

Tidal Flooding of 1st February 2002

Given in the IEI at 8pm

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Presented by Gerard O'Connell and Victor Coe, Dublin City Council.

Dublin City Tidal Flooding of 1st February 2002.

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On 1st February 2002 Dublin City experienced its highest recorded tide level in hundreds of years. This level was recorded by Dublin Port at 2.95M Malin Head Ordinance Datum.

All the levels in this lecture will refer to Malin Head Datum (MHD) which for the record is approximately 2.71M below Poolbeg Datum(PD) and approximately 2.51M below Dublin Port Lowest Astronomical Tide (LAT) Datum. For example 2.95M MHD equates roughly to 5.66M PD and 5.46LAT. In the last 8 years three of the seven highest tides for the last century have been recorded.

This talk is divided into three sections. If we could leave all questions to the end.

- 1.South City Flooding-G.O'Connell
- 2.North City Flooding-V.Coe
- 3.Causes, Return Period, Coastal Study, Barrages, Prediction and Prevention.

Section 1: South City Flooding

- (a) **Stella Gardens Area.**
- (b) **South Lotts Area**
- (c) **Newbridge Avenue**
- (d) **Marine Drive and Drummond Avenue**
- (e) **Merrion Gates**
- (f) **Beach Road and Strand Road, Sandymount.**
- (g) **The East Link Bridge**
- (h) **Victoria Quay**
- (i) **Other Areas**

(a) Stella Gardens Area.

The area around Stella Gardens, Irishtown, represented the largest and deepest area of flooding on the Southside of the City. The first emergency call was received by Dublin City Council at 13.08 pm. The water started coming over the river wall at a point on FitzWilliam Quay approximately 40M North of its junction with Dermot O'Hurley Avenue. It then turned through a right angle and travelled down Dermot O'Hurley Avenue into Aikenhead Terrace and proceeded to flood all of the Stella Gardens area out to the Irishtown Road to a maximum depth of 1.2M. The floodwaters then crossed the Irishtown Road and into St.Brendans Cottages where water depths reached 500mm.

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Floodwaters also went up Irishtown Road northwards to the next easterly street called the Square and some water went down same. Water travelled up FitzWilliam Quay as far as the entrance to Ashmore Ryder, around 100M from Ringsend Bridge. The large carpark of FitzWilliam Quay Apartments were flooded to a depth of 1.2M. Another underground carpark at the junction of Dermot O'Hurley Avenue and Irishtown Road called Summerfield was flooded to a depth of 2.1M through the Irishtown Road entrance.

The new bottle recycling centre at the old pumping station to the rear of the Dodder Siphon house on Fitzwilliam Walk, was also flooded. The caretaker reported that the river level was about 100mm below Quay level around 1pm that day when he was going home and that one of his customers saw the water coming over the quay wall there later on. There was evidence of same the following Monday.

From the initial breach over the quay wall the flood waters extended towards Ringsend Bridge and London Bridge in both directions until at the peak the breach extended over a section around 350metres long.

It is estimated that the flood waters started pouring into the Stella Gardens area around 12.50pm and continued until around 3.10pm a total of around 140 minutes. The total quantity of water flooding this area was around 50,000 cubic metres (11 million gallons). This would correspond to a river level of between 3.05 and 3.10M at Dermot O'Hurley Avenue giving an average rate of 6 cubic metres per second with a peak of around 90 cubic metres per second.

The local ESB sub-station was compromised and all power to the area was cut which meant that the whole area was in total darkness from 5.30pm. I arrived on site shortly after 6.10pm and met a local area manager Frank Lambe beside the siphon house. He was worried about paving slabs on the riverside walkway which were separating from each other. Just as I was about to study these closer a 35M section of the walkway moved and collapsed 4M into the river Dodder. It at 6.20pm. Frank took the Southern end of the collapse while I took the Northern end to warn pedestrians, cyclists, etc. Five minutes later another 10M section of Quay wall disappeared into the river.

About one hour later this section was sealed off with metal barriers. The Army arrived later with floodlights and three small pumps, two two inch and one three inch. I made my way to the Irishtown Road end of the site to co-ordinate the drainage of all of the seawater. Drainage drawings arrived on site from Inspector Ray Reid of the Marrowbone Lane Drainage Depot and this showed that the main sewer on Irishtown Road is 3'6" by 2'6" (1070 by 770) and that Dermot O'Hurley Avenue and Oliver Plunkett Avenue had separate sewers to same. One manhole on Oliver Plunkett Avenue had been located and the pipeline was surcharged to 600mm below surface level. The manholes on Dermot O'Hurley Avenue were still under 3' of water in near total darkness. After 15 minutes of searching two were found and this line could also be used to lower the water level. Slowly the water level started to drop.

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At 9pm the Irishtown Road was passable again and all road water was gone from St.Brendan's cottages.

I took a break at 11pm but had to come back for the high tide at 2.33am on Saturday morning to see how the clay embankment would cope without 45M of its Quay Wall. Everything went well as there was no sign of infiltration through the embankment. The flood waters had greatly subsided by 3am and they had totally gone by 8am on the Saturday morning. The Cleansing Department vanguard arrived at 6am to start tidying up of the Irishtown Road. Two underground car parks, Fitzwilliam Quay and Summerfield had been flooded by this extraordinary high tide. We (the Drainage Division) hired 5 pumps, two 6" and three 4" to pump these basements out. Work on these started at 9am on Saturday morning.

Fitzwilliam Quay Apartments Carpark was flooded to a depth of around 1.2M (4') which indicates a volume of around 3000 cubic metres. Work continued to 8pm that night, when some residents with young kids complained about the noise, and from 8am Sunday morning to around noon. At this time there was only 50mm of water left on the basement floor, there was very little fall on same and no obvious sump. We later found out that this was a self-draining floor. The last 50mm was problematic but we eventually cleared it by 6pm.

Summerfield Apartments were flooded to a depth of around 2.1M (7') indicating a volume of around 1500 cubic metres of water. Pumping out was more awkward than the Fitzwilliam Carpark as there was no river or main sewer manhole nearby so the floodwater had to be pumped into a local road gully. Work continued from 8am on Saturday to 8pm that night and from 8am on Sunday to 6pm. There was a drainage sump in this carpark which made the last part of the task relatively easy. When this carpark was pumped out one car which floated was found sitting on top of another car which had not.

