errors (1 standard deviation) for the sample means are registered in the parentheses; the market works so well that thorough incorporation of the values recorded within the sample of 25 strips was sufficient to support t-statistics consistently well in excess of 20, in most cases, and never less than 10.

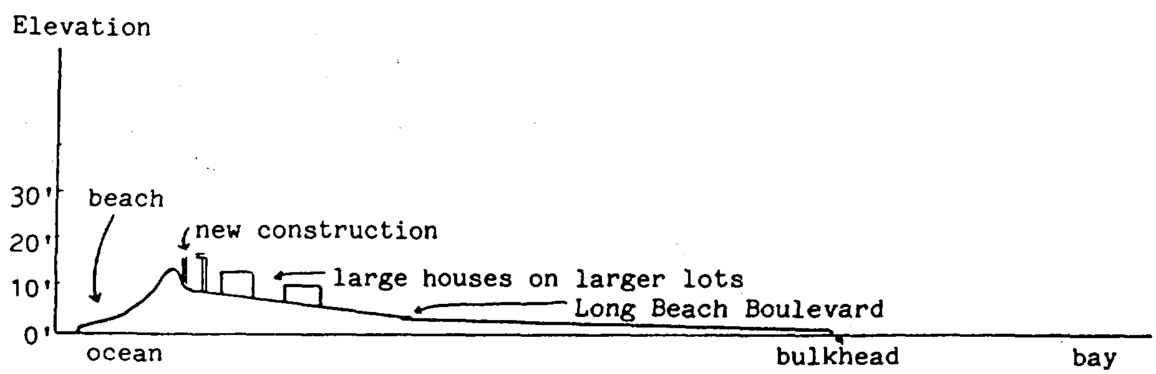
Notice that the total value attributed to the beach over the entire range of sea rise is $353 million. Comparing property values on Long Beach Island with the average of a small sample taken in Manahawkin Oust across the bay), produced a rough Knetsch/David estimate of $346 million in total property value differential between the island -and the mainland. There is, in addition, an estimated $89 million location premium for island property in direct proximity

Table 1. Sample Sites – Long Beach Island, New Jersey

Number	Tax ID	Southern Street	Northern Street
1	A-6	Cleveland Avenue	McKinley Avenue
2	A-33	Carolina Avenue	Inlet Avenue
3	A-52	Joshua Avenue	Magnolia Avenue
4	A-80	—	Marshall Avenue
5	D-27	17th Street	18th Street
6	E-22	25th Street	26th Street
7	F-38	33rd Street	34th Street
8	H-11	Marine Lane	Ryerson Lane
9	J-22	Mississippi Avenue	Idaho Avenue
10	K-10	Kansas Avenue	Lillie Avenue
11	L-13	Cape Cod Lane	Ocean View Drive
12	M-24	Rhode Island Avenue	Massachusetts Avenue
13	O-11	Burwell Avenue	Dayton Avenue
14	O-32	Dupont Avenue	Goldsborough Avenue
15	O-62	Beardsley Avenue	Kirkland Avenue
16	O-98	46th Street	45th Street
17	O-128	37th Street	36th Street
18	R-20	—	Windward Road
19	R-62	Roxie Avenue	—
20	R-100	—	Lagoon Road
21	T-7/8	87th Street	—
22	T-40	—	Loveladies Lane
23	T-144	—	Beacon Drive
24	T-176	North-south through Loveladies	
25	W-5/6	Amherst Road	Arnold Boulevard



South end of the island with a long stretch of land west of Long Beach Boulevard vulnerable to inundation from the bay and development packed up to land on top of the dune of a narrow beach.



North end of the island with less property to the west of Long Beach Boulevard and larger houses on larger lots placed further from the dune and a wider beach. Some new construction is going in on the west side of the dunes.

Figure 2.

