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Submission details

I am making this submission as	An academic/researcher
Submission type	I am making a personal submission
Consent to make submission public	I give my consent for this submission to be made public

Share your experience or tell your story

Terms of Reference (optional)

The Inquiry welcomes submissions that address the particular matters identified in its Terms of Reference

1.1 Causes and contributing	See attachment

factors

Supporting documents or images

Attach files

- Submission.pdf

Submission to the 2022 NSW Flood Inquiry

Lismore has experienced at least 32 major floods[1] since 1870, the largest of which occurred in February 2022. The underlying reasons for Lismore's floods are well documented[2] – high rainfall, a catchment bounded to the north by mountains reaching 800 m elevation, with steep creeks rushing to a flat floodplain, and Lismore effectively at sea level, but still 100 km by river from the sea. Despite this history and geography, Lismore remains ill-prepared for floods – why is this?

This lack of planning is especially perplexing given the excellent records that Lismore has of the 1974 floods (Figure 1), which illustrate the vast floodplains upstream of the Lismore town centre, and the constricted river valley downstream. One important take-home message from Figure 1 is that most of the land surrounding Lismore is either brown (closely-spaced contour lines, and hence steep), or blue (flat floodplain inundated in 1974). The other important observation is the 'waistline' at Lismore – the relatively narrow gap between the hills just south of the city. While Lismore was an ideal location to load and unload coastal sailing ships in the 1870s, Figure 1 suggests that Lismore (especially just south of the city centre) might be an ideal location to dam for a water reservoir – not for a city!

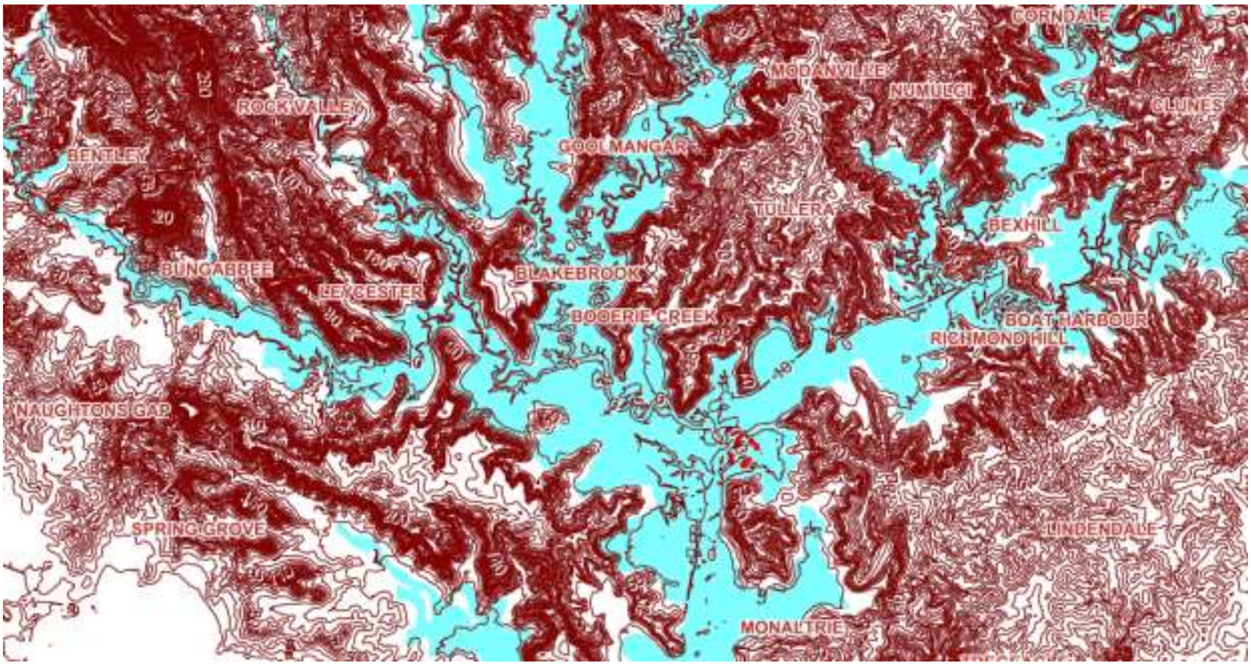

Figure 1. Extent of 1974 flooding[3] (blue), with Lismore CDB denoted by red dashed lines, and showing 10m contour lines. The embankment created by the Bruxner highway, and artificial mounds for industrial sites along the highway are evident at the bottom centre of this image.

This impression of Lismore as a choke point in the river is further reinforced by the flood levels displayed in the Lismore City Council Geographic Information System[3] (GIS), shown in Figure 2.

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[1] https://lismore.nsw.gov.au/files/Lismore_Flood_Events_1870-2017.pdf
[2] https://lismore.nsw.gov.au/a-short-history-of-flooding-in-lismore
[3] https://mapping.lismore.nsw.gov.au/intramaps99/default.htm?project=LismorePublic

Figure 2. Flood levels indicated in the Lismore GIS[3]. Note the large area of land upstream of Lismore that floods at 8m (green), and that must dissipate through a choke point west of the Lismore CBD (denoted by red dashes).

