# Impacts of Historical Channel Changes on the Distribution and Abundance of Macquarie Perch (*Macquaria australasica* Cuvier) in Hughes Creek, Victoria

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**Key Points**

- A sand slug developed on lower Hughes Creek by 1916 due to interaction and synchronization of activities associated with European settlement which caused channel incision and gullying.
- River reach analysis showed that Hughes Creek flowed over the headwaters as percolines and chain of ponds before falling through granite gorges into bedrock-confined reaches upstream of alluvial reaches. A large flood in 1916 was the erosional finale of sand slug development.
- Close lateral bedrock confinement reduced the impact of the sand slug on Macquarie perch.
- Sand exhaustion, gravel riffle reinstatement and pool enhancement are important river management strategies for the recovery of the endangered Macquarie perch population.

## Abstract

The Goulburn Broken Catchment Management Authority must understand historical channel changes to manage the improvement of aquatic habitat for the endangered fish, Macquarie perch (*Macquaria australasica* Cuvier) in Hughes Creek, Victoria. River reach analysis was used to classify Hughes Creek into 11 geomorphologically homogeneous reaches for which biogeomorphic processes were outlined. A sand slug on lower Hughes Creek had formed by 1928. A large flood in 1916 was the most probable cause combined with the interaction and synchronization of a number of activities associated with European settlement that led to erosion. By 1970, Hughes Creek had started to contract and vegetation had colonized higher parts of the former bed. Contraction rates accelerated after 1973. The contiguous Reaches 3, 4 and 5 were where electrofishing revealed that Macquarie perch are present. Macquarie perch is an obligate riverine spawner with benthic larvae. Recommended works aimed to:

1. Increase population size of Macquarie perch,
2. Extend the range, with ultimately a reasonable connection with the Goulburn River,
3. Increase connectivity between patches of suitable habitat for all life cycle stages,
4. Improve aquatic habitat, and
5. Improve spawning areas.

Highest priority works were reduced catchment erosion, reduced sand flux, improved riparian vegetation and recreation of instream habitat (reintroduction of large wood and large boulders) in reaches 3, 4 and 5.

## Keywords

Sand slug, chain of ponds, incised channel, gully erosion, spawning gravel, large wood induced scour

## Introduction

The continued presence of the Perchichthyid Macquarie perch (*Macquaria australasica* Cuvier) in Hughes

Creek, Victoria (Figure 1), especially after the millennium drought of 1990s–2000s, is a significant issue for the Goulburn Broken Catchment Management Authority (CMA) because Macquarie perch is an endangered species that has persisted in Hughes Creek (Erskine, 2016) despite the formation of a sand slug after European settlement (Erskine, 1993). However, the population is in decline (Erskine, 2016). The purpose of this paper is to determine the current morphologic state of Hughes Creek, its pathway or trajectory to recovery from historical sand aggradation and recommended management actions to maintain and improve the aquatic

