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Northeast Region
Philadelphia, Pennsylvania



Monitoring a Nauset Beach Breach and Inlet Formation, 2007-2008 on Cape Cod, Chatham, Massachusetts

Natural Resources Report NPS/NER/NRR 2010/144



ON THE COVER

View of two inlets looking south over the Town of Chatham towards Monomoy Island.

| Photograph by Christopher Seufert, 2008.

Monitoring a Nauset Beach Breach and Inlet Formation, 2007-2008 on Cape Cod, Chatham, Massachusetts

Natural Resources Report NPS/NER/NRR -- 2010/144

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Appendices

NPS and Cape Cod National Seashore Policies Pertaining to Coastal Change

Overview of National Environmental Policy Act Process

Quotes from the Pleasant Bay Alliance Symposium, Chatham MA, April 1, 2006:

“It is well understood that inlets to tidal estuaries systems exist as a result of the balance between the littoral drift and tidal flushing. In general, wave-induced currents along the coast transport sediment along the shoreline causing inlet shoaling and/or migration in the direction of the dominant littoral drift. Water elevation differences between the ocean and the estuarine system create tidal flows that prevent inlet closure by providing sufficient water velocity to scour sediments from the main channel. For many natural inlet systems, a period of barrier spit elongation is followed by episodic breaching of the barrier beach, resulting in a more hydraulically efficient inlet channel. For the Pleasant Bay system, the most recent cycle of barrier elongation and breaching took approximately 140 years, with significant alterations to the tide range and the associated tidal exchange (tidal flushing). These hydraulic changes can impact estuarine water over the same time periods.”

John Ramsey, Principal Coastal Engineer,
Applied Coastal Research and Engineering, Inc.

“Erosion of the wave-cut glacial cliffs of outer Cape Cod has produced remarkable depositional landforms to their north, Provincetown Hook, and to their south, the Nauset Beach-Monomoy barrier complex. Because Nauset Beach forms the eastern boundary of Pleasant Bay and Chatham Harbor, tides in the bay and harbor become distorted as the barrier beach migrates westward. This distortion causes the bay and harbor tides to lag behind the outer (ocean) tides, and periodically the time lag become sufficiently large to cause formation of a new tidal inlet through the barrier.”

“Present understanding of these processes is sufficient to permit estimates of future configurations of the Nauset Beach-Monomoy complex, however the reliability of such estimates is limited by two significant uncertainties. The first concerns the question of whether or not the complex continues to be a net depositional system or rather is a now-eroding remnant of a former deposit. The second uncertainty concerns the influence on the system of engineering structures designed to limit upland erosion.”

Graham Giese, Coastal Geologist,
Provincetown Center for Coastal Studies,
Oceanographer Emeritus
Woods Hole Oceanographic Institution.

Introduction

Cape Cod's postglacial coasts are valued ecological, recreational and community resources as well as a laboratories for observing coastal dynamics. Nauset Beach refers to a system of barriers and spits above the "elbow" of Cape Cod that have been transported and re-deposited in seasonal and multi-year cycles. Nauset barrier beach is entirely within the jurisdiction of Cape Cod National Seashore (Seashore) and spans the Towns of Orleans and Chatham.

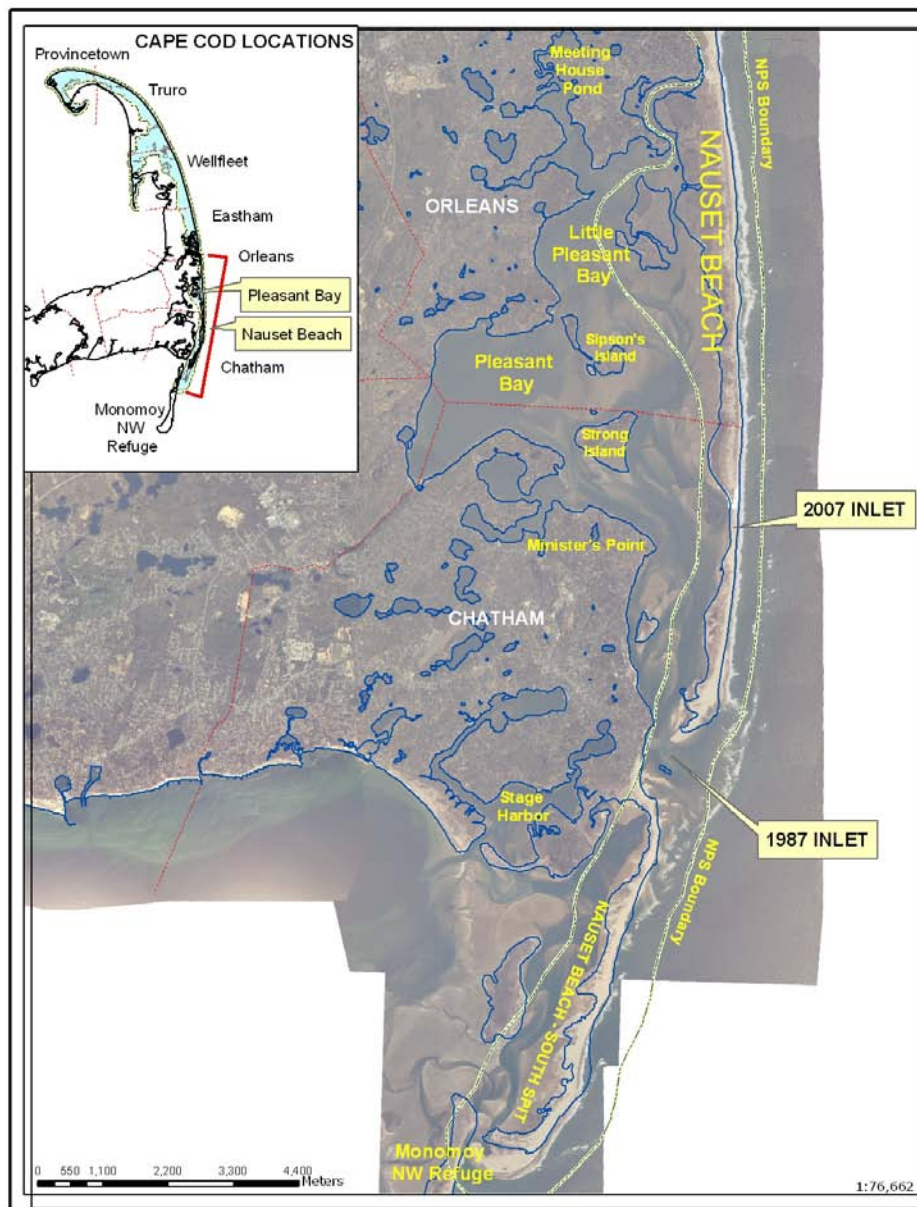


Figure 1. Location Map.

