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Technical visit: BDS conference 2014: report on conference tours

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This paper presents a single report that covers one preconference to Lagan Weir and four BDS conference tours: 'The Mournes' Silent Valley/Ben Crom reservoirs, 'Upper Bann', 'North West' Toome Sluice/Altnaheglish, and Carrickfergus' Carrick System and Titanic's Pump house.

1. A preconference tour: Lagan Weir

The preconference tour involved a visit to the Lagan Weir in the centre of Belfast. However, before the trip could start the group wanted to eat (see Figures 1 and 2).

The Lagan Weir impounds the river upstream of Donegal Quay to Stranmillis Weir, a distance of 4·8 km. The river varies in width from a maximum of 110 m below the McConnell Piers to 30 m at the narrowest stretch between Cutter's Wharf Restaurant and Stranmillis Weir. It is a low flow river with surface velocities reaching 1·5 m/s in flood conditions and is very safe for navigating and water-based activities.

The Department for Social Development owns, and is the navigation authority, for the stretch of the river from Stranmillis Weir to the Harbour Commissioners limit on the downstream side of the Lagan Bridge.

The Lagan Weir has helped in a very significant way in the regeneration of this area of Belfast; costing about £20 million, it is thought to have brought benefits in excess of £1 billion.

The Lagan Weir is located downstream of the Queen Elizabeth Bridge. It is a dynamic structure with five flap gates, each operated by a large hydraulic ram, and is used to control the water levels in the impoundment upstream to Stranmillis Weir. The Lagan Weir can operate automatically through linkages to water level gauges, or when conditions indicate, on manual override. The mechanism is able to respond to varying weather, tidal and water quality conditions, and affords a measure of flood protection from surge tides for the city centre. The gates can be operated to permit the passage of boats across the weir into the impoundment.

The River Lagan rises in the Dromara hills near Slieve Croob (close to Lough Island Reavy) and flows northwards, first through countryside and then into the cities of Lisburn and Belfast.

The catchment area at the gauging station at New Forge (upstream of Stranmillis in South Belfast) is 492 km^2 and the maximum recorded flow of 138 m^3/s was recorded in August 2008.

The weir provides protection against downstream extreme high tide events to a level of 3·00 m ordnance datum (OD). This is the same level as the surrounding quay levels throughout Belfast Harbour, but the predicted 1 in 200 years tide level, including for climate change conditions, is 3·2 m OD. This poses a significant flood risk to most of Belfast city centre.

Figure 1. Tour lunch

Figure 2. Tour lunch

Figure 3. High level walkway

Figure 4. The weir

The weir structure consists of five hydraulically operated fish belly gates, each 20 m long × 5·5 m high, fabricated from steel with an epoxy paint protection system. Each gate is operated from one end by a single 250 t capacity hydraulic ram, which incorporated a form of ceramic coating to minimise cylinder seal wear in a saline environment.

At the time of original design and construction these coatings and the control system operating the gates were considered to be state of the art. However, being in the saline conditions resulted in a gradual deterioration of both the gate coatings and the surface coating of the ram rod. This caused wear on the cylinder seals and the gradual increase in the rate of oil leakage into the adjacent marine environment.

A condition report on the structure identified the need for improvements and a programme of works was subsequently developed. The temporary works included the use of 18·2 m long stoplogs, originally designed to be used on the Ransome and Rapier gates on the Bann River, to allow isolation of each gate for detailed cleaning, assessment, testing and refurbishment. The gates were repainted in a controlled encapsulated environment within the stoplog cofferdam, while the cylinder rods were replaced with a new and improved form of ceramic coating. The project was completed early 2011.

Plans are currently being developed to change the high-level walkway over the weir into a feature bridge which will be more fitting with the high-quality public realm landscape that now exists (see Figures 3 and 4).

The installation of aeration equipment in the upper stretch of the river above the McConnell Piers assists improvement in water quality, which in turn helps sustain fish life and improves the aesthetic appearance of the river.

A tour of the structure allowed delegates to see the control mechanisms, to walk through the gallery in the base of the structure and to view the gates (Figure 5).

Figure 5. Tour of the gallery

Figure 6. Boarding the 'Mona'

Technical explanations of the recent refurbishment contracts were made before the delegates boarded the 'good ship Mona' to sail around the harbour area and the sites of the 'Titanic' quarter (see Figures 6 and 7).

