-LIFE11/NAT/IT000187 T.E.N.-

ACTION A7
Guidelines for the management of vegetation along watercourses in the Province of Trento

PROVINCIA AUTONOMA DI TRENTO

PRODUCED BY
Elementi - Studio Associato di Progettazione Ambientale

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Publication drafted in the framework of the project LIFE11/NAT/IT/000187 "T.E.N." (Trentino Ecological Network): a focal point for a Pan-Alpine Ecological Network - www.lifeten.tn.it

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1 Introduction

These guidelines were developed in the context of the Life+ T.E.N. “Trentino Ecological Network” project (LIFE11/NAT/IT/000187). The project aims to create a multifunctional ecological network in the province. This network will be based on the “Networks of Reserves” provided for by Provincial Law 11/2007, designed to enhance biodiversity in Trentino through decentralised management involving local communities, according to the principle of so-called “responsible subsidiarity”. The multifunctional ecological network will also be "open" to areas surrounding Trentino and will thus become an important part of continental, alpine and national ecological networks.

To summarise, T.E.N. intends to implement a new management model for the Natura 2000 network at regional level, revolving around a long-term strategic vision that is both economically sustainable and well-accepted socially, based on the three key concepts of responsible subsidiarity, participation and integration.

A specific action within the Life+ T.E.N. project regards the drawing up of provincial guidelines for the management of wetland forests representing priority habitat `91E0`* “Alluvial forests of *Alnus glutinosa* and *Fraxinus excelsior*” and vegetation along watercourses. This need has developed out of an awareness of the generally poor state of conservation of riparian formations in Trentino, a situation common to many other areas, caused first of all by the occupation of spaces naturally destined for the development of these plant formations by human activities and the consequential simplification and artificial nature of river systems. This primary impact, which has radically reduced the space available for the whole river ecosystem, vegetation representing just one of the components, is aggravated by work to cut down vegetation with the scope of reducing the risk linked to watercourses. The driving force behind the drawing up of these guidelines in the context of the Life+ T.E.N. project is the conservation of habitats and species, in the framework of the Habitats and Birds European Directives (respectively 92/43/EEC and 2009/147/EC). In this perspective, watercourses may be viewed both in their own right, as sites hosting important and significant habitats and home to animal and plant species of great value, and as the fundamental backbone of the ecological network in the area, therefore also serving to conserve species that choose to live in habitats away from watercourses.

Furthermore, the management of vegetation also influences the parallel but not identical question of achieving the “good ecological state” referred to in the Water Framework Directive (2000/60/EC). Assessment of the ecological state of a watercourse involves direct evaluation of the functioning of all the processes and roles characterising it, in both ecological and hydromorphological terms. Effective fulfilment of this complex combination of roles (namely a good ecological state) is a necessary prerequisite for ensuring that watercourses are capable of providing an extensive and indispensable range of ecosystem services, the vegetation along watercourses indeed having a fundamental role in this context.

Ecosystem services	**Functions**	**Role of riparian vegetation**
Regulation of episodes of flooding	Hydrological regulation, morphological regulation, photosynthesis/primary production	Flood lamination takes place through expansion of the waters into floodable areas without settlements and infrastructures, the vegetation increasing the roughness of these areas and hence water levels and flooding capacity

Continued from previous page

Ecosystem services	Functions	Role of riparian vegetation
Control of erosion	Hydrological regulation, morphological regulation, photosynthesis/primary production	Root systems are renowned for having a strong stabilising role, both in relation to gravitational phenomena and hydrodynamic stress. Protection from hydrodynamic stress is also offered by herbaceous vegetation and the flexible foliage of scrubland
Regulation of the availability of water	Hydrological regulation, morphological regulation, biogeochemical cycles, nutrient cycles, photosynthesis/primary production	The presence of vegetation on mature soils in floodplain areas favours the infiltration of water into the terrain. This can thus feed the aquifer or return into the hydrographic network in the long-term
Production and transport of sediment	Hydrological regulation, morphological regulation, photosynthesis/primary production	Live vegetation on the banks and dead ligneous material in the channel respectively slow down erosion of the banks and favour the temporary accumulation of sediment in the channel, thus regulating the flow of sediment and making the morphological structure of riverbeds more stable
Contribution to climate regulation	Hydrological regulation, morphological regulation, biogeochemical cycles, photosynthesis/primary production, construction of habitats	The presence of wooded areas is renowned for having beneficial regulatory effects on the microclimate
Control of nutrients and purification	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	Most biological, chemical and physical processes responsible for the removal of nutrients and other contaminants from waters revolve around the presence of wooded bands along watercourses
Conservation of flora and fauna	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	The role of riparian vegetation is obvious
Conservation of biodiversity	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	The role of riparian vegetation is obvious
Recreational/cul role	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	The main appeal of river environments is linked precisely to the presence of extensive and diversified forest stands