On April 15-16, 2007 a spring nor'easter coincided with spring tides and caused inundation and overwash of several sites along Nauset Beach. A breach in the barrier beach in Chatham gradually evolved into a persistent inlet, growing slowly throughout the summer and expanding more rapidly in late winter 2008. The breach was monitored via cooperative efforts between the Seashore, the Town of Chatham and the Pleasant Bay Alliance (a local non-profit) and observations were shared with resource managers, town officials and the public through forums, government meetings and the local press. The management response essentially followed existing National Park Service (NPS) policies and the consensus of town voters which dictated that coastal processes be allowed to continue unimpeded. In the short term, large volumes of sediment have been transported into the Pleasant Bay system and tidal circulation within the estuary has been re-oriented and increased. As many as 13 seasonal beach cottages have been inundated or removed and navigation for the Town's commercial and recreational fishing fleet has become more complicated due to sediment shoaling in channels.

The evolution of this new "North Inlet" mirrors similar historical events (e.g. ca.1846) but the eventual course of change remains to be seen. Cape Cod communities have long traditions of adapting to coastal change but current events highlight for a new generation an awareness of century-scale processes. As in most coastal communities, development, property values and intensity of use has dramatically increased in such a short time-frame that they have yet to be fully tested in the time-frame of geologic cycles.

Setting

The Nauset/North Beach barrier beach system encloses Pleasant Bay, a shallow estuarine system of about 6500 acres with a watershed of 21,600 acres in four towns (Pleasant Bay Management Plan Update, 2008). Chatham's South Beach (about 600 acres) is another barrier beach segment now separated from Nauset Beach by a 1987 breach. South Beach (or Nauset Beach south spit) has since become connected to the Town's mainland and to Monomoy National Wildlife Refuge to the south.

Generally, the Nauset Beach system has been supplied with sand from the eroding bluff coast of Eastham, Wellfleet and Truro – though the sand supply has likely diminished as more sediment has been directed toward the Provincetown hook in the last 6000 years. The diminished sand supply may have some effect on the cyclic growth of barrier spits enclosing Pleasant Bay. Storm driven overwash events are commonplace and bring sediment into Pleasant Bay, maintaining marsh elevations in the face of sea level rise. As the Nauset barrier beach has "migrated" westward and accreted southward, tidal circulation within Pleasant Bay has become more restricted and complex. The current north inlet allows Pleasant Bay tides to drain in several directions but has not eliminated phase differences between tides in the bay and the ocean (according to preliminary review of tide gage data). Current studies seek a clearer understanding of sediment movement along the barrier system and will be extremely helpful in managing human activities and planning monitoring protocols for these coastal features (Giese, G.S., and Adams, M., 2004). The new inlet adds a significant element of cross-shore sediment movement to the equation.

Overwashes and breaches have resulted from many of the named tropical storms and nor'easters in years past. In a few cases, inlets have formed, creating challenges for the NPS in implementing and communicating policy rationales to the public. In some cases, these events damage or threaten public facilities and private property. In determining how to implement management policies and meet regulatory requirements, managers must evaluate park and community needs, short- and long-term impacts, and long-term sustainability. In addition, managers must clearly communicate these considerations to the public within the context of complex geological processes and anthropogenic perturbations to those processes.

For example, prior to 1978, the Seashore operated a beach parking lot located on the northern end of the Nauset barrier beach - one of only two ocean beach parking lots in the Town of Eastham. An overwash during the Blizzard of '78 inundated and damaged this popular public facility. The Seashore's decision to not rebuild this facility is still questioned today by a group of Eastham residents advocating for development of a new beach parking lot on Town-owned land. Also in 1978, an inlet formed at Wood End in Provincetown and persisted through the early 1980s. An NPS-sponsored study (Ashley, 1986) explored the relationship of the stone dike in Provincetown Harbor with the persistence of the inlet. And in 1987 the current inlet to Pleasant Bay formed as a result of a breach of Nauset Beach opposite the Chatham lighthouse. Structures were lost on the mainland as well as beach camps on the barrier beach. The historic Old Harbor Life Saving Station was relocated by barge to Provincetown in advance of the storm. In the following years, extensive revetments were constructed along the mainland shore opposite the breach. Constriction of the inlet by mainland revetments and the growing spit of Nauset Beach may have helped set the stage for the Patriot's Day breach. In the course of coastal monitoring, observers noted that Nauset Beach had narrowed in width at what would become the North Inlet, indicating that inner bay shorelines were starved of sediment.

Geologic context

The present Chatham "North Inlet" at the southern terminus of Nauset Beach is located east of Strong Island/Minister's Point in Pleasant Bay in approximately the same place as the first reliably recorded location of the tidal inlet to Pleasant Bay – the location recorded by J.F.W. DesBarres (DesBarres, 1781) of the inlet in 1740 and named by him "Old Harbor" (Figure 2). The observed quasi-cyclic migrations of the inlet downdrift from the location of Old Harbor followed by renewed barrier breaching and inlet formation in the same general location have been much discussed (e.g., Mitchell, 1871; Goldsmith, 1972; and Giese, 1978). Let's briefly review that cyclic behavior. Geologists (e.g., Hitchcock, 1841) noted that during the last half of the 18th and first half of the 19th Centuries, southward-directed net littoral drifting lengthened Nauset Beach forcing the inlet southward from its 1740's position until it reached as far south as Inward Point on Monomoy in the mid-1800's.

