Inanga spawning habitats in the Wellington

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Executive Summary

Between 2 April and 7 April 2001, 21 streams and rivers in the western part of the Wellington region were surveyed to determine the location of inanga spawning sites. While neither spawning nor eggs were found, a number of shoals of inanga close to spawning condition were observed, and suitable areas for spawning were determined and geo-referenced with a GPS system. These data were exported into the Wellington Regional Council's GIS system.

Three waterways, the Wainuiomata and Otaki Rivers, together with Makara Stream, already had extensive areas of suitable vegetation for spawning. The spawning areas of another seven waterways were considered to offer potential for significant improvement, especially the Kakaho and Porirua Streams. There were several catchments surveyed which were deemed to be unsuitable as a habitat for inanga, and these included the Orongorongo River, and Karori Stream.

A number of management issues are discussed in respect to waterways in the study area, in particular unrestricted stock grazing along the waters edge, weeds, and instream structures.

1 BACKGROUND

For the 2000/2001 and 20002/2003 financial years, the Wellington Regional Council (WRC) will implement a substantial freshwater ecosystem programme. This will include an investigation of the Council's management of freshwater ecosystems, freshwater fish surveys, and identifying structures in the Region that may be a barrier to fish passage. The ecology of the Wairarapa water races will also be surveyed, and public awareness initiatives instigated.

A component of this programme will be surveys on the location, nature, and restorative potential of inanga (adult whitebait) spawning grounds in the Wellington region. For the 2000/2001 financial year, and the subject of this report, the western catchments were surveyed. Follow-up survey work in the Wairarapa is planned for 2001/2002, with the WRC to consider opportunities for the restoration of whitebait spawning habitat in the 2002/2003 year.

2 INTRODUCTION

There is only sparse information on inanga spawning in the Wellington region. After some public concerns in respect to the North Island whitebait runs in the 1920's, Captain Hayes researched the inanga life history, and observed whitebait spawning on the Manawatu River, just north of the Wellington region, and made the first observations on the deleterious impacts of stock grazing on spawning grounds (McDowall 1984, Hefford 1936). In the 1960's, ecological work was conducted on the breeding biology of inanga from a number of New Zealand rivers, including the Waikanae River, and the Waimeha and Makara Streams (McDowall 1968). Consequently, the location of the spawning grounds on the Waimeha and Waikanae Streams were determined and communicated to the writers, although this was not released in the 1968 work (R.M. McDowall pers. comm.).

Despite the known ecological vulnerability of inanga spawning grounds in the 1920's, little was done to protect spawning areas, and after public concerns resurfaced regarding the decline of the national whitebait run in the 1980's, a national effort was made to locate, protect, and database inanga spawning grounds using firstly Ministry of Agriculture and Fisheries (MAF) staff, and then Department of Conservation (DoC) personnel (Taylor *et. al* 1992). After extensive survey work in other areas of the country, a number of small spawning sites in the Hutt River were recorded by DoC staff in 1996 (National Inanga Spawning Database). There is some correspondence from DoC in respect to protecting the habitat from bank slumping and oil pollution (NIWA files). However, since the latest DoC restructuring, there have been no follow-up surveys.

2.1 Inanga life history

Inanga are the adult lifestage of the most abundant whitebait species, *Galaxias maculatus*. This fish normally spawns gregariously on spring-tide events during late summer and autumn, and are highly unusual in that spawning takes place amongst tidally-inundated riparian vegetation (Benzie 1968, Burnet 1965). Eggs develop within the moist litter-layer for 2-4 weeks, and hatch when the eggs are flooded by a later spring tide. The larvae are washed out to sea on the ebbing tide, where they feed and grow over the winter months. In the following spring, the whitebait enter river mouths from the sea, and mature in fresh water over the summer.

Inanga spawning vegetation comprises a number of forms that satisfy the stringent microhabitat demands required for egg development. Inanga eggs, like those of other fish, have no waterproof layer. However, because the eggs are usually exposed to the air for much of their development period, they are susceptible to desiccation (drying out) and ultimately death. Inanga minimise the risk of egg mortality by spawning amongst vegetation sufficiently thick as to trap a humid layer of air around the eggs.

In New Zealand, suitable vegetation has been demonstrated to have a number of forms. In pastoralised areas, they often comprise ungrazed pasture grasses, especially tall fescue, Yorkshire fog, and creeping bent. Such grasses form a thick root mat (tall fescue) or runner mat (creeping bent) over the soil surface facilitating egg adhesion and moisture retention. Yorkshire fog has limp, slightly hairy leaves, which form an ideal substrate when the dead leaves lie over the soil surface. In habitats with some native vegetation, inanga will spawn around the bases of the flax, or within raupo beds, where eggs will be found adhering to the decaying leaves around the stems. They are also found amongst thick stands of native rushes, but only where the salinity is low. In all cases, however, the soil must be capable of retaining moisture between the periods of rain, and/or tidal inundation. Soils with a high sand content drain too quickly, and consequently do not retain a high moisture content around the eggs. On the other hand, the eggs should not be flooded which can take place if, for example, the eggs are placed in a hollow, or the clay content of the underlying soil is too high. Bank profiles, therefore must be steep enough to facilitate drainage, but not so steep that the potential spawning zone is limited in area, or that eggs are washed away by rainfall or water currents.

2.2 Objectives

NIWA was commissioned by the WRC to undertake an inanga spawning habitat survey in the western part of the Wellington Region. In particular, to implement the following objectives:

- review existing information relating to the presence of whitebait spawning in localities in the Wellington Region

- carry out surveys of whitebait spawning habitat on 21 nominated rivers in the western part of the Wellington Region (Fig. 1).

- collect field information that will assist with mapping and describing identified whitebait spawning habitats.

- prepare a report (including in electronic form) that maps and describes whitebait spawning habitat, including any information that is relevant to management/restoration.

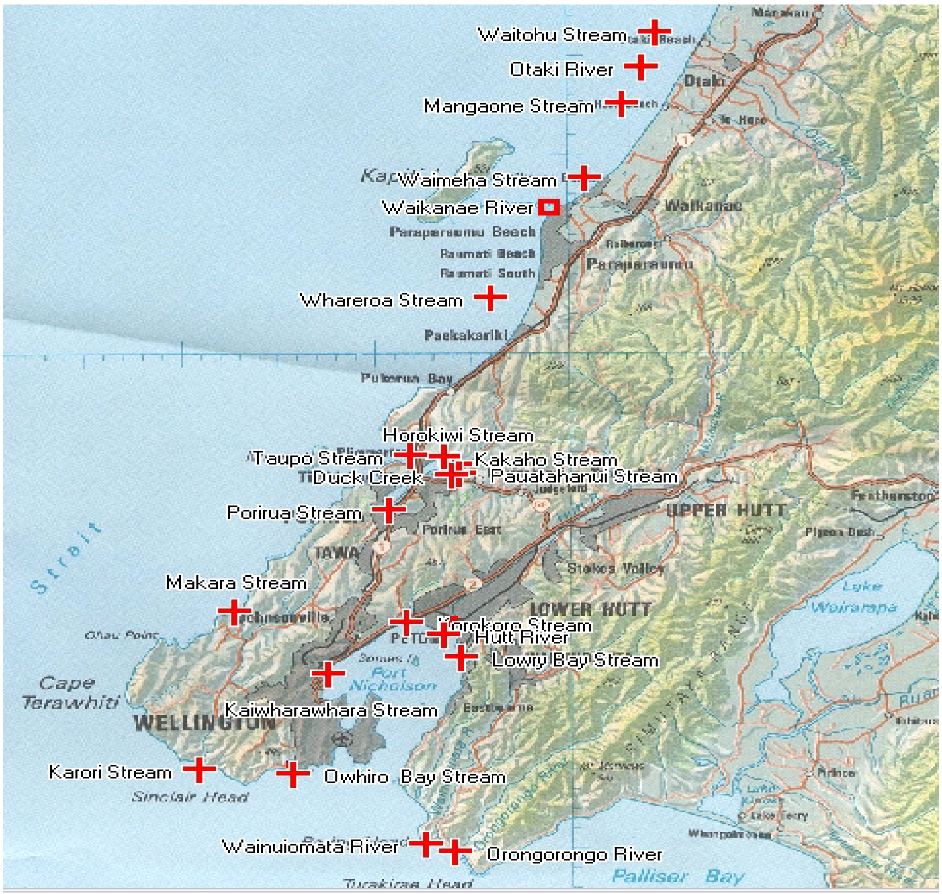

Figure 1: The 21 surveyed waterways in the Wellington region.

2.3 Methods

Field surveys were conducted by two personnel, with transport between and along rivers provided by a 4WD vehicle, and a motorised 2m aluminium dinghy. The dinghy was sufficiently light to be carried a short distance. High-tide salinity gradients were monitored with a Horiba® multi-parameter probe (Fig. 2), and suspected inanga spawning sites, and other areas of interest were geo-referenced with a Garmin® GPS (Global Positioning System) receiver. For presentation these positional data were overlaid onto NZMG 260 series maps, using FUGAWI 3.0 ® software. Distribution data was also provided in a format (ascii) compatible with use in ARCVIEW ® or ARCINFO ® software.

Figure 2: The multi-parameter probe in use. The transducer is slowly lowered into the water to known depths, and water conductivity (viz. salinity) is recorded from the LCD display readout.

2.4 Results

The survey results from the respective waterways are presented in geographic order, commencing from the most westward catchments, the Orongorongo and Wainuiomata Rivers, and proceeding eastwards around Port Nicholson and Sinclair Head. The order of presentation will then proceed northwards up the Kapiti coast to Waitohu Stream.

Owing possibly to the warmer-than-usual autumn water temperatures, we did not find inanga eggs or spawning during the field survey. However close examination of the riparian vegetation, observation of inanga spawning shoals, and the monitoring of the saltwater intrusion, allowed us to make a determination of where inanga were likely to spawn. This process was facilitated by the small size, and moderate gradient of many of the waterways.

To improve text clarity, only common names for riparian and aquatic plants are used in the text, scientific names are tabulated in Table 1.

Table 1: List of scientific names for common plants mentioned in the text.

Common name	Scientific name
Blackberry	*Rubus fruticosus*
Buttonweed	*Cotula coronopifolia*
Clover	*Trifolium* sp.
Cocksfoot	*Dactylis* sp.
Cow parsley	*Apium nodiflorum*
Creeping bent	*Agrostis stolonifera*
Dock	*Rumex neglectus*
Flax	*Phormium tenax*
Gorse	*Ulex europaeus*
Mint	*Mentha x piperita*
Monkey musk	*Mimulus guttatus*
Old Man's Beard	*Clematis vitalba*
Parrots feather	*Myriophyllum aquaticum*
Plantain	*Plantago major*
Raupo	*Typha orientalis*
Reed Sweetgrass	*Glyceria maxima*
Tall Fescue	*Festuca arundinacea*
Toetoe	*Cortaderia richardii*
Wandering Jew	*Tradescantia fluminensis*
Wiwi (New Zealand rush)	*Juncus gregiflorus*
Yorkshire fog	*Holcus lanatus*

2.5 Orongorongo River

It was apparent to us that this shallow braided river offered little rearing or spawning habitat for inanga (Fig. 3). This is because of the lack of riparian vegetation or soil on the floodplain that would support spawning in the main channel. Further, the mainstem hydrology is unsuitable for inanga rearing, as the fish prefer deeper and more sluggish flows. The river discharged directly to the sea with no lagoon formation, and lacked spring-fed feeders which in other braided systems (e.g. Ashley and Rakaia Rivers) offer some habitat for inanga spawning and rearing.

