RIVER ECOCLASSIFICATION
MANUAL FOR ECOSTATUS DETERMINATION
(Version 2)

MODULE G
INDEX OF HABITAT INTEGRITY

SECTION 1: TECHNICAL MANUAL

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STRUCTURE OF THE MANUAL

The manual consists of the following modules:

⇒ MODULE A: ECOCLASSIFICATION AND ECOSTATUS MODELS
⇒ MODULE B: GEOMORPHOLOGICAL DRIVER ASSESSMENT INDEX (GAI)
⇒ MODULE C: PHYSICO-CHEMICAL DRIVER ASSESSMENT INDEX (PAI)
⇒ MODULE D: FISH RESPONSE ASSESSMENT INDEX (FRAI)
⇒ MODULE E: MACRO-INVERTEBRATE RESPONSE ASSESSMENT INDEX (MIRAI)
⇒ MODULE F: RIPARIAN VEGETATION RESPONSE ASSESSMENT INDEX (VEGRAI)
⇒ **MODULE G: INDEX OF HABITAT INTEGRITY**
Section 1: Technical manual
Section 2: Model Photo guide

This is Module G, Section 1, which is referred to in the document and with reference to page numbers to **Module G1**. Module G1 provides the background to and scientific rationale for the IHI as well as a detailed guide on how to use the IHI model.

PURPOSE OF THE MANUAL: MODULE G1

The purpose of this manual is to guide assessors on how to execute the model. This is done through a step-by-step process where the inputs and outputs of the model are explained. The rationale of the method is explained. The collection and interpretation of data collected during aerial surveys are explained in the appendices.

First time users of the model should have the manual at hand when executing the model.

WHO SHOULD APPLY THESE MODELS?

An experienced river ecologist with experience (in application of the first IHI version) and or training in the application of the IHI.
NOTE: It is strongly recommended that the user participates in training courses and/or contact the authors of this manual when applying the models

Reference is made in this manual where relevant to the Module G, Section 2 (Model Photo guide). Module G, Section 2 is referred to as Module G2 in this document. Wherever there is reference to Module G2, it indicates the page of the appropriate photos that provides rating illustrations.

EXECUTIVE SUMMARY

The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans 1996).

This document is a manual for the execution of the Index of Habitat Integrity model. The main section is a step-by-step guideline on how to run the model and the primary premises on which it is based. Detail on the rationale of the model and its constituent parts are also provided.

Habitat integrity assessment is approached from an instream and riparian zone perspective. Both of these are formulated according to metric groups, each with a number of metrics that enable the assessment of habitat integrity. The model functions in an integrated way, using the results from the assessment of metric groups, or metrics within a metric group, for the assessment of other metric groups where appropriate.

Assessment of habitat integrity is based on an interpretation of the deviation from the reference condition. Specification of the reference condition follows an impact based approach where the intensity and extent of anthropogenic changes are used to interpret the impact on the habitat integrity of the system. To accomplish this, information on abiotic changes that can potentially influence river habitat integrity are obtained from surveys or available data sources. These changes are all related and interpreted in terms of modification of the drivers of the system, namely hydrology, geomorphology and physico-chemical conditions and how these changes would impact on the natural riverine habitats.

Metrics are rated according to:

IMPACT/SEVERITY CLASS	DESCRIPTION	RATING
None: reference	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are very small.	0.5-1.0
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are limited.	1.5-2.0
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are not influenced.	2.5-3.0
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	3.5-4.0
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	4.5-5.0

Interpretation of the severity of impacts is based on the natural characteristics of the river. The premise is that the severity of impacts on the habitat integrity of a river will vary according to the natural characteristics of the river, i.e. particular river types will be more sensitive to certain impacts than other types.

Three attributes were considered in defining river types and determining the weights of metrics within metric groups for both the instream and riparian zone. In order of consideration these are:

- Perenniality: Perennial or non-perennial.
- Longitudinal geomorphic zone (Rowntree and Wadeson, 1999): A simplified approach was followed by using only four zones: source, mountain stream (including mountain headwater stream), foothill (combining the upper, lowland and transitional zones) and lowland.
- River size (width): Three width classes are distinguished, <5 m, 5-15 m and >15 m wide.

The relative importance of each of the metrics was assessed according to these considerations by using a pairwise comparison of metrics in a metric group. This weighting is automatically applied in the model when the river type is specified.

INSTREAM HABITAT INTEGRITY ASSESSMENT

This assessment is based on five metric groups:

1. Hydrological modification is based on the modification assessment of three metrics:
- Base (low) flows. A change in seasonality as well as the natural degree of perenniality is used as the basis of the assessment.
- Zero (no) flows. A decrease or increase in the natural frequency of no flow conditions (e.g. on the continuum: perennial to ephemeral) is the basis of the assessment.
- Floods. A change in the natural frequency of floods is assessed in terms of a change in the seasonality of floods. Large and moderate floods (including freshes) are assessed separately and combined in a matrix to derive an integrated rating for the impact on the instream habitat.

Hydrological modification is considered to be a primary determinant of change in several habitat characteristics and changes to it are considered in all the other metric groups.

Where the rating for base flow or zero flow exceeds 3.9, this rating is taken as representative of the metric group

2. Physico-chemical modification is based on the alteration of seven metrics that should be considered in terms of generally expected reference conditions:
- pH
- Inorganic salts

- Nutrients
- Water temperature
- Water clarity
- Oxygen concentration
- Toxics. This modification is generally considered as an anthropogenic change.

Where the rating for pH, water temperature, oxygen or toxics exceed 3.9, this rating (or the highest if all three exceed 3.9) is taken as representative of the metric group.

The operator has the option to enter the calculated value in the model or adjust this value according to motivated expert knowledge.

3. Bed modification has a direct bearing on the amount and substrate characteristics of available habitats. This relates to the cover provided by the substrate as well as feeding opportunities associated with a particular substrate and is considered in terms of a decrease or increase in:
- Sedimentation.
- Benthic growth. (Algal growth)

Where the rating for sedimentation exceeds 3.9, this rating is taken as representative of the metric group.

4. Bank modification is considered based on a change in cover for biota provided by:
- Marginal characteristics (vegetation and abiotic (e.g., undercut banks).
- Non-marginal characteristics (vegetation and abiotic).

5. Connectivity modification is assessed according to changes that would influence the life-history stage requirements and recolonization options of instream biota. These relate to changes that influence movement in terms of the following dimensions:
- Longitudinal. This is associated with the upstream and downstream movement of biota to avoid detrimental conditions as well as movement to particular required habitats.
- Lateral. Movement of biota onto floodplains, and side channels within the main river channel should be considered.

Instream Habitat Integrity Calculation: The metric group ratings are weighted according to the following percentages:
- Hydrology 100
- Physico-chemical 85
- Bed modification 80
- Bank modification 45
- Connectivity 65

These weighted ratings are summed and expressed as a percentage.

RIPARIAN ZONE HABITAT INTEGRITY

This assessment is based on three metric groups:

1. Hydrological modification. Four metrics are considered:
- Baseflow (approached in the same way as for instream assessment)
- Zero flow (approached in the same way as for instream assessment)
- Moderate floods and freshes
- Large floods play a specific role in the functioning and geomorphic characteristics of the riparian zone and are considered separately but in the same fashion as for the instream assessment with regard to a change in frequency and seasonality.

2. Bank structure modification is based on two metrics:
- Marginal and
- Non-marginal

These two metrics are rated based on the maximum rating for any of the following indicators:
- Substrate exposure
- Invasive vegetation
- Physico-chemical changes
- Erosion
- Channel straightening

3. Riparian zone connectivity is assessed according to the same principles as the instream connectivity but is based on fragmentation in the riparian zone. Changes in the structure and hydrology are used to assess changes in connectivity in terms of:
- Lateral
- Longitudinal

Riparian Zone Habitat Integrity Calculation: The metric group ratings are weighted according to the following percentages:
- Hydrology 75%
- Bank structure modification 100%
- Connectivity 50%

These weighted ratings are summed and expressed as a percentage.

HABITAT INTEGRITY INTERPRETATION

Both the instream and riparian habitat integrity index values are generically interpreted as follows:

HABITAT INTEGRITY CATEGORY	DESCRIPTION	RATING (% OF TOTAL)
A	Unmodified, natural.	90-100
B	Largely natural with few modifications. The flow regime has been only slightly modified and pollution is limited to sediment. A small change in natural habitats may have taken place. However, the ecosystem functions are essentially unchanged.	80-89
C	Moderately modified. Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged.	60-79
D	Largely modified. A large loss of natural habitat, biota and basic ecosystem functions has occurred.	40-59
E	Seriously modified. The loss of natural habitat, biota and basic ecosystem functions is extensive.	20-39
F	Critically / Extremely modified. Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible.	0-19

ABBREVIATIONS

Note: This list represenst the abbreviations for all the manuals.

ASPT	Average Score Per Taxon
BOD	Biochemical oxygen demand
COD	Cheical oxygen demand
DWAF	Department of Water Affairs and Forestry
EC	Ecological Category
EcoSpecs	Ecological Specifications
EIS	Ecological Importance and Sensitivity
ER	Ecological Reserve
EWR	Ecological Water Requirements
FAII	Fish Assemblage Integrity Index
FHS	Fish Habitat Segment
FRAI	Fish Response Assessment Index
GAI	Geomorphology Driver Assessment Index
HAI	Hydrology Driver Assessment Index
IHI	Index of Habitat Integrity
ISP	Internal Strategic Perspective
IFR	Instream Flow Requirements
MCDA	Multi-Criteria Decision Analysis
MIRAI	Macro Invertebrate Response Assessment Index
MRU	Management Resource Unit
NRU	Natural Resource Unit
P	Perennial
PAI	Physico-chemical Driver Assessment Index
PES	Present Ecological State
RDM	Resource Directed Measures
REC	Recommended Ecological Category
RERM	Rapid Ecological Reserve Methodology
RHP	River Health Programme
RU	Resource Unit
RVI	Riparian Vegetation Index
S	Seasonal
SASS	South African Scoring System
SP	Semi-perennial
SPATSIM	Spatial and Time Series Information Modelling
SS	Semi-seasonal
TDS	Total Dissolved Salts
TSS	Total Suspended Solids
VEGRAI	Riparian Vegetation Response Assessment Index

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1. INDEX OF HABITAT INTEGRITY

1.1 BACKGROUND

The habitat integrity of a river refers to the maintenance of a balanced composition of physico-chemical and habitat characteristics on a temporal and spatial scale that are comparable to the characteristics of natural habitats of the region (Kleynhans 1996). It is seen as a surrogate for the assessment of biological responses to driver changes. It is also an integrated assessment of driver state (Kleynhans and Louw 2007).

The original Index of Habitat Integrity (IHI; Kleynhans 1996) arose from the need to assess the present ecological state of rivers within the instream flow requirement process of the Department of Water Affairs and Forestry. The IHI was applied in several reserve determinations and is one of the set of indices used in the River Health Programme (RHP).

During the application of this index in different river assessments and the development of the EcoStatus approach (Kleynhans and Louw 2007), it became clear that the index should be reviewed and upgraded to form a logical part of the EcoStatus suite of methods.

The purpose of this manual is to guide assessors on how to execute the model. This is done through a step-by-step process where the inputs and outputs of the model are explained. The manual also explains the rationale of the method. Details concerning the collection and interpretation of data collected during aerial surveys are contained in the appendices.

First time users of the model should have the manual at hand when executing the model.

1.2 USE OF IHI WITHIN ECOCLASSIFICATION

EcoClassification (Kleynhans and Louw, 2007) - the term used for the Ecological Classification process - refers to the determination and categorisation of the Present Ecological State (PES; health or integrity) of various biophysical attributes of rivers relative the natural or close to the natural reference condition. The results of EcoClassification provide the information needed to derive desirable and attainable future ecological objectives for the river.

Due to time and funding constraints, various levels of Reserve determinations are undertaken, each with its own Ecological Water Requirement (EWR) method and EcoClassification process. The EcoClassification process, and specifically the detail and effort required for assessing the metrics, varies according to different levels (referred to as EcoStatus levels) linked to different EWR levels. The process to

determine the EcoStatus also differs on the basis of different levels of information. There are five EcoStatus levels and they are linked to the different levels of Ecological Reserve determination:

⇒ Desktop Reserve method → Desktop EcoStatus Level.
⇒ Rapid I Ecological Reserve method → EcoStatus Level 1.
⇒ Rapid II Ecological Reserve methods → EcoStatus Level 2
⇒ Rapid III Ecological Reserve methods → EcoStatus Level 3
⇒ Intermediate and Comprehensive Reserve methods → EcoStatus Level 4

The five levels have been fixed considering the known constraints regarding the Reserve methods at different levels and the River Health Programme (RHP). However, the combinations of the various tools applied during the EcoStatus levels can be used in different ways. This will usually depend on the site-specific situation, the available information, available expertise, funding and time. The IHI forms one of these tools and are part of EcoStatus Level 4 and Level 3. The Quick Habitat Integrity (related to the IHI and described in Kleynhans and Louw 2007) forms part of all the other levels. For detailed information on the different levels and the use of the IHI and Quick Habitat Integrity, refer to Module A of the EcoClassification manuals (Kleynhans and Louw, 2007)

1.3 THIS MANUAL

This manual is Section 1 of Module G (referred to as **Module G1**) and consists of the main technical manual for the IHI. Section 2 of Module G (referred to as **Module G2**) is a supporting document to Module G1 and provides an illustrated (photo) guide to accompany Module G1.

Cross-reference is made in Module G1 to the illustrations in Module G2 where applicable.

2. THE RATIONALE OF THE IHI

2.1 HABITAT INTEGRITY

The following concepts and definitions are relevant to river habitat integrity assessment:

- Biological integrity is the ability to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of natural habitat of the region (Karr and Dudley, 1981).
- Ecological integrity is the ability to support and maintain a balanced, integrated composition of physico-chemical and habitat characteristics, and biotic components on a temporal and spatial scale that is comparable to the natural characteristics of ecosystems of the region (Kleynhans 1996).
- Habitat integrity then refers to the maintenance of a balanced, integrated composition of physico-chemical and habitat characteristics on a temporal and spatial scale that is comparable to the characteristics of natural habitats of the region (Kleynhans 1996).
- The habitat integrity status of a river provides the template for a certain level of biotic integrity to be realized.
- Habitat integrity assessment is a precursor of the assessment of biotic integrity.
- Habitat and biotic integrity together constitutes ecological integrity (Kleynhans 1996).

The following approach is followed to conduct habitat integrity assessment:

- Instream and riparian perspectives:

The instream and riparian zone aspects of the river are assessed separately. Both of these are formulated according to metric groups, each with a number of metrics that enable the assessment of habitat integrity. The model functions in an integrated way, using the results from the assessment of metric groups, or metrics within a metric group, for the assessment of other metric groups where appropriate (Table 2.1 and 2.2).

- Reference conditions:

The basis of habitat integrity assessment is the deviation from the reference condition. Specification of the reference condition follows an impact based approach where the intensity and extent of anthropogenic changes are used to interpret the impact on the habitat integrity of the system.

- Severity of impacts:

Interpretation of the severity of impacts is based on the natural characteristics of the river. The premise is that the severity of impacts on the habitat integrity of a river will vary according to the natural characteristics of the river, i.e. particular river types will be more sensitive to certain impacts than other types.

- River type context:

Three natural attributes were considered in defining river types and determining the weights of metrics within metric groups for both the instream and riparian zone. A group of seven river ecologists participated in the weighting process. These weights were built into the model and are listed in Appendix A. In order of consideration the attributes are:

⇒ Perennial or non-perennial: Perennial rivers were considered to be those that usually flow all year round. Non-perennial rivers included all other rivers, seasonal and ephemeral. More detailed considerations on perenniality are important for assessment of hydrological impact (see the next section).

⇒ The longitudinal geomorphic zone (Rowntree and Wadeson, 1999): A simplified approach was followed by using only four zones: source, mountain stream (including mountain headwater stream), foothill (combining the upper, lowland and transitional zones) and lowland.

⇒ River size (width): Three width classes are distinguished, <5 m, 5-15 m and >15 m wide.

The result of integrity assessment is a percentage that is used to derive a descriptive habitat integrity category for the instream and riparian zone components (Table 2.1). The description of the different categories in Table 2.1 need to be specified for each category following the setting of reference conditions (category A) and the appropriate river type.

Table 2.1 Habitat integrity assessment categories according to physical drivers and likely habitat responses (based on Kleynhans 1996)

HABITAT INTEGRITY CATEGORY	DESCRIPTION	RATING (% OF TOTAL)
A	**Unmodified, natural reference condition:** All physical drivers unmodified or virtually unmodified. If use of the resource is present, the impact of such use falls completely within the natural disturbance regimes both in terms of extent and severity.	90-100
B	**Largely natural with few modifications:** A small change in natural habitats may have taken place but the ecosystem functions are essentially unchanged. *Physical drivers:* • Hydrology: The flow regime has only slightly been modified • Geomorphic: limited to slight sediment changes • Physico-chemical changes: Water clarity may sporadically be slightly influenced. At worst, only sporadic traces of toxics present. Salts may sporadically be slightly increased. *Associated habitat conditions:* • Instream: Very little change in habitat types and their dimensions and frequency. Connectivity between habitats virtually unchanged. • Riparian: Riparian habitat close to natural in terms of biophysical characteristics. Very little modification and use of riparian zone. Virtually no fragmentation.	80-89
C	**Moderately modified:** Loss and change of natural habitat and biota have occurred, but the basic ecosystem functions are still predominantly unchanged. *Physical drivers:* • Hydrology: The flow regime may have been significantly modified and direct manipulation by impoundments may be present. • Geomorphic: sediment changes due to increased inputs or flow may have increased significantly. • Physico-chemical changes: changes in nutrients, salts, oxygen concentration and temperature may deviate significantly from the reference. Low levels of toxics may sporadically be present.	60-79

HABITAT INTEGRITY CATEGORY	DESCRIPTION	RATING (% OF TOTAL)
	Associated habitat conditions: • Instream: Dimensions and frequency of some habitat types have changed significantly. Fragmentation of habitats may often be present • Riparian: Changes in the structure of the zone may be common. Some fragmentation of the zone may often be present.	
D	**Largely modified.** A large loss and change of natural habitat, biota and basic ecosystem functions has occurred. *Physical drivers:* • Hydrology: The flow regime has been extensively modified and manipulation by impoundments may be present. • Geomorphic: Drastic changes in sediment loads due to increased inputs or flow modification may have occurred. • Physico-chemical changes: nutrients, salts, oxygen concentration and temperature may deviate considerably from the reference. Low levels of toxics may regularly be present. *Associated habitat conditions:* • Instream: Dimensions and frequency of some habitat types may differ drastically from the reference. Fragmentation of habitats may often and extensively be present. • Riparian: Extensive changes of the zone may be present. Significant fragmentation of the zone may have occurred.	40-59
E	**Seriously modified.** The loss of natural habitat, biota and basic ecosystem functions is extensive. *Physical drivers:* • Hydrology: The flow regime may have been extensively and severely modified and manipulation by impoundments is likely to be present. • Geomorphic: Extensive and severe changes in sediment loads due to increased inputs or flow modification may have occurred. • Physico-chemical changes: nutrients, salts, oxygen concentration and temperature may deviate severely and regularly from the reference. Significant levels of toxics may regularly be present. *Associated habitat conditions:* • Instream: Dimensions and frequency of some habitat types may differ extensively and severely from the reference. Fragmentation of habitats may regularly and extensively be present • Riparian: Severe and extensive changes of the zone may be present. Extensive fragmentation of the zone may have occurred.	20-39
F	**Critically / Extremely modified:** Modifications have reached a critical level and the system has been modified completely with an almost complete loss of natural habitat and biota. In the worst instances the basic ecosystem functions have been destroyed and the changes are irreversible. *Physical drivers:* • Hydrology: The flow regime may be extensively and extremely modified and manipulation by impoundments is often present. • Geomorphic: Extensive and extreme changes in sediment loads due to increased inputs or flow modification may have occurred. • Physico-chemical changes: Nutrients, salts, oxygen concentration and temperature may deviate extremely and very regularly from the reference. High levels of toxics may regularly be present. *Associated habitat conditions:* • Instream: Dimensions and frequency of some habitat types may differ extensively and extremely from the reference. Fragmentation of habitats may be severe. • Riparian: Extreme and extensive changes of the zone may be present. Fragmentation of the zone may be severe.	0-19

Although catchment impact information is used as an indication of changes from reference conditions, suitable empirical information should be used where available.

2.2 ASSESSMENT OF HYDROLOGICAL REGIME CHANGES

This section is applicable to both the instream and riparian zone.

Photo Guide: Pages G2:1 and G2:35

2.2.1 RELEVANCE AND CONCEPTS

Hydrology is the key determinant in shaping the habitat and response of biota on a temporal and spatial scale (Richter *et al*. 1998) and is the main driver in terms of the functioning of the river ecosystem through geomorphic processes and the resulting instream habitat components. Critical physico-chemical components of rivers, such as dissolved oxygen, channel geomorphology, and water temperature are strongly related to stream flow which influences the disturbance, abundance, and diversity of many aquatic plant and animal species. Biota have adapted to habitats, flows, and floods that have a particular frequency, magnitude and spatial and temporal characteristics. Modifications to the hydrology will cascade to other drivers (physico-chemical and geomorphic) and metric groups.

Hydrological regimes have five basic characteristics based on the resulting "water conditions" (Richter, *et al.* 1996) namely magnitude, timing, frequency, duration and rate of change.

- Magnitude: At any given time this is a measure of the availability or suitability of habitat, and defines such habitat attributes as wetted area or habitat volume, or the position of a water table relative to wetland or riparian plant rooting zones.
- Timing of occurrence (e.g. seasonality): The occurrence of particular water conditions can determine whether certain life cycle requirements are met, or influence the degree of stress or mortality associated with extreme water conditions such as floods or droughts.
- Frequency of occurrence: Specific conditions such as droughts or floods may be tied to reproduction or mortality events for various species, thereby influencing population dynamics.
- Duration: The time over which a specific water condition exists may determine whether a particular life cycle phase can be completed, or the degree to which stressful effects such as inundation or desiccation can accumulate.
- Rate of change: This may be tied to the stranding of certain organisms along the water's edge or in inundated depressions, or the ability of plant roots to maintain contact with phreatic (underground) water supplies.

a) PERENNIALITY

(http://en.wikipedia.org/wiki/Perennial_stream;accessed January 2008).

The degree of perenniality is central to the assessment of habitat integrity:

- "A perennial stream or perennial river is a stream or river (channel) that has continuous flow in parts of its bed all year round during years of normal rainfall".
- "Perennial" streams are contrasted with "intermittent or non-perennial" streams which normally cease flowing for weeks or months each year, and with "ephemeral" channels that flow only for hours or days following rainfall.