In 1846 a new inlet formed at approximately the same location as "Old Harbor" (opposite Strong Island/Minister's Point), and again it was forced southward as Nauset Beach extended its length during the last half of the 19th (Mitchell, 1871; Davis, 1896) and

much of the 20th centuries (Goldsmith, 1972; McClellenn, 1979). During the 1960's and 1970's the navigational difficulties associated with the long inside passage motivated discussion of possible engineering alterations and likely future natural inlet locations (e.g., USACE, 1968). Among the latter were projections of a possible future inlet formation at the historic inlet-initiation site east of Strong Island/Minister's Point (e.g., Giese, 1978). In fact, however, the only new inlet formation in the 20th century occurred farther south, opposite Chatham Light, in 1987. The conditions associated with that event and its aftermath have been discussed in many places (e.g., Giese, et al., 1989; Weishar et al., 1989; Liu et al., 1993; Fitzgerald and Montello, 1993; Stauble, 2001; Weishar et al., 2007; and Stauble et al., submitted).

It was only after another 20 years, in April, 2007, that the third iteration of Old Harbor was initiated east of Strong Island/Ministers Point. A review of North Inlet's development from storm-wave produced overwash/breach to major inlet is given above. The unexpected development of this second tidal inlet so soon after the creation of the South Inlet in 1987 posed two important questions: Why was it not anticipated and what pattern(s) of inlet/barrier evolution can be anticipated over the next few decades?

Giese et al. (2008, 2009a, 2009b, 2009c) have argued that formation of the second inlet was not anticipated due to lack of sufficient understanding of the processes and conditions associated with the historic inlet migration cycles. Drawing upon scientific and historical sources, their analysis suggests that the system's "cycles" proceed in two distinct phases. The first, the inlet development phase, begins with a breaching event that launches a new morphological cycle and initiates an extended period of instability characterized by multiple inlets, and changes in tides and tidal channels. The system is said to be "tide-dominated" in this phase in that tidal forces primarily determine inlet locations and changes.

The second, or inlet migration phase, commences after the system has achieved a stable configuration with a single inlet lying south of a mature barrier spit. This phase is characterized by southward growth of the spit and concurrent southward migration of the inlet. The system is said to be "wave-dominated" in this phase since wave induced southward alongshore sediment transport controls the inlet location.

According to this concept, at present the system is in the multiple-inlet stage of the inlet development phase. The authors estimate that a single, stable inlet will be in place in less than 20 years and that inlet migration will begin in less than 30 years. They anticipate that continued southward migration could position the inlet between Ministers Point and Chatham Light within 50 years (Figure 3).

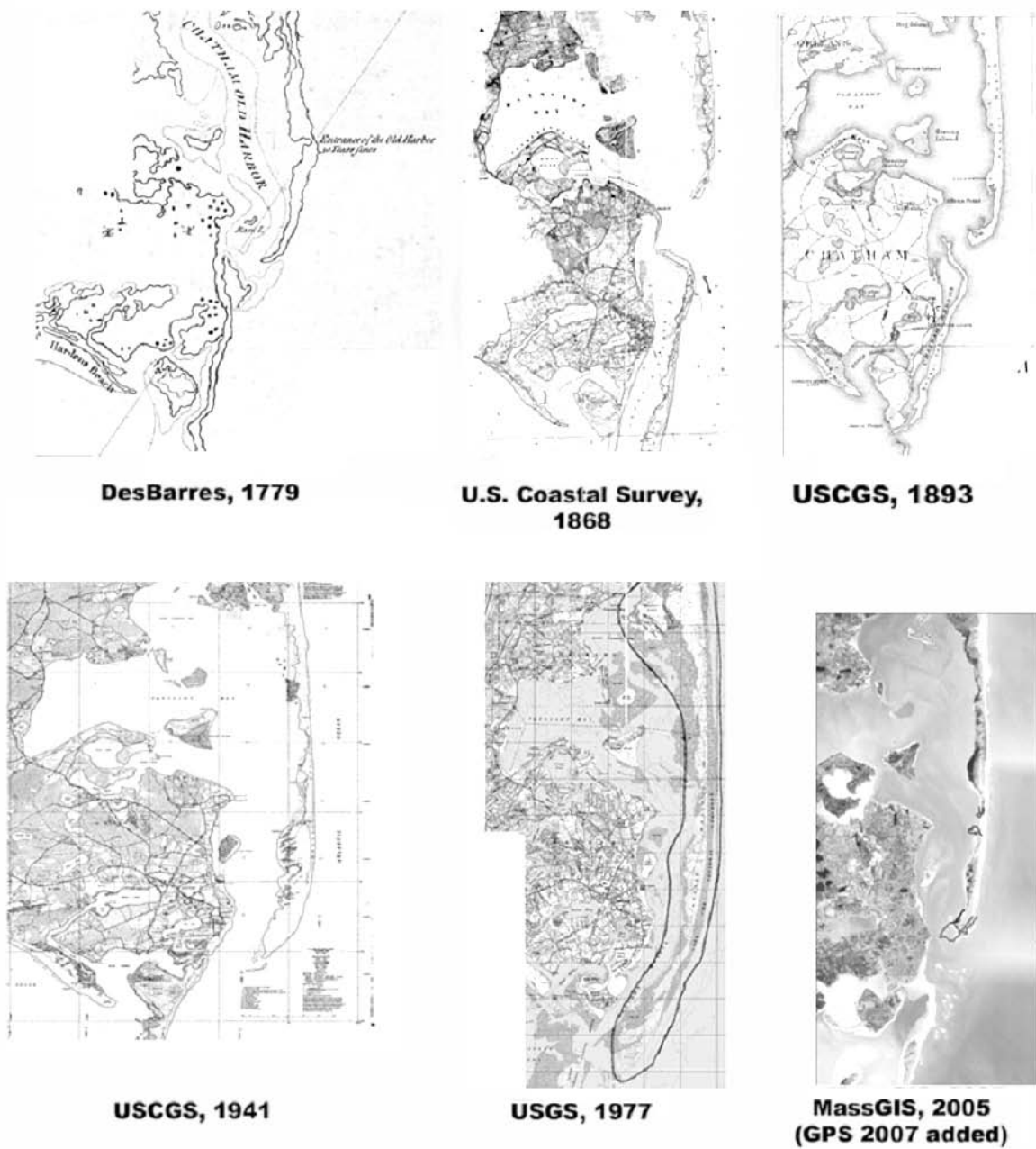


Figure 2. Historical map details showing the evolution and breakdown of Nauset barrier beach between 1779 and 2007.

