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Mining to mud: a multidisciplinary approach to understanding Victoria’s riverine landscape as a product of historical gold mining

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Introduction

The Victorian gold rush began in 1851, resulting in massive demographic, land use, and social changes (Serle 1968). Rivers, during much of the gold mining history of Victoria, were used as a “free” resource, both to extract and process sediment. The effect on river systems around the state was catastrophic. A quarter of the length of the main streams was damaged. Even though the devastating environmental impact of Victorian gold mining was recognised at the time, it appears to have been forgotten today (Figure 1). This is despite extensive documentation of the number of mining operations, methods used, resultant environmental impacts and consequent legislation. The ARC discovery project “Rivers of gold” set up a multi-disciplinary team to try and reconstruct the historical development of mining across the state of Victoria, and to determine the legacy of this mining.

Stage 1: Pre-European settlement (pre 1803)

A baseline dataset needed to be created to understand the environment that miners modified. These data are not readily available across Victoria, and conditions were only reconstructed for the focus catchments.

Evidence

Whilst the pre-European vegetation across Victoria has been described using Ecological Vegetation Classifications, and

Figure 1. Mining at Guildford, near Castlemaine, during the gold rush (left), and the same scene in 2018 (right).
bioregions have been mapped, there is only a patchwork of information about the geomorphology and geochemistry of pre-European settlement river systems. One source of information is early explorer reports. The River Loddon, for example, was crossed by Major Mitchell on 1 July 1836. Mitchell describes camping near a chain of ponds, which may be on Serpentine Creek. Further on, near Fernihurst, he crossed a river that had steep banks that were twenty feet high (~6 m).

The current bank-full height in this region is on average 3.6 m, with a maximum of 6.2 m. The banks seen by Mitchell were thickly covered in grass, with trees at the stream edge but not on the top of the banks. The water had a brown colour and was about nine feet (~2.7 m) deep. Flow was 1.5 miles an hour (0.7 m s$^{-1}$) and there were no large wood debris in stream.

Joseph Hawdon also crossed the river near Fernihurst in 1838 (Hawdon 1840). It was a drier year and he reports that,

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**Figure 2.** The annual gold yield and average number of employed miners across Victoria between 1850 and 1910 (Department of Mines 1910, 16).

**Figure 3.** Mining districts of Victoria with the study catchments of Hodgsons Creek (orange trace) in the Beechworth district, Loddon River in Sandhurst and Castlemaine districts (blue trace), and Leigh/Yarrowee in the Ballarat district (red trace).
as he travelled downstream, every 7–10 miles a little water was observed in the bed. Twenty three miles downstream of Fernihurst the channel was barely perceptible.

Another source within the Loddon catchment, Morrison (2002), recounts aboriginal descriptions of the pre-European environment. Water was mentioned as being scarce at times, as evidenced by the practice of using banksia flowers to filter the water from waterholes that were drying out.

**Interpretation**

Whilst it is difficult to generalise across the whole of the state, it appears from our focus catchments that smaller streams were originally dominated by waterholes and had less well-defined channels. The lower Loddon River had a fairly similar morphology with a deep well-defined channel, again with significant bed variability in terms of pools. This evidence aids in understanding the receiving waters into which the sludge was poured.

**Stage 2: Pre-mining (1803–1851)**

**Evidence**

Maps and surveyors’ notebooks provide information on the Victorian landscape as it was settled. Many early maps have been digitised and are available online from different sources, such as the State Library of Victoria. In our study areas we have geo-rectified the maps so that historic river channel locations can be viewed against the current river channel locations (Figure 4). The surveyor’s notebooks were more difficult to access, and many are not digitised so that physical copies had to be requested from the Public Record Office Victoria.

It has long been understood that European settlement, and the associated land clearance, resulted in reduced evapotranspiration and increased surface runoff and, as a consequence, increased soil erosion and gullying. These changes have been modelled across Australia by CSIRO using SEDNET (Prosser et al. 2001). Much of the landscape clearing was coincident with mining activities. However, the modelled yields do not include sediment directly produced by mining. The SEDNET yields have been compared to estimates of yields from mining (Figure 5), revealing that yields from mining can be up to 600 times the “natural” annual sediment loads.