Our thanks go to the Department for Social Development for hosting the visit.

Figure 7. The Titanic quarter

1.1 Tour 1: 'The Mournes' Silent Valley/Ben Crom reservoirs

Tour 1 visited the Silent Valley Dam and Ben Crom situated in the Mourne mountains in County Down. The tour was led by Dr Phil Donald, retired Chief Engineer of Graham Construction and was organised by the ICE PHEW – Northern Ireland.

After a very pleasant coach trip during which Phil Donald gave an excellent commentary on the history of the Silent Valley reservoirs, we arrived at the Silent Valley dam. This is the jewel in the crown of NI's reservoir stock, and is one of the main supply sources for Belfast and the urban areas of North Down to the northeast of Belfast.

Proposed by L.L. Macassey in 1891, the dam is a 24 m high, 460 m long earth embankment with a central puddle clay core. The reservoir is 3 km long and has a capacity of 13 638 Ml. The overflow is formed by a circular bellmouth spillway discharging to an outlet tunnel. Construction was delayed until 1923 and was completed in 1933 by contractors S. Pearson and Co and Sir E. Moir and Co, under the supervision of a three-man board chaired by W.J.E. Binnie, with G. Mclldowie as the resident engineer (Figure 8).

Of particular note was the difficulty experienced in digging the cut-off trench in a mixture of very fine silts, sand, gravels and boulders. The open excavation was abandoned due to the boil of silt and running sand, and was eventually completed by

Figure 8. Outlet tunnel from the bellmouth

Figure 9. Demonstration section of shafts and trench

sinking ten shafts used as pumping sumps to dewater the ground. The shafts were lined with cast iron segments, sunk under compressed air and then used as pumping sumps under free air. The maximum air pressure used was 0·24 N/mm^2 and by adopting a leap-frog technique, this was sufficient to allow shafts to be sunk to a maximum depth of 64·6 m, although the water table was reduced to only 24·7 m below ground level.

After the shafts were in operation, the intermediate sections of trench were excavated in free air and lined with cast iron segments that were strutted apart with 300 mm $\times$ 300 mm timbers. We were shown a demonstration section of the shafts and trench at the site which is formed from the original cast iron segments (Figure 9).

A splendid lunch was served at the Silent Valley Visitors Centre with the excellent Irish stew, which is a very popular choice. This was followed by a very informative presentation by Dr Phil Donald.

Our tour continued with a visit to Ben Crom which is the upper reservoir in the series at Silent Valley. The original proposal was by L.L. Macassey in 1891, and it was intended to build a reservoir in the Annalong Valley. However, due to foundation problems it was decided to divert the flow from the Annalong intake through a 3·4 km tunnel into the Silent Valley reservoir, with additional storage being provided at Ben Crom.

The Ben Crom Dam was designed by Binnie and partners and constructed by Charles Brand between 1953 and 1957. It is a concrete gravity dam with a central spillway. The total volume of concrete in the dam is 93 000 m^3 and the structure is 213 m long, 30·5 m wide at the base and 34 m high above the

Figure 10. Outlet from Ben Crom

riverbed. It is divided into blocks of length 16·5 m with rubber waterstops at the joints and upstream caulking grooves.

The central block of the dam contains the outlet works, which comprises one 685 mm dia. steel pipe controlled by a needle valve and jet disperser. The inlet end is fitted with trash racks, a sluice gate controlled from the dam crest and a guard valve controlled from the gallery, into which we were allowed to enter during the tour (Figure 10).

Great thanks are due to Dr Phil Donald for leading the tour and providing us with the benefit of his extensive knowledge and research into the Silent Valley reservoir series. Thanks are also due to the ICE Panel for Historic Engineering Works for arranging the tour.

2. BDS Biennial conference 2014 – Belfast

2.1 Tour 2 – 'Upper Bann' – Lough Island Reavy, Spelga and 'stop' at Fofanny

This paper is a report on the site visits undertaken during the 2014 BDS Biennial conference in Belfast.

Tour 2 was to the Upper Bann reservoirs that are situated in the Mourne Mountains to the south of Belfast and a visit to three reservoirs was planned (time allowing).

At the allotted hour we embarked the coaches, shared out water and chocolate biscuits and then we were off!

After journeying south from Belfast through the panoramic countryside and into the Mourne Mountains, we arrived at our first stop Lough Island Reavy Reservoir, once we had disembarked we separated into smaller groups to explore the dam and its pertinent structures.