Table 2. Economic Vulnerability*

Sea Level Rise	Property	Structure	Beach	INCREMENT	TOTAL
0-6 inches	$0 (0)	$0 (0)	$15 (1)	$15 (1)	$15 (1)
6-12 inches	$0 (0)	$0 (0)	$40 (2)	$40 (2)	$55 (2)
12-18 inches	$80 (4)	$83 (4)	$62 (2)	$225 (6)	$270 (6)
18-24 inches	$70 (4)	$72 (4)	$50 (2)	$192 (6)	$462 (9)
2-3 feet	$129 (9)	$137 (8)	$115 (5)	$381 (13)	$843 (16)
3-4 feet	$315 (8)	$345 (7)	$45 (2)	$705 (11)	$1548 (19)
4-6 feet	$175 (4)	$184 (5)	$26 (1)	$385 (7)	$1932 (20)

- Measured in millions of dollars. The numbers in parentheses represent standard errors of estimation around the sample means of total or incremental dollar vulnerability. The total value of the island stands at approximately $2 billion.

with the ocean and bay shorelines.[5] A total property value increment of $435 million can therefore be supported by a crude application of the Knetsch/David technique, suggesting that the structure/property based estimate of the social value of the beach reported in the tables is conservative.

[5]This additional premium is computed by looking at the property value gradients along both the bay side and the ocean side along its entire 18-mile length.

CHAPTER 3

DISCUSSION

Relating the vulnerability estimates of Table 2 to temporal, greenhouse induced sea level rise scenarios requires incorporating the natural 3.9 min increase per year trend of the ocean off New Jersey. Table 3 tracks, in 10-year increments, sea level scenarios that attribute 50-cm, 100-cm, and 200-cm increases to greenhouse warming, respectively. Each includes nearly 1.5 feet in historical trend sea level rise between now and the year 2100. Table 4 translates the cumulative cost estimates of Table 2 into time-dependent estimates for each of the three scenarios; Figure 3 portrays each trajectory graphically. Annual loses are reflected in Figure 4 and Table 5. Both highlight the losses which can be expected on an annual basis for the decade following the indicated year. The figures show that marginal costs do not always climb; for the 2-meter scenario, e.g., marginal cost at 2100 is zero because the island was completely lost by the year 2090.

When real estate markets work well, market values reflect the discounted value of a stream of housing service income, implicit in the case of owner-occupied housing or explicit in the case of rental property. It is therefore interesting to consider the trajectory of lost economic rent that would have supported property values that were lost. Figure 5 illustrates lost economic rent embodied in cumulative economic cost for an assumed 10% return on investment. Higher returns would, of course, produce higher loss profiles; lower returns, lower profiles.

Table 3. Amount of Sea Level Rise for Various Scenarios

Year	Scenario*		
	50 cm	100 cm	200 cm
2000	.14	.15	.18
2010	.31	.36	.47
2020	.51	.63	.87
2030	.73	.94	1.38
2040	.98	1.32	1.99
2050	1.25	1.74	2.71
2060	1.56	2.22	3.55
2070	1.89	2.76	4.49
2080	2.25	3.34	5.53
2090	2.63	3.99	6.69
2100	3.05	4.68	7.95

* Measured in feet, including natural trend of 3.9 mm per year. The scenario identification indicates the amount of sea level rise attributed to greenhouse warming above and beyond the natural trend.

Table 4. Cumulative Economic Vulnerability*

Year	50 cm	100 cm	200 cm
2000	$3	$4	$6
2010	$9	$11	$14
2020	$15	$23	$39
2030	$34	$49	$215
2040	$56	$175	$457
2050	$155	$355	$671
2060	$280	$527	$1168
2070	$315	$720	$1633
2080	$405	$1041	$1831
2090	$518	$1540	++
2100	$873	$1561	++

* Measured in millions of dollars. The scenarios are identified in Table 3; the source of the cost estimates is Table 2.

++ The entire island is lost at this point.

