DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Tasmania

Index of River Condition for the North Esk River Catchment

David Horner
Aquatic Ecologist
Water Assessment and Planning Branch
DPIWE.

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Natural Heritage Trust

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The Department of Primary Industries, Water and Environment

The Department of Primary Industries, Water and Environment provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.

The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

Executive Summary

This report provides a 'snapshot' picture of river condition, in relation to riparian condition, physical in-stream habitat and in-stream structures within the North Esk River catchment. The approach adopted for this study is a derivation of the original Index of River Condition (IRC) method utilised in previous 'State of River' reports by the Department of Primary Industries, Water and Environment (eg: Bobbi *et al*., 1999), and contains sub-indices taken from the Victorian Index of River Condition and adapted to Tasmanian conditions (CEAH, 1997a).

Field data collection of IRC parameters occurred at 44 representative sites within the North Esk River catchment. Thirteen of these were located on the main-stream North Esk River and 31 on tributary streams. Thirty-seven in-stream structures were assessed separately at relevant locations.

- On average the physical form sub-index rated as being in near natural condition for both the mainstream and tributaries. However lower values were recorded for sites within agricultural and/or urban areas. This was primarily due to poor rating scores for the parameters of Coarse Woody Debris (CWD) and Overall Stream Disturbance (OSD).

- On average the stream-side zone sub-index rated as in moderate condition for the main stream and the tributaries. Ratings for this sub-index were lower in agricultural and urban areas due to the presence of riparian weed species (primarily willows (*Salix fragilis*) and gorse (*Ulex europaeus*), poorly vegetated or denuded riparian zones, and uncontrolled stock access to river banks.

- Hydrological connectivity was found to be partially modified as a result of the presence of seventeen artificial structures that reduce the potential for fish passage to some degree. On average farm dams resulted in an extensive modification of condition, weirs and culverts a moderate modification and bridges a partial modification of condition. Eighty four percent of the North Esk catchment is affected to a moderate degree by the weir at Clarks Ford Bridge. A further eighty seven percent of the St Patricks catchment is affected by the weir at Nunamara which rated as having a moderate effect on connectivity.

It is evident that riparian (stream-side) zone rehabilitation and management is a significant issue for agricultural and urban areas of the North Esk catchment. Within urban areas it was found that the riparian zone was highly altered and that native species were in low proportions. Reaches in agricultural areas of the catchment, specifically those on the St Patricks River near Pecks Hill Road and the North Esk River along Blessington Road, were found to be in poor condition. This was evident by infestation by weed species, poor native plant cover and unrestricted stock access. Areas with poor riparian condition should be the focus of future catchment management activities to avoid further degradation, in addition to continued protection of areas that are of high conservation value or undisturbed.

Glossary of Terms

Anadromous	Fish that hatch in fresh water, then migrate to salt water to grow and mature, and inturn migrate back into fresh water to spawn and reproduce.
Amphidromous	Refers to fishes that regularly migrate between freshwater and the sea (in both directions), but not for the purpose of breeding, as in anadromous and catadromous species.
Catadromous	Fish that migrate from fresh water to salt water to spawn or reproduce
Commissional Water Right (C.W.R.)	Under the Water Act 1957, the right to take water from a water resource (watercourse, lake, river, stream or any surface water or groundwater) for commercial (irrigation) use.
cumec	A measure of flow discharge. 1 cubic meter per second; equivalent to 86.4 Ml/day
Coarse Woody Debris (CWD)	Dead or living tree (branch or root system) that has fallen into or is immersed (totally or partially) in a stream. Generally with diameter greater than 10cm and length exceeding 1metre.
Discharge	A volume of water passing a given point in unit time
Fish passage	The directed movement of a fish past a given point in a stream. Particularly relates to the engineering and biological aspects of restoring free passage at barriers.
Fish passage device	Structure incorporated into a barrier to promote fish movement
Fishways	Structures that allow for fish to pass barriers.
Megalitre	A measure of water equivalent to 1000 000 litres (or about the size of an Olympic swimming pool).
Pools	Deep, still water , usually within the main river channel.
Riffles	Areas of fast moving, broken water.
Riparian vegetation	Vegetation on the banks of streams and rivers.
Run SIGNAL	Unbroken, moving water. **S**tream **I**nvertebrate **G**rade **N**umber – **A**verage **L**evel. Grading based on the tolerance or intolerance of macroinvertebrates to various types of pollution and or disturbance
Snags	Instream woody debris.
Substrate	The structural elements of the river bed; boulder, cobble etc.
WIMS database	**W**ater **I**nformation **M**anagement **S**ystems database, designed for managing water usage and demand data

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1. INTRODUCTION

This study has been conducted to provide an assessment of riverine habitat condition within the North Esk catchment. The study has been carried out in association with other studies undertaken by the DPIWE to form the basis of 'State of Rivers' reporting for the catchment. Funding from the National Heritage Trust program has been utilised in this assessment of riverine habitat condition within the North Esk Catchment.

The Index of River Condition was implemented in Tasmania to provide a picture of the 'overall health' of reaches within a catchment. This was achieved through the assessment of hydrology, water quality, aquatic ecology, physical form and stream-side zone condition. The Tasmanian IRC method provided for an index of change from a natural state and is based on similar survey approaches carried out in Victoria (CEAH, 1995) and Queensland (Anderson, 1993). IRC assessments have been completed for several catchments within Tasmania (Great Forester, Ringarooma, Brid, Pipers and Mersey catchments) and the method has proven to be useful to assess river condition for Tasmanian rivers. In addition, IRC assessments for previous catchments have been used by community groups as a basis to target rehabilitation activities.

The IRC has changed since its inception to gather information on physical form, stream-side zone and hydrological connectivity (influence of barriers) as State of River reporting already provides comprehensive assessments of hydrology, water quality and aquatic life.

The broad objectives of the Tasmanian Index of River condition are:

- To identify reaches that have been modified in relation to in-stream condition.
- To identify reaches where the riparian zone has undergone modification.
- To develop a method for identifying hydrological breaks that act as barriers to native fish migration.
- To make recommendations regarding target management areas for in-stream and riparian rehabilitation

The current IRC is designed to identify reaches within a catchment where habitat modification has occurred. Habitat modification in this case relates to changes to in-stream habitat and riparian vegetation parameters. The approach has been focused to provide more detail on physical river condition via detailed assessment of the riparian zone and in-stream habitat conditions and should not be viewed simply as a truncated version of previous IRC methodologies. It is a tool that is ideal for identifying areas of habitat modification and determining the source of the disturbance. From this assessment specific management issues can be identified not only for individual reaches but the catchment as a whole. The method also provides the basis for long term monitoring of changes in habitat condition as it is envisaged that Index of River condition assessments may be conducted every five years. This is the review period previously identified for State of River reporting on Tasmanian catchments.

A detailed assessment of in-stream structures that have the potential to act as barriers has been incorporated into the study. All structures have been rated on their potential to impede fish passage and their influence on the hydrological connectivity of the system. Changes in hydrological connectivity can be a result of natural (waterfall, rapids) or artificial features (dams, culverts and weirs). This assessment is spatially independent of IRC ratings for physical form and streamside zone scores and therefore is discussed separately. Fish passage is the term used to describe the ability of fish to pass a point in a stream by directed movement. Eleven of Tasmania's 25 native fish species are migratory and require free passage in order to complete their lifecycles. Barriers can therefore have major implications for fish populations with the potential to cause localised extinctions, reduce fish abundance and lower genetic diversity (Thorncraft and Harris, 2000). Fish passage has been adopted as the measure of ecological integrity for this parameter.

Individual ratings for barriers can be applied to particular stream reaches and the cumulative effect of barriers on river reaches can be identified from these ratings. These findings would be useful to inform future management of water development within the catchment, through the determination of the cumulative effect and location of barriers. In the North Esk catchment the overall spatial coverage of previous fish surveys is insufficient to draw firm conclusions regarding fish distribution for the catchment. As fish records are limited for most of the reaches in which artificial barriers occur, caution must be taken in attributing the current pattern of fish distribution to the changes in hydrological connectivity associated with these barriers. As such each individual structure has been assessed on the basis of its effect on hydrological connectivity and it is from this assessment that the likely potential for fish passage has been determined.

Assessment of river condition in this study provides a baseline of information that can be used for comparative purposes to observe changes within the North Esk catchment over time. Ideally these assessments should be undertaken every 5 years using the same sites to determine if the overall condition of the catchment has improved or declined. This would be particularly useful for community groups in relation to monitoring the success of current and future restoration projects.

2. STUDY AREA

The North Esk catchment is situated in the north-east of the state (Figure 2) and flows north into the Tamar Estuary before entry into Bass Strait. Hydrologically the mainstream is unregulated although many tributary streams are regulated by on-stream water storage's. The largest water abstractions are associated with the domestic water supply for the greater Launceston area. There are few permanent water allocations in the catchment for irrigation purposes and the combined total of these for the summer irrigation period is less than 10 Ml/day (refer to Hydrology Report).

The lower catchment has been cleared for a mixture of agriculture and urban development. Agriculture also occurs within the middle catchment along Blessington Road and along sections of the St Patricks River. Forestry activities are common within the upper reaches of the both the St Patricks and North Esk River catchments.

Stream substrate grades are predominantly boulder/cobble within the gorge sections of the catchment such as Corra Linn, and the section between Nunamara and upstream of the confluence of the St Patricks and North Esk Rivers at Watery Plains. In the upper sections of the catchment, gravel and sand tend to be the dominant substrates. In-stream habitat is dominated by pools and runs with pools forming the dominant habitat units. The catchment geology is largely composed of Precambrian rock types. Precambrian granite outcrops

dominate in the upper reaches along with Mathinna bed sequences. Jurassic dolerite outcrops occur throughout most of the mid catchment and Precambrian sedimentary sequences including othoquartzites are interspersed with dolerite in the lower reaches. The total river length is approximately 91 km originating at an altitude of some 900m (Figure 1) and the catchment area is approximately 1065 km^2. The median summer and annual flows from the catchment 2.34 and 7.16 cumecs (618.6 and 202.2 Ml/day) respectively.

Figure 1. Longitudinal profile of the North Esk River.

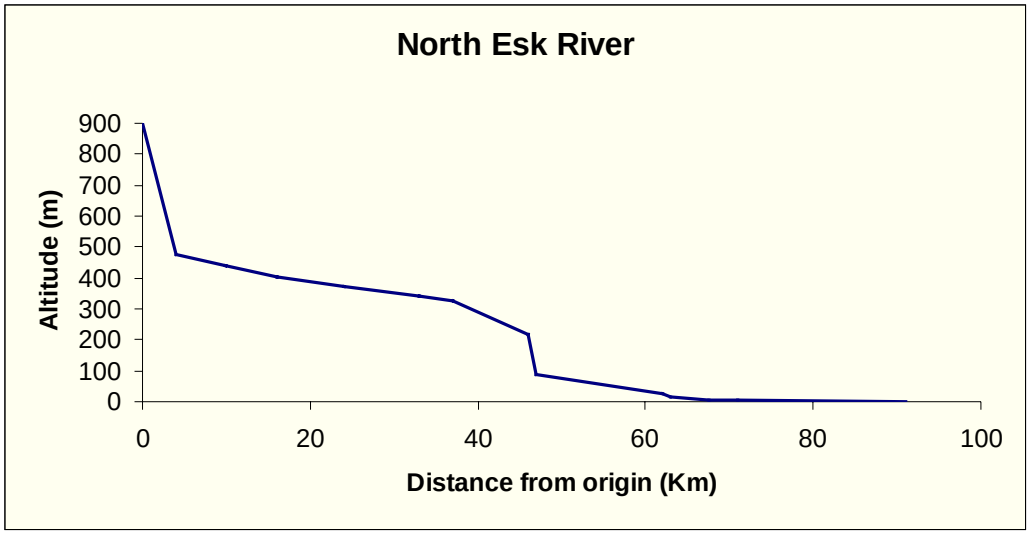
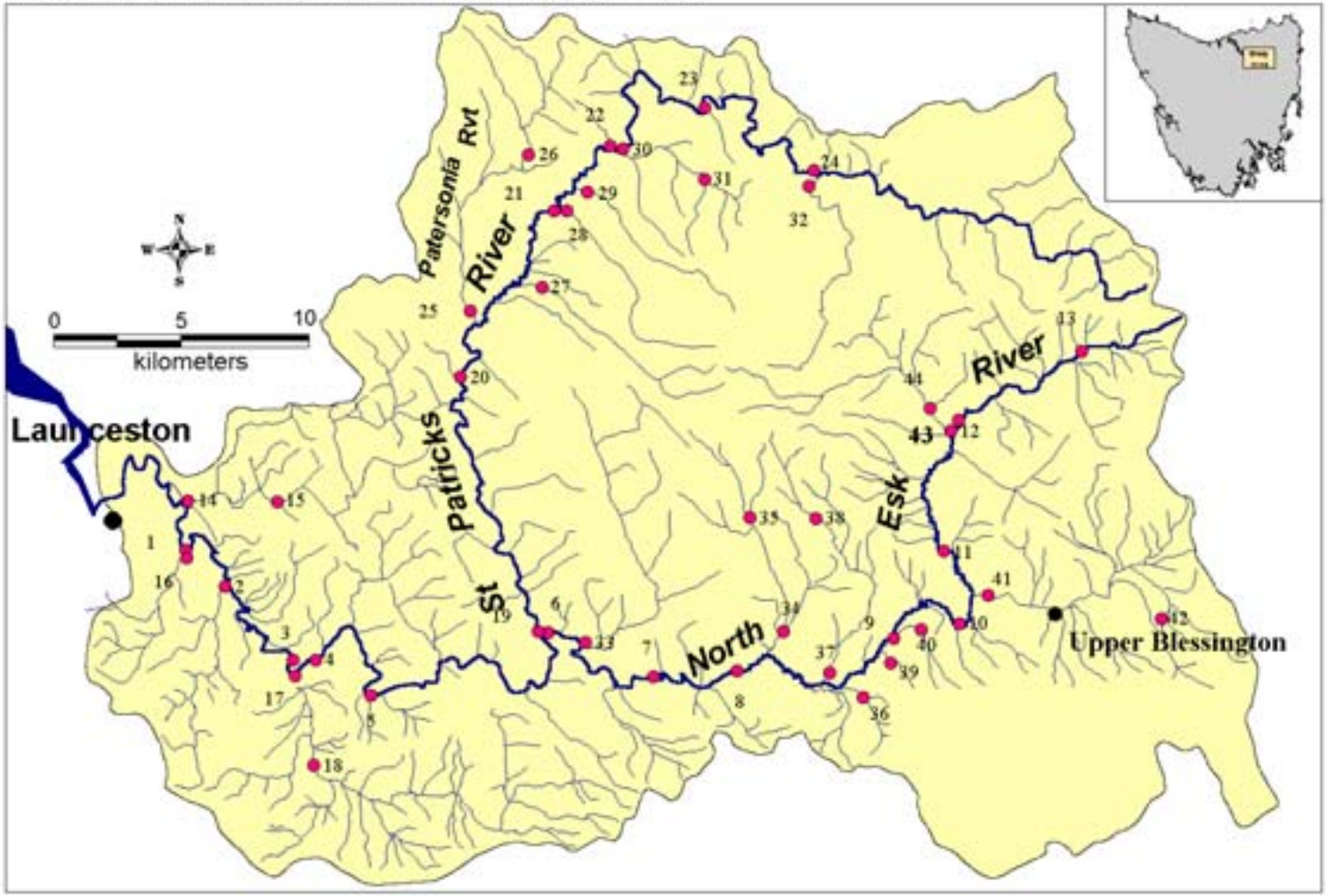


Table 1. Site Legend for North Esk IRC sites represented in Figure 2.