2.6 Wainuiomata River

The most downstream 1.5 km of river channel was surveyed (Fig. 4), and the mouth was closed at the time by a 40 m wide gravel bar. However, upstream of the bar, we recorded an extensive area suitable for inanga spawning (Fig. 5). Vegetation consisted of the introduced grasses creeping bent, tall fescue, and wiwi. The grasses, particularly, would not tolerate a high degree of saltwater exposure, so presumably the sea intrusion into the catchment is minor. This may be the case if the mouth is closed by Southerly wind conditions for protracted periods. The underlying soil was surprisingly moisture retentive, with a high proportion of clay particulates recorded.

Figure 3: Orongorongo River. Looking upstream from the bridge.

Further upstream, riparian vegetation was too dry, possibly because the underlying soil structure had changed to a more sandy composition. The area was subject to grazing pressure; and although most of this appeared fairly light, some areas were more intensively grazed.

2.7 Lowry Bay Stream

The tidally-influenced reaches of this stream were evaluated near the Eastern Bays Marine Drive. At the time of the survey the downstream end of the culvert was blocked by beach shingle, presumably by heavy sea conditions.

Lowry Bay Stream is a small heavily-shaded stream (Fig. 6) which is culverted under Eastern Bays Marine Drive. The steep, bush-vegetated nature of the catchment is more suitable for whitebait species other than inanga, particularly banded kokopu (*Galaxias*

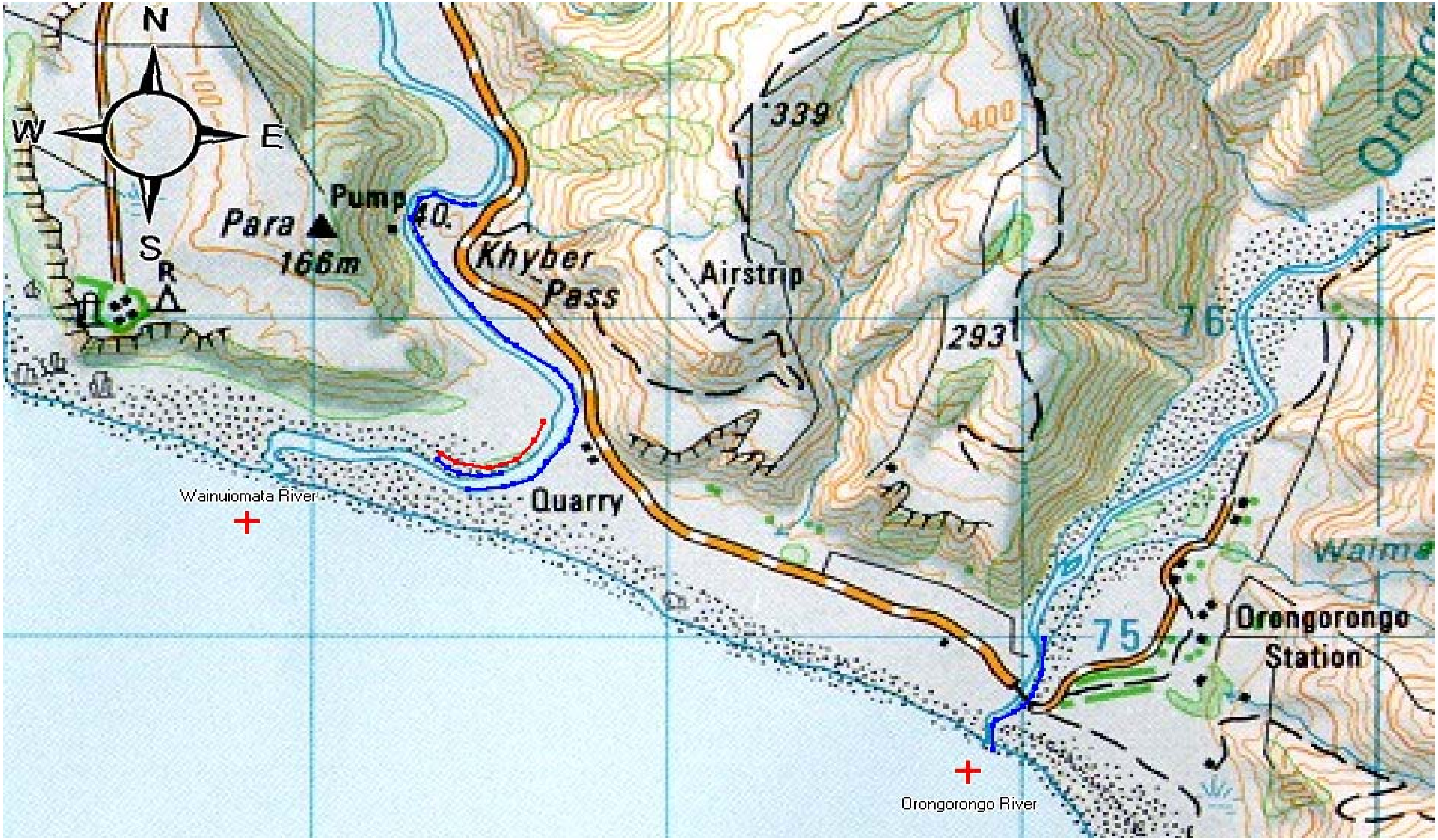

Figure 4: Suitable spawning habitat (red track) on the Wainuiomata River. The Orongorongo River was wholly unsuitable both for inanga spawning and rearing.

Figure 5: Looking downstream towards the mouth of the Wainuiomata River on full tide. Good spawning habitat is in the foreground.

Figure 6: The heavily-shaded Lowry Bay Stream. The pool upstream of the culvert mouth was occupied by approximately 10 banded kokopu, up to a length of 220 mm.

fasciatus). Of note, a small school of approximately 10 banded kokopu was seen near the upstream railing by the road. Some specimens were quite large for this species (c.a. 220 mm), and, at least in the tidally influenced area, the heavily-shaded nature of the stream is suitable rearing habitat for this species. Unfortunately, in the short reach which was visible from the road, the banks were vertical concrete walls, which would preclude spawning for this species. The fish spawns on flooded leaf detritus along the channel (McDowall 1990). The presence of banded kokopu reflects well on the general ecological health of the stream ecosystem, and although they are insensitive to high silt loads, they can be found in heavily shaded catchments in established residential areas.

While the stream is currently providing good rearing habitat for banded kokopu, the stream size and hydrology is unsuitable to support a large population of inanga. Therefore spawning potential or enhancement for inanga should not be a priority, but the retention of the good instream habitat values for other species should be. The closure of the mouth in October and November during the banded kokopu whitebait run would prevent annual recruitment into the stream, but this is not an issue of serious concern, with many other streams draining the Eastern Bays being of a similar nature. Locating and enhancing the spawning grounds for banded kokopu is a separate, and possibly more difficult exercise than that for inanga.

2.8 Hutt River

The extent of the survey, and locations of good spawning habitat are shown in Fig. 7. Historically, the Hutt River supported a productive whitebait fishery, and while the fishery in this river has undoubtedly declined; probably because of the industrial and residential development of the lower river; the river is still utilised by whitebaiters (McDowall 1984). Like many major rivers flowing through urban areas, the mainstem's course has been constrained by levees, and the banks in the tidally influenced areas clad with large rip-rap (quarried boulders). The steep hard rocky surface dries between successive tidal inundations, making it wholly unsuitable as a substrate for inanga spawning as inanga eggs are prone to desiccation (drying out).

Despite the general unsuitability of the mainstem for inanga spawning, there are recent (1996) records of whitebait spawning in areas where cladding is absent. These include observations near the Sladden Park boat ramp in Petone, and on the opposite bank along "Opahu" stream draining Lower Hutt (National Inanga Spawning Database).

2.9 Sladden Park

A foot survey of the Sladden Park area (near the boat ramp) indicated only patchy areas suitable for inanga spawning, and these were largely confined to tall fescue grass

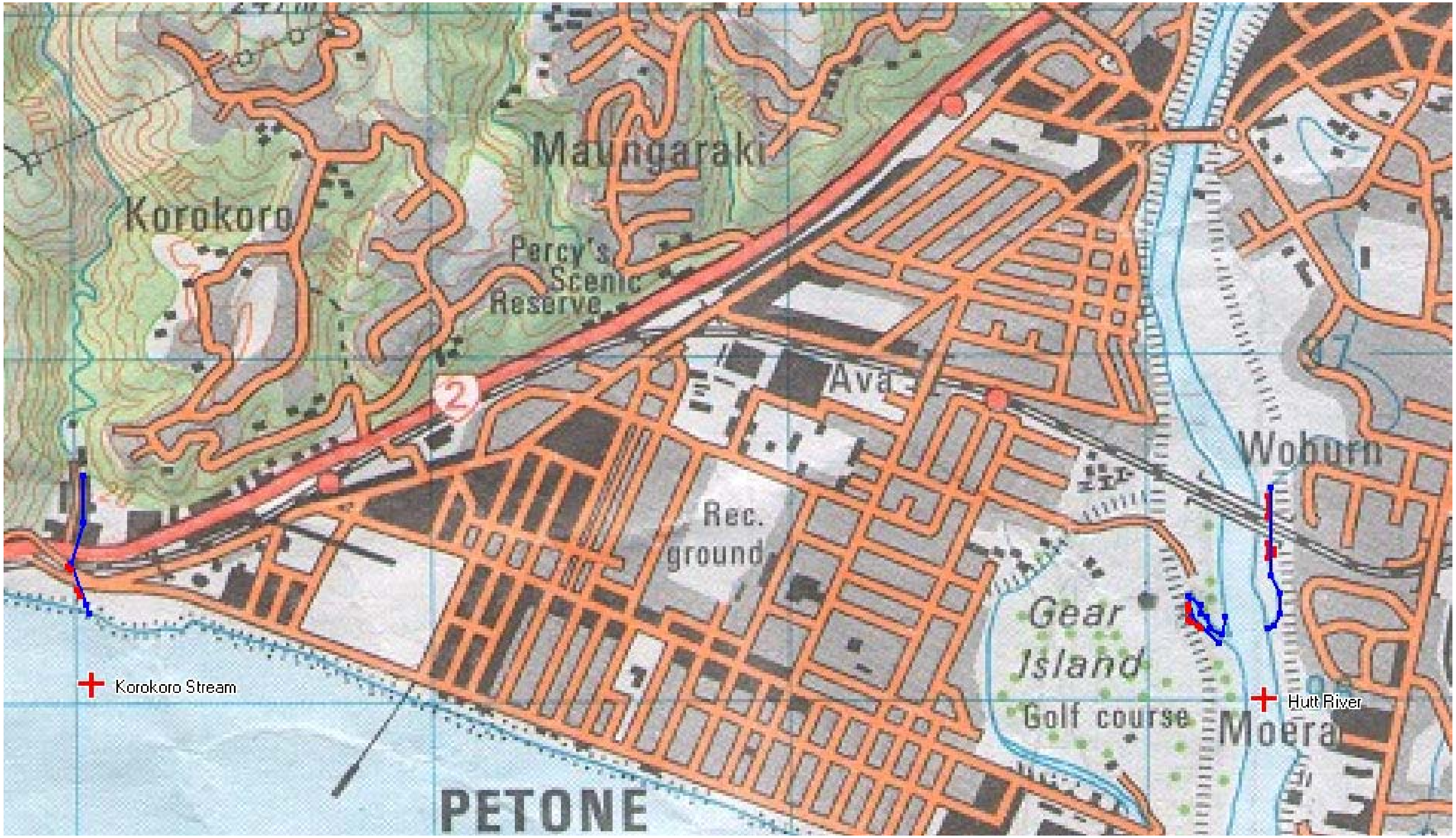

Figure 7: Suitable spawning habitats on the Hutt River and Korokoro Stream. The blue track shows the extent of spawning surveys, whereas the red track indicates the location of suitable spawning vegetation.

habitats on the south bank bordering the golf course. The north bank profile was unsuitable because it was nearly vertical, and collapsing in many areas around the playground (Fig. 8). Aside from the steep bank profile, the grass along this bank was insufficiently thick to maintain high soil surface humidity, although the presence of amphipods indicate some soil moisture.

