The Stewart et al. (2018) paper reports the results of groundwater geochemical and age tracer analyses for five Christchurch springs post the Mw 6.2 Christchurch Earthquake (22 February 2011). The importance of the paper’s content and the application of the methodology cannot be overstated for ongoing Christchurch Artesian System (CAS) groundwater monitoring and input into the Environment Canterbury groundwater management plan. The provenances and tritium analyses of two of the Stewart et al. (2018) sampled springs are particularly important – WL wetland reserve, Woolston and SB Sandbar spring, McCormacks Bay located adjacent to and within the Avon-Heathcote Estuary, south-east Christchurch at the Canterbury Plains–Port Hills margin. Fringe Banks Peninsula springs at Ferrymead and Mount Pleasant, sourced from volcanic rock groundwater, have been known long-term (Brown and Weeber, 1994) but not CAS-sourced artesian springs. If WL and SB are artesian springs they are the first totally CAS coastal artesian springs to have been identified at Christchurch. To date for the Christchurch coastal plains sector all springs are derived from near surface Waimakariri River gravel channels, rain and drainage water. The mean residence times estimated from tritium (TU) were 150 years for WL and >180 years for SB, showing accordance of age with CAS-sourced groundwater. The paper lacks geological input as to Christchurch subsurface stratigraphy and site-specific hydrogeology descriptions for the springs. When these are considered for one of the sampled spring sites there is a distinct possibility that the sample was derived from a leaking abandoned well rather than an artesian spring. Photographs of the springs would have enhanced the paper.

Bells Creek and several of the following mentioned wells are shown on the 1:25 000 Christchurch Urban Area geological map of Brown and Weeber (1992). The geological map also shows the former Sumner Borough Council’s well fields at Ferry Road, Rat Island and Fishermans Flat and well M36/w980 Christchurch City Council/Christchurch Drainage Board at the well field adjacent to Bells Creek and the site of WL. Brown and Weeber’s (1994) Figure 4 Woolston – Ferrymead well log cross section has the subsurface stratigraphy for the area of the strata and aquifers penetrated by the wells.

The WL wetland reserve spring at Woolston near the Ferry Road–Tunnel Road roundabout is in a Christchurch City Council reserve named Te Oranga Waikura Urban Forest and stormwater basin. The reserve site is associated with Bells Creek, a pre-European settlement, spring-origin creek. The sampled spring is a small spring upwelling in the course of a stream (Mike Stewart, pers. comm.). Bells Creek is spring,
rain and drainage sourced and originally flowed from the Linwood area adjacent to where Linwood High School is now for about 2.5 km southeast to the Heathcote River at Ferrymead. Its upper course is now totally changed by settlement and drainage. In the Woolston area a ridge 20 m below mean sea level (msl) on the Riccarton Gravel surface extends towards the Avon-Heathcote Estuary (Figure 70 of Brown and Weeber, 1992, shows contours of the surface of Riccarton Gravel). For a total CAS source, WL spring flow would have to be associated with upward groundwater flow through post 6500 yrs marine Christchurch Formation regression deposits. These are about 20 m thick at Woolston. In the Woolston–Linwood area there are subsurface postglacial Springston Formation Waimakariri River gravel flood channels within Christchurch Formation. The gravel channels have the potential to provide conduits for upward flow of groundwater from the underlying Riccarton Gravel artesian aquifer. The well logs show these Springston Formation gravel deposits are restricted to narrow, discrete channels at the eastern margin of central Christchurch (Brown and Weeber, 1992 – Fig. 15). In the catchment of Bells Creek they can be identified in some, but not all, well logs. Examples are gravel at 9.1–19.8 m overlying Riccarton Gravel at 32.3 m at Linwood Avenue School baths (M35/w2111), at 3.7–7.9 m with Riccarton Gravel at 21.3 m at the CCC Ensors Road pumping station, Opawa (M36/w932), and 9.8–12.5 m with Riccarton Gravel at 32 m at G.L.Bowron Company Limited Wool Tannery, Jubilee Street, Woolston (M36/w1080). The interbedded Springston Formation gravel channels become more sporadic, narrow and thin towards the coast and do not extend as far as Ferrymead. Their river flood channel deposition was constrained to the Linwood, Opawa and Woolston area by the coastal sand dune complex at Avonside, North Linwood and Bromley. These sand dunes, up to 7 m amsl, are the highest intact Christchurch Formation sand dunes. Linwood, Bromley and Woodlawn cemeteries are located on them. A radiocarbon date (NZ7837) of 2156 years BP of a buried (4 m above msl) estuarine shell sample at the Linwood Cemetery had suggested localised uplift in the area. Post-Christchurch Earthquake identification of a buried fault (Port Hills Fault; Beavan et al., 2015) at 6 km depth in this area provided an explanation for this seemingly anomalous uplifted beach deposit. During the Christchurch Earthquake, movement on the Port Hills Fault produced accompanying catastrophic liquefaction and subsidence at eastern Christchurch, but with 0.45 m uplift at the Avon-Heathcote Estuary (Tonkin & Taylor, 2012) in the vicinity of the fault. Sporadic localised uplift associated with buried faults may have facilitated the 20 m contour ridge on the Riccarton Gravel. The return period of the Mw 6.2 Christchurch Earthquake is 300 years (Elder et al., 1991), estimated prior to the discovery of the Port Hills Fault. The Linwood Cemetery shell radiocarbon date shows that for the last 3000 years the ‘cemetery’ sand dunes would have constrained Waimakariri River flood channels to their west. The channels are aligned to Ferry Road, which was described by the 1850s settlers as ‘high ground’ through the Christchurch swamps to the four avenues initial settlement area.