Site No.	Site	Site No.	Site
1	North Esk d/s confluence with Kings Meadows Rivulet	23	St Patricks River at Corkerys Rd
2	North Esk u/s of Clarks Ford Bridge	24	St Patricks River at East Diddleum Road
3	North Esk below Corra Linn	25	Patersonia Rivulet at Patersonia Rd
4	North Esk at Corra Linn	26	Patersonia Rivulet at Targa Hill
5	North Esk at White Hills	27	Coquet Creek at Tasman Highway (Trout Ck)
6	North Esk upstream confluence with St Patricks	28	Barrow Creek at Tasman Highway
7	North Esk at Ballroom	29	Bennies Creek at Tasman Highway
8	North Esk at Musselboro Rd	30	Seven Time Creek at Tasman Highway
9	North Esk at Burns Creek Road	31	Seven Time Creek at old bridge off Camden Hill Rd
10	North Esk at Wattle Corner (Camden Rd)	32	Camden Rivulet at Diddleum Road
11	North Esk off Camden Rd	33	Weavers Creek u/s North Esk confluence
12	North Esk at Ben Nevis Rd	34	Musselboro Creek u/s North Esk confluence
13	North Esk above "Northallerton" property	35	Musselboro Creek at track off Musselboro Rd
14	Distillery Creek u/s confluence with North Esk	36	Old Mill Creek at Blessington Road
15	Distillery Creek u/s of filtration plant	37	Burns Creek at "Elverton" property
16	Kings Meadows Rivulet at Punchbowl	38	Burns Creek upper site
17	Rose Rivulet above Nth Esk confluence	39	River O'Plain Creek at Blessington Road
18	Rose Rivulet at Lower White Hills Rd	40	Pig Run Ck at Blessington Rd
19	St Patricks at Watery Plains u/s of North Esk confluence	41	Ford River below Upper Blessington
20	St Patricks at Nunamara	42	Ford River above Upper Blessington
21	St Patricks River at Pecks Hill Road	43	Beckett Creek t Camden Rd
22	St Patricks River at Targa Hill Road Bridge	44	Beckett Creek at Simons Rd (off Camden Rd)

Figure 2: North Esk River Catchment. Index of River Condition (IRC) Sites



3. METHODOLOGY DESCRIPTION

The IRC approach has been developed to provide an assessment of current habitat condition within a catchment. This was achieved through collection of physical and ecological data from a range of reaches throughout a catchment and determining the degree of departure of physical and riparian conditions of these reaches from a natural state. The core methodology is based on two sub-indices (Physical form and Stream-side zone). Each sub-index represents a rating of one or more parameters or habitat attributes (Table 3).

Parameters for each sub index are rated on a 5 point rating scale where possible rather than absolute values (Table 2). The ratings are based on the degree of divergence of the current state from a natural state. The 5 point rating scale had been developed for the Victorian IRC (CEAH, 1997b) after rigorous trial of the original Index for Victorian conditions and this has subsequently proven to be an effective rating scale for Tasmanian catchments. According to Victorian authorities a scale with a higher or lower rating would be unrealistic given the current state of knowledge of the relationship between a change in the indicator and environmental effects (CEAH, 1997b).

Table 2. Habitat rating categories for individual sites.

Condition	**Very poor** **Highly modified**	**Poor** **Major modification**	**Moderate** **Some modification**	**Good** **Near natural**	**Excellent** **Essentially natural**
Total score	0 - 1	2 - 3	4 - 5	6 - 7	8 - 10
Habitat rating	0	1	2	3	4

3.1 Sub-index parameters

At each site a number of indicators for each sub index are assessed or rated. Descriptions of indicators for each sub-index parameter are detailed in Table 3.

Table 3. The sub-index parameters with associated indicator categories.

Sub-index	**Indicator**
Physical form	Bank condition Bed condition Density of coarse woody debris Influence of artificial barriers Overall site disturbance
Stream-side zone	Width of stream-side zone Structural intactness Native vegetation cover Native Vegetation regeneration Longitudinal continuity Overstorey regeneration Stream-side cover
Hydrological connectivity	Barrier effectiveness Barrier location Fish passage potential Deviation of flow Other in-stream structures Bank stability Overall disturbance

3.1.1 Physical form

Bank condition
Bank condition or stability is an assessment of the amount of erosion occurring at set points within the study site. Potential indicators of current bank stability include:

- lack of vegetative cover or exposed soil.
- irregularities and sharp bends in the stream course.
- undermining of the toe of the banks and exposed roots.
- water discolouration along the toe of the bank, and evidence of recent soil slips.

Bed condition
Bed condition is a measure of overall aggradation and degradation of the stream bed at each transect location. Potential indicators of current bed instabilities include:

- erosion heads.
- bank instabilities on both sides of the bank (this indicates bed degradation).
- any accumulations of sediment around obstructions (typically coarse woody debris), and the general width to depth ratio is low for degradation and high for aggradation.

Density and origin of coarse woody debris (CWD)
In-stream woody debris can represent an important habitat for aquatic animals. It provides a refuge for fish and invertebrates, food source for many macroinvertebrates, and is important for spawning for some fish species (e.g. river blackfish, *Gadopsis marmoratus*). The rating scale is based on the proportion of available CWD in the reach assessed. The rating assumes that the greater the proportion of snags available, the more habitat there is for in-stream fauna.

Influence of artificial barriers
The presence of artificial barriers indicates a clear change from natural conditions. Barriers include weirs, dams, culverts and bridges. Barriers largely affect fish movement but also impact available water downstream which can have an effect on other ecosystem processes. The rating for artificial barriers is based on seasonal changes in water availability across the structure and the frequency of structure inundation.

Overall site disturbance
For this parameter six disturbance categories were available (extreme, very high, high, moderate, low and very low) for each site. The categories are largely based on physical aspects of stream-side vegetation such as the degree of weed infestation, cover provided by native species and native species richness. Details of the six disturbance categories utilised in determining this parameter are provided in appendix 4.

3.1.2 Stream-side zone

Riparian vegetation plays an important role in the maintenance of stream condition. For example, stream-side vegetation can (Skills and Pen, 1995):

- increase bank roughness thereby reducing erosion potential.
- riparian roots bind and reinforce soil (bank stabilisation).
- roots also loosen soil allowing greater infiltration of rainwater.
- vegetation filters sediment and nutrients and promotes sediment deposition.
- Continuous vegetation provides ecological corridors and habitat availability for terrestrial animals and plants.

These factors directly and indirectly maintain the quality and ecological integrity of a waterway.

Width of stream-side zone
The stream-side zone is the interface between the aquatic and terrestrial environment and was assessed as the average distance of vegetation from waters edge at base flow to any cleared or developed land. This parameter is largely designed to determine how much vegetation is present from the river bank to when some form of disturbance, such as clearing, occurs. The stream-side zone may be extensive therefore anything over 40 m should be recorded as such. The width of the stream-side zone is important to determine how much of a buffering effect it is having from adjacent developed land and to indicate the continuous presence of vegetation which is important as faunal corridors and habitat.

Structural intactness
Structural intactness is an indicator of disturbance relating to the original distribution of stream-side vegetation. The ratings for structural intactness are based on a scale of continuous, patchy and sparse cover. The following definitions for the three structural layers are based on the Victorian model.

- Overstorey – those woody plants greater than 5 m tall.
- Understorey - those woody plants less than 5 m tall.
- Ground cover - other plants without woody stems.

Proportion of native vegetation cover
This category refers to the proportion of native and introduced plant species in the reach assessed. The relative proportion of native species present provides a rating of how near to natural the reach is. The presence of exotic species may be undesirable depending on the quantity and/or the particular exotic species. Ratings are according to the percentage cover that is present and is determined separately for each structural layer.

Presence of regeneration of native plant species
Regeneration of native vegetation is an important indicator of current condition. Due to the difficulty in assessing the regeneration of ground cover species, it has been applied to overstorey and understorey species only.

Longitudinal continuity
In essence, longitudinal continuity is simply a measure of how continuous stream-side vegetation is. Any gap that exists in a vegetation corridor has the potential to act as a barrier to terrestrial fauna movement or increase physical and ecological disturbance via erosion/ sedimentation/ runoff. The parameter specifications adopted here are the result of expert

panel discussions in Victoria (CEAH, 1997a). A significant discontinuity is defined as a gap in the stream-side vegetation greater than 10 m long and that has a width of 5 metres or less. The two factors applied are:

- proportion of bank length with vegetation greater than 5 m wide
- the number of significant discontinuities per unit length.

Overstorey stream-side vegetation regeneration
The regeneration of indigenous species within the stream-side zone is an important rating of its current condition. A well developed overstorey suggests long term stability of the area from previous disturbance events such as clearing, logging and fire.

Vegetative regrowth categories
This rating is based on the assumption that natural succession in vegetation culminates in the formation of a climactic community. Such an end point community receives the highest rating. The nature of the climax communities varies and is determined by environmental conditions within an area. For example high rainfall areas of the state support temperate rainforest as a climax community, whilst low rainfall areas may culminate in a sclerophyll community.

Stream-side cover
The indicators for this section are categorised as follows:

- canopy cover
- vegetation overhang
- root overhang
- bank overhang
- man-made overhang

The data collected for this section provides an assessment of available habitat in the form of shelter and shading for aquatic life. Overhanging trees may also provide a direct food source in the form of leaf and insect fall into the stream. Man-made overhangs relate to structures (eg: jetties and pontoons) that result in shading and or sheltering of the stream bed.

3.1.3 Hydrological connectivity

Hydrological connectivity, or the ability of water to move between river reaches has been identified as an important factor in assessing riverine condition. This index has been incorporated to highlight which indicators of hydrological connectivity have undergone modification within the catchment. As with the previously mentioned sub indices there are a number of parameters that have been identified that allow the formation of a rating scale for hydrological connectivity. A 5 point rating system has been developed for each parameter and details are given under each parameter heading below. The term "ideal' is used in preference to the term "natural" as used for stream side zone and physical form. Hydrological connectivity parameters are as follows:

1. Barrier effectiveness
This parameter determines the ability of an instream structure to act as a barrier.

		Rating
Nil	Structure is present which allows for essentially natural instream conditions.	**4**
Low	Potential barrier, open construction with near natural flow.	**3**
Moderate	Small barrier. Structure allows for flow for majority of year.	**2**
High	Obvious barrier, overflow is limited to times of high flow.	**1**
Extreme	Complete barrier, limited or no flow available for most of year.	**0**

2. Barrier location (subcatchment ratios)
It is important to consider both the effectiveness of the barrier to influence hydrological connectivity and also its position within the catchment. The degree of naturalness for this parameter is related to the relative catchment areas upstream and downstream of the structure.

		Rating
Essentially ideal	Minor tributary or main channel within the upper catchment. Limited catchment area upstream - low order stream Sub catchment ratio >10%.	**4**
Near ideal	Tributary or main channel within the upper catchment. Small catchment area upstream - low order stream Sub catchment ratio 10-25%	**3**
Good	Tributary or main channel Low proportion of catchment area upstream of barrier Medium order stream Sub catchment ratio 25-50%	**2**
Poor	Major proportion of main channel and or high proportion of tributaries upstream of barrier. Moderate stream order Sub catchment ratio 51-75%	**1**
Very poor	Within the lower catchment on High order stream. Either main stream or tributary (lower score for main channel) Sub catchment ratio <75%	**0**

3. Fish passage potential

Barriers to fish passage are known to result in a decline in the diversity and abundance of fish communities. The indicators identify departures from a natural condition under which fish passage is not impeded.

		Rating
Essentially ideal	Fish passage potential is essentially unaltered by the barrier present. This may be due to fish passage devices	**4**
Near ideal	High potential for passage Little deviation from natural passage conditions	**3**
Moderate modification from ideal	Moderate potential for passage Temporal barrier for some of the year. Loss of production due to passage delay	**2**
Major modification from ideal	Low potential for passage Partial barrier. Blockage of the weaker and or smaller fish	**1**
Highly modified from ideal	Very low potential for passage Nearly complete barrier, where only the strongest fish can pass or Complete barrier	**0**

4. Deviation of flow

Barriers alter the natural flow regime within the area they are located. The degree to which the flow is modified from natural conditions can be viewed in terms of upstream and downstream alterations. Typically upstream of a barrier water is impounded whilst downstream flow is restricted.

		Rating
Essentially ideal	Essentially natural conditions of flow on either side of barrier	**4**
Near ideal	Near natural flow downstream. Near natural conditions upstream of barrier. Minor impoundment and changes to flow regime.	**3**
Moderate modification from ideal	Flow partly restricted, some reduction in wetted width. Alteration to volume and velocity of flow. Small impoundment area. Natural channel accounts for > 75% impoundment width. Increased depth obvious	**2**
Major modification from ideal	Flow downstream obviously altered. Wetted width reduced. Small discharge volume with variable velocity. Replenish from output & tributary inputs. Moderate size impoundment Natural channel width accounts for 75-25% of impoundment width Depth moderate	**1**
Highly modified from ideal	Highly altered. Downstream no or extremely low flows (potentially high velocity). Relies on tributaries to replenish flows. Large impoundment area. Natural channel accounts for >25% of impoundment width. Highly modified depth	**0**

5. Other in-stream barriers

This parameter relates the ability of other in-stream structures to effect the barrier being reviewed and highlights the impact of multiple developments for particular reaches.

		Rating
Essentially ideal	Essentially unaffected by other barriers within the system.	**4**
Near ideal	Few structures natural or artificial influencing this point that act as fish barriers.	**3**
Moderate modification from ideal	Some barriers. For tributaries there may be no other barrier present on the tributary itself though present nearby on main channel.	**2**
Major modification from ideal	Several barriers affect this reach. Tributaries - at least one other barrier on same tributary.	**1**
Highly modified from ideal	Multiple barriers affect this reach..	**0**

6. Bank stability

The stability of the surrounding stream banks is an important factor to determine in relation to hydrological connectivity. Stable conditions have been set as the standard for naturalness.