Continued from previous page

Ecosystem services	Functions	Role of riparian vegetation
Use for the purpose of sports	Hydrological regulation, morphological regulation, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	Although the presence of vegetation along the banks is not strictly linked to the practice of sports activities (usually canoeing and canyoning), its presence increases the interest and appeal of the area where they take place
Use for the purpose of fishing	Hydrological regulation, morphological regulation, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	Riparian vegetation and ligneous material in rivers have a fundamental role in supporting fish populations.
Scientific and educational use	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	The scientific and educational interest is closely linked to obtaining in-depth knowledge and understanding of natural processes, largely connected to the presence of vegetation.
Timber	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production	Riparian biomass can be profitably used both to produce energy and as construction material
Availability of food	Hydrological regulation, morphological regulation, formation of the soil, biogeochemical cycles, nutrient cycles, photosynthesis/primary production, construction of habitats, composition of food chains	River ecosystems, largely centred on the presence of vegetation, are a source of food: fish, game, herbs, wild fruits and mushrooms

Table 1.1: Exemplification of ecosystem services, the functions that regulate their development and the role of riparian vegetation (adapted from [19])

The presence of vegetation along watercourses may also increase hydrological risk, and this is the main reason leading to the decision to cut down plants. There are two different types of problems to be dealt with. Firstly, the presence of vegetation on the banks and in the channel increases roughness, leading to the same flow transporting higher levels of water than in the absence of such vegetation. This increases the likelihood of flooding and therefore the danger and risk. Secondly, and this is the key issue within the province, wood transported by the current can become jammed in narrow sections or against the pillars of bridges, again increasing the likelihood of flooding. Alternatively, it may form temporary barriers along mountain streams that then collapse, resulting in violent flooding, or can be included within debris flows, again increasing risk and danger. When drawing up these guidelines, the management of vegetation was discussed simultaneously in relation to all three of the situations just presented, thanks to an extensive exchange of ideas between APPA (Agenzia Provinciale per la Protezione dell'Ambiente), the Biotopes and Natura 2000 Network Office of the Nature Conservation and Environmental Enhancement Department and the Mountain Valleys Department. The document is the result of this exchange of opinions. However, it effectively represents a starting point, as the indications gathered together here must now be put to the test in practice, dealing with all the problems associated with work on site, optimisation of the costs of intervention and monitoring of the actual efficacy of the management methods outlined. It is in the spirit of the Life+ T.E.N. project and the provincial law on forests and nature protection (LP no. 11 of 23 May 2007) to promote the involvement of the local community in the management of the environment. In this context, all the offices and departments concerned with the management of riparian bands must certainly make an extra effort to communicate and justify the work they will be called on to carry out and be open to exchanging ideas with the different stakeholders: farmers, shepherds, anglers, environmentalists, tourist operators, ordinary people exposed to the danger of flooding, persons and companies concerned with the use of riparian biomass. However, in order to ensure that this exchange of ideas is always profitable, the stakeholders must also make an effort to try and understand the problems dealt with and the technical questions behind the decisions that need to be made, making sure their requests are appropriate. In this context, we believe that this document, although not easy to understand given the nature of the questions discussed, can represent a useful tool in terms of raising awareness and increasing understanding. As regards the expectations that different stakeholders may have, we believe it is important to put the benefits it is legitimate to expect from more careful management of vegetation in the right context, because in terms of both hydrological risk and ecological state and conservation, they are in any case seriously conditioned by the overall changes that have taken place and the undermining of watercourses. In other words, implementation of optimal management of the vegetation present along watercourses cannot by itself repair the impact deriving from more extensive and profound changes to the hydrographic system, such as those resulting from changes to the liquid and solid flow regime and the artificial nature of riverbeds. Likewise, it can only partly deal with problems related to the low runoff capacity of sections, the presence of bridges with closely planted pillars in the riverbed and settlements and infrastructures in areas with a high risk from water flows. This document is divided into two parts.

the [first part] provides introductory information on the hydromorphological dynamics of watercourses, their interaction with the vegetation and the changes and problems that may arise following settlement of man in the area. It then proceeds to identify the specific characteristics and problems of the hydrographic network in Trentino in relation to the management of vegetation. Section introduces the most significant questions regarding the interaction between vegetation and hydromorphological dynamics, the role played by large wood in ecological and hydromorphological dynamics and the changes experienced by river systems and by riparian vegetation in particular, Three categories of change are discussed:

- land use and intervention to reduce risk;
- hydroelectric use, removal of sediment and modifications to land use at the level of the basin;
- the introduction of invasive alien plant species.