The 45M of collapsed Quay wall was replaced in the following two months by Ascon construction working for DCC, using 12M long interlocking sheet piles. DCC Roads Maintenance organised the construction of a 450mm high concrete bund wall from Londonbridge to close to Ringsend Bridge to protect against a similar event.

Two further sections of the Quay wall, a total length of 200M, are due for replacement in a Contract starting next month. A new rc wall to a minimum height of 3.8M will be constructed from Londonbridge to Ringsendbridge as part of this Contract.

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(b) South Lotts Area

On the western side of the Dodder just upstream of Ringsend Bridge contractors Cramptons were working for Green Property on a large new offices building with an underground carpark, when the water level in the Dodder rose and overflowed into their building site at around 1pm. Fortunately the contractor had dug a large hole on the site 30M long by 10M wide by 7M deep and this took around 35 minutes to fill up. This corresponds to an average flow of around 700 l/s. Once the hole was full up the water found its way out onto South Lotts Road under the site hoarding at the entrance to Shelbourne Park.

The flood water flowed down South Lotts into South Dock Road, Doris Street and Gordon Street. Around 40 houses in this area were flooded. The maximum water level was around 400mm. The flood waters went all the way along Gordon Street to Barrow Street before they started to subside.

As part of Crampton's Health and Safety procedures a very audible river alarm, which which went off when the river reaches a level of 2.2M, was installed. When the alarm sounded the site was immediately evacuated. The Contractor also installed a rc wall to a height of 3.5M for vthe complete width of his site.

Shelbourne Park received very little flooding but a building contractor working there was instructed to build an earthen embankment 500mm high at its river boundry.

The new embankment and retaining wall constructed by Dublin Corporation (now Dublin City Council) Drainage in 1995 from Londonbridge north to the Scouts Hall on the western bank of the Dodder was built to a level of 3.15M. Locals state that the water level came within 50mm of overtopping same, but it held and did its job of protecting Derrynane Gardens, Bath Avenue Gardens, Bath Avenue and possibly further afield.

(c) Newbridge Avenue

Flooding waters started to pour into the Newbridge Avenue/Landsdown Park Area around 2pm and continued until slightly after 2.30pm. Water came through viewing gaps in the wall of a small park area just downstream of the Newbridge (Landsdowne Road Bridge) at the junction of Herbert Road and Newbridge Avenue. This park area is known locally as the "jungle". Water from the jungle came out onto Newbridge Avenue, then headed towards Landsdown Park before veering down a laneway to the rear of Newbridge Avenue where it made its way into around 15 garages and back-gardens. Four houses were flooded upto a level of 450mm.

Water also made its way more directly into this laneway across the riverside footpath over steps and across Lansdown Park roadway into the laneway. A DCC Drainage Maintenance Gang was working on a surface water sewer near the jungle at the time. The foreman made note of the maximum height achieved by the flood water. This was later levelled in at 3.35M Malin Head. Some minor works are planned with the piling Contractor for Stella Gardens to make this area safe from a similar event. Temporary preventative measures are currently in place.

(d) Marine Drive and Drummond Avenue

This flooding was a result of some wave action as well as the high tide. Water came in through two pedestrian access gaps in the sea wall near the junction of Marine Drive and Beach Road. Some water was splashed over the sea wall which is at a level of around 3.5M at this location. The sea-water crossed Beach Road and headed down Marine Drive where it flowed almost to its junction with Sandymount Road reaching a peak level of around 2.2M. This flow branched off at Drummond Avenue and flowed half way up same towards Seafort Avenue. Flood waters reached a maximum depth of around 600mm and approximately 20 houses were flooded. Similar to Stella Gardens all power including street lighting and all gas supplies to Marine Drive were lost. Some of the telephone lines were also compromised. Fortunately on Drummond Avenue no houses were flooded.

When the floodwaters finally receded around 6.30pm large quantities of sea sand marked the extent of the flooding.

For the following three months of predicted high tides DCC Drainage Division maintained a barrier of twenty number one tonne sand bags at the junction of Marine Drive and Beach Road (which meant a temporary diversion for the No.3 bus route. The pedestrian openings in the sea wall have been temporarily sealed at this location.

(e) Merrion Gates

The South City River gang clears out various river racks every Friday in case of a storm over the weekend. So on Friday 1st February 2002 they were cleaning out the racks on the Elm Park stream in Caritas opposite Merrion Gates just off Merrion Road. At around 12.45pm the gang foreman, Brendan Murphy, noticed unusually high waves splashing against the sea wall across the Merrion Road. He went to investigate but at this stage sea-water had started to get in from the beach onto Strand road and into some of the house gardens off same. He went back to his gang, mobilised them, despite it being lunchtime and raised the alarm. When the gang got to the scene water was now pouring off the beach onto Strand Road to a depth of around 200mm through a gap 11M wide. This did not deter the traffic however which was still passing at high speed and pushing the water into the gardens at an accelerated rate.

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All the river gang could do, as they could not prevent the flow from the beach onto the roadway, was

- (1) To alert all the residents of the danger
- (2) To alert the oncoming traffic of the danger and try to get them to take an alternative route and
- (3) Go into each garden and try and drain the sea-water into the Drainage System to prevent house flooding.

They succeeded in alerting all the occupied houses of the danger. The traffic proved more difficult as most drivers ignored the DCC workers and ploughed on. They got into all of the 21 gardens and drained the threatening sea-water into the Drainage Network in 19 of these, however the last two houses had built over their garden manholes and these were flooded.

The tide continued to rise until around 2.30pm when it reached a depth of around 600mm at the entrance to the beach beside Merrion Gates and 1.2M at the low point on the roadway. By 3pm it had subsided and only the roadway was flooded. By 3.30pm it had largely disappeared except at isolated locations.

