Handbook of Coastal Construction

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Chapter- 1

Artificial Island

An **artificial island** or **man-made island** is an island or archipelago that has been constructed by people rather than formed by natural means. They are created by expanding existing islets, construction on existing reefs, or amalgamating several natural islets into a bigger island.

Early artificial islands included floating structures in still waters, or wooden or megalithic structures erected in shallow waters (e.g., crannógs and Nan Madol discussed below). In modern times artificial islands are usually formed by land reclamation, but some are formed by the incidental isolation of an existing piece of land during canal construction (e.g. Donauinsel and Dithmarschen), or flooding of valleys resulting in the tops of former knolls getting isolated by water (e.g. Barro Colorado Island).

Some recent developments have been made more in the manner of oil platforms (e.g., Sealand and Republic of Rose Island).

Artificial islands may vary in size from small islets reclaimed solely to support a single pillar of a building or structure, to those that support entire communities and buildings.

History

Despite a popular image of modernity, artificial islands actually have a long history in many parts of the world, dating back to the crannogs of prehistoric Scotland and Ireland, the ceremonial centers of Nan Madol in Micronesia and the still extant floating islands of Lake Titicaca. The city of Tenochtitlan, the Aztec predecessor of Mexico City that was home to 250,000 people when the Spaniards arrived, stood on a small natural island in Lake Texcoco that was surrounded by countless artificial *chinamitl* islands.

Many artificial islands have been built in urban harbors to provide either a site deliberately isolated from the city or just spare real estate otherwise unobtainable in a crowded metropolis. An example of the first case is Dejima (or *Deshima*), built in the bay of Nagasaki in Japan's Edo period as a contained center for European merchants. During the isolationist era, Dutch people were generally banned from Nagasaki and Japanese from Dejima. Similarly, Ellis Island, in Upper New York Bay beside New York City, a former tiny islet greatly expanded by land reclamation, served as an isolated immigration center for the United States in the late 19th and early 20th century, preventing an escape

to the city of those refused entry for disease or other perceived flaws, who might otherwise be tempted toward illegal immigration. One of the most well-known artificial islands is the Île Notre-Dame in Montreal, built for Expo 67.

The Venetian Islands in Miami Beach, Florida, in Biscayne Bay added valuable new real estate during the Florida land boom of the 1920s. When the bubble that the developers were riding burst, the bay was left scarred with the remnants of their failed project. A boom town development company was building a sea wall for an island that was to be called Isola di Lolando but could not stay in business after the 1926 Miami Hurricane and the Great Depression, dooming the island-building project. The concrete pilings from the project still stand as another development boom roared around them, 80 years later.

Dejima, not allowed direct contact with nearby Nagasaki

Eighty-year-old sea wall pilings from the failed Isola di Lolando construction project in Miami Beach, Florida

Our Lady of the Rocks (*Gospa od Škrpjela*) in Montenegro

Modern projects

In 1969, the Flevopolder in the Netherlands was finished, as part of the Zuiderzee Works. This island consists of the polders Eastern Flevoland and Southern Flevoland, and has a total land surface of 970 km², which makes it the largest artificial island in the world.

Kansai International Airport is the first airport to be built completely on an artificial island in 1994, followed by Chūbu Centrair International Airport in 2005 and the New Kitakyushu Airport and Kobe Airport in 2006. When Hong Kong International Airport opened in 1998, 75% of the property was created using Land reclamation upon the existing islands of Chek Lap Kok and Lam Chau.

In Mumbai, the present Salsette Island was formerly made up of several smaller islands, which were joined together during 1782-1838 through the Hornby Vellard project to form a single island. Many of the hills were cut down and used to enlarge the island by filling in the shallows and to link the islands to one another.

Dubai is home to several artificial islands projects, including the three Palm Islands projects, The World and the Dubai Waterfront. Only the Palm Jumeirah is inhabited so far.

The Flevopolder in the Netherlands is the largest artificial island in the world

A view of Kansai International Airport from space

Palm Jumeirah in Dubai

Northstar Island, an artificial island for oil drilling in the Beaufort Sea

Political status

Under the United Nations Convention on the Law of the Sea treaty (UNCLOS), artificial islands are not considered harbor works (Article 11) and are under the jurisdiction of the nearest coastal state if within 200 nautical miles (370 km) (Article 56). Artificial islands are not considered islands for purposes of having their own territorial waters or exclusive economic zones, and only the coastal state may authorize their construction (Article 60). However, on the high seas beyond national jurisdiction, any "state" may construct artificial islands (Article 87).

Chapter- 2

Beach Hut

Beach cabins in Knokke (Belgium)

A **beach hut** (also known as a **beach cabin** or **bathing box**) is a small, usually wooden and often brightly coloured, box above the high tide mark on popular bathing beaches. They are generally used as a shelter from the sun or wind, changing into and out of swimming costumes and for the safe storing of some personal belongings. Some beach huts incorporate simple facilities for preparing food and hot drinks by either bottled gas or occasionally mains electricity.

Beach huts at Southwold, Suffolk.

Beach huts at Aspendale, Victoria.

Beach huts, Coldingham, Scottish Borders

Locations

Beach huts in front of modern housing development, Wimereux, France

At many seaside resorts, beach huts are arranged in one or more ranks along the top of the beach. Depending upon the location, beach huts may be owned privately or may be owned by the local council or similar administrative body. On popular beaches, privately owned beach huts can command substantial prices due to their convenient location, out of all proportion to their size and amenity. A pre-war wooden beach chalet at West Bexington, Dorset sold at auction for £216,000 in 2006, and beach huts on Mudeford Spit reached £140,000. However these were unusual as in both cases overnight stays were possible. Prices in 2009 for typical huts around the UK ranged from £6,000 in Walton on the Naze to £130,000 for those at Mudeford.

Today there are believed to be around 20,000 beach huts in the U.K. Locations where beach huts can be seen include Lowestoft, Southwold, Walton-on-the-Naze, Abersoch, Langland Bay, Rotherslade, Rustington, St Helens, Isle of Wight, and Mersea Island. Locations in other countries include Wimereux, France, and Brighton and elsewhere around Port Phillip, Australia.

The colourful bathing boxes in the Melbourne suburb of Brighton are a tourist icon of the city. Middle Brighton pier and the city skyline are visible in the background

History

Beach huts at Great Yarmouth, Norfolk

The noted bathing boxes at Brighton in Australia are known to have existed as far back as 1862. The bathing boxes are thought to have been constructed and used largely as a response to the Victorian morality of the age, and are known to have existed not only in Australia but also on the beaches of England, France and Italy at around the same time.

They had evolved from the wheeled bathing machines used by Victorians to preserve their modesty. George III used a bathing machine at Mudeford in 1801, while Queen Victoria installed one at Osbourne House on the Isle of Wight in the 1840s.

In the early 20th century, beach huts were regarded as "holiday homes for the toiling classes", but in the 1930s their image revived, George V and Queen Mary spent the day at a beach hut in Sussex, and other owners have included the Spencer family and Sir Laurence Olivier.. During World War II all UK beaches were closed, the reopening in the late 1940s and 1950s led to resurgence of the British beach holiday and the heyday of the Beach Hut.

While many beach huts were former fishermen's huts, boatsheds or converted bathing machines some of the earliest purpose built beach huts in the UK were erected at Bournemouth, either side of Bournemouth Pier in around 1908 or 1909. Designed by F. P. Dolamore, Bournemouth's Borough Engineer, they were offered for hire for £12 10s per year. 160 huts, or bungalows as they were styled, were initially built before the first world war. The Council believes that some of the original 1909 huts are still standing, although the majority were renewed in the 1950s and 1960s. Today, Bournemouth features around 520 huts owned by the Council, There are in addition a further 1200 privately owned huts. They vary in style from the traditional, wooden, shed-like constructions to the ultra modern, concrete terrace style huts such as the 1950s Overstrand beach huts at Boscombe. These were renovated to designs by Wayne and Gerardine Hemingway, founders of the Red or Dead label, as Beach Pods for the Surf Reef opened in Autumn 2009.

Notable huts

The Queen's beach hut in Norfolk was destroyed by fire in 2003. The building had been owned by the Royal Family for 70 years and was known to be much loved by the Queen. More recently the artist, Tracey Emin, sold her Whitstable beach hut to the collector, Charles Saatchi, for £75,000. This hut was also destroyed by fire when the warehouse where it was stored burnt down.

Chapter- 3

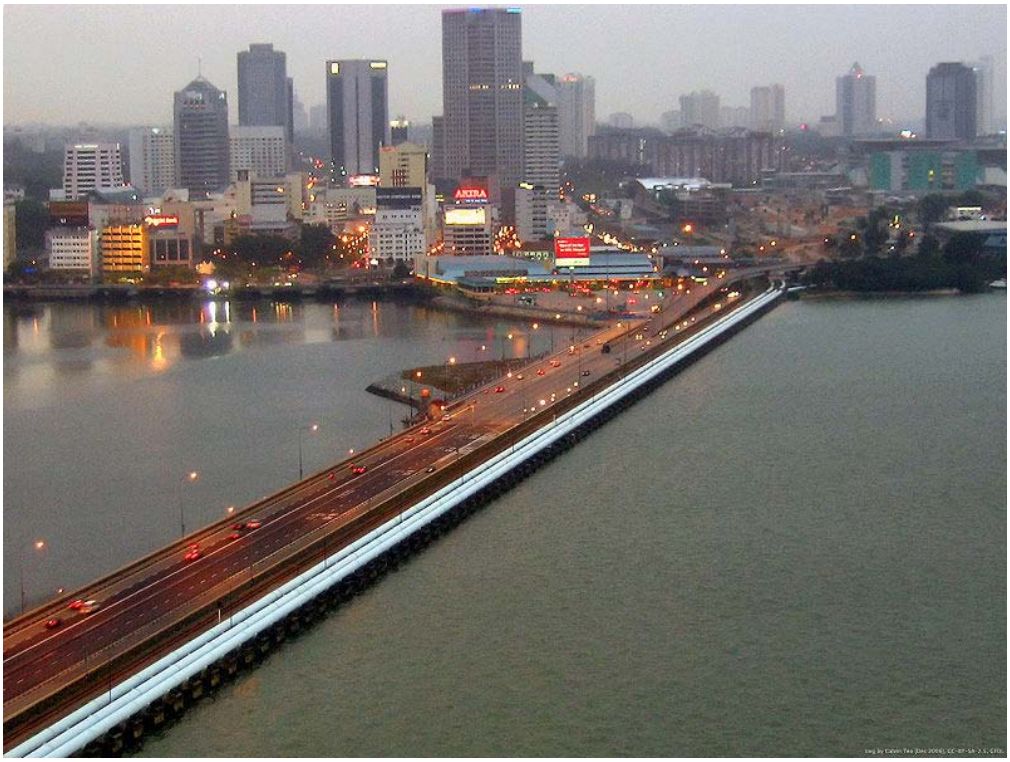
Causeway

Causeway

The *Hindenburgdamm Rail Causeway* across the Wadden Sea to the island of Sylt in Schleswig-Holstein, Germany

Carries	Traffic, Rail
Material	Concrete, Masonry, Earth-fill
Movable	No
Design effort	medium
Falsework required	No

The causeway to Antelope Island in the Great Salt Lake, Utah, USA



The Johor-Singapore Causeway is an important road which connects Singapore to Malaysia.

The Sorell Causeway in Tasmania, Australia

Lake Pontchartrain Causeway bridge in New Orleans.

The Julia Tuttle Causeway, one of the major arteries connecting the cities of Miami and Miami Beach in Florida.

Causeway across Colwyn Bay Beach, Wales, United Kingdom

In modern usage, a **causeway** is a road or railway elevated, usually across a broad body of water or wetland.

Etymology

When first used, the word appeared in a form such as “causey way” making clear its derivation from the earlier form “causey”. This word seems to have come from the same source by two different routes. It derives ultimately, from the Latin for heel, *calx*, and most likely comes from the trampling technique to consolidate earthworks. Anciently, the construction was trodden down, one layer at a time, often by slaves or flocks of sheep. Today, this work is done by machines. The same technique would have been used for road embankments, raised river banks, sea banks and fortification earthworks. (The layers, though not the trampling action, can be seen in the Bayeux Tapestry: Building Hastings Castle.)

The second derivation route is simply the hard, trodden surface of a path. The name by this route came to be applied to a firmly-surfaced road. It is now little-used except in dialect and in the names of roads which were originally notable for their solidly-made surface.

The word is comparable in both meanings with the French *chaussée*, from a form of which it reached English by way of Norman French. The French adjective, *chaussée*, carries the meaning of having been given a hardened surface, and is used to mean either paved or shod. As a noun *chaussée* is used on the one hand for a metalled carriageway, and on the other for an embankment with or without a road. Other languages have a noun with similar dual meaning. In Welsh, it is *sarn*. The Welsh is relevant here, as it also has a verb, *sarnu*, meaning to trample. The trampling and ramming technique for consolidating earthworks was used in fortifications and there is a comparable, outmoded form of wall construction technique, used in such work and known as pisé, a word derived not from trampling but from ramming or tamping.

A transport corridor that is carried instead on a series of arches, perhaps approaching a bridge, is a viaduct. In the U.S. a short stretch of viaduct is called an overpass. The distinction between the terms *causeway* and *viaduct* becomes blurred when flood-relief culverts are incorporated, though generally a causeway refers to a roadway supported mostly by earth or stone, while a bridge supports a roadway between piers (which may be embedded in embankments). Some low causeways across shore waters become inaccessible when covered at high tide.