		Rating
Stable	Erosion resistant soils; no undermining; usually gentle batter, good vegetative cover; no significant damage to bank structure or vegetation; no exposed roots.	**4**
Limited erosion	Good vegetative cover; some minor isolated erosion; no continuous damage to bank structure or vegetation, some exposed roots.	**3**
Moderate erosion	Banks held by discontinuous vegetation; some obvious damage to bank structure and vegetation; generally stable toe, moderate exposure of roots.	**2**
Extensive erosion	Little effective vegetation; mostly unstable toe; large numbers of exposed roots.	**1**
Extreme erosion	Evidence of unchecked rapid erosion; no effective vegetation; unstable toe; very recent bank movement.	**0**

7. Overall disturbance

This parameter allows for the determination of riparian condition around the barrier of interest. The riparian habitat plays an important role in maintaining the quality and ecological integrity of a waterway.

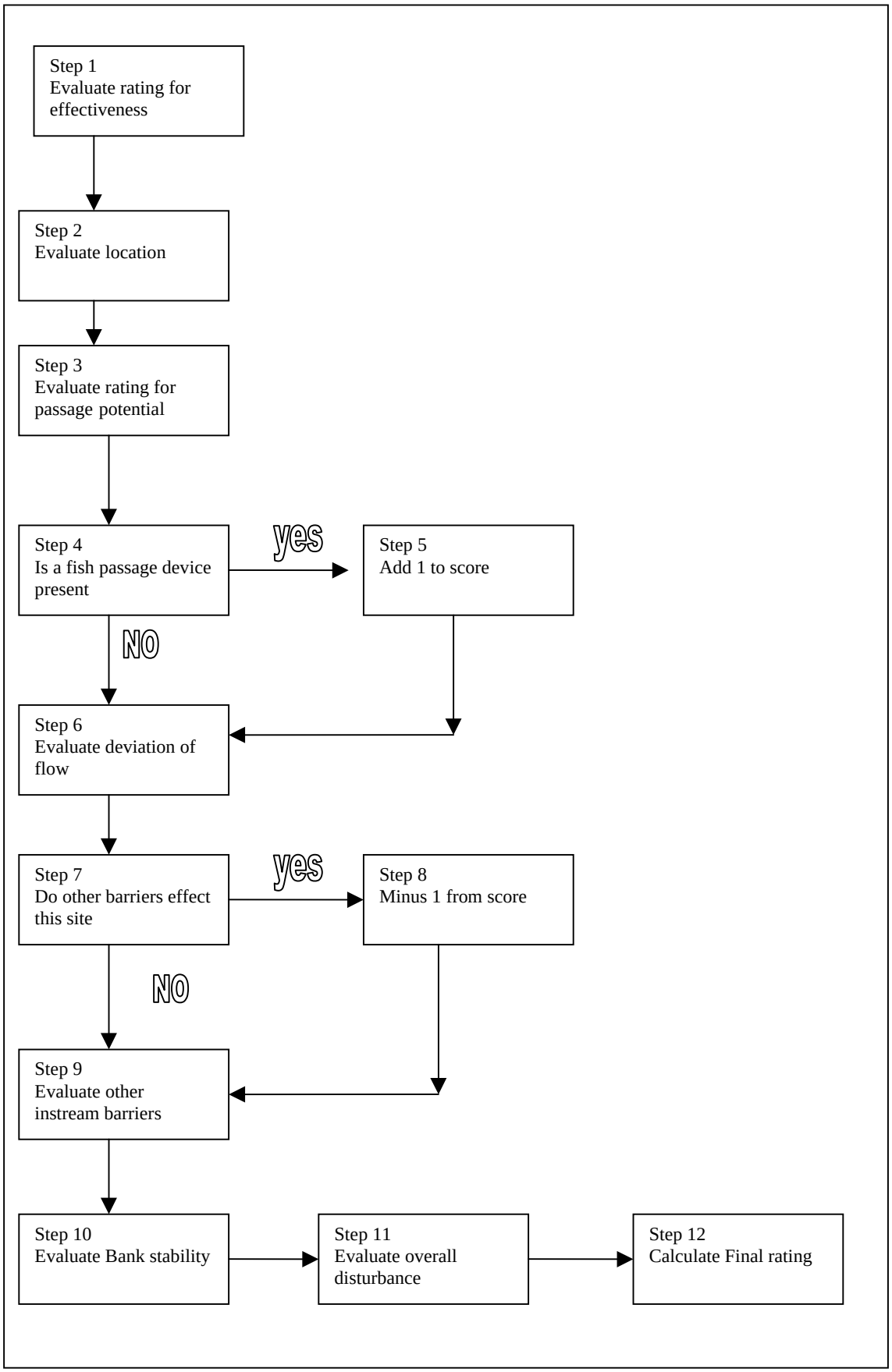
		Rating
Essentially ideal	Low Disturbance Native vegetation dominant, exotic species insignificant. Representative of pristine condition.	**4**
Near ideal	Native vegetation dominant on both sides. Few introduced species present. Any disturbance is minor	**3**
Moderate modification from ideal	Moderate disturbance Native species in reasonable numbers, the intrusion of introduced species is minor and of moderate impact. Moderate stock access	**2**
Major modification from ideal	Major Disturbance Riparian zone is modified. Native vegetation severly altered on one or more banks. Exotic species prolific. Disturbance from stock access evident	**1**
Highly modified from ideal	Extreme Disturbance Riparian zone absent or severly reduced. If present native species rare, exotics dominant. cleared both banks. Unrestricted stock access and severe disturbance	**0**

Analysis of all subindices provides an overall rating of how an individual barrier effects hydrological connectivity. In order to determine the effects of multiple barriers upon the system a decision tree was developed based on the aforementioned subindices. An overview of the decision tree is provided in Figure 3.

3.2 Site selection and survey methods

Site assessments were conducted during March, 2000. A total of 44 sites were surveyed within the catchment (Figure 2). Thirteen sites were located on the mainstream and 31 on major tributaries within the catchment. Each site was selected as being representative of the reach (length of river) where it occurs. Site selection was based on examination of maps and extensive groundtruthing prior to the survey. Selection of study sites overlapped with the sites used in the assessment of water quality and aquatic ecology. This allowed for the incorporation of existing long term water information for the catchment into this 'snapshot' assessment. During June 2001 an additional survey of parameters related to hydrological connectivity was undertaken. This allowed for the assessment of the potential for structures to act as barriers to fish migration or movement.

Figure 3: Procedure for calculating Hydrological connectivity



4. RESULTS

IRC Summary results for entire catchment

Results of the IRC assessment for the North Esk River catchment are presented for the main channel, tributaries, and for the catchment as a whole in Table 4.

Table 4. IRC sub-index values for the North Esk catchment.

	Numerical value (Rating)		
Category	**Main-stream North Esk R. Sites**	**North Esk R. tributaries**	**Average for all catchment sites**
Physical form	7.5	7.6	7.6 (Good)
Stream-side zone	4.2	4.4	4.3 (moderate)
Hydrological connectivity	6.85	5.88	6.4 (Near ideal)

Figure 4. Median rating values for different barrier types assessed within the North Esk catchment.

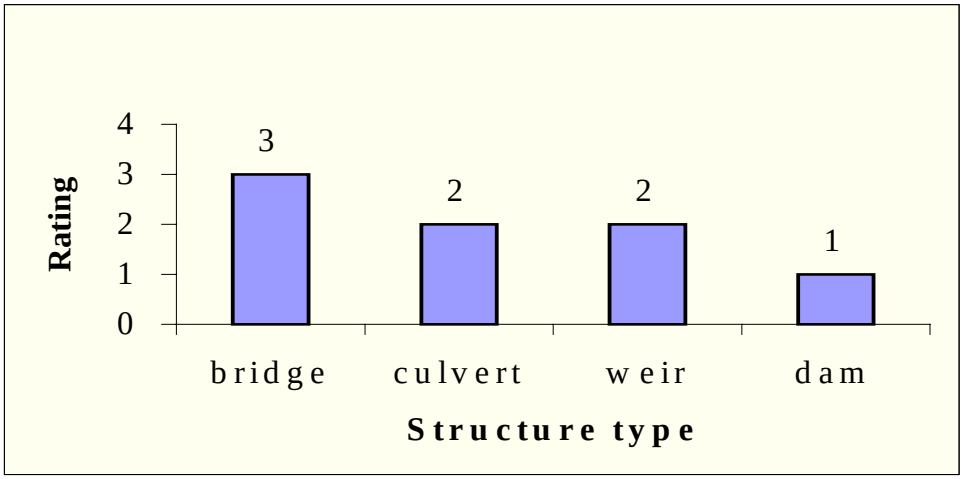


Figure 4 presents ratings for various types of structures in relation to hydrological connectivity. Essentially, bridges result in partially modified conditions, culverts and weirs result in moderately altered conditions and farm dams result in poor conditions for fish passage. Table 4 indicates that overall, the catchment as a whole and the mainstream provide "Near ideal" conditions for fish passage. As on-stream storages are almost exclusively located on associated tributaries, smaller order streams provide only "moderate" condition for passage. Figure 9 shows the distribution of structures and related fish passage values of structures that were surveyed within the catchment.

4.1 IRC Summary results for mainstream sites

A total of 13 sites were sampled on the main-stream (Figure 2) and Index of River condition ratings for the main-stream North Esk River are provided in Figure 5. Parameters that suggest major or extreme modification from a natural or ideal condition are presented in Appendix 2 along with any data gaps. Condition maps for the physical form and stream-side zone sub-indices on a reach scale are provided in Figures 7 and 8 respectively. Management issues for each mainstream site have been identified in Table 5.

Overall, the physical condition of sites surveyed in the mainstream showed partial modification (near natural condition). As expected sites in the extreme upper catchment rated as excellent (North Esk above "Northallerton" property (Site 13) to North Esk off Camden Road (Site 11)). The physical form index for the middle reaches of the North Esk mainstream rated as of moderate condition (North Esk at Musselbroe Rd (Site 8) North Esk at Burns Creek Road (Site 9), and North Esk at Wattle corner (Site 10)). The physical form index rated as in good condition for the North Esk at Ballroom (Site 7). Excellent ratings for physical form were recorded from the North Esk upstream of the confluence of St Patricks River (Site 6) the North Esk at White Hills (Site 5) and the North Esk at Corra Linn (Site 4). One site within the lower catchment rated as of good condition (North Esk below Corra Linn (Site 3). Two sites rated as being in moderate physical form condition (North Esk upstream Clarks Ford Bridge (Site 2) and North Esk downstream of the confluence with Kings Meadow Rivulet (Site 1)).

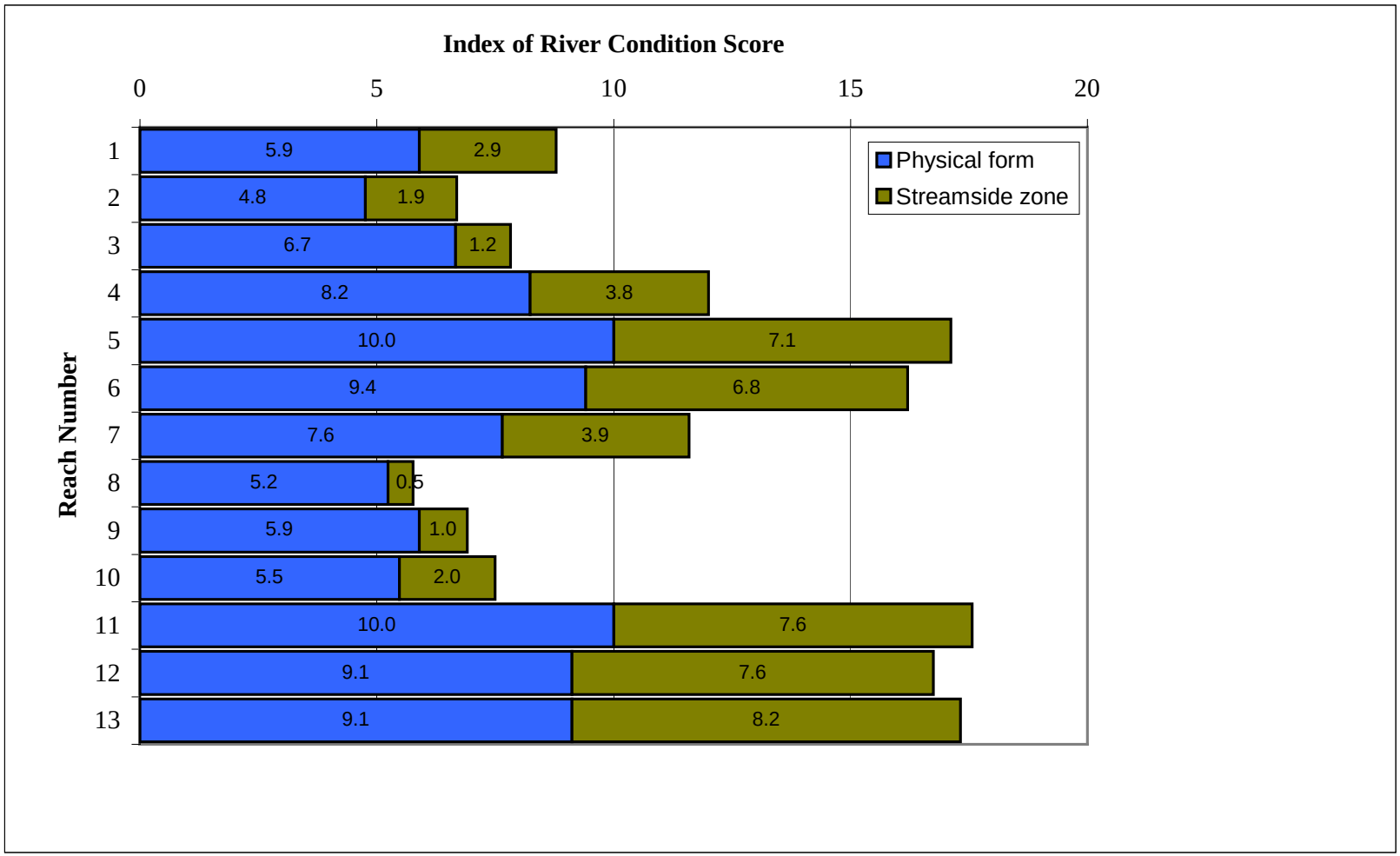
From Appendix 2 it is evident that major or extreme modification of individual physical form parameters occurs within agricultural and/or urban reaches of the North Esk mainstream. In the lower reaches the indicators for Overall Site Disturbance (OSD) and coarse woody debris (CWD) were extremely modified for Sites 1-3 which occur within lower urban areas in the lower catchment. These indicators were also extremely modified for Sites 8-10 that occur within agricultural reaches along Blessington Road.