As well as getting into residential gardens the flood water go onto Merrion Gates Dart line shortly after 1pm. The Dart line had to be closed. The floodwaters covered a 100M stretch of the line. They also crossed Beach Road and flooded the ESB sub-station which supplies the portion of the Dart line around Merrion Gates. All power was lost. When the floodwaters subsided at around 3.30pm the ESB substation was still flooded as it was at a much lower level than the roadway and one of the South City Drainage jet-vactors was called in to pump it out. The jet-vactor complete this task around 5pm. The power was turned on at 6pm but the attempt was unsuccessful and it was not until 6.30pm that full power was restored and the Dart Line could be used again.

This opening to the sea is now monitored on a continuous basis and blocked off temporarily when the tide threatens to come through.

(f) Beach Road and Strand Road, Sandymount.

Between Merrion Gates and Marine Drive there were a total of 20 openings in the sea wall. The one at Merrion Gates and the two at Marine Drive have been mentioned earlier. This leaves 17 which vary in width from 0.5M to 10M, in height from 0.3M to 1M and in level from 3.0M to 3.5M. Five of these openings are entrances and exits to carparking areas.

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Sea water came through all of these openings and most of Beach road and Strand Road were flooded. Unfortunately there are openings opposite Seafort Avenue, Newgrove Avenue, St.John's Road, Sydney Parade Avenue and Guildford Road and water in different quantities went down all of these. The lower floor of 25 and 27 Beach Road were flooded, as well as the Martello Tower at the junction of Beach Road and Strand Road and the garage beside 143 Strand Road was flooded. In all around twenty properties on the coast were flooded directly.

Water travelled down St.John's road to its junction with Park Avenue. On Guildford Road the water made its way down to Brabazon House opposite Gilford Terrace, it filled up the outside carpark and rose within 50mm of the ground floor. Brabazon house is a residential home for the elderly and infirm. It has slightly over one hundred occupants plus staff. The lower floor was evacuated upstairs. Some of the residents could walk while others had to be carried. After 30 minutes the water level subsided.

The flood waters also went down Newgrove Avenue which lead to the flooding of three shops on the Northeastern corner of Sandymount Green.

Water also flowed down St.Alban's Park but a local surface water drainage pumping station took care of this.

(g) The East Link Bridge

100M on the Southside of the Eastlink Toll booth the high tide started to flood the roadway around 1pm. By 2pm it had reached a dangerous level of around 400mm and the attendants tried to close the roadway. A number of commuters would not be desuaded however and drove quickly through the flood waters. Most made it, some however did not and this quickly closed the roadway. The waters subsided and by 2.30pm the toll road was back in business.

Surprisingly it only takes around 500mm (20") of water to float a vehicle, even a large vehicle. Slightly less depth is required in swiftly flowing water. It is mainly to do with loss of traction.

(h) Victoria Quay

This quay is the lowest of all of the City's Quays with a minimum road level beside the Liffey circa 2.35M and is prone to flooding. This is usually caused by rainwater not being able to escape to the river during a particularly high tide. This flooding rarely causes the closing off of the Quay to traffic.

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On 1st February 2002 road flooding started around 1pm and continued to 3pm. Flood levels peaked around 1.30pm then reduced and peaked again shortly after 2.30pm. The Quay was closed to cars from around 1.15pm and lorries from 1.30 to 2.45pm. The peak level was taken on the steps just upstream of Luke Kelly Bridge at 3.12M. The rear entrance to Guinness's was temporarily closed. The river came up almost to the top of the river wall but there was only minor splashing over it and infiltration through it.

(i) Other Areas

- (1) The sea also crossed City Quay to a depth of 50-75mm and went down Windmill Lane where the local drainage system which goes to a 3'6" by 2' brick pipe took care of it. This section was later sandbagged to prevent a reoccurrence.
- (2) Sir John Rogersons Quay experienced minor quay wall overtopping but this was catered for by the local Drainage System. Recently the Dublin Docklands Development Authority have proposed raising sections of the roadway along Sir John Rogerson's Quay.

Generally:

All of the flooded areas on the Southside of the City and most of those on the Northside of the City drain to the Mainlift Pumping Station at Ringsend. However during all of this flooding only 60% of pump capacity was used, indicating that the Drainage system was overloaded locally in the flooded areas.

Section 2: North City Flooding

- a) Shamrock Cottages
- b) Ossary Road.
- c) Blyth Avenue
- d) Abbercorn Terrace / Irvine Terrace
- e) East Wall Road
- f) Boardwalk
- g) The Quays in general
- h) Clontarf Road
- i) Wolfe Tone Quay / Benburb Street
- j) Miscvellaneous

My first indication of flooding was on Clontarf Road at its junction with Alfie Byrne Road, where I noticed at about 1 O'clock, that the linear park at that location, had been inundated by seawater, and the waves were lapping up onto the park.

The Northside Drainage Depot in Bannow Road, received its first alarm about flooding at 1.35 pm in Shamrock Cottages, where we were told that the river had burst its banks. We sent down our river gang overseer, who explained that it was not the river that was bursting its banks but in fact it was the canal. One of our jet vectors arrived on site at about 2 O'clock, it reported that the road was completely flooded. Waterways Ireland was informed at 2 O'clock, and they were asked if they could provide any assistance. Our Inspector arrived soon afterwards and when he saw how severe the problem was, he requested that as many men would stay back as was possible, as this flooding required significant numbers of staff. He met one of our City Councillors whose daughter lives in one of the houses.

Most of our men in Bannow Road stayed back, and were augmented by staff from Orchard Road, Roads Maintenance depot, from O'Rahilly Parade Waste Management depot, Collins Ave Roads Maintenance depot, and a number of men from other depots. These men arrived at 5pm. We got more men in the depot from other depots at approx. 9 pm. Waste Management gave us the use of 10 men and two trucks at 11pm.

We also had the use of Cleansing cars to deliver dam bags, Bedford Trucks from the paving section, and of course all the trucks large and small available to us in Drainage Division. We also got two Army trucks in the depot, but with all the trucks in the depot, we could not serve them as well, they then went to Roadstone in East Wall, That day we filled and estimated 2500 dam bags in the Bannow Road depot alone.

We also received a police escort for a number of our trucks, our Inspector recalls getting a great kick about racing through a 30 mile per hour zone, with a police escort, breaking all the red lights. Another driver rang the depot on his mobile phone while he was having a police escort, but had forgotten that if the police who were escorting him caught him he could be fined €100.