2.1.1 Lough Island Reavy

General details of the reservoir: constructed between 1837 and 1839 the reservoir has a capacity of 9000 Ml with a length of 2 km and a surface area of 102 ha.

The reservoir impounds water from and returns water to the river Muddock a tributary to the Bann which is the largest river in Northern Ireland. There are also two feeders resulting in a combined catchment of 1336 ha and an annual average rainfall of 1350 mm.

The reservoir is formed by four earth embankments totalling 1 km long, which are sited on the underlying mourne granite. The main embankment is depicted as having a puddle clay core with enhanced leakage protection provided by a 0·9 m thick layer of peat on the upstream face of the core and below the gravel of the upstream slope.

The dams remained virtually unchanged, save for some leakage sealing works until 1973, when the ownership was transferred to Northern Ireland Water (NIW). Following its acquisition NIW instigated works that included

- rockfill stability berm along the main embankment
- reconstruction of the 18 m-long spillway
- provision of a wave wall on the east dam
- construction of a new education tower.

On our tour of the reservoir we viewed the main embankment noting the additional rock berm and the modifications undertaken to the outlet works before following the spillway chute up to the spillway weir and the adjoining feeder inlet. After an inspection of the structure we headed along the crest to investigate the education tower (Figure 11).

Figure 11. Lough Island Reavy Education Tower

Once we had completed our visit to Lough Island Reavy we returned to the coaches to continue our journey further into the Mourne Mountains. Our journey included an interlude in Castlewellan where a hearty lunch was enjoyed and discussions of dams and countryside ensued, before continuing in a southerly direction to Spelga Dam, once we had disembarked we separated into smaller groups to explore the dam and its pertinent structures.

2.1.2 Spelga Dam

General details of the reservoir: constructed between 1955 and 1957 the reservoir had an original capacity of 2727 Ml, with a length of 1·1 km and a surface area of 58 ha. The reservoir catchment is rough upland at elevations ranging from 320 to 670 mAOD, with an area of 704 ha and an annual average rainfall of 1890 mm.

The reservoir is formed by a mass concrete gravity dam with a crest length of 305 m and maximum height of *c.* 28 m. The dam is founded on bedrock and the construction used the locally available Silurian rock as aggregate in the formation of the 13·7 m long blocks. There is a longitudinal inspection gallery, a central valve tower and originally profiled spill weirs. In 1978, four sets of three air regulated siphons were installed to increase the capacity to 3327 Ml. These siphons replaced the original weirs and sluice gates were installed to infill the remaining unaffected weir sections (Figure 12).

During our site visit we heard of the challenges faced by the Supervising Engineer fulfilling his remit of inspecting the siphons internally, roped access was the only applicable method, oh and a good head for heights was needed! (Figures 13 and 14).

Recent remedial works had been undertaken to the internal faces of the siphons (concrete repairs and application of a protective paint system), the replacement of the wave deflector and the provision of an access from ground level directly to the

Figure 12. Siphons and adjoining sluice gate

Figure 13. View from dam crest

inspection gallery. The ground level access was required to enable safe personnel access and provide the ability to evacuate a casualty should the need arise. The original access was by descending the valve tower and passing through a short connecting gallery. The new access was 7 m long and cut through the concrete, the undertaking of this proved challenging with issues regarding the strength of concrete encountered, the

Figure 14. Downstream face showing siphons and sluice gates

practicalities of cutting and removing large blocks of concrete and ultimately how to ensure the access is securely protected, but in a manner to allow ease of access when required.

Once we had completed our visit to Spelga we returned to the coaches to start our return journey north to Belfast, there was a scheduled short stop at Fofanny reservoir to view the earth embankment dam and recently completed adjacent subterranean water treatment works. The water treatment works were constructed below ground to limit the aesthetic impact within the area of outstanding natural beauty. Due to time constraints we were unable to enter the site to peruse the operational side of the water treatment site; however, travelling along the adjacent road confirmed the visual impact of the operational site was minimal.

On behalf of all the participants of tour 2, I thank NIW for hosting our visits and all those who assisted with the site tours, providing overviews of the salient features and history of the sites and more importantly fielding our often exuberant questioning.