Engineering

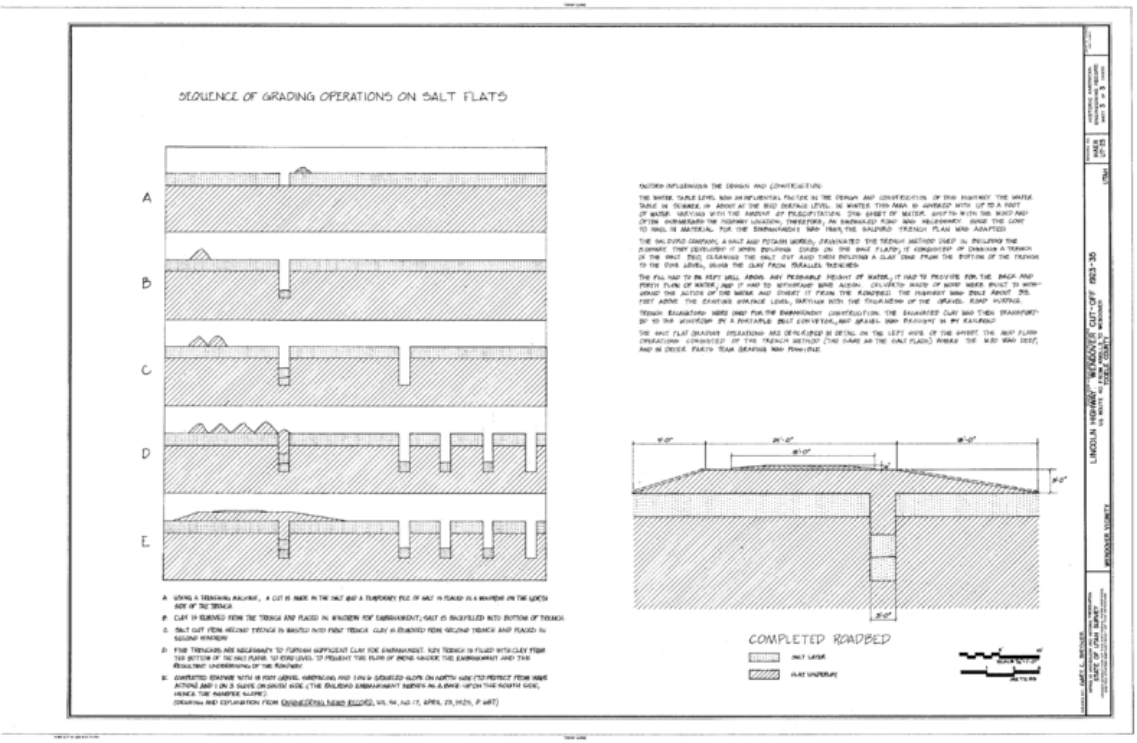


Diagram showing how the Wendover Cut-off was built across salt flats in the early 1920s

The modern embankment may be constructed within a *cofferdam*: two parallel steel sheet pile or concrete retaining walls, anchored to each other with steel cables or rods. This construction may also serve as a dyke that keeps two bodies of water apart, such as bodies with a different water level on each side, or with salt water on one side and fresh water on the other. This may also be the primary purpose of a structure, the road providing a hardened crest for the dike, slowing erosion in the event of an overflow. It also provides access for maintenance as well perhaps, as a public service.

Examples

Notable causeways include those that connect Singapore and Malaysia (the Johor-Singapore Causeway), Bahrain and Saudi Arabia (25-km long King Fahd Causeway) and Venice to the mainland, all of which carry roadways and railways. In the Netherlands there are a number of prominent dykes which also double as causeways, including the Afsluitdijk, Brouwersdam, and Markerwaarddijk. In Louisiana, two very long bridges, called the Lake Pontchartrain Causeway, stretch across Lake Pontchartrain for almost 38 km, making them the world's longest bridges (if total length is considered instead of span length). They are also the oldest causeways on the Gulf Coast that have never been put out of commission for an extended period of time following a Hurricane. In the Republic of Panama a causeway connects the islands of Perico, Flamenco, and Naos to Panama City on the mainland. It also serves as a breakwater for ships entering the Panama Canal. The Aztec city-state of Tenochtitlan had causeways supporting roads and aqueducts. The oldest engineered road yet discovered is the Sweet Track in England, dating from the 3800s BC.

Causeways are also common in Florida, where low bridges may connect several man-made islands, often with a much higher bridge (or part of a single bridge) in the middle so that taller boats may pass underneath safely. Causeways are most often used to connect the barrier islands with the mainland.

The Churchill Barriers in Orkney are of the most notable sets of causeways in Europe. Constructed in waters up to 18 metres deep, the four barriers link five islands on the eastern side of the natural harbour at Scapa Flow. They were built during World War II as military defences for the harbour, on the orders of Winston Churchill.

Specific causeways around the world

Various causeways in the world:

- Canso Causeway, Nova Scotia, Canada (45°38′39″N 61°25′06″W / 45.6443°N 61.4184°W)
- Hindenburgdamm, Germany (54°53′07″N 8°32′25″E / 54.8852°N 8.5404°E)
- Johor-Singapore Causeway (1°27′07″N 103°46′12″E / 1.4520°N 103.7700°E)
- Lake Ponchartrain, Louisiana (30°11′51″N 90°07′14″W / 30.1974°N 90.1205°W)

- Bahrain, Saudi Arabia (26°11′03″N 50°19′27″E / 26.1841°N 50.3241°E)
- Venice (45°27′13″N 12°17′56″E / 45.4535°N 12.2990°E)
- Mahim Causeway, Mumbai, India 19°02′55″N 72°50′17″E / 19.04871°N 72.83816°E
- Swarkestone causeway, derby
- Causeway across Haraldssund, Faroe Islands
- Causeway across Hvannasund, Faroe Islands

Precautions

Causeways affect currents and may therefore be involved in beach erosion or changed deposition patterns; this effect has been a problem at the Hindenburgdamm in northern Germany. During hurricane seasons, the winds and rains of approaching tropical storms--as well as waves generated by the storm in the surrounding bodies of water--make traversing causeways problematic at best and impossibly dangerous during the fiercest parts of the storms. For this reason (and related reasons, such as the need to minimize traffic jams on both the roads approaching the causeway and the causeway itself), emergency evacuation of island residents is a high priority for local, regional, and even national authorities.

Boaters should be aware that a causeway may represent a permanent barrier dividing two sections of water and are not as visible from the water as bridges and other landmarks.

Chapter- 4

Coastal Management

Oosterscheldekering sea wall, the Netherlands

In some jurisdictions the terms **sea defense** and **coastal protection** are used to mean, respectively, defense against flooding and erosion. The term *coastal defence* is the more traditional term, but *coastal management* has become more popular as the field has expanded to include techniques that allow erosion to claim land.

Historical background

Coastal engineering, as it relates to harbours, starts with the development of ancient civilizations together with the origin of maritime traffic, perhaps before 3500 B.C.

Docks, breakwaters, and other harbour works were built by hand and often in a grand scale.

Some of the harbour works are still visible in a few of the harbours that exist today, while others have recently been explored by underwater archaeologists. Most of the grander ancient harbor works have disappeared following the fall of the Roman Empire.

Most ancient coastal efforts were directed to port structures, with the exception of a few places where life depended on coastline protection. Venice and its lagoon is one such case. Protection of the shore in Italy, England and the Netherlands can be traced back at least to the 6th century. The ancients understood such phenomena as the Mediterranean currents and wind patterns and the wind-wave cause-effect link.

The Romans introduced many revolutionary innovations in harbor design. They learned to build walls underwater and managed to construct solid breakwaters to protect fully exposed harbors. In some cases wave reflection may have been used to prevent silting. They also used low, water-surface breakwaters to trip the waves before they reached the main breakwater. They became the first dredgers in the Netherlands to maintain the harbour at Velsen. Silting problems here were solved when the previously sealed solid piers were replaced with new "open"-piled jetties. The Romans also introduced to the world the concept of the holiday at the coast.

Middle Age

The threat of attack from the sea caused many coastal towns and their harbours to be abandoned. Other harbours were lost due to natural causes such as rapid silting, shoreline advance or retreat, etc. The Venetian Lagoon was one of the few populated coastal areas with continuous prosperity and development where written reports document the evolution of coastal protection works. Engineering and scientific skills remained alive in the east, in Byzantium, where the Eastern Roman Empire survived for six hundred years while Western Rome decayed.

Modern Age

Leonardo da Vinci could be considered the precursor of coastal engineering science, offering ideas and solutions often more than three centuries ahead of their common acceptance. Although great strides were made in the general scientific arena, little improvement was done beyond the Roman approach to harbour construction after the Renaissance. In the early 19th century, the advent of the steam engine, the search for new lands and trade routes, the expansion of the British Empire through her colonies, and other influences, all contributed to the revitalization of sea trade and a renewed interest in port works.

Twentieth century

Evolution of shore protection and the shift from structures to beach nourishment. Prior to the 1950s, the general practice was to use hard structures to protect against beach erosion or storm damages. These structures were usually coastal armoring such as seawalls and revetments or sand-trapping structures such as groynes. During the 1920s and '30s, private or local community interests protected many areas of the shore using these techniques in a rather ad hoc manner. In certain resort areas, structures had proliferated to such an extent that the protection actually impeded the recreational use of the beaches. Erosion of the sand continued, but the fixed back-beach line remained, resulting in a loss of beach area. The obtrusiveness and cost of these structures led in the late 1940s and early 1950s, to move toward a new, more dynamic, method. Projects no longer relied solely on hard coastal defence structures, as techniques were developed which replicated the protective characteristics of natural beach and dune systems. The resultant use of artificial beaches and stabilized dunes as an engineering approach was an economically viable and more environmentally friendly means for dissipating wave energy and protecting coastal developments.

Over the past hundred years the limited knowledge of coastal sediment transport processes at the local authorities level has often resulted in inappropriate measures of coastal erosion mitigation. In many cases, measures may have solved coastal erosion locally but have exacerbated coastal erosion problems at other locations -up to tens of kilometers away- or have generated other environmental problems.

Current challenges in coastal management

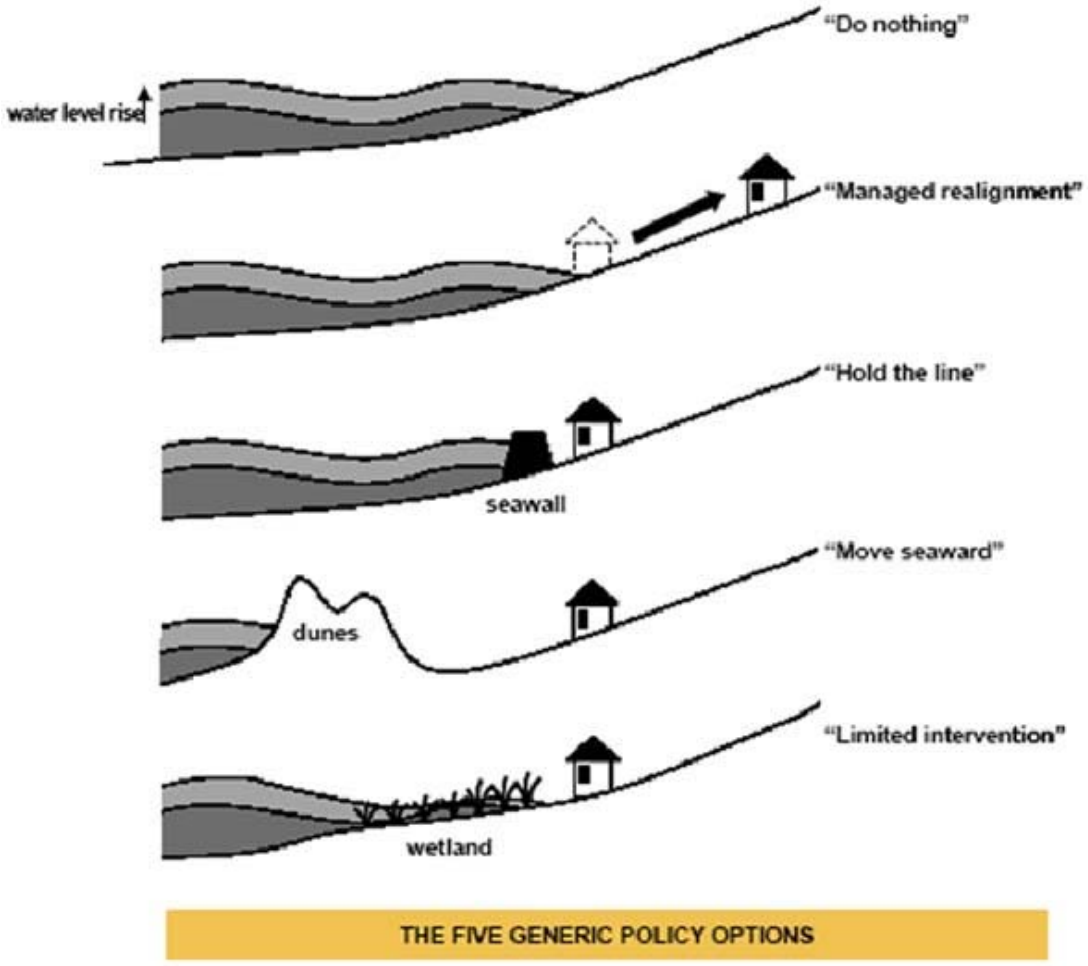
The coastal zone is a dynamic area of natural change and of increasing human use. They occupy less than 15% of the Earth's land surface; yet accommodate more than 50% of the world population (it is estimated that 3.1 billion people live within 200 kilometres from the sea). With three-quarters of the world population expected to reside in the coastal zone by 2025, human activities originating from this small land area will impose an inordinate amount of pressures on the global system. Coastal zones contain rich resources to produce goods and services and are home to most commercial and industrial activities. In the European Union, almost half of the population now lives within 50 kilometres of the sea and coastal zone resources produce much of the Union's economic wealth. The fishing, shipping and tourism industries all compete for vital space along Europe's estimated 89 000 kilometres of coastline, and coastal zones contain some of Europe's most fragile and valuable natural habitats. Shore protection consists up to the 50's of interposing a static structure between the sea and the land to prevent erosion and or flooding, and it has a long history. From that period new technical or friendly policies have been developed to preserve the environment when possible. Is already important where there are extensive low-lying areas that require protection. For instance: Venice, New Orleans, Nagara river in Japan, Holland, Caspian Sea

Protection against the sea level rise in the 21st century will be especially important, as sea level rise is currently accelerating. This will be a challenge to coastal management, since

seawalls and breakwaters are generally expensive to construct, and the costs to build protection in the face of sea-level rise would be enormous.