Figure 8: Sladden Park on Gear Island, Petone. There were records of inanga spawning along this reach in 1996.

2.10 Opahu Stream

Stone cladding was predominant upstream of the train-bridge, except on the true right bank immediately upstream. At this location, a 40m stretch of native rushes and long tall fescue grass provided excellent spawning habitat (Fig. 9). The survey ceased at the tidegates (Fig. 10), because inanga are known not to spawn upstream of such structures. It is thought that spawning behaviour is inhibited because stream-resident inanga are denied access to salt water during high spring-tide water levels. Patches of good spawning habitat on the true left bank were restricted to unclad banks downstream of the train-bridge (Fig. 11). DoC staff had found inanga eggs along this reach in 1996. Reed sweetgrass was observed growing in isolated stands along this tributary.

Figure 9: Opahu Stream looking upstream from the railway bridge. Good spawning habitat featured on the left bank, whereas the stone cladding on the right bank is unsuitable.

Figure 10: Opahu Stream tidegates. Such structure have been demonstrated to inhibit inanga spawning upstream of their placement.

Figure 11: A gently-shelved area suitable for spawning on the true left bank of Opahu Stream downstream of the railway bridge.

2.11 Korokoro Stream

The Korokoro Stream was foot-surveyed from the walkway bridge (Cornish Place) to the sea (Fig. 7). The tidally-influenced reaches of Korokoro stream is a heavily industrialised area of the Korokoro valley, but despite this, there were limited areas suitable for inanga spawning. The best location was downstream of a weir (Fig. 12), between the train track and the Esplanade turnoff, along both banks of the waterway for a distance of approximately 5 m (Fig. 13). Grasses here were largely constituted of tall fescue, and Yorkshire fog, with water-emergent herbs (cow parsley and musk) also common. Normal tidal range appeared to be of a low magnitude at this point.

Figure 12: Korokoro Stream. A 0.6 m high weir that would restrict inanga to habitat below this point. Suitable spawning vegetation was downstream of this structure.

Figure 13: Good quality spawning habitat on Korokoro Stream, near the railway line.

Another small area with some potential for inanga spawning was near the mouth of Korokoro Stream. However grass growth was weak, possibly due to saline influence. The best area, of a somewhat lower standard in terms of moisture retention, was near the large pipeline on the true right bank (Fig. 14).

Figure 14: Korokoro Stream mouth. The better spawning habitat was on the far bank amongst the grass and jointed rush stands.

Despite the heavily industrialised nature of the riparian zone, the lower river does support fish life, with a 800 g brown trout, and a number of bullies observed. Both of these were likely to have been stream-resident. While inanga were not seen, viewing conditions were rather poor at the time, and shoals could have easily escaped detection as we proceeded downstream.

2.12 Kaiwharawhara Stream

This was evaluated to have little potential for inanga spawning, owing to the paucity of riparian vegetation in any form. The water course is channelised and heavily shaded, with a long, dark reach that flows under the Hutt Road, SH2 and the railway before discharging into the harbour. Regrettably, a camera malfunction owing to rainwater damage meant that no photos were obtained from this site.

2.13 Owhiro Bay Stream

The survey extent and suitable spawning areas are depicted in Fig. 15. This small stream rises from the Wellington suburb of Brooklyn, and descends rapidly and parallel to Happy Valley Road before discharging directly into Cook Strait at Owhiro Bay. While there was good spawning habitat upstream of the bridge on the true right bank, the close vicinity of two instream structures (a permanent sealed ford and low weir, Fig. 16) further upstream are likely to deny inanga access to upstream rearing habitat. The limited accessible spawning vegetation near the bridge was comprised of the grass tall fescue, and a herb flora dominated by musk and cow parsley. There was no indication of tidal-influenced water fluctuation upstream of the extent of survey.

The invertebrate fauna was dominated by numbers of the common freshwater snail *Potamopyrgus*. The presence of planarians (freshwater flatworms) may indicate sub-optimal water quality, given the free-flowing nature of this stream.

2.14 Karori Stream

The survey extent is depicted in Fig. 15. This long stream rises in the Wellington suburb of Karori, yet for much of its length, derives flow from rural land. A sewer outfall near the stream mouth discharges into Cook Strait (Fig. 17). The landowner claimed the catchment used to have (brown) trout, but they are now absent, and dead eels have been found in the past.

At the time of the survey, after a period of drought, the mouth was closed, and surface water was restricted to several linked temporary pools approximately 150 m from the

Figure 15: **Survey extents (blue), and the isolated patch on suitable spawning vegetation on Owhiro Bay stream (red). Karori Stream lacked suitable vegetation.**

Figure 16: Owhiro Bay Stream. While there was riparian vegetation suitable for spawning, the concrete road ford and weir upstream would inhibit catchment access for inanga.

Figure 17: The lower reaches of Karori Stream. The lower reaches were dewatered, and the mouth was closed. The sewer pipe outfall can be seen in the top right of the photo.

sea. Soil was very thin and grazed, with riparian vegetation composed of a mixture of pasture grass, some weeds (dock, plantain), and buttonweed. Although a seemingly remote area, access to the public by 4WD is possible at low tide around Sinclair Head, and it was clear (from the presence of wheel ruts) that the river course had been used as a road. With these factors considered, and the limited potential for inanga rearing, the enhancement potential for spawning was regarded as quite poor (Fig. 18).

Figure 18: The lower reaches of Karori Stream under the impact of low flows, grazing, and 4WD vehicle traffic

Approximately 1km upstream, the aquatic habitat appeared more permanent, and bullies (probably common bullies) were observed in the shallows, along with the snails *Physa*, *Potamopyrgus sp.*, mayflies, and caddis flies. However, this area is likely to be beyond the tidal influence, and unsuitably shallow and fast-flowing for both inanga spawning or rearing.

2.15 Makara River

The extent of survey, and suitable spawning areas are depicted in Fig. 19. The Makara was a strong contrast from Karori Stream, even though they both rise in much the same area. The Makara catchment is largely rural and pastoral in nature, and lacks significant urbanisation or subdivision development issues. At least in the lower

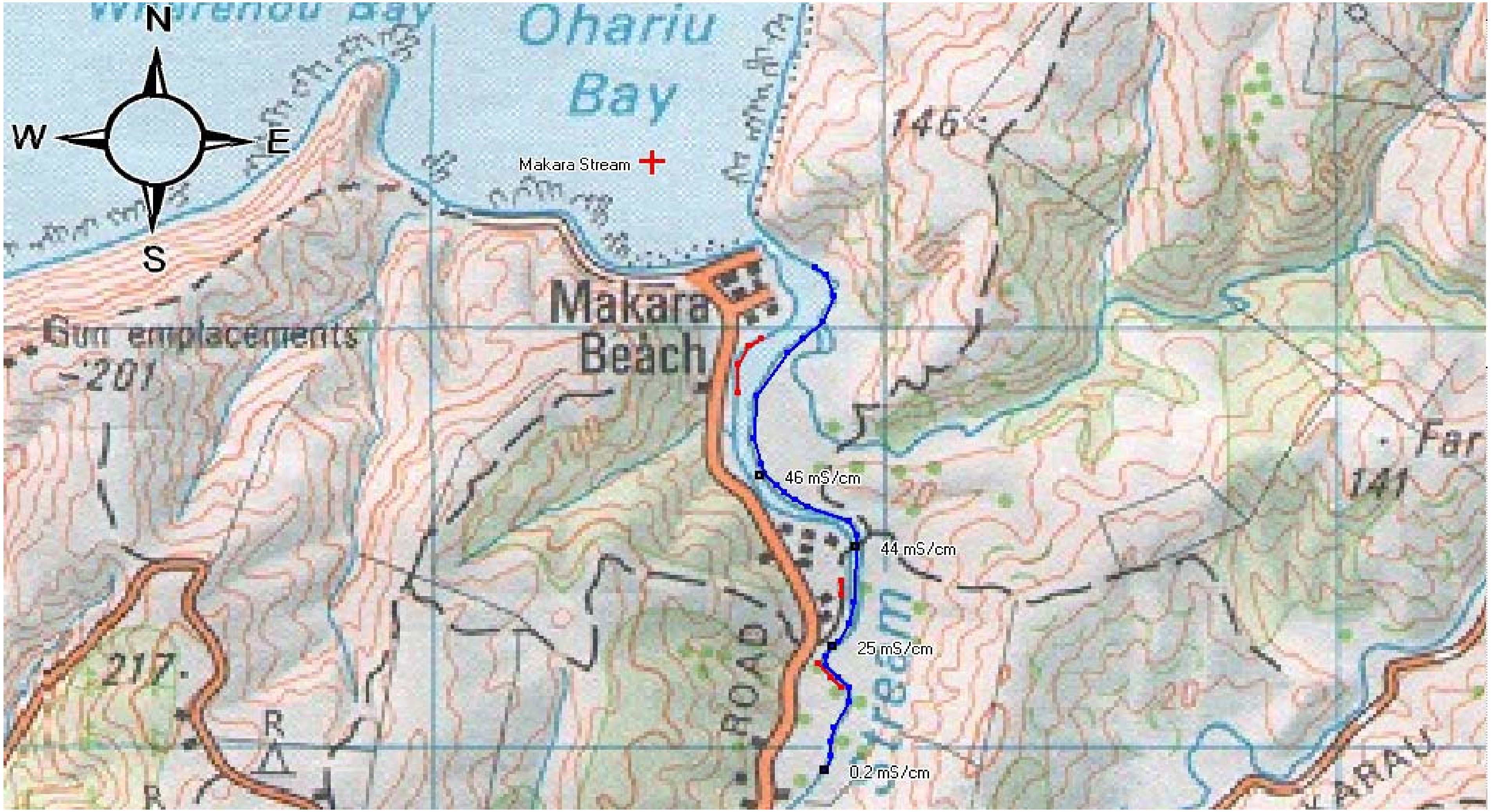

Figure19: Survey extent (blue), and potential inanga spawning grounds (red) on Makara Stream. Maximum salinity readings, recorded in an incoming tide, are indicated in black.

reaches, the banks are stable, and clad with rank riparian vegetation, while the deep sluggish water serves as an ideal habitat for inanga rearing. The tidally influenced region was navigated by boat for some distance.

The timing of the field survey coincided with a strong rising tide, so data were collected on the location of the saltwater wedge with upstream distance. On this river the saltwater wedge was terminated by an abrupt shallowing of the channel. We located 2 highly suitable areas, both on the true left bank. The first site was just downstream of the end of the saltwater wedge, and was approximately 80m in length. In this instance, the site was fenced from stock, and appears to have been deliberately stabilised by flax planting (Fig. 20). The second site, equally suitable and with a similar flora, was an island in the lower river with vegetation dominated by ungrazed tall fescue grass, and some flax (Fig. 21).

Figure 20: Makara Stream. An 80 m length of suitable spawning ground 200m downstream of the saltwater limit.

Figure 21: Suitable spawning habitat on a small island in the Makara River, near the Makara Beach township.

2.16 Porirua Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 22. The survey was conducted by foot along the mainstem, and the Kenepuru Stream tributary.

2.17 Mainstem survey

The survey began at the Kenepuru Reserve, upstream of the CBD (Central Business District) of Porirua City, and proceeded downstream. The mainstem constituted a continuous channelised run of uniform depth, with a riparian zone clad in large rip-rap, with a sparse covering in vegetation that appeared to be regularly sprayed. A low weir (Fig. 23) traversed the channel upstream of the area subjected to normal tidal variation. This structure would present a barrier to the upstream migration of whitebait at the low water levels observed during the survey, however at normal water levels in the spring, this structure is unlikely to inhibit whitebait migration.