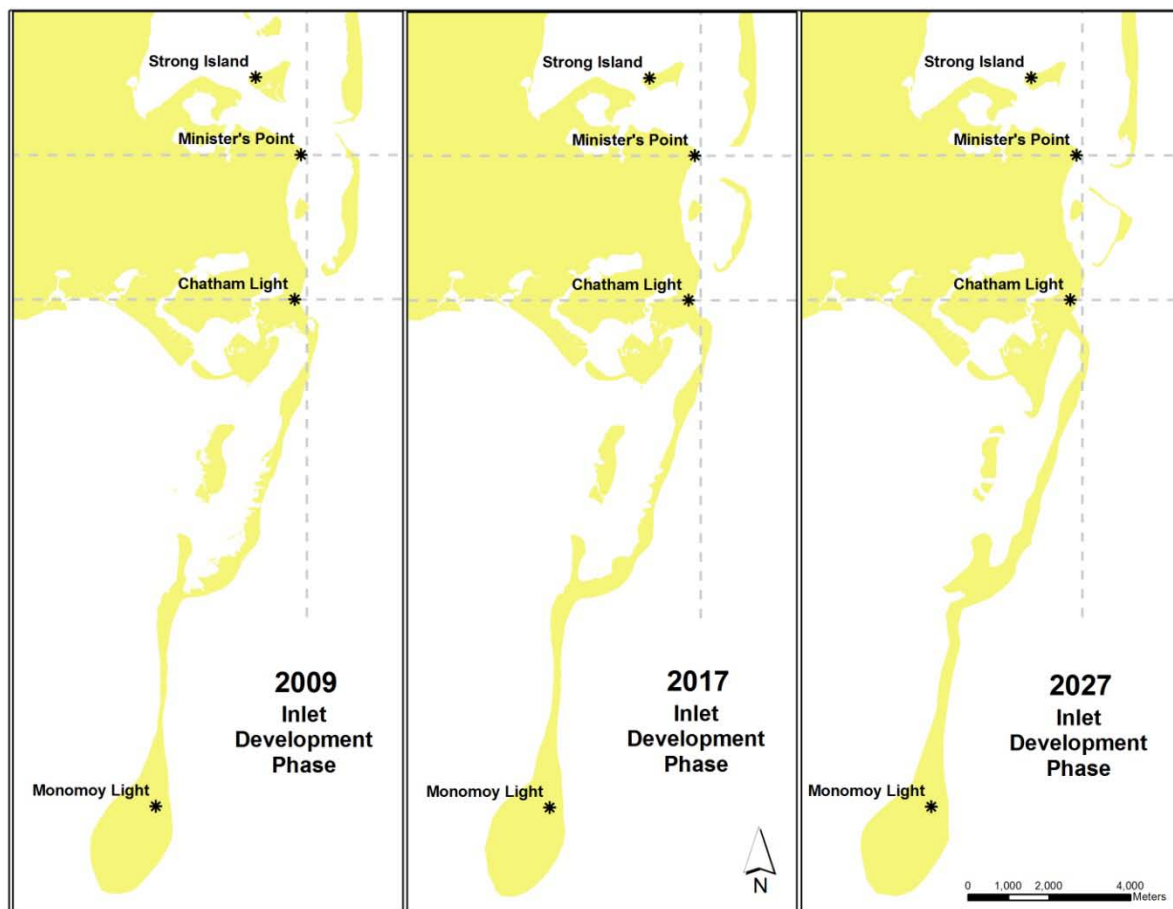


Figure 3: Estimated inlet development phase morphology 2009-2027.

The Patriot's Day Storm Breach Event

On the evening of April 15, 2007, a spring nor'easter hit Cape Cod during spring tides and lingered for several days of high winds and extreme tidal ranges. A number of overwash events ensued, one of which persisted and widened into a breach through Nauset Beach on a strip of NPS-owned land amidst a cluster of private beach cottages (the "North Village"). Expansion of the breach was incremental through mid-summer. Some observers speculated that a new inlet would expose mainland shorelines to increased energy and accelerated erosion as well. Similarly, concerns were raised that the increase in sediment delivery into the Bay coupled with a presumed decrease in the velocity of water moving through the 1987 inlet could impact navigation.

Initially the breach was shallow with considerable flood tide sediment extending into the bay toward Minister's Point/Allen's Point. A shipwreck appeared on the low tide flats that was likely moved from offshore into the bay with the tide. Flood tide deltas inside Pleasant Bay seemed to reinforce a division of flow within the Bay which likely existed before the breach. Tidal

exchange for the main body of Pleasant Bay seemed to flow to the south through the existing (1987) inlet. Tides from the north (Little Pleasant Bay) seemed to be captured by the new inlet. A series of shoals running north from the inlet to Strong Island were augmented by flood tide deltas. Navigation between the two halves of Pleasant Bay became nearly impossible at low tide. There was anecdotal evidence of increased tidal range within the Bay. However, preliminary evidence from the Meetinghouse Pond tide recorder indicated higher high tides but low tides that were unchanged or perhaps higher than before the breach. New sediment within the Bay may have actually constrained ebb tides from Little Pleasant Bay and reduced exchange between the two halves of Pleasant Bay.

Observers witnessed altered tidal patterns and circulation in Pleasant Bay. Due to large amounts of new sediment inside the breach a hydraulic gradient still existed between the upper bay and the ocean. Eventually, increasing storm activity in late summer and fall mobilized sediment and opened channels through these shoals within the bay. Tidal range increased and the north spit started its rapid retreat. As erosion accelerated, additional beach cottages were inundated.

Many interesting questions remain about the future status of the barrier beach, new and existing inlets, Pleasant Bay tidal circulation, cottage settlements (now gone on North Beach) and mainland shorefront neighborhoods. Coastal scientists from the National Park Service, the Provincetown Center for Coastal Studies and the Towns of Chatham and Orleans have been watching changes in the inlets and the rest of the system, looking for clues that might help managers anticipate effects on beach dynamics, erosion, and navigation.



4/23/07, 5/29/07



06/07/07



01/05/08



01/31/08

Figure 4. Aerial photos courtesy of the Town of Chatham.