The stream side index clearly stood out as the most modified as illustrated in Figure 5. Overall, the average stream-side zone sub-index rating for the main stream is of moderate condition. The condition of stream-side vegetation in the mainstream varied between reaches and like physical form ratings reflected adjacent land use practices. In agricultural and urban areas there was a trend for reduced ratings, indicating a higher degree of modification. This is highlighted in the lower catchment where Site 2 (North Esk upstream of Clarks Ford Bridge) and Site 3 (North Esk below Corra Linn) rated as in very poor condition, and Sites 1 (North Esk downstream of the confluence with Kings Meadow Rivulet) and Site 4 (North Esk at Corra Linn) rated as in poor condition. Near natural conditions were recorded for Sites 5 (North Esk at White Hills) and Site 6 (North Esk upstream of the St Patricks River confluence) which occur within areas that are adjacent to land not intensely used for agriculture. Moderate condition was recorded for the North Esk at Ballroom (Site 7). Site 8 (North Esk at Musselboro Road), Site 9 (North Esk at Burns Creek Road) and Site 10 (North Esk at Wattle Corner (Camden Road)) are clearly affected by surrounding land usage, with Sites 8 and 9 rating as in very poor condition and Site 10 in poor condition. The top 3 sites (North Esk of Camden Road to North Esk above “Northallerton”) are upstream of agricultural and urban impacts and stand out as in good (Sites 11 and 12) to excellent condition (Site 13). This sub-index clearly stood out as the most modified as illustrated in Appendix 2.

Table 5. Management issues identified for the main stream North Esk River sites.

Reach	Management issues
North Esk d/s confluence with Kings Meadows Rivulet	Weeds - Willows, blackberries (*Rubus fruticosus*). Limited riparian zone dominated by willows. Unrestricted access to river banks. Excessive silt build-up in-stream
North Esk u/s Clarks Ford Bridge	Weeds - Willows, blackberries,. Limited riparian zone dominated by willows. Stock access to right river bank. Limited indigenous plant regeneration.
North Esk below Corra Linn	Weeds - Blackberries, willows, gorse. Limited stock access to river banks some indigenous plant regeneration
North Esk at Corra Linn	Weeds - Willows, blackberries. Limited riparian zone
North Esk at White Hills	Weeds - Willows, blackberries, hawthorn (*Crataegus monogyna*). Moderate indigenous vegetation cover. Limited stock access
North Esk u/s confluence with St Patricks River	Weeds - Willows (low), gorse (extensive). Limited indigenous plant regeneration.
North Esk at Ballroom	Weeds - Willows, gorse, (extensive). Unlimited stock access to river banks.
North Esk at Musselboro Rd	Weeds - Willows, gorse. Limited riparian cover for both banks. Limited indigenous plant growth. Unrestricted stock access to left river bank.
North Esk at Burns Creek Road	Weeds - Willows, gorse, blackberries. Sparse riparian cover. limited indigenous plant regeneration. Partially restricted stock access to river banks.
North Esk at Wattle Corner (Camden Rd)	Weeds - Hawthorn, willows, ragwort (*Senecio jacobea*), Riparian zone willow dominated. No indigenous plant regeneration. Unlimited stock access to river banks resulting in evidence of bank erosion.
North Esk off Camden Rd	Stock access limited by native riparian zone. No other issues
North Esk at Ben Nevis Rd	Weeds - Willows, blackberries. Riparian zone of limited width. Limited stock access to river banks. Eucalypt plantation area
North Esk above "Northallerton" property	Weeds – Nettles (*Cirsium vulgare)*. Stock access limited by native vegetation. Upstream of current forestry operations. Potential erosion leading to channel erosion during high flows given small substrate size.

Figure 5. IRC results for the North Esk River mainstream sites.



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4.2 IRC Summary results – tributary sites

IRC ratings for the tributary streams of the North Esk catchment are provided in Figure 6. A total of 31 sites were sampled on 18 tributaries (Figure 2). Parameters that suggest major or extreme modification from a natural condition are highlighted in Appendix 2 along with data gaps. Descriptive maps for Physical form and Stream-side sub-indices values are provided in Figures 7 and 8 respectively.

Overall, the physical form sub-index rated as in good condition (near natural) for tributaries in the catchment. Where more than one site was surveyed on each tributary, a general trend of improved river condition at the upper reach of the tributary was noted. Distillery Creek improved from moderate condition at Site 14 (Distillery Creek upstream of the North Esk confluence) to excellent condition upstream of the filtration plant (Site 15). Seven Time Creek and Burns Creek were rated as in moderate condition at the lower sites (Sites 30 and 37, respectively) and in excellent condition at the upper sites (Sites 31 and 38, respectively). Patersonia Rivulet, Musselboro Creek, the Ford River, and Beckett Creek rated as in good condition at their lower sites (Sites 25, 34, 41, 43) and in excellent condition at the upper sites (Sites 26, 35, 42, 44).

Sites surveyed on the St Patricks River rated as in 'near natural' to essentially natural condition. Of these, the sites that rated lower (near natural condition) were within agricultural areas particularly, St Patricks at Pecks Hill Road (Site 21) and St Patricks at Targa Hill Road (Site 22). The lower section of the river from Site 19 (upstream of the North Esk confluence) to Site 20 (St Patricks at Nunamara) rated as essentially natural, as did the upper sites on Corkerys Road (Site 23) and East Diddleum Road (Site 24). Typically ratings were higher in reaches where adjacent land usage was minimal.

The physical form sub-index varied in its rating for tributaries on which a single site was selected from poor to essentially natural condition. As with the mainstream, physical form condition deteriorated in agricultural and urban areas. Kings Meadow Rivulet (Site 16) rated as in moderate condition due to urban influences. Barrow Creek (Site 28), Old Mill Creek (Site 36) and River O 'Plain Creek (Site 39) were adjacent to agricultural areas and were rated as in moderate condition. Near natural conditions were recorded for Coquet Creek (Site 27), Bennies Creek (Site 29), Camden Creek (Site 32) and Pig Run Creek (Site 40), all of which occur in partly developed agricultural zones. Site 33 (Weavers Creek upstream of the North Esk confluence) occurs within native bushland and was found to rate as in 'Essentially Natural' condition.

Overall, the stream-side zone sub-index rated on average as in moderate condition for the tributaries, though individual site ratings varied from very poor to excellent. As with the physical form sub-index general trends were noted that related site condition to position within the sub-catchment and surrounding land usage.

Distillery Creek improved from poor condition at Site 14 (Distillery Creek upstream of the North Esk confluence) to near natural condition upstream of the filtration plant (Site 15). Seven Time Creek varied from very poor condition at the lower site (Site 30) to excellent condition at the upper site (Site 31). Patersonia Rivulet and Becketts Creek ranged from in poor condition at the lower sites (Sites 25 and 43, respectively) to excellent condition at the upper sites (Site 31 and 44, respectively). Musselboro Creek, Burns Creek, and the Ford River were rated as in very poor condition at the lower sites (Sites 34,37 and 41, respectively) and in near natural condition for the upper sites (35, 38, and 42, respectively).

The stream-side zone at both Rose Rivulet sites rated as in very poor condition (Sites 17 and 18) due to encroachment of weed species and low indigenous plant cover, which is typical of reaches adjacent to agricultural zones within the catchment.

Sites on the St Patricks River varied from very poor to near natural condition. As with the physical form sub-index there was a distinct decrease in riparian condition within agricultural areas. The lower sites such as reaches surveyed above Watery Plains and at Nunamara (Sites 19 and 20) and the upper sites, those at Corkerys Road and at East Diddleum Road (Sites 23 and 24) rated as in 'near natural' condition. Those sites that rated in lower condition were adjacent to agricultural areas, with St Patricks River at Pecks Hill Road (Site 21) rated as very poor and St Patricks River at Targa Hill Road (Site 22) rated as in moderate condition.

There were no clear patterns and a wide variation for stream-side zone ratings for tributaries on which a single site was selected. These ranged from very poor to essentially natural condition. Kingsmeadows Rivulet (Site 16) and Old Mill Creek (Site 36) rated as in very poor condition. Coquet Creek, Barrow Creek, and Camden Rivulet (Sites 28, 29 and 32, respectively) rated as in poor condition. Stream side zones of moderate condition were surveyed at sites located on Bennies Creek and River O 'Plain Creek (Sites 29 and 39), whilst Weavers Creek (Site 33) rated as near natural.

Index ratings clearly illustrate a trend between the condition of stream reaches and adjacent land use with those sites rated with the greater degree of departure from a natural state within urban and agricultural areas. Ratings were generally found to improve in the mid-section and top of the main channel where development is low. This trend of improved condition upstream where development has been minimal also applies for most tributaries where multiple sites were assessed.

Figure 6. IRC results for the North Esk River tributaries.

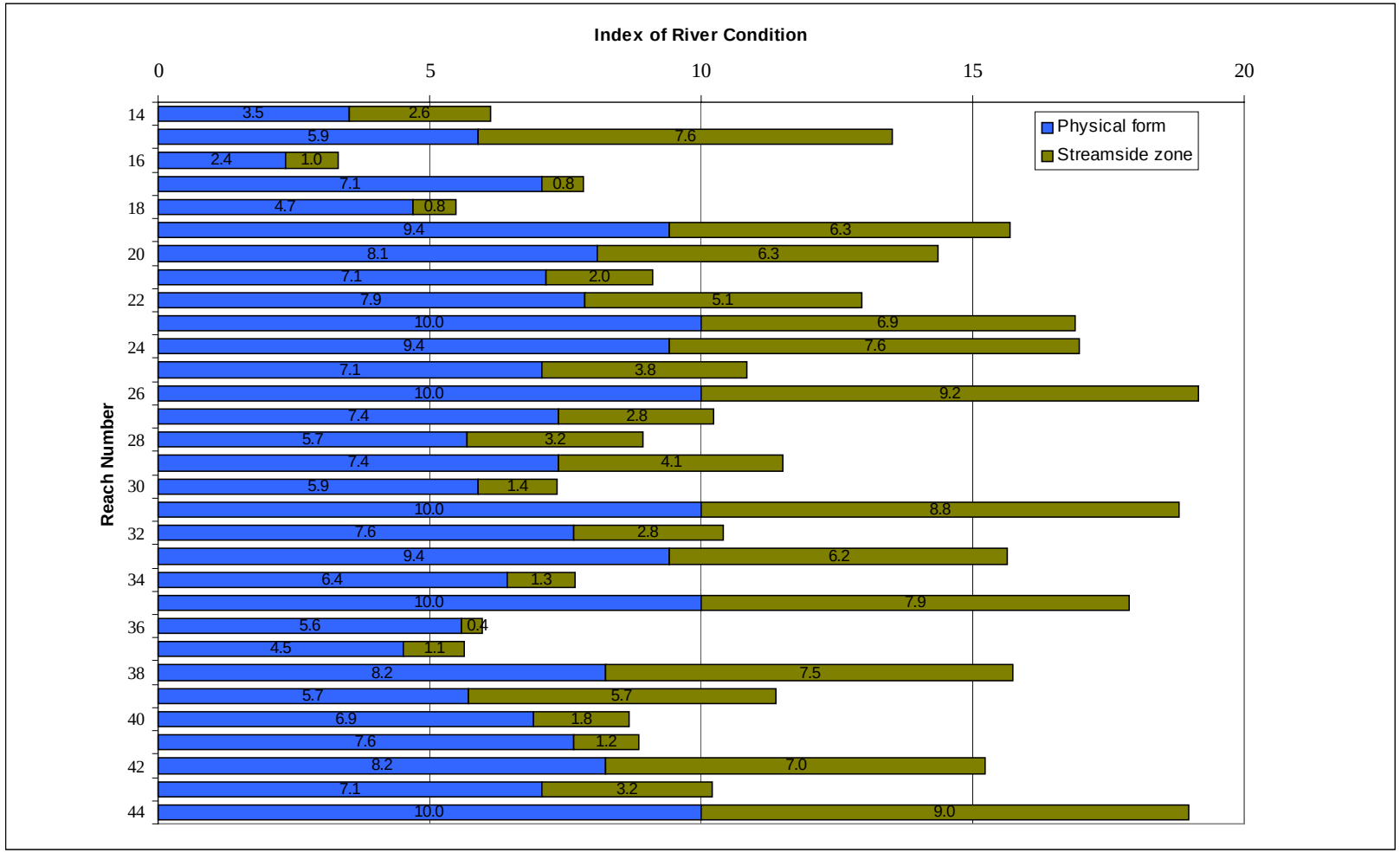


Figure 7. North Esk River Catchment. Physical form sub-index ratings.