Despite this evidence of a choke point, construction of a levee proceeded in 2005 (Figure 3), and served the CBD well for 12 years before overtopping in 2017, and failing twice earlier this year. Subsequent assessments of flood risk (especially those areas coloured orange and denoted 'flood fringe' in Figure 3) rely largely on the assumption that the levee is failsafe (Figure 3).

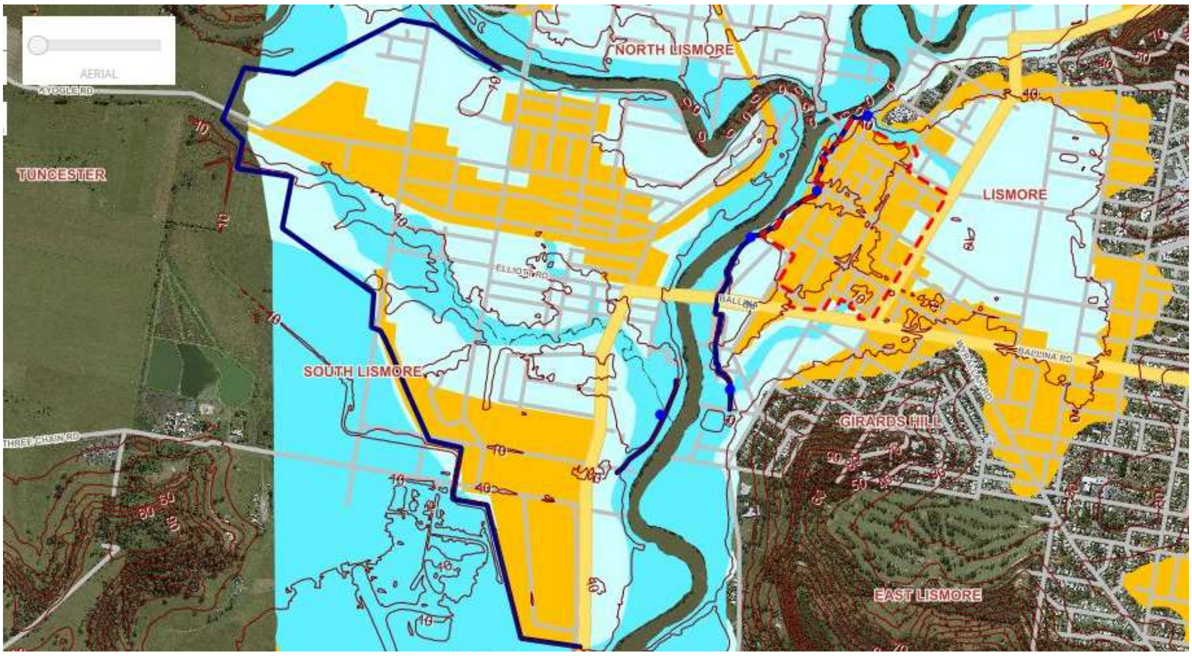

Figure 3. The Lismore CBD (red dashes) is protected by a levee (dark blue line) and pumps (blue dots) along the east bank of Wilsons River (brown). A second longer levee protects South Lismore. Floodways are shown in sky blue; vulnerable areas shown in pale blue, and areas considered 'flood fringe' are shown in orange (Lismore GIS[4]).

Additional engineering works were constructed following the 2017 flood[5]. The plan was to modify an existing floodway to the west of South Lismore (Figure 4) to divert water from Leycester Creek, with the

[4] https://mapping.lismore.nsw.gov.au/intramaps99/default.htm?project=LismorePublic
[5] https://www.dailytelegraph.com.au/news/nsw/lismore/8-million-flood-plan-could-drive-investment-in-cbd/news-story/0073832f63040ab4a9156aca7573697d

modest goal of reducing the peak of a major flood (of 12.38m, the 1% Annual Exceedance Probability AEP) by just 0.1m. This project claimed to be a $4.3m[6] or $8.2m[7] outlay, and was completed in 2019 - but it is unclear whether it has been effective or whether it achieved its objectives during the 2022 floods (Figure 5).

Figure 4. Earthworks (brown) nearing completion near the South Lismore sewerage plant (green), after moving 410,000m³ of soil from the floodplain outside the levee to a development site inside the levee (levee shown as dashed yellow line), and intended to direct water via a zig-zag drain (dashed blue line) into the river below Lismore (bottom right of image).

Figure 5: Photos by Rotorwing Helicopter Services[8] showing two views of these engineering works: (**left**, 10am 31-3-22) looking northwest across the completed earthworks (top centre), with the sewerage works top left, Leycester Creek top right, and zig-zag drain bottom left; (**right** 30-3-22) looking south across the partially-flooded airport towards the Bruxner Highway, showing the zig-zag drain filled to capacity with nowhere to flow.

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[6] https://seegroup.com.au/lismore-flood-diversion-channel/

[7] https://www.echo.net.au/2019/09/lismores-8-2-million-flood-mitigation-project/

[8] https://www.facebook.com/rotorwinghelicopters

These most recent engineering works rely in part on a LIDAR-based digital elevation model[9] that reflects an impressive amount of detail – but the geographic extent is rather limited, as it does not include Tuncester to the west (4.5km west of the Wilson-Leycester Creek junction), Woodlawn (3.2km) to the north-east, nor Sandy Point (4.8km) to the south… Was this really sufficient geographic extent to make useful inferences about the impact of major floods in Lismore?