- During unusually dry years, a normally perennial stream may cease flowing, becoming intermittent for days, weeks, or months depending on severity of the drought.
- The boundaries between perennial, intermittent, and ephemeral channels are indefinite, and subject to a variety of identification methods adopted by local governments, academics, and others with a need to classify stream-flow permanence.
- As stream-flow decreases in dry weather, visible flow above the stream bed may not be readily evident, especially in streams with coarse substrate (gravel and rocks), where water is flowing beneath and between these particles (hyporheic flow).
- From a biological perspective, a stream may be considered flowing if sufficient water is available to support flow-dependent aquatic life, including fish and gill-breathing amphibians, benthic insects, crustaceans, and molluscs, many of which survive in shallow hyporheic flow beneath rocks or logs. This extreme low flow may not be detectable on typical USGS stream-flow gauges, but is vital to stream ecology."

The following definitions are used in the IHI:

- Perennial stream (P): Flows throughout the year or most of the year (e.g. >95% of the time). The water table is located above the streambed for most of the year. Groundwater is the primary source of water for base flow. Run-off from rainfall is a supplemental source of water for base flow.
- Semi-Perennial stream (derived from definition of perennial stream) (SP): Flows throughout most of the year (i.e. >75% of the time). The water table is located above the stream bed for most of the year. Groundwater is the primary source of water for base flow. Even during periods of no surface flow, permanent but isolated and static pools are likely to often occur along the stream length. Run-off from rainfall is a supplemental source of water for base flow.
- Seasonal (intermittent) stream (S): Flowing water occurs during certain times of the year (>50% of the time), when groundwater provides water for stream flow. It ceases to flow occasionally or seasonally because bed seepage and evapo-transpiration exceed the available water supply. During dry periods, seasonal streams may not have flowing water but permanent, isolated, static pools are likely to occur regularly along the stream length. Runoff from rainfall is a supplemental source of water for stream flow.
- Semi-seasonal stream (derived from definition of seasonal stream) (SS): Flowing water occur during certain times of the year (i.e. >25% of the time), when groundwater provides water for stream flow. It ceases to flow regularly and seasonally because bed seepage and evapo-transpiration exceed the available water supply. During dry periods, semi-seasonal streams are unlikely to have flowing water. However, permanent but isolated and static pools may be present in sections of the stream. Runoff from rainfall is a supplemental source of water for stream flow.
- Semi-ephemeral stream (derived from definition of ephemeral stream) (SE): Flowing water occur only during, and for a short duration after precipitation events in a typical year. Semi-ephemeral stream beds are located above the water table year-round along the majority of the stream length. Groundwater is, therefore, a

source of surface water to a very limited extent and results in the presence of permanent but isolated static pools. Run-off from rainfall is the primary source of water for stream flow.

- Ephemeral stream (E): Flowing water occurs only during, and for a short duration after precipitation events in a typical year. Ephemeral stream beds are located above the water table year-round. Groundwater is not a source of water for the stream and permanent pools do not occur. Run-off from rainfall is the primary source of water for stream flow.

Sources consulted for definitions:
www.soil.ncsu.edu/publications/BMPs/glossary.html; accessed January 2007
www.lre.usace.army.mil/functions/rf/html/glossary_of_terms.htm; accessed Jan 2007
www.amsglossary.allenpress.com/glossary/html; accessed January 2007

b) HYDROLOGICAL CHANGE METRICS

Five major flow components are generally considered as fundamentally important for the functioning of riverine ecosystems (Table 2.2). Changes to these metrics from their reference condition are considered in the assessment of hydrological changes.

Table 2.2 The five riverine flow components (based on Mathews and Richter 2007)

	BASE (LOW) FLOWS	EXTREME LOW FLOWS	HIGH FLOW PULSES (FRESHES AND SMALL FLOODS)	MODERATE FLOODS	LARGE FLOODS
GENERAL DESCRIPTION	Occur most of the year. "The sustained or dry weather flow of streams resulting from the outflow of permanent or perched ground water, or from the drainage of large lakes and swamps." (www.rajirrigation.gov.in/glossary.htm). Base flows are considered in terms of the habitat that it provides for life-history stage requirements during the wet and dry season.	Occur during droughts. Zero flows are included and are rated in terms of an increase or decrease in occurrence and duration compared to the reference situation. To assess and rate the changes in zero flow occurrence and duration, the natural zero flow characteristics of the river are assessed against six categories (cf. section 2.2.1).	Small events often with duration of less than a day. These floods are often referred to as having a magnitude of double the base flow. Frequency of less than 1:1, i.e. they would normally occur every year .They are not important in terms of fluvial geomorphology, but an important ecological role (Hughes pers. comm. 2006)	Flows that overtop the main channel banks and occur frequently (e.g., every 2-10 years)	Rare occurrence. Follows periods or events of very high rainfall. Critical role in a river ecosystem
HABITAT	Flows that control the amount and characteristics (e.g., temperature, flow velocity, connectivity, etc.) of aquatic habitat that is available for most of the year.	Alter water chemistry. Associated with higher water temperature and lower dissolved oxygen conditions. Lower diversity of velocity-depth and associated cover types. Drying out of low-lying areas in the Floodplain.	Water levels are above low (base) flow levels but do not overtop the channel banks. Alleviate higher water temperatures and low dissolved oxygen conditions typical of low flow conditions. Flush wastes, and transport organic matter that nourishes the aquatic food web.	Connect channel to floodplains, secondary channels, sloughs and wetlands. Refuge from high velocity in main channel, lower water temperatures. May recharge shallow aquifers and the hyporheic zone.	Move significant amounts of sediment, large woody debris and other organic matter, Form new habitats, and refresh water quality conditions in both the main channel and floodplain water bodies. Scouring of spawning beds.

BIOTA	Superimposed upon the seasonally varying template of low flows, several kinds of flow ''events'' may occur that trigger responses in aquatic organisms. Depending on the species, each of the flow events superimposed upon the base flow can be a stressful time during which high rates of mortality may occur, or alternatively, may provide conditions essential for species persistence, such as habitat conditions necessary for reproduction.	Reduce connectivity, restricting movement of some aquatic organisms. Concentration of prey species, increased predation. Increased stress conditions due to increased temperatures and lowered oxygen concentrations.	For many organisms, these short-term changes in flow may provide refuge from stressful low-flow conditions Facilitate improved access to upstream or downstream areas for mobile organisms.	Recharge of shallow aquifers and hyporheic zone may be important to certain macroinvertebrates and riparian plants. Habitats created can provide significant food resources allowing for fast growth and for spawning and rearing habitat.	Transport of organisms downstream, Remove vegetation from bars, islands and banks: advantageous for some species and problematic for others.

Instream: For purposes of simplification, freshes and moderate floods are grouped together and considered in comparison with large floods to get an overall rating of floods.
Riparian: To simplify matters, freshes and moderate floods are combined in one assessment while large floods are assessed separately.

2.2.2 INDICATORS AND CONSIDERATIONS

The impact of hydrological regime changes can be assessed based on:

a) The potential impact of sources of hydrological regime modification such as:

- Weirs
- Dams
- Abstraction (run-of river)
- Runoff from urban areas, irrigation return flows, industries and mines
- Inter basin transfers

The operation of flow modification structures should be considered.

This approach is based on an expert knowledge rating system and is followed in the IHI. The best available hydrological information should be used to do the assessment

b) Hydrological regime indices:

Five indicators and seven corresponding metrics are available for this purpose based on changes between the present and reference condition (SKM 2005; Davies et al., 2008). These indices were not applied in the IHI but are considered valid for eventual inclusion in the model.

- Changes in High-Flow Events Indicator: High-Flow Metric, HF = Change in magnitude of high flows.
- Changes in Low- and Zero-Flow Events Indicator: Low-Flow Metric, LF = Change in magnitude of low flows
  Zero Flow Metric, PZ = Change in proportion of time with no flow.
- Changes in flow Variability Indicator: Monthly Variation Metric, CV = Change in coefficient of variation of monthly flows.

- Seasonality Indicator: Seasonal Period Metric, SP = Change in timing of minimum and maximum flows.
- Changes in Gross Volume Indicator: Mean Annual Discharge Metric, Median Annual Discharge Metric.

2.3 RELEVANCE AND INDICATORS OF PHYSICO-CHEMICAL CHANGE METRICS

Photo Guide: Pages G2:3

This section is primarily applicable to the instream assessment. However, physico-chemical modifications that could potentially influence riparian vegetation (e.g. nutrients, toxics, agricultural chemicals) are also relevant.

The South African Water Quality Guidelines for Aquatic Ecosystems (DWAF 1996) divides constituent-specific criteria into four categories based on the effects that the constituents may have on aquatic biota, and on the methodologies of derivation used in the criteria. The constituents were chosen on the basis of problems currently experienced in South African aquatic ecosystems. The four categories are toxic constituents, system variables, non-toxic inorganic constituents and nutrients:

- Toxics: Toxic constituents seldom occur in high concentrations in unimpacted systems in South Africa. Examples of typically toxic constituents are: Inorganic constituents, e.g. Al, As, Cd, Cu, F, Hg, Mn, NH - + ; Organic constituents, e.g. phenol, atrazine. The toxicity of several of these is increased by changes in other constituents such as dissolved oxygen or pH, etc;
- System variables: System variables such as temperature, pH and dissolved oxygen regulate essential ecosystem processes such as spawning and migration. The biota of aquatic ecosystems are usually adapted to the natural seasonal cycles of changing water quality which characterize these systems. Changes in the amplitude, frequency and duration of these cycles may cause severe disruptions to the ecological and physiological functions of aquatic organisms and hence the ecology of the system;
- Non-toxic inorganic constituents: This may cause toxic effects at extreme concentrations, but which are generally "system characteristics", in that their natural concentrations depend on localised geochemical, physical and hydrological processes: Total dissolved solids (TDS, salts) and total suspended solids (TSS);
- Nutrients: Generally not toxic but result in eutrophication if present in excess: Inorganic nitrogen (nitrate, nitrite, ammonium) and inorganic phosphorus (ortho-phosphates).

The following are also relevant for physico-chemical metrics:

- Aquatic biota evolved under particular physico-chemical conditions and depending on their tolerance can adapt to and survive a range of physico-chemical conditions;
- Physico-chemical modifications result from changes in the natural hydrology and from discharges from point and non-point sources;

Metrics included in the IHI assessment are based on the South African Water Quality Guidelines for Aquatic Ecosystems (DWAF 1996; Kleynhans *et al*. 2005).

2.3.1 pH

Relevance:

- Lowered pH (<6.0) can cause aluminium to dissolve in water. Dissolved aluminium has an acute and chronic toxic effect on aquatic organisms;
- The toxicity of several toxic constituents are pH related;
- An increase in pH (and temperature) increases the proportion and toxicity of un-ionized ammonia in aquatic ecosystems. Extreme rates of photosynthesis, whether natural or because of eutrophication, commonly result in very high pH values (>10) in standing waters during the night and lowered pH values during day.

Indicators and considerations:
Industrial activities generally cause acidification of rivers. Acidification is normally the result of three different types of pollution, namely:

- Effluents from industries, such as pulp and paper and tanning and leather industries;
- Mine drainage, which is nearly always acid, leading to the pH of receiving streams dropping to below 2;
- Acid precipitation resulting largely from atmospheric pollution caused by the burning of coal and the exhausts of combustion engines.

Elevated pH values can be caused by increased biological activity in eutrophic systems. The pH values may fluctuate widely from below 6 to above 10 over a 24-hour period as a result of changing rates of photosynthesis and respiration.

2.3.2 Salts (Total Dissolved Solids, TDS)

Relevance:

Effects of changes in the concentration of the total dissolved solids on aquatic organisms:

- Adaptations of individual species.
- Community structure.
- Microbial and ecological processes such as rates of metabolism and nutrient cycling.

Specific issues:

- The rate of change of the TDS concentration, and the duration of change, are probably more important than absolute changes in the TDS concentration. This is expected to be valid for systems where the organisms may not be adapted to fluctuating levels of TDS.
- Seasonal timing of the change in TDS concentration may also have important synergistic effects with water temperature on the total community composition and functioning.

- Organisms adapted to low-salinity habitats are generally sensitive to changes in the TDS concentration.

Indicators and considerations:
- Salt concentrations increase in a downstream direction due to natural processes and anthropogenic sources.
- Important anthropogenic sources include domestic and industrial effluent discharges, and surface runoff from urban, industrial and cultivated areas.
- Evaporation also leads to an increase in the total salts. The influence of a change in hydrology is important in this respect.

2.3.3 Nutrients

Nutrients are generally not toxic, but stimulate eutrophication (excessive algal and plant growth) if present in excess.

Relevance:
- Inorganic nitrogen (nitrate, nitrite, ammonium)
  - ⇒ Unionized ammonia is toxic to aquatic biota. An increase in pH and temperature will increase toxicity. The acute toxicity of ammonia to fish increases as dissolved oxygen decreases.
  - ⇒ Ionized ammonium contributes to eutrophication.
- Inorganic phosphorus (ortho-phosphates)
  - ⇒ Phosphorus is considered the principle nutrient controlling the degree of eutrophication in aquatic ecosystems.
- Eutrophication
  - ⇒ Excessive growth of plants can change the cover characteristics of the system, resulting in a change of the biological communities away from the reference.
  - ⇒ Often invasive macrophytes (native and alien) thrive in eutrophic conditions.
  - ⇒ The biological oxygen demand resulting from such decomposing vegetation can contribute to a decrease in oxygen concentrations.
  - ⇒ Riparian vegetation growth can be stimulated by nutrients, leading to a change in species composition, density and abundance. If marginal vegetation growth is stimulated, it can change available cover for instream biota thereby resulting in a change in species composition.

Indicators and considerations:
The relationship between physico-chemical conditions (dissolved solids, nutrients, sediments etc.) and large geographic scales of land use practices (agriculture, forest, urban, domesticated herbivore grazing) was indicated by Meador and Goldstein (2003).

- Inorganic nitrogen
  - ⇒ Commercial fertilizers contain highly soluble ammonia and ammonium salts. Following application of fertilizer, if the concentration of such compounds exceeds the immediate requirements of the plant, transport via the atmosphere or irrigation waters can carry these nitrogen compounds into aquatic systems.

- ⇒ Fish-farm effluent (un-ionized ammonia).
- ⇒ Sewage discharge.
- ⇒ Discharge from industries that use ammonia or ammonium salts in their cleaning operations.
- ⇒ Manufacture of explosives and use of explosives in mining and construction;
- ⇒ Atmospheric deposition of ammonia from distillation and combustion of coal, and the biological degradation of manure.

- Phosphorus
  - ⇒ Increased levels of phosphorus may result from point-source discharges such as domestic and industrial effluents.
  - ⇒ Diffuse (non-point) sources include atmospheric precipitation, urban runoff, and drainage from agricultural land, in particular from land on which fertilizers have been applied. In this case the phosphorus load is generated by surface and subsurface drainage.

2.3.4 Water temperature

Relevance:

- Temperature affects the rates of chemical reactions and therefore also the metabolic rates of organisms:
- It is one of the one of the major factors controlling the distribution of aquatic organisms.
- Natural variations in water temperature occur in response to seasonal and diel cycles and organisms use these changes as cues for activities such as migration, emergence and spawning.
- Artificially-induced changes in water temperature can impact on individual organisms and on entire aquatic communities.
- Higher temperatures reduce the solubility of dissolved oxygen in water, decreasing its concentration and thus its availability to aquatic organisms.
- If the organic load into a water body is high, oxygen depletion accelerates microbial activity which takes place at higher water temperatures.
- Elevated water temperatures increase metabolic rates, including respiration and thus oxygen demand, of aquatic organisms. Oxygen demand therefore increases leading to a decrease in dissolved oxygen supply.
- Unnaturally low temperatures, such as those induced by bottom releases of dam water, may induce fish mortalities in a river reach or suppress normal activities such as spawning.
- The toxicity of most substances, and the vulnerability of organisms to these substances, is intensified as water temperature increases.

Indicators and considerations:

- Anthropogenic sources which result in changes in water temperature include:
  - ⇒ Discharge of heated industrial effluents.
  - ⇒ Discharge of heated effluents below power stations.
  - ⇒ Heated return-flows of irrigation water.
  - ⇒ Removal of riparian vegetation cover, and thereby an increase in the amount of solar radiation reaching the water.
  - ⇒ Inter-basin water transfers; and
  - ⇒ Discharge of water from impoundments.

2.3.5 Water clarity (Measured as turbidity/total suspended solids (TSS))

Relevance:
A change in water clarity from reference conditions can:

- Have acute and chronic physiological effects on aquatic organisms, e.g. an increase in the TSS may lead to a decrease in water temperature as more heat is reflected from the surface and less absorbed by the water. This may affect temperature-sensitive organisms.
- Cause changes to ecosystem structure and functioning, e.g. predator prey dynamics may be influenced; growth rates of organisms and rate of photosynthesis may be changed with impacts on the overall food chain.
- If the suspended solids consist largely of organic solids, then the concentration of dissolved oxygen in the water body may decrease on oxidation of the solids by micro-organisms.

Indicators and considerations:

- Bad land use practices such as overgrazing, non-contour ploughing, removal of riparian vegetation and forestry operations accelerate erosion and result in increased loads of suspended solids in rivers;
- Discharge of domestic sewage;
- Discharge of industrial effluents (such as the pulp/papermill, china-clay, and brick and pottery industries);
- Discharge from mining operations;
- Fish-farm effluents (mostly organic suspended solids);
- Physical perturbations from road, bridge and dam construction;
- Urban runoff;
- Algal growth.

2.3.6 Oxygen

Relevance:

- Decreased dissolved oxygen in aquatic ecosystems result in chronic and acute physiological and behavioural in aquatic biota.
- Aerobic organisms are dependent for respiration on the presence of dissolved oxygen in water. Anoxic or hypoxic conditions may be lethal within short time scales.
- The sensitivity of many species, especially fish and invertebrates, to changes in dissolved oxygen concentrations depends on the species and the life stages (eggs, larvae or adult) and behavioural changes (feeding and reproduction).
- Juveniles of many aquatic organisms are more sensitive to physiological stress arising from oxygen depletion, and in particular to secondary effects such as increased vulnerability to predation and disease.
- Where possible, many species will avoid anoxic or oxygen-depleted zones.
- Cold-water-adapted species such as salmonids (e.g., trout) are especially sensitive to depletion of dissolved oxygen. Reproduction and growth in these species is reduced under continuous exposure to oxygen concentrations less than 100 % saturation. In South Africa, *Amphilius* spp. and certain *Chiloglanis* spp. are cold-water-adapted and are very sensitive to lowered dissolved oxygen

concentrations associated with perennial fast flows.

- Oxygen concentrations above saturation may cause gas bubble disease in fish;
- Supersaturated conditions also tend to inhibit photosynthesis in green algae, favouring instead cyanobacteria (bluegreen algae), which are more tolerant of super-saturation.
- The reversibility of toxic effects on organisms depends on the duration, frequency and timing of the occurrence of oxygen depletion. Physiological stress effects in adult or less sensitive life stages may be rapidly reversed if oxygen depletion is short-lived.
- Prolonged exposure of aquatic communities to dissolved oxygen concentrations less than 50 % of saturation can cause significant changes in community composition, as more tolerant species are favoured.

Indicators and considerations:

- Factors causing reduction in dissolved oxygen concentration:
  - ⇒ Resuspension of anoxic sediments, as a result of river floods or dredging activities;
  - ⇒ Turnover or release of anoxic bottom water from a deep lake or reservoir;
  - ⇒ The presence of oxidizable organic matter, either of natural origin (detritus) or originating in waste discharges, can lead to reduction in the concentration of dissolved oxygen in surface waters. The potential for organic wastes to deplete oxygen is commonly measured as biochemical oxygen demand (BOD) and chemical oxygen demand (COD);
  - ⇒ The amount of suspended material in the water affects the saturation concentration of dissolved oxygen, either chemically, through the oxygen-scavenging attributes of the suspended particles, or physically through reduction of the volume of water available for solution.

2.3.7 Toxics

See above.

2.4 RELEVANCE AND INDICATORS OF BED MODIFICATION METRICS

This section is applicable to the instream assessment.

Photo Guide: Pages G2:6

Bed modification concerns the availability of substrate for biota in terms of life-history stage requirements (Bain 1999; Novotny et al. 2005). It is important to consider that bed substrate as cover or for other biological requirements may increase or decrease compared to the reference conditions.

Two metrics are considered:

2.4.1 Sedimentation

Sedimentation is the result of increased input of sediment from the catchment or a decrease in the ability of the river to transport sediment (Gordon *et al.*, 1993). The

physico-chemical attributes of sediment (e.g. toxicity) are not addressed here (see: section 2.3).

Relevance:

- The reference instream biological assemblage may require different substrate conditions during different life-history stages. This includes rates of deposition and scouring as well as the characteristics of the sediment.
- Increase in suspended sediment decrease water clarity (Allan 2004).

Indicators and considerations:

- Deposition (with decreased flows) or scouring (with increased) flows (Gallagher and Stevenson 1999).
- Increased erosion from the riparian zone or the catchment (Bauer and Ralph 2001).
- A change in the characteristics of sediment (composition, particle size) due to catchment changes such as urbanization and covered surfaces (Bain 1999; Nerida *et al*. 2000).
- Physical removal of bed material, e.g. sand mining, removal of rapids for navigation (Hilden and Rapport, 1993) etc..
- Stabilization of substrate, e.g. channelization.

2.4.2 Benthic growth:

Relevance:

- This refers to an increase or decrease in benthic growth that can decrease or otherwise change substrate availability.

Indicators and considerations:

- Deposition or scouring due to changes in flow rates.
- A change in temperature or water clarity.
- A change in nutrient levels, e.g. eutrophication.

2.5 RELEVANCE AND INDICATORS OF BANK MODIFICATION METRICS

This section is applicable to both the instream and riparian zone.

Photo Guide: Pages G2:19

Bank modification includes assessment of both the marginal and non-marginal zones (cf. VEGRAI, Module F). The instream perspective focuses on an assessment of the impact of disturbances on instream habitat.

Relevance:

- Human impacts reduce bank vegetation, erosion resistance, structural stability and cover for instream (Stevenson and Mills 1999) and riparian biota.
- Bank vegetation damage leads to increased erosion and collapsed undercut banks. This causes degradation of cover for instream biota (Stevenson and Mills 1999).

- The increased sediment load that results from stream bank erosion reduces water clarity, smothers fish ova and benthos and reduces pool size and shallow water habitat (Stevenson and Mills 1999).
- Due to the importance of the transition between the instream and riparian zones, the condition of the marginal zone is usually considered to be relatively more important for instream biota than the non-marginal zone.
- Riparian zone attributes that are important for instream biota habitat include overhanging vegetation, marginal vegetation that stands partly in the water, undercut banks and root wads.
- Riparian vegetation removal can also influence water temperatures, inputs of litter and wood, retention of nutrients and pollutants and reduce the sediment trapping function of the zone (Allan 2004). Changes in the vegetation characteristics and structure (e.g. invasive native and alien vegetation) are similarly important.