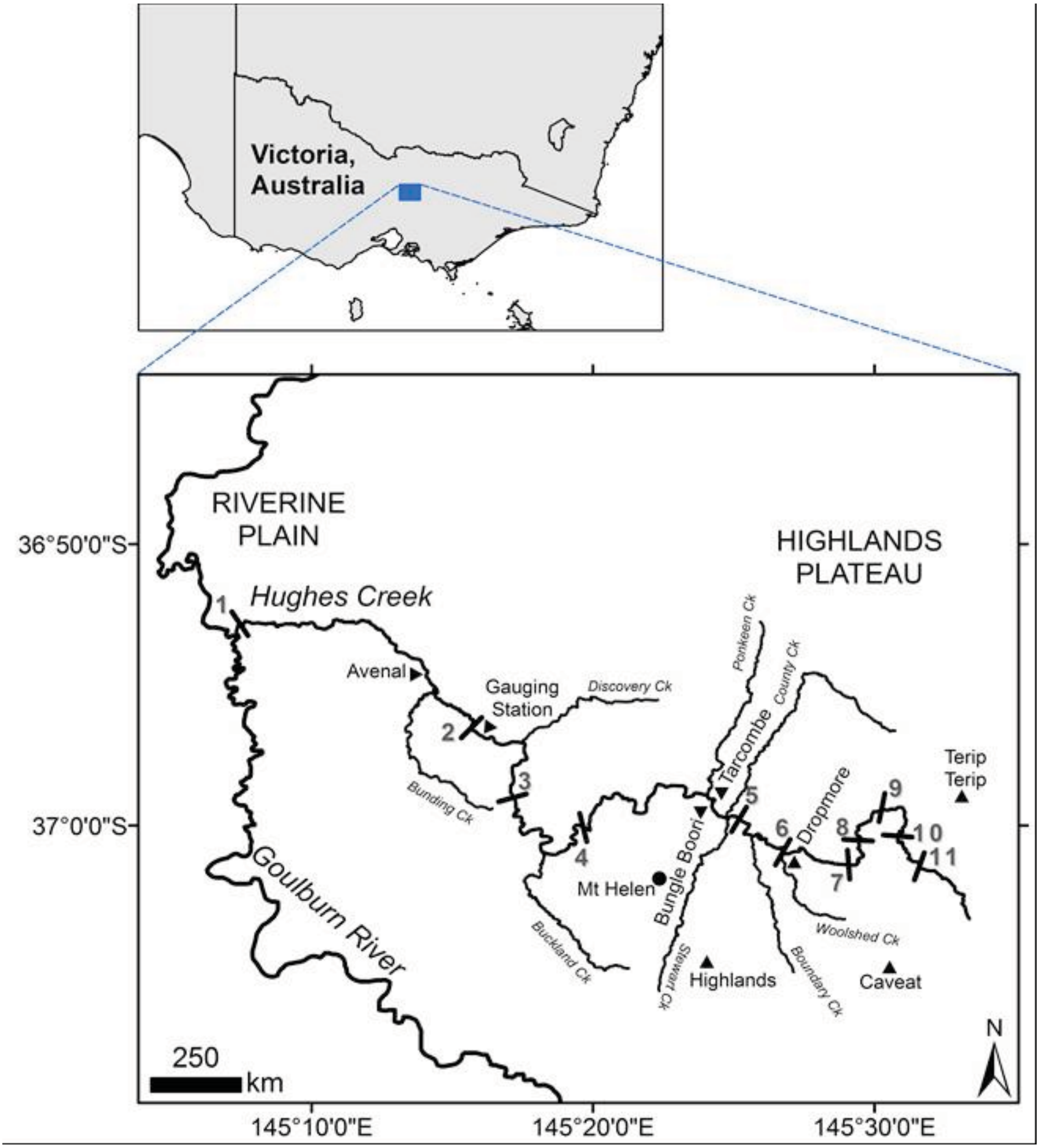

**Figure 1. Hughes Creek, a tributary of the Goulburn River in central Victoria, Australia, showing river reaches and important place names. For the name of the numbered reaches, see text below.**

habitat and population of Macquarie perch.

## Hughes Creek Catchment

The Hughes Creek catchment largely drains a pluton of Late Devonian Strathbogie Granite which is a holocrystalline rock ranging from fine to coarse grained. The granite has intruded the Wilson Creek Shale and Walhalla Group. These rocks are variably contact metamorphosed for up to 4 km from the granite (metamorphic aureole). Close to the granite, pelitic rocks have been altered to black massive and hard cordierite hornfels, and psammitic rocks to intensely spotted cordierite hornfels.

Avenel PO (Station No. 88002) has the longest rainfall record (1900–2014) of any station located within the catchment. For 1900–2013, inclusive mean annual rainfall at Avenel PO was 597 ± 15 mm (Standard Error), with a median annual rainfall of 586 mm. Maximum annual rainfall was 1034 mm in 1973 and minimum was 260 mm in 1982. The lowest annual rainfall during the Millenium Drought was 288 mm (2006).