Clearly, it is rather difficult to correctly predict future scenarios and to engineer viable solutions. So a good place to begin is with a careful assessment of the data available to support inferences about flooding and possible solutions.

Let's begin with a quick look at the Wilsons River catchment… Figure 6 illustrates eight of the major tributaries, but the left image is trimmed at the LGA boundary in the east, so omits the upper portions of the Wilson River and of Back Creek, and omits all of Byron and Pearces Creeks.

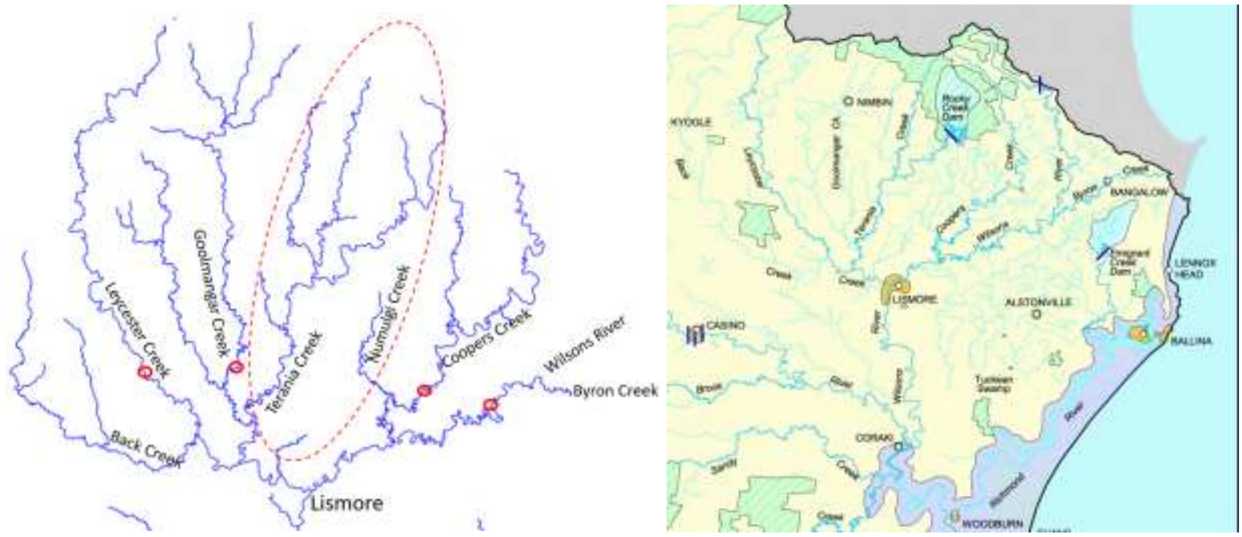

Figure 6. The major streams contributing to the Wilsons River at Lismore (left) from the Lismore GIS, trimmed at the LGA boundary, and (right) showing the broader context[10].

The Bureau of Meteorology (BOM) reports stream heights for the Back, Leycester, Goolmangar, Coopers and Wilsons tributaries (with multiple sites on some streams), but provides no reliable data on Terania Creek[11] (nor on Numulgi or Byron[12] Creeks – however, the Woodlawn site for Wilsons River is below the junction so is inclusive of both Numulgi and Bryon Creeks). WaterNSW[13] reports stream heights and flows for Leycester, Goolmangar, Coopers, and Wilsons tributaries (shown as red circles in Figure 6), but provides no data for Back, Terania or Numulgai Creeks. Terania Creek in particular, is not monitored consistently by either the BOM or WaterNSW, despite including Rocky Creek, the site for the proposed Dunoon Dam[14]. Dunoon, which sits on a ridge between Rocky and Numulgi Creeks, recently recorded

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[9] Worley-Parsons (2016) Lismore Flood Model - LiDAR Update, Final Report https://yoursay.lismore.nsw.gov.au/46886/documents/107853

[10] https://www.environment.nsw.gov.au/ieo/richmond/maplg.htm

[11] BOM stream height data appear to be available intermittently for Terania Creek at The Channon – data have been available since 6/4/22, but were not available during the recent flood events.

[12] To clarify – Byron Creek starts 3km from the sea just south of Byron, flows inland to join the Wilsons River, then returns to the sea via Lismore and Ballina.

[13] https://realtimedata.waternsw.com.au/

[14] Tenders were called in 2020 to estimate the acquisition costs of land for this dam (https://www.australiantenders.com.au/tenders/415242/dunoon-dam-future-water-strategy-land-acquisition-costs/), but the proposal has since been suspended.

the 2nd highest overnight rainfall in NSW[15], 775mm in 24 hours to 28 February, and this water would have drained into Numulgi and Terania Creeks, but neither of these creeks was monitored to record the resulting runoff or its impact on the record Lismore floods in the following days. Terania and Numulgi Creeks are not insignificant, collectively draining about 20% of the Wilsons catchment (shown as a dashed red oval in Figure 6) above Lismore – why do these streams remain unmonitored in NSW's most flood-prone catchment, where a $220 million dam[16] has been proposed, and where there is a long history of investigating and constructing flood mitigation devices?

The Bureau of Meteorology's website is a convenient and oft-used resource for checking recent rainfall and flood conditions – and has about 20 sites for rainfall, and about 20 for stream monitoring in the Richmond basin (Figure 7).