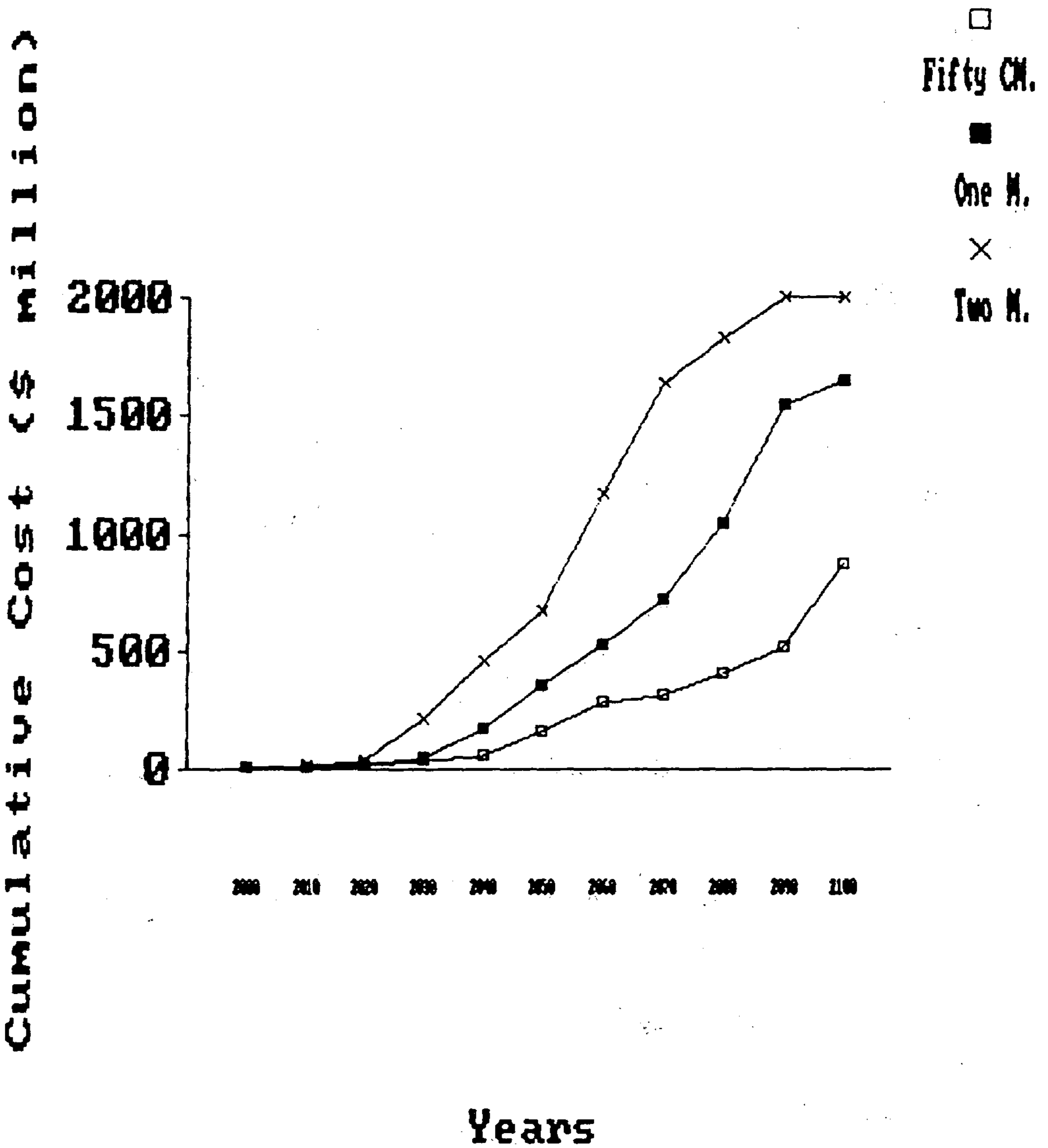

Fifty CM.
One M.
Two M.
Cumulative Cost ($ million)
2000
1500
1000
500
0
2010
2100
Years

Figure 3.