Section identifies the Natura 2000 habitats present along the Trentino hydrographic network, discusses the implications of different types of human pressure on their conservation and considers the effects that an appropriate management programme for vegetation can have on their improvement and conservation. On a geomorphological basis, and considering the interaction between hydromorphological and vegetation dynamics, Section 3 identifies the ten different categories of watercourse stretches that are significant for the purposes of vegetation management in Trentino.

the resulting are contained in the [second part]. The first section gathers together management directions of a general nature, while the second section identifies specific management guidelines for each category of watercourse stretch. The current situation for each category is described, providing examples through photos of stretches of watercourses representing the range of situations present in the province. Problem areas and potential possibilities are identified as regards both the reduction of hydrological risk and the conservation of habitats and species. The situation that it is intended to achieve is described, along with the management criteria that it is therefore necessary to apply. Each information sheet concludes with a section presenting proposals for improvement, aiming to further improve the ecological state of the watercourse and specific ecosystem services particularly relevant for the context, without calling into question the overall status of the watercourse and the surrounding area, and exploiting specific opportunities.

2 Overwiev of problems

2.1 1 Characteristics, dynamics and changes to riparian plant formations

2.1.1 1.1 Hydromorphological dynamics and vegetation

A full understanding of the reasons behind the management directions presented in the guidelines requires at least a basic knowledge of the concepts of fluvial ecology, forest botany and fluvial geomorphology. The presentation of a comprehensive introduction to these themes is beyond the scope of this document. However, a sufficiently exhaustive introduction can be found in the manual on the fluvial functioning index [34] and the manual on the morphological quality index [32], both easily obtainable through the Internet. The basic concepts and dynamics characterising natural watercourses, the basis for then understanding those of watercourses modified by human action, are nevertheless briefly introduced below. On plains and valley floors, watercourses are mostly of an alluvial nature1, namely they have the fundamental characteristic of being free to shape themselves, in short to choose their form in both altimetric and planimetric terms, flowing in a channel made up of the sediment transported there by the watercourses themselves [32]. The plano-altimetric configuration of alluvial watercourses is the result of interaction between the processes giving rise to their formation (the so-called driving variables, namely the solid and liquid flow regime) and the surrounding conditions, period when the valley floor was formed, sediment making them up (which may also be of different origin) and riparian vegetation [32].

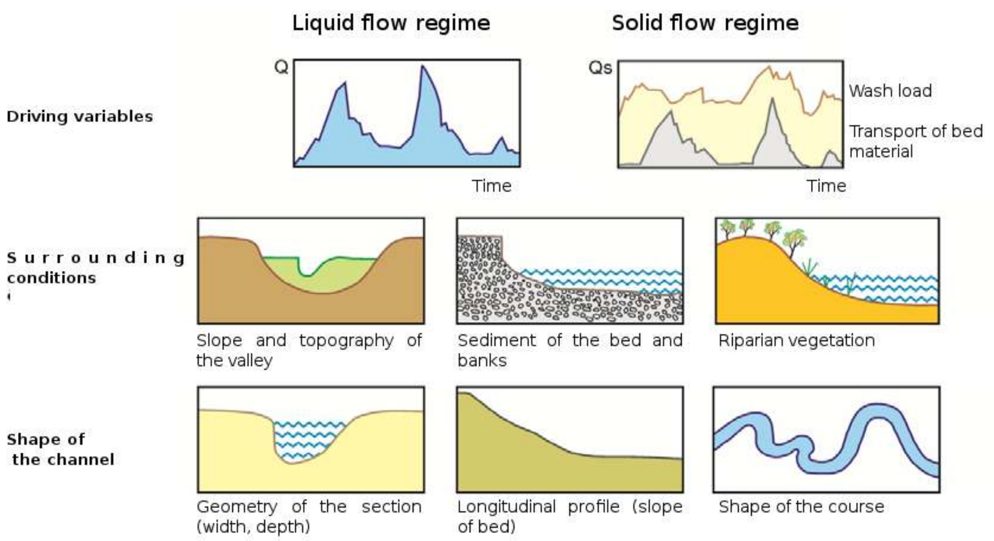


Figure 2.1: The shape of an alluvial riverbed as the result of interaction between driving variables and surrounding conditions ([32], adapted from [39]).