(a) Shamrock Cottages

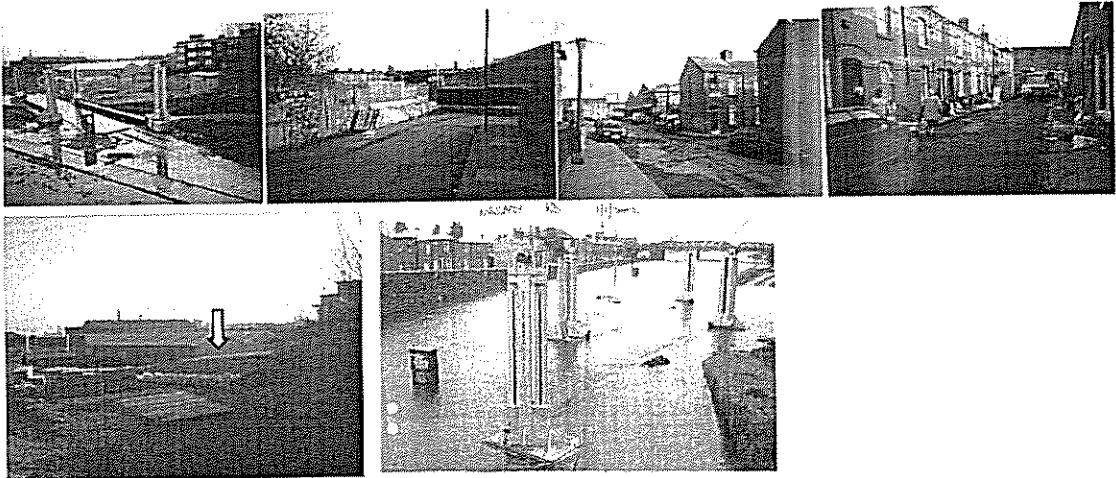
Water came from the royal canal, through a hydraulic lifting bridge over to Guilford place, through a break in the boundary walls, and down Guilford Place to Shamrock Cottages. Shamrock Cottages is one of the lowest areas in East Wall with levels 0.850m MH, thus being 2.095 metres below the tide level. It is roughly estimated that the tide rose 200mm over the level of the surrounding ground near the canal.

The flood levels rose to a depth of about 1 metre on the road, flooding all the houses, and the hallway of the adjoining public flat complex. We received no reports of flooding within the flats. We opened all the gullies and manholes in the road, and opened some of the manholes in the flat complex to relieve the floodwaters. At about 6 pm that evening the floods receded, as once the tide lowered the floodwaters stopped coming down from Guilford Place.

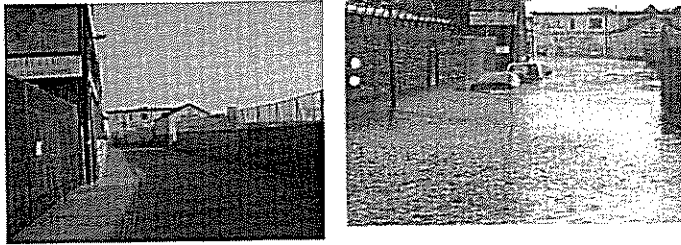
Drainage Division tried to place 1 ton dam bags onto the flow of water, but they got washed away, it was only when the tide receded that Drainage Division could build a temporary wall of 1 ton dam bags, and a couple of pallets of small bags to reduce the risk of flooding. This wall had to be re-instated a number of times due to un-sociable behaviour, this re-instatement work was carried out by the joint efforts of Drainage Division and CIE.

CIE also constructed a small wall along the length of the canal, down to the lifting bridge, and left a number of 1 ton dam bags around the bridge, which could easily be placed into position by CIE staff at short notice.

Later CIE built a permanent wall bounding their property and Guilford Terrace, preventing a similar flooding incident taking place.



(b) Ossary Road



There is a 2 metre high wall along the length of this road, this road is at a level 0.855m MH that is 2 metres below the flood level of 2.95. Water built up behind the wall, causing significant hydraulic pressure behind it. There were some weep holes in this wall, which allowed some relief from the head of water. The wall collapsed due to the head of water behind it, it collapsed along the line of these holes. Water behind this wall poured onto the road, and down into Ossary Road Business Park. All the factories in this estate got flooded. AI kitchens is located at the lowest point of this park, flood waters almost reached the second floor level of the building, to a depth of well over 1.5 metres. Other roads that we have reports of flooding are on Hyacinth Street, and the Crosbie Business Centre.

This wall is now been rebuilt to a higher standard. The existing wall was re-inforced by the construction of an inner leaf.

(c.) Blyth Ave



Water blew out a door on Blythe Ave, which was CIE's Personal Access door. The depth of water coming through the door rose to an approx height of 1.5m. This area is 2.6 metres below the flood level. Drainage Division and local residents tried on a number of occasions to dam the opening, but their combined efforts not reduce the flow of water through the door. Dam bags were constantly getting washed away. The water in this road was at a depth of over 750mm. Our inspector on the ground, requested a JCB to get dam bags and dump them in front of the doorway, to hold back the water. This JCB would then stay there and act as a support for the dam itself.

Most of East Wall got flooded from here, levels on this road reached reported depths of 500mm and the flooding travelled along roads such as;

Church Street, West Road, Church Road, Caloden Road, St. Mary's Road, Moy Elta Road, Fairfield Avenue, Killan Road, and Russell Avenue etc.

Hawthorn Terrace got hit quite badly, as it is the lowest street in the area, and it is the nearest street to Blyth Avenue.

All our manholes were opened in the area, but it did not make any difference as the drainage system in the East Wall area drains into a combined system, which was already overloaded.

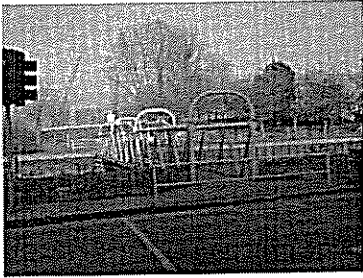
Later that evening our Inspector telephoned in at about 6, and explained that we were still getting significant flows through this door from the Spencer dock area, the tide was now well out, we quickly realised that the CIE lands were acting like a large reservoir, and they were holding back a significant amount of water. Major flows had stopped coming through this door at approx. 10pm, which gives us an indication of the volume of water, which the Spencer Docks can hold.