Between the upstream Station Road bridge, and the Titahi Bay Road bridge, 3 large schools of inanga were recorded (Fig. 22), but vegetation along this reach was vestigial, with little or no emergent vegetation at normal or elevated water levels (Fig. 24). The banks of Porirua Stream had been lined with vertical concrete walls through the CBD. Below "The Ramp" overbridge, the river became tidal mud flat, and was unsuitable for inanga spawning.

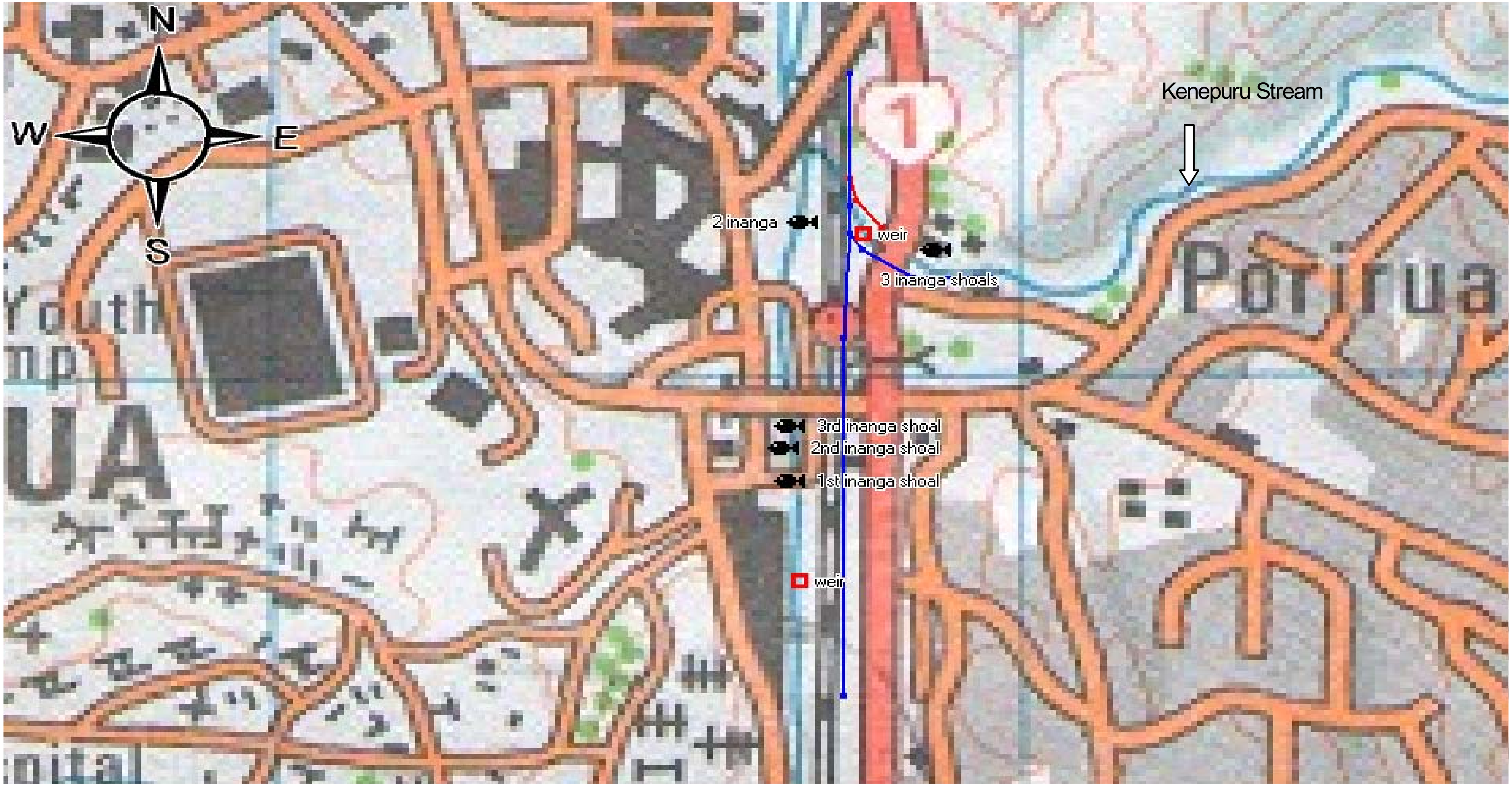

Figure 22: **Survey extent (blue), and area of potential spawning grounds (red) on the lower reaches of Porirua Stream.**

Figure 23: The low weir across the Porirua Stream.

Figure 24: Three large shoals of inanga were observed in the shallow reach of Porirua Stream between the two bridges. Note the vertical concrete-clad banks on each side of the stream.

2.18 Kenepuru Stream

More promising for inanga spawning was the tributary (Kenepuru Stream) entering the mainstem on the true right bank (Fig 22). Unlike the mainstem of the Porirua Stream, the banks of this stream had not been clad (although steep), and the stream course appeared to follow a fairly natural path between SH1 and the main river (Fig. 25). This small waterway included a small weir of unknown purpose (Fig. 26), and while it may partially inhibit fish passage, several large schools of inanga were recorded upstream of this structure and the SH1 bridge.

Figure 25: Kenepuru Stream, looking downstream below the weir. The right bank (S.H. 1 side) has the best potential for spawning habitat restoration. It already comprises established toe toe and raupo vegetation.

2.19 Duck Creek

The extent of survey, and suitable spawning areas are depicted in Fig. 27. Duck Creek is a small stream which flows though the Whitby golf course, and then enters a significant saltmarsh (Fig. 28) before discharging into Porirua Harbour. One area of suitable spawning vegetation was found downstream of the golf course, close to the sealed road (Fig. 29). A small school of inanga (10-12 fish) was observed here, where tall fescue grass, toetoe, and flax had been left to flourish. Further upstream, the stream passes through the golf course fairways, and the riparian vegetation had been mowed to an unsuitably short length.

Figure 26: A low weir on Kenepuru Stream that did not appear to serve any perceived purpose. Such structures are best removed, if they are obsolete.

2.20 Pauatahanui Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 27. At the time of the survey, a new bridge was being constructed over the stream. Because the survey coincided with a rising tide, salinity readings were recorded during the upstream excursion. Two suitable spawning areas were found. One, the more extensive, is on the true right bank upstream of the existing SH 58 bridge, and probably on road reserve land (Fig. 30). This site was dominated by tall fescue, but toetoe, blackberry, and mint were also present. Another potential spawning site was upstream of the new bridge site on the true left bank (Fig. 31). At this point the river shallowed to a depth of 0.4m, and no further saltwater intrusion was detected.

2.21 Horokiwi Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 32. The Horokiwi Stream occupies the drainage basin adjacent to Kakaho Stream, but the catchment is substantially larger in area, with a lower proportion of steeplands to river flats.

Areas suitable for inanga spawning were confined to areas mainly downstream of the bridge, with the exception of a short upstream section on the true right bank (Fig. 33).

Figure 27: Survey extents (blue), and suitable spawning vegetation (red) on Duck Creek, and Pauatahanui Stream.

Figure 28: Extensive saltmarsh at the mouth of Duck Creek.

Figure 29: Suitable spawning vegetation downstream of the Whitby golf course on Duck Creek. The plant community comprised a mixture of tall fescue, toetoe and flax.

Figure 30: **Suitable spawning habitat on the true right bank of the Pauatahanui Stream. This site was upstream of the SH 58 bridge.**

Figure 31: **Suitable inanga spawning habitat just upstream of the new bridge over Pauatahanui Stream, on the true left bank. Note the measures to control topsoil runoff around the construction site.**

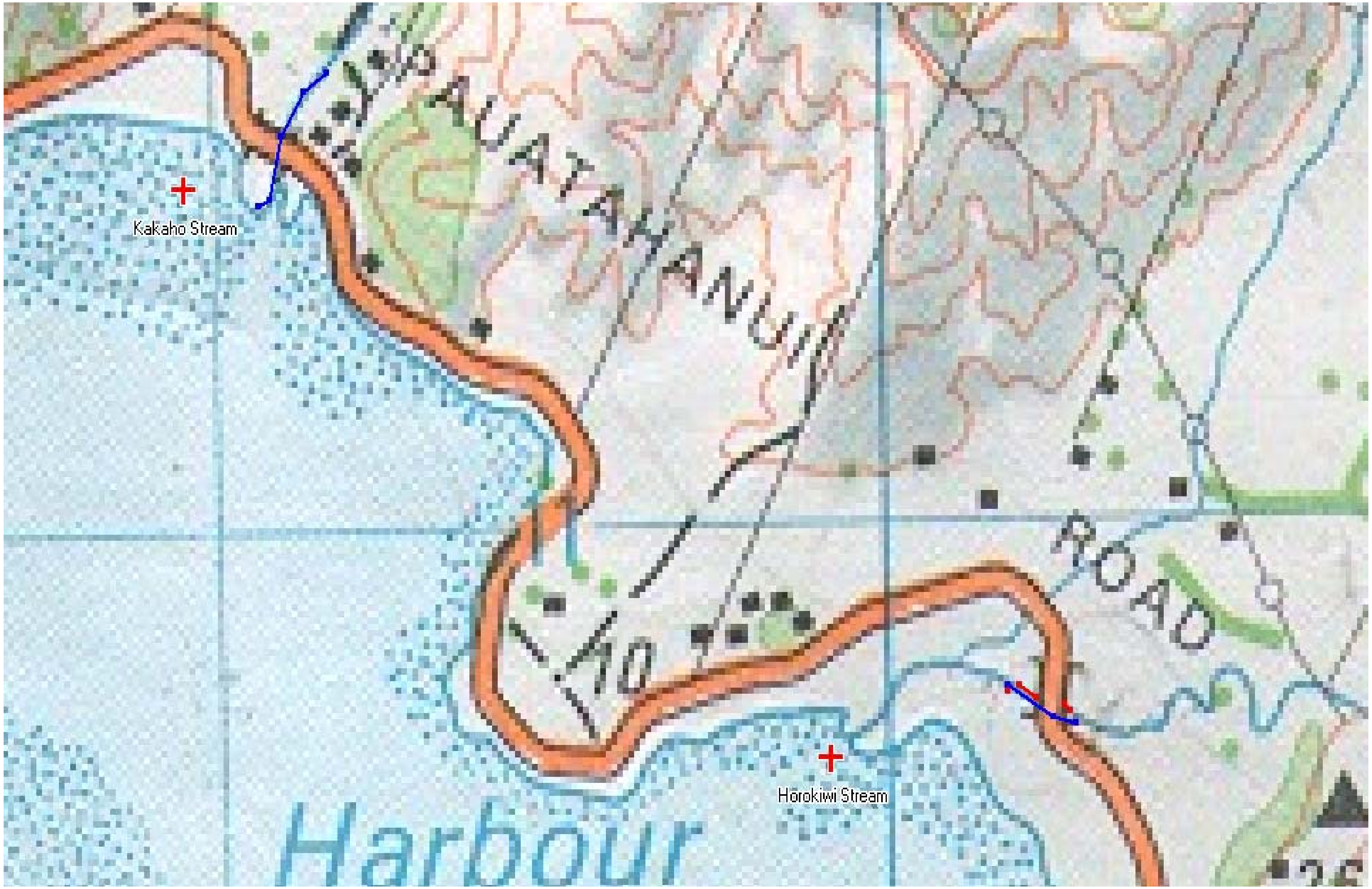

Figure 32. Survey extents (blue) and suitable areas for inanga spawning (red) on Kakaho and Horokiwi Streams.

Figure 33: The Horokiwi Stream looking upstream from the road bridge. The best spawning vegetation is the left bank in the photo. Upstream of the fence-line the banks are badly grazed and stock-damaged.