Indicators and considerations:
- Hydrological regime changes can cause a change in bank conditions in terms of vegetative cover and erosion rates.
- Human-related impacts that results in a degradation of bank vegetation and a loss of bank stability (cultivated lands, animal farming, grazing, forestry, physical removal of vegetation, channel straightening, urbanization, alien vegetation, etc.).

2.6 RELEVANCE AND INDICATORS OF CONNECTIVITY MODIFICATION METRICS

This section is applicable to both the instream and riparian zone.
Photo Guide: Pages G2:31 and G2:31

Fragmentation of natural continuity of habitats, species and ecological processes is the issue. This can be the result of any biotic and abiotic factors that limit the ability of species to move or migrate among subpopulations and between components of their habitat critical for different life-stages. Fragmentation can be caused by structural and physico-chemical modification (Novotny, *et al*. 2005).

The most important type of connectivity is habitat linkages for dispersal because the resultant gene flow counteracts isolation due to fragmentation (Noss and Cooperrider 1994 in: Novotny, *et al.* 2005).

Relevance:
- Lateral and longitudinal connectivity is of concern. It is an essential link in migration and dispersal of riparian and aquatic organisms and enhances the recovery process following disturbances (Søndergaard and Jeppesen 2007). Although vertical connectivity (lack of stream-groundwater interchange) is also an issue (Novotny, *et al*. 2005), it is not addressed here.
- Connectivity also refers to the continuity of ecological processes such as nutrient, sediment, phytoplankton and zooplankton movement from a floodplain into the river during a flood pulse event (Bain and Stevenson 1999). The longitudinal movement of sediment and nutrients is also included in this concept. Impoundments may change the downstream thermal regime and influence

migration cues.
- Access to refugia from where recolonization may take place following periods of disturbance (Novotny, et al. 2005).

Indicators and considerations:
- Hydrological modifications may limit passage during periods when migration occurs or limit and even prohibit escape routes for biota during stressful periods (e.g. low flows, or artificially high flows). Laterally, even within the stream channel, access to certain habitats required for completion of certain phases of the life-cycle such as side channels and backwaters, may be broken.
- Biologically impassable structures: Dams, culverts, road crossings, bridges, etc.
- Structures such as dams may alter downstream temperature regimes and may also function as sediment and nutrient traps and modify ecological processes and eventually biological assemblages (Søndergaard and Jeppesen 2007).
- Urban areas, mines and industries may all be pollution sources that limit or prohibit fish passage through a zone where they formerly moved freely. Thermal plumes from industrial activities may also result in fragmentation (Novotny, *et al*. 2005).
- Artificially modified river sections (concrete-lined channels, culverts) with supercritical flow may have velocities too high for fish to traverse or may lack suitable resting places (Novotny, *et al.* 2005). In addition, such structures may limit lateral access to floodplains.

2.7 HABITAT INTEGRITY ASSESSMENT METRICS

2.7.1 INSTREAM

The five metric groups and their constituent metrics are indicated in Table 2.3.

Table 2.3 Structure of the instream component of the IHI

	METRIC GROUPS				
	HYDROLOGICAL MODIFICATION	**PHYSICO-CHEMICAL MODIFICATION**	**BED MODIFICATION**	**BANK MODIFICATION**	**CONNECTIVITY MODIFICATION**
METRICS	Baseflows	pH	Sediment	Marginal	Longitudinal
	Zero flows	Salts	Benthic growth	Non-marginal	Lateral
	Floods	Nutrients			
		Water Temperature			
		Water clarity			
		Oxygen			
		Toxics			

2.7.2 RIPARIAN

The three metric groups and their constituent metrics are indicated in Table 2.4.

Table 2.4 Structure of the riparian zone component of the IHI.

	METRIC GROUPS			
	HYDROLOGICAL MODIFICATION	**BANK STRUCTURE MODIFICATION**		**CONNECTIVITY MODIFICATION**
METRICS	Base flow (low flow)	Marginal	Non-marginal	Longitudinal
	Zero flows	Bank structure modification indicators:		Lateral
	Moderate floods	Substrate exposure Invasive vegetation (native and alien) Physico-chemical Erosion Channel straightening		
	Large floods			

3. STEPS IN THE DETERMINATION OF THE IHI

The main steps followed in the determination of the IHI are indicated in Table 3.1 and elaborated on in the particular subsections that follow.

Table 3.1 Main steps and procedures in the determination of the IHI

STEP	PROCEDURE
3.1. Selection of river section earmarked for assessment	As for study requirements and design.
3.2. Collect and collate all existing information that has a bearing on reference and present ecological conditions in the river.	Information sources may include: • Land cover database (CSIR/ARC land cover 1996, Thompson 1996 or CSIR/ARC land cover 2000), topo-cadastral maps at 1:250 000 and 1:500 000 scale • Aerial photographs • Aerial videography • Google earth images • Satellite remote sensing data • Catchment study reports of DWAF • ISP reports of DWAF • Ecoregional context (Kleynhans *et al.* 2005) • Geomorphic zones (DWAF, 1:500 000 scale) • Water quality data (cf. http://www.dwaf.gov.za/iwqs/) • Hydrological information (e.g. SPATSIM; Hughes 2005a)
3.3. Determine reference instream and riparian conditions and naturally homogenous river sections.	• Use historical data on modifications and reconstruct the reference condition. • Use ecoregional information to derive the reference condition based on streams in the same ecoregional context and with fewer modifications. • Use ecoregional information and geomorphic zones to derive naturally homogenous sections.
3.4. Synoptically categorize modifications of naturally homogenous sections	In each naturally homogenous section, use available information to: • Determine river lengths with homogenous types of impacts. • Capture data on the form section of the model.
3.5. Select assessment units/sites for ground surveys and river sections for aerial surveys	Ground sites: • Number of naturally homogenous sections and the number of sections within these with homogenous types of disturbances will provide an indication of the number of sites required to represent integrity in a representative way. Aerial surveys: • Determine which sections are priorities for aerial surveys by considering ecological importance and sensitivity and possibly planned resource development. The scale and EcoStatus level of the study will determine whether aerial and/or ground sites are required.
3.6. Conduct ground and/or aerial surveys	Aerial surveys: • Navigation and capturing of data; follow procedure as indicated in Appendix B. Data is usually captured per 5 km sector and analyzed per assessment unit. Videography as indicated in Kleynhans (1999). Ground surveys: • Survey selected sites. Visit as many sections of the river as possible. The extent and size of IHI sites will be linked to biological assessment sites (i.e. RHP sites and EWR sites) where these form part of the study.
3.7. Execute IHI model	• The basis of the IHI determination is the assessment unit. All aerial as well as site based data need to be interpreted according to the defined assessment units. • Consult all collected data to fill in the form section of the model. • Use available data to assess and determine the instream habitat integrity. • Use available data to assess and determine the riparian habitat integrity.

3.1 STUDY OF THE RIVER SECTION EARMARKED FOR ASSESSMENT

This step is common to the overall EcoStatus assessment and will provide the necessary spatial framework for IHI assessment.

3.2 COLLECTION AND COLLATION OF EXISTING DATA

The purpose is to collect and collate all relevant data that assist in guiding the specification of a reference condition. In addition, these data will provide a synoptic view of disturbances in the system.

Information sources include:

- Land cover database (CSIR/ARC land cover 1996 (Thompson 1996) or CSIR/ARC land cover 2000), topo-cadastral maps; 1:250 000 and 1:500 000 scale.
  - ⇒ GIS coverages for these are buffered to within 500 m on both sides of the river. The various land cover classes are quantified in terms of the area (ha) that it covers. From this information the types of activities around the river can be obtained. Depending on availability and resources, either the 1996 or 2000 land cover information can be used.
  - ⇒ Topo-cadastral maps provide general information on catchment activities.
- Aerial photographs. Photographs that span a period of time prior to major modifications up to most recent can be obtained from The Chief Surveyor General, Department of Land Affairs.
- High resolution Google Earth images in particular provide useful information on relatively recent development.
- Low altitude aerial videography where available.
- Satellite remote sensing data can be used where readily available and where the expertise is available to process these.
- DWAF catchment study reports are available for certain catchments. The DWAF library in Pretoria can provide information on these.
- ISP (Internal Strategic Perspective) reports of DWAF (www.dwaf.gov.za).
- Ecoregional context (Kleynhans *et al*. 2005)
- Geomorphic zones (DWAF, 1:500 000 scale)
- Hydrological information can be obtained from http://www.dwaf.gov.za/hydrology/, Midgley et al. (1994) and SPATSIM (Hughes 2005a).
- Water quality data and are available from sources listed at http://www.dwaf.gov.za/iwqs/.

3.3 IDENTIFICATION OF ASSESSMENT UNITS

The purpose is to identify homogenous river reaches based on natural characteristics. Within these reaches, sections with similar types of impact can then be identified. This will indicate which river sections within a reach that should be assessed separately within a reach, i.e. assessment units. Representative sites within these assessment units can then be selected.

a) Delineation of naturally homogenous river sections and reference conditions.

This is the first step in the assessment of the relative deviation of present conditions from reference conditions. This is the basis of the interpretation of habitat integrity.

The following are used to define river sections:

- EcoRegions (including consideration of the components used to define EcoRegions).
- Longitudinal geomorphic zones.
- River size (e.g. stream order and width) and hydrological information (e.g. SPATSIM Hughes 2005a).

These river reaches are referred to as Natural Resource Units (NRU; Kleynhans and Louw, 2008). The process is based on Waddle (2001).

Standardized reference conditions for rivers in a particular ecoregional context have not been formulated. The current approach to derive reference conditions is based on:

- Anthropogenic impacts are interpreted according to their likely influence on determinants of habitat integrity while taking into account the natural characteristics of the river.
- These changes are all related and interpreted in terms of modification of the drivers of the system, viz. hydrology, geomorphology and physico-chemical conditions and how these changes would impact on the natural riverine habitats. The river type is a key factor when interpreting such changes.
- To accomplish this, information on abiotic changes that can potentially influence river habitat integrity are obtained from available data sources.
- Where rivers or river sections in the same ecoregional context but in a less modified condition are present, these can obviously be used as pointers of the reference condition.

b) Homogenously impacted river reaches

The aim is to characterize identified river natural homogenous reaches according to the diversity of impacts. To do this, it is necessary to identify broad sections of the river reach with relatively similar types of impacts. This is comparable to the Management Resource Unit (MRU) as used in ecological reserve determination (Kleynhans and Louw, 2008) and the approach followed for the VEGRAI (EcoStatus Module F).

- A broad assessment of the types of land cover along each river reach is conducted and this provides an indication of impacts and habitat modification (cf. 1.3.2).
- Where impacts and modification along a river reach are not homogenous, this may indicate that these sections should be assessed separately to provide a representative indication of the habitat integrity.
- Combining the different types of modification can be considered if they do not represent radically different types of disturbance (e.g. contrasting cultivated lands with urban development).
- Results of the assessment are calculated in terms of the length of the river reach.

- The principle of calculating the overall habitat integrity for a river reach is that the length of a river section with a particular type of modification is used to weight the contribution of the section's IHI value based on its proportion of the total length of the reach:

  WC= (L/TL) X C

  Where:
  WC = Weighted contribution of section's IHI index value
  L = Length of the river section (i.e. MRU) with a particular type of modification
  TL = Total length of the reach
  C = IHI value for the section (%)

  The IHI for the total Reach is calculated by:

  $Ri = \sum WC$

  Where:
  Ri = Reach IHI

3.4 SELECTION OF ASSESSMENT REACHES AND SITES

a) Aerial surveys

Aerial surveys are expensive and often only a few selected river reaches can be surveyed. The prioritization and selection process should use the latest version of the ecological importance and sensitivity (EIS) database (e.g., Kleynhans 2000) and take into account the scale, nature and locality of resource development.

Most of the EIS information, currently available is for main stem rivers in quaternary catchments. Where streams not included in the database are studied, the EIS of these streams should be assessed separately.

b) Ground level surveys

Sites for ground level assessment should be as representative as possible of the different river reaches and the impacted sections in each reach. The EIS information should be used as an indication of the number of sites per section. Practical considerations such as accessibility are important.

3.5 CONDUCT IHI SURVEYS

a) Aerial surveys

Appendix B contains information about preparation for aerial surveys, navigation and capturing of data during the survey. The aim is that data recorded during the flight be useful in executing the model and also that the aerial observations be captured in a database for future reference. A continuous video of the river reach is taken during the flight. This material should be studied in conjunction with the data captured by the

navigator. The basic approach for doing videography is indicated in Kleynhans and Kemper (2000).

b) Ground surveys

The selected sites should be visited and the appropriate data recorded. It is important that as many sections and sites be visited during the ground survey as possible.

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4. STRUCTURE OF IHI MODEL

The IHI model was developed in MS Excel 2003. The model is structured according to sheets in different sections. The user navigates to different sheets in the model by clicking on hyperlinks on each sheet (Table 4.1).

- Conventions
  - ⇒ All grey cells in the manual and model indicate where the operator should enter data. This includes information and ratings.
  - ⇒ Information relating to the purpose, origin and links of cells are indicated in italics in the manual.

- Contents

The first sheet in the model provides a description of habitat integrity and a guide to the sheets that constitute the model. The contents indicates the overall structure of the model according to sheet groups, the sheet name in the model and a short descriptive name for each sheet (Table 4.1). The sheet names are hyperlinked to the specific sheet in the model. The hyperlinked sheet list is repeated on each sheet.

- Sheets and Forms

Sheets and forms relate to the identification and description of the assessment unit and relevant information required to do assessments of various indicators of instream, riparian and catchment condition (Table 4.1).

- Instream Habitat Integrity Assessment

- Riparian Zone Habitat Integrity Assessment

Table 4.1 IHI model sheets

SHEET GROUP	SHEET NAME IN MODEL	DESCRIPTION
CONTENTS	CONTENTS	SHEETS THAT CONSTITUTE THE MODEL.
ASSESSMENT INDICATORS	LOC_TYP (Table 5.1)	LOCALITY AND RIVER TYPE
	RAT_SCHEME (Table 5.2)	RATING SCHEME
	LANDCOV_1996 (Table 5.3)	LANDCOVER 1996
	LANDCOV_2000 (Table 5.4)	LANDCOVER 2000
	INS_SUM (Tables 5.5a & b)	INSTREAM SUMMARY
	RIP_SUM (Tables 5.6a, b & c)	RIPARIAN SUMMARY
	CATCH_SUM (Table 5.7)	CATCHMENT SUMMARY
HYDROLOGY	HYD_MOD_IND (Table 5.8; sheet hidden in model)	HYDROLOGICAL MODIFICATION INDICATORS
	HYD_SEASON (Table 5.9)	HYDROLOGY SEASONALITY
	IBASEFLOW (Tables 5.10a & b)	INSTREAM BASEFLOW
	RBASEFLOW (Table 5.11a & b)	RIPARIAN BASEFLOW
	IZEROFLOWS (Table 5.12)	INSTREAM ZEROFLOW
	RZEROFLOWS (Table 5.13)	RIPARIAN ZEROFLOW
	IFLOODS (Table 5.14)	INSTREAM FLOODS
	RFLOODS (Table 5.15)	RIPARIAN FLOODS

INSTREAM	HYD_MOD (Table 6.1)	INSTREAM HYDROLOGY
	PC_MOD (Table 6.2a & b)	INSTREAM PHYSICO-CHEMICAL MODIFICATION
	BED_MOD (Table 6.3a & b)	BED MODIFICATION
	BANK_MOD (Table 6.4a & b)	INSTREAM BANK MODIFICATION
	CON_MOD (Table 6.5a & b)	INSTREAM CONNECTIVITY MODIFICATION
	INSTREAM IHI (Table 6.6)	INSTREAM IHI
RIPARIAN	HYDRIP_MOD (Table 7.1)	RIPARIAN HYDROLOGICAL MODIFICATION
	BANK_S_MOD (Table 7.2a & b)	RIPARIAN BANK STRUCTURE MODIFICATION
	CONRIP_MOD (Table 7.3a & b)	RIPARIAN CONNECTIVITY MODIFICATION
	RIPARIAN IHI (Table 7.4)	RIPARIAN IHI
SUMMARY: IHI RESULTS	INSTREAM (Table 8.1)	
	RIPARIAN (Table 8.2)	

5. EXECUTING THE IHI MODEL

This section explains the sheets in the model in the order in which they occur in the spreadsheet.

5.1 ASSESSMENT INDICATORS

5.1.1 LOCALITY AND RIVER TYPE (LOC_TYPE, Table 5.1)

This sheet provides information on the locality and general information on the assessment unit (Table 5.1). The perenniality, geomorphic (slope) zones and river width information are used to determine the weight of the various metric groups and metrics and should be filled in for the model to run.

Table 5.1 Assessment unit information for model sheet LOC_TYPE

ASSESSMENT UNIT INFORMATION	DESCRIPTION
ASSESSMENT UNIT	*A unique code that identifies the unit*
UPPER LATITUDE*[1]	*Upstream latitude of the unit*
UPPER LONGITUDE	*Upstream longitude of the unit*
UPPER ALTITUDE	*Highest altitude of unit*
LOWER LATITUDE	*Lowest altitude of unit*
LOWER LONGITUDE	*Downstream latitude of the unit*
LOWER ALTITUDE	*Downstream longitude of the unit*
SURVEY SITE (if applicable)	*Unique code for survey site. Use RHP site code if applicable.*
SITE LATITUDE (if applicable)	*Latitude at site*
SITE LONGITUDE (if applicable)	*Longitude at site*
SITE ALTITUDE (if applicable)	*Altitude at site*
WMA	*DWAF Water management area code*
QUATERNARY	*Quaternary code as used in WR90 (Midgley et al. 1994)*
ECOREGION 2	*DWAF Ecoregion level 2 (Kleynhans et al. 2005)*
DATE	*dd/mm/yy*
RIVER	*River name according to Rivers database structure, 1:500 000 scale (http://www.dwaf.gov.za/IWQS/)*
TRIBUTARY	*Tributary name according to Rivers database structure, 1:500 000 scale. (http://www.dwaf.gov.za/IWQS/)*
PERENNIAL (Y/N)*[2]	*Indicate perennial=Y* *Indicate non-perennial=N* *This refers to whether the river is perennial or non-perennial under reference conditions.* *This is based on SPATSIM data (Hughes 2005a) or the best available knowledge*
GEOMORPH ZONE*[2]	*Combination of geomorphic zones according to Rowntree and Wadeson (1999):* • Source • Mountain stream (including mountain headwater stream) • Foothill (inclusive of transitional, upper and lower foothill) • Lowland
WIDTH (m)*	*Width (m) of the stream according to the groupings* • >0-2 • 2-15 • >15 *Only the active channel should be considered. This also applies to multiple channels.*

*1: WGS84datum

*2: Essential input for model to run. These characteristics were weighted during an expert workshop. The relevant weights were built into the model. See Appendix A.

5.1.2 RATING SCHEME (RAT_SCHEME, Table 5.2)

This provides descriptive classes and ratings that are used in the model. These ratings are included in pull-down lists and the appropriate value should be clicked to enter it in the cell. Ratings are indicated with 0.5 class intervals. Depending on the characteristics of the metric or impact being rated, there can be an increase or decrease away from the reference situation. A decrease is indicated with a "-" in the pull-down list. Do not interpret an increase or decrease as positive or negative for the system. Any change away from the reference is regarded as an impact and the sign is only used to indicate the direction of change.

Table 5.2 Descriptive classes and ratings for the assessment of modifications to habitat integrity

IMPACT/SEVERITY CLASS	DESCRIPTION	RATING
None: reference	No discernible impact or the modification is located in such a way that it has no impact on habitat quality, diversity, size and variability.	0
Small	The modification is limited to very few localities and the impact on habitat quality, diversity, size and variability are very small.	0.5-1.0
Moderate	The modifications are present at a small number of localities and the impact on habitat quality, diversity, size and variability are also limited.	1.5-2.0
Large	The modification is generally present with a clearly detrimental impact on habitat quality, diversity, size and variability. Large areas are, however, not influenced.	2.5-3.0
Serious	The modification is frequently present and the habitat quality, diversity, size and variability in almost the whole of the defined area are affected. Only small areas are not influenced.	3.5-4.0
Critical	The modification is present overall with a high intensity. The habitat quality, diversity, size and variability in almost the whole of the defined section are influenced detrimentally.	4.5-5.0

5.2 ENVIRONMENTAL INDICATORS

5.2.1 LAND COVER 1996 (LANDCOV_1996, Table 5.3)

The 1996 land cover classes and land cover types within 500 m of both sides of the assessment unit are indicated here. A very rough idea of the level of disturbance is obtained by calculating the modification rating per cover class (Table 5.3).

This sheet is optional and should be completed if the data is available. Either LANDCOV_1996 or LANDCOV_2000 can be filled in.

Table 5.3 Assessment of land cover classes and types within 500 m both sides of a river

1996 LAND COVER CLASSES & TYPES. BOLD & UPPER CASE= COVER CLASSES, NORMAL & LOWER CASE=COVER TYPES WITHIN EACH GROUP	AREA (Ha) COVERED BY EACH LAND COVER TYPE	% OF TOTAL AREA COVERED BY EACH LAND COVER TYPE	SUM OF % PER LAND COVER CLASS	MODIFICATION RATING PER CLASS (0-5)*
NATURAL				
Forest (indigenous)				
Shrubland & Low Fynbos				
Thicket; Bushland; Bush Clumps; High Fynbos				
Herbland				
Unimproved Grassland (natural)				
Bare Rock & Soil (natural)				
Forest & Woodland (Woodland and Wooded Grassland)				
IMPROVED GRASSLAND				
FOREST PLANTATIONS (EXOTIC)				
WATERBODIES (MAY BE NATURAL OR ARTIFICIAL)				
WETLANDS (MAY BE NATURAL OR ARTIFICIAL)				
EROSION				
Bare Rock & Soil (erosion surfaces)				
DEGRADED LANDS				
Degraded Lands (Forest & Woodland)				
Degraded Lands (Thicket; Bushland; Bush Clumps; High Fynbos)				
Degraded Lands (Unimproved Grassland)				
Degraded Lands (Shrubland & Low Fynbos)				
Degraded Lands (Herbland)				
CULTIVATED LANDS				
Cultivated Lands (permanent crops - commercial - irrigated)				
Cultivated Lands (permanent crops - commercial - dryland)				
Cultivated Lands (permanent crops - commercial - sugar cane)				
Cultivated Lands (temporary crops - commercial - irrigated)				
Cultivated Lands (temporary crops - commercial - dryland)				
Cultivated Lands (temporary crops - subsistence - dryland)				
URBAN/RESIDENTIAL				
Urban / Built-up Land (residential)				
Urban / Built-up Land (residential - smallholdings - forest & woodland)				
Urban / Built-up Land (residential - smallholdings - thicket; bushland ...etc)				
Urban / Built-up Land (residential - smallholdings - shrubland & low fynbos)				
Urban / Built-up Land (residential - smallholdings - grassland)				
Urban / Built-up Land (commercial)				
Urban / Built-up Land (industrial; transportation)				
MINES & QUARRIES				
% MODIFIED[1]				

*: (SUM OF % PER LAND COVER CLASS/100) X5

1: (SUM OF AREA MODIFIED)/(SUM OF AREA MODIFIED)+(SUM OF AREA NATURAL) X 100

2: (SUM OF AREA NATURAL)/(SUM OF AREA MODIFIED)+(SUM OF AREA NATURAL) X 100

3: % OF AREA MODIFIED x 5

5.2.2 LAND COVER 2000 (LANDCOV_2000, Table 5.4)

The approach is the same as for LANDCOV_1996. This sheet is optional and should be completed if the data are available. Either LANDCOV_1996 or LANDCOV_2000 can be filled in.