Changes on sea level have a direct adaptative response from beaches and coastal systems, as we can see in the succession of a lowering sea level. When the sea level rises, coastal sediments are in part pushed up by wave and tide energy, so sea-level rise processes have a component of sediment transport landwards. This results in a dynamic model of rise effects with a continuous sediment displacement that is not compatible with static models where coastline change is only based on topographic data.

Planning approaches



Five general coastal management strategies

There are five generic strategies for coastal defense:

- inaction leading to eventual abandonment

- Managed retreat or realignment, which plans for retreat and adopts engineering solutions that recognise natural processes of adjustment, and identifies a new line of defence where to construct new defences
- Hold the line, shoreline protection, whereby seawalls are constructed around the coastlines
- Move seawards, by constructing new defenses seaward the original ones
- Limited intervention, accommodation, by which adjustments are made to be able to cope with inundation, raising coastal land and buildings vertically

The decision to choose a strategy is site-specific, depending on pattern of relative sea-level change, geomorphological setting, sediment availability and erosion, as well a series of social, economic and political factors.

Alternatively, integrated coastal zone management approaches may be used to prevent development in erosion- or flood-prone areas to begin with. Growth management can be a challenge for coastal local authorities who often struggle to provide the infrastructure required by new residents seeking seachange lifestyles. Sustainable transport investment to reduce the average footprint of coastal visitors is often a good way out of coastal gridlock. Examples include Dongtan and the Gold Coast Oceanway.

Do nothing

The 'do nothing' option, involving no protection, is a cheap and expedient way to let the coast take care of itself. It involves the abandonment of coastal facilities when they are subject to coastal erosion, and either gradually landward retreat or evacuation and resettlement elsewhere. This option is very environmental friendly and the only pollution produced is from the resettlement process. However it does mean losing a lot of land to the sea and people will lose their houses and their homes.

Managed retreat

Managed retreat is an alternative to constructing or maintaining coastal structures. Managed retreat allows an area that was not previously exposed to flooding by the sea to become flooded. This process is usually in low lying estuarine or deltaic areas and almost always involves flooding of land that has at some point in the past been reclaimed from the sea. Managed retreat is often a response to a change in sediment budget or to sea level rise. The technique is used when the land adjacent to the sea is low in value. A decision is made to allow the land to erode and flood, creating new sea, inter-tidal and salt-marsh habitats. This process may continue over many years and natural stabilization will occur.

The earliest managed retreat in the UK was an area of 0.8 ha at Northey Island in Essex, that was flooded in 1991. This was followed by Tollesbury and Orplands in Essex, where the sea walls were breached in 1995. In the Ebro delta (Spain) coastal authorities have planned a managed retreat in response to coastal erosion (MMA 2005, Sitges, Meeting on Coastal Engineering; EUROSION project).

Cost – The main cost is generally the purchase of land to be flooded. Housings compensation for relocation of residents may be needed. Any other human made structure which will be engulfed by the sea may need to be safely dismantled to prevent sea pollution. In some cases, a retaining wall or bund must be constructed inland in order to protect land beyond the area to be flooded, although such structures can generally be lower than would be needed on the existing coast. Monitoring of the evolution of the flooded area is another cost. Costs may be lowest if existing defenses are left to fail naturally, but often the realignment project will be more actively managed, for example by creating an artificial breach in existing defences to allow the sea in at a particular place in a controlled fashion, or by pre-forming drainage channels for created salt-marsh.

Hold the line

Human strategies on the coast have been heavily based on a static engineered response, whereas the coast is in, or strives towards, a dynamic equilibrium (Schembri, 2009). Solid coastal structures are built and persist because they protect expensive properties or infrastructures, but they often relocate the problem downdrift or to another part of the coast. Soft options like beach nourishment, while also being temporary and needing regular replenishment, appear more acceptable, and go some way to restore the natural dynamism of the shoreline. However in many cases there is a legacy of decisions that were made in the past which have given rise to the present threats to coastal infrastructure and which necessitate immediate shore protection. For instance, the seawall and promenade of many coastal cities in Europe represents a highly engineered use of prime seafront flange-eating space, which might be preferably designated as public open space, parkland and amenities if it were available today. Such open space might also allow greater flexibility in terms of future land-use change, for instance through managed retreat, in the face of threats of erosion or inundation as a result of sea-level rise. Foredunes areas represent a natural reserve which can be called upon in the face of extreme events; building on these areas leaves little option but to undertake costly protective measures when extreme events (whether amplified by gradual global change or not) threaten. Managed retreat can comprise 'setbacks', rolling easements and other planning tools including building within a particular design life. Maintenance of those structures or soft techniques can arrive at a critical point (economically or environmental) to change adopted strategy.

- Structural or hard engineering techniques, i.e. using permanent concrete and rock constructions to "fix" the coastline and protect the assets locate behind. These techniques--seawalls, groynes, detached breakwaters, and revetments--represent a significant share of protected shoreline in Europe (more than 70%).

- Soft engineering techniques (e.g. sand nourishments), building with natural processes and relying on natural elements such as sands, dunes and vegetation to prevent erosive forces from reaching the backshore. These techniques include beach nourishment and sand dune stabilization.

Move seaward

The futility of trying to predict future scenarios where there is a large human influence is apparent. Even future climate is to a certain extent a function of what humans choose to make of it, for example by restricting greenhouse gas emissions to control climate change. In some cases - where new areas are needed for new economic or ecological development - a move seaward strategy can be adopted. Some examples from EUROSION are: Koge Bay (Dk) Western Scheldt estuary (NI), Chatelaillon (F), Ebro delta (E)

There is an obvious downside to this strategy. Coastal erosion is already widespread, and there are many coasts where exceptional high tides or storm surges result in encroachment on the shore, impinging on human activity. If the sea rises, many coasts that are developed with infrastructure along or close to the shoreline will be unable to accommodate erosion, and will experiment a so-called "coastal squeeze". This occurs where the ecological or geomorphological zones that would normally retreat landwards encounter solid structures and are squeezed out. Wetlands, salt marshes, mangroves and adjacent fresh water wetlands are particularly likely to suffer from this squeeze.

An upside to the strategy is that moving seaward (and upward) can create land of high value which can bring the investment required to cope with climate change.

Limited intervention

Limited intervention is an action taken whereby the management only solves the problem to some extent, usually in areas of low economic significance. Measures taken using limited intervention often encourage the succession of haloseres, including salt marshes and sand dunes. This will normally result in the land behind the halosere being more sufficiently protected, as wave energy will be dissipated by the accumulated sediment and additional vegetation residing in the newly formed habitat. Although the new halosere is not strictly man-made, as many natural processes will contribute to the succession of the halosere, anthropogenic factors are partially responsible for the formation as an initial factor was needed to help start the process of succession. This must not be confused with 'accommodate' which is about property e.g. effective insurance, early warning systems and not about habitat.

Construction techniques

The following is a catalogue of relevant techniques that could be employed as coastal management techniques. *The costs given are very rough estimates made during 2005, based on UK Pound sterling.*

Hard Engineering methods

Groynes

Groyne at Mundesley, Norfolk, UK

Groynes are wooden often made of greenhart, concrete and/or rock barriers or walls perpendicular to the sea. Beach material builds up on the updrift side, where littoral drift is predominantly in one direction, creating a wider and a more plentiful beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. However, there is a corresponding loss of beach material on the downdrift side, requiring that another groyne to be built there. Moreover, groynes do not protect the beach against storm-driven waves and if placed too close together will create currents, which will carry sand material offshore.

Groynes are extremely cost-effective coastal defence measures, requiring little maintenance, and are one of the most common coastal defence structures. However, groynes are increasingly viewed as detrimental to the aesthetics of the coastline, and face strong opposition in many coastal communities.

Many experts consider groynes to be a "soft" solution to coastal erosion because of the enhancement of the existing beach.

But groyne construction creates a problem known as Terminal Groyne Syndrome. The terminal groyne prevents longshore drift from bringing material to other nearby places.

This is a common problem along the Hampshire and Sussex coastline in the UK; a perfect example is Worthing.

Sea walls

Walls of concrete or rock, built at the base of a cliff or at the back of a beach, or used to protect a settlement against erosion or flooding. Older style vertical seawalls reflected all the energy of the waves back out to sea, and for this purpose were often given recurved crest walls which also increase the local turbulence, and thus increasing entrainment of sand and sediment. During storms, sea walls help longshore drift

Modern seawalls aim to destroy most of the incident energy, resulting in low reflected waves and much reduced turbulence and thus take the form of sloping revetments. Current designs use porous designs of rock, concrete armour (Seabees, SHEDs, Xblocs) with intermediate flights of steps for beach access, whilst in places where high rates of pedestrian access are required, the steps take over the whole of the frontage, but at a flatter slope if the same crest levels are to be achieved.

Care needs to be taken in the location of a seawall, particularly in relation to the swept prism of the beach profile, the consequences of long term beach recession and amenity crest level. These factors must be considered in assessing the cost benefit ratio, which must be favorable in order to justify construction of a seawall.

Sea walls can cause beaches to dissipate rendering them useless for beach goers. Their presence also scars the very landscape that they are trying to save.

Modern examples can be found at Cronulla (NSW, 1985-6), Blackpool (1986–2001), Lincolnshire (1992–1997) & Wallasey (1983–1993). The sites at Blackpool and Cronulla can be visited both by Google Earth and by local webcams (Cronulla, Cleveleys).

A most interesting example is the seawall at Sandwich, Kent, where the Seabee seawall is buried at the back of the beach under the shingle with crest level at road kerb level.

Sea walls are probably the second most traditional method used in coastal management.

Revetments

Wooden slanted or upright blockades, built parallel to the sea on the coast, usually towards the back of the beach to protect the cliff or settlement beyond. The most basic revetments consist of timber slants with a possible rock infill. Waves break against the revetments, which dissipate and absorb the energy. The cliff base is protected by the beach material held behind the barriers, as the revetments trap some of the material. They may be watertight, covering the slope completely, or porous, to allow water to filter through after the wave energy has been dissipated. Most revetments do not significantly interfere with transport of longshore drift. Since the wall greatly absorbs the energy instead of reflecting, it erodes and destroys the revetment structure; therefore, major

maintenance will be needed within a moderate time of being built, this will be greatly determined by the material the structure was built with and the quality of the product.

The *Cost* – Confirmed by material used; est. $2340 – $4000. Average $10 per meter built.

Rock armour

Also known as riprap, rock armour is large rocks piled or placed at the foot of dunes or cliffs with native stones of the beach. This is generally used in areas prone to erosion to absorb the wave energy and hold beach material. Although effective, this solution is unpopular due to the fact that it is unsightly. Also, longshore drift is not hindered. Rock armour has a limited lifespan, it is not effective in storm conditions, and it reduces the recreational value of a beach. The cost is around £300 per metre, depending on the type of rocks used.

Gabions

Boulders and rocks are wired into mesh cages and usually placed in front of areas vulnerable to heavy erosion: sometimes at cliffs edges or jag out at a right angle to the beach like a large groyne. When the seawater breaks on the gabion, the water drains through leaving sediments, also the rocks and boulders absorb a moderate amount of the wave energy.

Gabions need to be securely tied to prevent abrasion of wire by rocks, or detachment of plastic coating by stretching. Hexagonal mesh distributes overloads better than rectangular mesh.

Downsides include wear rates and visually intrusiveness.

Cost – est. £11 per m

Offshore breakwater

Enormous concrete blocks and natural boulders are sunk offshore to alter wave direction and to filter the energy of waves and tides. The waves break further offshore and therefore reduce their erosive power. This leads to wider beaches, which absorb the reduced wave energy, protecting cliff and settlements behind. The Dolos which was invented by a South African engineer in East London has replaced the use of enormous concrete blocks because the dolos is much more resistant to wave action and requires less concrete to produce a superior result. Similar concrete objects like the Dolos are the A-jack, Akmon, Xbloc and the Tetrapod, Accropode.

Cost – est. £1,950 per m. Water depth may increase the cost.

Cliff stabilization

Cliff stabilization can be accomplished through drainage of excess rainwater of through terracing, planting, and wiring to hold cliffs in place. Cliff drainage is used to hold a cliff together using plants, fences and terracing, this is used to help prevent landslides and other natural disasters.

Entrance training walls

Rock or concrete walls built to constrain a river or creek discharging across a sandy coastline. The walls help to stabilise and deepen the channel which benefits navigation, flood management, river erosion and water quality but can cause coastal erosion due to the interruption of longshore drift. One solution is the installation of a sand bypassing system to pump sand under and around the entrance training walls.

Cost – Expensive - Gold Coast Seaway was a A$50M project in the 1980s and the adjacent sand bypassing project costs A$3M per year to pump 500,000 cubic meters of sand across the trained entrance.

Floodgates

Storm surge barriers, or floodgates, were introduced after the North Sea Flood of 1953 and are a prophylactic method to prevent damage from storm surges. They are habitually open and allow free passage, but close when the land is under threat of a storm surge. The Thames Barrier is an example of such a structure.

Soft Engineering methods

Beach nourishment

Beach nourishment or replenishment is one of the most popular soft engineering techniques of coastal defence management schemes. This involves importing alien sand off the beach and piling it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so it can integrate with the natural processes occurring there, without causing any adverse effects. Beach nourishment can be used alongside the groyne schemes. The scheme requires constant maintenance: 1 to 10 year life before first major recharge. *Cost* – est. £5,000-£200,000 per 100 metre, plus control structures, ongoing management and minor works.

Sand dune stabilization

Vegetation can be used to encourage dune growth by trapping and stabilising blown sand.

Cost – est. of £1.1 million per annum

Beach drainage

Beach drainage or beach face dewatering lowers the water table locally beneath the beach face. This causes accretion of sand above the drainage system.