**Interpretation**

The relatively limited amount of data available on the intervening period between European settlement and the gold rush suggests that minimal disturbance had occurred in upstream mining areas. In recent times layers of modern sediment found deposited on floodplain surfaces, or exposed on riverbanks, have been ascribed to land clearance. These deposits have been called “Post European Settlement Alluvium” (PESA). In mining regions sediment yields were well above the natural rates, and care needs to be taken in how these sediments are interpreted.

![Figure 4. The 1855 stream position of Hodgsons Creek at Tarrawinge overlain with the 2010 position.](image-url)
Stage 3: Gold rushes (1851–1880)

Evidence

Data on the initial gold rush is limited to anecdotal information in various reports and miners’ journals. Regulation of miners’ activities, and the issuing of mining leases, meant that data needed to be collected on the number of miners and the location of their activities. Much of this information was recorded so that it could be reported to the Government. From records of different mining districts, such as appear in the Mineral Statistics of Victoria (MSV) reports, it is possible to reconstruct the number of miners and the mining techniques that they were using for the period 1859–91. Estimates were then made about the volume of sediment that each different enterprise would produce in order to give an overall sediment yield (Figure 6).

Records were originally compiled for each of the gold mining districts (Figure 1). In order to fully understand the impact of the mining operations on river systems these data needed to be separated into river catchments. The VICPROD and VICMINE datasets (Department of Primary Industries c.2002) provided a compilation of around 16 000 gold mines across the state with approximate mining dates and locations alongside other attributes such as whether the mine was mining primary or placer deposits (Figure 7). These data are undoubtedly an underestimate of mining activities, and will certainly miss the earlier phase of artisanal mining, however they do act as a guide as to where most of the mining activity occurred.

The estimated volumes for each mining district were distributed across the known mines in the region, and this allowed each mine to be allocated a volume of sediment. This has allowed the volume of sediment produced in each river catchment to be estimated and then compared with other data such as the SEDNET yields (Figure 5).

The VICPROD dataset also allowed for the relative position of mines in their river catchments to be determined using the BOM Geofabric. Mined sub-catchments had an average size of 73 km² and were most common on Strahler 2nd order streams. This means that mines were on average 12 km from the headwaters, and 714 km from the river outlet. In most cases they were in confined or partly confined valley settings with a limited area of floodplain on which to deposit sediment. This meant that the sludge deposition was greatest once the river debouched onto a floodplain after valley confinement was reduced.

The impacts of increased sediment yield downstream were reported in contemporary newspapers (available on the TROVE archive). The impacts were so great that in 1886 an inquiry was...
set up to take evidence on the matter (Shakespear, Walker, and Rowan 1887). The descriptions recorded of sludge impacts could be linked to either a property or a general locality and thus could be mapped. Where it was possible to get estimates of depths of sedimentation or erosion from the evidence these were collated and mapped. It was also possible to infer rates of change from these data, which were also mapped.

**Interpretation**

After the dispersed disturbance from prospectors searching for gold, there was the sudden focus of attention to specific sites where gold had been discovered. Shallow shafts were excavated to the contact with palaeo riverbeds. Coarse sediment was left close to the shafts, and fine sediment, which was more likely to contain placer gold, was removed for processing. Riverbeds and banks were also dug up.

Rivers were employed as an industrial processing stage to winnow away the fines and to leave the gold. Different techniques were used including cradling, puddling, sluice boxes and ground sluicing. These techniques needed water to a greater or lesser extent. Ground and box sluicing predominated in the northeast of Victoria in areas such as the Ovens River. Puddling was more common in the drier more seasonal rivers in the west, (Figure 6). The different techniques influenced both the volume of sediment being delivered into the river and its size distribution. Puddlers supplied a much finer range of sediments, whilst sluicing tended to have slightly coarser sediment delivered to the stream. Our calculations suggest that 58% of the sludge came from ground and box sluicing (Davies et al. 2018a). The cumulative effect of large numbers of small-scale mining operations massively changed both the area of mining and the rivers downstream.

The volume of sediment from mining operations would have, on its own, completely changed the sediment budget of the river systems. An added factor was the change in the size of sediment being delivered during low and medium flows. Sands, silts and clays predominated, rather than the usual mix of fine to coarse sediment. The result of this constant delivery of sediment was that channel beds aggraded. Waterholes that were metres in depth filled up first, and then the channels as a whole started to fill. This loss of channel capacity, sometimes combined with an upstream diversion of water and the loss of vegetation, meant that channels spilled onto their floodplain more frequently.