Figure 5. View of two inlets in 2008 (Courtesy of Christopher Seufert Photography, Chatham MA)

Breach Monitoring Activities

In 2005 (prior to the New Inlet formation), Dr. Graham Giese, coastal geomorphologist from the Provincetown Center for Coastal Studies, and Kelly Chapman, hydrologic technician from the Seashore decided to test observations that tides in Pleasant Bay were out of phase with ocean tides nearby. They deployed a pressure recorder in the upper reaches of Pleasant Bay at Meeting House Pond collecting a 50-day record in 2005, a 45-day record in 2006 and a nearly continuous record from before the 2007 Patriot's Day storm to the present (with one 6-week gap). Survey grade RTK GPS was used to establish elevations for the recorder and a harmonic analysis is planned after correction for barometric pressure. More recently, the Town of Chatham has placed a tide recorder at the Town Fish Pier near the 1987 inlet. These data will give a better picture of tide phases and ranges in Pleasant Bay and will inform us of how the double inlet situation is affecting circulation and tides at both ends of the Bay.

Throughout the course of the breach and inlet formation, Dr Giese and Mark Adams, the Seashore's GIS specialist, have conducted site visits with Chatham Coastal Director Ted Keon to record high and low tide shorelines on either side of the breach with differential GPS (Figure 6). Throughout 2008 and into 2009, Thadd Eldridge, a private surveyor, has continued mapping shorelines around the affected "North Village". Rates of retreat for the southern tip of the north spit have been compiled (see table 1, below).

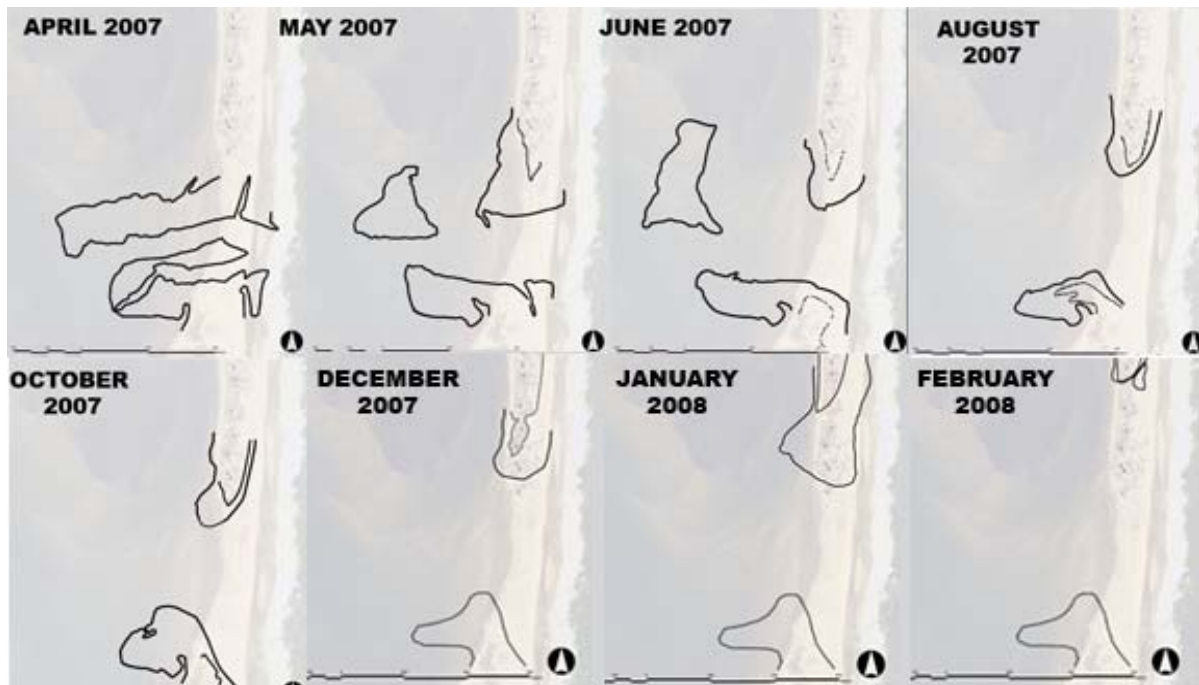


Figure 6. GPS shorelines at low tide and estimated breach widths for each date. Note that the location of the south side of the breach is estimated after October (based on aerial images) and has not changed significantly.

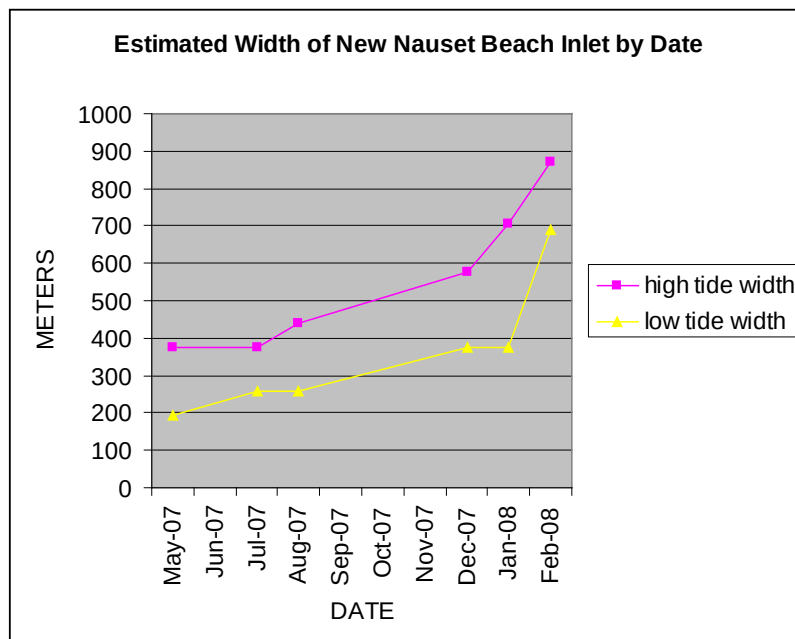


Figure 7. Inlet width estimated by GPS and GIS.

ESTIMATE 2.29.2008
 GPS 01.31.2008
 GPS 12.18.2007
 GPS 8.29.2007
 GPS 7.03.2007
 GPS 5.31.2007

200 100 0 200 400 600 800 1,000
 Meters

Produced by CACO GIS

Site visits have also yielded qualitative observations of sediment accumulation and movement within Pleasant Bay. We have compiled a time series of map overlays based on charts and aerial photos.