(d) Abbercorn Tce / Irvine Tce



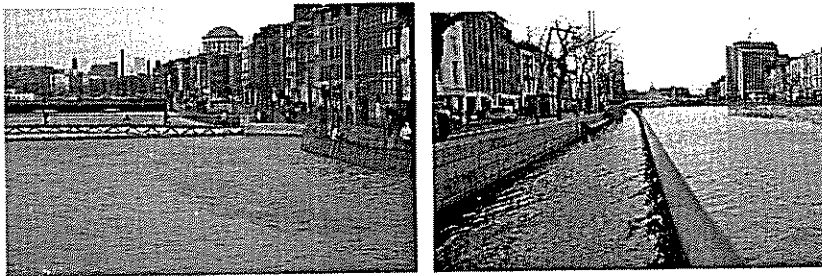
This area has a very low wall, of about 6 metres wide, bounding the CIE lands, this wall is only a couple of centimetres over the ground level of the tracks, was easily over topped. About 20 houses were flooded here, to approx. depth of half a metre. This was one of the last areas to drain away as the tracks stored a significant amount of water, the bulk of which was released through the door on Blyth Avenue, approx 400 metres away. In Irvine cottages some people are still not back in their homes.

(e) East Wall Road.



There were reports of flooding from the footbridge on East Wall Road, but we are not aware that it caused any property damage. Road levels are at 3.3m Malin head, which is very close to the high tide level, taking it and the flow in the Tolka River into consideration, concerns were raised into the possible flooding of East Wall Road. During a number of high tides post the 1st of Feb 2002 Drainage Division placed bags across this entrance. Since then we constructed a flood defence barrier, which can be lowered into place if there was an impending flood. This is located in our pumping station in East Wall Road, which is manned on a 24 hour basis.

(f) Boardwalk



This flooded to a depth of approx. 300mm. As can be seen from the photographs. There are four low entries to the boardwalk, which are 5 metres wide, and are at levels of 3.2m, 3.25m, 3.35m and 3.4m, the lowest being 100mm above the flood level.

Concern was raised about these openings, due to the fact that if there was a significant storm, combined with a very high tide, and if the levels rose to approx. 100mm over the lowest of these openings, then water would travel un-abated down Liffey Street and Strand Street, to Jarvis Street.

As an interim measure sand bags were placed along these openings, to ensure that the quays were not flooded.

It is proposed to install a more permanent removable structure, which can be easily put into place if there was a dangerous impending high tide.

A second boardwalk is proposed from O'Connell Street to Butt Bridge.

(g) The Quays in General



As can be seen from the photos they show that the tide looks as if it is about to submerge the bridges, and Civic Offices. On Wood Quay it was approx 300 mm above the road level. North Wall Quay flooded also, on this road floodwaters rose only 30 to 40 mm above this quay, but caused no reported property damage.

(h) Clontarf Road

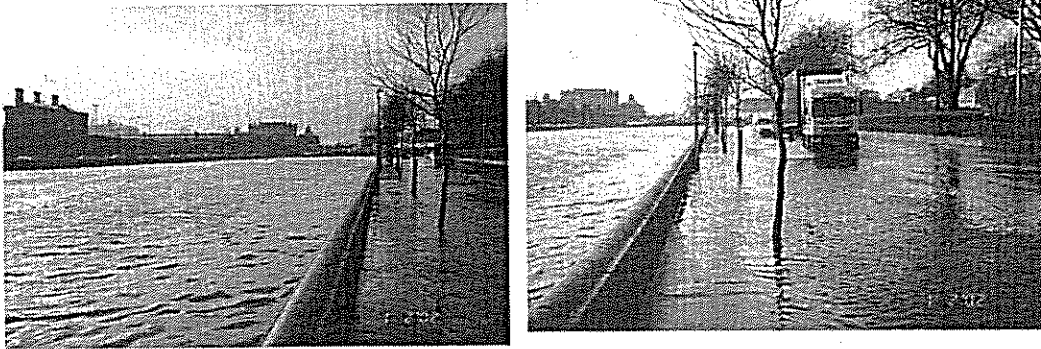


The water levels rose over the linear park along Clontarf Road near the Clontarf Baths, it endangered houses at this location, and near Alfie Burn Road.

There is a berm along the park, which was designed we assume as a flood defence mechanism, the cycle track and pedestrian walkway rises and fall over this berm at various locations. Flooding occurred in three locations along Clontarf Road, one location was due to the removal of a small wall along the footpath, and the other two locations were due to a low level of parkland. There is a large surface water storage culvert running along the length of Clontarf Road, which was overpowered. There were no reports of flooding in houses, but near the Clontarf baths water did get into a front porch, and into one garage. All the houses and shops on the road were sandbagged, which prevented water entering homes.

There is an Arterial Watermain and new Public Sewer planned along this stretch of Clontarf Road, and a high berm can easily be installed with this construction.

(i) Wolfe Tone Quay / Benburb Street



This road flooded as the level of the tide rose over the quay wall on Wolfe Tone Quay, both Wolfe Tone quay and Benburb Street were flooded to a depth of 300mm. A number of properties on Benburb Street, including a hotel, had dam bags laid across their entrances. Most gullies on Benburb Street are connected to a 600mm public combined sewer, and not to the Liffey, so this pipeline must also have been overpowered.

(j) Miscellaneous

There were other areas which we got reports of flooding, a number of weeks after the event, these roads were Newcomen Avenue, this road is located very near Ossary Road, we know that the combined sewer was overpowered, as this road is connected to the same system, and is lower than the flood level on Ossary Road. We can assume that this road suffered flooding from the floodwater in Ossary Road. We also received reports of flooding on North Strand Road a number of weeks after the event, we can assume that flooding occurred here due to similar circumstances. There was also some flooding of properties on Annesleybridge Road due to the flooding of the system.

At present there is a study, which is ongoing, studying the Royal Canal, a report is due by the summer.