It would appear that stock grazing on private land upstream of the bridge had been detrimental to riparian vegetation, and bank stability. In contrast, there was no stock grazing below the bridge, and immediately downstream of the bridge (on the true right) a shelved grassy bank had been planted in flaxes that offered good microhabitat for inanga spawning (Fig. 34). Somewhat further downstream this bank steepened, but habitat loss was compensated for by a thick root hair mat (of tall fescue) which overhung the water (Fig. 35).

2.22 Kakaho Stream

The extent of survey is depicted in Fig. 32. It was clear at the time of our visit, that there was no possibility of inanga spawning habitat in this system. Upstream of the bridge, the riparian margin had been either mechanically graded (Fig. 36), or had been damaged by stock, with the riparian vegetation intensively grazed (Fig. 37). The shallow, silted streambed was covered in places by filamentous algae, but no macrophytes (i.e. large vascular aquatic plants) were present. The snail *Potamopyrgus*, and some caddis fly larvae were observed on the stream gravels. The uniform hydraulic nature of the lower stream reaches also appeared unsuitable for inanga, which prefer somewhat deeper, and slower water.

Figure 34: The true right bank of the Horokiwi Stream, downstream of the road bridge. This area, recently planted in flax, was regarded suitable for inanga spawning.

Figure 35: Horokiwi Stream. The steep left bank of tall fescue grass obscures a thick mat of roothairs overhanging the water. This microhabitat is often utilised by spawning inanga.

Figure 36: Kakaho Stream, looking upstream from Pauatahanui Road bridge. The banks have been mechanically graded and stripped of vegetation.

Figure 37: Kakaho Stream upstream from the bridge.

The short length of waterway downstream of the bridge was being replanted in saltmarsh plants, but this vegetation (in our experience) is not associated with inanga spawning, and was unsuitably sparse (Fig. 38).

Figure 38: The Kakaho Estuary, looking downstream from Pauatahanui Road, showing the partially completed saltmarsh planting programme.

2.23 Taupo Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 39. Owing to constraints on vehicle parking, the waterway was foot-surveyed in a upstream to downstream direction.

The most upstream reaches of Taupo Stream surveyed, within the Plimmerton Domain were badly weed-choked and the banks were too closely mown to support inanga spawning (Fig. 40). However downstream of the Domain boundary, the stream deepened and cleared, but importantly for inanga spawning, the riparian grass was maintained at a greater height (Fig. 41). The short (100m) reach downstream of the Domain was considered to be the best area for inanga spawning. Downstream of this area, the stream became enclosed and shaded by native shrubs and trees, and the growth of soft foliage vegetation suitable for inanga spawning was inhibited by lack of light (Fig. 42). However this environment would provide good rearing habitat for inanga.

Figure 39: **Extent of survey (blue) and potential spawning area (red) on Taupo Stream.**

Figure 40: Taupo Stream at the Plimmerton Domain. The channel is partially dewatered, and the banks mown.

Figure 41: Suitable inanga spawning habitat on Taupo Stream, downstream of the Plimmerton Domain. The right bank (true left) appeared to be the most suitable.

Figure 42: The dark, shaded conditions of the lower reaches of Taupo Stream. While this area would be good for inanga rearing, the paucity of soft vegetation makes it unsuitable for spawning.

2.24 Whareroa Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 43. The lower Whareroa Stream follows a convoluted course in its lower reaches, flowing through the Queen Elizabeth Park which comprises regenerating native vegetation, willow trees, and pastoral land. Incidentally, there appears to be a major problem with outbreaks of old man's beard, blackberry, and *Convolvulus* sp. which, in some areas, is inhibiting the growth of the regenerating native vegetation.

The survey coincided with a high and rising tide, therefore conductivity readings (Fig. 43) were taken to determine the general area most likely to be utilised for inanga spawning. The limit of saltwater intrusion was approximately 700 m upstream from the sea, and coincided approximately with location of a footbridge. Two schools of large inanga were seen near the end of the saltwater wedge. The vegetation here, again, was mainly rank tall fescue growing over shelved, stable, and ungrazed banks (Figs. 44, 45). While the underlying soil had a fairly high component of sand (est. 50%, and making the topsoil rather porous), we believe there is still some scope for spawning to take place.

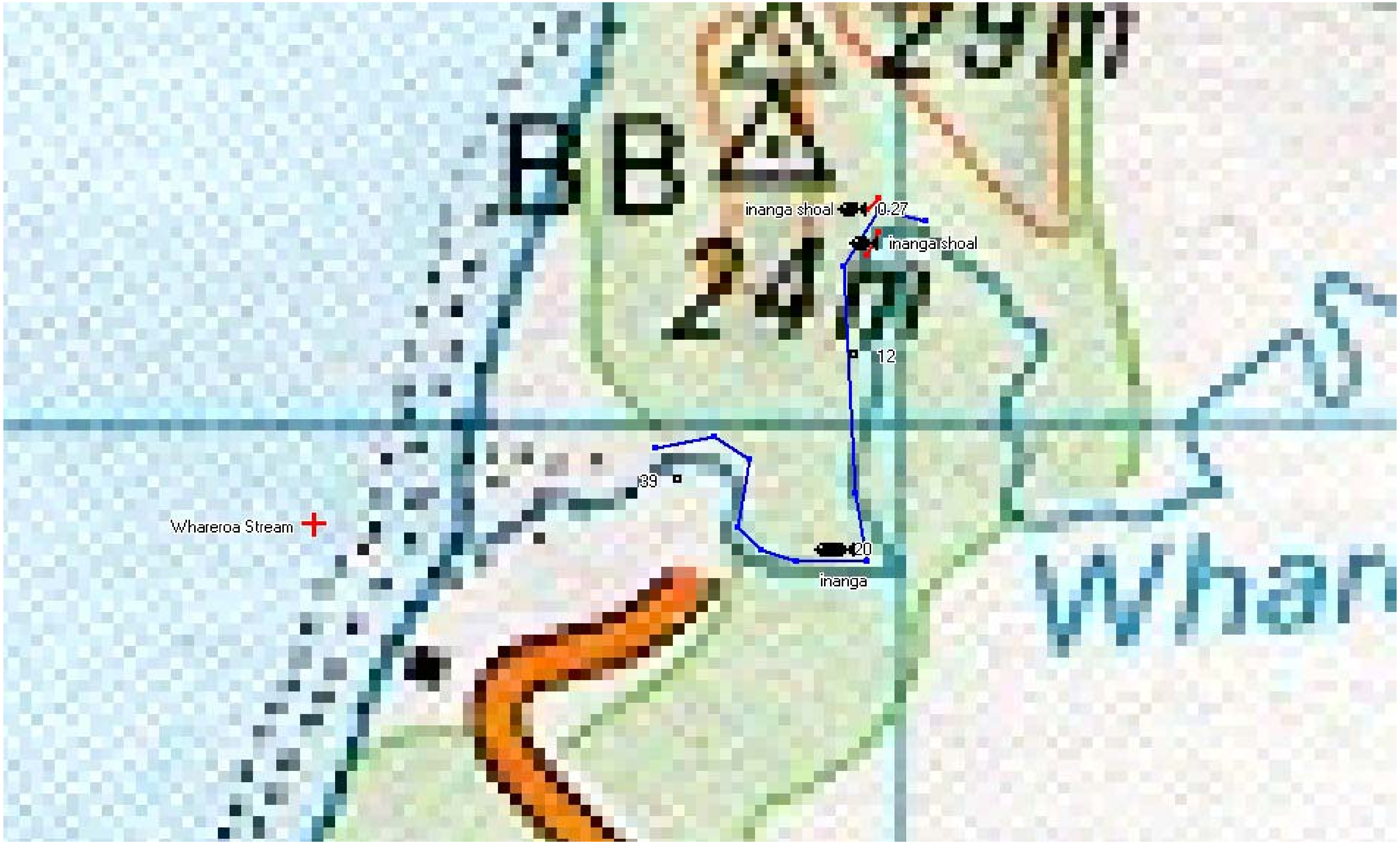

Figure 43: **Extent of survey (blue) and potential spawning area (red) on Whareroa Stream. Figures are water conductivity (mS/cm) measurements on the high and incoming tide. The fish symbol indicates the location of inanga shoal**

Figure 44: **Suitable spawning vegetation on the Whareroa Stream, near the end of the saltwater wedge.**

Figure 45: **Good spawning habitat near the terminus of Whareroa Stream.**

Figure 46. Extent of surveys (blue) and potential spawning areas (red) on Waimeha Stream, and Waikanae River

2.25 Waikanae River

The extent of survey, and potential spawning grounds are depicted in Fig. 46. As typically found on larger rivers, suitable spawning areas on the Waikanae River were patchy in distribution. A number of small suitable areas were located within and downstream of the Otaihanga Reserve, but predominantly on the true left (south) bank (Fig. 47). While the bank was steep in some places, with some bank stabilisation by willow trees, the north-facing bank aspect meant that underlying grasses were not shaded by tall vegetation in most areas, and therefore grass growth was sufficiently luxuriant to support spawning. These grasses were predominated by tall fescue and creeping bent. At the downstream limit of the Reserve, overgrowths of blackberry and old man's beard on the true left bank may be also reducing potential inanga spawning habitat. At the downstream limit of the reserve on the south bank, the grassy bank slope was more gentle, and thus offering a potentially greater surface area for spawning.

Figure 47: The mainstem of the Waikanae River looking downstream from the Otuhaima Reserve footbridge. The best spawning habitat was on the left bank in between the flaxes and toetoe.

In contrast, the true right bank was heavily shaded by tall pine trees, with an underlying gravel bank with an unsuitably thin layer of soil and tall fescue. Soil moisture retention of this bank would be low in these areas, and utilisation by inanga for spawning would not be expected.

The litter-layer invertebrate fauna in the reserve attested to an entirely freshwater habitat. This included amphipods, isopods (woodlouse), the freshwater snail *Potamopyrgus antipodarum*, and millipedes.

2.26 Waimeha Stream

The extent of survey, and potential spawning grounds are depicted in Fig. 46. The Waimeha Stream drains the coastal wetlands and oxidation ponds north of the Waikanae River, and is one of the few areas in the study area where inanga spawning grounds has been reliably reported in recent history (McDowall 1968).

High tide conductivity readings indicated that the stream ran fresh at the time of the survey. The most suitable bank was the true left (south) bank, which, although mown, had uncut grass of sufficient length to support inanga egg development (Fig. 48). In contrast, the true right bank had a sandy soil type, and therefore unlikely to retain sufficient litter-layer humidity.

The discharge from the Ngarara Stream tributary was noticeably turbid at the time of the survey, and an invasive aquatic weed (parrots feather) completely blocked the channel (Fig. 49), at one point downstream of its confluence.

2.27 Mangaone Stream

The extent of survey, and suitable spawning areas are depicted in Fig. 50. Mangaone Stream drains a small, pastoralised catchment south of the Otaki River. At the time of the survey, the tidal reach was choked with driftwood – probably driven in from the sea on a high tide - and this formed a floating mat across the water surface. Bordering, and upstream of the sea drift, the open water surface was markedly reduced to a small channel by a floating and thick mat of reed sweetgrass. (Fig. 51).

Figure 48. Waimeha Stream looking upstream from the road bridge. The grass on the right bank, though mown, is of sufficient length and thickness to offer suitable spawning habitat.

Figure 49: Overgrowth of parrots feather in Waimeha Stream.