The term “alluvial” is commonly used as a synonym of “flooding”, but in technical-scientific language “alluvial” is more appropriately used to indicate an accumulation of sediment transported by a water course; hence the term “alluvial river” to describe a river that generates alluvial deposits and forms its own riverbed by digging through alluvial deposits. Thus when referring to “alluvial watercourses”

no reference is made to the greater or lesser frequency with which these may flood human settlements and activities.
The visible manifestation of these complex dynamics and interactions are the different channel morphologies and the different forms and surfaces (distinguishable in terms of morphology, sediment and vegetation) that can be identified within a channel and in the surrounding areas, briefly described below, drawing on the content of the "Linee guida per l'analisi geomorfologica degli alvei fluviali e delle loro tendenze evolutive" [37].
Alluvial watercourses have the following main types of course:

Straight , in an almost straight line; in general this indicates an artificial situation, as it is a type of morphology that is rare in nature and when present is usually found over very limited stretches.

Sinuous , a course marked by a certain sinuosity, but which does not have a succession of meanders.

Straight or sinuous with alternating banks , similar to the two previous categories as regards the course layout of the channel, but in contrast with these, it is characterised by the almost continuous presence of alternating bars of sediment.

Meandering , a single channel generally characterised by a more or less regular succession of meanders.

Wandering , a transitional form between meandering and braided, characterised by a relatively wide channel, the presence of almost continuous lateral bars, with local situations marked by braiding and the presence of relatively widespread islands.

Braided , a riverbed characterised by the presence of several channels separating bars and islands. The individual channels have a certain sinuosity, but this is generally less marked than in the case of a meandering riverbed. A main channel can often be identified among the various channels present.

Anastomosing , a riverbed characterised by several channels, with a high level of sinuosity and separated by islands made up of fine material with vegetation. These islands are very stable if compared with the bars and islands of braided rivers. The conditions suitable for generating this type of river are not present in Trentino, so it is only listed here for the sake of completeness.

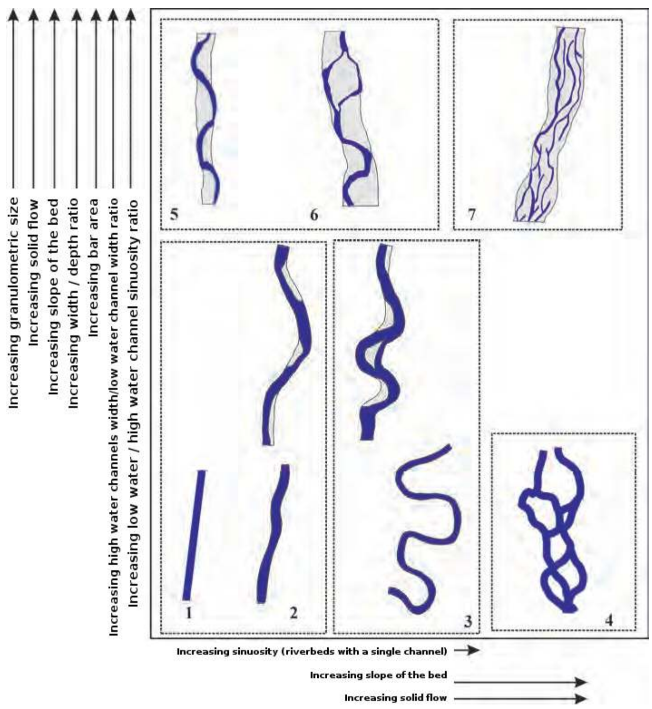


Figure 2.2: Fluvial morphology. 1: straight channel; 2: sinuous; 3: meandering; 4:anastomosing; 5: sinuous with alternating bars; 6: wandering; 7: braided [37].

The morphological units that can be found along alluvial watercourses are as follows.

Channel or channels , as in the case of a braided watercourse, representing the lowered parts of the riverbed. The channels are generally marked by water flows, but may be dry in low water conditions.

Thalweg , indicates the line of lowest elevation of the channel/s, and hence of the riverbed.

Bar , this is a part of the riverbed that has usually emerged because it is only concerned by water flows during flooding. A bar may be considered as such even if it is partially covered by vegetation: the vegetation is not however of a continuous nature and is herbaceous or bushy (seasonal growth or lasting a few years).

High bar , this can frequently be found in gravelly braided or transitional riverbeds. As compared to other bars it is characterised by: a higher topographical position, a greater presence of fine surface sediment and more extensive plant coverage (in any case plants and bushes a few years old).