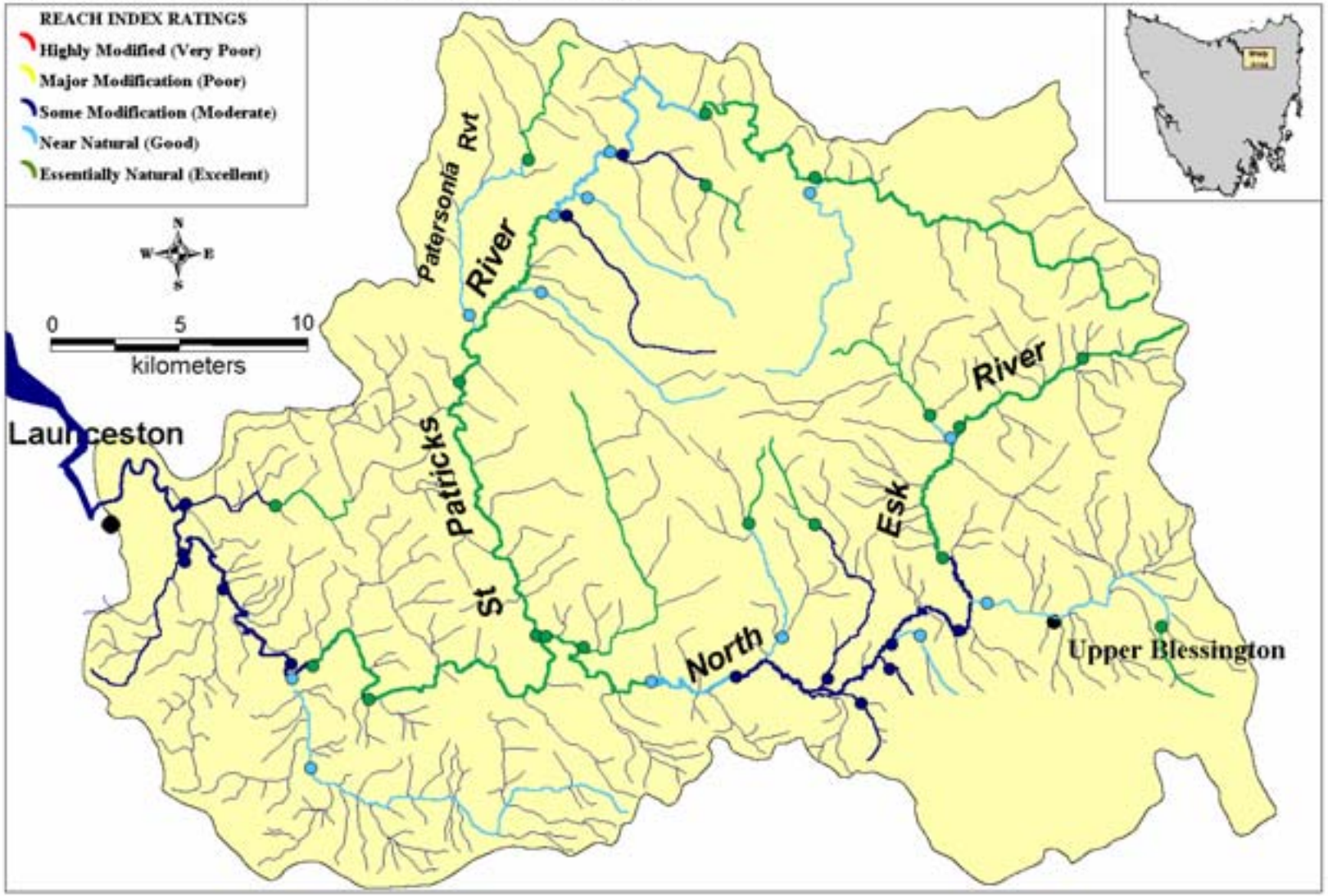
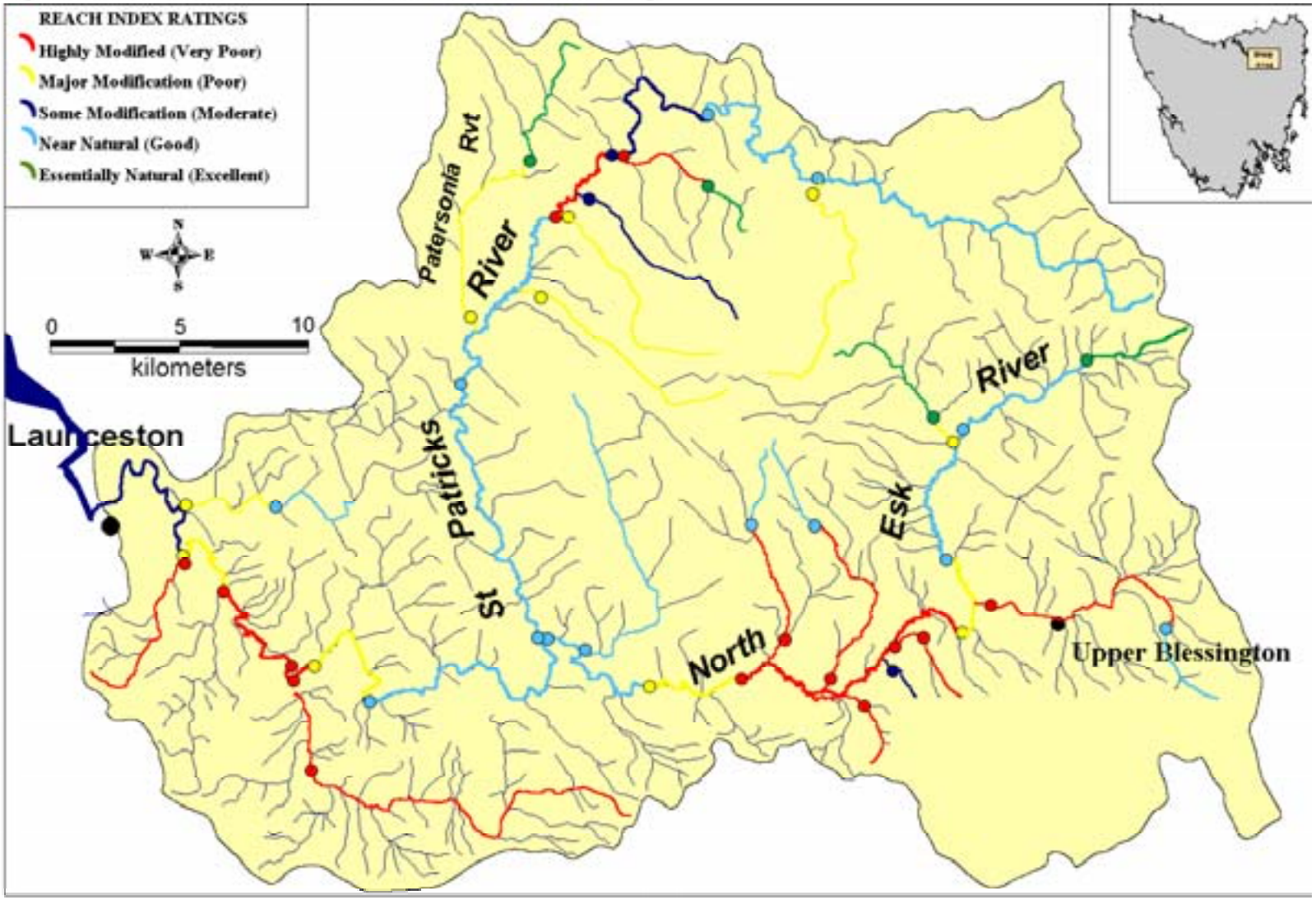


Figure 8. North Esk River Catchment.Streamside zone sub-index ratings



4.3 Hydrological Connectivity

Records of fish locations have been reviewed for the North Esk catchment. Table 6 provides a summary of which native and introduced species are known from the catchment, the fishes movement habit and the number of verified records.

Of the 120 records below 42% relate to native fish whilst 58% are from introduced species. *Gadopsis marmoratus* (River Blackfish) is the only native fish recorded for the catchment that is non-migratory. This species has however been translocated to the North Esk catchment (D.Jarvis, Inland Fisheries Service, pers.comm., 2000).

Table 6. Inventory of fish species for the North Esk catchment (IFS database).

Species name	Common name	Movement	Number of records
Anguilla australis	Short-finned eel	Catadromous	28
Geotria australis	Pouched lamprey	Anadromous	1
Galaxias brevipinnis	Climbing galaxias	Diadromous	2
Galaxias maculatus	Jollytail	Diadromous	1
Gadopsis marmoratus	River Blackfish	non migratory	8
Mordacia mordax	Short-headed lamprey	Anadromous	9
Prototroctes maraena	Australian grayling	Amphidromous	1
Oncorynchus mykiss	Rainbow trout	Anadromous	1
Salmo trutta	Brown trout	Anadromous	69

Fish surveys previously carried out in this catchment have concentrated on the main streams of the North Esk and St Patricks river systems, and also in major tributaries. Therefore no information is available for the minor tributaries on which many of the dams and culverts are situated. Analysis of fish distribution records in respect to barrier location indicates that large weirs (those on the St. Patricks River at Nunamara and North Esk River at Chimney Saddle) are likely to have the greatest effect on fish movement within the catchment.

Dam sites for the North Esk system were identified from the WIMS (Water Information Management System) database and their positions within the catchment are provided in Appendix 3a, with rating details in Appendix 3c and Figure 9. Figure 9 clearly illustrates that the majority of dams occur within the lower section of the main catchment on tributaries and along the St Patricks River. Proposed dam developments for the catchment have been located on tributaries and therefore the hydrological connectivity on smaller rivers and streams are likely to be further fragmented. This means dams will exert the greatest effect on tributaries rather than the mainstream. The pattern of development has implications for the catchment in terms of fish movement management as several individual tributary systems have the potential to become hydrologically disconnected from the remainder of the catchment.

Thirty nine in-stream structures were assessed within the catchment to determine their potential effect on fish movement. Seventeen of these were identified as moderate to extensive barriers to fish passage. An overview of barriers of concern is given in Table 7 below. Four digit numbers indicate identifiers in the Water Information Management System (WIMS) database. Only one of these was located on the North Esk mainstream and the remaining 16 on tributaries. The location, type and rating for all barriers surveyed for the catchment are provided in Appendix 3c.

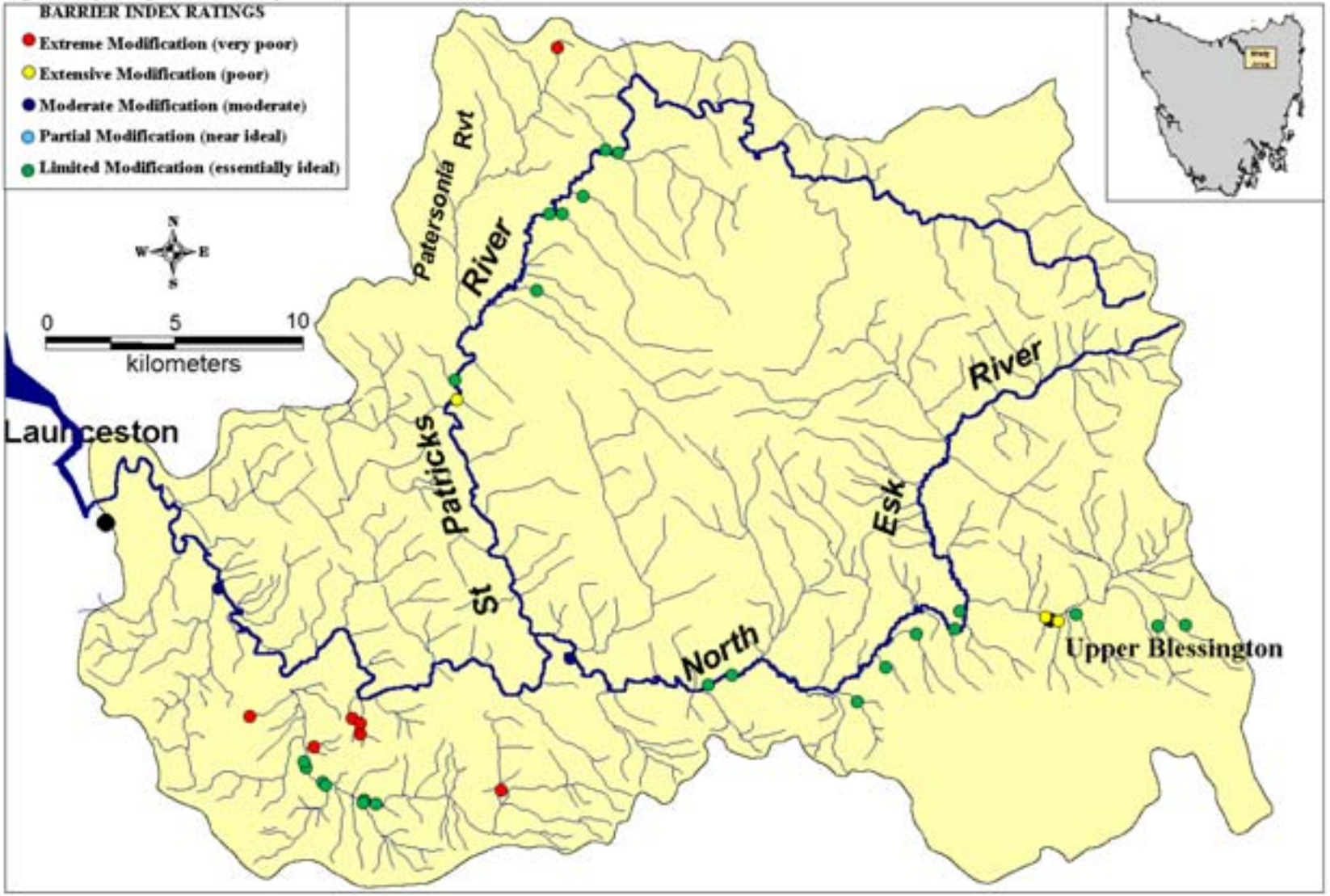
Culverts and dams within the catchment tend to be situated on minor tributaries. The small sub-catchment areas upstream of these structures represents a small proportion of the overall habitat available within the catchment and as such are likely to have little effect on fish passage in relation to the catchment as a whole.

Table 7. In-stream structures rated as moderate to extensive barriers to fish passage.

Barrier location	Easting (m)	Northing (m)	Type	Rating
Dam (2652)	521300	5404000	Dam	extensive
Dam(2651)	521000	5404600	Dam	extensive
Dam(2653)	521300	5404400	Dam	extensive
Dam(2670)	529000	5431200	Dam	extensive
Dam(2671)	529000	5430800	Dam	extensive
Dam(2672)	529000	5430800	Dam	extensive
Dam(2673)	529000	5430800	Dam	extensive
Dam(6814)	519500	5403500	Dam	extensive
Rose Rivulet at Elverton Lane	521900	5401250	Bridge	moderate
Rose Rivulet at Relbia Rd	519850	5402100	Bridge	moderate
Tributary off Rose Rivulet	519950	5402000	Bridge	moderate
Tributary off Roses Tier Rd	548050	5408550	Culvert	moderate
Tributary off Roses Tier Rd (2)	548550	5408400	Culvert	moderate
Dam (2645)	517000	5404700	Dam	moderate
Dam (2647)	526800	5401800	Dam	moderate
North Esk at Clarks Ford weir	515750	5409700	Weir	moderate
St Patricks at Nunamara off take	525090	5417050	Weir	moderate

Of the in-stream structures surveyed, 2 major weirs were identified to have the greatest effect on overall fish movement. The weir on the St. Patricks River at Nunamara was rated as a more complete barrier than the weir on the North Esk River at Clarks Ford Bridge. Clarks Ford Weir also scored a lower rating due to poor stream-side conditions and the weirs position within the lower catchment. The Chimney Saddle water supply weir rates as partially modified (although the rating bordered the “moderate” band). In the absence of the fish passage device the weir would have rated as of moderate effect upon condition.