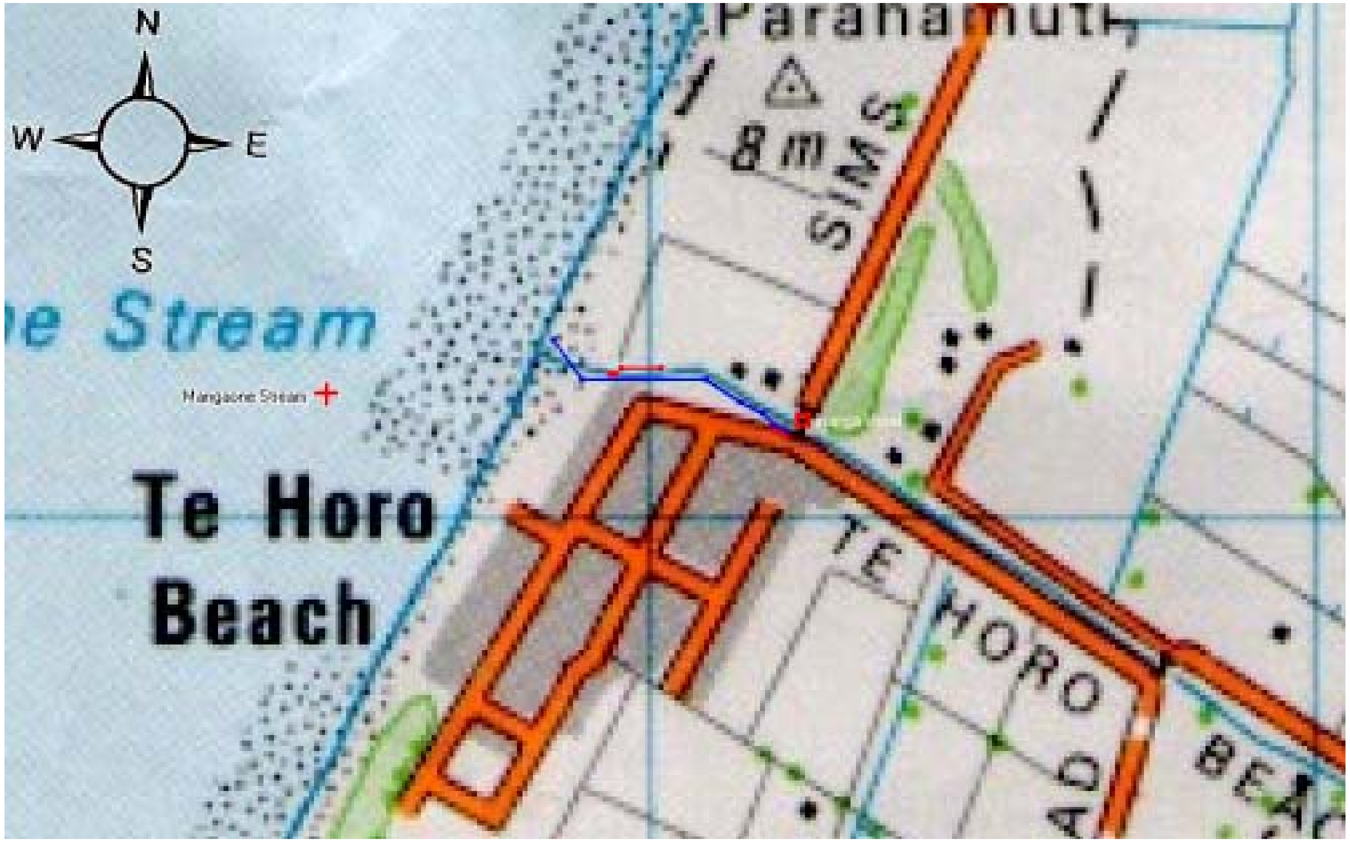

Figure 50: **Extent of survey (blue) and potential spawning area (red) on Mangaone Stream. A shoal of inanga were seen amongst the vegetation on the true left bank**

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Figure 51: A grass-infested raupo stand which provides good spawning habitat on the lower reaches of the Mangaone River (far bank). Floating beds of reed sweet grass blocked the lower channel on this waterway.

The tide was high during the time of the survey, and the stream ran down the beach to the sea as a shallow run. Not surprisingly under these conditions, conductivity was low indicating almost entirely fresh water. However, some excellent spawning habitat was found amongst a stand of creeping bent grass on the true right bank, and just upstream of this point, an area of raupo also appeared suitable (Fig. 51). An outbreak of *Convolvulus* was smothering the raupo in some places. The true left bank offered little potential, owing to its steep profile, lack of soil structure, and therefore lack of moisture retention. Despite this, a shoal of inanga were seen amongst the grass near the bridge on this bank, around the base of toetoe.

2.28 Otaki River

The extent of survey, and suitable spawning areas are depicted in Fig. 52. The lower reaches of the Otaki River mainstem are somewhat braided, with the watercourse flowing over a broad gravel floodplain. While the mainstem, lacking riparian vegetation, would be unsuitable for inanga spawning, there are 2 spring-fed tributaries in the lower reaches which offer the good habitat for inanga spawning. Both of these systems drain pastoral land, and probably as a consequence of this, incorporate floodgates.

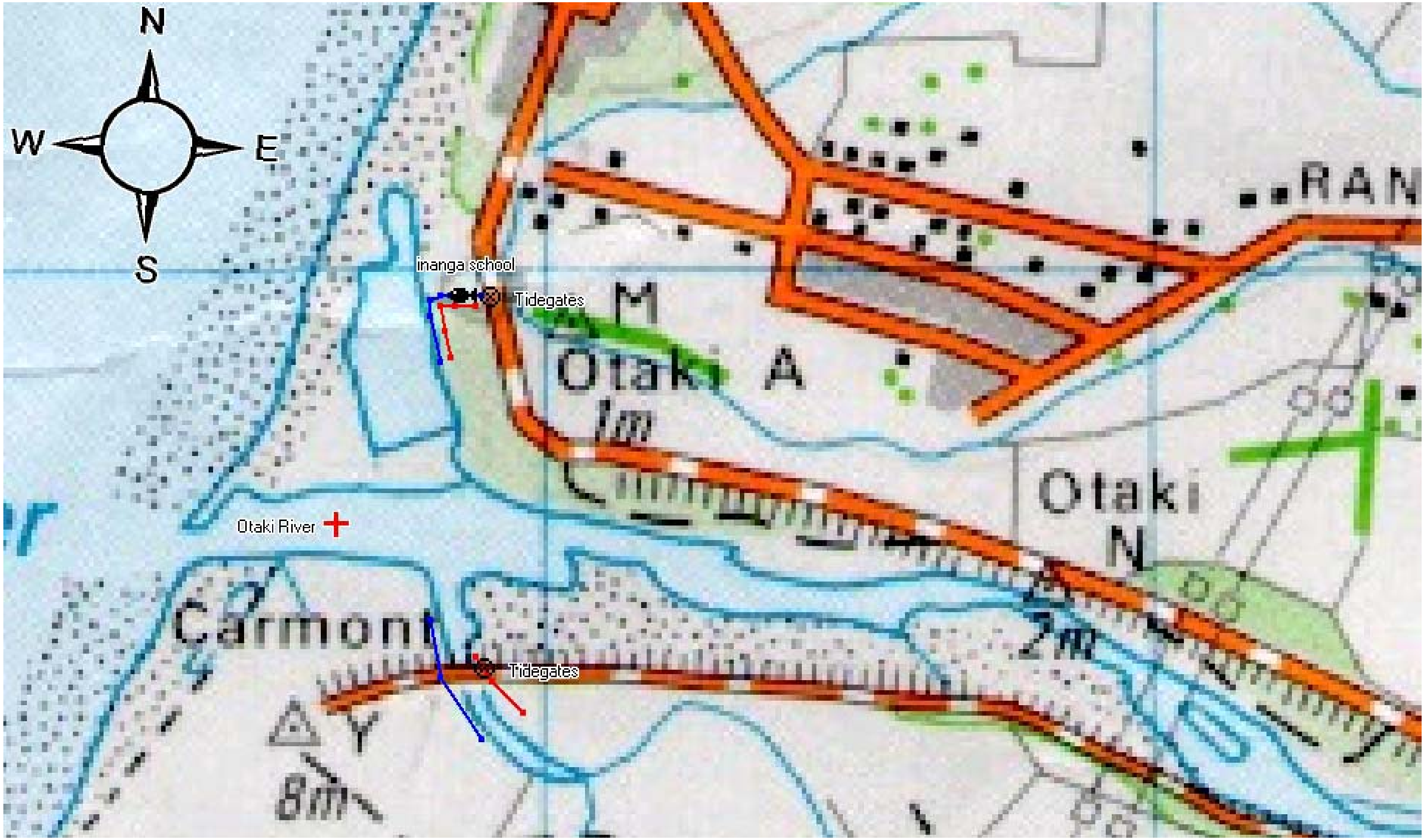

Figure 52: **Extent of survey (blue) and potential spawning area (red) on the Otaki River.**

Downstream of the flap-valve tidegates on the north-side tributary (Nga Toko Toko), the system opens out into a broad lagoon, with an extensive area of raupo, flax, and grasses (Figs. 53, 54). It is this raupo and grass plain which offers good habitat for inanga spawning. The normal tidal range in the area was approximately 1m, sufficient to inundate the margins of this area, and the area was quite moist underfoot. While some *Convolvulus* was present here, it appeared to have been sprayed. This area would be available to inanga resident in the lagoon - a shoal of inanga were seen below the tidegates - and upstream-resident inanga that could negotiate the tidegates before they close.

The south-side tributary has been pastoralised with some native vegetation comprising flaxes and cabbage trees. However the riparian zone is dominated by tall fescue downstream of the tidegates with a component of creeping jenny upstream. Both of these grasses are suitable for spawning, but the best habitat (in terms of area, thickness and composition) was found upstream of the tidegates (Fig. 55). The upstream watercourse has formed a second blind-ended branch which also offered good spawning potential. However, despite its suitability, it is unknown to what extent the upstream area would be utilised when the tidegates are shut on the spring tides. There was also suitable habitat, of a slightly lower standard, on the downstream side of the tidegates (Fig. 56).

2.29 Waitohu Stream

The extent of survey is depicted in Fig. 57. the Waitohu Stream meanders through remnant coastal dunelakes before discharging into the sea approximately 5 km north of the Otaki River. The lower reaches are largely pastoralised, with some residential development from the Otaki Beach township.

Conductivity readings were taken on the high an rising tide, and the thickness of the saltwater wedge monitored along the water course. Despite several shoals of inanga being observed in the river and the apparent lushness of the riparian grass (Fig. 58) the underlying soil structure (100% sand) was unsuitably sandy for inanga spawning (Fig. 59).

3 DISCUSSION

3.1 Overview of inanga spawning potential in the study area

The waterways studied during this survey could be classified into 3 categories depending on their potential and current value for inanga spawning habitat (Table 2).

Figure 53: Looking downstream at raupo beds in the lagoon area of the Nga Toko Toki river (Otaki River Catchment).

Figure 54: This raupo bed provides good spawning habitat on the lower reaches of the Nga Toko tributary of the Otaki River.

Figure 55: Looking upstream of the tidegates on the tributary on the south bank of the Otaki River. The vegetation here was highly suitable for inanga.

Figure 56: Spawning habitat in an unnamed tributary of the Otaki River (on the south bank), looking downstream of the tidegates.