Table 5.4 Assessment of land cover classes and types within 500 m both sides of a river

2000 LAND COVER CLASSES & TYPES. BOLD & UPPER CASE= COVER CLASSES, NORMAL & LOWER CASE=COVER TYPES WITHIN EACH GROUP	AREA (Ha) COVERED BY EACH LAND COVER TYPE	% OF TOTAL AREA COVERED BY EACH LAND COVER TYPE	SUM OF % PER LAND COVER CLASS	MODIFICATION RATING PER CLASS (0-5)*
NATURAL				
Forest (indigenous)				
Woodland (previously termed Forest & Woodland)				
Thicket, Bushland, Bush Clumps, High Fynbos				
Shrubland and Low Fynbos				
Herbland				
Natural Grassland (previously termed Unimproved Grassland)				
Bare Rock and Soil (natural)				
PLANTED GRASSLAND (previously termed Improved Grassland)				
PLANTATIONS				
Forest Plantations (Eucalyptus spp)				
Forest Plantations (Pine spp)				
Forest Plantations (Acacia spp)				
Forest Plantations (Other / mixed spp)				
Forest Plantations (clearfelled)				
WATERBODIES (MAY BE NATURAL OR ARTIFICIAL)				
WETLANDS (MAY BE NATURAL OR ARTIFICIAL)				
EROSION				
Bare Rock and Soil (erosion : dongas / gullies)				
Bare Rock and Soil (erosion : sheet)				
DEGRADED LAND				
Degraded Forest & Woodland				
Degraded Thicket, Bushland, etc				
Degraded Shrubland and Low Fynbos				
Degraded Herbland				
Degraded Unimproved (natural) Grassland				
CULTIVATION				
Cultivated, permanent, commercial, irrigated				
Cultivated, permanent, commercial, dryland				
Cultivated, permanent, commercial, sugarcane				
Cultivated, temporary, commercial, irrigated				

Cultivated, temporary, commercial, dryland				
Cultivated, temporary, subsistence, dryland				
Cultivated, temporary, subsistence, irrigated				
URBAN				
Urban / Built-up				
Urban / Built-up (rural cluster)				
Urban / Built-up (residential, formal suburbs)				
Urban / Built-up (residential, flatland)				
Urban / Built-up (residential, mixed)				
Urban / Built-up (residential, hostels)				
Urban / Built-up (residential, formal township)				
Urban / Built-up (residential, informal township)				
Urban / Built-up (residential, informal squatter camp)				
Urban / Built-up (smallholdings, forest & woodland …)				
Urban / Built-up (smallholdings, thicket, bushland …)				
Urban / Built-up (smallholdings, shrubland …)				
Urban / Built-up (smallholdings, grassland …)				
Urban / Built-up, (commercial, mercantile)				
Urban / Built-up, (commercial, education, health, IT)				
Urban / Built-up, (industrial / transport : heavy)				
Urban / Built-up, (industrial / transport : light				
MINES				
Mines & Quarries (underground / subsurface mining)				
Mines & Quarries (surface-based mining)				
Mines & Quarries (mine tailings, waste dumps)				
% MODIFIED1				
% NATURAL2				
MODIFICATION RATING FOR ASSESSMENT UNIT (0-5)3				

*: (SUM OF % PER LAND COVER CLASS/100) X5

1: (SUM OF AREA MODIFIED)/(SUM OF AREA MODIFIED)+(SUM OF AREA NATURAL) X 100

2: (SUM OF AREA NATURAL)/(SUM OF AREA MODIFIED)+(SUM OF AREA NATURAL) X 100

3: % OF AREA MODIFIED x 5

5.2.3 INSTREAM SUMMARY (INS_SUM, Table 5.5a and 5.5b)

This sheet relates directly to the instream field form (Table 5.5a), the land cover data (Table 5.3 or 5.4) or any of the information sources indicated in Table 3.1. If an aerial survey was conducted (Appendix B), data from the survey are automatically transferred from the aerial survey database to Table 5.5b. This table provides a summary that is used to assist in the ratings in Table 5.5a. The overall modification ratings in Table 5.5a are transferred directly to different metric group tables where these ratings are used to inform the rating of particular metrics.

Table 5.5a Rating of instream modifications

INSTREAM MODIFICATION RATINGS *Enter rating: 0-5 (cf. Table 5.2)*					
MODIFICATION	ASSESSMENT UNIT OVERALL Rating	ASSESSMENT UNIT RATING	ASSESSMENT UNIT COMMENT	UPSTREAM ASSESSMENT UNIT Rating	UPSTREAM ASSESSMENT UNIT COMMENT
	GUIDELINES FOR USE				
	Consider upstream assessment unit rating to provide representative overall rating.	*Provide rating for the assessment unit on its own i.e. how severe is the influence in terms of intensity & extent*	*For example: number of structures and extent and land cover information*	*Provide rating of modifications upstream i.e. how severe is the influence in terms of intensity and extent*	*For example: number of structures and extent and land cover information*
Weirs					
Dams					
Crossings low water					
Abstraction (run-of river)					
Runoff/effluent: Urban areas					
Runoff/effluent: Irrigation					
Runoff/effluent: Industries					
Runoff/effluent: Mining					
Inter basin transfers					
Bed: sedimentation					
Bed: benthic growth					
Bed: scouring					
Bed: stabilization (e.g. concrete)					
Bed: material disturbance/ removal					
Water column: Exotic Aquatic macrophytes					
Water Column: Algal growth					
Introduced habitat modifying fauna					
Rubbish dumping					

Table 5.5b Rating of instream modifications based on aerial observations.

MODIFICATION INDICATOR FROM AERIAL OBSERVATIONS	**RATING OF SEVERITY** *(transfer manually from Aerial Survey Database)*
Weirs	
Dams	
Crossings low water	
Abstraction (run-of river)	
Bed: sedimentation	
Bed: benthic growth	
Bed: scouring	
Bed: stabilization (e.g. concrete)	
Bed: material disturbance/removal	
Water column: Exotic Aquatic macrophytes	
Water Column: Algal growth	
Rubbish dumping	

5.2.4 RIPARIAN SUMMARY (RIP_SUM, Table 5.6a, Table 5.6b and Table 5.6c)

This sheet relates directly to the instream field form, the land cover data (Table 5.3 or 5.4) or any of the information sources indicated in Table 3.1. If an aerial survey was conducted (Appendix B), data from the survey are manually transferred from the aerial survey database to Table 5.6b. This table provides a summary that is used to assist in the ratings in Table 5.6a. The overall modification ratings in Table 5.6a are

transferred directly to different metric group tables where these ratings are used to inform the rating of particular metrics. Information from Table 5.6a is also used to assist in the assessment of the substrate exposure, alien vegetation and erosion (Table 5.6c). Ratings from Table 5.6c are transferred to the BANK_S_MOD metric group of the riparian zone assessment.

Table 5.6a Rating of riparian modifications

RIPARIAN MODIFICATION RATINGS *Enter rating: 0-5 (cf. Table 5.02)*					
MODIFICATION	ASSESSMENT UNIT OVERALL Rating	ASSESSMENT UNIT Rating	ASSESSMENT UNIT COMMENT	UPSTREAM ASSESSMENT UNIT Rating	UPSTREAM ASSESSMENT UNIT COMMENT
	GUIDELINES FOR USE				
	Consider upstream assessment unit rating to provide representative overall rating.	*Provide rating for the assessment unit on its own i.e. how severe is the influence in terms of intensity & extent.*	*For example: number of structures and extent and land cover information.*	*Provide rating of modifications upstream i.e. how severe is the influence in terms of intensity and extent.*	*For example: number of structures and extent and land cover information.*
Erosion					
Rubbish dumping					
Trampling					
Mining					
Roads					
Riparian vegetation removal					
Invasive alien vegetation					
Invasion, native vegetation					
Forestry					
Industries					
Channel Straightening					
Urbanization					
Off-channel dams					
Artificial covering					
Animal farming					
Dry land farming					
Irrigation					

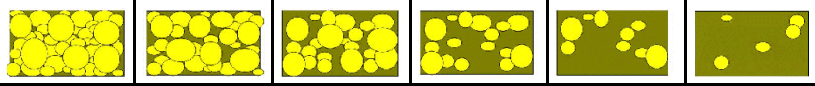
Table 5.6b Rating of riparian zone modifications based on aerial observations

MODIFICATION INDICATOR FROM AERIAL OBSERVATIONS	**RATING OF SEVERITY** *(Transfer manually from Aerial Survey Database*)
Erosion	
Rubbish dumping	
Trampling	
Mining	
Roads	
Vegetation removal	
Invasive alien vegetation	
Invasion, native vegetation	
Forestry	
Industries	
Channel Straightening	
Urbanization	
Off-channel dams	
Artificial covering	
Animal farming	
Dry land farming	
Irrigation	
Bank Stabilization	

Table 5.6c Assessment tables and matrices for rating substrate exposure, alien invasion and erosion

SUBSTRATE EXPOSURE:

based on the illustrations, mark the appropriate % cover for both the present and derived reference situation in the grey cell



Circles represent % extent of bare substrate

% cover	100 to 80	80 to 60	60 to 40	40 to 20	20 to 10	>10
Present					x	
Reference						x

The intersection of the reference column and row (present) provide an indication fo the rating that the assessor can modify based on expert knowledge

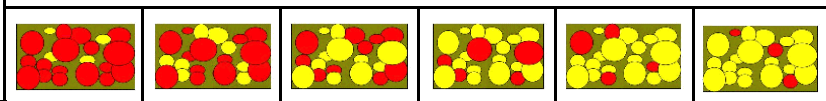
Reference (%):

based on the above assessment, locate the corresponding column with ratings

Present %: *based on the above assessment, locate the corresponding row with ratings*	100 to 80	80 to 60	60 to 40	40 to 20	20 to 10	>10
100 to 80	**0 to 1**	1 to 2	2 to 3	3 to 4	4 to 5	5
80 to 60	1 to 2	**0 to 1**	1 to 2	2 to 3	3 to 4	4 to 5
60 to 40	2 to 3	1 to 2	**0 to 1**	1 to 2	2 to 3	3 to 4
40 to 20	3 to 4	2 to 3	1 to 2	**0 to 1**	1 to 2	2 to 3
20 to 10	4 to 5	3 to 4	2 to 3	1 to 2	**0 to 1**	1 to 2
<10	5	4	3 to 4	2 to 3	1 to 2	**0 to 1**

INVASION NATIVE OR ALIEN:

based on the illustrations, mark the appropriate % cover of invasibe vegetation

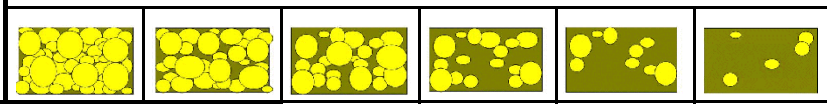


Red circles represent cover by aliens

% cover	100 to 80	80 to 60	60 to 40	40 to 20	20 to 10	>10
Present					x	

EXTENT OF EROSION:

based on the illustrations, mark the appropriate % cover for both the present and derived reference situation in the grey cells



Circles represent % extent of erosion

% area	100 to 80	80 to 60	60 to 40	40 to 20	20 to 10	>10
Present					x	
Reference						x

The intersection of the reference column and row (present) provide an indication fo the rating that the assessor can modify based on expert knowledge

Reference (%):

based on the above assessment, locate the corresponding column with ratings

Present %: *based on the above assessment, locate the corresponding row with ratings*	100 to 80	80 to 60	60 to 40	40 to 20	20 to 10	>10
100 to 80	**0 to 1**	1 to 2	2 to 3	3 to 4	4 to 5	5
80 to 60	1 to 2	**0 to 1**	1 to 2	2 to 3	3 to 4	4 to 5
60 to 40	2 to 3	1 to 2	**0 to 1**	1 to 2	2 to 3	3 to 4
40 to 20	3 to 4	2 to 3	1 to 2	**0 to 1**	1 to 2	2 to 3
20 to 10	4 to 5	3 to 4	2 to 3	1 to 2	**0 to 1**	1 to 2
<10	5	4	3 to 4	2 to 3	1 to 2	**0 to 1**

BANK STRUCTURE MODIFICATIONS	**MARGINAL RATING:** *Enter rating: 0-5 (cf Table 5.2). Automatically transferred to BANK_S_MOD metric group*	**NON-MARGINAL RATING:** *Enter rating: 0-5 (cf Table 5.2). Automatically transferred to BANK_S_MOD metric group*
SUBSTRATE EXPOSURE		
INVASIVE ALIEN VEGETATION	*The maximum of invasive native or alien vegetation should be used as guidance (also see Table 5.6 a & b)*	*The maximum of invasive native or alien vegetation should be used as guidance (also see Table 5.6 a & b)*
EROSION		

5.2.5 CATCHMENT SUMMARY (CATCH_SUM, Table 5.7)

This sheet relates directly to the riparian field form, the land cover data (Table 5.3 or 5.4), data obtained from an aerial survey or any of the information sources indicated in Table 3.1. The overall modification ratings in Table 5.7 are transferred directly to different metric group tables where these ratings are used to inform the rating of particular metrics.

Table 5.7 Rating of catchment modifications

MODIFICATIONS	**UPSTREAM CATCHMENT MODIFICATION RATINGS** *(0-5; cf. Table 5.02)*	**COMMENT**
Erosion		
Roads		
Catchment Urbanization		
Catchment Vegetation removal		
Waste disposal		
Catchment Trampling		
Industries		
Mining		
Catchment Invasive alien vegetation		
Catchment, Invasive native vegetation		
Catchment Forestry		
Animal farming		

5.3 INDICATORS OF HYDROLOGICAL CHANGE

The information from the previous section is used here to assess particular hydrological changes from an instream and riparian perspective. The resulting evaluations are then used to rate particular metrics within each metric group.

5.3.1 GENERAL HYDROLOGICAL INDICATORS (HYD_MOD_IND Table 5.8; HIDDEN)

The purpose of this sheet is to summarize information from the field survey. This information is duplicated in the following sheets to contribute in assessments but the Table itself is hidden in the model:

HYD_SEASON
IBASEFLOW
RBASEFLOW
IZEROFLOWS
RZEROFLOWS
IFLOODS
RIPFLOODS

Table 5.8 Summary of information from the field assessment sheets for HYD_MOD_IND assessment

MODIFICATION INDICATOR	IMPACT RATING: TRANSFERRED FROM
Weirs	*INS_SUM*
Dams	*INS_SUM*

Abstraction (run-of river)	*INS_SUM*
Off-channel dams	*RIP_SUM*
Runoff: Urban areas	*INS_SUM*
Runoff: Irrigation	*INS_SUM*
Runoff: Industries	*INS_SUM*
Runoff: Mining	*INS_SUM*
Inter basin transfers	*INS_SUM*
Catchment Forestry	*CATCH_SUM*
Forestry, riparian	*RIP_SUM*
Riparian invasive alien vegetation	*INS_SUM*
Catchment Invasive vegetation	*CATCH_SUM*
Riparian vegetation removal	*RIP_SUM*
Catchment Vegetation removal	*CATCH_SUM*
Catchment Urbanization	*CATCH_SUM*
Riparian zone trampling	*RIP_SUM*
Catchment trampling	*CATCH_SUM*

5.3.2 HYD_SEASON (Table 5.9)

The change in the seasonal distribution of runoff compared to the reference conditions is assessed here. The emphasis is on changes brought about by a change in floods (high flows). Such changes will also have an influence on base flows (low flows).

Ratings are transferred to the sheets that require consideration of the change in seasonality.

Hydrological information should be used if available. If not, information that indicates a change in seasonality (cf. INS_SUM, Table 5.5a) should be resorted to.

Table 5.9 Rating of change in seasonal distribution of runoff

DESCRIPTION: SEASONALITY CHANGES Seasonality: Natural climatic changes in the flow volume between the wet and dry season that usually indicates a higher volume during the wet than in the dry season.	**RATING**
No change from reference	0
Small change in seasonality - seasonal distribution still close to natural	1
Moderate change in seasonality - wet and dry season however more similar than under natural conditions.	2
Large change in seasonality - Dry and wet season largely similar but still distinguishable seasonal distribution still occurs.	3
Serious change in seasonality - Continuous base flow for whole year (wet and dry season limited difference).	4
Extreme change in seasonality - Reversal of seasons (wet to dry and vice versa)	5
SEASONALITY CHANGE: FRESHES & MODERATE FLOODS (Hughes (2005b) Freshes: *Are small events that often last for less than a day. These floods are often referred to as having a magnitude of double the base flow. They are not important in terms of fluvial geomorphology, but play an important ecological role.* Moderate floods: *Are the floods that occur with a frequency of less than 1:1, i.e. they would normally occur every year and usually contained within the active channel: For purposes of simplification, the above two types of floods have been grouped together.*	*Enter rating here: automatically transferred to: IFLOODS sheet*
SEASONALITY CHANGE: LARGE FLOODS Large floods: *These are floods that occur with a frequency of more than 1:1, i.e. 1:2 year floods. They are large and often fill or overtop the active channel, inundate flood benches or the flood plain.*	*Enter rating here: automatically transferred to: IFLOODS sheet*

5.3.3 BASEFLOWS: INSTREAM (IBASEFLOW (Tables 5.10a & b)

Photo Guide: Page G2:1

Changes in the seasonality and volume of base flow are integrated as indicated in Table 5.10a. The ratings derived for the dry and wet seasons are used to find the intersection value in the appropriate matrix (Table 5.10b). This value should be considered and adjusted if necessary based on the assessor's knowledge before it is entered in the "BASE FLOW CHANGE" cell. This value is automatically carried over to the BASEFLOW metric in the HYD_MOD sheet (metric group). It is important that the natural characteristics of the riparian zone be considered when doing this assessment.

Table 5.10a Assessment of severity of changes in base flow during the dry and wet seasons for instream assessment

<table>
<tr><td>FROM TABLE BELOW, INDICATE: DRY SEASON RATING (INDICATE DECREASE WITH "-")</td><td colspan="3">Enter rating: 0-5 (cf. Table 5.2). This rating is used in the dry season rating matrices (Table 5.10b)</td><td>FROM TABLE BELOW, INDICATE: WET SEASON RATING (INDICATE DECREASE WITH "-")</td><td colspan="3">Enter rating: 0-5 (cf. Table 5.2). This rating is used in the wet season rating matrices (Table 5.10b)</td></tr>
<tr><td colspan="8">BASE FLOW : COMPARED TO REFERENCE</td></tr>
<tr><td rowspan="2">RATING</td><td colspan="3">DECREASE</td><td colspan="4">INCREASE</td></tr>
<tr><td></td><td>DRY SEASON</td><td>WET SEASON</td><td></td><td>DRY SEASON</td><td colspan="2">WET SEASON</td></tr>
<tr><td rowspan="6">1</td><td colspan="3">FLOW: Minimal decrease of flows, usually only short periods</td><td colspan="4">FLOW: Minimal increase of flows, usually only short periods</td></tr>
<tr><td colspan="3">HABITAT</td><td colspan="4">HABITAT</td></tr>
<tr><td>Feeding</td><td rowspan="3">Slightly <</td><td rowspan="3">Slightly <</td><td>Feeding</td><td rowspan="3">Slightly ></td><td colspan="2" rowspan="3">Slightly ></td></tr>
<tr><td>Refuge</td><td>Refuge</td></tr>
<tr><td>Flow sensitive habitats (if present under reference)</td><td>Flow sensitive habitats (if present under reference)</td></tr>
<tr><td>Breeding</td><td>-</td><td>Breeding</td><td>-</td><td colspan="2">Breeding</td></tr>
<tr><td>Riparian vegetation stress</td><td colspan="2">None</td><td>Riparian vegetation stress</td><td colspan="3">None</td></tr>
<tr><td rowspan="6">2</td><td colspan="3">FLOW: Moderate decrease of flows, usually only for short periods. Cessation of flows could happen, but only for short periods.</td><td colspan="4">FLOW: Moderate increase of flows, usually only for short periods.</td></tr>
<tr><td colspan="3">HABITAT</td><td colspan="4">HABITAT</td></tr>
<tr><td>Feeding</td><td rowspan="3">Moderately <</td><td rowspan="4">Moderately <</td><td>Feeding</td><td rowspan="3">Moderately ></td><td colspan="2" rowspan="4">Moderately ></td></tr>
<tr><td>Refuge</td><td>Refuge</td></tr>
<tr><td>Flow sensitive habitats (if present under reference)</td><td>Flow sensitive habitats (if present under reference) Breeding</td></tr>
<tr><td>Breeding</td><td>-</td><td>Breeding</td><td>-</td><td colspan="2">Breeding</td></tr>
<tr><td>Riparian vegetation stress</td><td colspan="2">None</td><td>Riparian vegetation stress</td><td colspan="3">None</td></tr>
<tr><td rowspan="6">3</td><td colspan="3">FLOW: Large decrease in flow and/or flow cessation regularly occurs for short periods and/or flow cessation could occur irregularly, but for a long duration.</td><td colspan="4">FLOW: Large increase in flow regularly occurs for short periods and/or flow increase could occur irregularly, but for a long duration.</td></tr>
<tr><td colspan="3">HABITAT</td><td colspan="4">HABITAT</td></tr>
<tr><td>Feeding</td><td colspan="2" rowspan="3">Largely <</td><td>Feeding</td><td colspan="3" rowspan="3">Largely ></td></tr>
<tr><td>Refuge</td><td>Refuge</td></tr>
<tr><td>Flow sensitive habitats (if present under reference)</td><td>Flow sensitive habitats (if present under reference)</td></tr>
<tr><td>Breeding</td><td>-</td><td>Largely <</td><td>Breeding</td><td>-</td><td>Largely ></td></tr>
<tr><td>Riparian vegetation stress</td><td colspan="2">Slightly ></td><td>Riparian vegetation stress</td><td colspan="2">Slightly <</td></tr>
</table>