Figure 9. Hydrological connectivity for the North Esk catchment



5. DISCUSSION

Physical River Condition and Stream Side Zones

The variable nature of the IRC ratings for both stream-side zones and the physical condition of reaches surveyed reflects the diverse nature of land use in the North Esk River catchment. The comparatively undisturbed condition of the stream-side zone and physical condition of reaches is evident in the upper 3 sites surveyed on the North Esk River mainstream. It is clear from the information collected that the index scores of some sites within the catchment vary away from a 'near natural' state to moderate or significant degree for either or both indices (27 of 44 sites). Management issues have been identified in relation to poor ratings for physical form and stream-side zone (refer to Figure 8) and are provided in Tables 9 and 10. There was a clear trend for an improvement in river condition in an upstream direction for tributaries on which multiple sites were surveyed. This is clearly shown in Seven Time Creek, Ford River and Patersonia Rivulet, where both index ratings were markedly improved at the upper sites. Rose Rivulet did not follow this trend as it was influenced to the same degree by adjacent land usage practices throughout its length. The predominant factors influencing site condition throughout the catchment were the presence of a variety of exotic species in the stream-side zone. Introduced species such as Crack Willow (*Salix fragilis)*, blackberries (*Rubus fruticosus)*, hawthorn (*Crataegus monogyna)* and thistles (*Cirsium vulgare*), were found to be well established in certain sections of North Esk River and many of the tributaries. Blackberries were found at 22 of the 44 sites. Many exotic species commonly found along riverbanks in Tasmania are early colonising species with high reproductive rates and rapid dispersal capabilities (Read, 1999). Such species are well adapted to colonising areas where riparian disturbance has occurred. The prolific growth of weed species can be inhibitory to the growth of native species within the riparian zone (CEAH, 1997c). For example, intense shading by willow tree canopies can inhibit the light environment suitable for the growth of seedlings of many native species (Read, 1999). In addition, the presence of pasture grass and other weeds does not provide the deep soil-root matrix required to support the river embankment, particularly from the effects of erosion (Abernethy and Rutherford, 2000). It was also noted at many sites that stock has unrestricted access to stream banks. This frequently creates excessive bank erosion and may lead to increased sediment load into a watercourse. Willows also occur at 22 of the 44 sites including 11 sites on the mainstream. The effects of willows, if they become too well established, include:

- altered run off patterns due to a lack of understorey (Collier, 1995);
- altered in-stream habitat (Read and Barmuta, 1999);
- inhibition of primary production through reduced light penetration (Nelson, 1999a);
- increased sedimentation and organic load - nutrient increases (Suter, 1990);
- reduced low flows - decreased dissolved oxygen levels (Bobbi, 1999).

Generally, sites located within agricultural and urban areas usually lacked riparian vegetation. The stream-side zone is the interface between the aquatic and terrestrial environment and acts as an important buffer to any activities that may occur in the adjacent land zone. Riparian vegetation can provide significant protection for streams through:

- reducing potential sediment runoff from forestry, farming or roadwork activities (Collier, 1995);
- filtering chemical sprays from intensive agriculture or forestry (Davies *et al.*, 1994);
- increasing stability and inhibiting erosion (Abernethy and Rutherford, 1999); and
- reducing water temperature through shading effects (Collier, 1995).

Hydrological Connectivity

The location of a barrier within a catchment can influence its impact on fish populations. Where the catchment area upstream of a barrier is small, the proportion of upstream habitat in relation to the whole catchment is low. In such instances even a complete barrier may isolate only a small proportion of a catchment and prevent fish populations from travelling past it. As a result, the impacts in relation to the whole catchment are comparatively small. In contrast, barriers to fish migration in the lower reaches of a system have the potential to cause the greatest effect on fish recruitment and distribution upstream. The cumulative effect of barriers along a river may result in populations becoming reduced, even when individual barriers have a low effect on movement.

Dissimilarities often occur in relation to fish community composition on either side of a physical structure and the degree of dissimilarity is largely a function of how effective a barrier is to preventing passage. Barrier effectiveness is also partly determined by the ability of each fish species to migrate past it. For example, species such as the short-finned eel (*Anguilla australis*) which can move across land and the Climbing galaxias (*Galaxias brevipinnis*) which can climb steep gradients are able to negotiate barriers more easily than those species that rely purely on swimming, such as the Jollytail (*Galaxias maculatus*).

Overall, fish passage and hydrological connectivity was found to be of a partially modified condition. In addition to artificial structures such as weirs, farm dams, culverts, and road crossings that have the potential to act as physical barriers, less tangible physical and behavioural barriers are also likely to affect fish movement within the system. For instance erosion control, willow removal and other kinds of in-stream works can act as temporary barriers to fish movement during operations and depending on the degree of disturbance may prevent fish movement for a period of time after works have been completed. Physical disturbance of the in-stream environment may evoke a behavioural response as a result of changes to water quality parameters. Such changes may include low oxygen levels, high turbidity, high nutrient loads and reduced flow. These changes have the potential to affect fish physiology and movement. As adverse conditions may be inadvertently created during in-stream rehabilitation works, the timing of river management activities taking into consideration the requirements of migrating fish species and periods of peak fish movement (e.g. migration) is an important when planning river restoration activities.

Main-stream North Esk River

The IRC assessment indicates that the sites on the main-stream North Esk River display varying degrees of departure from a natural condition. It is evident that some impacts are related to adjacent agricultural and urban land use practices. Stream side zone conditions at each site are also influenced by the presence of non-native species in the stream-side zone, principally crack willow, gorse and blackberries.

Physical form rated as in good condition overall, while the condition of the stream-side zone was clearly more impacted, particularly in the lower and middle sections of the catchment. The overall stream-side zone condition rated as in moderate condition, though the stream-side zone index borders on poor condition.

Specific management issues identified for the mainstream North Esk River sites are provided in Table 5. Identified management issues include the presence of Crack Willow at 11 of the 13 sites (effectively throughout the mainstream reaches), the presence of understorey weed species such as blackberries and thistles, limited riparian zones at most sites, stock access and resultant bank side erosion at a number of sites.

The hydrological connectivity of the mainstream was identified as altered at 1 site (Clarks Ford Bridge weir) by a moderate degree. The open structure of the Clarks Ford weir allows for drowning out throughout the majority of the year and thus is likely to provide little impediment to fish passage. The moderate rating site at this site has resulted from an extremely modified riparian zone and the position of the barrier within the lower catchment rather than barrier effectiveness. It must be noted that 84% of the catchment occurs upstream of this barrier.

The weir at the Chimney Saddle was rated as having a partial to moderate effect on hydrological connectivity and was assessed as likely to have a greater effect on fish passage than the weir at Clarks Ford. This is due to barrier effectiveness as the Chimney Saddle weir is a closed structure that relies on a full impoundment to drown out. A fish passage device has been incorporated into the weir, which may facilitate fish passage. Delays in passage are likely to be due to various species locating the device and also in relation to smaller species encountering difficulties negotiating the device itself due to flow resistance. However, it was beyond the scope of this study to determine passage rates for fish species through this device.

Of the 25 species of native freshwater fish in Tasmania, 11 are known to have migratory components to their lifecycles (Fulton, 1990). However regardless of migratory habit, all fish species require "within river" movement to find preferred habitat and this may require movement and colonisation over varying distances depending on territoriality and individual species preferences. Six native fish species have been recorded from the North Esk catchment that require unimpeded passage between the lower reaches and headwaters**.** Fish are frequently denied access to areas upstream of physical barriers (Walker, 1999) and in many instances habitat present in these upstream reaches (eg; spawning sites on gravel beds) are essential for the completion of the fishes life history.

Analysis of fish distribution records (Inland Fisheries Services database and GTSPOT) inidicate that four native fish species occur upstream of the Chimney Saddle weir. These are *A. australis, G. brevipinnis,* the pouched lamprey (*Geotria australis*), and the translocated *G. marmoratus*. *G. marmoratus* is non-migratory and also occurs below the Chimney Saddle weir. *G. brevipinnis* and *A. australis* are capable of climbing and or movement across moist surfaces (Walker, 1999) and therefore it is unlikely that populations would be affected by the weir. A single *G. australis* record is known upstream of the weir suggesting poor conditions of passage for this species.

If passage across is not favourable for different species, there is the potential for genetically distinct populations to arise. This has ramifications for genetic diversity with the potential to lower the populations ability to adapt to changes in environmental conditions (Walker, 1999). Unfortunately, it was beyond the scope of this study to determine passage rates for fish species through this structure.

Tributaries of the North Esk River

The condition of tributary streams in the North Esk catchment were found to be influenced by adjacent land use practices such as farming and in certain areas urbanisation in a similar fashion to mainstream sites. Overall, physical form rated as in good condition whilst stream-side zones were rated as in moderate condition. Of these two indices, the overall river condition of tributary reaches was primarily influenced by riparian condition. The predominant impacts surveyed are as follows:

- Stream bank erosion due to the lack of stream-side zones.
- Uncontrolled stock access to stream banks.
- Presence of exotic plant species.
- Limited indigenous plant regeneration.
- Farming practices that limit riparian zones.

The most common disturbances to the riparian zones on tributaries were related to extensive weed infestation (crack willow and blackberries) or conversely, limited to no riparian vegetation. Stock access to stream banks was also identified as a significant impact. Specific management issues for each tributary study reach are provided in Table 8.

Overall the hydrological connectivity of the tributaries displayed some modification with the ratings for individual tributaries varying throughout the catchment. A general trend was observed for improved hydrological connectivity for tributaries within the upper catchment.

Given the particular nature of disturbance to physical river condition at each tributary site, details on site condition in relation to ratings for physical in-stream condition, stream-side zone and hydrological connectivity ratings are discussed below.

Distillery Creek. (Sites 14 and 15)

Site 14 is the lowest on this tributary and was rated as in moderate condition in respect to physical form and in poor condition in relation to the stream-side zone. Site 15 was rated as in excellent condition for physical form and good condition for stream-side zone. In general, riparian vegetation health for the Distillery Creek is very poor, with sparse indigenous plant regeneration. Excessive siltation and unlimited stock access was evident for the lower tributary site. In addition, Distillery Creek is a conduit for water transfer from the St Patricks River to Esk Water Reservoirs. Therefore the system has an augmented flow regime and this has been shown to deleteriously impact on elements of the aquatic biota (Read and Seamer, 1998, Krasnicki *et al*., 2001). Hydrological connectivity has also been altered within this system through the input from the St Patricks River. The water race is likely to provide limited opportunities for fish passage. Fish passage up to this point is little influenced by in-stream barriers. Poor water quality (refer to Water Quality report) and physical factors such as erosion may also influence the movement of fish into the tributary.

Kings Meadows Rivulet (Site 16)

Only one site was assessed for this tributary. The physical-form sub-index indicates a high degree of modification (moderate condition) for the site. Physical form indicators of Coarse Woody Debris and Overall Site Disturbance highlight the major or extreme variation of this site from ideal conditions (see Appendix 2). The stream-side zone sub index rates as highly modified from natural condition. With the exception of structural intactness the stream side zone indicators suggest major to extreme modification of condition. The limited riparian zone is dominated by exotic species such as willow, hawthorn, poplar (*Populus spp.*) and

blackberry. Indigenous plant regeneration is limited for the reach. Extensive areas of erosion were also identified during the survey.

Hydrological connectivity for this system has been extensively modified. Extensive channel alteration is evident with multiple culverts, road crossings and other structures due to urbanisation. Poor water quality (refer to Water Quality report) and physical factors such as erosion are likely to be an impediment for fish movement within this tributary.

Rose Rivulet (Sites 17 and 18)

The physical form sub-index rates as good or near natural for both Site 17 (lower tributary) and Site 18 (upper tributary). Of all physical form indicators, Coarse Woody Debris and Overall Site Disturbance were the most modified from a natural state.

The stream-side zone sub index rates as very poor for the entire tributary. All stream side zone indicators for this index display major or extreme modification from a natural condition (Appendix 2). The poor stream-side zone rating is reflected by the lack of indigenous plant regeneration, dominance of exotic species such as crack willow and Cumbungi (*Typha spp.*) and overall limited riparian cover.

The hydrological connectivity of this system is one of the most fragmented within the catchment. There is some direct effect on the main tributary from road crossings and in-stream structures such as dams. Many of the minor tributaries have on-stream dams, which have a cumulative effect on hydrological connectivity. This has implications for fish passage, as movement is limited by the low availability of water. This effect is a function of reduced habitat availability for fishes under low flow conditions. At the time of sampling many of the minor tributaries were typified by disconnected pools or completely de-watered. Changes to flow regimes in regulated rivers have been identified as a factor influencing fish passage (Mallen-Cooper, 2000).

The poor water quality for the tributary (see Water Quality report) has the potential to invoke behavioural avoidance responses in fish that are present. Behavioural barriers arise when changes to the aquatic environment affect fish physiology and result in individuals avoiding conditions that can cause physiological stresses (Thorncraft and Harris, 2000). These factors may further reduce the likelihood of successful fish passage into this tributary. In this instance low oxygen concentrations, high conductivity and elevated turbidity levels are likely to invoke behavioural responses. These factors have been found to be key elements that result in physiological stress in fish (Mallen-Cooper, 2000).

St Patricks River (Sites 19 to 24)

St Patricks River is the second biggest stream within the North Esk River catchment. This system is also highly influenced by agricultural practices. For this reason 6 sites were chosen to comprehensively assess river condition in this system. A high degree of variation in river condition was evident along the St Patricks River. The physical form sub-index rates as excellent for Sites 19,20,23 and 24, and as good for Sites 21 and 22. The stream-side zone for the remaining sites rated as in near natural condition. Management issues include the presence of weed species such as blackberries (Sites 20 & 21), gorse (Sites 21 & 24), willows (Sites 20-22) and hawthorn (Sites 21 & 22). There is also limited to no riparian zone and limited to no indigenous plant regeneration at Sites 21 and 22. Stock access to the river banks was evident at Sites 20 -22. It is evident that intensive agricultural activities have clearly affected the middle reaches of the St Patricks mainstream.

The hydrological connectivity for the St Patricks tributary rates as of moderate condition. This is based on ratings for the Nunamara weir and 3 road crossings. The weir at Nunamara rated as moderate in relation to hydrological connectivity as upstream of this point, 87% of the St Patricks catchment area is subject to modified fish movement conditions. Four migratory native fish species have been recorded from upstream of the weir (*A. australis*, *G. maculatus*, *G. australis* and the short-headed lamprey *M. mordax*).

Patersonia Rivulet (Sites 25 and 26)

Patersonia Rivulet displays a trend of increasing naturalness in an upstream direction. This is a common trend for the entire catchment, where it has been found that index condition typically reflects the intensity of surrounding land usage. The physical form sub index for the lower section rates as near natural, with no indicators suggesting a major or extreme difference from the natural condition. The physical form sub-index for the upper section rates as excellent or essentially natural. Stream-side zone condition was markedly different between Sites 25 and 26. Site 25 rates as in poor condition for 4 of the 7 indicators indicating a major or extreme change from natural condition (Appendix 2). In addition, poor riparian structure, limited cover by native species, a high proportion of exotics (willow, blackberry, hawthorn and ragwort (*Senecio jacobea*)) along with poor longitudinal continuity are obvious management issues for this reach. In contrast the stream-side zone at Site 26 was rated as essentially natural, with no indicators suggesting extreme or major modification and therefore no specific management issues have been identified for this site.

Hydrological connectivity is relatively unaffected for this tributary. Four in-stream dams (off Old Lisle Rd) have an extensive influence on hydrological connectivity by regulating the headwaters of one minor tributary (Figure 9). These are likely to have limited overall effect from a catchment perspective due to the small catchment area upstream. The ability of fish to move into this system will be further influenced by the Nunamara weir.

Coquet Creek (Site 27)

The physical form sub-index was rated as near natural, whilst the stream-side zone sub-index was rated as poor (major modification) for the single site assessed on Coquet Creek. Impacts included the extensive cover of blackberries, poor riparian vegetation cover and continuity, unrestricted stock access to stream banks and spot erosion on the stream banks. Fish passage potential for this tributary was rated as partially modified. The highway crossing provides for natural stream bed conditions and no other in-stream barriers were recorded. The weir at Nunamara is likely to further influence fish passage in this tributary.