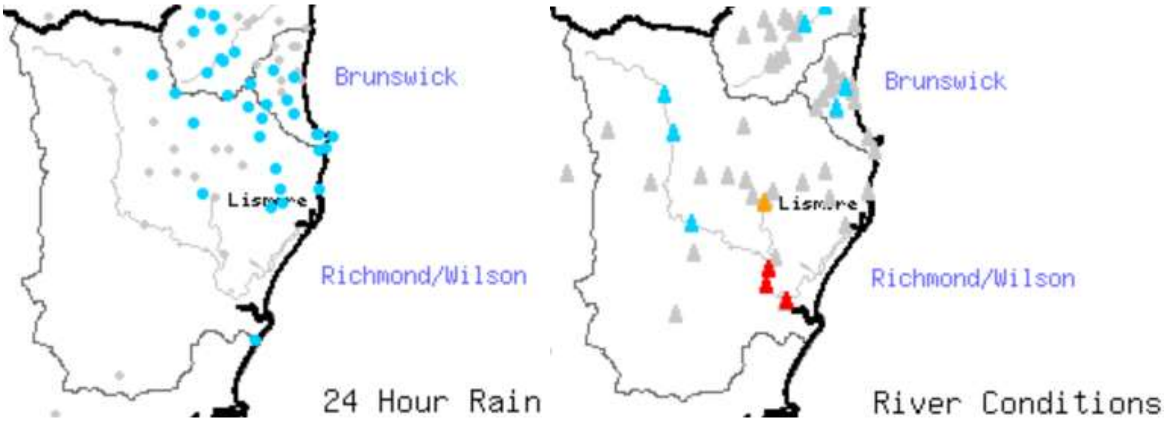

Figure 7. Bureau of Meteorology[17] monitoring sites for rainfall (left) and river heights (right).

The BOM is pretty handy for a quick look at rainfall, but it is a bit confusing for stream monitoring, because different gauges have different reference marks – some use Australian Height Datum (AHD, corresponding to mean sea level at Ballina), some use Richmond Valley Datum (the low water of an ordinary spring tide, between 0.81 and 0.86 below than AHD, depending on the site), and others use an Assumed Datum (so indicates the depth of water above the bottom of the stream)[18]. If you want to drive your vehicle across a ford, you want to know the depth over the ford (hence the assumed datum), but if you want to compare an upstream with a downstream reading, you need to know the datum used for each, preferably the AHD. Unfortunately, the BOM website doesn't always reveal which datum is used, or how to convert from one datum to another. But these data can still offer interesting insights (Figure 8).

[15] https://www.weatherzone.com.au/news/second-heaviest-daily-rainfall-ever-observed-in-nsw/536322
[16] https://rous.nsw.gov.au/cp_themes/widgets/faq_001.asp?b=20#f20-2
[17] http://www.bom.gov.au/nsw/flood/northcoast.shtml
[18] Richmond River Flood Warning and Evacuation Management Review. R.B20357.004.01 Final Report, 2016 https://rous.nsw.gov.au/page.asp?f=RES-FWT-11-04-76