Floodplains aggraded 1 m a⁻¹ on average by 1886, and up to a maximum of 2.4 m (Figure 8). Extensive areas of floodplain were covered, up to 4–5 miles (6–8 km) laterally on the Ovens River. This inundation homogenised the floodplain surface and, in some places, the sludge was enough to kill the surface vegetation. This could be because the rate of deposition was too great, or the sludge baked hard after it was deposited creating a crust that inhibited plant growth. The combination of infilling and reduced vegetation roughness would have resulted in...
in a feedback effect, increasing the extent that water, and its associated sediment, could flow over the floodplain.

In some systems the mining of tributaries and the main channel led to aggradation to such an extent that tributaries were blocked and the streams back filled. This was the case in Tullaroop Creek and the Loddon River, where the confinement of the valley sides near the confluence resulting in the river channel being completely choked.

Whilst the fine and dissolved sediment fractions would have been transported all the way down river system, such as into the River Murray, the rest of the sediment appears to have deposited proximal to the mine sites, and was only transported 10's of km. Fans of sediment built up on floodplains downstream of the mines. The stream type and network configuration clearly played a part in determining how far sediment travelled. By 1886 stream avulsions were reported in 11 streams, forming new channels on the floodplain.

Stage 4: High volume mining (1880–1905)

Evidence

In the 1880s there was a gradual transition from a high number of dispersed mining leases with relatively low output operations, to a lower number mining leases in higher production centres. This transition was partly a result of technological advances, and partly a consequence of the reduction in the grade of available ore.

Hydraulic sluicing was a progression from ground sluicing, and was introduced into Victoria in 1860. Water was pumped under pressure through a monitor (nozzle) at the base of mining claims (Figure 9). Undercutting the sediment led to collapses from which the large clasts were extracted and stacked locally. The rest of the sediment was directed into sluice boxes, eventually ending up in the river system.

Giant monitors were introduced in the 1880s and needed large volumes of water. This equipment was mainly used in northeast Victoria particularly around Beechworth, Yackandandah and Mitta Mitta. Mineral Statistics of Victoria reveals that that up to 1.5 million m$^3$ of washdirt was produced per year (MSV, 1888). This resulted in around 13% of the state-wide sediment yield being produced by hydraulic mining between 1859 and 1891 (Davies et al. 2018a). The scars left on the landscape from sluicing can be detected using LiDAR imagery. One distinctive method of sluicing, also found in New Zealand, was herringbone sluicing (Figure 10). This concentrated sluicing approach results in a feather type pattern on the LiDAR. Subsequent revegetation makes this impact harder to distinguish in photographic imagery.

The upper part of one of our study catchments, 3 Mile Creek, a tributary of Hodgsons Creek (Figure 3) had been hydraulically sluiced. Using the LiDAR available from DEWLP we mapped the area of the hole left behind by the sluicing (Figure 11). A 35$^\circ$ slope was used as a mask to help delineate the top of the scarp faces. This produced an area of 1 185 740 m$^2$. Mining had not
occurred uniformly in the hole, and there were some pillars of sediment remaining on the valley floor that showed where the original surface had been. The elevation of these pillars was extracted and modelled using ARCGIS, along with the elevations of the tops of surrounding scar walls, to approximate the old valley surface. The two surfaces were extracted from each other and the volume change was calculated as $-5,327,642 \text{ m}^3$.

Mining of primary deposits resulted in adits being blasted along quartz reefs associated with the gold. In order to reach underground deposits, the overburden was removed, and this was often stacked locally. Processed sediment was also stacked in mullock heaps. Some of these heaps are listed in the Heritage Council of Victoria's database. Mullock heaps that were proximal to river systems contributed sediment directly into the river system, especially during high rainfall flood events (Figure 12).

Once the ore rock was extracted it was crushed. Mechanisation of this process increased over time, leading to the development of large stamp batteries. Crushing produced fairly standard sand sized clasts. These sand grains were less rounded than fluvially transported grains, and can be used as a physical tracer in some environments. This was the case in the Leigh and Yarrowee Rivers where sand was deposited on the floodplain, blown up the hillsides and, ultimately, into sheep wool causing a reduction in wool value.

Data on the location of mining for primary deposits is in the VICProd/VicMine database (Figure 7). This database also contains attributes relating to shaft dimensions and orientation, alongside estimates of gold production.