4	FLOW: Serious decrease in flow occurs right through the dry season and/or flow cessation occurs for significant periods of time.			FLOW: Serious increase in flow occurs right through the wet season and/or flow increase occurs for significant periods of time.		
	HABITAT			HABITAT		
	Feeding	Extensively <		Feeding	Extensively >	
	Refuge			Refuge		
	Flow sensitive habitats (if present under reference)			Flow sensitive habitats (if present under reference)		
	Breeding	-	Extensively <	Breeding	-	Extensively >
	Riparian vegetation	Largely >	Largely >	Riparian vegetation	Largely <	Largely <
5	FLOW: River barely flowing (trickle) and/or flow cessation occurs for most of the time.			FLOW: Increases bordering on fresh conditions for most of the time		
	HABITAT			HABITAT		
	Feeding	Extremely <		Feeding	Extremely >	
	Refuge			Refuge		
	Flow sensitive habitats (if present under reference)	0	0	Flow sensitive habitats (if present under reference)		
	Breeding	-	Extremely <	Breeding	-	Extremely >
	Riparian vegetation	Extremely >		Riparian vegetation	Extremely <	

Table 5.10b Assessment of severity of increases in base flow during the dry and wet seasons for instream assessment

BASE FLOW CHANGE (DECREASE="-")	Use the appropriate table (A-D) below to find the value at the intersection of the wet and dry season ratings (cf. Table 5.10a). This value is automatically transferred to the IBASEFLOW metric of the HYD_MOD metric group.						
ASSESSMENT OF SEVERITY OF BASE FLOW CHANGES							
A	**Decrease: Wet season**						
	Rating	0	-1	-2	-3	-4	-5
Decrease: Dry season	0	0	-1	-2	-3	-4	-5
	-1	-1	-1	-2	-3	-4	-5
	-2	-2	-2	-2	-3	-4	-5
	-3	-3	-3	-3	-3	-4	-5
	-4	-4	-4	-4	-4	-4	-5
	-5	-5	-5	-5	-5	-5	-5
B	**Decrease: Wet season**						
	Rating	0	-1	-2	-3	-4	-5
Increase: Dry season	0	0	-1	-2	-3	-4	-5
	1	0.5	-1	-2	-3	-4	-5
	2	1	-1	-2	-3	-4	-5
	3	1.5	-1	-2	-3	-4	-5
	4	2	-1	-2	-3	-4	-5
	5	2.5	-1	-2	-3	-4	-5
C	**Increase: Wet season**						
	Rating	0	1	2	3	4	5
Decrease: Dry season	0	0	0.5	1	1.5	2	2.5
	-1	-1	-1	-1	-1	-2	-2
	-2	-2	-2	-2	-2	-3	-3
	-3	-3	-3	-3	-3	-3	-3
	-4	-4	-4	-4	-4	-4	-4
	-5	-5	-5	-5	-5	-5	-5
D	**Increase: Wet season**						
	Rating	0	1	2	3	4	5
Increase: Dry season	0	0	0.5	1	1.5	2	2.5
	1	0.5	0.5	1	1.5	2	2.5
	2	1	1	2	1.5	2	2.5
	3	1.5	1.5	1.5	1.5	2	2.5
	4	2	2	2	2	2	2.5
	5	2.5	2.5	2.5	2.5	2.5	2.5

5.3.4 BASEFLOWS: RIPARIAN (RBASEFLOW Table 5.11a & b)

Photo Guide: Page G2:35

Two perspectives of the riparian zone are considered, viz. the marginal and non-marginal zones (cf. VEGRAI Module F). The responses in terms of increased or decreased stress are considered for both zones for decreased and increased base flows. Changes in the seasonality as well and changes in the volume of base flow are assessed in an integrated way in Table 5.11a. The ratings, derived for the dry and wet seasons, are used to find the intersection value in the appropriate matrix (Table 5.11b). This value should be considered and adjusted if necessary based on the assessor's knowledge before it is entered in the "BASE FLOW CHANGE" cell. This value is automatically carried over to the BASEFLOWS metric in the HYDRIP_MOD sheet (metric group). It is important that the natural characteristics of the riparian zone be considered when doing this assessment.

Table 5.11a Assessment of severity of changes in base flow during the dry and wet seasons for riparian zone assessment

FROM TABLE BELOW, INDICATE: DRY SEASON RATING (INDICATE DECREASE WITH "-")	Enter rating: 0-5 *(cf. Table 5.02). This rating is used in the dry season rating matrices* (Table 5.10d)	FROM TABLE BELOW, INDICATE: WET SEASON RATING (INDICATE DECREASE WITH "-")	Enter rating: 0-5 *(cf. Table 5.02). This rating is used in the wet season rating matrices* (Table 5.10d)

BASE FLOW : COMPARED TO REFERENCE						
RATING	DECREASE			INCREASE		
		DRY SEASON	WET SEASON		DRY SEASON	WET SEASON
1	FLOW: Minimal decrease of flows, usually only for short periods			FLOW: Minimal increase of flows, usually only for short periods		
	Marginal zone stress:	very few species slightly >	None	Marginal zone stress:	very few species slightly <	None
	Non-marginal zone stress:	None		Non-marginal zone stress:	None	
2	FLOW: Moderate decrease of flows, usually only for short periods. Cessation of flows could happen, but only for short periods.			FLOW: Moderate increase of flows, usually only for short periods.		
	Marginal zone stress:	Few species slightly >	Very few species slightly>	Marginal zone stress:	Few species slightly <	Very few species slightly <
	Non-marginal zone stress:	Very few species slightly >	None	Non-marginal zone stress:	Very few species slightly <	None
3	FLOW: Large decrease in flow and/or flow cessation regularly occurs for short periods and/or flow cessation could occur irregularly, but for a long duration.			FLOW: Large increase in flow regularly occurs for short periods and/or flow increase could occur irregularly, but for a long duration.		
	Marginal zone stress:	Several species moderately >	Few species slightly>	Marginal zone stress:	Several species moderately <	Few species slightly <
	Non-marginal zone stress:	Few species slightly >	Very few species slightly>	Non-marginal zone stress:	Few species slightly <	Very few species slightly <
4	FLOW: Serious decrease in flow occurs right through the dry season and/or flow cessation occurs for significant periods of time.			FLOW: Serious increase in flow occurs right through the wet season and/or flow increase occurs for significant periods of time.		
	Marginal zone stress:	Most species seriously>	Several species moderately >	Marginal zone stress:	Most species seriously <	Several species moderately <
	Non-marginal zone stress:	Several species moderately >	Few species slightly >	Non-marginal zone stress:	Several species moderately <	Few species slightly <
5	FLOW: River barely flowing (trickle) and/or flow cessation occurs for most of the time.			FLOW: Increases bordering on fresh conditions for most of the time		
	Marginal zone stress:	Most species extremely >	Most species extremely >	Marginal zone stress:	Most species extremely <	Most species extremely <
	Non-marginal zone stress:	Several species seriously>	Several species moderately >	Non-marginal zone stress:	Several species seriously <	Several species moderately <

Table 5.11b Assessment of severity of increases in base flow during the dry and wet seasons for riparian zone assessment.

CONSIDERING THE DECREASE-INCREASE OF BASEFLOW, RATE THE OVERALL BASE FLOW CHANGE CONSIDERING TO THE APPROPRIATE MATRIX (A-D) BELOW (DECREASE="-")	CONSIDERING THE DECREASE-INCREASE OF BASEFLOW, RATE THE OVERALL BASE FLOW CHANGE CONSIDERING TO THE APPROPRIATE MATRIX (A-D) BELOW (DECREASE="-")						
ASSESSMENT OF SEVERITY OF BASE FLOW CHANGES							
A	**Decrease: Wet season**						
Decrease: Dry season	Rating	0	-1	-2	-3	-4	-5
	0	0	-1	-2	-3	-4	-5
	-1	-0.5	-1	-2	-3	-4	-5
	-2	-1	-1.5	-2	-3	-4	-5
	-3	-2	-2.5	-3	-3	-4	-5
	-4	-2	-2.5	-3	-3.5	-4	-5
	-5	-2.5	-3	-3.5	-4	-4.5	-5
B	**Decrease: Wet season**						
Increase: Dry season	Rating	0	-1	-2	-3	-4	-5
	0	0	-0.5	-2	-3	-4	-5
	1	0.5	-1	-1.5	-3	-4	-5
	2	1	-1.5	-2.5	-3	-4	-5
	3	1.5	-2	-2.5	-3.5	-4	-5
	4	2	-2.5	-3	-3.5	-4	-5
	5	2.5	-3	-3.5	-4	-4	-5
C	**Increase: Wet season**						
Decrease: Dry season	Rating	0	1	2	3	4	5
	0	0	0.5	1	1.5	2	2.5
	-1	-0.5	-0.5	-1	-1.5	-2	-2.5
	-2	-1	-1.5	-2	-2	-2.5	-3
	-3	-1.5	-2	-2.5	-3	-3	-3
	-4	-2	-2.5	-2.5	-3	-3	-3.5
	-5	-2.5	-2.5	-3	-3	-3	-3.5
D	**Increase: Wet season**						
Increase: Dry season	Rating	0	1	2	3	4	5
	0	0	0.5	1	1.5	2	2.5
	1	0.5	0.5	1	1.5	2	2.5
	2	1	1	2	1.5	2.5	3
	3	1.5	1.5	2	2	2.5	3
	4	2	2	2.5	2.5	3	3
	5	2.5	2.5	2.5	3	3	3

5.3.5 Zero flows: Instream (IZEROFLOWS, Table 5.12)

Photo Guide: Page G2:1

The matrix in Table 5.12 is used to rate the change in zero flow duration according to the reference and present situation. Information captured in the HYD_MOD_IND sheet should be used to guide severity of changes in base flows (Table 5.8, duplicated in the IZEROFLOWS sheet). The value at the intersection of the reference and present situation provides an indication of the rating. This value should be considered and a decision made on the most appropriate rating which is entered in the grey cell.

Table 5.12 Assessment matrix for changes in zero flow duration for instream assessment

Decrease in zero flow duration in rivers with different degrees of flow duration.							
DECREASED ZERO FLOW		**REFERENCE**					
		E	**SE**	**SS**	**S**	**SP**	**P**
PRESENT	**E**	0					
	SE	0.5/1	0				
	SS	1.5/2	0.5/1	0			
	S	2.5/3	1.5/2	0.5/1	0		
	SP	3.5/4	2.5/3	1.5/2	0.5/1	0	
	P	4.5/5	3.5/4	2.5/3	1.5/2	0.5/1	0
Increase in zero flow duration in rivers with different degrees of flow duration.							
INCREASED ZERO FLOW		**REFERENCE**					
		P	**SP**	**S**	**SS**	**SE**	**E**
PRESENT	**P**	0					
	SP	0.5/1	0				
	S	1.5/2	0.5/1	0			
	SS	2.5/3	1.5/2	0.5/1	0		
	SE	3.5/4	2.5/3	1.5/2	0.5/1	0	
	E	4.5/5	3.5/4	2.5/3	1.5/2	0.5/1	0
ZERO FLOW CHANGE RATING (indicate decrease with "-")		Enter rating derived from the above matrix here. This rating is automatically transferred to the zero flow metric of the HYD_MOD metric group.					

5.3.6 Riparian (RZEROFLOWS, Table 5.13)

Photo Guide: Page G 2.35

The matrix indicated in Table 5.13 is used to rate the change in zero flow duration according to the reference and present situation. Information captured in the HYD_MOD_IND sheet should be used to guide severity of changes in base flows (Table 5.8, duplicated in the RZEROFLOWS sheet). The value at the intersection of the reference and present situation provides an indication of the rating. This value should be considered and a decision made on the most appropriate rating which is entered in the grey cell.

Table 5.13 Assessment matrix for changes in zero flow duration for riparian zone assessment

Ratings for decrease in duration of zero flow conditions in rivers with different degrees of flow duration.							
DECREASED ZERO FLOWS		**REFERENCE**					
		E	**SE**	**SS**	**S**	**SP**	**P**
PRESENT	**E**	0.0					
	SE	0.5	0.0				
	SS	1-1.5	0.5-1	0.0			
	S	2-2.5	1.5-2	0.5-1	0.0		
	SP	3-3.5	2.5-3	1.5-2	1-1.5	0.0	
	P	4-4.5	3.5-4	2.5-3	2-2.5	1.5-2	0.0

Ratings for increase in duration of zero flow conditions in rivers with different degrees of flow duration.							
INCREASED ZERO FLOWS		**REFERENCE**					
		P	**SP**	**S**	**SS**	**SE**	**E**
PRESENT	**P**	0.0					
	SP	-0.5/-1	0.0				
	S	-1.5/-2	-0.5/-1	0.0			
	SS	-2.5/-3	-1.5/-2	-0.5/-1	0.0		
	SE	-3.5/-4	-2.5/-3	-1.5/-2	-0.5/-1	0.0	
	E	-4.5/-5	-3.5/-4	-2.5/-3.5	-1.5/-2.5	-0.5-1	0.0
ZERO FLOW CHANGE RATING (indicate decrease as "-")		Enter rating derived from the above matrix here. This rating is automatically transferred to the zero flow metric of the HYDRIP_MOD metric group.					

5.3.7 Floods: Instream (IFLOODS, Table 5.14)

Photo Guide: Page G2:2

Freshes and moderate floods are combined in the instream flood assessment. This combination and large floods are rated according to a change in frequency and seasonality (cf. Table 5.9). These two ratings are combined in a separate matrix to arrive at a combined rating for floods overall for the instream assessment (Table 5.14).

The values provided in the matrices should be considered as a guideline by the assessor and changed where deemed necessary.

Table 5.14 Assessment and rating of change in seasonality and frequency of large floods and freshes and moderate floods in terms of the instream assessment

Large floods: assessment based on seasonality & frequency									
LARGE FLOODS		**FREQUENCY**							
		0	**1**	**2**	**3**	**4**	**5**		
SEASONALITY	**0**	0	1	2	3	4	5	**SEASONALITY**	Seasonality rating carried over from Table 5.09 (HYD_SEASON sheet) and used in combination with frequency rating to find value at intersection.
	1	0.5	1.5	2	3	4	5		
	2	1	2	2.5	3	4	5	**RATING: (indicate decrease with "-")**	**Enter rating derived from the intersection of the seasonality and frequency matrix.**
	3	1.5	2.5	2.5	3.5	4	5		
	4	2	3	3	3.5	4.5	5		
	5	2.5	3.5	3.5	4	5	5		
Moderate floods & freshes: assessment based on seasonality & frequency									
FRESHES & MODERATE FLOODS		**FREQUENCY**							
		0	**1**	**2**	**3**	**4**	**5**		
SEASONALITY	**0**	0	1	2	3	4	5	**SEASONALITY**	*Seasonality rating carried over from Table 5.09 (HYD_SEASON sheet) and used in combination with frequency rating to find value at intersection.*
	1	1	1.5	2	3	4	5		

	2	2	2.5	2.5	3	4	5	**RATING: (indicate decrease with "-")**	**Enter rating derived from the intersection of the seasonality and frequency matrix.**
	3	3	3.5	3.5	4	4.5	5		
	4	3.5	4	4	4	4.5	5		
	5	4	4	4.5	4.5	5	5		

Integration of large floods & moderate floods for overall impact rating (consider ratings for Large & Freshes & moderate floods)									
FLOODS (OVERALL)		**LARGE FLOOD RATING**							
		0	**1**	**2**	**3**	**4**	**5**		
MODERATE FLOOD RATING	**0**	0	0.5	1	2	3	3		
	1	1	1	1.5	2	3	3	**FLOODS, OVERALL RATING: (indicate decrease with "-")**	**The ratings for large floods and freshes and medium floods are used to find the intersection value which is entered here. Rating carried over to HYD_MOD.**
	2	2	2	2.5	2.5	3.5	3.5		
	3	3	3	3.5	3.5	3.5	4		
	4	4	4	4	4.5	4.5	5		
	5	5	5	5	5	5	5		

5.3.8 Floods: Riparian (RIPFLOODS, Table 5.15)

Photo Guide: Page G2:36

Freshes and moderate floods are combined in the riparian zone flood assessment. Large floods are assessed separately because of its importance in determining the structure and functioning of the riparian zone. These two ratings are transferred to the HYDRIP_MOD metric group.

The values provided in the matrices should be considered as a guideline by the assessor and changed where deemed necessary.

Table 5.15 Assessment and rating of change in seasonality and frequency of large floods and freshes and moderate floods in terms of the riparian assessment

Moderate floods and freshes assessment based on seasonality & frequency									
FRESHES & MODERATE FLOODS		**FREQUENCY**							
		0	**1**	**2**	**3**	**4**	**5**		
SEASONALITY	**0**	0	1	2	3	4	5	**SEASONALITY**	*Seasonality rating carried over from Table 5.09 (HYD_SEASON sheet) and used in combination with frequency rating to find value at intersection.*
	1	1	1.5	2	3	4	5		
	2	2	2.5	2.5	3	4	5		
	3	3	3.5	3.5	4	4.5	5		
	4	3.5	4	4	4	4.5	5		
	5	4	4	4.5	4.5	5	5	**FRESHES & MODERATE FLOOD RATING:(indicate decrease as "-")**	Enter rating derived from the intersection of the seasonality and frequency matrix. Rating carried over to HYDRIP_MOD

Large flood assessment based on seasonality & frequency									
LARGE FLOODS		FREQUENCY							
		0	**1**	**2**	**3**	**4**	**5**		
SEASONALITY	**0**	0	1	2	3	4	5	**SEASONALITY**	*Seasonality rating carried over from Table 5.09 (HYD_SEASON sheet) and used in combination with frequency rating to find value at intersection.*
	1	0.5	1.5	2	3	4	5		
	2	1	2	2.5	3	4	5		
	3	1.5	2.5	2.5	3.5	4	5		
	4	2.0	3	3	3.5	4.5	5		
	5	2.5	3.5	3.5	4	5	5	**LARGE FLOOD RATING (indicate decrease as "-")**	Enter rating derived from the intersection of the seasonality and frequency matrix. Rating carried over to HYDRIP_MOD

6. EXECUTING THE IHI MODEL: INSTREAM HABITAT INTEGRITY ASSESSMENT

All metric ratings were weighted according to the river type (i.e. perenniality, geomorphic zone and width; Appendix A):

$$Mwr = Mur \times (Wt/100)$$

Where:
Mwr = Weighted metric rating
Mur = Unweighted metric rating
Wt = Weight according to river type (%)

Metric group values were calculated by:

$$Mg = \frac{\sum Mwr}{\sum (Wt \times 5)/100}$$

Where:
Mg = Metric group

$\sum (Wt \times 5)/100$ = The scaled total (based on the weights of individual metrics) that is used to calculate the metric group value.

All metric and metric groups are calculated according to this procedure, except where specified threshold values are exceeded. Where more than one metric in a metric group has a threshold value and more than one of these are exceeded, the metric with the highest value is taken as representing the metric group value.

Each metric group sheet in the model is provided with an "IHI GAUGE". This provides information on the overall instream IHI value and allows the assessor to consider the effects of changing particular metrics.

6.1 INSTREAM HYDROLOGY MODIFICATION: HYD_MOD METRIC GROUP (TABLE 6.1)

Photo Guide: Page G2:1

The integration of instream hydrological modification metrics are presented in Table 6.1. The ratings of metrics in this group are the result of the assessment of various aspects of the hydrology as assessed in Tables 5.9 to 5.12. The assessor is required to enter the confidence rating for metrics and consider the metric ratings. If the metric ratings are suspect, the assessor has to back-track and reconsider the assessments in Table 5.9 to 5.12a.

Table 6.1 Integration of hydrology metric assessments to provide the HYD_MOD metric group rating.

METRIC	RATING	THRESHOLD EXCEEDED?	CONFIDENCE RATING *Enter below:* *1 – low confidence* *2 – low to medium confidence* *3 - medium confidence* *4 – medium to high confidence* *5 – high confidence*
BASE FLOWS	*Carried over from: IBASEFLOW. This rating is also carried over to the information table in the PC_MOD, BED_MOD, BANK_MOD and CON_MOD metric groups.*	*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
ZERO FLOWS	*Carried over from: IZEROFLOWS. This rating is also carried over to the information table in the PC_MOD, BED_MOD, BANK_MOD and CON_MOD metric groups.*	*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
FLOODS	*Carried over from: IFLOODS. This rating is also carried over to the information table in the PC_MOD, BED_MOD, BANK_MOD and CON_MOD metric groups.*	*No threshold specified for this metric.*	
INSTREAM HYDROLOGY MODIFICATION RATING	*HYD_MOD metric group rating. This value is automatically carried over to HYDM_CALC sheet (hidden) where it is weighted according to the stream size, perenniality and geomorphic zone. The weighted rating is transferred to the INSTREAM IHI sheet.*	MEAN CONF →	*Average confidence rating for the 3 metrics: Carried over to INSTREAM IHI sheet*

IHI GAUGE: *The information below is transferred from the integrated instream habitat integrity assessment, to the INSTREAM IHI sheet.*	
INSTREAM IHI %	INSTREAM IHI CATEGORY
IHI expressed as %. Used to provide indication of overall change when HYD_MOD individual metrics are changed.	*Calculated IHI category (A to F)*

6.2 PHYSICO-CHEMICAL MODIFICATION: PC_MOD METRIC GROUP (TABLE 6.2A & B)

Photo Guide: Page G2:3

The modification indicator column of the PC_MOD metric group provides an opportunity for the assessor to consider the impact ratings for these indicators in terms of their influence on various physico-chemical attributes (Table 6.2a). These ratings are summarized and used to rate the various physico-chemical metrics of this group (Table 6.2b). Where possible the information gleaned from the PAI (Module C), should be used to inform the assessment of the PC_MOD metric group. It must be emphasized that the PC_MOD metric group focuses on the general responses of biota. The deviation of the metric from the reference condition is used to interpret the response of the biota and is not rated per se.