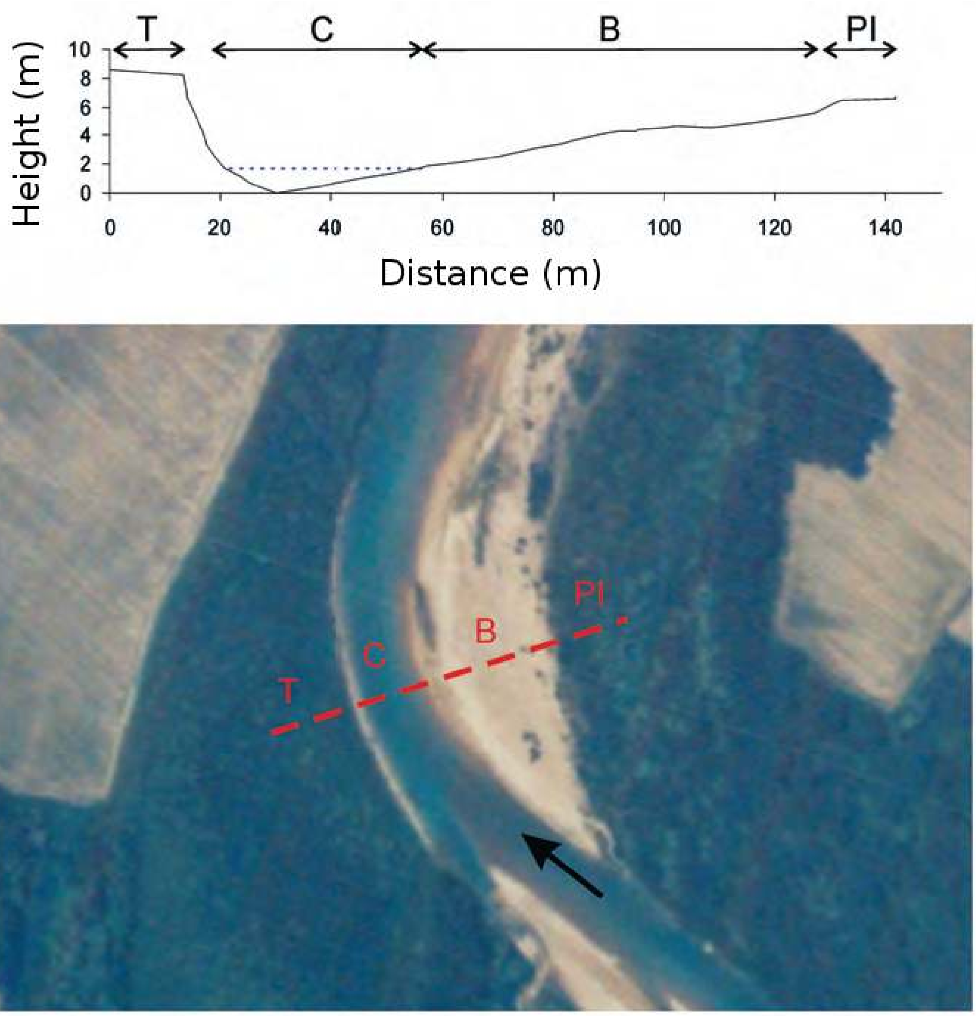


Figure 2.3: Cross-section of a single channel riverbed (sinuous) showing the various morphological surfaces present. C: channel; B: bar; Pl: floodplain; T: terrace. The cross-section is indicated with a dotted red line on the aerial photo, while the black arrow shows the direction of the current [37]).

Island , part of the riverbed covered by herbaceous, bushy and arboreal vegetation. In terms of height, islands represent the highest parts of the riverbed and are submerged less frequently than bars. Islands usually have a different depth of fine materials (sand, mud and clay) over their surface, in a similar way to the floodplain. It is possible to distinguish between “stable islands” (using the term stable in a relative sense), when the fine sediment covering them is of a significant thickness (several dozen centimetres or even up to 1.5-2 m) and the vegetation coverage is almost total, and "pioneer islands", when the vegetation and structural characteristics are not so marked.

Bank , surfaces, usually steep, delimiting the sides of the riverbed; the bank generally separates the riverbed from the floodplain or a terrace.