Under agreements between the Town of Chatham, the non-profit Pleasant Bay Alliance and John Ramsey of Applied Coastal Research and Engineering, the Army Corps of Engineers (ACOE) and the USGS acquired LIDAR coverage of the breach location in May and October of 2007. The LIDAR data also includes partial bathymetry of Pleasant Bay. This new data awaits analysis. John Ramsey has created a hydrological model of Pleasant Bay for the Pleasant Bay Alliance and is running it again under conditions resulting from the new inlet.

Several ancillary studies will also support better understanding of breach and barrier beach dynamics. In the 1880s, 229 coastal profiles from Provincetown's Long Point to Chatham (the site of the current breach) were surveyed by US Coastal Surveyor Henry Marindin, including upland elevations and bathymetry. These profiles were partially surveyed again by Ziegler et al in 1964 (Zeigler, J.M., Tasha, H.J. and Giese, G.S., 1964). Over the past several years, the Seashore and the Provincetown Center for Coastal Studies have been resurveying these profiles. NPS funding will support completion of the resurvey effort and analysis of the coastal profiles. The NPS has also mapped high tide shorelines using differential GPS annually since the 1990s as part of an effort to develop a shoreline-change monitoring protocol for the Northeast Coastal and Barrier Network parks. And the NPS and Pleasant Bay Alliance are currently collaborating to map the sediments and habitats in Pleasant Bay.

Observations of the New Inlet's formation and development have yielded new information about along-shore and cross-shore sediment movement throughout the Nauset Beach system and have helped frame new questions. The Nauset barrier beach system from the bluff section to North Chatham erodes even more rapidly than the coast to the north, and that the rate of erosion continues to increase southward. However, for much of this coastal section net alongshore sediment flux is directed southward, causing it to be "unstable" according to systems theory. Contemporary as well as historical observations of this coast confirm its instability and the extreme difficulty in anticipating change.

In the future we propose to compile more detailed and systematic observations of the Nauset Beach system using aerial photography, RTK-GPS surveys, and contemporary LIDAR data. By comparison with similar data and historical maps and written accounts from the past century, we hope to track and describe the decadal-scale development of such features as washover fans, dune scarps, fore dune deposits and tidal inlets. Through analysis of the observed changes, we will describe the characteristic behavior and trends of this unstable and rapidly retreating, albeit critical, barrier system. Managers need a better understanding of how sediment supply to the rapidly changing spits and barriers of Orleans and Chatham affects inlet stability, circulation of Pleasant Bay and navigability/safety of its channels. Public use areas, listed species habitat and high-value improved properties are affected. Information about these complex coastal systems will guide management response in the face of shoreline change, storm response and sea level rise.



Figure 9. Nauset beach changes 1960 - 2007

Other Ongoing Physical and Biological Monitoring in Pleasant Bay Environs

Salt Marsh monitoring

The Seashore's salt marsh monitoring program includes 14 transects in Pleasant Bay site on the bay side of the barrier beach east of Hog Island. This long-term monitoring project follows a protocol developed in 1999 and has been implemented in Seashore marshes since 2002 (Roman, C., M. James-Pirri, and J. Heltshe. 2001). In 2003, 34 permanent 1-m² plots along transects were established in Pleasant Bay and sampling was initiated that year. These transects, plus 11 additional ones established in 2008, were sampled again in 2008. Parameters monitored include, plant cover, ground surface elevations, hydrology, soil properties, and porewater chemistry. In addition to ground-level monitoring, we have also analyzed aerial photography to document significant changes in salt marsh vegetation over time (1947 to 2005). In 2007, the Pleasant Bay Alliance and the Seashore established transects along the western margin of the Bay are being monitored by Alliance volunteers.

Estuarine Nutrient Enrichment monitoring

Pleasant Bay is also included in the Seashore's estuarine nutrient enrichment monitoring program. This program follows a protocol developed by the USGS for Northeast Coastal and Barrier Network parks (Kopp and Neckles 2007). Protocol components monitor nutrient input effects on water quality, sediment, and submerged aquatic vegetation (SAV). USGS initiated the SAV component in 2003, and SAV was monitored again in 2004, and 2005. The Seashore began partial implementation of the water quality monitoring component in 2006 with full implementation following in 2007. The parameters monitored include temperature, dissolved oxygen, specific conductance, salinity, chlorophyll, depth, turbidity, and photosynthetically active radiation. The Pleasant Bay Alliance (the Alliance) was formed in 1998, primarily to implement a Resource Management Plan approved jointly by the surrounding towns. Under the Plan framework, the Alliance has conducted water quality monitoring of the bay since its inception.

Barrier Beach Management and Response

Cape Cod has a long tradition of living with and adapting to coastal change. Most of the ocean shorelines and barrier beaches within the Seashore boundary are unarmored and allowed to respond to change without human interference. The Seashore was created in 1962 when coastal development was only beginning to become significant hence land use inside the Seashore boundary was generally frozen in time (with a few exceptions). Previous development was smaller in scale and coastal residents were accustomed to building lightly and moving structures in response to erosion. Seasonal cottages on barrier beaches and in the Province Lands have a long history of relocation in response to change.

While the Nauset barrier beach is entirely within NPS jurisdiction, land ownership is varied. The Towns of Orleans and Chatham hold title to about 1000 acres, private owners hold 50 acres and the NPS holds 150 acres on Nauset Beach. (These estimates are rough since GIS ownership data

does not reflect short term shoreline changes). (NPS GIS data) Chatham's south beach is also within NPS jurisdiction, under Town ownership and is entirely undeveloped.

Within these land holdings stand about 30 residential structures (including 13 structures inundated since 2007), some quite rustic and inhabited seasonally. Some cottages on the barrier beach date back to the 1920s and or survive as remnants of earlier structures. A number of current structures were rebuilt or relocated to the beach in the late 1950s when Monomoy National Wildlife Refuge was created and its cottage residents were removed. A court decision in 1958 cleared title for many Nauset Beach parcels which were sold and rebuilt in the few brief months before the Cape Cod National Seashore was established and new construction was halted in 1959. (Higgins, 2004)

There are no hardened roads or services on the outer beach and four wheel drive vehicle access is regularly interrupted by flooding, overwashes and extreme weather. While the barrier system remains largely undeveloped, the mainland shores of Pleasant Bay have become densely built in recent decades with high-value residences. Needless to say, the management and regulatory regimes on the mainland are quite different from the outer beach.