Barrow Creek (Site 28)

The physical form sub-index was rated as of moderate condition at this site while the stream-side zone was found to be in poor condition (major modification) with four of the seven parameters of the stream-side zone sub-index subject to major to extreme modification. Management issues identified for this reach include the erosion and channelisation of stream banks, the presence of blackberries and limited indigenous plant regeneration. The hydrological connectivity for this tributary rated as partially modified. This rating is based on assessment of a single road crossing (Tasman Highway). Again, the weir at Nunamara has been identified as a downstream barrier that may further affect fish populations in this tributary.

Bennies Creek (Site 29)

For this tributary physical form rates as in good or near natural condition, whilst the stream-side zone shows some modification. Management issues include the presence of extensive blackberry growth, limited indigenous plant regeneration and spot erosion. At present the cover of blackberries acts as a barrier to stock access to the stream banks. Stock access issues will need to be incorporated into weed management strategies for this site.

A natural barrier is present on this tributary (Barrow Falls) which was assessed as an impediment to fish movement. Hydrological connectivity within this tributary is little altered by artificial structures and was found to be only partially modified. As this tributary is upstream of the Nunamara, recruitment rates will be influenced by changes in hydrological condition at the weir.

Seven Time Creek (Sites 30 and 31)

The Seven Time Creek catchment like many other tributaries along the North Esk shows an improvement in river condition scores from the lower to the upper site. Site 30 shows some modification to physical form and high modification to the stream-side zone with 6 of the 7 parameters for stream-side zone being modified to an extreme or major degree (see Appendix 2). For Site 31 both sub-indices were rated as excellent. Management issues for the lower site include the presence of willow and blackberry, limited riparian width and poor indigenous plant cover. Unrestricted stock access has also been identified as a potential management issue. No specific management issues have been identified for the upper reach.

The hydrological connectivity of this tributary was rated as partially modified. A small barrier is associated with the highway crossing. This may result in a delay of fish passage during low flows when the barrier is not drowned out. Fish passage for this section is further influenced by the Nunamara weir.

Camden Rivulet (Site 32)

The physical form rating was near natural for this site whilst the stream-side zone rating was in poor condition. The riparian zone was sparse with limited indigenous plant regeneration and consisted largely of introduced species, primarily gorse and thistles. Stock access to the stream banks was evident. Adjacent land usage in the area is dominated by forestry activities.

As with the other tributaries of the St Patricks River fish passage potential for this tributary is partly effected by the Nunamara weir. No in-stream barriers were surveyed for the tributary. Forestry operations within the area are likely to have led to an increase in the number of minor road crossings within the tributary. Typically, crossings of minor streams incorporate elements, such as culverts, into their design. When such crossings are poorly constructed (eg: a perched culvert) the altered flow regime impacts upon hydrological connectivity and access to upstream habitat for fish species.

Weavers Creek (Site 33)

Physical form for this reach was rated in excellent condition while the stream-side zone was rated as in good condition. The structural intactness and overstorey regeneration indicators of stream-side zone suggest an extreme to major modification to natural condition. This is a result of the patchy canopy cover being provided by native vegetation. Previous fire damage to the riparian zone is evident and is a likely influence on the present condition through the promotion of understorey vegetation regeneration.

No in-stream structures have been identified that alter hydrological conditions from the headwater to the confluence of the tributary with the North Esk River. Fish passage within the mainstream leading to the tributary is affected by Clarks Ford weir within the lower catchment.

Musselboro Creek (Sites 34 and 35)

The physical form of the lower site (Musselboro Creek upstream of North Esk confluence) rated as near natural, although the reach showed evidence of moderate modification. Physical form for the upper site was rated as essentially natural. Stream-side zone condition for the lower site rated as very poor, whilst that of the upper site rated as near natural. Management problems for the lower tributary include the presence of weed species such as blackberries, limited to no riparian zone and no regeneration of indigenous plant species. No specific management issues were identified for the upper site. Hydrological connectivity for the tributary is little altered as all structures present allow for unimpeded flow conditions. Fish passage may be indirectly influenced by the Chimney Saddle weir and Clarks Ford weir on the North Esk mainstream.

Old Mill Creek (Site 36)

The physical form sub-index for this site displayed some modification (moderate) with the parameters of bed, CWD, and OSD being modified by a major or extreme degree (refer to Appendix 2). The stream-side zone was in very poor condition with all 7 indicators being modified to a major or extreme degree. The lack of indigenous plant cover, the very poor condition of the riparian zone and high proportion of exotic species all contribute to the low rating for the site. Management issues for the site include the presence of blackberry and thistles, poor riparian zone, spot erosion and uncontrolled stock access.

Hydrological connectivity rated as partially modified for this tributary, based on the assessment of the Blessington Road crossing. The poor IRC ratings for the study site indicate that conditions for fish passage may be unfavourable. Poor water quality for the site (refer to Water Quality section), particularly elevated conductivity and low dissolved oxygen have the potential to effect fish passage rates by invoking behavioural avoidance responses.

Burns Creek (Sites 37 and 38)

Physical form in the upper reach was rated in excellent condition while the lower reach was rated as in poor condition. Similarly, stream-side zone ratings were very poor for the lower reach and excellent for the upper reach. All 7 stream-side zone indicators suggest a major or extreme modification in the lower reach (refer to Appendix 2). Lower reach riparian vegetation was dominated by exotic weeds such as blackberries, willows, hawthorn and gorse. The upper reach had extensive groundcover of bracken fern (*Pteridium esculentum*) and nettles (*Urtica incisa*). Spot erosion was also identified as a management issue at both sites.

Hydrological connectivity in this system is little altered by in-stream structures. Road crossings were assessed as resulting in partial modification to connectivity within the tributary. Fish passage will be further influenced to some degree by the weir at the Chimney Saddle and Clarks Ford Bridge.

River O'Plain Creek (Site 39)

Both the physical form and stream-side zone were rated as of moderate condition, although these rating values lie close to the border of good condition (Appendix 2). Management issues for this site include the presence of weed species such as gorse, blackberries and bracken fern, low level regeneration of indigenous plant species within the riparian zone and stock access to the stream banks.

This tributary is affected by hydrological conditions at the Chimney Saddle weir on the North Esk and Clarks Ford Bridge weir. Poor water quality may act as a behavioural barrier to fish entering the tributary. Conditions within the tributary rated as partially modified on the basis of the Blessington Road crossing, which was the only potential barrier identified.

Pig Run Creek (Site 40)

Only one reach was surveyed on Pig Run Creek. The physical form sub-index was rated as near natural condition although the stream-side zone ratings indicate that condition of riparian vegetation is highly modified. Six of the seven parameters for the stream-side zone are modified by a major or extreme degree. Management issues include the presence of exotic weed species (bracken fern and thistles), poor riparian structure and cover, unrestricted access by stock and spot erosion.

Hydrological connectivity has undergone a partial modification to condition within the tributary, based on assessment of the Blessington Road crossing. The weir at Chimney Saddle out take is likely to influence fish movement into the region of the confluence. Fish movement into and within the tributary is likely to be influenced by the state of water quality, as well as the degree of hydrological connectivity.

Ford River (Sites 41 and 42)

The physical form rating was higher for the upper site (excellent condition) than for the lower site (good condition). At both sites the indicator for overstorey regeneration (Appendix 2) shows major or extreme variation from natural conditions. The stream-side zone rating also varied between the sites. The top site was found to be in good (near natural) condition, while the lower site was in moderate condition. Management problems for the lower reach were identified as the presence of weed species such as willows and blackberries, the low regeneration rate of indigenous plant species, the limited extent of the riparian zone and, partial stock access to the stream banks. No management issues were identified for the upper site.

Six road crossings were assessed for this tributary, 2 of which were bridges on the main channel and 4 were culvert crossings on minor tributaries. Both bridges were found to have a partial effect on hydrological connectivity whilst the culverts either had a partial or moderate effect. The culverts that rated as of moderate effect were on minor tributaries within areas lacking of riparian zone and subject to unchecked erosion. The potential for fish passage was reduced for these culverts due to the hanging nature of culvert structures. Icehouse Creek (a tributary of the Ford River) rated as partially modified due to poor passage condition (ie. presence of a culvert at bed level).

Beckett Creek (Sites 43 and 44)

Beckett Creek was the highest catchment tributary sampled. For the lower site physical form rated as in good condition, whilst the stream-side zone rated as in poor condition. Four parameters of stream-side zone deviate by a major or extreme degree from natural conditions (Appendix 2). The physical form and stream-side zone indices both rated as in excellent condition for the upper site. Management issues for the lower site are associated with the potential for stock access and potential for erosion and channelisation of the watercourse. No management issues were evident for the upper site.

Fish passage in this tributary may be affected by poor conditions near the confluence with the North Esk. Though in-stream structures vary hydrological conditions to a small degree, poor stream-side conditions have the potential to lower water quality (primarily through increased turbidity) and thereby deter fish passage as a deterioration in water quality may trigger avoidance behaviour in fishes.

As with the main-stream of the North Esk River, the tributary sites are subject to impacts resulting from adjacent land use practices such as farming and to a lesser extent forestry. These small streams have been found to be heavily influenced by riparian practices. General issues and impacts for tributaries overall include the following:

- erosion due to destruction of stream-side zones.
- uncontrolled stock access to streambanks.
- presence of exotic plant species.
- lack of stream-side vegetation.
- forestry practices including extensive plantations with no natural stream-side zones and limited understorey.
- limited indigenous plant regeneration.

Comparisons of physical form and stream side zone ratings indicate that the greatest loss of condition for tributary streams occurs in the stream-side zone. No single site stood out as badly impacted (poor or very poor condition) for both indices, though six sites scored within the moderate condition band for physical form and rated as either poor or very poor for stream-side condition (Figure 6). The most common problems encountered for the tributary streams were the presence of exotic weed species, unrestricted stock access to stream-side zones and limited stream-side vegetation at many sites. Management issues identified for individual sites are provided in Table 8.

Table 8. Management issues identified for the North Esk River tributary sites.

Reach	Management issues
Distillery Creek u/s confluence with North Esk	Weeds - Blackberry, willow. Limited to no riparian zone. Sparse indigenous plant regeneration. Potential stock access to river banks via no fencing.
Distillery Creek u/s of filtration plant	Potential for erosion during very high flows.
Kings Meadows Rivulet at Punchbowl	Weeds - Willow, blackberry, hawthorn, poplar. Limited riparian zone. Limited to no indigenous plant regeneration. Stock access to left bank. Potential erosion during high flows.
Rose Rivulet above confluence with North Esk River	Weeds - Gorse, willow, hawthorn, cumbungi. Unrestricted stock access to river banks. No indigenous plant regeneration.
Rose Rivulet at Lower White Hills Rd.	Weeds - Gorse, willow, hawthorn, blackberries and cumbungi (extensive cover). No indigenous plant regeneration.
St Patricks River at Watery Plains (u/s Nth Esk confluence)	Weeds - Gorse (sparse cover). Moderate indigenous plant regeneration. Stock access to river banks limited by riparian vegetation.
St Patricks River at Nunamara	Weeds - Blackberry (extensive cover), willow, bracken fern. Moderate indigenous plant regeneration. Stock access to river banks unrestricted.
St Patricks River at Pecks Hill Road	Weeds - Blackberry, willow, gorse, hawthorn, thistles. Limited riparian zone width and cover. Partial stock access to river banks. Potential for bank erosion
St Patricks River at Targa Hill Road Bridge	Weeds - Willow, hawthorn, ragwort and thistles. Moderate willow infestation. Limited indigenous plant regeneration. Unrestricted stock access to river banks.
St Patricks at Corkerys Rd	Native forest. No specific management issues.
St Patricks at East Diddleum Road	Weeds - Gorse (extensive cover).
Patersonia Rivulet at Patersonia Rd	Weeds - Willows, blackberry, hawthorn and ragwort. Limited riparian zone downstream of bridge. Stock access points associated with zones of erosion.
Patersonia Rivulet at Targa Hill	No specific issues.
Coquet Creek at Tasman Highway (Trout Ck)	Weeds - Blackberries. Poor riparian zone condition with limited indigenous species regeneration. Unrestricted stock access to river banks. Spot erosion associated with access points.
Barrow Creek at Tasman Highway	Weeds - Blackberries. Limited indigenous plant regeneration and cover. Some bank erosion and channelisation evident.
Bennies Creek at Tasman Highway	Weeds - Thistles, blackberries with extensive cover. Limited indigenous plant growth. Some bank erosion. Stock access limited by blackberry cover.
Seven Time Creek at Tasman Highway	Weeds - Blackberry and willow. Unrestricted stock access to each bank. Moderate erosion. Limited riparian zone width, poor indigenous cover.
Seven Time Ck at disused bridge off Camden Hill Rd	No specific issues.
Camden Rivulet at Diddleum Road	Weeds - Gorse and thistles. Limited indigenous plant regeneration and sparse riparian zone. Unrestricted stock access to river banks. Forestry plantation area
Weavers Ck (u/s. Nth Esk confluence)	Siltation of stream bed from forestry operations upstream.
Musselboro Creek u/s North Esk	Weeds - Blackberries. Limited riparian zone.
Musselboro Ck at track off	Forestry operations upstream. No other isssues

Musselboro Rd	
Old Mill Creek at Blessington Road	Weeds – Blackberry, thistles. Poor riparian zone. Spot erosion. Unrestricted stock access.
Burns Creek at "Elverton" property	Weeds – Blackberry, gorse, willow, hawthorn. Poor riparian zone. Spot erosion.
Burns Ck upper site	Weeds – Bracken fern, nettles and gorse. Spot erosion.
River O'Plain Creek at Blessington Road	Weeds - Blackberries, gorse, bracken fern. Some indigenous plant regeneration. Stock access evident.
Pig Run Ck at Blessington Rd	Weeds – Bracken fern. Poor riparian zone cover and width. Spot erosion. Unrestricted stock access to river banks.
Ford River below upper Blessington	Weeds - Blackberry, willow. Limited indigenous cover in riparian zone. Limited indigenous plant regeneration. Partial restriction to stock access.
Ford River above Upper Blessington	No management issues
Beckett Creek at Camden Rd	Potential stock access to river banks. Potential for erosion and channelisation
Beckett Creek at Simons Rd (off Camden Rd)	No management issues

6. CONCLUSION

The Index of River Condition methodology has identified potential issues for each reach within the North Esk catchment. Using the ratings generated from this study it is possible for river managers and community groups to target areas for river rehabilitation activities with management options aimed at improving the overall condition of impacted areas. These may include:

- Better stream-side zone management to allow the re-establishment of an appropriate buffer strip of native species
- Weed reduction and long term control programs
- Stream bank protection by limiting stock access and control of stream bank erosion.