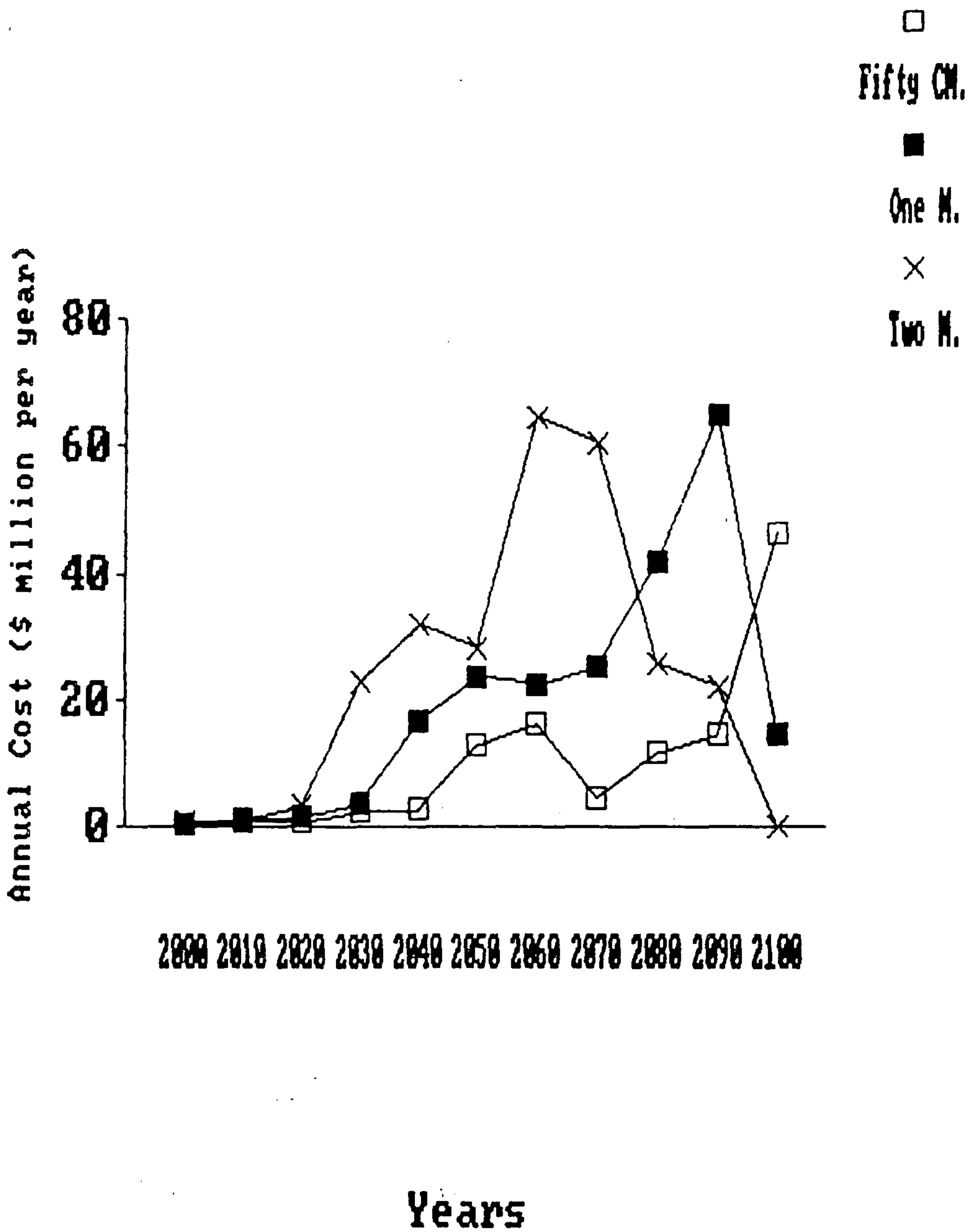

Fifty CM.
One M.
Two M.
Annual Cost ($ million per year)
80
60
40
20
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years

Figure 4.