Section 3: Studies, Barrages, Prediction and Prevention

- (a) Global Warming
- (b) Tidal Barrages
- (c) Dublin Coastal Study
- (d) Prediction of high tides
- (e) Actual high tides
- (f) Pumping versus Drainage versus Wall Height
- (g) The Nightmare Scenario

(a) Global Warming

Global warming is nothing new. It has been going on since the end of the last Ice Age, 10,000 years ago apart from a few hiccups (eg. mini-Ice Age 1550-1850). World temperatures have increased by 5deg.C (9degF) since the last Ice Age. Sea levels have almost continuously risen since then by well over 30M (100feet) and are continuing to rise. Last century it is estimated that global sea levels went up by between 100mm and 250mm (IPCC 2000) and that a 100-200mm rise per century has been typical of the last few hundred years.

What has changed is that there appears to be an acceleration in global warming. In the twentieth Century average global temperatures rose by 0.6degC (1.1deg.F) and half of this rise occurred in the last 30 years of the century. The 1990's are thought to have been the warmest decade in the last millenium. In Ireland this rise has been closer to 1deg.C in the 20th Century. This has set alarm bells ringing and a number of centres and organisations have been set up around the world to try to monitor and predict this effect.

The main culprit to this warming appears to be greenhouse gases. These are principally Carbon Dioxide, Methane, Water Vapour and Ozone. Certain quantities of these are essential for life as we know it on earth. The way that the greenhouse effect works is;- Sunlight hits the land which warms it. Infra red radiation later tries to leave the warmed earth into space but some of it hits molecules of the greenhouse gases which reflect a portion back to the earth. Molecules with three atoms or more work best for this job. Carbon Dioxide rise gives a very close correlation to Global Temperature rise. An Irish Engineer called Tyndall was the first to propose this principal, he was born in Carlow in 1820 and was one of the leading scientist of his day. He is the "father" of the greenhouse effect and one of the Major British Research Centres for Climate Change, the Tyndall Centre, is called after him.

The above analysis caused the levels of the greenhouse gases to be monitored very closely and Carbon Dioxide (CO₂) in particular. It was discovered that between 900AD and 1800AD the level of CO₂ stayed fairly close to 280ppm. Since then it has risen dramatically to around 370ppm in 2001, a rise of 32%. Most of this rise has been in the last century. Currently the net rise is around 2ppm per annum.

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It takes approximately 30 years for CO₂ to make its presence felt in the atmosphere so we are currently feeling the effects of 1973 emissions. This also means that no matter what we do regarding emissions it will have little effect until 2033.

Of the other greenhouse gases water vapour is the most prevalent. Over the last century its levels globally have increased by 1-5%. Methane levels have increased dramatically in the distant past with higher global temperatures. Ozone, which protects us from high energy UV radiation, is recovering, however it is also a greenhouse gas. Aerosols and volcanic eruptions actually reduce the greenhouse scenario but unfortunately both have dangerous side effects.

What does the future hold?

The UKCIP02 briefing report, which is based on a number of Global Climate Models and their interpretation by leaders in the field of climate change looks at four scenarios: Low Emission of CO₂, Medium Low, Medium High and High. Low appears to be everyone complying with Kyoto, Medium Low-most comply, Medium-High some comply and High virtually nobody complies.

The Medium-High scenario gets the most attention and this predicts land temperature rises in Ireland of 3degC in summer and 1degC in winter with 2/3 of these rises occurring at night, by 2080. This scenario also predicts 10% wetter winters and 10-20% drier summers in the Dublin Region. The predicted increase in rainfall intensity is up to 20% in the winter. The predicted sea level rise including extreme events is estimated at around 400mm by 2080 of which 300mm of this seems to be attributable to sea rise. The land around the Dublin area is meant to be sinking by around 0.3mm per annum as part of a general land recovery from the last Ice Age.

There are warnings about the Western Antarctic Ice Sheet (where 70% of the world's fresh water resides) melting and raising average sea level by 1-3M very quickly i.e. within a few decades. Another danger concerns the North Atlantic Drift which if stopped could decrease British and Irish temperatures by up to 8degC.

Most of the sea rise is attributable to expansion of seawater due to warmer temperatures and a lesser amount is due to the melting Ice Sheets.

(b) Barrages for Dublin City

Tidal barrages have been considered in the past both on environmental (keeping a certain level of water in the upper tidal region of the Liffey) and on flood protection grounds. A large tidal barrage was built on the Thames to protect London many years ago at a cost of str.£500M. It is due for replacement in the next twenty years at a cost of billions. Four locations have been mooted over the years for the Dublin Barrage, all on the river Liffey. Starting from the Matt Talbot Bridge and going downstream:

- (1) Just downstream of Georges Quay, beside IFSC. The width would be around 120M. There would be sea gates, etc. to allow small ships and boats to get around it.

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- (2) Just downstream of Commons Street, Creighton Street, width 130M. Again sea gates, etc., were proposed to allow small ships and boats to get around it.
- (3) Just downstream of the Royal canal at Spencer Dock, width 140M and again sea gates etc. were proposed to allow small ships and boats to get around it.
- (4) Just downstream of the East-Link Toll Bridge, width 200M. There would be sea gates, etc. to allow small ships and boats to get around it. This would have the biggest restriction on Dublin Port as a number of ship berths would be lost. This proposal would give access from the Grand Canal to the Royal Canal assuming that other remedial work was completed.

As you go down the Liffey the river gets wider and deeper and so the cost of a barrage escalates. The starting price for (1) would probably be around €40M rising to around €400M for (4). Only option (4) would protect the Dodder, Royal Canal and Grand Canal as well as the Liffey. In all cases the overflow height/gates openings would have to be carefully calculated.

(5) Dublin Coastal Flood Risk Assessment Study (DCFRAS)

This study which is due to start in May 2003. It will use an existing Western Atlantic high tide model and adapt a portion of it off Dublin Bay for more detailed scrutiny. This new model will be the property of DCC and Fingal CC. It will consist of three Zones. North of Howth, Liffey to Howth and Liffey to Booterstown. The Model combined with local knowledge should provide an early warning system of potential high tides. There will be an option in the model to add to mean sea level for Global Warming.