Grant (1946) – the elevation of the beach watertable had an important bearing on deposition and erosion across the foreshore. A high watertable coincided with periods of accelerated beach erosion, and conversely, a low watertable coincided with pronounced aggradation of the foreshore A lower watertable (unsaturated beach face) facilitates deposition by reducing flow velocities during backwash and prolonging laminar flow. In contrast, a high watertable results in condition favoring beach erosion. With the beach in a saturated state, Grant proposed that backwash velocity is accelerated by the addition of groundwater seepage out of the beach within the effluent zone.

Turner and Leatherman (1997) moving from the origins and development of the dewatering concept to field and laboratory studies available at the time of writing concluded that there was too little evidence for being convinced that the systems had a positive effect. None of the case studies provide full scientific evidence of undisputable positive results regarding beach stabilisation although in some cases an overall positive performance was reported. In many cases no adequate long-term monitoring was undertaken at a frequency high enough to discriminate the response to high energy erosive events.

A useful side effect of the system is that the collected seawater is very pure because of the sand filtration effect. It may be discharged back to sea but can also be used to oxygenate stagnant inland lagoons /marinas or used as feed for heat pumps, desalination plants, land-based aquaculture, aquariums or seawater swimming pools.

Beach drainage systems have been installed in many locations around the world to halt and reverse erosion trends in sand beaches. Twenty four beach drainage systems have been installed since 1981 in Denmark, USA, UK, Japan, Spain, Sweden, France, Italy and Malaysia.

Costs

The costs of installation and operation per meter of shoreline protection will vary due to

- system length (non-linear cost elements)
- pump flow rates (sand permeability, power costs)
- soil conditions (presence of rock or impermeable strata)
- discharge arrangement /filtered seawater utilization
- drainage design, materials selection & installation methods
- geographical considerations (location logistics)
- regional economic considerations (local capabilities /costs)
- study requirements /consent process.

The costs associated with a beach drainage system are generally considerably lower than hard engineered structures. They also compare very favorably with beach nourishment projects, particularly when long-term project economics are considered (nourishment projects often have a limited life or a program of re-nourishment).

Monitoring coastal zones

Coastal zone managers are faced with difficult and complex choices about how best to reduce property damage in the shorelines. One of the problems they face is error and uncertainty in the information available to them on the processes that cause erosion of beaches. Video-based monitoring lets collect data continuously at low cost and produce analyses of shoreline processes over a wide range of averaging intervals.

Event warning systems

Event warning systems, such as tsunami warnings and storm surge warnings, can be used to minimize the human impact of catastrophic events that cause coastal erosion. Storm surge warnings can also be used to determine when to close floodgates to reduce the physical impact of such events.

Wireless sensor networks can be deployed quickly to set up a coastal erosion monitoring system, and scaled accordingly.

Shoreline Mapping

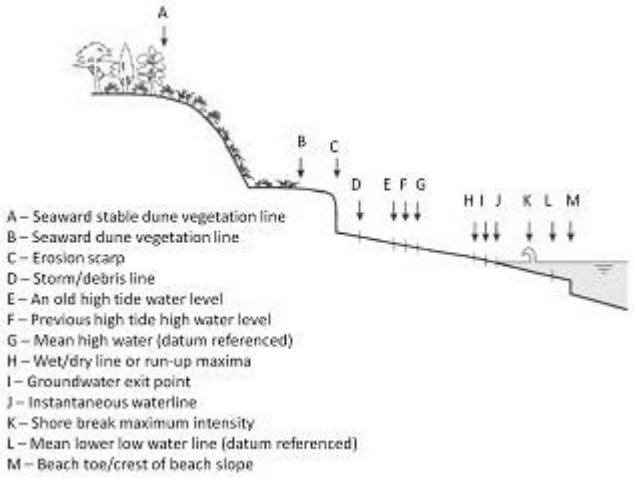
Defining the shoreline is a difficult task due to the dynamic nature of the coast and the intended application of the shoreline (Graham et al. 2003; Boak & Turner 2005). Given this idea the shoreline must therefore be considered in a temporal sense whereby the scale is dependent on the context of the investigation (Boak & Turner 2005). The following definition of the coast and shoreline is most commonly employed for the purposes of shoreline mapping. The coast comprises the interface between land and sea, and the shoreline is represented by the margin between the two (Woodroffe, 2002). Due to the dynamic nature of the shoreline coastal investigators adopt the use of shoreline indicators to represent the true shoreline position (Boak & Turner 2005).

Shoreline Indicator

The choice of shoreline indictor is a primary consideration in shoreline mapping. According to Leatherman (2003) it is important that indicators are easily identified in the field and on aerial photography. Shoreline indicators may be physical beach morphological features such as the berm crest, scarp edge, vegetation line, dune toe, dune crest and cliff or the bluff crest and toe. Alternatively, non-morphological features may also be used. These indicators are based on water level including the high water line, mean high water line, wet/dry boundary, and the physical water line (Pajak &

Leatherman 2000). Figure 1 provides a sketch of the spatial relationship between many of the commonly used shoreline indicators.

The high water line (HWL), defined as the wet/dry line (H in Figure 1) is the most commonly used shoreline indicator because it is visible in the field, and can be interpreted on both colour and grey scale aerial photographs (Leatherman, 2003; Crowell et al. 1991). The HWL represents the landward extent of the most recent high tide and is characterised by a change in sand colour due to repeated, periodic inundation by high tides. The HWL is portrayed on aerial photographs by the most landward change in colour or grey tone (Boak & Turner 2005).



A diagram representing the spatial relationship between many of the commonly used indicators. (Adapted from Boak and Turner 2005)

Importance and application

The location of the shoreline and its changing position over time is of fundamental importance to coastal scientists, engineers and managers (Boak & Turner 2005; Pajack & Leatherman 2002). Present day shoreline monitoring campaigns provide information about historic shoreline location and movement, and about predictions of future change (Appeaning Addo et al. 2008). More specifically the position of the shoreline in the past, at present and where it is predicted to be in the future is useful for in the design of coastal protection, to calibrate and verify numerical models to assess sea level rise, map hazard zones and formulate policies to regulate coastal development. Accurate and consistent delineation of the shoreline is integral to all of these tasks. The location of the shoreline also provides information regarding shoreline reorientation adjacent to structures, beach width, volume and rates of historical change (Boak & Turner 2005; Pajack & Leatherman 2002).

Data sources

A variety of data sources are available for examining shoreline position however, the availability of historical data is limited at many coastal sites and so the choice of data source is largely limited to what is available for the site at a given time (Boak & Turner 2005). Shoreline mapping techniques applied to data sources have moved towards automation in association with technological advances and the need to reduce uncertainty. Although these changes have resulted in improvement in coastal data processing and storage capabilities, the frequent change in technology has prevented the emergence of one standard method of shoreline mapping. This has occurred because each data source and associated method have their own unique capabilities and shortcomings (Moore 2000). A number of the data sources used for shoreline mapping and their associated advantages and disadvantages are discussed below.

Historical maps

In the event that a study requires the shoreline position to be mapped before the development of aerial photographs, or if the location has poor photograph coverage it is necessary to employ historical maps in order to detail shoreline position (Moore 2000). The main advantage and reason for using historical maps is that they are able to provide a historic record that is not available from other data sources. Many potential errors however are associated with historical coastal maps and charts. Such errors may be associated with scale, datum changes, distortions from uneven shrinkage, stretching, creases, tears and folds, different surveying standards, different publication standards, and projection errors (Boak & Turner 2005). The severity of these errors depends on the accuracy standards met by each map and the physical changes that have occurred since the publication of the map (Anders & Byrnes 1991). The oldest reliable source of shoreline data in the United States dates back to the early-to-mid-19th century and is the U.S Coast and Geodetic Survey/National Ocean Service T-sheets (Morton 1991). In the United Kingdom, many maps and charts were deemed to be inaccurate until around 1750. The founding of the Ordnance Survey in 1971 has since improved the accuracy of the mapping.

Aerial photographs

Aerial photographs have been used since the 1920s to provide topographical information about an area. They are therefore a good database for compilation of historical shoreline change maps. Aerial photographs are the most commonly used data source in shoreline mapping because many coastal areas have extensive aerial photo coverage therefore providing a valuable record of shoreline position (Moore 2000). In general, aerial photographs provide good spatial coverage of the coast however temporal coverage is very much site specific depending on the flight path of the aeroplane. A second disadvantage associated with aerial photography is that the interpretation of the shoreline position is subjective given the dynamic nature of the coastal environment. This combined with various distortions inherent in aerial photographs can lead to significant error levels (Moore 2000). The minimisation of further errors is discussed below.

Object space displacements

Conditions outside of the camera can cause objects in an image to be displaced from their true ground position. Such conditions may include ground relief, camera tilt and atmospheric refraction.

Relief displacement is prominent when photographing a variety of elevations. This situation causes objects above ground level to be displaced outward from the centre of the photograph and objects below ground level to be displaced toward the centre of the image (Figure 2). The severity of the displacement is affected negatively with decreases in flight altitude and as radial distance from the centre of the photograph increases. This distortion can be minimised by photographing numerous swaths and creating a mosaic of the images. This technique will create a focus for the centre of each photograph where distortion is minimised. It is important to note that this error is not common in shoreline mapping is the relief is fairly constant. It is however important to consider when mapping cliffs (Moore 2000).

Ideally aerial photographs are taken so the optical axis of the camera is perfectly perpendicular to the ground surface thereby creating a vertical photograph. Unfortunately this is not often the case and virtually all aerial photographs experience tilt whereby up to 3° is not uncommon (Camfield et al. 1996). In this situation the scale of the image will be larger on the upward side of the tilt axis and smaller on the downward side. Moore, (2000) notes that many coastal researchers have not realised the severity of this error and therefore do not consider it in their methods.

An example of relief displacement. All objects above ground level are displaced outwards from the centre of the photograph. The displacement becomes more evident near the edges.

Radial Lens Distortion

Lens distortion varies as a function of radial distance from the iso-centre of the photograph meaning that the centre of the image is relatively distortion free, but as the angle of view increases the distortion becomes more prominent. This is a significant source of error in earlier aerial photography but as technology has increased and camera lens have become more refined it has become less of an issue with later photographs. Such a distortion is impossible to correct for without knowing the make and model of the lens used to capture the image. However if overlapping images have been acquired one can digitize the centre portions of the aerial photographs (Crowell et al. 1991).

Delineation of the shoreline

The dynamic nature of the coast has meant that accurate mapping of an instantaneous shoreline position has been associated with significant uncertainty. This uncertainty arises because at any given time the position of the shoreline is influenced by the short-term effect of the tide and a wide variety of long term effects such as relative sea-level rise and along shore littoral sediment movement. Not only does this affect the accuracy of computed historic shoreline position but also any predicted future positions (Appeaning Addo et al. 2008). As mentioned earlier the HWL is most commonly used as a shoreline indicator. This can usually be seen as a significant tonal change on aerial photographs. There are however many errors associated with using the wet/dry line as a proxy for the HWL and shoreline. The errors of largest concern are the short term migration of the wet/dry line, interpretation of the wet/dry line on a photograph and measurement of the interpreted line position (Leatherman 2003; Moore 2000). Systematic errors such as the migration of the wet/dry line may arise from tidal and seasonal changes. Storm-induced erosion is another factor which may cause the wet/dry line to migrate landward. Field investigations have shown that these changes can be minimised by using only summertime data (Moore 2000; Leatherman 2003). Furthermore, the error bar can be significantly reduced by using the longest record of reliable data to calculate erosion rates (Leatherman 2003). Finally it is important to note that errors may arise due to the difficulty of measuring a single line on a photograph. For example where the pen line is 0.13 mm thick this translates to an error of ±2.6 m on a 1:20000 scale photograph.

Beach profiling surveys

Beach profiling surveys are typically repeated at regular intervals along the coast in order to measure short-term (daily to annual) variations in shoreline position and beach volume. (Smith & Zarillo 1990). Beach profiling is a very accurate source of information however measurements are generally subject to the limitations of conventional surveying techniques. Shoreline data derived from beach profiling is often spatially and temporally limited due to the high cost associated with such a labour intensive activity. Shorelines are generally derived by interpolating between a series of discrete beach profiles. It is important to note however that the distance between the profiles is usually quite large and so the accuracy of the interpolating becomes compromised. In contrast to aerial photographs, survey data is limited to smaller lengths of shoreline generally less than ten kilometres (Boak & Turner 2005). Beach profiling data is commonly available in from

regional councils in New Zealand such as those compiled by the Hawkes Bay Regional Council.

Remote sensing

Technological advancement over the last decade has led to the development of a range of airborne, satellite and land based remote sensing techniques (Smith & Zarillo 1990). Some of the remotely sensed data sources are listed below:

- Multispectral and hyperspectral imaging
- Microwave sensors
- Global positioning system (GPS)
- Airborne light detection and ranging technology (LIDAR)

Remote sensing techniques are attractive as they are cost effective, reduce manual error and remove the subjective approach of conventional field techniques (Maiti et al. 2009).Remote sensing is a relatively new concept and so extensive historical observations are unavailable. Given this idea, it is important that coastal morphology observations are quantified by coupling remotely sensed data with other sources of information detailing historic shoreline position from archived sources (Appeaning Addo et al. 2008).