Table 6.2a Overview of information that contribute to the rating of the PC_MOD metrics

MODIFICATION INDICATOR	IMPACT RATING. *Use these to assist in rating of physico-chemical severity ratings. Imported from:*	PHYSICO-CHEMICAL METRIC SEVERITY RATINGS: *Enter rating below: 0-5 (cf. Table 5.02). Rate only those considered relevant*						
		pH	**Salts**	**Nutrients**	**Water Temperature**	**Water clarity**	**Oxygen**	**Toxics**
HYDROLOGY								
BASEFLOWS	*HYD_MOD*							
ZERO FLOWS	*HYD_MOD*							
FLOODS	*HYD_MOD*							
OTHER MODIFICATIONS								
Weirs	*INS_SUM*							
Dams	*INS_SUM*							
Off-channel dams	*INS_SUM*							
Runoff/effluent: Urban areas	*INS_SUM*							
Runoff/effluent: Irrigation	*INS_SUM*							
Runoff/effluent: Industries	*INS_SUM*							
Runoff/effluent: Mining	*INS_SUM*							
Industries, catchment	*CATCH_SUM*							
Mining, catchment	*CATCH_SUM*							
Exotic Aquatic macrophytes	*INS_SUM*							
Water Column: Algal growth	*INS_SUM*							
Forestry	*RIP_SUM*							
Roads	*RIP_SUM*							
Invasive alien vegetation	*RIP_SUM*							
Introduced habitat modifying fauna	*INS_SUM*							
Vegetation removal	*INS_SUM*							
Bed: material disturbance/removal	*INS_SUM*							
Inter basin transfers	*INS_SUM*							
Catchment trampling	*CATCH_SUM*							
Riparian animal farming	*RIP_SUM*							
Riparian irrigation	*RIP_SUM*							
Catchment animal farming	*CATCH_SUM*							
Catchment Urbanization	*CATCH_SUM*							
Catchment roads	*CATCH_SUM*							
Catchment industries	*CATCH_SUM*							
Catchment mining	*CATCH_SUM*							
Riparian zone trampling	*RIP_SUM*							
Erosion, riparian	*RIP_SUM*							
Erosion, catchment	*CATCH_SUM*							
Rubbish dumping catchment	*CATCH_SUM*							
Rubbish dumping instream	*INS_SUM*							
MAXIMUM →	*Automatically calculated for other modifications: use these values and hydrological modifications to assess the metrics*							
MEAN →								
MEDIAN →								
MODE →								

Table 6.2b Rating and calculation of PC_MOD metrics

METRIC	RATING *Enter rating below: 0-5 (cf. Table 5.02).*	THRESHOLD EXCEEDED?	CONFIDENCE **Enter rating below:** *1 – low confidence* *2 – low to medium confidence* *3 - medium confidence* *4 – medium to high confidence* *5 – high confidence*
pH		*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
Salts		*No threshold specified for this metric.*	
Nutrients		*No threshold specified for this metric.*	
Water Temperature		*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
Water clarity		*No threshold specified for this metric.*	
Oxygen		*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
Toxics		*Rule: If rating > 3.9 then this rating is considered to represent the rating for hydrological modification.*	
CALCULATED PHYSICO-CHEMICAL MODIFICATION RATING	*This calculated value results from the PC_M_CALC sheet (hidden) where weights according to the stream size, perenniality and geomorphic zone are applied to the metrics.*	**MEAN CONF→**	*Average confidence rating for the 7 metrics: Carried over to INSTREAM IHI sheet.*
FINAL PHYSICO-CHEMICAL MODIFICATION RATING	*PC_MOD metric group rating.. If the calculated PC rating is accepted it should be carried over to this cell. .If the calculated value needs adjustment, that value should be entered here. The rating is transferred to the INSTREAM IHI sheet.*		

IHI GAUGE: *The information below is transferred from the integrated instream habitat integrity assessment, to the PC_MOD sheet.*	
INSTREAM IHI %	**CATEGORY**
IHI expressed as %. Used to provide Indication of overall change when PC_MOD metrics are changed individually.	*Calculated IHI category (A to F)*

6.3 BED MODIFICATION: BED_MOD METRIC GROUP (TABLE 6.3A & B)

Photo Guide: Page G2:6

The modification indicator column of the BED_MOD metric group provides the opportunity for the assessor to consider the impact ratings for these indicators in terms of their influence on factors that affect the stream bed. These ratings are summarized and used to rate the two metrics of this group (Table 6.3a & b).

Table 6.3a Information that contribute to the rating of the BED_MOD metrics

MODIFICATION INDICATOR	IMPACT RATING IMPACT RATING. *Use these to assist in rating of bed modification severity ratings. Imported from:*	SEVERITY RATING *Enter rating: 0-5 (cf. Table 5. 2)*	
		SEDIMENT	BENTHIC GROWTH
HYDROLOGY			
BASEFLOWS	*HYD_MOD*		
ZERO FLOWS	*HYD_MOD*		
FLOODS	*HYD_MOD*		
OTHER MODIFICATIONS			
Water Temperature	*PC_MOD*		
Nutrients	*PC_MOD*		
Bed: material disturbance/removal	*INS_SUM*		
Bed: sedimentation	*INS_SUM*		
Bed: benthic growth	*INS_SUM*		
Bed: scouring	*INS_SUM*		
Bed: stabilization (e.g. concrete)	*INS_SUM*		
Rubbish dumping, instream	*INS_SUM*		
Mining	*RIP_SUM*		
Roads	*RIP_SUM*		
Vegetation removal	*RIP_SUM*		
Invasive alien vegetation	*RIP_SUM*		
Introduced habitat modifying fauna	*RIP_SUM*		
Riparian zone erosion	*RIP_SUM*		
Catchment erosion	*CATCH_SUM*		
Trampling	*RIP_SUM*		
Crossings low water	*INS_SUM*		
MAXIMUM : →	*Automatically calculated for other modifications : Use these values and hydrological modifications to assess the metrics.*		
MEAN: →			
MEDIAN: →			
MODE: →			

Table 6.3b Rating and calculation of BED_MOD metrics

METRIC	RATING *Enter rating: 0-5 (cf. Table 5.02).*	THRESHOLD EXCEEDED?	CONFIDENCE **Enter:** *1 – low confidence 2 – low to medium confidence 3 - medium confidence 4 – medium to high confidence 5 – high confidence*
SEDIMENT ***Page G2:6***		*Rule: If rating > 3.9 then this rating is considered to represent the rating for bed modification*	
BENTHIC GROWTH ***Page G2:18***		*No threshold specified for this metric*	
BED MODIFICATION RATING	*This calculated value results from the BED_M_CALC sheet (hidden) where weights according to the stream size, perenniality and geomorphic zone are applied to the metrics. Weighted rating is transferred to the INSTREAM IHI sheet.*	**MEAN CONF →**	*Average confidence rating for the 2 metrics: Carried over to INSTREAM IHI sheet.*

IHI GAUGE: *The information below is transferred from the integrated instream habitat integrity assessment, to the BED_MOD sheet.*	
INSTREAM IHI %	**CATEGORY**
IHI expressed as %. Used to provide Indication of overall change when BED_MOD metrics are changed individually	*Calculated IHI category (A to F)*

6.4 BANK MODIFICATION: BANK_MOD METRIC GROUP (TABLE 6.4A & B)

Photo Guide: Page G2:19

Bank modification in terms of the instream perspective of the IHI should consider how changes to the bank would influence the instream habitat (Table 6.4a & b). It is important that this should not be confused with the riparian zone assessment of the IHI.

Table 6.4a Information that contribute to rating the BANK_MOD metrics

MODIFICATION INDICATOR	**IMPACT RATING** *Use these to assist in rating of bank modification severity ratings. Imported from:*	**SEVERITY RATING** *Enter rating: 0-5 (cf. Table 5.2)*	
		MARGINAL	NON-MARGINAL
HYDROLOGY			
BASEFLOWS	*HYD_MOD*		
ZERO FLOWS	*HYD_MOD*		
FLOODS	*HYD_MOD*		
OTHER MODIFICATIONS			
Weirs	*INS_ SUM*		
Dams	*INS_ SUM*		
Vegetation removal	*RIP_ SUM*		
Invasive vegetation	*RIP_ SUM (THE MAXIMUM OF ALIEN OR NATIVE INVASIVES IS TAKEN)*		
Roads	*RIP_ SUM*		
Erosion	*RIP_ SUM*		
Trampling	*RIP_ SUM*		
Channel Straightening	*RIP_ SUM*		
MAXIMUM →	*Automatically calculated for other modifications : Use these values and hydrological modifications to assess the metrics.*		
MEAN →			
MEDIAN →			
MODE →			

Table 6.4b Rating and calculation of BANK_MOD metrics

METRIC	**RATING** *Enter rating: 0-5 (cf. Table 5.02)*		**CONFIDENCE** *Enter:* *1 – low confidence* *2 – low to medium confidence* *3 - medium confidence* *4 – medium to high confidence* *5 – high confidence*
MARGINAL			
NON-MARGINAL			
BANK MODIFICATION RATING	*This calculated value results from the BANK_M _CALC sheet (hidden) where weights according to stream size, perenniality & geomorphic zone are applied. The weighted rating is transferred to the INSTREAM IHI sheet*	**MEAN CONF→**	*Average confidence rating for the 2 metrics: Carried over to INSTREAM IHI sheet*

IHI GAUGE: *The information below is transferred from the integrated instream habitat integrity assessment, to the BANK_MOD sheet.*	
INSTREAM IHI %	**CATEGORY**
IHI expressed as %. Used to provide Indication of overall change when BANK_MOD metrics are changed individually	*Calculated IHI category (A to F)*

6.5 CONNECTIVITY MODIFICATION: CON_MOD METRIC GROUP (TABLE 6.5A & B)

Photo Guide: Page G2:31

The impact of a change on connectivity in terms of importance of habitat in both a longitudinally and laterally must be considered. Longitudinal connectivity refers to connectivity in terms of movement upstream and downstream to habitats required for particular life-history phases and for refugia. Lateral connectivity refers to movement to and from floodplains and also within the stream channel where the availability of particular habitats may be critical for survival (e.g. nursery areas, feeding areas and refugia).

Table 6.5a Information that contribute to the rating of the CON_MOD metrics

MODIFICATION INDICATOR	**IMPACT RATING:** *Use these to assist in rating of connectivity modification severity ratings. Imported from:*	**SEVERITY RATING** *Enter rating: 0-5 (cf. Table 5.02)*	
		LONGITUDINAL	**LATERAL**
HYDROLOGY			
BASEFLOWS	*HYD_MOD*		
ZERO FLOWS	*HYD_MOD*		
FLOODS	*HYD_MOD*		
OTHER MODIFICATIONS			
Weirs	*INS_ SUM*		
Dams	*INS_ SUM*		
Crossings low water	*INS_ SUM*		
Trampling	*SUM_RIP*		
Roads	*SUM_RIP*		
Exotic Aquatic macrophytes	*INS_ SUM*		
Toxics	*PC_MOD*		
Oxygen	*PC_MOD*		
pH	*PC_MOD*		
Water Temperature	*PC_MOD*		
Bed modification	*BED_MOD*		
Bank modification	*BANK_MOD*		
MAXIMUM →	*Automatically calculated for other modifications : use these values and hydrological modifications to assess the metrics.*		
MEAN →			
MEDIAN →			
MODE→			

Table 6.5b Rating and calculation of CON_MOD metrics

METRIC	**RATING** *Enter rating: 0-5 (cf. Table 5.02).*	**CONFIDENCE** *Enter:* *1 – low confidence* *2 – low to medium confidence* *3 - medium confidence* *4 – medium to high confidence* 5 – high confidence	
LONGITUDINAL			
LATERAL			
CONNECTIVITY MODIFICATION RATING	*This calculated value results from the CON_MOD_CALC sheet (hidden) where weights according to the stream size, perenniality and geomorphic zone are applied to the metrics. The weighted rating is transferred to the INSTREAM IHI sheet.*	**MEAN CONF→**	*Average confidence rating for the 2 metrics: Carried over to INSTREAM IHI sheet*
IHI GAUGE *The information below is transferred from the integrated instream habitat integrity assessment, to the CON_MOD sheet.*			

INSTREAM IHI %	CATEGORY
IHI expressed as %. Used to provide Indication of overall change when CON_MOD metrics are changed individually	*Calculated IHI category (A to F)*

6.6 INSTREAM IHI (TABLE 6.6)

The calculation of the instream IHI (IIHI) is formulated as follows:

$$IIHI = 100 - \left(\left(\frac{\sum Mg \times Wt}{\sum (Wt \times 5)/100} \right) \times 100 \right)$$

Where:
IIHI = Instream index of habitat integrity, expressed as a percentage
Mg = Metric group values
Wt = Metric group weight

$\sum$ (Wt x 5)/100 = The scaled total (based on the weights of individual metric groups) that is used to calculate the IIHI value.

Table 6.6 summarizes the results of the instream habitat integrity assessment.

The generic interpretation of the IHI results and categories are indicated in Table 2.1 (duplicated in the INSTREAM IHI sheet). The description and specification that delineate each category need to be formulated based on the characteristics of the particular river.

Table 6.6 Instream habitat integrity indicating ratings for metric groups

METRIC GROUP	**RATING** *Transferred from:*	**CONFIDENCE** *Transferred from:*
HYDROLOGY MODIFICATION	*HYD_M_CALC (hidden). Weight applied to metric group rating: 100%*	*HYD_MOD*
PHYSICO-CHEMICAL MODIFICATION	*PC_M_CALC (hidden). Weight applied to metric group rating: 85%*	*PC_MOD*
BED MODIFICATION	*BED_M_CALC (hidden). Weight applied to metric group rating: 80%*	*BED_MOD*
BANK MODIFICATION	*BANK_M_CALC (hidden). Weight applied to metric group rating: 45%*	*BANK_MOD*
CONNECTIVITY MODIFICATION	*CON_MOD_CALC (hidden). Weight applied to metric group rating: 65%*	*CON_MOD*
INSTREAM IHI%	*Threshold: when the physico-chemical metric group rating is >3.9, this rating is considered to represent the instream habitat integrity if the integrated IHI value represents a lower value.*	
CATEGORY	*Calculated IHI category (A to F)*	
CONFIDENCE	*Mean confidence of metric groups.*	

7. EXECUTING THE IHI MODEL: RIPARIAN ZONE HABITAT INTEGRITY ASSESSMENT

All metric ratings were weighted according to the river type (i.e. perenniality, geomorphic zone and width; Appendix A):

$$Mwr = Mur \times (Wt/100)$$

Where:
Mwr = Weighted metric rating
Mur = Unweighted metric rating
Wt = Weight according to river type (%)

Metric group values were calculated by:

$$Mg = \frac{\sum Mwr}{\sum (Wt \times 5)/100}$$

Where:
Mg = Metric group

$\sum (Wt \times 5)/100$ = The scaled total (based on the weights of individual metrics) that is used to calculate the metric group value.

All metric and metric groups are calculated according to this procedure, except where specified threshold values are exceeded. Where more than one metric in a metric group has a threshold value and more than one of these are exceeded, the metric with the highest value is taken as representing the metric group value.

Each metric group sheet in the model is provided with a "RIPARIAN IHI GAUGE". This provides information on the overall riparian IHI value and allows the assessor to consider the effects of changing particular metrics.

7.1 RIPARIAN ZONE HYDROLOGY MODIFICATION: HYDRIP_MOD METRIC GROUP (TABLE 7.1)

Photo Guide: Page G2:35

The integration of riparian zone hydrological modification metrics are presented in Table 7.1. The ratings of metrics in this group are the result of the assessment of various aspects of the hydrology as assessed in Tables 5.11a to 5.14. The assessor is required to enter the confidence rating for metrics and consider the metric ratings. If the metric ratings are suspect, the assessor has to back-track and reconsider the assessments in Table 5.11a to 5.14.

Table 7.1 Integration of hydrology metric assessments to provide the HYDRIP_MOD metric group rating

METRIC	RATING		CONFIDENCE Enter below: 1 – low confidence 2 – low to medium confidence 3 - medium confidence 4 – medium to high confidence 5 – high confidence
BASE FLOW	*Carried over from: RBASEFLOW. This rating is also carried over to the information table in the BANK_S_MOD, CONRIP_MOD metric groups.*		
ZERO FLOWS	*Carried over from RZEROFLOWS. This rating is also carried over to the information table in the BANK_S_MOD, CONRIP_MOD metric groups.*		
MODERATE FLOODS	*Carried over from: RIPFLOODS. This rating is also carried over to the information table in the BANK_S_MOD, CONRIP_MODmetric groups.*		
LARGE FLOODS	*Carried over from: RIPFLOODS. This rating is also carried over to the information table in the CONRIP_MOD metric groups.*		
RIPARIAN ZONE HYDROLOGY MODIFICATION RATING	*HYD_MOD metric group rating. Calculation is done in the HYDRIP_CALC sheet (hidden) where it is weighted according to the stream size, perenniality and geomorphic zone. The weighted rating is transferred to this cell of the HYDRIP_MOD sheet.*	MEAN CONF→	Average confidence rating for the 4 metrics: Carried over to RIPARIAN IHI sheet.

RIPARIAN HABITAT INTEGRITY (IHI) GAUGE: *The information below is transferred from the integrated riparian zone habitat integrity assessment, to the RIPARIAN IHI sheet.*	
RIPARIAN ZONE IHI %	**RIPARIAN ZONE CATEGORY**
IHI expressed as %. Used to provide indication of overall change when individual HYDRIP_MOD metrics are changed.	*Calculated IHI category (A to F)*

7.2 BANK STRUCTURE MODIFICATION: BANK_S_MOD METRIC GROUP (TABLE 7.2A & B)

Photo Guide: Page G2:37

The marginal and non-marginal zones are assessed separately.

Ratings for substrate exposure, encroachment by invasive vegetation and erosion are taken directly from Table 5.6c and transferred to the appropriate cells in Table 7.2b. Invasive vegetation includes both alien vegetation and native vegetation. Native vegetation would refer to terrestrialization in the riparian zone, e.g. when flows are restricted and regulated to such a degree that vegetation usually associated with drier conditions invades the riparian zone. Invasion by reeds (Phragmites spp.) is often associated with the control of floods which results in the stabilization of sediment banks by reeds. Detail as to the type of invasive vegetation should be recorded in the comments section of Table 5.6a.

The possible impact of physico-chemical changes is rated based on input from Table 6.2a & b. Channel straightening is assessed based inputs from Table 5.6a.

Table 7.2a Information that contribute to the rating of the BANK_S_MOD metrics

MODIFICATION INDICATOR	**IMPACT RATING** *Use these to assist in rating of bank structure modification severity ratings. Imported from:*	**SEVERITY RATING** *Enter rating: 0-5 (cf. Table 5.2).*	
		MARGINAL	NON-MARGINAL
HYDROLOGY			
BASE FLOW	*HYDRIP_MOD*		
ZERO FLOWS	*HYDRIP_MOD*		
MODERATE FLOODS	*HYDRIP_MOD*		
LARGE FLOODS	*HYDRIP_MOD*		
OTHER MODIFICATIONS			
Mining	*RIP_SUM*		
Off-channel dams	*RIP_SUM*		
Riparian irrigation	*RIP_SUM*		
Rubbish dumping	*RIP_SUM*		
Erosion	*RIP_SUM*		
Riparian vegetation removal	*RIP_SUM*		
Forestry	*RIP_SUM*		
Trampling	*RIP_SUM*		
Roads	*RIP_SUM*		
Riparian urbanization	*RIP_SUM*		
Nutrients	*PC_MOD*		
Pesticides (toxics)	*PC_MOD*		
Channel straightening	*RIP_SUM*		
Dry land farming	*PC_MOD*		
MAXIMUM→	*Automatically calculated for other modifications : use these values and hydrological modifications to assess the metrics*		
MEAN→			
MEDIAN→			
MODE→			

Table 7.2b Rating and calculation of BANK_S_MOD metrics

BANK STRUCTURE MODIFICATIONS	**MARGINAL RATING**	**NON-MARGINAL RATING**	
SUBSTRATE EXPOSURE *(Table 7.2a information used for rating.) Page G2:37*	*Transferred from RIP_SUM*	*Transferred from RIP_SUM*	
INVASIVE VEGETATION *(Table 7.2a information used for rating). The maximum of invasive native or alien vegetation should be used as guidance. Page G2:40*	*Transferred from RIP_SUM*	*Transferred from RIP_SUM*	
EROSION *(Table 7.02a information used for rating). Page G2:40*	*Transferred from RIP_SUM*	*Transferred from RIP_SUM*	
PHYSICO-CHEMICAL *Page G2:44*	*Enter rating: 0-5 (cf. Table 5.02).*	*Enter rating: 0-5 (cf. Table 5.2).*	
CHANNEL STRAIGHTENING *Page G2:47*	*Enter rating: 0-5 (cf. Table 5.02).*	*Enter rating: 0-5 (cf. Table 5.2).*	
METRICS	**MAXIMUM RATING**		**CONFIDENCE RATING** Enter below: 1 – low confidence 2 – low to medium confidence 3 - medium confidence 4 – medium to high confidence 5 – high confidence
MARGINAL	*Calculated in BANK_S_CALC (hidden) where the maximum of bank structure modification rating is taken and is weighted according to the stream size, perenniality and geomorphic zone. This rating is transferred to this cell of the BANK_MOD sheet*		
NON-MARGINAL	*Calculated in BANK_S_CALC (hidden) where the maximum of bank structure*		

	modification rating is taken and is weighted according to the stream size, perenniality and geomorphic zone. This rating is transferred to this cell of the BANK_MOD sheet.		
BANK STRUCTURE MODIFICATION RATING	*Calculated in BANK_S_CALC (hidden)where the zone weights are applied, integrated and transferred to this cell of the BANK_MOD sheet.*	MEAN CONF→	*Average confidence rating for the 4 metrics: Carried over to RIPARIAN IHI sheet*

RIHI GAUGE: *The information below is transferred from the integrated riparian zone habitat integrity assessment, to the RIPARIAN IHI sheet.*	
RIPARIAN ZONE IHI %	**RIPARIAN ZONE CATEGORY**
IHI expressed as %. Used to provide indication of overall change when individual BANK_MOD metrics are changed.	*Calculated IHI category (A to F)*

7.3 RIPARIAN ZONE CONNECTIVITY MODIFICATION: CONRIP_MOD METRIC GROUP (TABLE 7.3A & B)

Photo Guide: Page G2:50

The marginal and non-marginal zones are assessed separately.

Connectivity related to lateral and longitudinal movement of biota and physico-chemical processes that take place in the riparian zone should be considered.

The impact ratings in Table 7.3a are considered in the rating of changes in longitudinal and lateral connectivity (Table 7.3b).