Table 5. Annual Increase in Economic Vulnerability*

Year	50 cm	100 cm	200 cm
2000	$0.0	$0.0	$0.0
2010	$0.4	$0.5	$0.7
2020	$0.6	$1.0	$1.2
2030	$1.3	$1.8	$9.8
2040	$2.0	$7.8	$20.9
2050	$6.0	$14.3	$22.8
2060	$11.2	$16.6	$35.5
2070	$3.0	$18.3	$48.3
2080	$9.0	$25.7	$33.7
2090	$10.2	$41.0	$17.0
2100	$18.4	$30.5	++

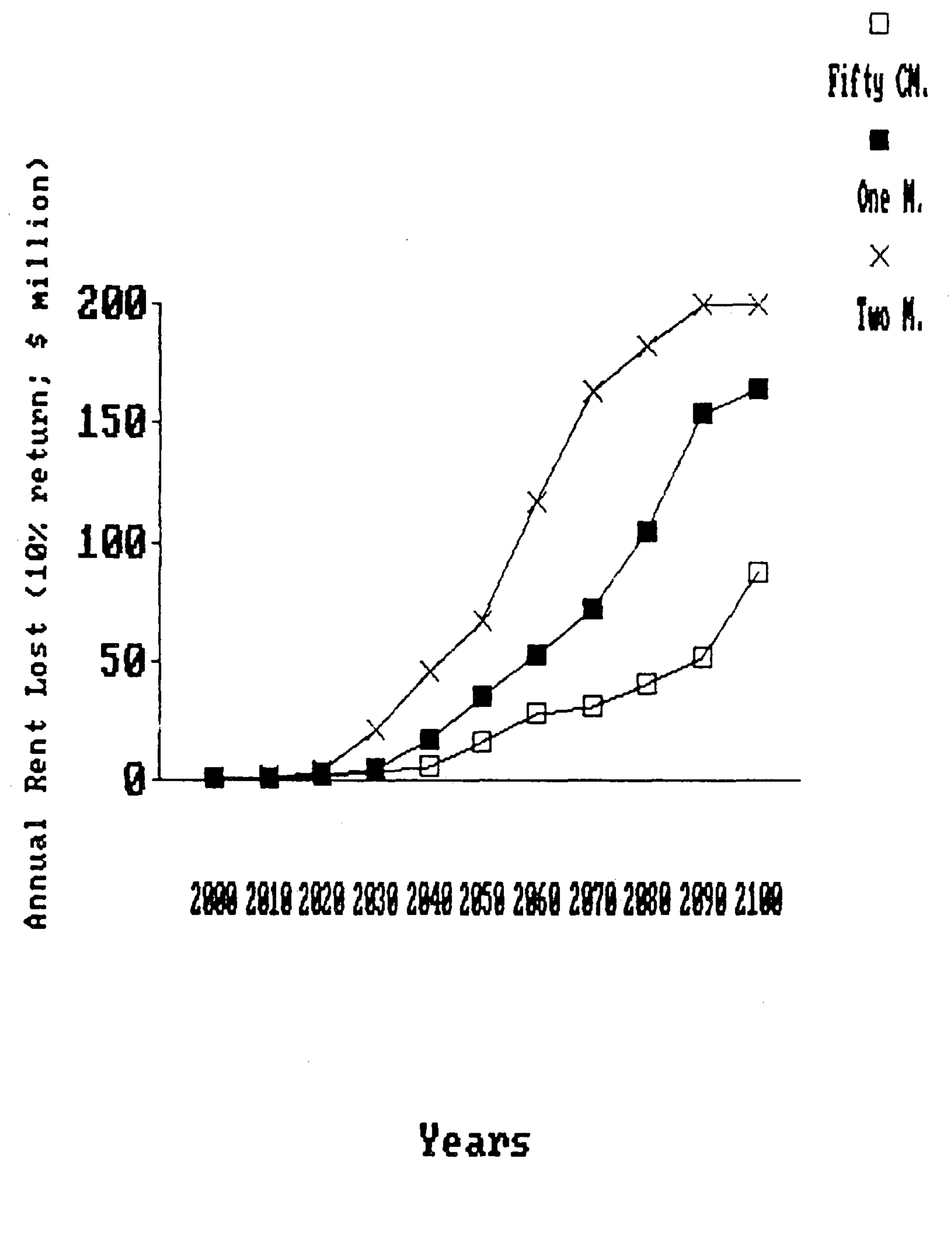

Fifty CM.
One M.
Two M.
Annual Rent Lost (10% return; $ million)
200
150
100
50
0
2000 2010 2020 2030 2040 2050 2060 2070 2080 2090 2100
Years

Figure 5.