Riverbed , the combination of channels, bars and islands make up the riverbed. The limits of the riverbed can be defined by the banks, but may sometimes be less clear morphologically, in the case of a gradual passage between the riverbed and the floodplain for example. In this last case, the distinction between the riverbed and the floodplain is based on evidence related to topography, sediment and vegetation. The limit of the riverbed is established as coinciding with the so-called bankfull level, namely the hydrometric level associated with the maximum flow that can be contained in the riverbed before flooding outside the banks takes place.

Figure 2.4: Digital model of the riverbed (DEM obtained from LiDAR data) and aerial photo of a braided river, with indication of the various morphological surfaces present: C: channel; B: bar; BA: high bar; I: island; PI: floodplain; T: terrace. The blue arrow shows the direction of the current [37].

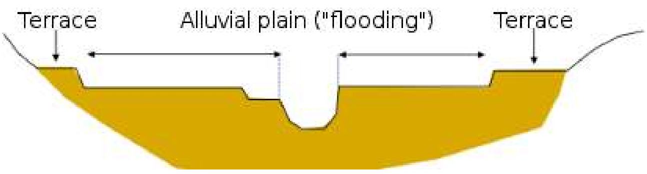
Floodplain , flat surface adjoining the riverbed and genetically linked to the watercourse in the current flow regime conditions (hydrological-climatic and morphological conditions). The floodplain is normally subject to flooding roughly every 1-3 years. It can be recognised by its stable vegetation coverage, although the vegetation can be relatively young, the height slightly above the level of the riverbed (similar to or slightly higher than the islands) and the muddy-sandy granulometry of the sediment.

Terrace , flat surface adjoining the riverbed or the floodplain, originating as a floodplain in less recent times, when the watercourse regime was different. The terrace may be subject to flooding, but less frequently than the floodplain (for example with a frequency of around 5-10 years or less). There may be several levels of terrace present.

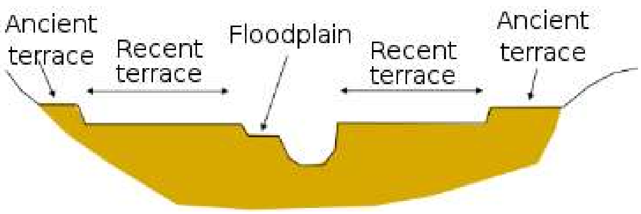
Recent terrace , a floodplain that due to recent entrenchment of the riverbed, typically as a result of human changes to hydromophological dynamics, has been excluded from usually frequent flooding, and now finds itself significantly above the level of the channel. The term recent is usually adopted with reference to the last 100-150 years.

Figure 2.5: Floodplain along the Rio Sporeggio below the Maso Milano, in the Rocchetta provincial nature reserve. Note the limited height of the floodplain as compared to the riverbed (*Ph.* Giuliano Trentini).

Reference is often made to the **alluvial plain**, a term often adopted in geological maps. The concepts of the floodplain and recent terrace represent a more detailed interpretation, paying greater to the short-term dynamics of watercourses, significant for management purposes.



(a) Terminology normally adopted in geological maps



(b) Terminology adopted in fluvial geomorphology [32]

Figure 2.6: Distinction between alluvial plain and floodplain

While alluvial watercourses on the valley floor are those that interact with the main urban areas and strategic infrastructures, there is no doubt that streams are the most typical and representative type

of watercourse in the provincial territory. Alluvial watercourses are generally characterised by moderate to low steepness, small-grained sediment as compared to the width of the riverbed and limited or inexistent confinement. In contrast, streams normally have a steep slope, large riverbed material in relation to the width of the riverbed and a high level of confinement.
Confinement refers to the limitations imposed on the course of the stream or river by the valley slopes or ancient terraces. Except in rare situations, streams flow along the floor of narrow valleys and are undoubtedly confined. Alluvial watercourses, on the other hand, are usually subject to little or no confinement, but in some stretches they may be confined by narrow gorges or terraces, this situation being not uncommon 2.7).

(a) The Avisio stream at Rover, confined by the slopes of the valley

(b) The River Sarca above Dro, confined by terraces

Figure 2.7: Two examples of confined alluvial watercourses (*Ph.* **(a)** Agenzia Provinciale per la Protezione dell'Ambiente della Provincia Autonoma di Trento, **(b)** Giuliano Trentini).

