

Extract from News & Comment

New Orleans one year after Katrina

Tony Waltham writes A drive across the USA gave a chance to check on the state of New Orleans almost exactly a year after its disastrous flooding due to Hurricane Katrina (*Geology Today*, 2005, v.21, pp.225–231). The jazz plays on in the French Quarter, but the suburbs that were flooded last year are still in awful condition.

The levee breaks have been repaired, but only to their original height, and high concrete walls again loom over residential areas that are well below sea level (Fig. 8). Nearly all the flooded areas were dry within three weeks, except for some smaller re-flooding during Hurricane Rita just a month after Katrina. The streets were then cleared, and water lines, sewerage and electricity were restored across the flood zones within a month or two. Such was the immediate response by the city, but the rest was then left largely up to the homeowners. With 200 000 homes damaged or totally wrecked, this will take time.

Perhaps the area hardest hit by the flooding was the Ninth Ward, immediately east of the Industrial Canal whose west bank fell to Katrina's surge. Damaged and empty houses line the streets, and



Fig. 8. An intact section of levee along the London Avenue Canal holding back water that stands well above the houses—which were flooded when water swirled round from a levee break below the distant crane on the left.

Fig. 9. Close to the levee break in the Ninth Ward, a timber house floated off its footings, to land on an upturned car that was already on the foundation slab of another house.



endless piles of rubbish tell of ongoing repair activity. But perhaps only a quarter of the residents have yet come back. Signs on the houses are dominated by 'We're back' or 'We're coming back'; but there is a scatter of 'Please demolish' signs, alongside sad advert boards that shout 'We tear down houses'. Strong wooden frames, notably of cypress, on the older houses survived their few weeks under water—though their plasterboard walling is now useless. One returned resident showed us his house, looking good from the outside, but only a skeleton inside, as he starts the task of replacing the wall panels. However, many wooden houses floated off their foundations (which were concrete slabs, low brick columns or short piles), many to be wrecked when they came down on uneven ground (Fig. 9). Brick houses survived the flood well; we saw some only six years old that just needed a major clean after flooding by water 2.7 m deep, although their contents were beyond saving.

Still within the Ninth Ward, the area immediately in front of the Canal's levee break was much harder hit. For some few hundred metres, the torrent of water from the break tore everything before it. Wooden houses were ripped off their footings and smashed, even the few brick houses lost walls, and cars were tumbled around like toys. The streets are now clear, but most only lace across open space



Fig. 10. The newly rebuilt levee along the Industrial Canal rises above a part of the Ninth Ward that was stripped of its houses by the inrush of water, except for the concrete steps that once led to a front veranda.

where bare slabs of concrete were once foundation pads for homes (Fig. 10).

The mood of the people that we met was surprisingly up-beat. They are rebuilding their own homes, and are confident that more neighbours will return. They are vitriolic about the government for failing in their support, and even more so about insurance companies who are inventing escape clauses on a daily basis to avoid paying out. They feel abandoned by Big Business which will not re-open shops and services until there are more customers; they have to drive for an hour to reach a builder's merchant for supplies to rebuild. Some respite comes from a stream of church and volunteer groups; we saw a church group cleaning the streets, and a school group from Ohio giving a street party for local kids who had returned. Neighbourhood spirit does not come easy in a wasteland, but is exactly what ensures that these parts of New Orleans will eventually be rebuilt.

A local joke is that the government 'now has a plan to make a plan'. This justified frustration from people who are struggling to recover has to be tempered by the sheer scale of the task facing state and federal planners. It is implausible not to rebuild – the flooded areas are home to a quarter of a million people, and their land is all they now have. Some people have moved away, but many have no option and no place to go. America has plenty of space, but a substitute city where people are given new land would be unworkable; New Orleans is their home.

Rebuilding on land below sea level is inevitable, as there is just not enough space in the whole Mississippi delta that is above sea level. There is talk that rebuilding may be prohibited in some areas. But no single area is worse than the next; even the zones of total destruction are no guide, as the next levee breaks will be at different points. Most residents with repairable wooden houses simply accept that a repeat of the flooding is inevitable while sea levels rise and hurricanes increase due to global warming. Of those landowners rebuilding from scratch, we saw just a few who were building on stilts 3-m tall to keep above foreseeable flood levels. Some insurance companies are insisting that rebuilds are 1 m above ground level, but that is a useless compromise for houses nearly 2 m below sea-level. Over 100 000 people are eligible for federal grants, either towards the cost of rebuilding or as buy-outs for those who move away. But grants are only partial. Huge losses are borne by all those who were flooded, and the rebuilding of the city seems to be largely dependant on the positive outlook of the returnees.

A sustainable New Orleans does need adequate flood defences, but higher levees will incur massive costs. The federal budget has now posted \$3.7bn to



upgrade the levees, but it is estimated that over \$200bn will be required in the next 20 years to keep the city dry. Post-Katrina repairs to the existing levees cost \$3.1bn alone, far more than had been saved in the recent years of shrinking budgets and false economies. There is high-minded talk of 'restoring the wetlands' that are the natural defence against coastal onslaught. Certainly wetland losses in the delta have been massive, and have been accelerated by artificial changes to drainage systems and by subsidence after oil extraction. But the major losses are along the south side of the delta, and Katrina's flood surge came in from the east where the wetlands have remained stable.