Table 7.3a Information that contribute to the rating of the CONRIP_MOD metrics

MODIFICATION INDICATOR	**IMPACT RATING** *Use these to assist in rating of bank structure modification severity ratings. Imported from:*	**SEVERITY RATING** *Enter rating: 0-5 (cf. Table 5.02).*	
		LONGITUDINAL	**LATERAL**
HYDROLOGY			
BASEFLOWS	*HYDRIP_MOD*		
ZERO FLOWS	*HYDRIP_MOD*		
MODERATE FLOODS	*HYDRIP_MOD*		
LARGE FLOODS	*HYDRIP_MOD*		
OTHER MODIFICATIONS			
Off-channel dams	*RIP_SUM*		
Marginal vegetation: structure modification	*BANK_S_MOD*		
Non-Marginal vegetation: structure modification	*BANK_S_MOD*		
Weirs	*INS_SUM*		
Dams	*INS_SUM*		
Roads	*RIP_SUM*		
Riparian Invasive alien vegetation	*RIP_SUM*		
Riparian zone urbanization	*RIP_SUM*		
Vegetation removal	*RIP_SUM*		
Channel straightening	*RIP_SUM*		
Erosion	*RIP_SUM*		
MAXIMUM →	*Automatically calculated for other modifications : Use these values and hydrological modifications to assess the metrics (Table 7.03b).*		
MEAN →			
MEDIAN →			
MODE →			

Table 7.3b Rating and calculation of CONRIP_MOD metrics

METRIC	RATING *Enter rating: 0-5 (cf. Table 5.2)*	CONFIDENCE *Enter below:* *1 – low confidence* *2 – low to medium confidence* *3 - medium confidence* *4 – medium to high confidence* *5 – high confidence*
LONGITUDINAL		
LATERAL		
CONNECTIVITY MODIFICATION RATING	*Calculated in CONRIP_CALC (hidden)where the zone weights are applied, integrated and transferred to this cell of the CONRIP_MOD sheet.*	*Average confidence rating for the 2 metrics: Carried over to RIPARIAN IHI sheet*

RIHI GAUGE: *The information below is transferred from the integrated riparian zone habitat integrity assessment, to the RIPARIAN IHI sheet.*	
RIHI (%)	**EC**
IHI expressed as %. Used to provide indication of overall change when individual CONRIP_ MOD metrics are changed	*Calculated IHI category (A to F)*

7.4 RIPARIAN ZONE IHI (TABLE 7.4)

The calculation of the riparian zone IHI (RIHI) is formulated as follows:

$$RIHI = 100 - \left(\left(\frac{\sum Mg \times Wt}{\sum (Wt \times 5)/100} \right) \times 100 \right)$$

Where:

RIHI = Riparian zone index of habitat integrity, expressed as a percentage

Mg = Mg values

Wt = Metric group weight

∑ (Wt x 5)/100 = The scaled total (based on the weights of individual metric groups) that is used to calculate the RIHI value.

Table 7.4 summarizes the results of the riparian habitat integrity assessment.

The generic interpretation of the riparian IHI results and categories are indicated in Table 6.7. The description and specification that delineate each category need to be formulated based on the characteristics of the particular river.

Table 7.4 Instream habitat integrity indicating ratings for metric groups

METRIC GROUP	RATING *Transferred from:*	CONFIDENCE *Transferred from:*
HYDROLOGY	*HYDRIP_CALC (hidden). Weight applied to metric group rating: 75%*	*HYDRIP_MOD*
BANK STRUCTURE MODIFICATION	*BANK_S_CALC (hidden). Weight applied to metric group rating: 100%*	*BANK_S_MOD*
CONNECTIVITY MODIFICATION	*CONRIP_CALC (hidden). Weight applied to metric group rating: 50%*	*CONRIP_MOD*
RIPARIAN INDEX OF HABITAT INTEGRITY (RIHI) (%)	*Riparian habitat integrity (%) based on calculation of metric group ratings and weights. No thresholds are specified.*	
CATEGORY	*Calculated RIHI category (A to F)*	
CONFIDENCE	*Mean confidence of metric groups*	

8. SUMMARY OF IHI RESULTS (TABLE 8.1 AND 8.2)

Tables 8.1 and 8.2 summarize the results of respectively the instream and riparian IHI.

Table 8.1 Summary of instream IHI assessment

METRIC GROUPS & METRICS	MANAGEMENT RESOURCE UNIT/ ASSESSMENT UNIT
	Indicate unit here (cf. Table 5.1)
Base Flows	*TRANSFERRED FROM: HYD_MOD*
Zero Flows	
Floods	
HYDROLOGY MODIFICATION	
pH	*TRANSFERRED FROM: PC_MOD*
Salts	
Nutrients	
Water Temperature	
Water clarity	
Oxygen	
Toxics	
PC MODIFICATION RATING	
Sediment	*TRANSFERRED FROM: BED_MOD*
Benthic Growth	
BED MODIFICATION RATING	
Marginal	*TRANSFERRED FROM: BANK_MOD*
Non-marginal	
BANK MODIFICATION RATING	
Longitudinal Connectivity	*TRANSFERRED FROM: CON_MOD*
Lateral Connectivity	
CONNECTIVITY MODIFICATION	
INSTREAM IHI %	*TRANSFERRED FROM: INSTREAM IHI*
INSTREAM IHI EC	
INSTREAM CONFIDENCE	

Table 8.2 Summary of riparian IHI assessment

METRIC GROUPS & METRICS	MANAGEMENT RESOURCE UNIT/ ASSESSMENT UNIT
	TRANSFERRED FROM TABLE 8.1
Base Flows	*TRANSFERRED FROM : HYDRIP_MOD*
Zero Flows	
Moderate Floods	
Large Floods	
HYDROLOGY RATING	
Substrate Exposure (marginal)	*TRANSFERRED FROM : BANK_S_MOD*
Substrate Exposure (non- marginal)	
Invasive Alien Vegetation (marginal)	
Invasive Alien Vegetation (non- marginal)	
Erosion (marginal)	
Erosion (non- marginal)	
Physico-Chemical (marginal)	
Physico-Chemical (non- marginal)	
Marginal	
Non-marginal	

BANK STRUCTURE RATING	
Longitudinal Connectivity	*TRANSFERRED FROM : CONRIP_MOD*
Lateral Connectivity	
CONNECTIVITY RATING	
RIPARIAN IHI %	*TRANSFERRED FROM :RIPARIAN IHI*
RIPARIAN IHI EC	
RIPARIAN CONFIDENCE	

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APPENDIX A: DETERMINATION OF METRIC WEIGHTS FOR DIFFERENT RIVER TYPES FOR APPLICATION IN THE INDEX OF HABITAT INTEGRITY

The following river characteristics were considered in the weighting of various impacts on different river types:

- Perenniality: Perennial or non-perennial.
- Longitudinal geomorphic zone (Rowntree and Wadeson, 1999): A simplified approach was followed by using only four zones: source, mountain stream (including mountain headwater stream), foothill (combining the upper, lowland and transitional zones) and lowland.
- River size (width): Three width classes are distinguished, <5 m, 5-15 m and >15 m wide.

The relative importance of each of the metrics in terms of impact on habitat integrity when modified, was assessed according to these considerations. A pair-wise comparison of metrics (USACE 1980; Salustri 2005) was used to weight the importance of instream and riparian metrics respectively.

Seven river ecologists participated in the weight determination workshop:

Dr. C. Dickens
Dr. M. Graham
Mr. D. MacFarlane
Ms. C. Thirion
Ms. C. Todd
Ms. D. Louw
Dr. C. Kleynhans

The weights indicated in Tables A1-8 were built into the IHI model.

Table A.1 Weights (%) for instream hydrological metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Base flows	65.0	65.0	65.0	60.0	60.0	60.0	70.0	50.0	50.0
Zero flow duration	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Floods	20.0	35.0	40.0	40.0	50.0	60.0	35.0	65.0	70.0
NON-PERENNIAL									
Metric	Weight (%)								
Base flows	100.0	100.0	95.0	100.0	95.0	95.0	100.0	85.0	90.0
Zero flow duration	75.0	65.0	70.0	60.0	70.0	70.0	80.0	65.0	65.0
Floods	30.0	75.0	100.0	80.0	100.0	100.0	70.0	100.0	100.0

Table A.2 Weights (%) for instream physico-chemical metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	**0-2**	**0-2**	**2-15**	**<2**	**2-15**	**>15**	**<2**	**2-15**	**>15**
PERENNIAL									
Metric	Weight (%)								
pH	50.0	50.0	50.0	50.0	50.0	50.0	60.0	60.0	60.0
Salts	60.0	60.0	60.0	55.0	50.0	50.0	55.0	50.0	50.0
Nutrients	70.0	55.0	55.0	60.0	65.0	65.0	75.0	75.0	70.0
Temperature	50.0	55.0	55.0	50.0	55.0	60.0	50.0	55.0	60.0
Water clarity	70.0	65.0	65.0	60.0	55.0	50.0	60.0	50.0	50.0
Oxygen concentration	65.0	75.0	75.0	75.0	75.0	75.0	60.0	65.0	65.0
Toxics	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
NON-PERENNIAL									
Metric	Weight (%)								
pH	50.0	50.0	50.0	50.0	50.0	50.0	55.0	55.0	55.0
Salts	60.0	55.0	55.0	55.0	55.0	55.0	50.0	50.0	55.0
Nutrients	65.0	65.0	65.0	65.0	70.0	65.0	75.0	76.0	70.0
Temperature	50.0	50.0	50.0	50.0	50.0	55.0	50.0	55.0	60.0
Water clarity	70.0	65.0	65.0	65.0	60.0	55.0	55.0	55.0	50.0
Oxygen concentration	60.0	75.0	75.0	75.0	75.0	70.0	65.0	65.0	65.0
Toxics	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Table A.3 Weights (%) for bed modification metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	**0-2**	**0-2**	**2-15**	**<2**	**2-15**	**>15**	**<2**	**2-15**	**>15**
PERENNIAL									
Metric	Weight (%)								
Sediment	65.0	100.0	100.0	100.0	100.0	100.0	65.0	45.0	45.0
Benthic growth	100.0	65.0	65.0	65.0	45.0	65.0	100.0	100.0	100.0
NON-PERENNIAL									
Metric	Weight (%)								
Sediment	65.0	100.0	100.0	100.0	100.0	100.0	65.0	65.0	45.0
Benthic growth	100.0	65.0	65.0	65.0	65.0	65.0	100.0	100.0	100.0

Table A.4 Weights (%) for instream bank modification metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Marginal zone	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Non-marginal zone	10.0	100.0	100.0	65.0	65.0	65.0	100.0	65.0	65.0
NON-PERENNIAL									
Metric	Weight (%)								
Marginal zone	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Non-marginal zone	25.0	100.0	100.0	100.0	67.0	67.0	100.0	100.0	100.0

Table A.5 Weights (%) for instream connectivity metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Longitudinal	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lateral	100.0	10.0	10.0	10.0	25.0	45.0	25.0	45.0	65.0
NON-PERENNIAL									
Metric	Weight (%)								
Longitudinal	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lateral	100.0	10.0	10.0	10.0	25.0	45.0	25.0	45.0	65.0

Table A.6 Weights (%) for riparian zone hydrological metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Low flows	95	85	75	85	70	70	95	65	65
Zero flow duration	100	100	100	100	100	90	100	75	75
Moderate events	70	70	80	70	80	85	60	85	85
Floods	40	45	70	45	85	100	50	100	100
NON-PERENNIAL									
Metric	Weight (%)								
Low flows	100	100	90	100	80	65	100	70	55
Zero flow duration	60	60	55	60	50	40	95	50	40
Moderate events	80	80	100	80	95	95	85	95	85
Floods	70	75	100	75	100	100	75	100	100

Table A.7 Weights (%) for bank structure modification metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Marginal zone	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Non-marginal zone	10.0	65.0	100.0	25.0	65.0	100.0	25.0	65.0	100.0
NON-PERENNIAL									
Metric	Weight (%)								
Marginal zone	100.0	100.0	100.0	100.0	65.0	45.0	100.0	67.0	25.0
Non-marginal zone	25.0	66.7	100.0	25.0	100.0	100.0	25.0	100.0	100.0

Table A.8 Weights (%) for the riparian zone connectivity metric ratings for different river types

Geomorphic zone	Source	Mountain	Mountain	Foothills	Foothills	Foothills	Lowland	Lowland	Lowland
Size (width, m)	0-2	0-2	2-15	<2	2-15	>15	<2	2-15	>15
PERENNIAL									
Metric	Weight (%)								
Longitudinal	45.0	100.0	100.0	100.0	100.0	100.0	45.0	100.0	100.0
Lateral	100.0	10.0	25.0	45.0	45.0	65.0	100.0	100.0	100.0
PERENNIAL									
Metric	Weight (%)								
Longitudinal	45.0	100.0	100.0	100.0	100.0	100.0	45.0	100.0	100.0
Lateral	100.0	10.0	25.0	45.0	45.0	65.0	100.0	100.0	100.0

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APPENDIX B: CAPTURING HABITAT INTEGRITY DATA DURING AERIAL SURVEYS

B.1 BACKGROUND

The aerial river sector approach (Kleynhans 1996; Kleynhans and Kemper 2000) is the original way of assessing habitat integrity and is still accepted as a very effective way of obtaining comprehensive information that can assist in evaluating the instream and riparian habitat integrity in the IHI model.

With this approach, information on impacts of disturbance is obtained by means of a low-level (80 – 100m) helicopter survey during which a continuous DVD recording is made of the river. The DVD as well as supplemental data from sources such as Land Cover data sets, biomonitoring reports, hydrological data etc. is then used to rate the impacts on a quantitative basis per 5 km sector of the river.

Although an aerial survey of a river is a rapid and efficient method and provides easy access to difficult terrain, it is a very expensive exercise, emphasising the need to gain as much information as possible during the survey.

Previously tape recorders or handwritten notes were often used to record supplemental and/or descriptive and/or site-specific information during the survey. In recent years, the development and availability of sophisticated data capturing equipment and software has led to the development of a precise yet rapid method of data capturing during aerial surveys. With this approach geo-referenced data on visual characteristics of the river and surrounding area, as well as activities/modifications are captured on a handheld computer (PDA) with GPS capabilities and downloaded to a customised IHI survey database, from which the data can be exported as tables or maps.

The format in which the data is logged and presented has been set up in accordance with the Metric Groups used in the IHI Model and also makes provision for the data capturer to assign an impact rating to every sighting.

Other advantages of this approach are that it enables the recording of activities/modifications that are not always clearly visible on the DVD, for example pumps that are obscured by vegetation, or any activity/modification that occur outside the area captured on the DVD, it enables the identification of invasive vegetation and it allows for the mapping of any of the activities/modifications as it can be incorporated into a Geographic Information System (GIS).

B.2 METHODS

B.2.1 Preparation prior to survey

B.2.1.1 Determination of 5 km river sectors

The river(s) that will be assessed must be divided into numbered 5 km long sectors prior to the survey. The coordinates of the upstream and downstream boundaries (start and end point) of each sector are determined on a 1:50 000 scale Topographical map, or could be generated with a GIS. The coordinates and number of each sector are downloaded to a Global Positioning System (GPS) that will be used for navigational purposes.

B.2.1.2 Database preparation

CyberTracker software[1] was used to develop a customised IHI survey database to which geo-referenced data gathered during the aerial survey can be downloaded, processed and mapped and/or exported to other programs or applications. A generic IHI survey database, data capturing sequence and data processing tables [2] have been developed for use with the IHI Model, but the sequence should preferably be customised prior to the survey to include options applicable to the specific river(s) (e.g. the list of alien/invasive plants should only include the names of plants known to occur, and those with a high probability of occurring along the specific river). The customised data capturing sequence is loaded onto a Handheld computer (PDA) with GPS capabilities that will be used during the survey.

B.2.2 Equipment required

A personal computer with Windows 2000 (or higher) is required for running the CyberTracker software that can be downloaded from the CyberTracker website. It is recommended that the CT3 Professional Version should be used as it supports ESRI shapefiles.

A Handheld computer (PDA) with PDA Desktop software (Windows Mobile or PalmOS) is required to gather and map an unlimited amount of data. As the data required for the river surveys must be geo-referenced, the PDA must have GPS capabilities. The GPS can either be built into the PDA, as is the case with All-in–One Pocket PC/GPS Handheld Units or could be a Bluetooth GPS, in which case the PDA must have Bluetooth wireless-technology to establish a connection with the GPS. As large quantities of data have to be captured within a very short period of time, it is essential that a PDA/GPS system with a very fast acquisition time must be used. PDA/Bluetooth GPS combinations generally offer much faster acquisition times than PDA's with a built-in GPS.

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[1] Detailed information available at: www.cybertracker.co.za

[2] Data processing tables available on the IHI CD. CyberTracker IHI aerial survey sequence available from E. Schulze, eschulze@absamail.co.za, 0829232628.

A separate GPS is required for navigational purposes. As river sectors and sector numbers will be displayed on this GPS, the GPS should be mounted in a position in the helicopter where it will have good satellite reception and where it will be clearly visible to the data recorder and preferably also to the pilot.

B.2.3 The aerial river survey

B.2.3.1 Navigation

The pilot is responsible for navigating to- and along the river. He can use the GPS displaying the 5 km river sectors and sector numbers for this purpose. It is useful to set the GPS to a scale at which at least two sectors are displayed on the screen as this would enable the pilot to see upcoming tributary junctions and help him navigate along the main river channel. The survey is conducted at an altitude of 80 – 100m in an upstream or downstream direction, depending on the time of day the survey is conducted as well as taking logistical arrangements into account.

The data recorder is responsible for calling out and logging the start of every sector according to the sector number displayed on the GPS. The “display track” function on the GPS is used to monitor progress along the river course.

B.2.3.2 Data capture

The data recorder establishes a connection between the PDA and GPS and logs all the relevant activity/modification data on the PDA by “paging through” a sequence of screens containing options for the various impact (activity/modification) groups, followed by screens with impact locality options (where applicable) and an impact rating screen. A GPS coordinate is recorded every time the last screen in a sequence is reached. The pilot and an observer (preferably a person who is familiar with the river) can assist the data recorder with the identification of activity/modifications and with allocating an impact rating. The system also allows for “special features” to be logged, for example potential biomonitoring sites.

Every activity/modification that is logged must be allocated an impact rating that describes the impact of that specific activity/modification at that specific locality. The impact rating is based solely on the visual detectability and severity of the impact caused by the activity/modification. Table B.1 provides descriptive classes and ratings that are used during the aerial river survey. Ratings are indicated with 1.0 class intervals.

Table B.1 Descriptive classes and ratings for assessing the impact/severity of an activity/modification on habitat integrity during the aerial river survey

IMPACT/SEVERITY CLASS	DESCRIPTION	RATING
None (reference)	The activity/modification has no discernible impact on the habitat.	0
Small	The activity/modification has a very limited discernable impact on the habitat.	1
Moderate	The activity/modification has a moderate discernable impact on the habitat.	2
Large	The activity/modification has a clearly visible, large, detrimental impact on the habitat.	3
Serious - Critical	The activity/modification has a clearly visible, severely detrimental impact on the habitat.	4

B.2.4 Data analysis

After the aerial survey, the captured data is downloaded from the PDA to the CyberTracker IHI survey database on the personal computer, by performing a Hotsync or Activesync operation. The data is automatically incorporated into customised tables which can be exported directly to Excel Spreadsheets. Two Excel master files[3], IG master (Impact Group master) and MG master (Metric Group master) are used for analyzing the data.

The "track" recorded on the GPS used for navigation can also be downloaded and used to map the course of the river. This is especially helpful in cases where the river has changed its course or where the available Topographical maps are outdated.

B.3 PRESENTATION OF RESULTS

In CyberTracker data can be viewed in table and/or map format, depending on the type of data that was captured. The data in the IHI survey database can be viewed as tables and maps and can be exported in a variety of formats such as Excel Spreadsheets, ESRI shapefiles as well as in Bitmap or JPEG File Interchange format.

The presentation of results in tabular (Excel Spreadsheet) format provide tables containing data on groups of activities/modifications (Impact Groups) that could influence the habitat integrity of a river (Hydrology, Connectivity, Water quality, Alien vegetation, Vegetation removal, Cultivation, Erosion and Mining). These tables are consolidated in the IG master file. An example of an Impact Group table is provided in Table B.2. Data on activities/modifications which have been identified as being relevant for determining severity ratings for Instream Modification and Riparian Modification in the IHI model (INS_SUM and RIP_SUM) is presented in the MG master file.

[3] Available on the IHI CD.

Table B.2 Example of an Impact Group table for Water quality impacts

Date	Time	Lat	Long	Sector No	Water quality impact	Solid waste disposal locality	Point-source pollution type	Rating
2/6/2006	10:39:17	-25.9086	26.8609	1				
2/6/2006	10:39:50	-25.9069	26.8561	2				
2/6/2006	10:40:43	-25.9023	26.8460	2	Algae bloom			2
2/6/2006	10:40:51	-25.8925	26.8303	3				
2/6/2006	10:42:43	-25.8891	26.8229	4				
2/6/2006	10:52:35	-25.8665	26.7874	5				
2/6/2006	10:54:07	-25.8657	26.7801	5	Algae bloom			1
2/6/2006	10:54:17	-25.8596	26.7778	5	Solid waste disposal	Instream		2
2/6/2006	10:54:50	-25.8503	26.7748	6				
2/6/2006	10:56:35	-25.8478	26.7718	7				
2/6/2006	10:58:31	-25.8453	26.7588	7	Algae bloom			1
2/6/2006	10:58:39	-25.8425	26.7562	8				
2/6/2006	10:59:59	-25.8409	26.7556	8	Point-source pollution		Other	1
2/6/2006	11:00:07	-25.8315	26.7526	9				
2/6/2006	11:00:47	-25.8302	26.7534	9	Point-source pollution		Feedlot	2
2/6/2006	11:00:55	-25.8301	26.7559	10				
2/6/2006	11:02:16	-25.8257	26.7630	11				
2/6/2006	11:03:05	-25.8242	26.7619	11	Algae bloom			2
2/6/2006	11:03:16	-25.8213	26.7619	11	Point-source pollution		Other	4
2/6/2006	11:03:40	-25.8151	26.7594	12				
2/6/2006	11:04:41	-25.8137	26.7591	12	Algae bloom			1
2/6/2006	11:04:50	-25.8108	26.7571	12	Solid waste disposal	Instream		2
2/6/2006	11:04:58	-25.8097	26.7571	12	Point-source pollution		Feedlot	1
2/6/2006	11:08:22	-25.8086	26.7575	13				
2/6/2006	11:10:18	-25.8066	26.7574	13	Point-source pollution		Sewage	4
2/6/2006	11:10:32	-25.8064	26.7554	14				
2/6/2006	11:20:37	-25.8029	26.7511	14	Algae bloom			2
2/6/2006	11:20:56	-25.8019	26.7498	15				
2/6/2006	11:21:44	-25.8023	26.7486	15	Colour change			2
2/6/2006	11:23:02	-25.7789	26.7383	16				
2/6/2006	11:23:23	-25.7786	26.7406	16	Return flow - aquaculture			3
2/6/2006	11:24:47	-25.7716	26.7364	16	Return flow - aquaculture			2

The data contained in the Impact Group tables can be exported as ESRI shapefiles to a GIS. An example of a GIS generated map representing data from an Alien vegetation Impact Group table is provided in Figure B.1.