Video analysis

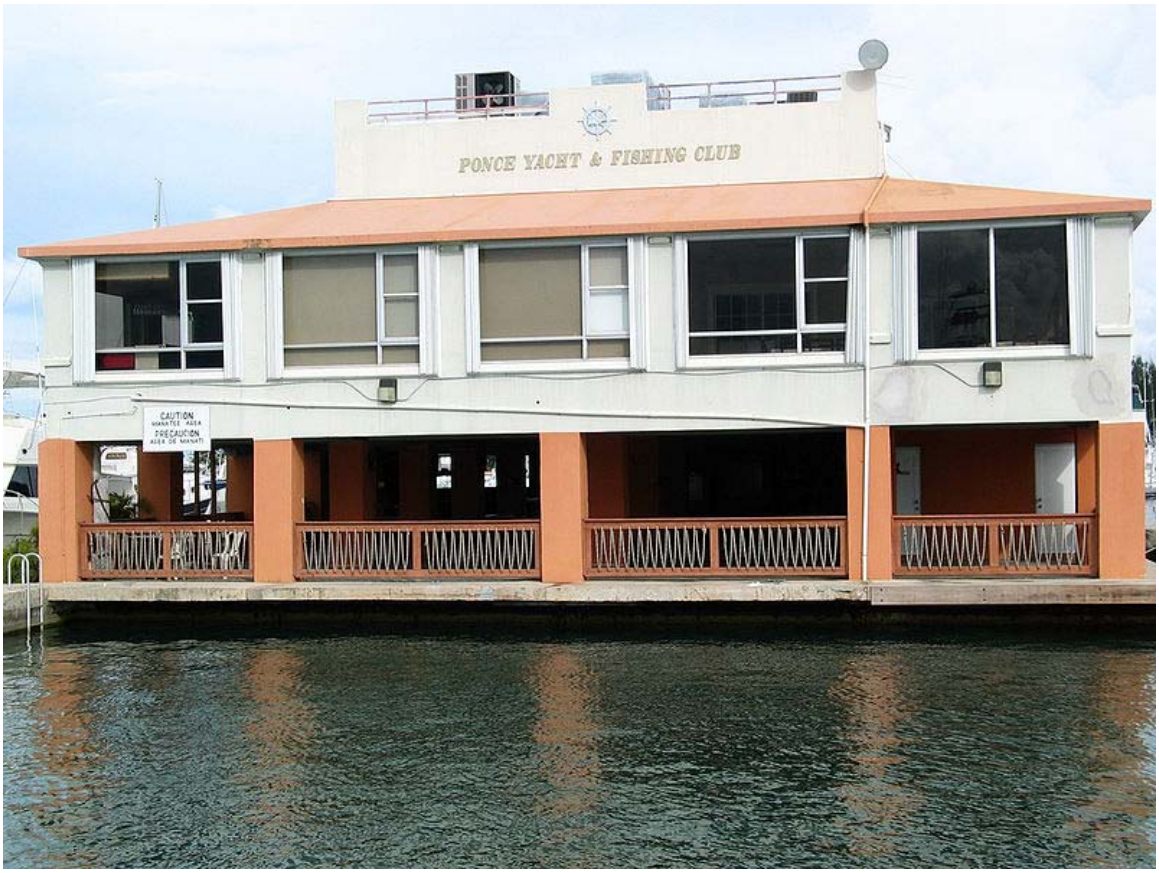
Video analysis provides quantitative, cost-effective, continuous and long-term monitoring beaches (Turner et al. 2004). The advancement of coastal video systems over the past 15 years has resulted in the extraction of large amounts of geophysical data from images. Such data includes that about coastal morphology, surface currents and wave parameters. The main advantage of video analysis lies in the ability to reliably quantify these parameters with high resolution and coverage in both space and time. This in particular highlights their potential importance as an effective coastal monitoring system and an aid to coastal zone management (Van Koningsveld et al. 2007). Interesting case studies have been carried out using video analysis. Turner et al. (2004) used a video-based ARGUS coastal imaging system to monitor and quantify the regional-scale coastal response to sand nourishment and construction of the world-first Gold Coast artificial (surfing) reef in Australia. In addition, Smit et al. (2007) demonstrated the added value of high resolution video observations for making short-term predictions of near shore hydrodynamic and morphological processes, at temporal scales of meters to kilometres and days to seasons.

Chapter- 5

Dock (Maritime)

Docks in St. Petersburg, Russia

A **dock** (from Dutch 'dok') is a human-made structure or group of structures involved in the handling of boats or ships, usually on or close to a shore. However, the exact meaning varies among different variants of the English language. "Dock" may also refer to a dockyard (or *shipyard*) where the loading, unloading, building, or repairing of ships occurs.




Restaurante El Comodoro

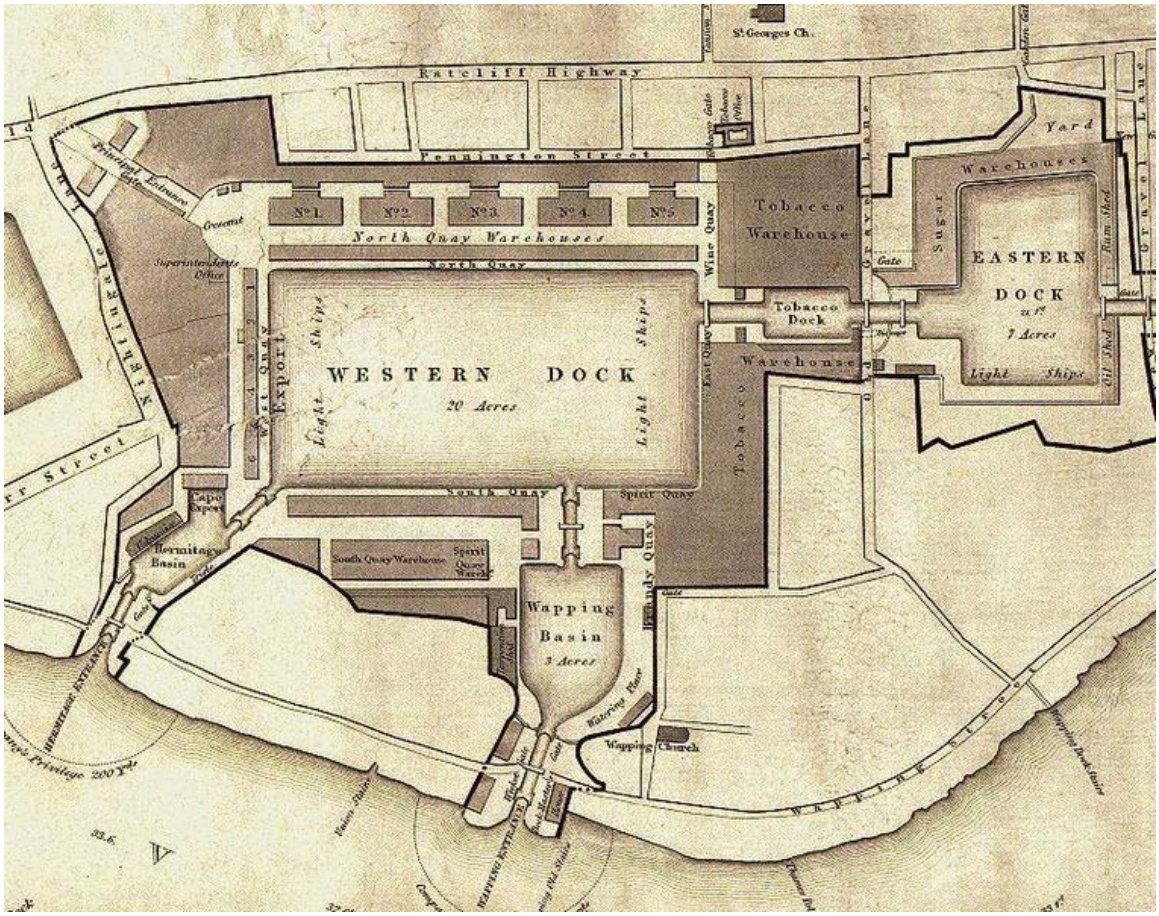
History

The world's oldest known dock at Lothal (2400 BCE) was located away from the main current to avoid deposition of silt. Modern oceanographers have observed that the Harappans must have possessed great knowledge relating to tides in order to build such a dock on the ever-shifting course of the Sabarmati, as well as exemplary hydrography and maritime engineering. This was the earliest known dock found in the world, equipped to berth and service ships. It is speculated that Lothal engineers studied tidal movements, and their effects on brick-built structures, since the walls are of kiln-burnt bricks. This knowledge also enabled them to select Lothal's location in the first place, as the Gulf of Khambhat has the highest tidal amplitude and ships can be sluiced through flow tides in the river estuary. The engineers built a trapezoidal structure, with north-south arms of average 21.8 metres (71.5 ft), and east-west arms of 37 metres (121 ft).

British English

A small dry dock in Gloucester, England

In British English, a dock is an enclosed area of water used for loading, unloading, building or repairing ships. Such a dock may be created by building enclosing harbour walls into an existing natural water space, or by excavation within what would otherwise be dry land.

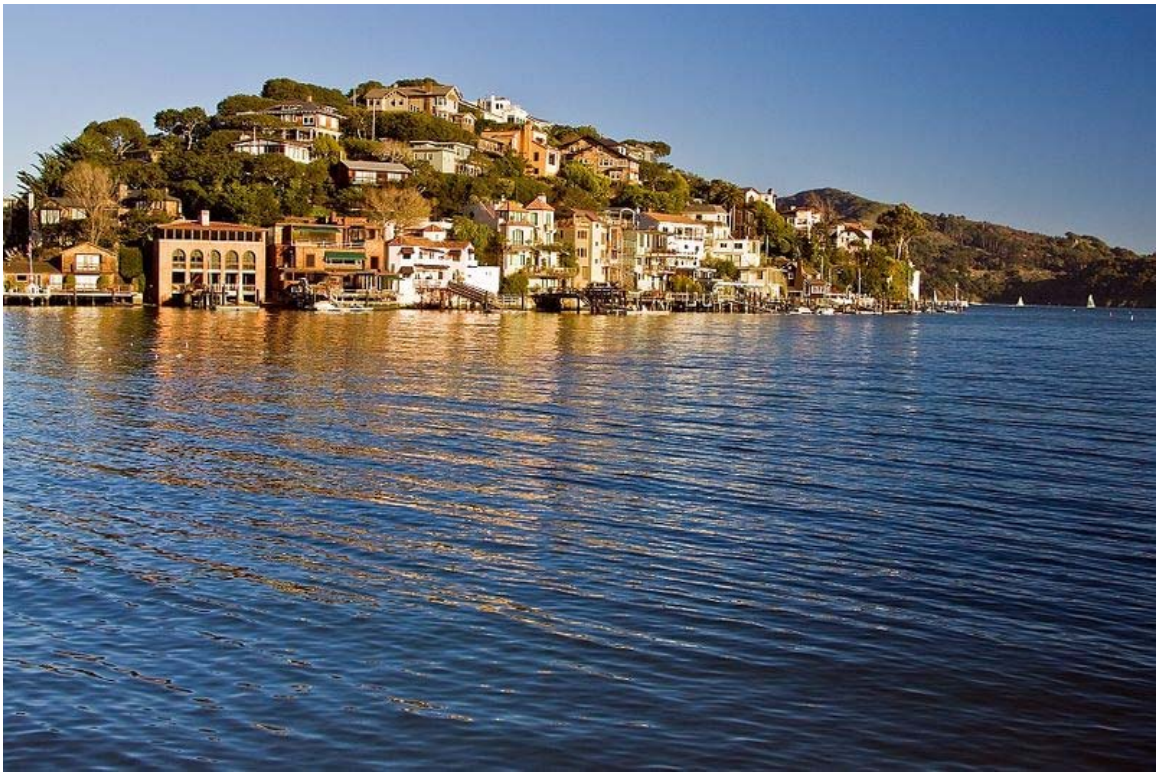


There are two specific elaborations of the dock:

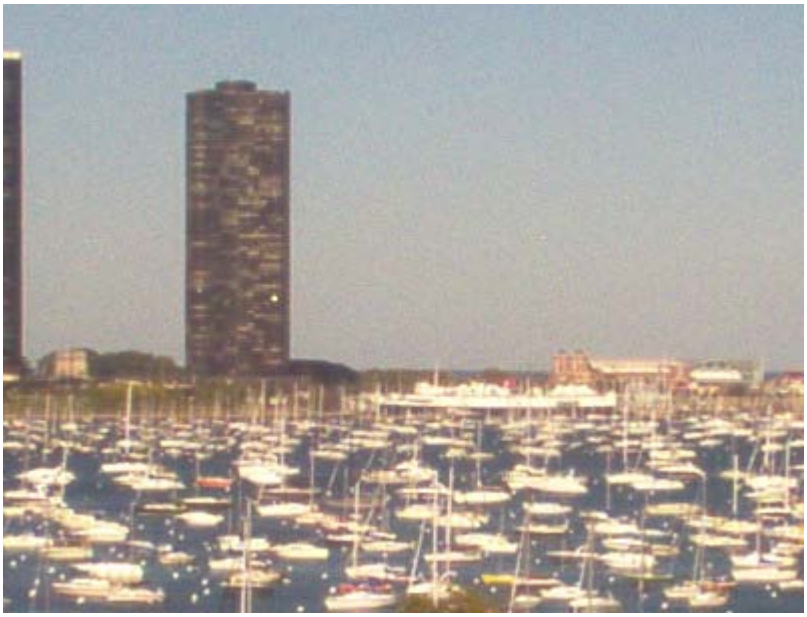
- A **wet dock** (or **impounded dock**) is a variant in which the water is impounded either by dock gates or by a lock, thus allowing ships to remain afloat at low tide in places with high tidal ranges. The world's first enclosed wet dock with lock gates to maintain a constant water level irrespective of tidal conditions was the Howland Great Dock on the River Thames, built in 1703. The dock was merely a haven surrounded by trees, with no unloading facilities. The world's first commercial enclosed wet dock, with quays and unloading warehouses, was Steers Dock at Liverpool, built in 1715. This reduced ship waiting giving quick turn arounds, greatly improving the throughput of cargo.
- A *drydock* is another variant, also with dock gates, which can be emptied of water to allow investigation and maintenance of the underwater parts of ships.

A dockyard (or "shipyard") consists of one or more docks, usually with other structures.

American English



Docks along San Francisco Bay in Tiburon, California



A boat dock on Lake Michigan in Chicago.

Small wooden docks can be constructed with few tools and minimal materials.