2.2 Tour 3: 'North West' Toome Sluice/Altnaheglish

Tour 3 headed west out of Belfast to reach Toome Sluices. These sluices impound Lough Neagh, the most extensive lake in the British Isles at 30 km long and covering 393 km^2, which supplies 40% of the region's drinking water. The sluices discharge water out of the lough to the River Bann which then flows north to the Atlantic Ocean.

The sluices comprise of five vertical lift steel sluice gates each 18·3 m wide, between two 130 m-long fixed crest side weirs and a fish pass, all of which are required to maintain the lough within a 150 mm level tolerance. An adjacent navigation lock permits boat passage along the River Bann to pass into Lough Neagh.

The group first stopped at the left bank, from where a good view of the whole sluice structure was visible, and then moved to the right bank and crossed the lough to reach the sluices.

After climbing up the steps to the walkway over the sluices the group had an excellent view of the lough and also the river downstream, although most were busy inspecting the gate operating machinery on the walkway. The Rivers Agency staff operated one of the gates a short distance to demonstrate the system, and told the group that due to the long response time (due to the run-off attenuation provided by the very large lough) there was no automatic gate operation – staff attended and operated the gates as necessary.

After a good lunch at a Toome hostelry, the group continued westwards and upwards (into the drizzle) to Altnaheglish Dam, a water supply reservoir owned and operated by NIW. Access was by way of small, unclassified roads, so the final stage of the journey up to the dam was made by transferring to a minibus (Figure 15).

The dam, featured on the cover of the conference proceedings, has a height of 29 m and a crest length of 110 m.It, is slightly curved in plan, retaining a volume of 2270 Ml by impounding the 730 ha catchment of the Altnaheglish River. The dam was originally a conventional concrete gravity dam, but concerns over its stability led to it being stabilised in 1987 using a rock fill berm on the downstream side, as well as the incorporation of a grout curtain and uplift relief wells.

Despite the weather, the group was able to walk over the crest of the dam, down the steps beside the spillway chute, and through the gallery, where the scour valve outlet and the pipework for water supply to the distribution network was located. NIW staffs were available throughout the visit to answer the many questions raised by the interested members of the BDS group (Figure 16).

2.3 Tour 4: 'Carrickfergus' Carrick System and Titanic's Pump house

Tour 4 commenced with a short coach journey to Copeland Reservoir, and those delegates travelling on Coach 1 benefitted from a commentary by Alan Cooper, who had delivered the previous evening's Binnie Lecture. Copeland reservoir was completed in 1881 and has a catchment comprising rough upland area of peat and forest with an area of 1269 ha, including the upstream Lough Mourne catchment. The dam is ~625 m long, 19 m high and impounds the Beltoy River with a maximum storage volume of 607 Ml. Between 1975 and