Along every watercourse in a natural state it is possible to identify a belt genetically linked to the recent action of the watercourse, inundated or saturated by the bankfull flow. The part of the biosphere supported by this belt is of a very particular nature, and the herbaceous, bush and arboreal vegetation that typically colonises it is described as "riparian" [27]. In the case of alluvial watercourses, this belt is made up of the riverbed and the smaller or larger floodplain that surrounds it. In the case of streams it is certainly made up of the riverbed, in addition to other surface areas clearly affected by previous flooding or with a greater content of water in the soil, acting as transitional elements between the bars and the plain or neighbouring slopes, described by some authors as channel shelves or benches [27]. In general a genuine floodplain is not formed, although occasionally a small floodplain can be found, just as the presence of islands along larger streams is relatively common.
It should be noted that "riparian" is not synonymous with "bank" or "riverside", as is instead often assumed. "Riparian" is an attribute given to vegetation with characteristics suitable for growth in the belt adjoining watercourses, whereas "bank" and "riverside" relate to a topographical position, over and beyond the composition in terms of species [34]. The distribution of plant associations and hence of habitats within the watercourse band is regulated by hydromorphological processes, so each formation can be associated with one or more specific morphological units [27]. Given that riparian vegetation is of a marked pioneering nature, it tends to evolve spontaneously towards more mature formations. This tendency is however hindered by periodic modification of the sediment in the riverbed and the mobility of its course, which leads to continuous demolition of more mature formations due to the erosion, creating the conditions for new settlement by pioneer species. In alluvial watercourses on the valley floor, semi-confined and unconfined, these dynamics are very clear, and take concrete form in a transversal succession of associations, as shown in Fig. 22, in which the greatest distance from the riverbed corresponds with the longest time since a certain surface area was created by the river and the least disturbance from hydromorphological processes.

Streams differ from alluvial watercourses in terms of their low variability over time, as only events of a certain intensity are capable of mobilising material in the riverbed and adjoining bands [32]. Even stretches of streams on alluvial fans formed by them when side valleys flow into the main valley experience low variability of the riverbed over time. Modifications may take place during extreme events, with mass transport that can lead to sudden changes in the course of the riverbed, given the absence of confinement. The high level of confinement and permeability of the substrate (which means that saturation is unlikely) usually significantly limits the width of the adjoining belt, which usually stretches only a little way beyond the riverbed. This combination of factors means that the evolution of riparian formations towards other more mature forest formations, typically with the entry of the spruce, is favoured along streams (but also along confined alluvial watercourses) [17].

Figure 2.8: Recovery of fallen trees following the debris flow of 15 August 2010 along the Rio Val Molinara (*Ph.* Autonomous Province of Trento's Mountain Basin Department).

n the case of streams, it is also important to distinguish between steeper stretches, indicatively with a slope of 8-10%, and those with a lesser slope. Debris and hyperconcentrated flows may originate or transit along the former [38], while along the latter one can only observe deposits from phenomena originating further upstream.

Figure 2.9: Island along the Sarca in Val Genova (seen facing downstream), with a predominance of spruce trees (*Ph.* Giuliano Trentini).

The live vegetation and deadwood present in the riverbed and along the banks interact significantly with the ecological and morphological dynamics of watercourses.

The ability of live parts of plants transported and deposited downstream by the current to take root and develop new plants is one of the fundamental characteristics developed by willow and poplar plants to adapt to the continuously changing environment represented by watercourses. However, the water also transports deadwood of differing size downstream, indeed this is predominant. The smallest component of this debris, represented by leaves, twigs and small branches, is one of the fundamental energy sources for aquatic habitats, which are fundamentally heterotrophic in a mountain context such as Trentino ([34]. The larger component, conventionally established as debris with a diameter of over 10 cm and a length of over 100 cm [13], but which also includes trunks and large branches, is known as “large wood”, abbreviated to LW, and has a series of effects on hydromorphological and ecological processes.

By contributing to the diversification of hydrographic and sedimentary conditions in the riverbed, deadwood represents a fundamental factor in the diversification of aquatic habitats, thus supporting richer benthonic and fish communities, in terms of both quantity and the diversification of species [20].