For 1900–2013, inclusive mean and median monthly rainfall were lowest at Avenel PO in February when mean monthly rainfall was 35 ± 4 mm (SE) and median monthly rainfall was 23 mm. Monthly rainfall then progressively increased until July when it peaked at a mean of 64 ± 3 mm (SE) and a median of 61 mm. Monthly rainfall then progressively declined until February. Temperature varied inversely with rainfall.

Orographic effects on rainfall showed that median annual rainfall increased by 78 mm for each 100 m increase in elevation through the Hughes Creek catchment and mean annual rainfall increased by 81 mm for each 100 m increase in elevation.

There is only one gauging station on Hughes Creek at Tarcombe Road (No. 405228)(Figure 1). Mean annual runoff was 138 mm for 1976 to 2013. Mean and median monthly runoff were lowest in February when mean monthly runoff was 991 ± 204 ML and median monthly runoff was 579 ML. Monthly runoff then progressively increased until August when it peaked at a mean of 14220 ± 1750 ML and a median of 13370 ML. This seasonal Mediterranean runoff trend shows a winter runoff peak and a late summer minimum (February).

A major flood occurred throughout northern Victoria in early September 2010. In the Hughes Creek catchment peak rainfall occurred on 4 September 2010 when the maximum 48 hour rainfall at Temagog (Caveat) was 73 mm. Maximum recorded gauge height at the Tarcombe Road gauge was 4.41 m which is higher than the maximum gauging. Estimated peak flow was 414.4 $m^3/s$. The estimated average recurrence interval for the flood peak was 30 years on the annual maximum series (log Pearson Type III distribution).

## River Reaches

River reaches are homogeneous lengths of channel within which hydrologic, geologic and adjacent catchment conditions are sufficiently constant so that a uniform morphology or a consistent pattern of alternating river morphologies is produced (Erskine, 2016). Formal names have been given to reaches for local residents and river managers to identify with, and take a management interest in, their local river reach. River reaches can then be classified into specific river types using various approaches (see Erskine, 2016). However, broad river categories are preferred because each reach of the same river category has not necessarily progressed through the same evolutionary pathway or trajectory. Hughes Creek has been classified into 11 geomorphologically homogeneous river reaches. Figure 1 shows the spatial distribution of these reaches and Figure 2 shows the location of the river reaches on the long profile.

Hughes Creek commences in the Black Range (*Kendalee Headwaters Reach – Reach 11*) and flows across the plateau as swamps, percolines and chain of ponds (*Kendalee Headwaters Reach*, *Terip Terip Percolines Reach* – Reach 10- and *Ruffy Chain of Ponds Reach – Reach 9*) before descending into the Hughes Creek Valley via two granite gorges (*Springfield* and *The Peak Granite Gorges –Reaches 8 and 6, respectively*) separated by a short granite-confined reach (*Dropmore Granite-Confined Reach – Reach 7*). There are few active sediment sources above the Springfield Granite Gorge and most sand supplied to the channel in the upper catchment originates from unsurfaced roads and tracks. Once below the Highlands plateau, Hughes Creek is closely confined by granite through Bungle Boori (*Bungle Boori Granite-Confined Reach - Reach 5*) before flowing through the highly resistant hornfels of the metamorphic aureole of the Strathbogie Batholith (*Kulaba Hornfels-Confined Reach – Reach 4*). The tributaries entering the Bungle Boori Granite-Confined Reach have been active sand sources in the past (Erskine, 2016) and include Stewart, County and Ponkeen Creeks. Hughes Creek re-enters the Strathbogie Batholith at Booroola (*Booroola Granite-Confined Reach – Reach 3*) before debouching onto the Riverine Plain just upstream of Avenel (*Avenel Recovering Sand Slug Reach – Reach 2*). The recovering sand slug continues until Hughes Creek almost reaches the Goulburn River where there is a short backwater-affected reach (*Goulburn Backwater Reach - Reach 1*). Landcare has been active in the Hughes Creek catchment (Erskine, 2016) and there are now many tree plantings for various purposes and pasture improvement that have increased greatly ground cover over the last 20 years.