The tritium analyses for WL confirm direct upward flow from the Riccarton Gravel aquifer through the capping Christchurch Formation without any mixing with groundwater derived from the Springston Formation gravels and infiltrating rain, as occurs for the other western Christchurch springs in Stewart et al. (2018). Another
process for a Riccarton Gravel source for the WL spring would be an abandoned leaking artesian well. This can be tested quite easily. The flow of a leaking well will respond due to the tide rise and fall and high tide estuary water ‘loading’ of the artesian aquifers, whereas spring flow tidal-induced fluctuations would most likely be eliminated during the groundwater flow ascent through the overlying 20 m of strata. A relevant comparison is Oborn (1960) for a study of Lake Ellesmere spring flows facilitated by interbedded Springston Formation gravel channels and Christchurch Formation coastal marine deposits. Prior to WL the only known New Zealand examples of total artesian groundwater-sourced springs in overlying postglacial marine deposits were at the Wairau Plain – Cloudy Bay coast, Marlborough (Taylor et al., 1992) where the artesian gravel aquifer underlies 20–30 m of postglacial marine Dillons Point Formation (Brown, 1981) at a geological environment similar to that at Woolston. The Wairau Plains are in New Zealand’s highest earthquake risk zone. At the coastal Wairau Plain, marine deposits are displaced by the Wairau Fault (Fig. 2 of Ota et al., 1995). There are no surface displacements at Christchurch.

The SB sandbar spring is 3 km to the east of Woolston adjacent to the Causeway at McCormacks Bay. Stewart et al. (2018) assume the spring is also sourced by the natural up flow of Riccarton Gravel artesian water. The grid reference plots the spring in the Avon-Heathcote Estuary where a former Sumner Borough Council (amalgamated with Christchurch City Council in 1945) well field was located on Rat (Skylark) Island. The Sumner Borough Council had three water supply well fields and these were restricted to the Estuary–Banks Peninsula margin by engineering and geography constraints: Rat Island; Fishermans Flat 1 km to the east near Redcliffs where SBC wells only encountered Wainoni Gravel at about 120 m, and at Ferry Road; Ferrymead 2 km to the west of Rat Island where water was abstracted from both Riccarton and Linwood Gravel. At Rat Island five wells were drilled between 1911 and 1921. By 1922 Rat Island was a mudflat completely covered at high tide (Brown and Weeber, 1992), having been eroded away because of the changed tidal flow patterns after the construction of the tram causeway (1903–1907). In October 1944 another well was drilled adjacent to the north side of the Causeway about 200 m to the south of the Rat Island site. All the wells were drilled by Job Osborne. All the Rat Island wells encountered Riccarton Gravel at about 23–43 m and four of the five Rat Island wells encountered Linwood Gravel at about 80 m. At Rat Island the 24 m capping Christchurch Formation is logged as blue sand or sand and clay. The Causeway well (M36/w1011) had Riccarton Gravel at 23.2–33.0 m, no Linwood, Burwood or Wainoni gravel, and broken rock and gravel on top of volcanic rock with artesian water at 117.4–117.7 m suggesting volcanic rock beach rubble deriving groundwater from fringe CAS and possibly Banks Peninsula volcanics. At the SB site there is a distinct possibility an abandoned well could be the source of the spring. During fieldwork for an MSc thesis (Charteris, 1999) the Rat Island wells were located flowing to waste. They are probably still flowing to waste (John Weeber, pers. comm).

Spring flow response to tidal fluctuations would help identify a water source for WL and SB. If WL is definitely directly connected to the Riccarton Gravel aquifer, regular or continuous flow monitoring should be established as part of the CAS monitoring programme. It would be the most eastern natural outlet of CAS groundwater and thus a very important first indicator of CAS groundwater depletion.
References


Tonkin & Taylor 2012: Effects of sea level rise for Christchurch. Tonkin & Taylor for Christchurch City Council (Ref. 61707).
RESPONSE TO COMMENT:

Mike Stewart and Uwe Morgenstern

Len Brown's comment on our paper (Stewart et al., 2018) raises interesting questions regarding the provenance of the water from the two eastern springs in the study (WL – Wetland Reserve, Woolston, and SB – Sandbar Spring, McCormacks Bay). The tritium and other measurements support the origin of these springs from the Christchurch Aquifer System (CAS), most probably from the Riccarton Gravel Aquifer, but Brown points out that the waters are likely to be flowing from leaking abandoned wells rather than being natural artesian springs. He suggests that their responses to estuary loading due to tidal fluctuations would help to identify their natures; leaking wells would show variations in flow related to the tidal rise and fall whereas artesian springs would probably not because their ascent through 20 m of overlying strata would damp out their responses.

Brown also commented that photographs of the springs would have enhanced our paper. We attach photographs of the five springs here. The sampling period (8-10 December 2017) was very dry, and many springs that had been planned to be sampled could not be because there was no water. Briefly, Redwood Springs (RW in our paper) had a good flow, Avonhead Spring (AH) had a bare trickle of water, Knights Reserve Spring (KR) had a small flow, Sandbar Spring (SB) (which is only accessible at low tide) occupied a large pool fed from a paddle-deep hole in the middle of it from which the sample was taken, and Wetland Reserve spring (WL) occupied a very small pool but did not overflow it (there was assumed to be a small flow from the spring because at least evaporation had not dried it up). Flows of some of the springs were described by Webster-Brown and Barr (2016).

Given the wealth of geological evidence and potential candidates for wells given by Brown, we think it very probable that SB and WL are from leaking abandoned wells (especially SB). With regard to testing for tidal influences in SB and WL, this may not be possible in SB but may be quite feasible for WL during a wetter period when there is a larger flow.
References