The Coastal Study will also look at existing sea defences and areas at risk from sea flooding or associated flooding and propose solutions to prevent same. It will also look at wave overtopping mechanisms.

The Study will also model the Liffey, Dodder and Tolka (to Annesley Bridge) tidal reaches.

This Study will look at local flood prevention devices, similar to current ones being investigated by DCC.

A report is due in mid 2004.

(6) Prediction of High Tides.

One of my recent jobs, after the 1st February flooding, was to try and predict future high tides levels at the Alexandra Basin Lighthouse. I first tried to think of all the factors involved and the to quantify them. The principal of these are:-

- a. **Celestial bodies, the Moon and the Sun.**
- b. **Atmospheric pressure.**
- c. **The wind.**
- d. **Rainfall**
- e. **Local topography and**
- f. **Flows from dams at Bohernabreena and Leixlip.**

(1) The Celestial bodies are covered, fortunately, by the tide tables issued by Dublin Port which give the predicted high and low tide levels and times for each day of a particular year. Dublin Port also record actual tide levels both digitally and by analog at their Alexandra Basin Lighthouse. Dublin City Council has established a telemetry link with same to their Drainage and Mechanical Services Divisions. Dublin tide levels are now monitored 24 hours per day, 365 days per year. These levels are predicted to two places of decimals in the Dublin Port Tide yearbooks eg. tonight the high tide is predicted at 3.19M LAT which is 0.68M Malin Head which makes it one of the lowest high-tides of the year. The predicted high tide time is 4.52am.

The next high tide of note is on Thursday 20th March at 12.43pm and its predicted level is 4.47M LAT (1.96M Malin Head).

(2) Atmospheric Pressure is the next easiest to predict. Standard Pressure which used to be recorded as 1000mbar is now 1013.25hPa. For every hPa below this pressure, at sea level the tide is observed to rise by close to 10mm and for every hPa above this standard pressure the tide is observed to rise by slightly less than 10mm.

(3) The wind. This is the first of the tricky ones.

A wind from the East is the most dangerous and has been observed to raise sea level by approximately 12mm per mph. As many weather charts measure wind in Knots, an adjustment of 1 Knot = 1.15 mph has to be made. An East wind also causes significant wave action, wave height within the Dublin Port equates roughly to 10mm per mph, outside the harbour the height is greater say 15mm per mph. With an East wind the high tide tends to be later than predicted, upto 1 hour depending on strength.

A wind from the West tends to reduce the sea level by around 10mm per mph. High Tide is earlier than predicted by as much as 45minutes again depending on strength.

A wind from the South tends to raise the sea level by around 7mm per mph. It delays the time of the high tide. If a wind from the south blows continuously over two high tides the it can have a cumulative effect on the second high tide. This is called a Seiche.

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A wind from the North tends to depress the sea level by around 7mm per mph. It normally makes the high tide earlier. If a wind from the north blows continuously over two high tides the it can have a cumulative effect on the second high tide.

Winds in between these bearings express characteristics of both. A wind from the South West has little effect on the high tide. Only winds from the East or Northeast cause significant waves within the harbour on the coastline while any component of East wind will cause some waves within the bay. These waves are more prevalent during high tides due to the half tide breakwater being over-topped.

(4) Rainfall. Another tricky one.

From observing rainfalls over the City area and slightly beyond, I worked out a rough relationship between the average rainfall in mm/hr over the whole greater City Area and the rise in the high tide at Alexandra Basin. For small rainfalls of upto 10mm/hr over the Liffey/Dodder/Cammac/Poddle catchment the rise in high tide was around 30mm per mm/hr at Alexandra Basin tide guage and for rainfalls of 20mm/hr it equated to a rise of 23mm per mm/hr.

(5) Local Topography

Wave action going upstream only occurs at Alexandra Basin when there is a large component of East in the wind direction. This however does seem to elevate the river level upstream even though at high tide waves are largely stopped by O'Connell Bridge. Wave action along Sandymount is also very important. The Department of the Marine has a permanent buoy situated approximately 25 miles due East of Dublin Bay. It often records wave heights of 4M in strong winds. Just outside the bay wave heights of two metres should be possible. At Sandymount a wave height of close to one metre should also be possible as heights of around 500mm have been observed in medium/strong winds. Also along Sandymount sideways waves seem to elevate sea levels at the Marine Drive end and the Merrion Gates Strand end.

(6) Flows from Bohernabreena and Leixlip Dams.

If these flows occur at high tide they can have a significant effect on the tide level. The further up from Alexandra Basin that they are the greater their effect. Bohernabreena is normally managed very well keeping the lower reservoir half full when a storm is pending. It takes flood water approximately two hours to get from Bohernabreena to the City. Hurricane Charlie brought an estimated 250m³/s down the Dodder. The bridges on the Dodder restricted the quantity getting to the Liffey estuary but it would have been around 200m³/s which would raise the level at Alexandra Basin by around 500mm. The Dodder normally has a two to three hour flash peak due to its steep gradient so this gives a 25% chance of it coinciding with the peak of a high tide.

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Leixlip Dam has no choice but to release water after a flood when it gets to a certain level behind the dam. It takes around three hours to reach the city area. In recent years the largest quantity was less than 90m³/s, this would raise the high tide level by around 250mm at Alexandra Basin.

All of this gives us the formula:-

$$\text{Estimated Tide level} = \text{predicted} + (1013-P) \times 0.01 + W_i \times \text{mph} + R + W_a + D$$

P = predicted atmospheric pressure I hPa

W_i = allowance for wind per mph + allowance for wind blowing in same direction for two high tides.

R = Rainfall allowance in mm/hr x 30 to 20 depending on quantity.

W_a = Wave height allowance. W_a by 2 to prevent most splashing. (W_a=1/2 Amplitude).

D = Allowance for Dams Discharge.

This formula has been used approximately 50 times for high tides and most of the high tides were predicted to within 100mm. Let us look at what it makes of the high tide of 1st February 2002.

Data:-

Predicted high tide level Dublin Port Handbook = 4.44M LAT (1.93M MH Datum).

Atmospheric pressure during event 986hPa.