Figure 10. Photos of Chatham's North Village after the storm of 1978. (from Higgins, Frances 2004, *Drifting Memories: Nauset Beach Camps on Cape Cod*. Lower Cape Publishing, Orleans MA). Photos by Richard Kelsey. Courtesy of Warren Quinn.

In the weeks and months following the breach, the media reported public concerns that exposure of the developed inland shoreline could result in erosion and damage to shoreline homes, and the Town of Chatham explored the idea of filling the breach artificially. At that time some observers still thought that littoral drift might close the breach without intervention. As the dimensions of the breach slowly increased, the feasibility of intervention diminished.

Local, State and Federal Compliance

By early June 2007, town officials decided to begin exploring the regulatory steps for developing an intervention plan. Due to the estimated high costs of environmental review (\$150,000) and

implementation (\$4,100,000), the Town also needed approval from Town Meeting voters before proceeding. A public forum was sponsored by the Pleasant Bay Alliance and public information sessions were held at town board meetings.

At the request of the Town of Chatham, a forum was held at the Massachusetts State House in Boston on June 11, 2007 to convene regulatory and elected officials to review compliance process for coastal management activities that might be pursued by the town and local residents. Attendees included Congressional and Senate staff, State Representatives and State Senators, Federal officials and representatives of Massachusetts regulatory agencies. Discussion covered possibilities of coordinated review procedures, mandatory timeframes and costs. No specific proposals were presented and the discussion was hypothetical. Participants concurred that the review process for any proposed intervention to fill the breach was likely to take anywhere from six months to two years.

Proponents of intervention presented some possible scenarios: that sediment would continue to enter Pleasant Bay via the breach, that navigation routes from the existing Fishing Pier would be difficult to maintain, that intertidal and benthic habitat would be lost, that tide and wave energy would increase erosion along the inner residential shores of Pleasant Bay, that the new barrier beach island would remain isolated with limited access, that beach cottages would be lost to erosion and that, if two inlets persisted, then neither inlet would carry sufficient tidal flow for secure navigation without dredging. Finally, the Town cautioned that without immediate action the breach would grow and intervention would soon be infeasible.

Benefits of not intervening were also identified including: that sediment transport into the Bay would build up marsh elevations and supply sand to inner beaches, the new inlet would enhance tidal exchange and improve water quality in the Bay. On the other hand, intervention would increase the likelihood of a new breach forming elsewhere in the barrier beach system, and would be a costly endeavor with uncertain public benefit.

At a special Town Meeting in August of 2007, voters rejected the proposal to fill the breach and also defeated funds for feasibility studies.

After a period of rapid widening in which all 13 of the North Village cottages were inundated or removed the inlet's northward progression has slowed. Flood tide deltas have continued to evolve. No significant increased erosion to the developed inner shorelines of Pleasant Bay have been noted to date. Tide level monitoring continues and changes in circulation and tidal range within Pleasant Bay will be reported in future reports.

References

- Ashley, Gail M., 1986. Assessment of the Stability and Longevity of the Wood End Cut (inlet), Cape Cod National Seashore. Center for Coastal and Environmental Studies, Rutgers University, New Brunswick NJ.
- Borrelli, Mark, 2005, 173 Years of Shoreline Change in Pleasant Bay: 1868-2005. Prepared for the Pleasant Bay Resource Management Alliance, Chatham MA.
- Davis, W.M., 1896, The outline of Cape Cod, *in* Proceedings of the American Academy of Arts and Sciences, v. 31, pp. 303-332.
- DesBarres, J.F.W., 1781, The Atlantic Neptune, The Admiralty, London.
- FitzGerald, D. M. and Montello, T.M., 1993, Backbarrier and inlet sediment response to the breaching of Nauset Spit and formation of New Inlet, Cape Cod, Massachusetts, *in* Aubrey, D., and Giese, G. (eds.), Formation and Evolution of Multiple Tidal Inlet Systems, AGU, Washington, DC, 237 p.
- Giese, G.S., 1978, The barrier beaches of Chatham, Massachusetts, *in* Cape Cod Chronicle, 1 June 1978, Special Supplement, 7 p.
- Giese, G.S., Aubrey, D.G., and Liu, J.T., 1989, Development, Characteristics and Effects of the New Chatham Harbor Inlet. Woods Hole Oceanographic Institution Technical Report, CRC-89-4, 32 p.
- Giese, G.S., and Adams, M., 2004, Cape Cod Shoreline Change and Resource Protection, A Proposal to the National Park Service. PMIS 105313.
- Giese, G.S., T. L. Keon, and M. B. Adams, 2009, Science in Aid of a Community Adapting to an Unexpected New Tidal Inlet: Chatham Massachusetts. Proceedings of Coastal Zone 2009, Boston Massachusetts.
- Giese, Graham, Mark B. Adams, Theodore Keon and Stephen T. Mague, 2009. Observations of a Pre-migration Phase in a Natural Tidal Inlet Migration 'Cycle'. Northeast Beaches Conference, Northeast Shore and Beach Preservation Association, Woods Hole, September 21-23, 2009.
- Goldsmith, V., 1972, Coastal processes of a barrier island complex and adjacent ocean floor: Monomoy Island – Nauset Spit, Cape Cod, Massachusetts. Unpublished doctoral dissertation, Univ. Massachusetts, 469 p.
- Higgins, Frances, 2004, Drifting Memories, The Nauset Beach Camps on Cape Cod. Lower Cape Publishing, Orleans MA, 270 p.
- Hitchcock, E., 1841, Reports on the Geology of Massachusetts, v. I, J.S & C. Adams, Publisher, Amherst, Massachusetts.

Keon, Theodore, 2009, Early Assessment of the Development of a Two Inlet System, Cape Cod, MA. Northeast Beaches Conference, Northeast Shore and Beach Preservation Association, Woods Hole, September 21-23, 2009.