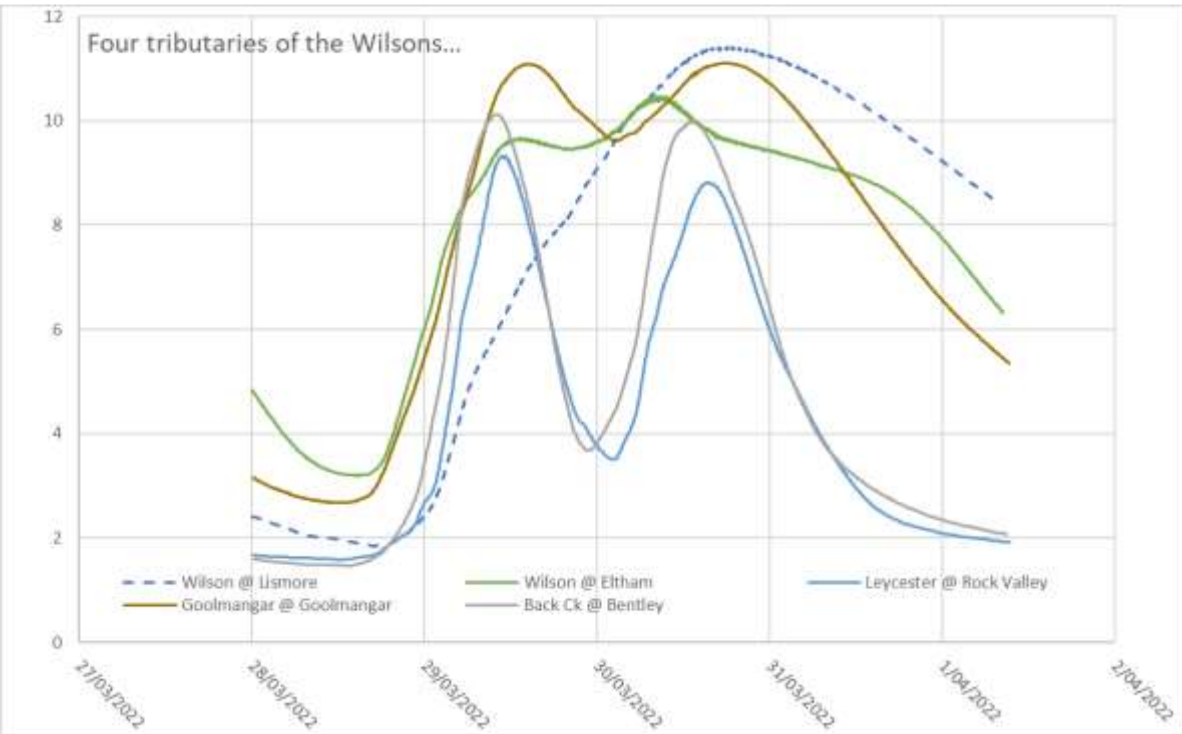

Figure 8. River heights in four major tributaries, and in the Wilsons River at Lismore, as recorded by the BOM, during the March 2022 event.

This graph shows four of the major tributaries of the Wilson above the Wilson-Leycester Creek junction (near the Lismore town centre, at Union, Woodlark & Bridge Streets). In the western part of the catchment, Back and Leycester Creeks exhibit two distinct peaks, one on 29th and another on 30th March. Further east, the peaks in Goolmangar Creek are a little higher and conjoined. Still further east at the Eltham on Wilsons River, peaks from the two rainfall events have merged. Below their junction where they form the Wilsons River in Lismore, these peaks blur into a single peak. These five lines tend to fluctuate independently, but during 30 March, the Goolmangar and Wilson@Lismore curves are parallel, in lock step… - is this because the eastern tributaries delivered so much water that water is backing up into the Goolmangar; because the Goolmangar carried the major flow on this day; or because the unmonitored Terania Creek flow dominated both the Goolmangar and Wilson@Lismore heights? It is impossible to shed light on these questions, in part because it is not clear which datum each gauge utilizes; because only heights and no flows are recorded; and because Terania Creek remained unmonitored…

However, these height data from the BOM also have a hidden danger as a small change in stream height can mean a large change in water volume. For instance, the calibration curve for the WaterNSW Eltham site[19] (on Wilsons River, Figure 9) shows that an increase in water height from 9 to 10m, means that water volume increases from 20,000 to 50,000 Megalitres/day – a 10% increase in height corresponds to a 2.5-fold increase in volume. Obviously, this depends on the topography at each monitoring site, but the relative increase in water volume is always greater than the relative increase in height, often much greater. So the convenient BOM stream height data do carry some danger of complacency.

[19] https://realtimedata.waternsw.com.au/

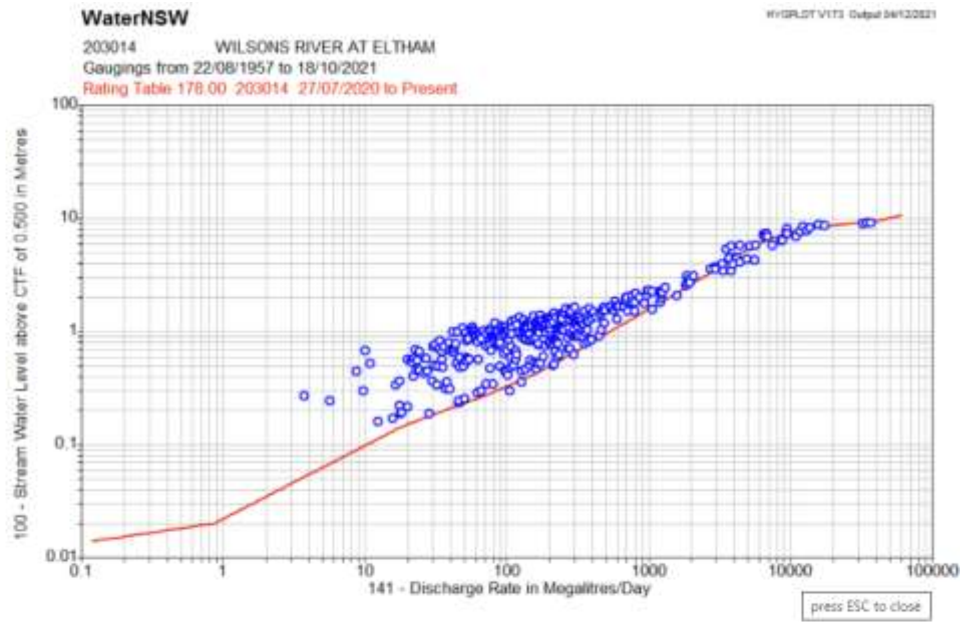

Figure 9. WaterNSW calibration curve for Wilsons River at Eltham.