## Historical Channel Changes on Hughes Creek

Significant channel changes on Hughes Creek have occurred since European settlement in 1835?, particularly the development of the sand slug in Reach 2. Erskine (1993) concluded that the sand slug developed during the early twentieth century based on a series of photographs of sand aggradation at Avenel from 1920 to 1937. A sand slug is a bedload wave where sand oversupply produces substantial and rapid bed aggradation (up to 4 m in 4-5 years) and sandy overbank deposition on the floodplain. Subsequent sand reduction causes bed degradation which produces the wave form (Erskine 2016). Channel recovery can be rapid, being effected by 4–5 events over 5–10 years or can persist for many decades. Research on the dynamics of hydraulic mining debris originating from gold mining by hydraulic slucing in the Sierra Nevada mountains in California and its impact on the Sacromento River and floodplain is the best known example of a sand slug. Formation of many sand slugs in the eastern USA following accelerated soil erosion and gully erosion caused by the introduction of European style agriculture, as on Hughes Creek, are also well known.

The first surveys of Hughes Creek and its tributaries were conducted by Pickering in the early 1840s (see Erskine, 2016 for details). The resultant maps show all of the following:

1. Hughes Creek was a continuous channel from the headwaters to the Goulburn River,
2. Anabranches were only depicted on Hughes Creek up- and downstream of Avenel in Reach 2,
3. A sand slug (Avenel Recovering Sand Slug Reach) was not shown in Reach 2 and further upstream,
4. Close bedrock confinement of the channel was depicted in Reach 4 (Kulaba Hornfels-Confined Reach),
5. A short bedrock gorge was shown in the upper part of Reach 6 (The Peak Granite Gorge), and
6. A series of short bedrock gorges and “falls” were shown in Reach 8 (Springfield Granite Gorge).

There is no doubt that the sand slug postdates European settlement and that tributary incision also occurred after initial European settlement.

The interaction and synchronization of a number of activities associated with European settlement caused extensive channel incision and gullying that generated large volumes of sand that created sand slugs on the neighbouring ‘Granite Creeks’. In relation to the timing of erosion, the 1916 flood and the wet periods of the 1950s, 1960s and 1970s were important with a renewed phase during the 1993 flood. The 1916 flood seemed to be responsible for synchronizing erosion throughout all three neighbouring granite streams and was also important on upper Hughes Creek. The sand slug created a long section of channel that was relatively flat, shallow and ecologically featureless with low aquatic habitat complexity (see Erskine, 2016 for details).