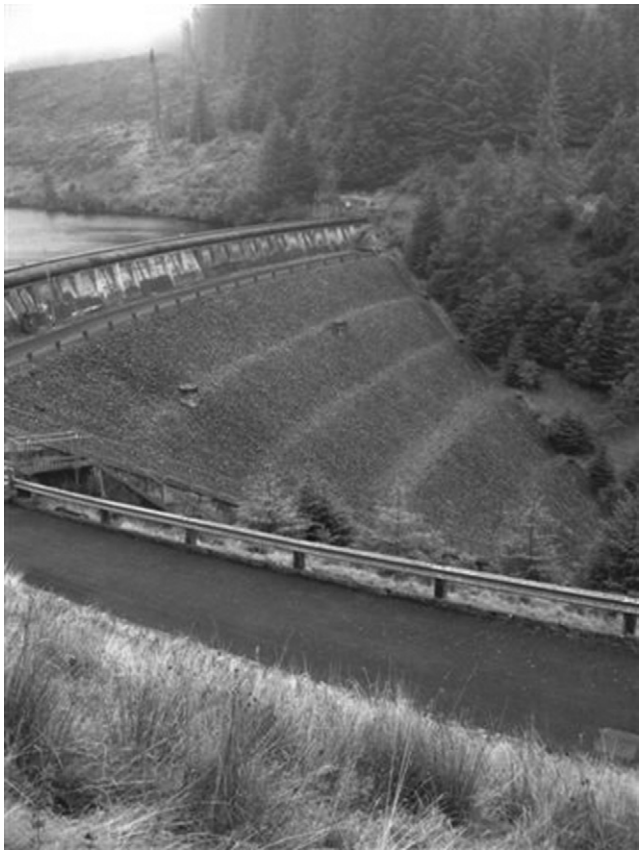

Figure 15. Altnaheglish Dam

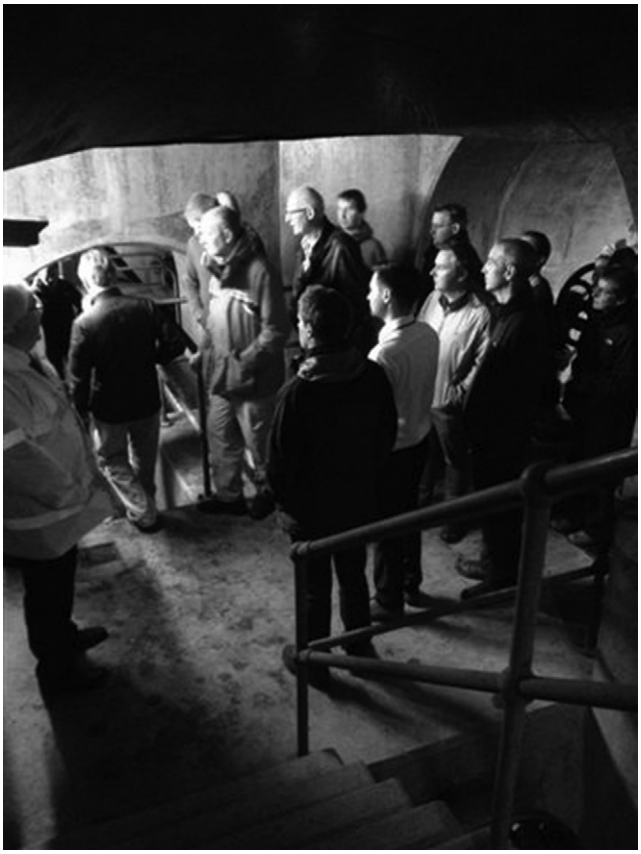

Figure 16. Entering the gallery

Figure 17. Thompson Graving Dock – construction completed in 1911

Figure 18. Thompson Graving Dock – temporary home of the Titanic

1982 a range of improvements were carried out including a wave wall, a new profiled spill weir, cascade spillway channel and a rockfill stability berm with a filter.

After a well-earned pub lunch at the Wind Rose in Carrickfergus, the tour continued to the nearby Woodburn Reservoir cascade. The South Woodburn Reservoir impounds the South Woodburn River and was completed in 1876. The catchment is rough upland and forest area extending to 599 ha. The reservoir is ~840 m long and impounds 1669 Ml. The dam consists of an earthfill embankment with a central puddle clay core. The dam structure is 500 m long and has a maximum height of 22 m. The toe is submerged until the Middle South Reservoir is drawn down by 8 m.

Between 1975 and 1982 a range of improvements were carried out including a wave wall, additional spillway capacity and a stability berm with a filter. The draw-off arrangements were again refurbished in 2013/2014.

The delegates were able to walk along the crest and downstream mitres of the embankment to observe the stability works.

The tour then progressed to the Middle South Reservoir. This dam was completed in 1868. The catchment is rough upland and forest area extends up to 1350 ha. The dam is ~600 m long, 26 m high and impounds 2135 Ml.

Between 1975 and 1982 a range of improvements were carried out including additional spillway capacity and a rock stability berm with a filter. The draw-off arrangements were also refurbished in 2014.

The visit to Woodburn then concluded at the Lower South Woodburn Reservoir. This dam was completed in 1880 and is 325 m long and 19 m high. A wave wall was constructed in 1982.

Not content with the previous evening's entertainment at Titanic Belfast, the tour concluded with the theme and visited the Titanic's Dock and Pump house. The Titanic sat in the dry dock at Belfast on the eve of her first and last voyage in April 1912. Titanic is remembered for the dramatic story of her sinking, but in 1912, she was an icon for all that was great about the twentieth century – she was the most innovative, the most luxurious and the most awe-inspiring thing ever created by the hand of man.

The impressive dry dock gave a sense of scale to the vast ship-building industry that had once dominated the area. It was the largest dry dock ever constructed at the time, a feat of Edwardian engineering in its own right. Inside the pump house, the massive pumps and hydraulic accumulator, still very well preserved, served as a good reminder of the legacy of engineering excellence of which Belfast could be proud (see Figures 17 and 18).