CHAPTER 4

EXTENSIONS TO A NATIONAL STUDY

Straightforward application of the basic. methodology recorded in Chapter I to a coastal sampling conducted by Park et al. (this volume) can be used to produce national and regional estimates of economic vulnerability. Park's study looked at the effects of 0.5-, 1-, and 2-meter sea level rise scenarios on 46 sites selected at regular intervals around the country. Together, these sites accounted for 10% of the U.S. coastal zone. Taking every other site to generate a first cut at an estimate of total vulnerability would therefore cover 5%.of the coastal zone, and guarantee that particular regions would be included in the estimate roughly in proportion to their area. Basing a national estimate on this subsample would not support a precise result, but it would be sufficient to support an order of magnitude estimate of vulnerability. Going further may, in fact, give the spurious impression of increased precision given the uncertainties with which we view the distant future. More importantly, using the 5% subsample should certainly identify regions for which initial translations of vulnerability to cost would be most productive.

The precise details of applying the theory of Chapter 1 to the Park sample results need not be covered here, but at least one limitation should be mentioned. The Park surveys for each site usually record the effects of sea level rise for quadrants measuring 500 meters by 500 meters. Applying the notions of property value gradients outlined above to Park grids whose patterns frequently include quadrants extending 1000 feet inland is therefore troublesome, at best. It should, as a result, be expected that estimating vulnerability on the basis of average property values for each quadrant, taken from tax maps or housing and business census data, is the greatest precision which the inundation scenarios will support. How much accuracy is thereby lost? Initial comparisons of estimates derived from Park scenarios for Long Beach Island and the estimates reported in Chapters 2 and 3 above suggest that the answer to this question is "Not much." The law of large numbers seems to apply quite nicely, but any work toward a national estimate based on the Park surveys will include, as a quality check, a careful comparison. with the more detailed work on Long Beach Island reported here.

CHAPTER 5

EXTENSIONS FROM VULNERABILITY TO COST

Frictional adjustment costs were first mentioned in Chapter 1, but they were dismissed there as being more closely related to costs than vulnerability. It is immediate., therefore, that modeling needs to be done to reflect their potential as the focus moves away from measuring the economic vulnerability to sea level rise and toward measuring the economic cost of sea level rise. Their very nature is, however, extremely suggestive. If the rate of greenhouse-induced sea level rise were known with certainty and there were enough time to respond, it is possible that the economic cost of sea level rise would be confined to adjustment costs and the value of the inundated land. Structure is mobile and would presumably be moved; coastal services can be provided by the new coastline. The question becomes, then, a matter of determining what happens when time is short and our foresight is imperfect and uncertain.

An initial line of analysis should look at the simpler component of this question. Some long-term growth modeling along a certain sea level rise trajectory should unravel the dependence of both relocation costs and the lost value of structure abandoned because time was too short on rates of economic growth, rates of economic depreciation, and rates of dislocation. It should include a thorough analytical structure which reflects how people and markets might reasonably respond to the effects of the trajectory, so it can reflect the time dependence of intertemporal costs. Only then can a decision whether or not to protect a particular piece of coastline be cast in a context that considers both the timing and the degree of protection.

A second line of analysis should then build on the first to incorporate uncertainty and risk. Critical here should be not only how people and markets respond to uncertainty over the long term, but also how people and markets learn what is going on. Figure 6 illustrates the current state of our knowledge about greenhouse-induced sea level rise, and the decisions we make now are dependent upon the relative likelihoods that we place on each possibility shown there. Our subjective distribution of possible futures will be different in the year 2000, and 2010, and so on; so we should expect that our decisions might change. Protection decisions, contingent upon certain events actually occurring, should, in fact, be considered explicitly -- perhaps as exogenous changes in economic environment made at certain times, but perhaps as endogenous variables in the modeling itself. In either case, it becomes important to explore the value of the information upon which decision makers weigh the costs of protecting a region against the costs of not protecting that region.