WaterNSW offers an alternative source of data that includes levels (ie, heights) and discharges (ie, rates of water flow; some sites also include rainfall, water quality and other attributes), and also facilitates access to historic data. It is instructive to compare the stream heights and flows during the record-breaking flood of February 2022 (Figure 10), and note how stream flows convey quite a different impression than stream heights…

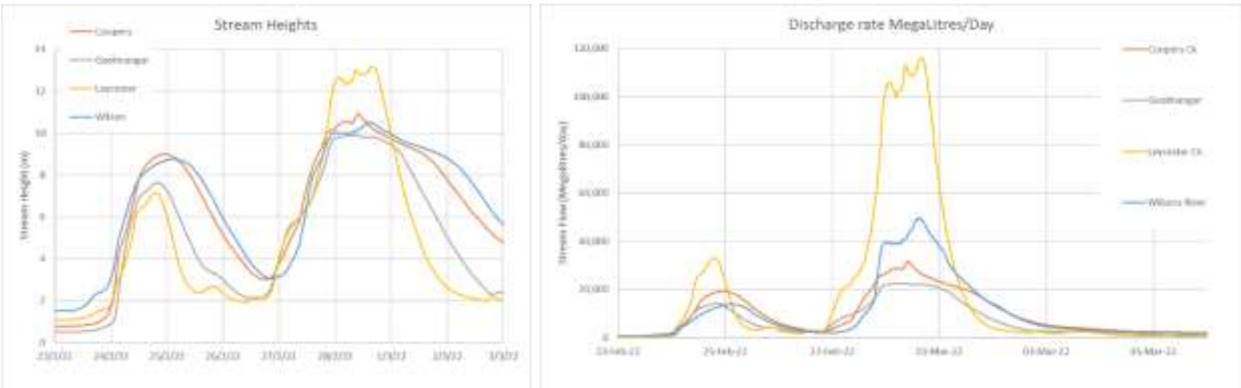

Figure 10. Stream heights (left) and flows (right) for the major tributaries of the Wilsons River during the February 2022 flood.

The cumulative flows for the 7-day period (from midday 26 Feb) reach 400 and 260 Gigalitres – to put this into context, the 400 Gl recorded in the February flood represents 70% of the volume of Sydney Harbour passing through these 4 stream gauges, and ignores any contribution from the Terania, Numulgi and Back Creek catchments. It is as if the entire contents of Sydney Harbour had been dropped on the southern slopes of the Nightcap range during the night of 27-28 February (given the record-breaking rainfall in Dunoon is seems reasonable to assume that Terania Creek likely contributed a substantial volume, bringing the total to a 'Sydney Harbour' or more).

It is also worth comparing various flood events, and observing that every flood is different (Figure 10).

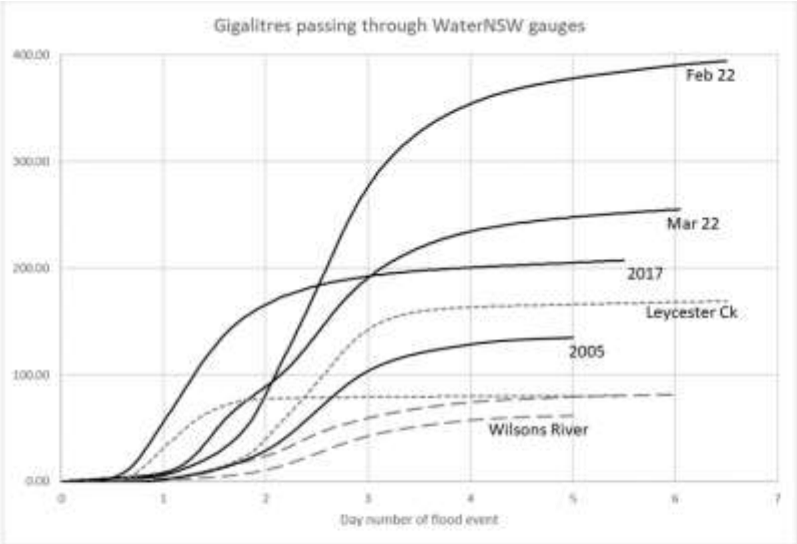

Figure 11. Cumulative recorded flows in the Wilsons River and in the tributary contributing the greatest portion of the flow, during the peak flow, for four flood events (2005, 2017, Feb 2022 & Mar 2022).

Figure 11 summarizes four floods since the $19m levee[20] was constructed in 2005, showing both the total recorded stream flow, and the tributary with the largest recorded contribution. The 2005 flood threatened to overtop the levee even before it was officially opened[21] (but fortunately peaked just below the top of the levee). The 2017 flood was the first to overtop the levee, and the two 2022 floods need no further comment. In 2017 and Feb 2022, Leycester Creek had the largest contribution of the four monitored tributaries. In 2005 and March 2022, Wilsons River had the largest contribution (but Goolmangar Creek was not monitored in 2005). And the total flow remains undocumented, as Terania Creek was not monitored, and it may be – as in any sleight-of-hand magician's act – that the crucial action happens where no-one is watching.

In Figure 8 above, it is notable that the Wilsons at Lismore quickly approaches the heights observed in the four tributaries, and it is instructive to look downstream and observe how the flood peak travels below Lismore (Figure 12). Downstream, the floodplain is wide and flat, so the dynamics are very different, but despite this room for the river, the flood peak at Lismore dissipates gradually downstream, illustrating that one of the issues for Lismore is the slow downstream flow through the choke points within and below Lismore.

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[20] https://www.dailytelegraph.com.au/news/nsw/lismore/after-all-its-a-wonder-wall/news-story/7a415fb33948c17813cfb16bc6543727

[21] https://www.abc.net.au/news/2005-06-30/lismore-residents-evacuated-ahead-of-flood-peak/2048020

Figure 12. River heights in the Wilsons River at Lismore, and at three downstream monitoring sites, during the March-April 2022 flood.