Meanwhile, the cleanup of the suburbs is slow and costly. Much of the initial federal funding was spent on temporary housing for people flooded out of their homes. Over 50 000 caravans were supplied, and most are still in use on the front lawns of houses that are being slowly repaired. There are still mountains of rubbish in the streets, even though 75 million m³ have already been moved out; target date for final clearance is the end of 2006, and federal funds cover the cost until then. Wrecked cars still litter the streets;

Fig. 11. A two-storey Lakeview house that lost most of its ground floor to the flood surge.

they cannot be towed away, but are forklifted onto trucks. Street clearance is by local and outside contractors, but they are in short supply because there are so few places for them to live.

The total lack of rented accommodation is just one change in New Orleans. Tourist numbers are down (though bus-tours of the flood zones are a local success), and few conventions have returned. So hotel bookings are down a quarter on last year, and airport use is down to half, at a time when the city really does need the income. The population of New Orleans has dipped to half of what it was pre-Katrina, and the entire city has just slowed down. Recovery has a way to go.

The Lakeview and Gentilly suburbs lie to the north, between the city centre and Lake Ponchartrain. They were completely flooded by the levee breaks along the Canals of 17th Street and London Avenue—canals that were created to drain water out of the city, and not feed it in. More affluent than the Ninth Ward, the northern areas have a greater proportion of residents that have already returned—though many of them still live in front-lawn caravans while they make their homes habitable. More of the houses have two storeys. Many of these sustained major damage to their ground floor, while the upper floors remained unharmed, unless they lost all their support (Fig. 11).

A feature in parts of Gentilly has been localized ground subsidence. Many of the roads are distorted by wavy profiles, and local height loss is indicated by manholes and drain covers that now stand proud by 50 mm or more (Fig. 12). Comparable ground movement is shown by some houses built on piles that now stand clear of the ground around them (Fig. 13). The soil profile in these areas has 3 m of very soft clays, over 1–2 m of peat, with more soft clay down to 12 m deep. Compaction of the peats and clays, due to water removal, had already caused the subsidence that took the ground below sea level, and further volume loss was not likely due to the flooding cycle of saturation and then drying. It is more likely that this ground subsidence was caused by the lateral flow of groundwater, as the Katrina flood pulse moved into the area. This would have carried soil away, in a miniature version of piping, and would have been directed by lateral variations in soil permeability—as along the strips of sub-base installed for road construction.

Failure modes for the levees A typical New Orleans levee is an earth bank 3–5 m high, capped by a concrete wall 2.5 m tall (Fig. 6); a steel, sheet-pile core at least 6 m tall is set 1.5 m into the base of the concrete wall to stabilise it, and gains its own stability from within the earth wall, where it also constitutes



Fig. 12. In a Gentilly road near the London Avenue Canal, drain rings stand 50 mm above the subsided tarmac around them.



Fig. 13. A Gentilly house built on a piled box that now stands about 150 mm clear of the ground that has subsided, with a very visible gap through the broken steps.



Fig. 14. An office building at Gulfport had its ground floor ripped out by waves on the storm surge even though it stands well back from the sea.

the waterproof barrier. Unfortunately the sheet-piles do not continue deep enough into the soil profile to prevent seepage underflow through the very permeable peat.

The levee beside the Industrial Canal was overtopped by the storm surge that swept in from Lake Borgne (which is actually a bay on the Gulf of Mexico). This surge reached up to 3 m above the outer levees and breached these in more than a dozen places, then to pour water into existing wetlands. The surge was lower at the Ninth Ward breach, but overtopping water massively scoured the dry side of the levee, and thereby removed much of its lateral support. The water pressure was then enough to push the entire earth bank 12 m out of line, stretching and rotating the internal sheet-piles, and so causing total failure.

But overtopping was not a feature on the levees beside the two canals that were breached to flood the northern suburbs. Contrary to initial opinion, the storm surge on Lake Ponchartrain was only about 3.4 m (above sea level). The lake levees reach about 5.4 m, and were only overtopped by minor wave wash. The canal levees reach to just over 4 m, so they too were not overtopped. They failed because massive seepage flows passed beneath the short internal sheet-piles. This caused soil piping that undermined the entire earth banks until they collapsed, followed by rotation of the unsupported sheet-piles and total failure of the levee. Post-Katrina surveys have suggested that some of the land in these areas, already a metre below sea level, is continuing to subside by 25 mm/year, at five times the rate previously estimated. Subsidence of the levees built on this land could have caused overtopping and breaks, though the seepage failures appear to have got there first in the Katrina event.

Wind damage in the city was relatively minor, because it was hit only by weakened winds that came from inland due to the storm's rotation. But the coast towards and beyond Gulfport received the full force of the winds directly off the open sea. The combination of howling winds and pounding waves on top of some metres of storm surge was lethal. The entire coast was devastated. Waves reached high enough to wreck the first three floors of the harbour-front Gulfport Casino. A little further inshore, buildings had their ground floors torn out, and the upper floors only survived on strong frames (Fig. 14). Beyond the worst of the water impact, wind caused most of the damage (Fig. 15).

A side effect of the storm was the huge volumes of sand thrown up from the beaches into the wrecked housing areas. This was most noticeable on the barrier islands east of Gulfport, where sand was swept from the sea-side beaches, crossed the narrow islands and was dumped onto the lagoon-side beaches. Sadly most of the popular beach-houses-on-stilts faced the open sea, and 300 of them were wrecked on Alabama's Dauphin Island alone.

The impact of Hurricane Katrina was truly massive, both in New Orleans and along so much of the Gulf coast. Recovery is in progress, but it is inevitably slow, and now continues into its second year.

Fig. 15. The storm surge through the ground floors and wind damage to the upper floors, wrecked an estate of new houses in from the shore near Gulfport.