This second phase of the theoretical work will be difficult, so it should be conducted as one part of a two-part extension of the certainty modeling. With the results of the first cost analysis well established, it should also prove fruitful to apply the insights that it provides to specific regions taken from the vulnerability subsample. Looking at likely sources of costs for specific regions along the three scenarios will reveal which of the theoretical issues are more important than others and whether or not the ranking of their relative importance depends upon the region selected. Extension of the region-specific analysis to the more complex uncertainty modeling will then be able to focus on the most productive issues without wasting time on concerns that turn out, at least for one region, to be less significant.

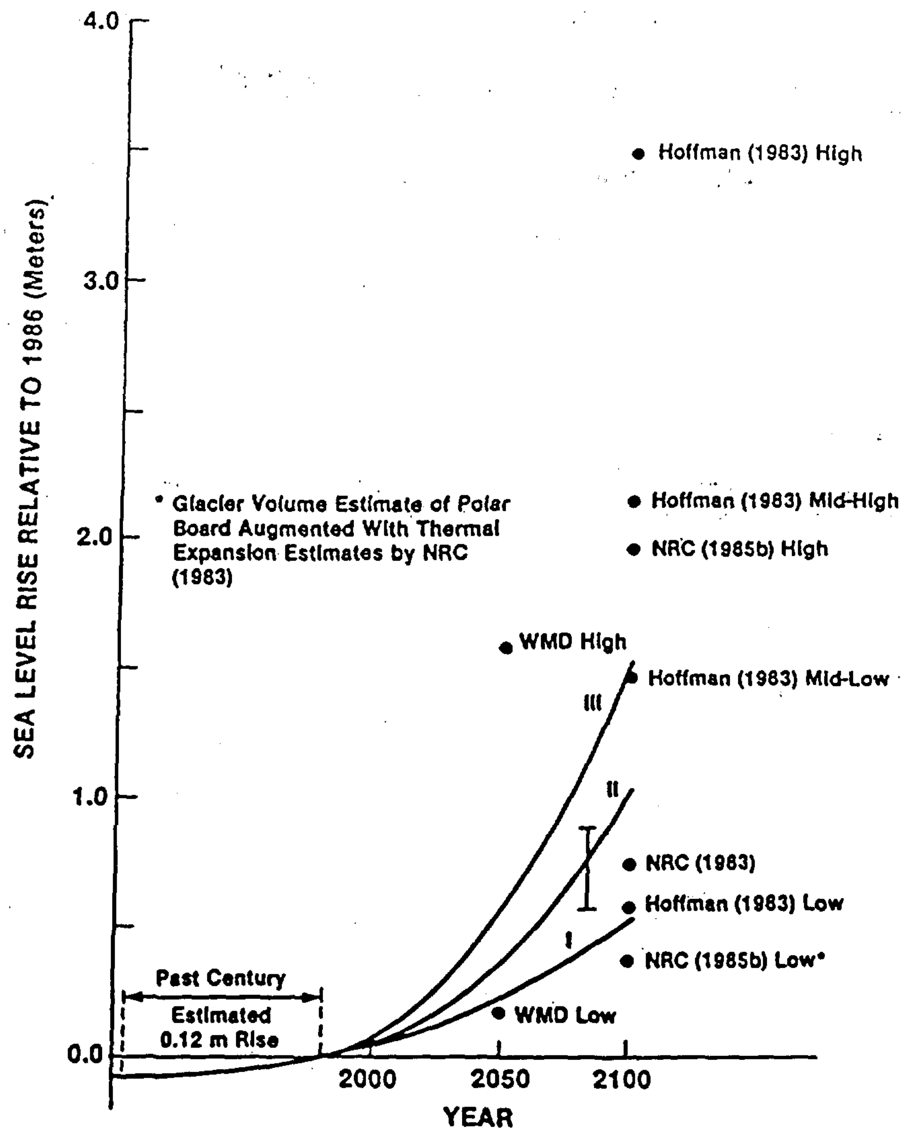


Figure 6. Estimates of future sea level rise (Hoffman, 1983, 1986; Meier, 1985; Revelle, 1983).

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