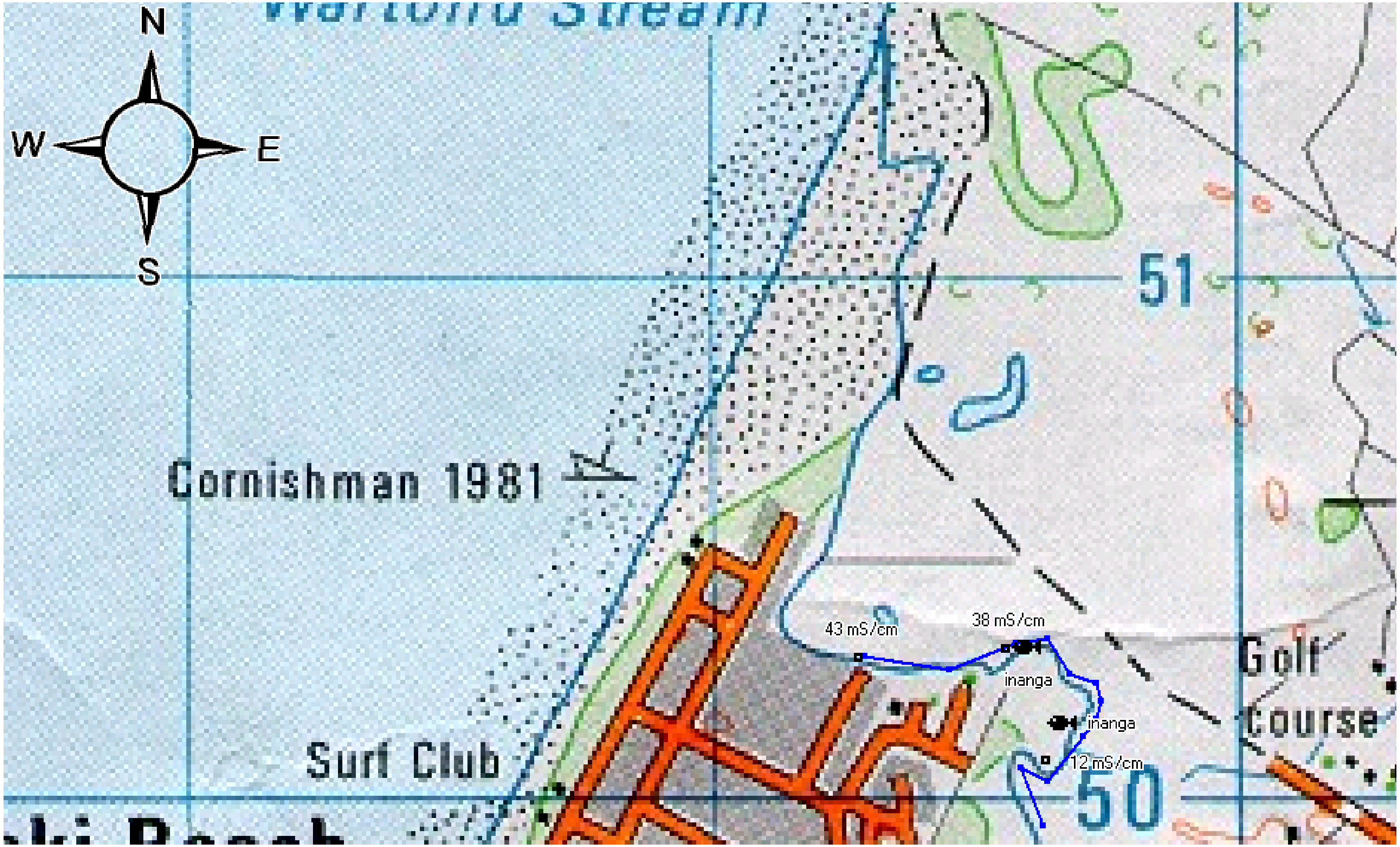

Figure 57: **Extent of survey (blue), location of inanga shoals, and some conductivity records obtained from the Waitohu Stream**

Figure 58: Riparian grassy vegetation on Waitohu Stream. Surprisingly, the vegetative cover at ground level was sparse.

Figure 59: The sandy soil and thin covering of tall fescue grass and herbs in the lower Waitohu stream. This vegetation was regarded as unsuitably sparse for inanga spawning.

Table 2: Subjective rankings of actual and potential value of inanga spawning habitats in 21 catchments in the greater Wellington area.

Catchment	Potential value (0-6 high)	Present value (0-6 high)	Difference (0-6 high)
Kakaho Stream	4	1	3
Porirua Stream	4	2	2
Duck Creek	4	2	2
Waimeha Stream	4	2	2
Mangaone Stream	4	2	2
Hutt River	3	1	2
Horokiwi Stream	3	1	2
Wainuiomata River	6	5	1
Makara Stream	5	4	1
Otaki River	5	4	1
Pauatahanui Stream	4	3	1
Waikanae River	3	2	1
Korokoro Stream	2	1	1
Taupo Stream	4	4	0
Whareroa Stream	3	3	0
Owhiro Bay Stream	1	1	0
Waitohu Stream	1	1	0
Karori Stream	0	0	0
Orongorongo River	0	0	0
Lowry Bay Stream	0	0	0
Kaiwharawhara Stream	0	0	0

3.2 Kakaho Stream

This ranking exercise isolates the Kakaho Stream catchment as possessing the best (and realistic) potential for habitat restoration. However, this is as equally due to the severely degraded nature of the riparian habitat, as to its potential. Upstream of the bridge, the potential for spawning had been considerably reduced by both unrestricted stock-grazing practices along the waterway, and some mechanised attempt at watercourse alignment (Figs. 36 & 37). Its potential for inanga was regarded as high firstly because of the significant amount of suitable rearing habitat for adult inanga which extended for 2km inland from Porirua Harbour. Secondly, apart from the fact that the banks were grazed to a stubble, the bank slope for inanga spawning in the tidally-influenced fresh water zone was ideal. It is possible that spawning habitat is better upstream beyond the area surveyed, but this area is too far upstream, as it would be beyond the tidal influence. To restore values in this catchment it is to necessary to prevent unrestricted stock access to the lower reaches of the waterway. Ideally, water troughs should be used, and stock excluded from the waterway's entire length, but failing that, stock should have access only to specific drinking areas.

3.3 Porirua Stream

A number of other catchments also exhibit good potential, which include Porirua Stream. The potential of the Porirua Stream lies less in the value of the mainstem, and more in the Kenepuru Stream tributary. This small tributary does not seem to suffer from the same flow management conflicts as the Porirua Stream mainstem, and would appear to be a good area for some spawning habitat restoration. Some bank regrading would be recommended to reduce the slope of the true right bank between the weir and the railway bridge, and, if the weir serves no present function, we would recommend its removal. This area already contains areas of toetoe and raupo contained in a small wetland, and this would integrate well with the habitat restoration, particularly if it was linked with the stream. Such habitats serve as both rearing habitats for inanga and other fish species, and serves to buffer high flows.

The length of the Porirua Stream where large numbers of inanga were congregating had little potential for inanga spawning. The main river was constrained within low concrete walls, with a near absence of tidally-inundated vegetation. Presumably, a priority issue in this waterway is protection of Porirua City from high flood levels, but unfortunately this does little to enhance ecological values, including inanga spawning habitat. Management options could be revisited should flow management priorities change.

3.4 Duck Creek

Like Kakaho Stream, Duck Creek also flows into Porirua Harbour, but unlike the former system, Duck Creek does not suffer from stock access problems. Upstream of the saltmarsh, the system provides some good spawning habitat, which abruptly ceases at the boundary of the Whitby Golf Course. The short grass, presumably to facilitate golf ball retrieval, is too short for inanga spawning. However, while the catchment is low-lying and generally suitable for inanga rearing, it is also small, and therefore the inanga population may also be low. It is possible, but unlikely, that their spawning requirements may already be met by the limited amount of suitable habitat downstream of the golf course.

3.5 Waimeha River and Mangaone Stream

The area around the Waimeha River bridge has been known to be a reliable inanga spawning site in the 1960's, and in fact featured in an early film about whitebait (R.

M. McDowall, pers. comm.). Eggs were identified from this location in June (McDowall 1968), much later than the known spawning season in other parts of the country, and even the other known location in Wellington (Hutt River). However, based on the proportions of maturing fish, the spawning season in the adjacent Waikanae River ran from March to May in 1964 (McDowall 1968). The mechanism that triggers spawning amongst ripe fish has not been determined, but stream temperature, and thus current climatic conditions may play an important part. Spawning vegetation in the previous study was described as tall fescue grass, cocksfoot, and clover, little different from what is present today, although the catchment has undergone residential development since then.

This development has led to oxidation pond discharge entering a major tributary (Ngarara Stream) of the Waimeha River, which enters the area just upstream of the bridge spawning site, and the invasion of the exotic macrophyte ‘parrots feather’ (P. Champion, NIWA, pers. comm.) into the main channel. In this instance, the foliage bridged the channel entirely (Fig. 49). This species is one of the National Surveillance Plant Pests, and we encountered this plant in other locations along the Kapiti Coast. It is unknown what effect this macrophyte has on inanga spawning or fish migrations, but it could well be detrimental. This plant was considered to “cause serious fish and wildlife habitat problems in ponds, streams, and other waterways by blocking out sunlight, altering water temperatures, slowing water flows, and reducing oxygen concentrations in the water” based on a environmental report on the San Joaquin River catchment in California, U.S.A. It is conceivable that thick bank-to-bank growths could inhibit spawning inanga from reaching the riparian margins, but we have no supporting evidence that that would occur.

Reed sweetgrass, on the other hand, is a species potentially more damaging to inanga spawning than ‘parrots feather’. It was recorded from a number of areas otherwise suitable for spawning on this survey, and had almost clogged the lower reaches of Mangaone Stream. In addition to its cyanogenic properties (Coffey & Clayton 1988), its growth form does not form a microhabitat for inanga eggs. In recent years it is becoming more frequently encountered in inanga spawning habitats in the South Island (Taylor 2001, in press), where it has displaced tall fescue grass from the riparian zone of otherwise suitable inanga spawning grounds.

3.6 Hutt River

The Hutt River mainstem margins are heavily stone-clad along most of the reach in the vicinity of the known spawning areas, rendering them entirely unsuitable for inanga spawning, and DoC implied that little (but presumably some) spawning was recorded in unclad areas (NIWA correspondence). Unfortunately, this correspondence did not specify the location of the small mainstem spawning site, and the low tide did not allow us to initiate a search on this major river. There is some unrealised potential for inanga spawning in its lower tributaries, particularly the Opahu Stream (which drains Lower Hutt), and possibly Waiwhetu Stream near Gracefield.

It was clear from 1996 correspondence with Department of Conservation (DoC) that there were management problems with this site (NIWA correspondence). Specifically, DoC was concerned about the potential impacts caused by fuel pollution from boats using the ramp, and from boat wakes on the surrounding banks, causing slumping. The Hutt City Council has apparently been notified (by DoC) about the ecological sensitivity of this site.

Stone-cladding appears to being used for stabilising the steep banks along the lower reaches of the Opahu stream, but inanga will not use this desiccation-prone surface for egg deposition. By means of an alternative, crushed gravel has been used successfully on steep banks on the Avon River in Christchurch, when reinforced with ‘Enkamat®’ synthetic mesh. The smaller particle size allows grasses (especially creeping bent) to grow through the gravel, quickly covering the gravel surface with foliage. After several years, a fine layer of root hairs forms across the gravel and mesh, which forms an excellent micro-habitat for inanga spawning. This alternative along the lower reach of Opahu Stream would provide not only a more natural riparian appearance, but enhance the bankside ecology, including inanga spawning.

Functional tidegates have been demonstrated to inhibit inanga spawning upstream, but allow upstream spawning to occur when they are wedged open (DoC correspondence). Unfortunately, there have not been any effective trials (or solutions) to allow upstream protection of lowlands from elevated water-levels, and yet allow inanga to spawn.

We understand that industrial pollution has been a problem in Waiwhetu Stream in the past (WRC, pers. comm.) , but inanga appear to possess a degree of resilience from pollution, and this river, with its grassed riparian margins, may be a possible inanga spawning site worth investigating in the future. The Sladden Park habitat, where a few eggs were found in 1996 by DoC, appears to have deteriorated further from the problems recorded during the DoC survey, particularly bank collapse. While DoC has corresponded with the Hutt City Council in the past in respect to the ecological sensitivities of the area, there has been no response from the Council (NIWA correspondence).