So far, we have looked at how a flood unfolds over time at a given site. It is also interesting to consider how a flood appears at a given time across a linear transect along the river. Figure 13 (below, drawn from BOM data) shows river heights at five sites down the Wilsons River, from Woodlawn (near the head of navigation), during the March 2022 flood. The topmost solid line shows the river gradient at the flood peak at Woodlawn; dashed lines show the trend as the river rises, and dotted lines record the falling river.

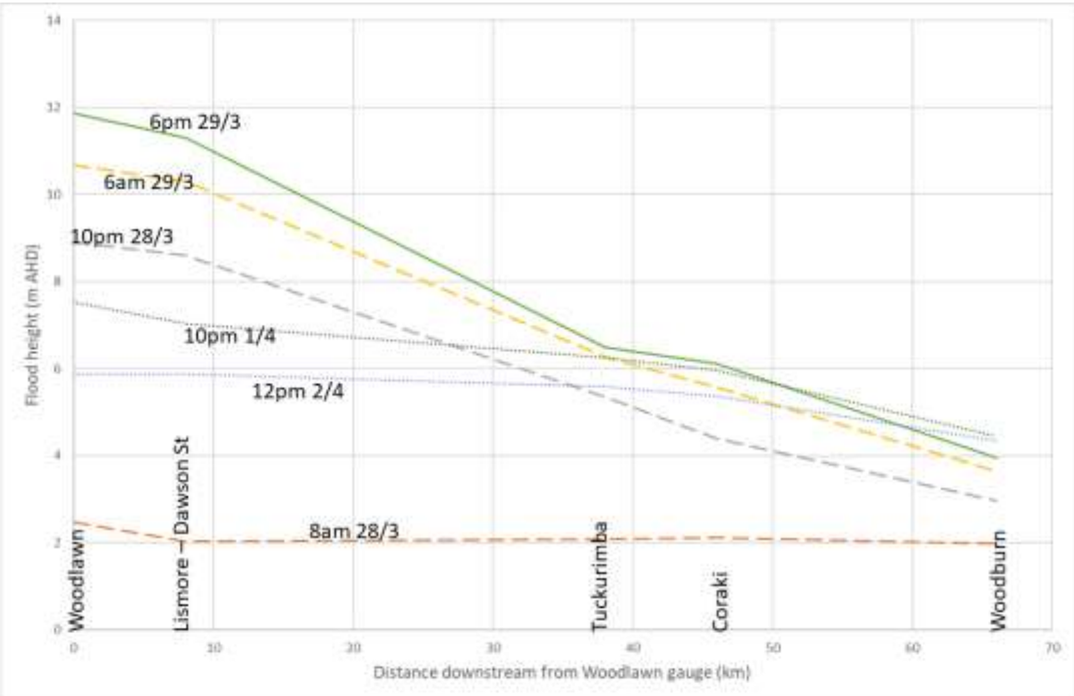

Figure 13. River gradients between five monitoring sites along the Wilsons and Richmond Rivers. The horizontal axis represents the distance along the river from Woodlawn, and the vertical axis is the stream height (m AHD) recorded on the BOM gauge.

The dashed line at the bottom shows the state of the river at the first indication of a flood, showing that (as expected for a liquid) water finds its own level and is almost horizontal across the whole river basin. The lines get steeper and steeper as the river rises, and then gradually level out as the river falls. However, it is notable that the gradient between Lismore and Tuckurimba is always the steepest (except when river heights are falling), implying that there are choke points hampering the natural flow of the river.

For the most part, the floodplain below Lismore is wide and flat, allowing room for floods to disperse, however, some potential choke points are evident in Figure 14 (left, from Lismore GIS, with 10m contours). The floodplain south of Bunnings (Three Chain Road) has several structures above 10m that impede floodwaters – a natural levee on the east bank opposite the recent 'Masters' excavation (below, top centre of middle image); the Bruxner Highway embankment; and several mounds in the vicinity of Sandy Point Road (bottom centre of the middle and rightmost images).