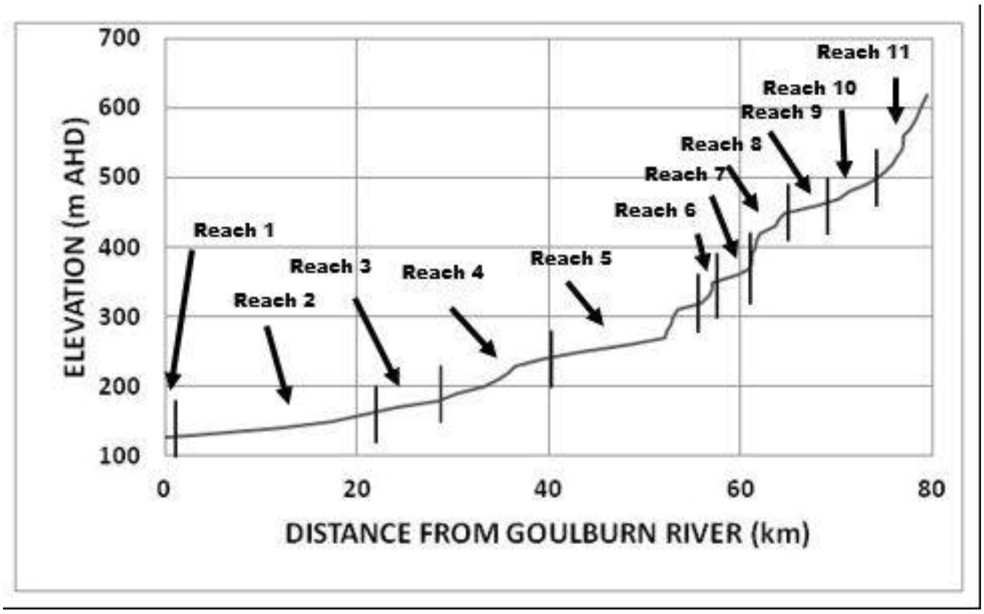

**Figure 2. Long profile of Hughes Creek showing location of river reaches.**

Rabbits appeared in the catchment in the latter part of the 1880s, apparently invaded the district from Tarcombe on upper Hughes Creek and became a major problem for agriculture after 1900. This is consistent with the known chronology of the dispersion of rabbits into the Goulburn catchment (Erskine, 2016). At least in some cases, the coming of the rabbit was the final blow to the viability of small land holders. Given that closer settlement occurred during the 1860s, extensive catchment vegetation clearing occurred after that and rabbits reduced land productivity during and after the 1880s up to the introduction of myxamatosis in the early 1950s (Erskine, 2016). It seems that the sand slug on Hughes Creek developed during or after the 1880s. However, it must be stressed that it was the interaction of vegetation clearing, livestock grazing and rabbit invasion with drought that led to a severe lack of ground cover in the catchment (Erskine, 2016).

The sand slug had formed by 1928 when the low flow channel flowed through all six arches of the Avenel stone arch bridge. By 1973, Hughes Creek had started to contract and vegetation had colonized the higher parts of the former bed. The rate of contraction accelerated after 1973 (Erskine 1993). The 1916 flood was the large-scale disturbance that caused channel erosion on Hughes Creek. It is concluded that the sand slug formed and reached Avenel by 1916. It is suspected that the 1916 flood was the erosional finale of the post-settlement phase of erosion but that substantial sand transport continued for a few decades thereafter.

Erskine (1993) first recorded that Hughes Creek was starting to recover from the sand slug by bed degradation, bank deposition and contraction, vegetation colonization by dense stands of *Phragmites* and substantial sand deposition on the floodplain. Recovery, in the geomorphic sense, means that downstream sand progradation and aggradation slowed or even stopped and that the slug became partially vegetated. Contraction had commenced by 1970. Minor channel contraction of 2–3 m has occurred immediately upstream of the Avenel stone arch bridge between 1991 and 2014. The present channel only occupies two of the six arches with flood flows occupying a third arch. The current bed level is about 0.3 m below the bottom of the pile cap on the old Hume Highway bridge and has not changed for the last 23 years.

Channel changes on Hughes Creek effected by the flood of 4 September 2010 were determined by comparing vertical air photos of 31 August 2006 and 4 January 2011 (Erskine, 2016). The September 2010 flood:

1. Did not cause any channel changes in the headwater reaches (Reaches 8, 9, 10 and 11);

2. Significantly reworked temporary sand stores in the middle reaches of Hughes Creek (Reaches 3, 4 and 5) where there are Macquarie perch;
3. Caused minor channel changes in the remaining river reaches (Reaches 1, 2, 6 and 7); and
4. Channel recovery is now well advanced from the 2010 changes in the most impacted reaches (Reaches 3, 4 and 5).

There is now a disconnection of sand supply from the catchment to the channel of Hughes Creek. Therefore, future floods are unlikely to cause as much remobilisation of sand as the September 2010 flood. Riparian revegetation, fencing and off-channel stock watering should be extended as fast as possible in Reaches 3, 4 and 5 of Hughes Creek.