In American English, a dock is technically synonymous with pier or wharf—any human-made structure in the water intended for people to be on. However, in modern use, pier is generally used to refer to structures originally intended for industrial use, such as seafood processing or shipping, and more recently for cruise ships, and dock is used for most everything else, often with a qualifier, such as ferry dock, swimming dock, ore dock and others. However, pier is also commonly used to refer to wooden or metal structures that extend into the ocean from beaches and are used, for the most part, to accommodate fishing in the ocean without using a boat.

In American English, the term for the water area between piers is "slip".

In the cottage country of Canada and the United States, a dock is a wooden platform built over water, with one end secured to the shore. The platform is used for the boarding and offloading of small boats.

Chapter- 6

Hurricane-Proof Building

Tornadoes, cyclones, and other strong winds damage or destroy many buildings. However, with proper design and construction, the damage to buildings by these forces can be greatly reduced. Over time, a variety of methods have been studied and tested (both formally and incidentally by actual storms) that can help a building survive strong winds and storm surge. Local building departments may mandate their use in high velocity hurricane zones, or areas where buildings are likely to have to withstand a hurricane in their lifetime.

Storm surge considerations

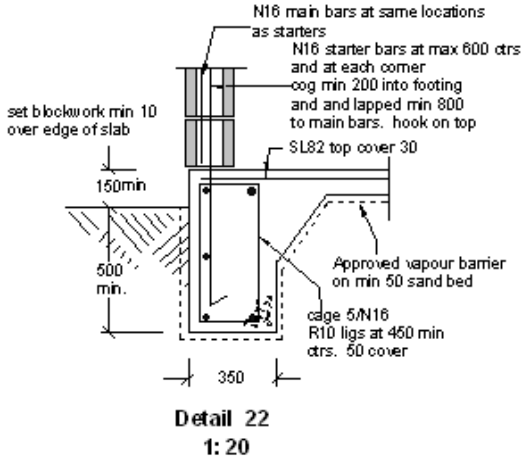
A common problem for buildings during hurricanes is storm surge. Flooding occurs frequently in coastal areas and waves contain a tremendous amount of energy which can literally batter a building to pieces. Beach front buildings should be able to withstand the ocean rising 20 or more feet, with large waves on top of that. They should preferably be built on high ground where possible, in order to avoid waves knocking the building down.

If waves can reach the building site, the building should be elevated on steel, concrete, or wooden pilings and/or anchored to solid rock. Whether it is intended or not, walls on the first floor are often built with sheetrock, which can completely deteriorate when wet and/or exposed to lateral forces, leaving structural members in place, and allowing water (or high winds) to pass through. This "gutting" occurs frequently in storm surge areas. Designing so as to "sacrifice" the walls of the first floor in this way can save the rest of the building from destruction, although it is not an ideal solution. Building contents left on that level will be lost, and considerable damage to the building could still result in costly repairs such as mold, rot, and termite problems.

Examples of Cyclonic Construction Methods

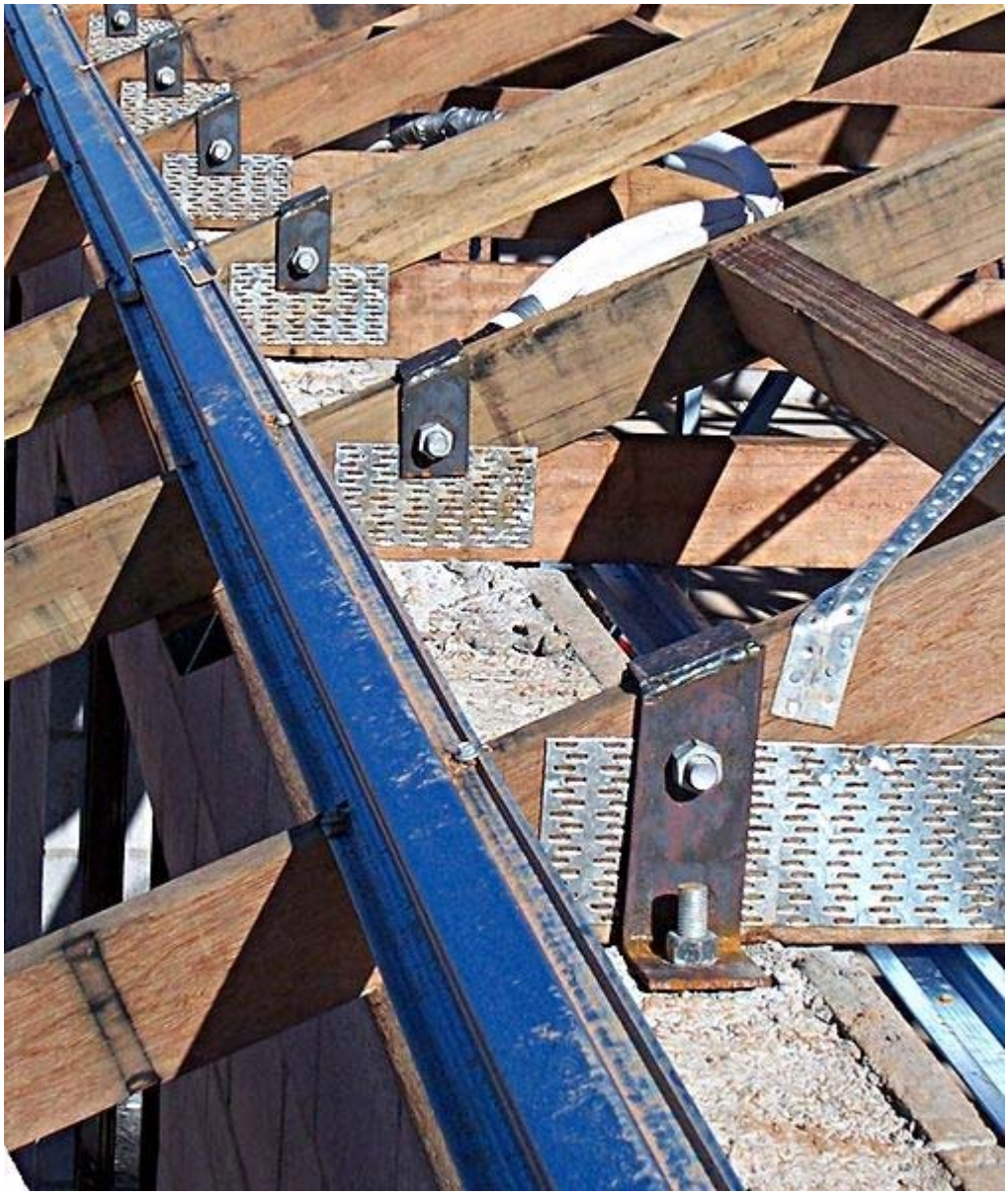
Residential construction in Darwin Northern Australia

Starter bars cast into concrete slab for blockwork wall reinforcing,



Detail of reinforcing steel at edge of concrete raft slab

16mm Cast in hold down bolts. 150 to 300 long cast into blockwork bond beams

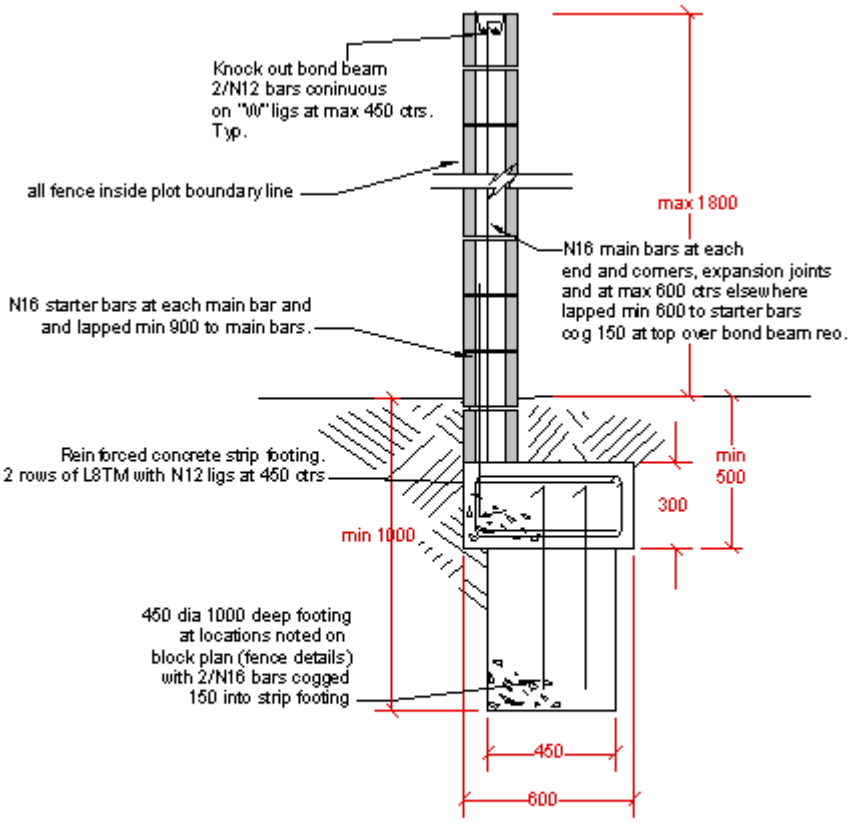


HD bolt to truss connection. also seen, metal roof batten fixing, speedbrace end fixing.

Typical roof member connector straps.

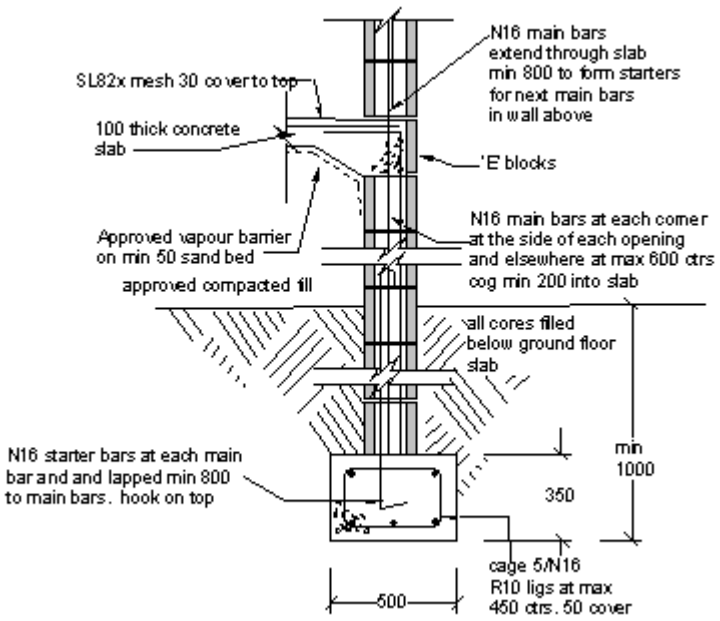
Internal mig welded shearwalls

Shearwall to slab connection, M12 chemsets through 6 plate washers, typ. at ends and 900ctrs.



Section Through Front Boundary Fence
Fence Type 'C'
1:20

Sketch of 200 series reinforced blockwork fence wall. Terrain category 3 (close to sea front)



Sketch of typical foundation layout for sloping ground.

Wind loading considerations

The foundation

A Monolithic dome in Pensacola Beach, Florida after Hurricane Dennis in 2005

Wind acting on the roof surfaces of a building can cause negative pressures that tend to create a lifting force. This is one of the most common ways a building can be destroyed during a storm. Gravity alone may not be sufficient to prevent the roof from lifting, or "peeling," off the rest of the building. Once this occurs, the building is weakened considerably and the rest of the building will likely fail as well. To minimize this, the upper structure should be securely anchored through the walls to the foundation.

Several methods can be used to securely anchor the roof. Traditionally, roof trusses were simply "toenailed" into the top of the walls. These nails provide little to no actual structural advantage; they're mainly used to hold the trusses in place while the rest of the roof is being built. Gravity and friction then ensure the roof stays put. Various products have been developed that can actually anchor the roof to the walls, which should then be anchored to a solid foundation. Metal straps that nail into the wall and wrap over the trusses are one method. Other methods, including temporary straps made of a special low-elongation material, have successfully been used and have an advantage, in that a building built before 1993 which may not be constructed to withstand wind loading can

be quickly and temporarily strapped to the foundation to ensure structural stability. Hurricane harness strapping can easily be applied and removed after the storm to ensure the highest level of protection in extreme high wind storms.

Mobile home tie down to the foundation

In the bulk of instances when interlocking metal pan roof systems installed on mobile homes are exposed to extreme high winds, such as hurricanes and the outer band winds of a tornado, irreparable damage occurs to the overall building structure once the fasteners attaching the metal roof panels to the structural frame begin to tear or rip through the aluminum metal pan base, under the pressure differential (lift) created by the high velocity winds passing over the surface plane of the roof. This event becomes compounded by the high velocity of wind entering the carport or other building add-on, which causes a mode of wind capture: transfer of the kinetic energy of the wind lifts the underside of the roof panels, resulting in complete devastation of the roof system and the roof line/siding section.

To mitigate this pressure differential, pre-installed aluminum tabular channels can permanently be fastened perpendicularly across the top of the interlocking ribs of the metal roof system without disturbing the flow of rainwater at the eaves, mid-span, and ridge locations of the building. Variable lengths of an extremely strong, low elongation, hurricane harness strap are cut to length, placed over the channels and fastened into ratchets which are attached to a variety of anchoring methods on opposite sides of the building. This engineered design provides an uninterrupted continuous load path between anchors. The ratchets apply a uniform counteractive load throughout the channel systems and throughout the roof assembly. The structure literally becomes sandwiched within the strapping and the anchors with addition to providing a positive active dead load to the outer wall systems and column supports, increasing the resistance to the lateral wind force being applied to the main structure during a storm event. In addition, this secondary measure of protection will visually alleviate any unforeseen building deficiencies within the structural confines of the building, or rusted or inadequate earth support ties to the lower frame chassis of the structure.