**Interpretation**

Hydraulic sluicing of alluvial deposits was concentrated in northeast of the state and resulted in localised higher rates of deposition on floodplains. It also contributed a broader range of sediment sizes into the river channel. This method has resulted in holes in upland landscapes that now have a very limited capacity for adjustment.

Mining for primary deposits was much more targeted than mining for secondary/alluvial deposits. Mercury and cyanide were also used in processing (Rae, 2003). As a consequence, there are more likely to be higher concentrations of contaminants in the sludge derived from mining for primary deposits. Conversely, the sludge is more likely to contain sand sized grains that are less likely to adsorb contaminants than finer silts and clays.
Stage 5: Environmental regulation (1905–1950)

Evidence

Parliamentary Acts and inquiries, alongside newspaper reports, reveal that initially the regulatory approach to managing sludge was to move it elsewhere, such as via channels to larger streams. Mining claims were also protected by constructing infrastructure so that the sludge did not halt mining activities. Later legislation attempted to deal with the sludge at source, penalising miners for polluting channels (Lawrence and Davies 2014). The Mines Act of 1904, and its amendment in 1907, led to the creation of the Sludge Abatement Board (SAB). Inspectors from the SAB could impose fines for polluting waterways.

The detention of sludge near to its source and its stacking at mine sites were some of the consequences of this change in legislation. Sludge dams were built around mine sites, changing the landscape of many tributaries and resulting in localised accumulation of fines either in channels or close by. On Hodgsons Creek these sludge dams are recorded in early maps, and can be seen in the current LiDAR imagery. It is easy to see them by using a slope layer derived from the DTM as they are flat surfaces on the landscape (Figure 13). They are estimated to contain up to 0.3 million m$^3$ of sediment.

Whilst some detention dams were used as a terminal store for sediment, there are records to suggest that some were flushed during high flows, when inspectors would be unable to detect...
the activity. This would explain the relatively small volume of the dams on Hodgsons Creek compared to the volume of sediment produced.

**Inference**

Increased regulation led to much greater storage of sediment proximal to mine sites. Sludge yields would have decreased, although there would still have been sediment accidentally or deliberately discharged during flood events. The result is that there are pockets of fine sediment stored in stream headwaters, and these sediments may include contaminants.

As environmental regulation of sludge was being enforced there was also a decline in gold yields. Fixed gold prices and the First World War meant the end for large scale alluvial and quartz reef mining.

**Stage 6: Dredging (1899–1950)**

**Evidence**

“Since dredging started the sludge had alarmingly increased in volume, and now possessed chemical properties which threatened to gradually convert the flats into waste land. Farmers stated that there was no place within six miles south of Eddington where stock could obtain water at the river, and serious losses must occur during the summer. The capacity of the Laanecoorie Weir had been reduced by fully one half, and the water trusts should know that the weir would be practically useless in a few years. It was estimated that at high’ water mark there was an average depth of only four feet” (The Age 1905, 6)

Dredging commenced at around 1899 and was the last major technological change in gold mining in Victoria (Davies et al. 2018b). Initially steam driven, and later electric powered, dredges minimised the use of manpower and maximised the volumes of sediment that could be excavated (Figure 14). There are various types of dredging. Within the VicProd, VicMine and Mineral tenements “Minten” (DEDJTR 2013) databases dredging data can be extracted, however these data include sluicing as well as dredging. We have extracted bucket dredging from the data as this was extensive across Victoria and had reasonable records. From these data we estimate over 100 000 000 m$^3$ of sediment was excavated by more than 115 bucket dredgers, mostly in the Ovens and Loddon catchments in northern Victoria.

LiDAR and aerial data from 2009–2010 were used to examine the sites identified using the spatial data. These data were used to look for any evidence of dredging. Features included...
dredge pools, and depressions or linear marks that indicated a dredge track (Figure 15). The absence of floodplain features such as palaeo-channels was also evidence that dredging had occurred (Figure 16). The 2010 land use present at the dredge sites was identified using high resolution aerial (0.15 m² pixels) and satellite imagery, and was manually classified by the vegetation type and the presence of urban features (Figure 17).

Bucket dredges were a floating factory up to 167 m in length. They either sat in the channel or had an artificial lake formed on the floodplain to house them. At the front of the dredge was a chain of steel buckets that could be manoeuvred and raised up and down so that the sediment in front of the machine could be excavated (Figure 14). They did not operate well in stiff clays, but were able to excavate coarse sediment up to the size of cobbles. Clean, reliable and plentiful water was essential for dredging operations, firstly to enable the dredge to float, and secondly for the treatment of alluvium. Water from upstream or from bores was used, and settling ponds both settled fine sediment and provided a clean source of water to be re-used.