Like the Waimeha Stream and the Hutt River, the Horokiwi has had a reputation as providing a reasonable whitebait run. That may still be the case, but spawning is unlikely to be extensive, particularly upstream of the road bridge. As with the neighbouring Kakaho catchment, the lack of stock control has damaged and denuded the riparian vegetation of these areas.

3.7 Wainuiomata, Makara, and Otaki Rivers

The Wainuiomata, Makara, and Otaki Rivers are similar in that they still have extensive areas suitable for inanga spawning, and it is no coincidence that stock grazing along the waters-edge is either non-existent or of a light intensity. Accordingly, little management is required on these systems, other than to ensure the *status quo* is maintained. The Otaki River spawning grounds are not on the gravel mainstem, but rather on spring-fed feeders entering from either side, and may be vulnerable to shifts in the river mouth. At the time of the survey, arable land was being eroded from the south bank, and a mechanised attempt was being made to direct the main river discharge further north. Care needs to be taken to ensure that a large area of raupo in the Nga Toko Toko lagoon on the south bank is not endangered by gravel wash or increased saline influence. Raupo does not tolerate significant salt levels around its roots.

The Wainuiomata and Makara Rivers are more sluggish, un-braided rivers, which offer inanga spawning and rearing habitat in their relatively confined mainstems rather than the tributaries. In both of these rivers, but particularly the Makara, stock control and bank planting are evident.

3.8 Pauatahanui Stream, Waikanae River

Pauatahanui Stream included suitable habitat for inanga spawning, and prudent sediment control around a major bridge construction site minimised sediment input and bank damage in the vicinity. This precaution proved to be worthwhile, because suitable spawning areas were found very close to the construction area.

Inanga spawning in the Waikanae River was considered to have taken place in March, April, and May in 1964, with eggs found only in June near the Otaihanga Reserve (McDowall 1968). At least in 1964, a low weir just downstream of the main road bridge truncated the upstream range of inanga in the Waikanae River (McDowall 1968). However, there is sufficient habitat downstream of the weir to support a reasonable inanga population. This is in stark contrast to the situation in Owhiro Bay stream where instream obstructions close to the sea deny migratory freshwater fish to a good deal of otherwise good aquatic habitat.

After 37 years, there are still riparian elements along the mainstem of the Waikanae River that support inanga spawning, albeit somewhat patchy. The option of using riparian vegetation (toetoe, flax etc.) to support the banks is likely to be of more ecological benefit, than the concrete walls as seen on the Porirua Stream. The grasses utilised by spawning inanga grow amongst the taller vegetation, which offers the softer vegetation both protection from the water current, and the overzealous use of grass mowing machinery.

3.9 Korokoro Stream

Even the heavily developed Korokoro Stream catchment offered isolated areas where the banks could not be mowed or clad. The small patch of located spawning habitat is probably sufficient to cater for the inanga population in this system. The lack of mechanised access to this land parcel has facilitated the luxuriant re-growth of native shrubs and tall grasses that are preferred by spawning inanga. Sunlit sites of this nature with no pedestrian traffic or stock grazing pressure can also undergo a gradual community succession, with unsuitable tall woody plants displacing the more suitable grasses. Fortuitously, tree growth at this location may be already being controlled because of the hazard that tall vegetation would represent to the railway line and major roads nearby. The industrialised nature of the immediate riparian zone will lead to some pollution impacts, and notably, at the time of the survey, a small flow of turbid industrial discharge was observed entering the stream. Oil has been implicated in inhibiting spawning at other locations (National Inanga Spawning Database).

The 0.6m high weir may truncate the natural range of inanga in the catchment, although probably by not much, as most of the suitable rearing habitat, and spawning habitat, is below this obstruction. However, it is important to note that the weir, with a vertical waterfall of 0.6m also represents a significant instream obstruction for migratory bullies (common bullies). Non-migrating bullies (upland and/or Crans bully) and resident trout would be unaffected by this weir, and migrating eels could negotiate it without difficulty.

3.10 Taupo and Whareroa Streams

The Taupo and Whareroa Streams have some natural properties in common which rank them highly as inanga habitats. Slow, deep, sluggishly-flowing water in the lower reaches, and adequate spawning vegetation, and a lack of obvious instream obstructions. However, the soil structure along the riparian margins of Whareroa Stream was rather sandy, which may limit is potential for spawning inanga. The Taupo catchment, although rather more industrialised in the lower reaches, had swampy habitat further upstream, and better soil structure to support egg survival.

3.11 Orongorongo River, and the Karori, Kaiwharawhara, Lowry Bay, Waitohu, Owhiro Bay Streams

These 6 catchments ranked low in terms of both actual and potential values for inanga spawning. Four of these waterways, the Orongorongo River, and the Karori, Kaiwharawhara, and Lowry Bay Streams were unsuitable for both inanga rearing or spawning. The lower reaches of the Orongorongo and Karori are shallow, and braided, with little riparian vegetation. Vegetation is also lacking on the artificially channelised Kaiwharawhara stream near Wellington, although some inanga may shoal there. Lowry Bay Stream has fish values for other whitebait species, especially banded kokopu, and Waitohu Stream, although providing good rearing habitat, possesses a riparian 'soil' that is almost all sand, and unsuitably porous for spawning. Owhiro Bay Stream represents a system which, aside from recent pollution issues, has been compromised from a fish values perspective by the placement of instream obstructions close to the sea. This includes a concrete ford across the stream bed (and on public land), even though there appears to have been adequate room for a bridge and its approaches. While such instream obstructions remain, there is little point in considering the stream for whitebait spawning habitat, as the resident inanga population would be small to non-existent.

3.12 Management issues

There are a number of management issues specific to the region, whereas others are wider in scope. Of major concern is the extent that aquatic and terrestrial weeds are modifying the floral composition around the stream margins. In recent years, it has become clear to the writers that sweet reed grass is becoming a national threat to inanga spawning grounds, and appears to be pre-adapted to wet riparian habitats that serve as inanga spawning habitats. Reed sweetgrass invaded the inanga spawning grounds on the Kaituna River in the Bay of Plenty, to the point inanga did not use it, but spawned on the outside margins of a fenced area, where the surrounding land had been used for maize cropping (Mitchell 1993). We have not encountered the aquatic milfoil 'parrots feather' in the South Island, but this aggressive adventive plant could also become a problem with much wider implications for stream ecology, which could include inhibiting fish passage and movement. Willow, particularly the aggressive crack willow, has been a problem in other areas of New Zealand, by preventing luxuriant grass growth by shading spawning grasses. However, we did not find that willow was a major problem at sites surveyed in this study, possibly because of the small, steep nature of most of the waterways, and the fortuitous orientation of the river banks in relation to the sun which means sometimes banks were not heavily shaded.

A number of surveyed waterways incorporated instream obstructions, and, depending on their placement in respect to habitat, may be influential on inanga spawning success. Firstly, because inanga are poor negotiators of instream obstructions, weirs can limit the area of rearing and spawning habitat to the area downstream of the structure. If such a structure is close to the sea, then clearly much of an entire catchment is excluded from colonisation, not just for inanga, but for other sea-migratory fishes. The weir and ford in Owhiro Bay Stream, are a good example of this, and the weir on Korokoro Stream though the impact of this structure is likely to be less because it is further upstream. Two low weirs were observed in the Porirua catchment, and there was a weir across the Waikanae River near the main road bridge which truncated the distribution of inanga in that system (McDowall 1968).

Tide and/or floodgates are considered to inhibit inanga spawning upstream of their location, not so much by physically blocking fish passage (though this is likely to happen), but by confusing the physiological cues that inanga use to co-ordinate their spawning behaviour. In systems without tidegates, shoals of inanga migrate downstream on the high spring tide until they detect the upstream limit of the saltwater wedge. This may be a mechanism to ensure that larvae are close to the sea (in which they develop) when the hatch from the eggs. Once the inanga detect salt water, they will start evaluating riparian vegetation for spawning habitat suitability, and will swim a considerable distance upstream or downstream until they find it. On the other hand, if they migrate downstream on the spring tide and never encounter salt water because the tidegates are closed, they become disorientated and don't appear to spawn. Field trials on the Buller River in Westland, showed that inanga spawning on successive spring tides would either take place or not depending on whether the intermittently operational flap-valve tidegate was working. After consultation with DoC, the Buller District Council removed the structure. However, often the risk of flooding neighbouring land precludes this option, and other solutions have yet to be fully evaluated.

Tidegates, however, are less likely to completely stop the upstream migration of fish as do weirs, including whitebait, because migrants will congregate below the closed gates until they open on the ebbing tide. However, during the time they are congregating they can be subject to predation by trout, eels, and birds, and possibly excessive whitebaiting pressure.

The overgrazing and trampling of stream margins by stock is a nation-wide problem, and one that recently has gained a higher public profile in respect to the decline in brown trout numbers. But native fish too, are vulnerable to riparian habitat destruction in a number of ways, including as detailed here, for inanga spawning. Riparian fencing allows spawning grounds to redevelop surprisingly quickly, depending on the extent of original damage, and moisture levels, with spawning being reported from fenced areas after only 1 year of grass growth. While the improvement in egg numbers can be dramatic, so too can the abandonment of the site if woody or otherwise unsuitable adventive plants (e.g. reed sweetgrass) are not monitored and controlled. The plant community succession has been more of a problem in the North Island, rather than the

South Island. This may be because of the cooler temperatures (particularly in winter) in the South Island, and the time delay in the dispersal of noxious plants from the North Island. Fortunately trials allowing access by grazing stock to fenced spawning grounds in the spring and summer (when inanga are not usually spawning) appeared to alleviate the woody-plant succession problem.

There are many New Zealand case histories available on the enhancement of inanga spawning grounds by excluding stock. These include many rivers in Otago (e.g. Waiareka Creek, Shag River, Waikouaiti River, Waitati, Orokonui Stream, Ravenscroft 1999). Of note in the North Island is in the Hawke Bay area, with fencing on the Clive, Ngaruroro, Tukituki, Esk, and Tutaekuri Rivers (NIWA correspondence, H. Rook 1997). Likewise, in the Bay of Plenty, with the fencing (and problems outlined above) on the Kaituna River, and the experimental trials conducted on the Rangitaiki River (Mitchell 1993).

Of course, stock are not a problem in urban environments, but pedestrian traffic, inappropriate cladding, and over-steepening of banks is common. However, this too, is reversible, and spawning can be re-established and/or enhanced even after bank regrading and resowing (Fig. 60). However bank vegetation, and consequently inanga spawning can take several years to establish. In the case of the Heathcote River site, an existing spawning site was regraded, and resown in the summer of 1995, and spawning took place in April 1998 (Taylor 1998). Since then the original spawning ground has been extended downstream, and a number of woody adventives have been removed. To date, reed sweetgrass or other problem plants have not appeared.

Figure 60: The establishment of native rushes and exotic grasses at the Heathcote River spawning site in Christchurch.

Generally, the study rivers were characterised as draining dissected, hilly terrain, and often with concentrated and disjointed regions of residential and/or urban development. The geographically disjointed nature of population centres, and the differing time-scales upon which they have developed, has probably led to localised problems with resource management and waste disposal. Subsequently, this has led to compromises in the ecological health of some of the waterways. While the direct effects of many pollutants on inanga spawning have not been researched, oil pollution has been demonstrated to inhibit inanga spawning at one South Island spawning site (DoC correspondence). It is likely that a range of other contaminants will also have a similar effect. Spawning inanga avoid silted substrates, and sedimentation after eggs are deposited tends to coat the eggs (pers. obs.). In this context, it was pleasing to see the considerable effort contractors were taking and controlling erosion around the bridge construction site on the Pauatahanui Stream. This is particularly so as the construction site has so much suitable habitat in the vicinity.

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