Earth sheltering

Earth sheltered construction is generally more resistant to strong winds and tornadoes than standard construction. It is for this reason that cellars, and other earth sheltered components of other buildings, can provide safe refuge during tornadoes.

Dome homes

The physical geometry of a building affects its aerodynamic properties and how well it can withstand a storm. Geodesic dome roofs or buildings made from wood, steel, or concrete have low drag coefficients and can withstand higher wind forces than a square building of the same area.

Even stronger buildings result from monolithic dome construction.

Building components

Garages, windows, doors, and other openings

These are generally the weak points susceptible to breakdown by wind pressure and blowing debris. Once failure occurs, wind pressure builds up inside the building and in seconds, may lift the roof off a building. Hurricane shutters can also provide effective protection.

Doors

An inward opening door can be blown into the house by wind causing potential structural failure. Various companies offer new doors that comply with the local building codes. Some companies offer retro-fit devices that can be professionally installed. These kits are often just as expensive as a new door. A good source for products include the Miami-Dade building code website . It shows how the products are to be installed to withstand the most punishing of winds. Some of the companies are local and many products were in use prior to Hurricane Andrew.

Windows

It is usually a requirement to install 150 miles per hour tested windows in hurricane prone areas. These windows should have plastic panes, shatter-proof glass or glass with protective membranes (Impact Glass). The panes have to be more firmly attached than normal window panes (possibly even using screws or bolts through the edges of larger panes).

Windows protected by steel or heavy aluminum shutters may be best in some hurricane prone areas.

Building materials

The choice of building materials can affect the ability of a building to withstand high winds. Although it is not always possible to use different materials, if the area is extremely susceptible to high winds, it is good practice to use the most resistant materials available.

Wood

Wood is the most common building material as it is readily available, relatively inexpensive, and has a degree of flexibility which can be beneficial in certain high stress situations. However, termite and dry rot are frequent problems in timber buildings located in areas susceptible to hurricanes, particularly in warm, humid climates. Weakened

buildings cannot withstand wind loads as well as intact buildings can. To combat this, certain building codes require the use of pressure-treated wood for all structural elements of the building, which is designed to prevent rot and deterioration.

Also, wood and paper backed sheetrock provide food for black mold which can grow if the inside of the building gets wet during a storm. The mold can then be costly to remove and must be considered as a factor when deciding which building materials to use.

A building constructed with wood can effectively be built to withstand fairly high wind loads. However, flying debris - furniture, trees, parts of other buildings which are common in such a storm - can still damage or destroy a well-designed wood building even if the wind isn't sufficient to do so itself.

Concrete

Reinforced concrete is a strong, dense material that, if used in a building that is designed properly, can withstand the destructive power of very high winds, pounding waves, and even high-speed debris. Concrete used in home construction must be reinforced with steel (commonly known as "rebar"). While the rebar can rust in wet or humid environments, there are various effective means to retard or prevent rebar corrosion due to moisture.

Chapter- 7

Lake Shore Drive

Lake Shore Drive

View of Lake Shore Drive at the edge of Lake Michigan crossing the Chicago River

Length:	15.83 mi (25.48 km)
South end:	Marquette Drive (6600 South)
North end:	Hollywood Avenue (5700 North)

Construction

Completion:	1937
Inauguration:	1946

Lake Shore Drive (colloquially referred to as **LSD** or simply **Lake Shore** or **The Drive**) is a mostly freeway-standard expressway running parallel with and alongside the shoreline of Lake Michigan through Chicago, Illinois, USA. Except for the portion north

of Foster Avenue (5200 North), Lake Shore Drive is designated as part of U.S. Highway 41.

The downtown part originally opened as **Leif Ericson Drive** in 1937, named for Norse explorer Leif Ericson. The roadway was also called **Field Boulevard**; it was renamed **Lake Shore Drive** in 1946.

History

Left: The double-decker Link Bridge across the Chicago River; Wacker Drive is visible in the background; Left center: The S-Curve, 1963 (Charles W. Cushman collection); Right center: Looking northeast across Lakeshore East at triple-decker Wacker Drive. The road to the west is older; only the middle level continues east. Lake Shore Drive used to intersect the upper level and turn west here. The Link Bridge is in the background; Right: Palmer Mansion

Lake Shore Drive's origins date back to Potter Palmer, who coerced the city to build the street adjacent to his lakefront property to enhance its value. Palmer built his "castle" at 1350 N. Lake Shore Drive in 1882. The drive was originally intended for leisurely strolls for the wealthy in their carriages, but as the auto age dawned it took on a different role completely.

In 1937, the double-decker Link Bridge over the Chicago River opened, along with viaducts over rail yards and other industrial areas connecting to both ends of it. The lower level was intended for a railroad connection, but it was never used until LSD was rebuilt in 1986. At the time the bridge was built, it was the longest and widest bascule bridge in the world. The Lake Shore Drive (Outer Drive) and Link Bridge Photograph Album, c1937, documents the bridge's construction. The album is held by the Ryerson & Burnham Libraries at the Art Institute of Chicago.

North of the river, LSD intersected Ohio Street at grade, and then passed over Grand Avenue and Illinois Street on its way to the bridge South of the river. LSD came from the south on its current alignment, but continued straight at the curve north of Monroe Street, rising onto a viaduct. It intersected Randolph Street at grade and then continued north above the Illinois Central Railroad's yard. At the river, it made a sharp turn to the right, and another sharp turn to the left onto the bridge. These curves (actually a pair of 90-degree turns) were known locally as the "S-Curve" or the "S-Turn", and were a bottleneck to drivers for many years until the 1980s reconstruction.

The Historic Edgewater Beach Apartments mark the northern end of the Drive

Lake Shore Drive was extended from Belmont Avenue (3200n) north to Foster Avenue (5200n) in 1933, where it terminated until the 1950s when it was extended — first briefly to Bryn Mawr (5600n) & then in 1957 to its present terminus at Hollywood Avenue (5700n). The landfill used for the 1930s extension was mostly dirt, but the 1950s extension included rubble and debris from the destruction of homes razed for the construction of the Congress Expressway (now the Eisenhower Expressway). Portions of the drive between Irving Park Road and Foster Avenue still contain the original concrete from the 1930s, but this is scheduled for replacement in the near future.

Traffic near Lake Point Tower

Prior to the extension to Hollywood, traffic was funneled onto Foster, then north onto Sheridan Road, which still remains a wide 4-lane street to this day, though most traffic doesn't rejoin Sheridan until LSD ends at Hollywood Avenue now. Sheridan Road south of Foster narrows to 2 lanes of traffic with street parking on each side as well.

When Wacker Drive was extended east to LSD in the 1970s, its upper level ended at LSD at the west curve (the lower level dead-ended underneath). A new development at the northeast corner of the Randolph Street intersection resulted in an extension of Randolph across LSD.

Construction began in 1982 on a realignment of LSD south of the river (along with a reconstruction north of the river). A whole new alignment was built, greatly smoothing the S-curve (later named, in a fortuitous coincidence, for Chicago Bears founder George **S.** Halas). The northbound side opened in October 1985, and the southbound side opened in November 1986. A new lower level was built, using the lower level of the bridge, and providing access to the new Wacker Drive and the roads on the north side of the river.

The old road south of Randolph became a Cancer Survivors Plaza; the east–west part was reconstructed as part of Wacker Drive (which was being rebuilt at the time). The rest, between Randolph and Wacker, was kept for several years as Field Boulevard, but was

demolished in 1994. Only some old street lighting, sidewalks & fire hydrants remain, marking the former route. Current plans are for new upper level streets in the area as part of the Lakeshore East development.

2009 view from Lake Shore Drive of Chicago River, the south border (right) of the Near North Side and Streeterville and north border (left) of Chicago Loop, Lakeshore East and Illinois Center (with Trump International Hotel and Tower at jog in the river in the center)

On November 10, 1996, new northbound lanes opened next to the original southbound lanes at Soldier Field, eliminating the original wide median from 1943. Prior to this 1996 reconstruction, the northbound lane ran on the east side of Soldier Field while the southbound lane ran on the west side.

On March 20, 2003, some 15,000 anti-war protesters marched along Lake Shore Drive the day after the United States invasion of Iraq, stopping all traffic for several hours. The spontaneous direct action occurred after the original protest route through downtown Chicago, as planned by the Chicago Coalition Against War & Racism, was blocked by law enforcement. Approximately 900 marchers were arrested and a City Council investigation was held before all charges were dropped.

Future extension plans

Extension of Lake Shore Drive is currently being constructed to provide access to new development in South Chicago of the old US Steel plant site. A thirty year development plan estimated to cost $4 billion dollars was approved by the city in September 2010, for the former site of the huge steel mill, which operated along the neighborhood's shoreline from 1880 to 1992. The site has undergone extensive demolition and environmental remediation since 1992. The plan includes extension of **Lake Shore Drive**.

By contrast, the extension of Lake Shore Drive to the North has been the subject of controversy in recent years. In 2004, a private foundation solicited plans, and the Chicago Park District considered a feasibility study, to extend Lake Shore Drive farther north through Rogers Park and into Evanston. Residents protested against cutting

neighborhoods off from the lake, and Rogers Park and Edgewater voters rejected the extension in a referendum placed on the ballot by citizen initiative in November 2004. However, in spring, 2005, the Chicago Park District spent $350,000 on plans for new marinas along Lake Shore Drive, including one at Devon-Granville, and in July, 2005, Cong. Jan Schakowsky (IL-9) obtained federal funding reported variously as $800,000 and $1 million for a study of the possible extension of the Chicago North lakefront path; both of these developments fueled residents' suspicion of a secret city plan to extend the Drive. The controversy remained an issue through the 2007 aldermanic election in the 49th Ward. In 2008, proposals by Friends of the Parks to extend the lakefront park system north, possibly through offshore manmade islands linked by bike paths, met with similar resident opposition. Despite statements by FOP that no extension of the Drive was contemplated, activists contended that the Park District "has plans already drawn up that clearly show Lake Shore Drive immediately east of" Edgewater and Rogers Park.

Streeterville portion of Lake Shore Drive

from south during Bike The Drive

from south

Gold Coast from Streeterville

A political moniker

In the 20th century, the tiny neighborhoods near Lake Shore Drive came to be occupied by exclusive high-rise apartment, condominiums and co-op buildings. To the political columnist Mike Royko, Lake Shore Drive was goo-goo territory, a land occupied by Chicago's wealthy "good-government" types. Royko sometimes used Lake Shore Drive as a political moniker. Though he often agreed with the reformers, he looked upon them with the same cynical eye as his fictional Chicago everyman, Slats Grobnik.

Parallel roads

The Chicago Half Marathon is an annual Chicago Marathon tune up that takes place along Lake Shore Drive on the South Side.

Lake Shore Drive contains both an inner and an outer drive.

The original **inner drive** (or local) is used for slower local traffic and is connected to the street grid. The local drive runs from downtown in Streeterville to North Avenue (1600n), (becoming Cannon Drive). Then the inner drive reappears just south of Diversey Parkway (approx. 2700n), continuing north to Irving Park Road (4000n). The portion from Belmont (3200n) to just south of Irving Park (3900n) was previously named Sheridan Road (which can still be seen carved in stone in at least one vintage high-rise).

The **outer drive** (or express) with limited-access runs from the south side of the city, north to the terminus at Hollywood Avenue (5700n) in the Edgewater neighborhood. The outer drive limits the ability of pedestrians to access the lake directly from the street grid.

Lake Shore Drive runs both north-south and east-west. Other streets in Chicago that run both north-south and east-west include Wacker Drive, Sheridan Road, and Hyde Park Blvd.

The Lakefront Trail, a 18-mile (29 km) multi-use trail, parallels Lake Shore Drive on the east side for most of its length. Pedestrians can access the lake at several points along Lake Shore Drive through underpasses that connect the lake with the rest of the city.

Link Bridge

The **Link Bridge** is the official name of the bridge carrying the Lake Shore Drive portion of U.S. Route 41 over the main branch of the Chicago River. It is designed as a bascule bridge, and is one of only two in the city to have an upper and lower deck.

The Link Bridge was constructed in 1937. At the time of its construction, it was considered to be both the widest and longest bascule bridge in the world.

Chapter- 8

Land Reclamation

Reclaiming in Perth, Australia 1964

Land reclamation, usually known as **reclamation**, is the process to create new land from sea or riverbeds. The land reclaimed is known as **reclamation ground** or **landfill**.

Habitation

The entire East Coast Park in Singapore was built on reclaimed land with a man-made beach.

The creation of new land was for the need of human activities. Notable examples in the West include large parts of the Netherlands, parts of New Orleans (which is partially built on land that was once swamp); much of San Francisco's waterfront has been reclaimed from the San Francisco Bay; Mexico City (which is situated at the former site of Lake Texcoco); Helsinki (of which the major part of the city center is built on reclaimed land); the Cape Town foreshore; the Chicago shoreline; the Manila Bay shoreline; Back Bay, Boston, Massachusetts; Battery Park City, Manhattan; Liberty State Park, Jersey City; the port of Zeebrugge in Belgium; the southwestern residential area in Brest, Belarus, the polders of the Netherlands; and the Toronto Islands, Leslie Street Spit, and the waterfront in Toronto. In the Far East, Hong Kong, Macau, Japan, the southern Chinese cities of Shenzhen, the Philippine capital Manila, and the city-state of Singapore, where land is in short supply, are also famous for their efforts on land reclamation. One of the earliest and famous project was the Praya Reclamation Scheme, which added 50 to 60 acres (240,000 m^2) of land in 1890 during the second phase of construction. It was one of the most ambitious projects ever taken during the Colonial Hong Kong era. Some 20% of land in the Tokyo Bay area has been reclaimed. Monaco and the British territory of Gibraltar are also expanding due to land reclamation. The city of Rio de Janeiro was largely built on reclaimed land, as was Wellington, New Zealand.

Artificial islands are an example of land reclamation. Creating an artificial island is an expensive and risky undertaking. It is often considered in places that are densely populated and flat land is scarce. Kansai International Airport (in Osaka) and Hong Kong International Airport are examples where this process was deemed necessary. The Palm Islands, The World and hotel Burj al-Arab off Dubai in the United Arab Emirates are other examples of artificial islands.