Wind speed 30mph gusting upto 65mph generally South. Some eye witnesses stated that the wind picked up and changed direction to more Easterly.

Rainfall 5-6mm County wide 1-2 hours before the event.

Some waves were noted in the Sandymount Area.

No significant dam discharge.

$$\text{So estimated tide level} = 1.93 + (1013-986) \times 0.01 + 65 \times 0.07 + 5.5 \times 30$$

$$= 2.82\text{M without any wave allowance or wind turning}$$

Easterly. While this is 130mm below the actual wave height reached it is well above the danger level of the time which was around the 2.5M Malin Head. The danger level is now around the 3.0M level.

A second method of prediction is to estimate the average high tide rise one, two and three hours before a peak. With a high tide of note the rise is normally 300mm in the last hour, 700mm in the second last hour and 900mm in the third last hour. Thus is the tide level reaches 1.5M with more than two hours to go to high tide the on-call Inspector is notified.

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(7) Actual High tides

Since 1st February last year I have been analysing every high tide in Dublin Bay. To date this accounts for over 800. The actual level has been separated from the predicted to give the surge. These have been compiled in chart form and represent roughly a typical standard deviation curve. The tails of this curve are slightly thicker than usual.

The first unusual feature of this curve is that the average surge is 120mm above zero. Excessive rainfall for 2002 would only explain 1mm of this. The standard deviation (S.D.) for the curve is 202mm. Taking out the event of 1st February makes negligible difference to these. On studying four other bays in Britain that exhibit similar S.D.s. An average surge of slightly more than 0.5 standard deviations above zero surge was observed in each. This difference is meant to be caused by the difference in tidal movement due to low pressure events and high pressure events.

The six highest surges in the 14 month survey period were 1.02M, 0.78M, 0.77M, 0.74, 0.73 and 0.7M respectively, while the lowest surge was -0.82M. All were associated with significant low and high pressure events.

From this analysis and the four other analyses (which were done over much longer periods (11 to 17 years)) the high tide of 1st February 2002 would give a surge event of $1.02M/0.202M = 5$ S.D. which indicates a return of around 1 in 2100 tides. As there are 706.5 tides per year this means once every 3 years. However such a surge has to be combined with a particularly high tide of 1.93M to reach a level of 2.95M or more. On average there are 10 of these per year so this gives an estimated return period on this surge combining with a predicted tide of 1.93M (or above) as $706.5/10 \times 2100 = 148,365$ (or once in 212 years currently).

This is not however the full story as it does not include for the possibility of a higher surge combining with a lower predicted tide, for example a 1.21M surge combining with a 1.74M predicted tide. When all of these possibilities are combined it brings the return period down towards the 1 in 85,000 mark (120 year return period currently).

High tide studies recommend using results over a nineteen year period, which corresponds to the Lunar Tide cycle and almost two solar Tide cycles, so clearly further analysis is required, however I would be surprised at drastic changes in these return periods.

With accelerated global warming and no breaks on same for the first thirty years these return periods should drop by around 30% every 25 years i.e. for a 2.95M high tide at 1 in 85,000 (120 years) 2002, equates to a 1 in 60,000 (85 years) in 2027, or a 1 in 42,000 (60 years) in 2052 or a 1 in 32,600 (46 years) by 2080. The last two are assuming the Medium/High CO2 scenario.

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The above high tides relate to a 2.95M level at Alexandra Basin on 1st February 2002 but it has to be remembered that as you go up the Liffey and the Dodder the river levels rose, particularly as there was some flow in these rivers at the time.

At Alexandra Quay a peak level of 2.95M was recorded. The estimated level coming in at Stella Gardens was between 3.05 and 3.1M. Between the siphon house and Londonbridge the peak level was around 3.15M. In the "jungle" beside Newbridge the level was recorded at 3.35M.

On the Liffey the only other recorded levels were around 3.1M on the boardwalk at the halfpenny bridge and 3.12M just upstream of Luke Kelly bridge. As the tide level rises the bridge restrictions and the quantity of flow in the rivers become more and more important. The above level difference between Luke Kelly Bridge and Alexandra basin was 170mm, but level differences of close to 600mm have been observed.

(8) Pumping versus Drainage System versus Wall Height

This section compares using pumping, the existing drainage system or a higher wall to prevent tidal/river flooding.

A 4" (100mm) pump can normally pump 200 gallons per minute = 15 l/s,
A 6" (150mm) pump can normally pump 500 gallons per minute = 38 l/s,
An 8" (200mm) pump can normally pump 1000 gallons per minute = 75 l/s.
These are all assuming that there is somewhere nearby to pump to.

A 9" (225mm) diameter pipe, severely surcharged can cope with a flow of 120 l/s.
A 12" (300mm) diameter pipe, severely surcharged can take a flow of 210 l/s.
A 3' 6" (1050mm) by 2' 6" (750mm) sewer, severely surcharged can take a flow of 1900 l/s.

In Stella gardens it took 19 hours to drain away all of the sea water at road level or above.

Taking a river wall with a gap in it so many millimetres deep and so many metres wide these are the estimated corresponding flows:-

Depth (mm)	1M wide (l/s)	2M wide (l/s)	3M wide (l/s)	4M wide (l/s)	5M wide (l/s)
100	52	111	164	221	285
200	148	313	477	642	806
300	272	574	877	1,179	1,481
400	419	884	1,350	1,815	2,280
500	585	1,236	1,887	2,537	3,188

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It can be clearly seen from the above table that “prevention is better than cure” and that pumping and designing improved drainage systems do not compare to raising the height of a river wall or installing one in the first place. In many instances this wall does not need to be very high to keep back major quantities of sea or freshwater.

(9) The Nightmare Scenario

This involves a very low pressure passing over the Wicklow mountains. This would set up heavy rainfall in the Dublin Bay catchment as well as high East winds, low pressure and large waves.

References:

- (1) UKCIP02
- (2) www.met.ie
- (3) www.tyndall.ac.uk
- (4) www.IPCC.ch
- (5) Weird weather-Paul Simons
- (6) Flood Shock-Antony Milne
- (7) Dodder Flood Study – J.B.Barry
- (8) www.met-office.gov.uk/research/hadleycentre