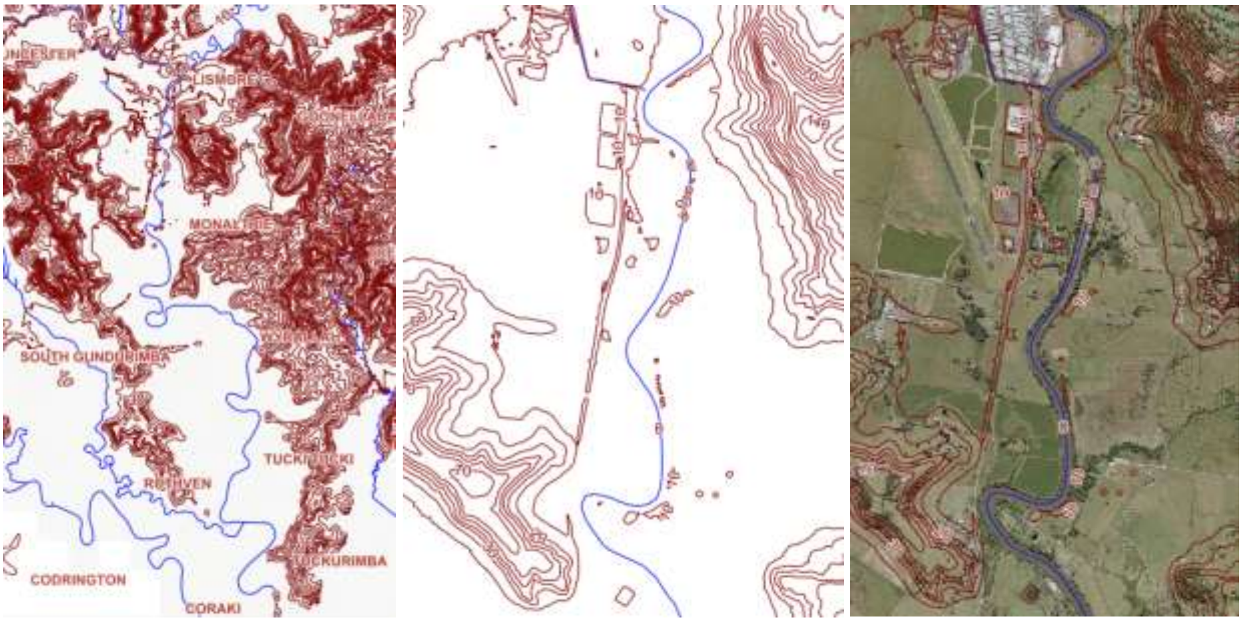

Figure 14. Images from the Lismore GIS: (left) illustrating the width of the river floodplain upstream of Coraki (with 10m contours indicated); (middle) showing detail of the section from Bunnings (Three Chain Road) to Sandy Point Road, with the Bruxner Highway and industrial estates evident above the 10m contour; (right) the same image, with aerial photography for context.

In particular, the river channel just below Bunnings is only 155m wide at 10m elevation (Figure 15), despite the recent 'Masters' excavations (to improve a floodway to the west of the main channel) and the modification to the zig-zag canal (just south of this point; bottom left of Figure 15 left). Further south, at Sandy Point, the channel is 1300m wide at 10m elevation but is obstructed by numerous mounds higher than 10m (Figure 15 right). These restrictions are likely to contribute to the slow drainage of floodwater from Lismore.

Figure 15. Stream widths at the 10m contour for two choke points below Lismore, (left) 155m just south of the Masters/Spotlight roundabout, and (right) 1300m at Sandy Point with numerous obstructions.

So what are the options for flood mitigation measures? Firstly, we need better data. There are no publicly-available calibrations of discharge rates at the Lismore (Dawson Street) gauge, so the true volume of water involved in Lismore floods remains unknown, and estimates derived from summing flows in four of the tributaries remain an underestimate, possibly a large underestimate. No LIDAR data of the water surface has been collected during a flood peak to offer closer insights into river flow and the river gradient to assist future planning.

Secondly, we should observe that 'hard' infrastructure (canals, levee embankments) are expensive, depend strongly on data quality (small biases in data and assumptions can have major consequences), and are prone to sudden failure (eg, when a levee overtops). In contrast, soft interventions (that facilitate or calm river flow across floodplains) can operate at any scale, and do not have sudden points of failure. So hard infrastructure would appear to be a poor investment at this time of poor data and changing flood patterns.

There is evidence that floodwater drains more slowly below Lismore, in the Lismore-Tuckurimba section of the river, than in other parts of the catchment, so it seems desirable to remove buildings, artificial mounds and other impediments to water flow in this section of the river, and to maintain these floodplains as pasture and low crops. Conversely, floodplain management upstream of Lismore could include initiatives to slow and calm approaching floodwaters to encourage a slower, shallower flood- by restoring wetlands (such as the localities of Howards Grass and Lagoon Grass, that were likely swamps in former times), by reducing soil compaction (excluding stock when waterlogged), and regenerating floodplain forests[22] (like the Boatharbour and Booyong Nature Reserves), establishing koala habitat, and encouraging horticulture (such as the pecan orchards near Boatharbour).

It is understandable that communities downstream of Lismore may be concerned at any initiatives to hasten the flow of water away from Lismore. However, if Lismore places equal emphasis on slowing the water above Lismore, and increasing the downstream flow, then the combined effect of these initiatives on downstream communities should be small. In addition, the typical width of the river (at the 10m contour) as it flows through Lismore is <300m, whereas it is typically 3000m at Wyrallah, 4500m at Tuckurimba, and even wider at Coraki, so a 1m height reduction at Lismore may be expected contribute a rise of only 10cm at Wyrallah and only a few centimetres at Coraki.

The most important measure is to relocate vulnerable businesses and housing out of the floodplain. In the past 150 years, Lismore has had 18 floods[23] that have exceeded the levee height - and we should

[22] See e.g., Cooper et al (2021) Role of forested land for natural flood management in the UK: A review. https://dx.doi.org/10.1002/wat2.1541

[23] https://lismore.nsw.gov.au/files/Lismore_Flood_Events_1870-2017.pdf

expect flooding to get worse. Climate change means storm events will be more frequent and more intense[24]. And changes in in our catchment continue to increase runoff – grazing leads to soil compaction and more runoff; horticulture often involves plastic sheeting that increases runoff; urban development includes hard surfaces that increase runoff volume and speed. The result is more flooding, and more intense flood events, so the only durable solution is to relocate infrastructure away from the floodplain.

[24] https://www.climatecouncil.org.au/resources/climate-change-floods/#:~:text=Climate%20change%20is%20affecting%20our,a%20greater%20risk%20of%20floods.