ABSTRACT

Urban tidal inlets often lend themselves to economically important port development. In many cases, such inlets are artificially deepened and maintained for continuous human use. A range of ecological, hydrological, sedimentological and financial impacts can result from such manipulation. A good understanding of a sedimentary system provided by a comprehensive sediment budget allows informed decisions and planning and encourages sustainable coastal management.

The aim of this research was to develop, for the first time, a sediment budget for Otago Harbour, on the southeast coast of New Zealand. Otago Harbour is a highly modified tidal inlet that occupies two river-incised (and/or fault-incised) volcanic valleys. Previous research has investigated many sediment inputs and outputs for Otago Harbour but there is a lack of research relating to sediment storage, thickness and sedimentation rate. This thesis assesses sediment thickness throughout Otago Harbour using three complementary methods: (1) a geometric bedrock model, (2) land-based gravity anomaly profiling, and (3) marine seismic reflection surveying.

The geometric model, developed from topography and bore records using a maximum bedrock depth of 120 m (sea level at the last glacial maximum), estimated a maximum sediment volume in Otago Harbour of almost 5 billion m$^3$. Land gravity surveys (at Aramoana, Upper Harbour Basin and St Kilda/St Clair) and marine seismic reflection surveys refined this estimate to 1.62 billion m$^3$. Gravity modelling found the maximum sediment thickness to be $\sim$100 m at the modern harbour entrance and $>70$ m at the St Kilda paleo-river mouth, whereas the seismic survey found the greatest basement depth ($\sim$76 m) just inside the entrance at Harington Point. Taken together, these findings suggest that the sediment package accumulated at a rate of $\sim$90,000 m$^3$/y since the last glacial maximum (equivalent to $\sim$2 mm/y). However, this rate of storage no longer occurs because of the current dredging regime.

In the present sediment budget, sediment entering the harbour on the flood tide (619,000 m$^3$/y) is the dominant sediment input to the system (626,000 m$^3$/y), though most of it exits the harbour on the ebb tide (516,000 m$^3$/y). The difference is more than compensated for by seafloor dredging, which removes more sediment than the net
amount entering the harbour (-28,000 m³/y), thus removing stored sediment. As a result, the harbour’s sedimentary system is in deficit, and the deficit is likely to increase in the future if dredging continues at the same long-term rate (244,000 m³/y).

Otago Harbour can no longer be deemed an “infilling harbour”; human intervention has overturned that natural balance. Instead, the system’s deficit may explain recent erosion at Te Rauone Beach. Furthermore, the lack of carbonate sediment accumulation, due also to changes in early seafloor processes, means that Otago Harbour plays a reduced role in preservation of carbonate information and sequestering of atmospheric CO₂. Human activities in other urban tidal inlets may have caused similar deficits. As modelled for Otago Harbour, the next century promises to bring a great deal of change (climate, ocean chemistry, urban development) with unexpected consequences for urban tidal inlets.