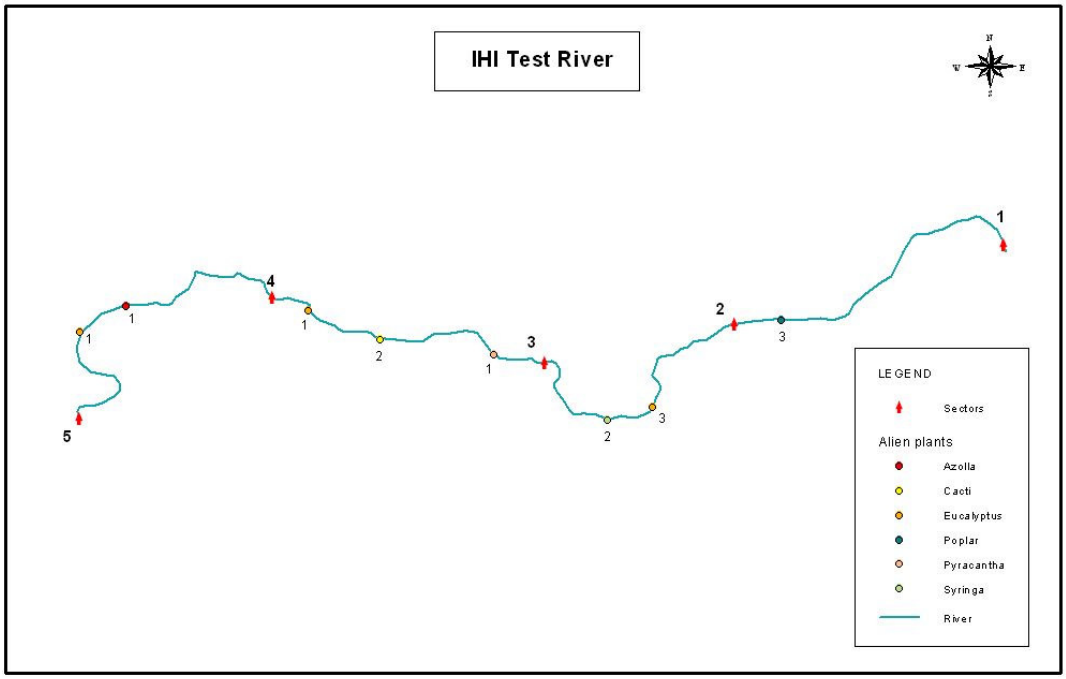

Figure B.1 Occurrence of alien plant infestations along the Test River.

B.4 EXECUTING THE AERIAL SURVEY ASSESSMENT

The steps followed in executing the aerial survey assessment are indicated and explained in the order in which they have to be executed. The process is also graphically illustrated in Figure B.2.

The Aerial Survey Assessment consists of three elements:

- Exporting tables from the IHI survey database
- Completing the Impact group master (IG Master)
- Completing the Metric group master (MG Master)

B.4.1 Exporting tables from the IHI survey database

Data captured during the aerial survey, is downloaded from the PDA to the IHI survey database in the CyberTracker program. The downloaded data is automatically incorporated into two groups of customised views (tables based on pre-set queries), one group of views containing Impact group data and the second group containing Metric group data.

Actions required:

- Open the IHI survey sequence/database (IHI survey.MDB) in the CyberTracker program.
- Set the data range to the date(s) of the survey.
- Export the different IG views/tables (Hydrology, Connectivity, Water quality, Alien

vegetation, Vegetation removal, Cultivation, Erosion, Mining and Special features views) and the MG view/table (All impacts view) to the IHI aerial survey folder using the Export View button. The file type must be Microsoft Excel Spreadsheet.

- Save the database.

The IHI survey sequence/database is protected and the only actions allowed are downloading the IHI survey sequence to the PDA, downloading data from the PDA to the IHI survey database, changing the date range and exporting views.

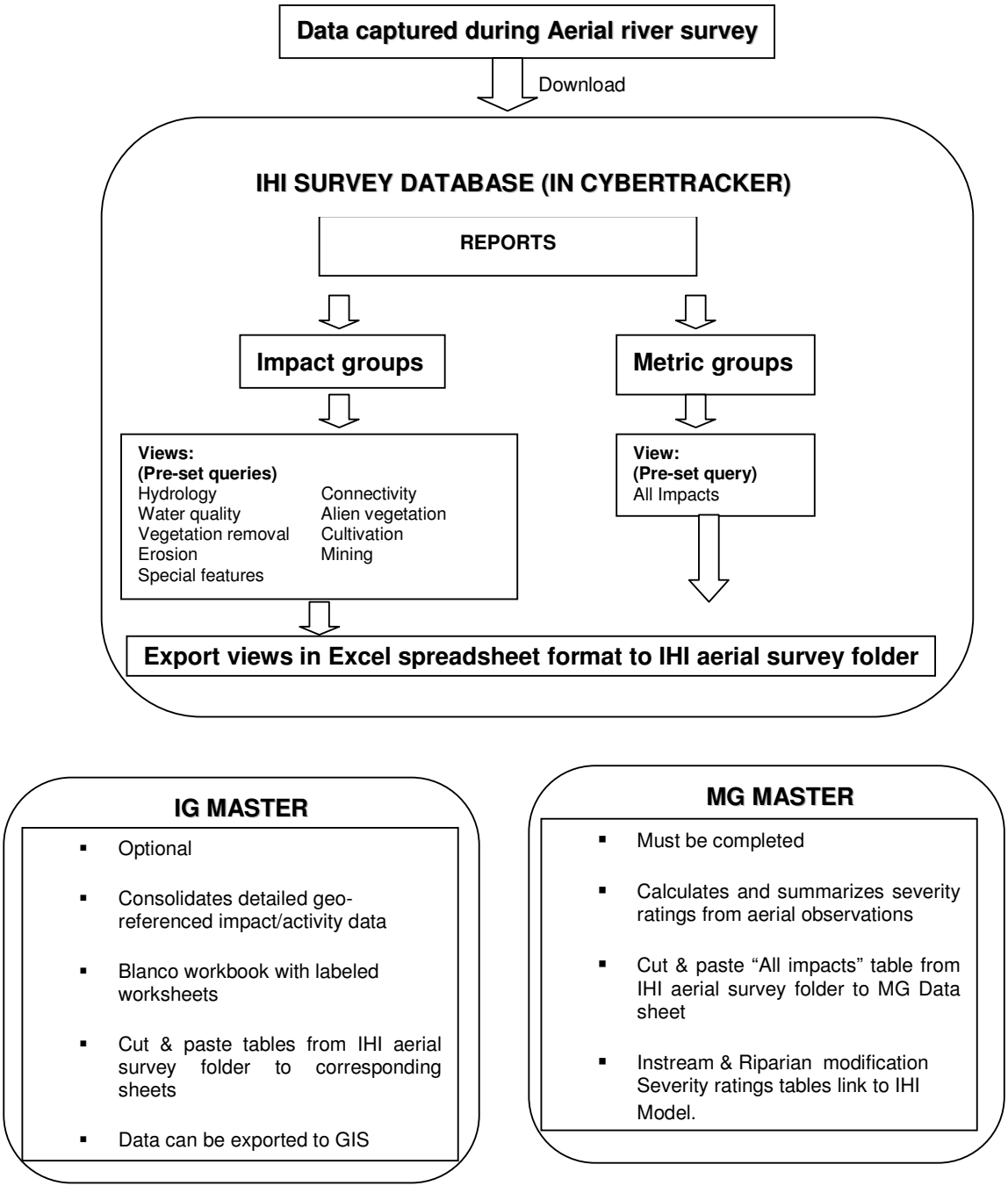

Figure B. 2 Diagram illustrating the Aerial survey assessment process

B.4.2 Completing the Impact group master

The completion of the Impact group master is optional and does not influence the rest of the assessment and and/or incorporation of data in the IHI model in any way. The main purpose of completing the IG master is to consolidate all the detailed information on every group of activities/modifications that could influence the habitat integrity of the river, in one file (workbook). As GPS coordinates are provided for each data entry, this information can be used in a GIS and/or for impact mapping purposes.

The Impact group master is a blanco workbook, containing a labelled sheet for each impact group. The sheets are:
Sectors, Hydrology, Connectivity, Water_quality, Alien_veg, Veg_removal, Cultivation, Erosion, Mining and Spec_features.

Actions required:

- Cut and paste the different Impact group tables from the IHI aerial survey folder to the corresponding worksheets in the IG master file.
- Save file and incorporate data in GIS if/when required.

A description of the information supplied in the tables in the Impact group master are provided in Table B.3 to 12

Table B.3 Sectors

Date	Time	Latitude	Longitude	Sector number
Aerial survey date	Time when entry is logged	GPS Coordinate of the starting point of the sector		Number allocated to specific sector

Table B.4 Hydrology

Date	Time	Latitude	Longitude	Sector number	Hydrology	Weir type	Dam type	Abstraction type	Runoff/ Effluent type	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Activity / Modification type. Options: Weirs Dams Water abstraction Runoff/effluent Other water inlet Inter basin transfer	Options: Weir with fishladder Weir – no fishladder Broken weir	Options: Dam (Large instream reservoir) Impoundment	Options: Pump Pumpstation Other	Options: Urban area Irrigation Industries Mining Treated sewage return flow	Impact rating on a scale of 0 - 4

Table B.5 Connectivity

Date	Time	Latitude	Longitude	Sector number	Connectivity	Roads & Crossing type	Bed mod type	Bank mod type	Debris type	Rating
Aerial survey date	Time when entry	GPS Coordinate of the locality where the activity/modification is		Sector in which the activity/	Activity / Modification type.	Options: Road – dirt	Options: Bulldozing Channel	Options: Canalization / furrow	Options: Instream Riparian	Impact rating on a

	is logged	seen and the impact is assessed.	modification is situated.	Options: Roads & crossings Mechanical bed mod. Mechanical bank mod. Debris Instream vegetation	Road – tar Bridge – high water Crossing or drift – low water	straightening Stabilization Bed scouring Other mechanical modification	Artificial bank covering Stabilizing works Development / Recreation area Other mechanical modification	zone	scale of 0 - 4

Table B.6 Water quality

Date	Time	Latitude	Longitude	Sector number	Water quality	Solid waste disposal locality	Point-source pollution type	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Activity / Modification type. Options: Solid waste disposal Point-source pollution Return flow – aquaculture Algae bloom Colour change Dead fish	Options: Instream Riparian zone	Options: Feedlot Sewage Thermal Other	Impact rating on a scale of 0 - 4

Table B.7 Alien vegetation

Date	Time	Latitude	Longitude	Sector number	Alien vegetation	Alien trees	Alien shrubs	Alien water plants	Alien other	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Alien vegetation type Options: Alien trees Alien shrubs Alien water plants Alien other	Options: River specific	Options: River specific	Options: River specific	Options: River specific	Impact rating on a scale of 0 - 4

Table B.8 Vegetation removal

Date	Time	Latitude	Longitude	Sector number	Vegetation removal	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Vegetation removal type. Options: Grazing Clearing – alien vegetation Clearing – natural vegetation Logging Wood Trampling	Impact rating on a scale of 0 - 4

Table B.9 Cultivation

Date	Time	Latitude	Longitude	Sector number	Cultivation	Cultivation locality	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Cultivation type. Options: Irrigated Dry land Fallow land Forestry	Options: In riparian zone Outside riparian zone Both	Impact rating on a scale of 0 - 4

Table B.10 Erosion

Date	Time	Latitude	Longitude	Sector number	Erosion	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Erosion type and/or locality. Options: Bank Riparian zone Bank & Riparian zone Catchment Stabilizing structure	Impact rating on a scale of 0 - 4

Table B.11 Mining

Date	Time	Latitude	Longitude	Sector number	Mining	Mine type	Rating
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the activity/ modification is situated.	Mining locality. Options: River bed In riparian zone Outside riparian zone	Options: Sand Peat Open-cast Other river specific options	Impact rating on a scale of 0 - 4

Table B.12 Special features

Date	Time	Latitude	Longitude	Sector number	Special feature
Aerial survey date	Time when entry is logged	GPS Coordinate of the locality where the activity/modification is seen and the impact is assessed.		Sector in which the special feature is situated.	Options: River specific list.

B.4.3 Completing the Metric group master

The customised Metric Group table that is exported from the IHI survey database to the MG master summarises data regarding activities/modifications which have been identified as being relevant for determining aerial survey guidance ratings that can assist with completing the Instream and Riparian Modification rating tables [INS_SUM (5.5b) and RIP_SUM (5.6b)] in the IHI Model.

The MG master contains the following sheets:
MG Data, Impacts, INS MOD RATINGS and RIP MOD RATINGS

B.4.3.1 Bringing data into the MG master (MG Data)

The MG master file can be used to obtain severity ratings from aerial observations for the river as a whole and/or for the different river reaches.

Actions required:

Whole river

- Open the MG master file
- Go to the Impacts sheet and fill in the name of the River, the evaluated reaches and the total number of sectors in the grey coloured cells.
- Save file with unique name.
- Cut and paste the Metric Group table (All Impacts) from the IHI aerial survey folder to the MG Data sheet in the MG master file. The Heading line (1) must be copied with the data. (Always ensure that the data is pasted to cell A1 on the MG Data sheet).

River reaches

- Open the MG master file.
- Go to the Impacts sheet and enter the name of the River, the reach and the number of sectors in the reach in the grey coloured cells.
- Save file with a unique name e.g. MGElands_1 for reach no 1 of the Elands River. Repeat the process for all the reaches of the river.
- Cut and paste the data from the MG Group table (All Impacts) from the IHI aerial survey folder to the MG Data sheet in the different MG reach files. Be sure to only copy the data relevant to the sectors in that specific reach. The Heading line (1) must also be copied with every group of sectors. (Always ensure that the data is pasted to cell A1 on the MG Data sheet).

As all calculations are performed automatically, the processed data can be viewed in the other sheets in the MG master / MG reach files as soon as the data has been pasted on the MG Data sheet and the grey cells have been filled in.

B.4.3.2 Summary of all Impacts (Impacts)

The Impacts sheet contains a table with a summary of all the impacts as well as the calculated Frequency (F), Average rating (AR) and Guidance rating (GR) values (Table 4). All the ratings are calculated automatically. Enter the name of the River, the reach and the number of sectors in the reach on this sheet. This information will automatically be copied to the other sheets in the workbook.

The following formulas are used to calculate the values in the Impacts table.

Frequency (F) = A / B

Average rating (AR) = C / A

Guidance rating (GR) = A x AR

Where

A = number of localities at which a specific activity/modification is recorded
B = number of sectors being assessed
C = sum of all the ratings (0 – 4) for a specific activity/modification

Table B.13 Example of the Impacts table with calculated Frequency, Average Rating and Guidance Rating values (Impacts sheet, MG Master)

RIVER:	Test							
Reach:	1							
Number of sectors:	3							
Impact/modification group	F	AR	GR		Impact description	F	AR	GR
Hydrology								
Weirs	1.00	1.67	1.7		Weir with fishladder	0.33	1.00	0.3
					Weir - no fishladder	0.33	3.00	1.0
					Broken weir	0.33	1.00	0.3
Dams	0.67	3.50	2.3		Dam (Large instream reservoir)	0.33	5.00	1.7
					Impoundment	0.33	2.00	0.7
Water abstraction	1.00	3.00	3.0		Pump	0.33	3.00	1.0
					Pumpstation	0.33	4.00	1.3
					Other	0.33	2.00	0.7
Runoff/effluent	1.67	3.40	5.7		Urban area	0.33	3.00	1.0
					Irrigation	0.33	2.00	0.7
					Industries	0.33	5.00	1.7
					Mining	0.33	4.00	1.3
					Treated sewage return flow	0.33	3.00	1.0
Other water inlet	0.33	3.00	1.0					
Inter basin transfer	0.33	5.00	1.7					
Connectivity								
Roads & crossings	1.33	2.00	2.7		Road - dirt	0.33	1.00	0.3
					Road - tar	0.33	2.00	0.7
					Bridge - high water	0.33	2.00	0.7
					Crossings low water	0.33	3.00	1.0
Mechanical bed modification	1.67	2.80	4.7		Bulldozing	0.33	3.00	1.0
					Channel straightening	0.33	4.00	1.3
					Bed scouring	0.33	4.00	1.3
					Stabilization	0.33	2.00	0.7
					Other	0.33	1.00	0.3
Mechanical bank modification	1.67	2.40	4.0		Canalization / furrow	0.33	2.00	0.7
					Artificial bank covering	0.33	3.00	1.0
					Stabilizing works	0.33	1.00	0.3
					Development / Recreation area	0.33	4.00	1.3
					Other	0.33	2.00	0.7
Debris	0.67	2.50	1.7		Instream	0.33	4.00	1.3
					Riparian zone	0.33	1.00	0.3
Instream vegetation	0.00							
Water quality								
Solid waste disposal	0.67	2.50	1.7		Instream	0.33	2.00	0.7
					Riparian zone	0.33	3.00	1.0
Point-source pollution	1.33	1.75	2.3		Feedlot	0.33	1.00	0.3
					Sewage	0.33	4.00	1.3
					Thermal	0.33	1.00	0.3
					Other	0.33	1.00	0.3

Table B.13 Continue

Return flow - aquaculture	0.33	4.00	1.3		
Algae bloom	0.33	1.00	0.3		
Colour change	0.33	1.00	0.3		
Dead fish	0.33	5.00	1.7		
Alien vegetation					
Alien trees	0.33	3.00	1.0		
Alien shrubs	0.33	3.00	1.0		
Alien water plants	0.33	4.00	1.3		
Alien other	0.33	1.00	0.3		
Riparian vegetation removal					
Grazing	0.33	1.00	0.3		
Clearing - alien vegetation	0.33	1.00	0.3		
Clearing - natural vegetation	0.33	3.00	1.0		
Logging	0.33	5.00	1.7		
Wood	0.33	0.00	0.0		
Trampling	0.33	1.00	0.3		
Cultivation					
Irrigated	0.33	3.00	1.0		
Dry land	0.33	1.00	0.3		
Fallow land	0.33	0.00	0.0		
Forestry	0.33	4.00	1.3		
Erosion					
Bank	0.33	1.00	0.3		
Riparian zone	0.33	3.00	1.0		
Bank & riparian zone	0.33	3.00	1.0		
Catchment	0.33	5.00	1.7		
Stabilizing structure	0.33	3.00	1.0		
Mining					
River bed	0.33	4.00	1.3		
In riparian zone	0.33	2.00	0.7		
Outside riparian zone	0.33	1.00	0.3		

F = Frequency
AR = Average rating
GR = Guidance rating

Instream modification severity ratings from aerial observations (INS MOD RATINGS)
The INS MOD RATINGS table provides the summarized Aerial survey severity ratings that will be used to help assess the Instream IHI. All the ratings are calculated automatically. Data from this table is manually transferred to aerial survey table on the INS_SUM (Table 5.5b) sheet in the IHI Model.

Table B.14 Aerial data captured for Instream Integrity assessment (INS MOD RATINGS sheet, MG Master)

MODIFICATION INDICATOR FROM AERIAL OBSERVATIONS	BASIS OF ASSESSMENT PER ASSESSMENT UNIT	RATING OF SEVERITY (According to guidance rating or combined guidance rating, cf. Impacts sheet)
Weirs	Number and extent of impact, all types of weirs	
Dams	Number and extent of impact, all dams and impoundments	
Crossings low water	Number and extent of impact, low water crossings	
Abstraction (run-of river)/increased flows	Relative extent and intensity as indicated by pumps, pumpstations and other abstraction activities	
Runoff/effluent: Urban areas	Relative extent and severity as indicated by all incidences of runoff/effluent from urban areas	
Runoff/effluent: Irrigation	Relative extent and severity as indicated by all incidences of runoff/effluent from irrigation	
Runoff/effluent: Industries	Relative extent and severity as indicated by all incidences of runoff/effluent from industries	
Runoff/effluent: Mining	Relative extent and severity as indicated by all incidences of runoff/effluent from mining activities	
Inter basin transfers	Relative extent and severity as indicated by inter basin transfers	
Bed: sedimentation	Relative extent and intensity as indicated by all mechanical bed modifications, river bed mining activities, instream solid waste disposal, vegetation removal, instream modification, erosion, crossings & drifts and dirt roads	
Bed: benthic growth	Relative extent and intensity as indicated by point-source pollution from feedlots, sewage and thermal origin as well as algae bloom	
Bed: scouring	Relative extent and severity as indicated by all incidences of bed scouring	
Bed: stabilization (e.g. concrete)	Relative extent and severity as indicated by all attempts at bed stabilization	
Bed: material disturbance/removal	Relative extent and severity as indicated by all mechanical bed modifications and river bed mining activities	
Water column: Exotic Aquatic macrophytes	Relative extent and severity as indicated by alien water plant infestations	
Water column: Algal growth	Relative extent and severity as indicated by algae blooms	
Rubbish dumping	Relative extent and severity as indicated by instream rubbish dumping	

Riparian modification severity ratings from aerial observations (RIP MOD RATINGS)
The RIP MOD RATINGS table provides the summarized Aerial survey severity ratings that will be used to help assess the Riparian IHI. All the ratings are calculated automatically. Data from this table is manually transferred to aerial survey table on the RIP_SUM (Table 5.6b) sheet in the IHI Model.

Table B.15 Aerial data captured for Instream Integrity assessment (RIP MOD RATINGS sheet, MG Master)

MODIFICATION INDICATOR FROM AERIAL OBSERVATIONS	BASIS OF ASSESSMENT PER ASSESSMENT UNIT	RATING OF SEVERITY (According to guidance rating or combined guidance rating, cf. Impacts sheet)
Erosion	Relative extent and severity as indicated by bank and riparian zone erosion	
Rubbish dumping	Relative extent and severity as indicated by incidences of rubbish dumping in the riparian zone	
Trampling	Relative extent and severity as indicated by trampling	
Mining	Relative extent and severity as indicated by all mining activities in the riparian zone	
Roads	Number and extent of impact, all types of roads and crossings	
Vegetation removal	Relative extent and severity as indicated by vegetation removal activities in the riparian zone	
Invasive alien vegetation	Relative extent and severity as indicated by all alien plant infestations in the riparian zone	
Forestry	Relative extent and severity as indicated by forestry activities	
Industries	Relative extent and severity as indicated by all incidences of runoff/effluent from industries	
Channel Straightening	Relative extent and severity as indicated by channel straightening and canalization activities	
Urbanization	Relative extent and severity as indicated by all incidences of runoff/effluent from urban areas	
Off-channel dams	Number and extent of impact, impoundments	
Artificial covering	Relative extent and severity as indicated by all incidences of artificial bank covering	
Animal farming	Relative extent and severity as indicated by feedlots as well as grazing and trampling activity	
Dry land farming	Relative extent and severity as indicated by dry lands and fallow lands	
Irrigation	Relative extent and severity as indicated by irrigated lands	
Bank Stabilization	Relative extent and severity as indicated by bank and erosion stabilizing structures	

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