The largest dredges could dig down into fluvial gravels to a depth of 40 m. During the excavation the dredge separated out coarse and fine sediment using a rotating cylindrical screen. The fines were passed over undulating riffles allowing the gold to settle out in the hollows. Mercury was sparingly used to amalgamate the gold, however, the full details of its use are unknown (Davies, Lawrence, and Turnbull 2015).

The excavated sediment was deposited out of the back of the dredge, either into the dredge hole or into a settling dam. The result of this was a complete stratigraphic change in the channel margins or the floodplain, often leaving behind layers of fines topped by coarse sediment. Early complaints about the coarse material deposited near the surface led to the use of more advanced redistributors that put fines on the surface. Advance stripping was also undertaken by removing the top layer of soil and storing it nearby. Once the dredging was completed the soil would be replaced over the surface. The stacked sediment, and the dredge pond itself, were exposed to flooding and were a continuing source of sediment.

**Interpretation**

Whilst we understand the likely volume of sediment that was excavated on floodplains, we do not yet fully understand the impact of the early in-stream dredging, or how much sediment entered waterways from dredge operations on floodplains. Clearly

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**Figure 15.** A linear dredge track, and an associated channel diversion, shown using aerial photography (left) and LiDAR (right). (source: Department of Environment, Land, Water and Planning).

**Figure 16.** A dredged floodplain on the Ovens River indicated by the loss of palaeochannels, shown using aerial photography (left) and LiDAR (right). (source: Department of Environment, Land, Water and Planning).
there were circumstances where there were releases of sediment into the channel, some of which may have been deliberate and others accidental. Any sludge that was released entered into a channel already modified by previous mining, exacerbating the issues of overbank deposition and reducing water quality.

Dredging activities also included the straightening of river channels, or when the channel itself needed to be mined, the relocation and replacement of a channel – in the same position with the original dimensions. This latter practice makes it difficult to identify where dredging had altered the channel, however, sometimes the channel was “rocked” to limit channel migration into the subsequent mining pond.

Increased numbers of reservoirs for water supply and flood mitigation had been constructed by the time dredging commenced. This suggests that any offsite impacts from sediment mobilisation might be mitigated by storages north of the divide in the west of Victoria, but this was not the case in the rest of the state. In particular in the Ovens River, where the majority of dredges operated, no dams and weirs have been constructed. Thus, any disturbed sediment could have been transported throughout the Ovens River.

The Bendigo Advertiser (1906, 2) suggests that Laanecoorie weir was considerably built up with sludge, with about 18 inches (0.45 m) of silt on the bed, and 10 inches (0.25 m) on the sides. More sediment was deposited at the head of the reservoir. When the water level dropped a channel 14 ft (4.2 m) wide and about half a mile (800 m) long was cut through the sludge and the resulting sediment was deposited downstream for about ¾ of a mile (1.2 km) on the riverbed.

The differential deposition of sediment in the dredged area led to unworkable surfaces for agriculture and, even with surface pre-stripping, the lower soil structure was not favourable to plant growth. Sub-surface groundwater flows removed layers of fines leading to sinkhole development. The current land use patterns in these areas (Figure 17) shows that they are not being used for intensive agriculture, and it is likely they will never fully recover because of the depth of disturbance.

Stage 7: Incision and downstream redistribution (non-dredged sites approximately 1890s, dredged sites approximately 1930s – 80s)

Evidence

The reduction in mining activities, mining sludge legislation and its enforcement, removal of in-stream wood, construction of levee banks, bank stabilisation and continued regulation of river systems led to rapid incision of channels. The reduction of sediment yield combined with the increased catchment runoff after vegetation clearance meant that both natural and artificial channel deepening occurred and this reduced flood risks. The current stream network in Victoria has many examples of incised streams; however, the exact timing of their incision is not well documented. We have used historic photos, reports and newspapers to suggest that much incision may have occurred before dredging started. In some cases where dredging occurred there was further aggradation in the channel followed by incision when it stopped. Most of the evidence appears to suggest that incision in mined streams had occurred by the 1930s, or was underway by that point in time (Figure 18).