Agriculture

Agriculture was a drive for land reclamation before industrialisation. In South China, farmers reclaimed paddy fields by enclosing an area with a stone wall on the sea shore near river mouth or river delta. The species of rice that grow on these grounds are more salt tolerant. Another use of such enclosed land is creation of fish ponds. It is commonly seen on the Pearl River Delta and Hong Kong. These reclamation also attracts species of migrating birds.

A related practice is the draining of swampy or seasonally submerged wetlands to convert them to farmland. While this does not create new land exactly, it allows commercially productive use of land that would otherwise be restricted to wildlife habitat. It is also an important method of mosquito control.

Beach restoration

Beach rebuilding is the process of repairing beaches using materials such as sand or mud from inland. This can be used to build up beaches suffering from beach starvation or erosion from longshore drift. It stops the movement of the original beach material through longshore drift and retains a natural look to the beach. Although it is not a long-lasting solution, it is cheap compared to other types of coastal defences.

Landfill

As human overcrowding of developed areas intensified during the 20th century, it has become important to develop land re-use strategies for completed landfills. Some of the most common usages are for parks, golf courses and other sports fields. Increasingly, however, office buildings and industrial uses are made on a completed landfill. In these latter uses, methane capture is customarily carried out to minimize explosive hazard within the building.

An example of a Class A office building constructed over a landfill is the Dakin Building at Sierra Point, Brisbane, California. The underlying fill was deposited from 1965 to 1985, mostly consisting of construction debris from San Francisco and some municipal wastes. Aerial photographs prior to 1965 show this area to be tidelands of the San Francisco Bay. A clay cap was constructed over the debris prior to building approval.

A notable example is Sydney Olympic Park, the primary venue for the 2000 Summer Olympic Games, which was built atop an industrial wasteland that included landfills.

Another strategy for landfill is the incineration of landfill trash at high temperature via the plasma-arc gasification process, which is currently used at two facilities in Japan, and will be used at a planned facility in St. Lucie County, Florida.

Environmental impact

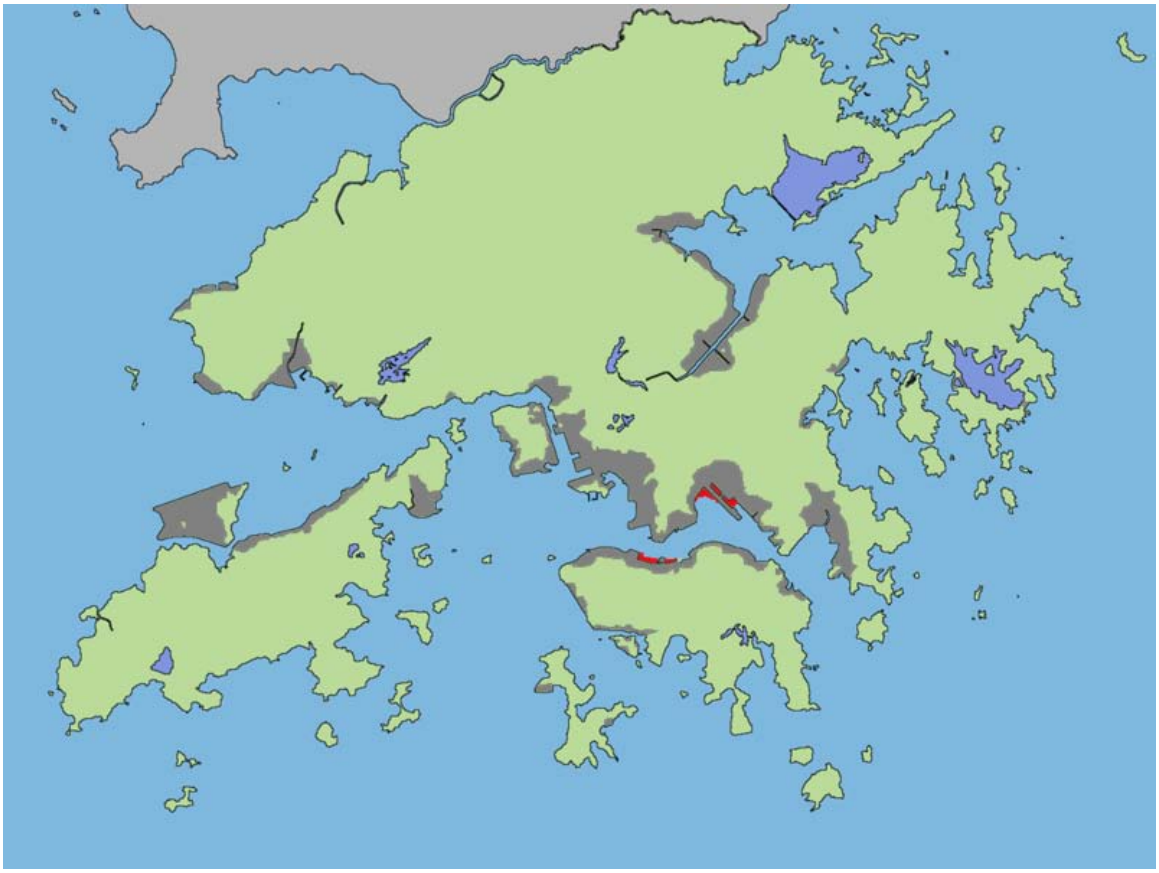
Parts (highlighted in brown) of the San Francisco Bay were reclaimed from wetlands for urban use.

Draining wetlands for ploughing, for example, is a form of habitat destruction. In some parts of the world, new reclamation projects are restricted or no longer allowed, due to environmental protection laws.

Environmental legislation

Hong Kong legislators passed the Protection of the Harbour Ordinance in 1996 in an effort to safeguard the increasingly threatened Victoria Harbour against encroaching land development.

Land amounts added



Land reclamation in Hong Kong: Grey (built), red (proposed or under development). Most of the urban area of Hong Kong is on the reclaimed land.

- **Netherlands** - about 1/5 land from land reclamation or about 7,000 km^2.
- **South Korea** - As of 2006, 38 percent or 1,550 km^2 of coastal wetlands reclaimed, including 400 km^2 at Saemangeum.
- **Singapore** - 20% of the original size or 135 km^2. As of 2003, plans for 99 km^2 more are to go ahead, despite the fact that disputes persist with Malaysia over Singapore's extensive land reclamation works.
- **Hong Kong** - Praya Reclamation Scheme began in the late 1860s and consisted of two stages totaling 50 to 60+ acres. Hong Kong Disneyland, Hong Kong International Airport, and its predecessor, Kai Tak Airport, were all built on reclaimed land. In addition, much reclamation has taken place in prime locations on the waterfront on both sides of Victoria Harbour. This has raised environmental issues of the protection of the harbour which was once the source

of prosperity of Hong Kong, traffic congestion in the Central district, as well as the collusion of the Hong Kong Government with the real estate developers in the territory.

In addition, as the city expands, new towns in different decades were mostly built on reclaimed land, such as Tuen Mun, Tai Po, Shatin-Ma On Shan, West Kowloon, Kwun Tong and Tseung Kwan O.

- **Macau** - 170% of the original size or 17 km^2
- **Mumbai**
- **Tokyo Bay, Japan** - 249 km^2.
- **Kobe, Japan** - 23 km^2 (1995).
- **Bahrain** - 76.3% of original size of 410 km^2(1931–2007).
- **New Zealand** - significant areas of land totalling several hundred hectares have been reclaimed along the harbourfront of Auckland, Wellington and Dunedin. In Dunedin - which in its early days was nicknamed "Mudedin" - around 2.5 km^2, including much of the inner city and suburbs of Dunedin North, South Dunedin and Andersons Bay is reclaimed from the Otago Harbour, and a similar area in the suburbs of St Clair and St Kilda is reclaimed swampland.

Chapter- 9

Pier

A simple pier on Lake Mapourika in New Zealand

Southend Pier in England is the longest pleasure pier in the world, at 1.34 miles (2158 m)

A **pier** is a raised structure, including bridge and building supports and walkways, over water, typically supported by widely spread piles or pillars. The lighter structure of a pier allows tides and currents to flow almost unhindered, whereas the more solid foundations of a quay or the closely-spaced piles of a wharf can act as a breakwater, and are consequently more liable to silting. Piers can range in size and complexity from a simple lightweight wooden structure to major structures extended over a mile out to sea. In American English, pier may be synonymous with dock.

Piers have been built for several different purposes, and because these different purposes have distinct regional variances, the term *pier* tends to have different nuances of meaning in different parts of the world. Thus in North America and Australia, where many ports

were, until recently, built on the multiple pier model, the term tends to imply a current or former cargo-handling facility. In Europe however, where ports have tended to use basins and river-side quays rather than piers, the term is principally associated with the image of a Victorian cast iron pleasure pier. However, the earliest piers pre-date the Victorian age.

Types of pier

Piers can be categorized into different groupings according to the principal purpose. However there is considerable overlap between these categories. For example, pleasure piers often also allow for the docking of pleasure steamers and other similar craft, whilst working piers have often been converted to leisure use after being rendered obsolete by advanced developments in cargo-handling technology.

Working piers

Pier in Maraetai Beach in New Zealand used to convey cattle.

Working piers were built for the handling of passengers and cargo onto and off ships or (as at Wigan Pier) canal boats. Working piers themselves fall into two different groups. Longer individual piers are often found at ports with large tidal ranges, with the pier stretching far enough off shore to reach deep water at low tide. Such piers provided an economical alternative to impounded docks where cargo volumes were low, or where specialist bulk cargo was handled, such as at coal piers. The other form of working pier, often called the finger pier, was built at ports with smaller tidal ranges. Here the principal advantage was to give a greater available quay length for ships to berth against compared to a linear littoral quayside, and such piers are usually much shorter. Typically each pier would carry a single transit shed the length of the pier, with ships berthing bow or stern in

to the shore. Some major ports consisted of large numbers of such piers lining the foreshore, classic examples being the Hudson River frontage of New York, or the Embarcadero in San Francisco.

The advent of container shipping, with its need for large container handling spaces adjacent to the shipping berths, has made working piers obsolete for the handling of general cargo, although some still survive for the handling of passenger ships or bulk cargos. One example, is in use in Progreso, Yucatán, where a pier extends more than 4 miles into the Gulf of Mexico, making it the longest pier in the world. The Progreso Pier supplies much of the peninsula with transportation for the fishing and cargo industries and serves as a port for large cruise ships in the area. Many other working piers have been demolished, or remain derelict, but some have been recycled as pleasure piers. The best known example of this is Pier 39 in San Francisco.

At Southport and the Tweed River on the Gold Coast in Australia, there are piers that support equipment for a sand bypassing system that maintains the health of sandy beaches and navigation channels.

Pleasure piers

Print of Victorian pier in Margate, 1897

Pleasure piers were first built in England, during the 19th century. The earliest structures were Ryde Pier, built in 1813/4, Leith Trinity Chain Pier, built in 1821, and Brighton Chain Pier, built in 1823. Only the oldest of these piers still remains. At that time the introduction of the railways for the first time permitted mass tourism to dedicated seaside resorts. However, the large tidal ranges at many such resorts meant that for much of the day, the sea was not visible from dry land. The pleasure pier was the resorts' answer, permitting holiday makers to promenade over and alongside the sea at all times. The longest Pleasure pier in the world is at Southend-on-sea, Essex, and extends 2,158 metres (1.34 mi) into the Thames estuary. The longest pier on the West Coast of the United States is the Oceanside Pier.

Pleasure piers often include other amusements and theatres as part of the attraction. Such a pier may be open air, closed, or partly open, partly closed. Sometimes a pier has two decks.

Early pleasure piers were of wooden construction, with iron structures being introduced with the construction in 1855 of Margate Jetty, in Margate, England. Margate was wrecked in storms in 1978 and was never repaired. The oldest iron pleasure pier pier still remaining is in Southport, England, and dates from 1860 - however the world's oldest iron pier dates from 1834 and is in Gravesend, Kent. Gravesham council have recently purchased and refurbished this passenger pier.

Fishing piers

Many piers are built for the purpose of providing land locked anglers access to fishing grounds that are otherwise inaccessible.

Piers of the world

England and Wales

Victorian pier at Clevedon, Somerset, England

The Scheveningen pier, near The Hague

The pier of Blankenberge

The first recorded pier in England was Ryde Pier, opened in 1814 on the Isle of Wight, as a landing stage to allow ferries to and from the mainland to berth. It is still used for this purpose today. However it has had a leisure function in the past, with the pier head once containing a pavilion. There are still refreshment facilities today. The oldest cast iron pier in the world is Gravesend Town Pier, in Kent, which opened in 1834. However, it is not recognised by the National Piers Society as being a seaside pier.

In their heyday, there were many pleasure piers across England and Wales. These were found in most fashionable seaside resorts during the Victorian era. There are still a significant number of piers of architectural merit still standing, although some have been lost. The most well known piers are perhaps the two at Brighton in East Sussex and the three at Blackpool in Lancashire. Two piers, Brighton's now derelict West Pier and Clevedon Pier, were Grade 1 listed:Brighton West lost its status after a series of fires and storms. The Birnbeck Pier in Weston-super-Mare is the only pier in the world that is

linked to an island. The National Piers Society gives a figure of 55 surviving seaside piers in England and Wales.

Netherlands

Scheveningen, the coastal resort town of The Hague, boasts the largest pier in the Netherlands, it was completed in 1961. A crane, built on top of the pier's panorama tower, provides the opportunity to make a 60 metres (200 ft). high bungee jump over the North Sea waves. The present pier is a successor of an earlier pier, which was completed in 1901 but in 1943 destroyed by the German occupation forces.

Belgium

In Blankenberge a first pleasure pier was built in 1894. After its destruction in the World War I, a new pier was built in 1933. It remained till the present day, but was partially transformed and modernized in 1999-2004.