## Distribution and Abundance of Macquarie perch in Hughes Creek

Historically, Macquarie perch used to extend upstream on Hughes Creek to “Tarcombe” where Springfield Granite Gorge (Reach 8) created a natural barrier to the passage of all native fish species which do not climb. While recent fish sampling has shown that Macquarie perch are still present in Hughes Creek, they are restricted predominantly to Reaches 3, 4 and 5. The sand slug limits their downstream dispersion and poor habitat quality and multiple migration barriers limit their upstream dispersion. Their population is highly variable and susceptible to reduced abundance during severe droughts. As pools are drought refuges, pool enhancement work would increase the survival of Macquarie perch during droughts. As gravel riffles are required spawning sites, recruitment and hence recovery from hydrological and anthropogenic disturbances would be hastened by increasing the length, number and condition of riffles. Both actions would increase the resilience of the remaining population. However, Macquarie perch may be starved for food where sand slugs occur. This further highlights the need for reinstatement of gravel patches on Hughes Creek, even if the effects may be inconsistent between sand-bed streams. Furthermore, Carp may have a competitive advantage over Macquarie perch for accessing invertebrates in sand slugs (P.S. Lake, 2014, written communication). Stock exclusion and riparian revegetation in Reach 4 are essential.

## Recommended River and Catchment Works to Improve Macquarie perch Abundance and Habitat

To improve the Macquarie perch population and aquatic habitat in Hughes Creek it is recommended that the following issues be addressed by the CMA in the identified reaches:

1. Reduced sand supply from catchment slopes to Hughes Creek, especially upstream of reach 4 by maintaining ground cover at more than 70 %
2. Reduced sand transport by Hughes Creek, especially downstream of reach 6 by revegetating channel margins
3. Improved riparian vegetation condition and density on Hughes Creek in all reaches but especially reaches 2, 3, 4 and 5 to reduce sand mobility
4. Increased length of gravel riffles and gravel patches in reaches 3, 4 and 5 improve spawning and feeding areas
5. Increased number, length and depth of refuge pools in reaches 3, 4 and 5 by reintroduction of large wood
6. Construction of pool improvement works by reintroducing large wood in reaches 3, 4 and 5
7. Reduced competition from alien fish species downstream of reach 6
8. Effective monitoring and species management of the Macquarie perch population in Hughes Creek in reaches 2, 3, 4 and 5.

## Conclusions

River reach analysis was carried out on Hughes Creek and 11 reaches were described. Lower Hughes Creek was characterised by pools, runs, riffles and bars at the time of first settlement. A sand slug formed between the end of the nineteenth century and 1916 when accelerated erosion of the upstream catchment and tributaries downstream of Dropmore overloaded the main channel with sand. Bedrock-confined reaches (Reaches 3, 4 and 5) contain the best pools but the more resistant hornfels of Reach 4 produce the best Macquarie perch habitat. Low order channels exhibited swampy reaches with percolines and chain of ponds at the time of first settlement. Tributaries eroded at different times but most had undergone at least one phase of incision by 1970. Following initial incision, the tributaries stored substantial sand for a short time period after which sand was reworked to the main channel. Where riparian revegetation and fencing have been completed colonisation by rhizomatous emergent macrophytes has occurred and chain of ponds have reformed. Where no riparian fencing and revegetation have been completed, sand has been totally removed and formerly incised channels have started to recover slowly by revegetation. The 1916 flood marked the erosional finale of the post-settlement phase of erosion on Hughes Creek, which produced an extensive sand slug in Reach 2 and sand aggradation further upstream. A reduction in sand input after 1970 resulted in reworking of sand in the bed with progressive bed degradation which also caused the channel to contract. Rhizomatous emergent macrophytes stabilised the channel margins and accelerated the rate of contraction. There is currently a decoupling of catchment from the channel network in terms of sand because of the extensive Landcare activities and improved farm management. A large store of sand remains in the channel.

Macquarie perch is found in Hughes Creek in Reaches 3, 4 and 5 with Reach 4 being the stronghold. Spawning areas are relatively shallow gravel riffles close to pools. Relatively deep pools are holding areas for spawning aggregations and refuge areas for non-spawning fish. Therefore restoration of Macquarie perch aquatic habitat should involve reinstatement of clean, open framework, gravel riffles and relatively deep pools with high loadings of large wood, significant contact with native vegetated banks with overhanging cover.

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