The recently developed hydrological connectivity index has effectively demonstrated that it has the potential to identify the potential for in-stream structures to act as barriers to fish migration. The interpretation of ratings has identified areas in the catchment that restrict fish passage at present and should provide a basis for the planning of future in-stream storage development for the catchment. Future planning should aim to maintain and or alternatively improve hydrological connectivity within the system and ideally protect tributaries that currently have unrestricted fish passage.

The IRC has provided a baseline of information that can be used for comparative purposes to observe changes within the catchment over time. Ideally, to detect improvement or deterioration in riverine condition over time, an IRC assessment using the existing baseline sites should be repeated to determine if the overall condition of the catchment has improved or declined. The timeframe for re-assessment would depend on the scale of future river rehabilitation activities in the North Esk catchment.

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8. APPENDICES

APPENDIX 1. North Esk catchment site list with grid references for each study location.

Site No.	Site	Easting (m)	Northing (m)	Altitude (m)	Area (Km^2)
1	North Esk d/s confluence with Kings Meadows Rivulet	514200	5411100	5	935.6
2	North Esk u/s Clarks Ford Bridge	515750	5409700	5	893.6
3	North Est below Corra Linn	518400	5406800	18	801.8
4	North Esk at Corra Linn	519300	5406800	25	778.8
5	North Esk at White Hills	521450	5405400	88	769.5
6	North Esk u/s confluence with St Patricks	528400	5407850	218	434.5
7	North Esk at Ballroom	532500	5406100	325	362.6
8	North Esk at Musselboro Rd	535800	5406300	342	346.5
9	North Esk at Burns Creek Road	541900	5407550	375	313.2
10	North Esk at Wattle Corner (Camden Rd)	544500	5408100	390	203
11	North Esk off Camden Rd	543900	5410950	405	112.3
12	North Esk at Ben Nevis Rd	544200	5415600	440	45
13	North Esk Above "Northallerton" property	549350	5418700	475	7.2
14	Distillery Creek u/s confluence with North Esk	514300	5413050	10	51.1
15	Distillery Creek u/s of filtration plant	517800	5413000	120	36.4
16	Kings Meadows Rivulet at Punchbowl	514250	5410800	15	14.9
17	Rose Rt above Nth Esk	518500	5406200	20	81.7
18	Rose Rt at Lower White Hills Rd	519200	5402700	38	60.1
19	St Patricks at Watery Plains (u/s Nth Esk confl)	528000	5407900	210	335
20	St Patricks at Nunamara	525000	5417800	350	292
21	St Patricks at Pecks Hill Road	528700	5424300	375	202
22	St Patricks at Targa Hill Road Bridge	530900	5426800	390	165
23	St Patricks at Corkerys Rd	534600	5428300	435	125
24	St Patricks at East Diddleum Road	538900	5425800	540	108.5
25	Patersonia Rt at Patersonia Rd	525400	5420400	355	53.7
26	Patersonia Rivulet at Targa Hill	527700	5426500	400	17.6
27	Coquet Creek at Tasman Highway (Trout Ck)	528200	5421300	374	9.3
28	Barrow Creek at Tasman Highway	529200	5424300	380	13.5
29	Bennies Creek at Tasman Highway	530000	5425000	385	9.6
30	Seven Time Creek at Tasman Highway	531400	5426700	390	20.6
31	Seven Time Ck at disused bridge off Camden Hill Rd	534600	5425500	560	9.5
32	Camden Rivulet at Diddleum Road	538700	5425200	555	35.5
33	Weavers Ck (u/s. Nth Esk confluence)	529850	5407450	270	43.5
34	Musselboro Creek u/s North Esk	537600	5407850	355	30.4
35	Musselboro Ck at track off Musselboro Rd	536300	5412300	480	14.5
36	Old Mill Creek at Blessington Road	540700	5405250	380	9.9
37	Burns Ck at "Elverton" property	539400	5406200	365	19.4
38	Burns Ck (upper site)	538900	5412250	488	4.3
39	River O'Plain Creek at Blessington Road	541800	5406600	385	31.9
40	Pig Run Ck at Blessington Rd	543000	5407900	380	19.7
41	Ford below upper Blessington	544700	5408800	410	59
42	Ford above Upper Blessington	552410	5408240	525	13.6
43	Beckett Ck at Camden Rd	544200	5415600	440	30.7
44	Beckett Ck at Simons Rd (off Camden Rd)	543400	5416500	470	29.5

Appendix 2. IRC Sub-index ratings and indicator values for the North Esk River catchment sites.

		Physical form						Stream-side zone							
Site	Morphology	Physical form rating	Bank	Bed	Barrier	CWD	OSD	Stream-side rating	Riparian width	Struct. int.	% indig.	Regen.	LC	Overst regen.	SC
North Esk d/s confl. with Kings Meadows Rvlt	floodplain	5.9						2.9							
North Esk u/s Clarks Ford Bridge	floodplain	4.8						1.9							
North Est below Corra Linn	floodplain	6.7						1.2							
North Esk at Corra Linn	valley	8.2						3.8							
North Esk at White Hills	valley	10.0						7.1							
North Esk u/s confluence with St Patricks	valley	9.4						6.8							
North Esk at Ballroom	valley	7.6						3.9							
North Esk at Musselboro Rd	floodplain	5.2						0.5							
North Esk at Burns Creek Road	floodplain	5.9						1.0							
North Esk at Wattle Corner (Camden Rd)	floodplain	5.5						2.0							
North Esk off Camden Rd	valley	10.0						7.6							
North Esk at Ben Nevis Rd	valley	9.1						7.6							
North Esk Above "Northallerton" property	mountain	9.1						8.2							
Distillery Creek u/s confl. with North Esk	valley	5.9						2.6							
Distillery Creek u/s of filtration plant	valley	8.2						7.6							
Kings Meadows Rivulet at Punchbowl	valley	4.7						1.0							
Rose Rt above Nth Esk	valley	7.1						0.8							
Rose Rt at Lower White Hills Rd	valley	7.1						0.8							
St Patricks at Watery Plains (u/s Nth Esk confl.)	valley	9.4						6.3							
St Patricks at Nunamara	floodplain	8.1						6.3							
St Patricks at Pecks Hill Road	floodplain	7.1						2.0							
St Patricks at Targa Hill Road	floodplain	7.9						5.1							
St Patricks at Corkerys Rd	valley	10.0						6.9							
St Patricks at East Diddleum Rd	mountain	9.4						7.6							
Patersonia Rt at Patersonia Rd	valley	7.1						3.8							
Patersonia Rivulet at Targa Hill	valley	10.0						9.2							
Coquet Creek at Tasman Highway (Trout Ck)	floodplain	7.4						2.8							
Barrow Creek at Tasman Highway	floodplain	5.7						3.2							
Bennies Creek at Tasman Highway	floodplain	7.4						4.1							
Seven Time Creek at Tasman Highway	floodplain	5.9						1.4							
Seven Time Ck off Camden Hill Rd	valley	10.0						8.8							
Camden Rivulet at Diddleum Rd	mountain	7.6						2.8							
Weavers Ck (u/s. Nth Esk confluence)	valley	9.4						6.2							
Musselboro Creek u/s North Esk	floodplain	6.4						1.3							
Musselboro Ck at track off Musselboro Rd	mountain	10.0						7.9							
Old Mill Creek at Blessington Road	valley	5.6						0.4							
Burns Ck at "Elverton" property	floodplain	4.5						1.1							

Appendix 2. IRC Sub-index ratings and indicator values for the North Esk River catchment sites.

River O'Plain Creek at Blessington Road	floodplain	5.7						5.7							
Burns Ck (upper site)	valley	8.2						7.5							
Pig Run Ck at Blessington Rd	valley	6.9						1.8							
Ford below upper Blessington	valley	7.6						1.2							
Ford above Upper Blessington	valley	8.2						7.0							
Beckett Ck at Camden Rd	valley	7.1						3.2							
Beckett Ck at Simons Rd (off Camden Rd)	valley	10.0						9.0							

Indicator suggests major or extreme. difference from natural or ideal conditions

Inadequate data to evaluate sub-index.

Adequate data to evaluate indicator and ratings suggest changes have not been extreme or major.

CWD = Coarse woody debris
OSD = Overall site disturbance.
LC = Longitudinal continuity
SC = Stream-side cover.
Regen = regeneration of indigenous species.

Appendix 3a: Existing in-stream dam location details for the North Esk Catchment.

DAM_ID	EASTING	NORTHING	PURPOSE
2645	517000	5404700	IRRIGATION
2647	526800	5401800	IRRIGATION
2651	521000	5404600	STOCK & DOMESTIC
2652	521300	5404000	STOCK & DOMESTIC
2653	521300	5404400	STOCK & DOMESTIC
2670	529000	5431200	IRRIGATION
2670	529000	5431200	IRRIGATION
2671	529000	5430800	IRRIGATION
2671	529000	5430800	IRRIGATION
2672	529000	5430800	IRRIGATION
2672	529000	5430800	IRRIGATION
2673	529000	5430800	IRRIGATION
2673	529000	5430800	IRRIGATION
3518	514700	5403200	IRRIGATION
4140	517500	5402200	IRRIGATION
4521	544400	5410200	STOCK
6814	519500	5403500	STOCK & DOMESTIC

Appendix 3b: Proposed in-stream dam location details for the North Esk Catchment.

DAM_ID	EASTING	NORTHING	PURPOSE
6159	522100	5408100	STOCK & DOMESTIC
6160	523500	5409500	STOCK & DOMESTIC
6161	524600	5411500	STOCK & DOMESTIC
6210	530000	5428250	STOCK
6211	530150	5428250	STOCK
6212	530250	5428150	STOCK
6227	530000	5424100	STOCK
6210	530000	5428250	STOCK
6211	530150	5428250	STOCK
6212	530250	5428150	STOCK
6227	530000	5424100	STOCK

Appendix 3c: Artificial barriers - locations, type and rating for the North Esk River

Site	Easting (m)	Northing (m)	Type	value (0-10)	rating (0-5)
Barrow Creek at Tasman Highway	529200	5424300	bridge	6.6	3
Bennies Creek at Tasman Highway	530000	5425000	bridge	7.1	3
Coquet Creek at Tasman Highway (Trout Ck)	528200	5421300	bridge	6.9	3
Ford River above Upper Blessington	544700	5408800	bridge	7.1	3
Ford River below upper Blessington	552410	5408240	bridge	6.6	3
North Esk @ Wattle Corner (Camden Rd)	544500	5408100	bridge	6.6	3
North Esk @Aplico	534900	5405900	bridge	6.6	3
North Esk @Musselboro Rd	535800	5406300	bridge	6.6	3
Old Mill Creek at Blessington Road	540700	5405250	bridge	5.1	2
Pig Run Ck @ Blessington Rd	543000	5407900	bridge	6.6	3
River O 'Plain Creek at Blessington Road	541800	5406600	bridge	7.1	3
Rose Rivulet @ Elverton Lane	521900	5401250	bridge	4.3	2
Rose Rivulet @ Everton Property	521450	5401400	bridge	5.7	2
Rose Rivulet @ White Hills Rd	519200	5402700	bridge	5.4	2
Rose Rivulet @ Relbia Rd	519850	5402100	bridge	4.6	2
Rose Rivulet @ Watery Banks	519100	5402900	bridge	5.1	2
Seven Time Creek at Tasman Highway	531400	5426700	bridge	5.4	2
St Patricks @ Nunamara	525000	5417800	bridge	5.7	2
St Patricks @ Targa Hill Road Bridge	530900	5426800	bridge	6.3	3
St Patricks at Pecks Hill Road	528700	5424300	bridge	6.3	3
Tributary off Rose Rivulet	519950	5402000	bridge	4.6	2
Tributary off Rose Rivulet (2)	521400	5401300	bridge	6.6	3
Icehouse Ck @ Roses Tier Road	553500	5408270	culvert	6.6	3
Phillips Ck	549250	5408700	culvert	5.4	2
Tributary off Roses Tier Rd	548050	5408550	culvert	3.4	1
Tributary off Roses Tier Rd (2)	548550	5408400	culvert	3.4	1
dam (2651)	521000	5404600	dam	3.1	1
dam (2645)	517000	5404700	dam	3.4	1
dam (2647)	526800	5401800	dam	3.4	1
dam (2652)	521300	5404000	dam	2.9	1
dam(2653)	521300	5404400	dam	2.9	1
dam(6814)	519500	5403500	dam	2.9	1
North Esk @ Clarks Ford weir	515750	5409700	weir	3.7	1
North Esk@ Chimney Saddle out take	529500	5406950	weir	4.6	2
St Patricks @ Nunamara out take	525090	5417050	weir	4.0	2

Appendix 4: Overall site disturbance indicator categories for the physical form sub-index

1. EXTREME DISTURBANCE	
Riparian vegetation	**Absent or severely reduced. Vegetation present is severely disturbed - i.e.**
dominated by exotic	**species. Native species are rare or absent.**
Surrounding vegetation	**Agriculture and/or cleared BOTH sides. Plants present are virtually all exotic**
species (pines,	**willows, etc.)**
2. VERY HIGH DISTURBANCE	
Riparian vegetation	**Some native vegetation present, but it is severely modified BOTH sides by**
grazing	**or the intrusion of introduced species. Native species severely reduced in numbers**
(species richness) and cover.	
Surrounding vegetation	**Agriculture and/or cleared BOTH sides. Plants present are virtually all exotic**
species (pines,	**willows, etc.).**
3. HIGH DISTURBANCE	
Riparian vegetation	**Moderately disturbed by stock or through the intrusion of introduced species,**
though native species	**remain in reasonable numbers and abundance.**
Surrounding vegetation	**Agricultural land and/or cleared on ONE side; native vegetation on the other**
clearly disturbed or	**with a high percentage of introduced species.**
4. MODERATE DISTURBANCE	
Riparian vegetation	**Native vegetation on BOTH sides with canopy intact or with native species**
widespread and common.	**The intrusion of introduced species is minor and of moderate impact.**
Surrounding vegetation	**Agricultural land and/or cleared on ONE side; native vegetation on the other in a**
relatively	**undisturbed state.**
5. LOW DISTURBANCE	
Riparian vegetation	**Native vegetation on BOTH sides of the river in generally good condition with few**
introduced species	**present. Any disturbance is minor.**
Surrounding vegetation	**Native vegetation present on BOTH sides of the river with a virtually intact**
canopy. Minor	**disturbance present through introduced species.**
6. VERY LOW DISTURBANCE	
Riparian vegetation	**Native vegetation on both sides of the river in an undisturbed state. Introduced**
species are rare or	**insignificant. Representative of pristine condition.**
Surrounding vegetation	**Native vegetation on both sides of the river with an intact canopy. Introduced**
species are rare or	**insignificant. Representative of pristine condition.**