Liu, J., Stauble, D., Giese, G., and Aubrey, D., 1993, Morphodynamic evolution of a newly formed tidal inlet, *in* Aubrey, D., and Giese, G. (eds.), Formation and Evolution of Multiple Tidal Inlet Systems, AGU, Washington, DC, 237 p.

McClennen, C.E., 1979, Nauset Spit: model of cyclic breaching and spit regeneration during coastal retreat, *in* Leatherman, S.P., ed., Environmental Geologic Guide to Cape Cod National Seashore, Field Guide for the Eastern Section of the Society of Economic Paleontologists and Mineralogists, pp. 109-118.

Mitchell, H., 1871, Report concerning Nausett Beach and the Peninsula of Monomoy. Annual Report of the Director of the U.S. Coast Survey for 1871, pp. 134-143.

Stauble, D., 2001, Morphodynamic evaluation of a highly dynamic inlet to improve channel navigation: Chatham Harbor Massachusetts, USA, *in* Proceedings Coastal Dynamics '01, Lund, Sweden, p. 232-241.

Stauble, Donald K., Theodore Keon and William M. Kavanaugh, 2007. The Formation and Evolution of a New Breach at Chatham MA: Implications for Regional Sediment and Navigation Management in a Multiple Inlet System. U.S. Army Engineer Research and Development Center, Coastal and Hydraulics Laboratory. Northeast Shore and Beach Preservation Association, Woods Hole, September 2009

Roman, C., M. James-Pirri, and J. Heltshe. 2001. Monitoring Salt Marsh Vegetation: A Protocol for the Long-term Coastal Ecosystem Monitoring Program at Cape Cod National Seashore. USGS Patuxent Wildlife Research Center, University of Rhode Island, Narragansett, RI. 47pp.

U.S. Army Corps of Engineers, 1968, Survey Report: Pleasant Bay, Chatham, Orleans, Harwich, Massachusetts. New England Division, USACE, Waltham, MA, 61 p.

Weishar, L.L., Stauble, D. and Gingerich, K., 1989, A Study of the Effects of the New Breach at Chatham, Massachusetts. Reconnaissance Report to New England Division, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Weishar, L.L., Keon, T., and Stauble, K., 2007, Effects of large scale morphological changes to a back-barrier system, *in* Kraus, N., and Rosati, J. (eds.), Coastal Sediments '07, ASCE, Reston, VA, p. 814-827.

Zeigler, J.M., Tasha, H.J. and Giese, G.S., 1964, Erosion of the cliffs of outer Cape Cod: Tables and graphs. Woods Hole Oceanographic Institution, No. 64-21. Woods Hole, MA, 59 p.

APPENDICES

NPS and Cape Cod National Seashore policies pertaining to coastal change.

Cape Cod National Seashore (Seashore) has maintained a consistent management response to barrier beach changes throughout its 36-year tenure. The Seashore's General Management Plan articulates a policy of "...letting nature take its course." Where beach changes are accelerated by human activities such as structures and foot/vehicle traffic, "soft" coastal management measures are not unusual (sand fencing, beach grass planting).

CACO Enabling legislation:

Section 459 b-6, b. – "In order that the Seashore shall be permanently preserved in its present state, no development or plan for the convenience of visitors shall be undertaken therein which would be incompatible with the preservation of the unique flora and fauna or the physiographic conditions now prevailing..."

Section 459 b-6, c. – "The secretary shall not interfere with navigation of waters within the boundaries of the Cape Cod National Seashore by such means and in such areas as are now customary."

CACO General Management Plan Excerpts

Goal: Allow natural shoreline processes to take place unimpeded, while also counteracting human-caused disturbances.

Strategies: Inlet formation, overwash, dune migration and formation – criteria:

Allow all overwashes and blowouts to occur without human disturbances, except for minor intervention such as sand fencing and dune grass planting where there is evidence of human-induced impacts, with consideration of public safety.

Prevent artificial beach nourishment on NPS land and discourage beach nourishment on town and private land within the national seashore.

Prevent revetment of marine scarps on NPS land and discourage such activities on town and private land within the national seashore.

Monitor inlet formations, overwash, dune migration and formation and initiate follow-up actions on a case-by-case basis.

Where town and private lands are involved, the national seashore will assist in scientific analysis to plan ahead for natural shoreline changes that may affect public and private facilities or interests. Analysis may include participation in evaluating the problems, conducting research and predictive modeling, developing a full range of options, and generating possible mitigating actions. Where beach nourishment or revetment occurs on private or town land, the National

Park Service will work actively to minimize adverse effects on federal property and national seashore resources by attempting to influence the design and management of the project and its mitigations.

... the National Park Service will continue to discourage the deposition of dredge spoils on town and private lands within the national seashore, and it will not allow the deposition of such spoils on NPS lands due to the level of interference with natural coastal processes.

... no habitat alteration will be permitted and there will be no attempt to interfere with a progressive coastal erosion situation

[Public facilities and cultural resources threatened by coastal erosion criteria for management: Is the facility serving a core public use? Is the facility impeding a natural coastal process? Is extensive maintenance required to keep the facility safe and open to the public? Is it causing impacts to adjacent residences? Is there an alternative location available? Does the facility conform to relevant state and federal environmental laws?]

Overview of National Environmental Policy Act Process

The National Environmental Policy Act (NEPA) requires Federal agencies to engage in a public decision-making process that is based on a thorough and balanced alternatives analysis. As implemented by the NPS, the NEPA process for evaluating whether or not to fill a breach in a barrier beach system would likely proceed as follows:

Step:	Likely Duration:
Prepare Notice of Intent (NOI) to prepare an EIS and publish in the Federal Register	1 to 4 months
Public Scoping; initiated by publication of NOI in the Federal Register	*30 days
Prepare Draft EIS	9 months to 1.5 years depending on complexity and whether or not additional studies or modeling is needed
Public review and comment on DEIS; initiated by publication of a Notice of Availability in the Federal Register	*60 days
Respond to comments and prepare Final EIS	6 months
Waiting period to sign Record of Decision; initiated by publication of a Notice of Availability in the Federal Register	*30 days
Implementation can begin when a Notice of Availability for the Record of Decision is published in the Federal Register	2-6 weeks

times w/ * are set by regulation or NPS policy

As the nation's primary conservation agency, the Department of the Interior has responsibility for most of our nationally owned public land and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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