Channel incision meant that the sludge deposited on the surface was removed and often the erosion continued down into the original pre-sludge floodplain. The riverbanks clearly show a transition between a darker pre-sludge floodplain and a lighter sludge layer. Similar layering results from clearance triggered deposition followed by erosion, but deposition resulting from mining is indicated by finer clast sizes with less evidence of coarse sediment in flood couplets.

To verify the source of the sludge sediment on the Loddon River we used an Olympus Delta XRF gun in the field and in the lab. The stratigraphy of the riverbanks was described, and XRF measurements were taken on the riverbank surface providing
a range of elemental compositions within 90 seconds. The samples were then removed, sieved and re-analysed using XRF and acid digestion. Source sediment was taken from spoil heaps at the top of the catchment. Arsenic was found to be a good indicator of mined sediment, most likely associated with the primary source of the gold. Manganese and a higher organic content appear to be good indicators of the contact sediment in the pre-sludge floodplain.

An attempt was made to use multispectral satellite imagery to identify sludge extents, following the method of Kotsonis and Joyce (2003), which was used in Bendigo. This was not successful, and we found that we could not repeat the process in the same location or elsewhere.

In the Hodgsons Creek system transects were hand cored across the floodplain looking for a change in colour, sediment size and chemical composition. These cores have been combined with data from prospecting carried out under exploration licenses. (Figure 19). This has allowed an estimate of the deposited sludge volume to be made of 2.5–3.5 million m$^3$. This means that Hodgson Creek may contain most of the eroded sediment from the upper catchment (Figure. 20).

**Inference**

Whilst our analyses of the chemical composition of sludge is still ongoing, it is clear there is a downstream reduction of sludge volume and concentration as expected. The incision of the sludge with the cessation of mining meant that there was a secondary pulse of sludge that had the potential to move further down the river system, however, this may have been limited in places by increased regulation.

The depth and appearance of sludge when exposed in an incised riverbank is fairly obvious, especially proximal to mining where it is particularly thick. Further down the system and out onto the floodplain it becomes more difficult to identify visually, and this is where the geochemistry has been extremely useful. Sampling does, however, need to take into account the likely sedimentation processes that have occurred both in-channel and out-of-channel.
and on the floodplain. Down the Loddon system there was a geomorphological change from confinement to an open floodplain, and then further confinement before a large slope change as the system becomes anabranching. This means that incised sludge could be found upstream, but not in the confined mid-lower catchment as there were limited surfaces for its deposition. The depositional downstream reaches are not as incised, and the sludge appears to have been laterally accreted within the channel and thus is only found in limited quantities on the floodplain.

Conclusions

The eighth and contemporary stage of channel management is one of stabilisation. Channels are being assessed for their stability and managers are actively strengthening channel margins to reduce “loss of land”. This approach is slowly changing, however, with rivers being allowed the freedom to move where infrastructure is not threatened. Knowing the fate of historically mined sediments will become increasingly important in helping to understand how this new management ethos will affect the mobilisation of contaminants stored on the floodplain.

We have calculated that over 25% of the length of major streams in Victoria have been affected by sludge generated by mining. Much of the adjacent floodplain has been able to revegetate and become agriculturally productive. The past damage has been forgotten. The upstream scars produced by hydraulic sluicing and the mining of primary deposits will take an extremely long time to recover, and many now remain as forested regions as their productive use is limited. The same is true of the dredge holes created by bucket dredging.

The multidisciplinary approach described in this paper used historical research to understand the volumes and locations of sediment production. Combining these data with sediment geochemistry has meant we could describe the consequences of the supply of sediment from mining into river systems. The original stream channel geomorphology and current catchment characteristics were paired with historical descriptions of sludge impacts. This allowed the size, location and chemistry of deposited sediments to be budgeted against its original supply characteristics.

This project also provides a stepping stone for a better understanding of where aboriginal artefacts might be found. They will be underneath the sludge rather than on the surface. There are also implications for reconstructing pre-European settlement landscapes and vegetation, and pre-sludge floodplain sediments have the potential to act as seed banks.

The creation of a higher resolution flood record alongside a detailed stratigraphic description of floodplain deposits is currently being undertaken, aided by the use of Optically Stimulated Luminescence. This should help to determine whether the depositional sequences observed are the result of mining operations, flood conditions or a combination of the two. The project is also trying to develop a better understanding the bioavailability of heavy metals in the sludge and the consequences for human health.

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