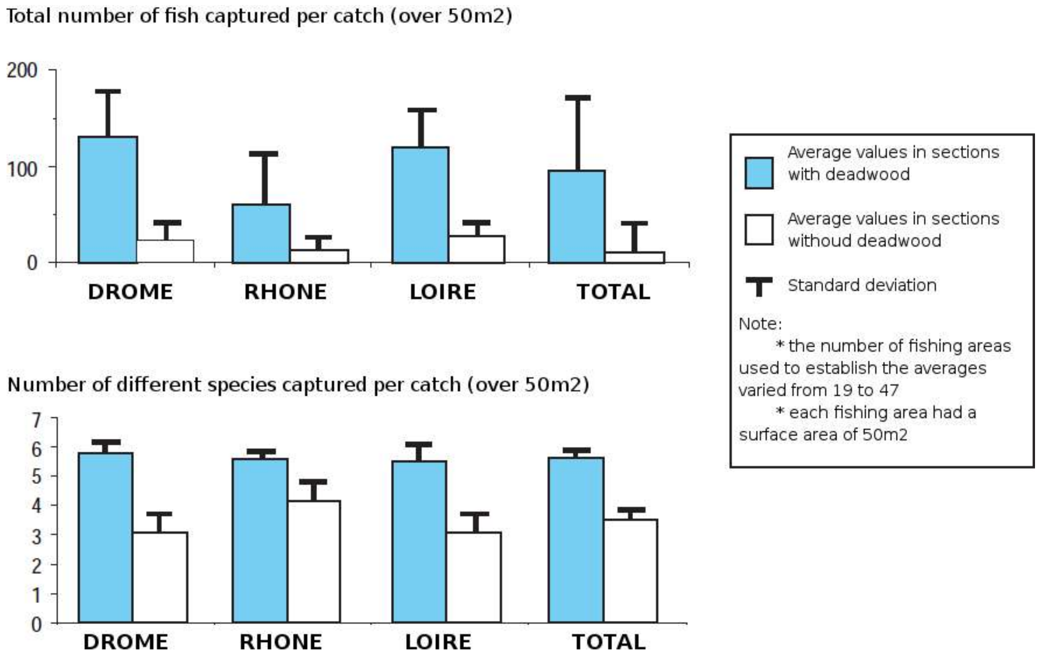


Figure 2.10: The influence of large wood on fish populations: comparison between comparable stretches along the same river, differentiated only by the presence (in blue) or absence (white) of wood in the riverbed [20]

(a) A hollow created around the stump of a willow bush that is still alive

(b) Fish fry collecting in a pool created by wood.

Figure 2.11: Ecological effects of wood at the mouth of the Avisio (*Ph.* Giuliano Trentini).

River system production and feeding mechanisms, processes of mobility and transport and deposition processes can be identified for wood, as well as for sediment [13]. By understanding these mechanisms, it is possible to better comprehend to what extent deadwood can influence and increase the risk of flooding. It is consequently possible to attempt to establish management criteria that provide for a controlled presence of such wood, recognising the ecological importance of deadwood in the riverbed. Various production mechanisms can lead to the presence of wood in the riverbed. Some of these can be considered to be passive mechanisms from the point of view of the river system: movement of the slopes, avalanches, dead plants, the action of wind, snowfall, fires, death of plants due to living organisms. There are instead other active recruitment mechanisms that are the fruit of the hydromorphological dynamics typical of watercourses: mass transport phenomena along streams, erosion of the banks, direct erosion of the internal surfaces of the riverbed and the floodplain. The extent and size of the ligneous material in alluvial watercourses is strongly dependent on the morphology of the riverbed (Gurnell et al., 2002). Higher levels, with material of a larger size, can be observed in meandering watercourses in the foothills, given their greater dynamism and the chances

they have to demolish more mature parts of the floodplain, with trees of larger size. Rivers with a transitional morphology or braided courses, such as those in Trentino, are characterised by such a high level of dynamism that they mostly demolish very young parts of the floodplain, with relatively small plants. Watercourses on lowland plains, while flowing through very mature alluvial plains, are characterised by low wood levels, as a result of minimal mobility in terms of the riverbed course. Transport and deposition are influenced by the geometric characteristics of the wood and the riverbed, and by the type of hydromorphological dynamics.
One of the central factors is the relationship between the length of the wood and the width of the riverbed, on the basis of which watercourses can be classified as “small”, “medium” and “large”, characterised by the different relative importance of the various retention mechanisms [13]. Indicatively, watercourses in which the width of the active riverbed is less than the average length of the wood are considered to be “small”, those in which width of the riverbed is less than upper quartile of the length of the wood are considered to be “medium” and those in which the width of the active riverbed is greater than the length of all the wood transported are considered to be “large”.
Per il legname, al pari dei sedimenti si possono identificare meccanismi di produzione e alimentazione del sistema fluviale, processi di mobilità e trasporto, processi di deposizione [13]. Attraverso la comprensione di questi meccanismi si può meglio comprendere come e in quale misura il legname morto possa incidere sul rischio da inondazione aggravandolo conseguentemente, riconosciuta l’importanza ecologica del legname morto in alveo, si può tentare di definire dei criteri gestionali che ne prevedano una presenza controllata.

	Relative size of the watercourse			
	Small	**Medium**	**Large**	**Comment**
Hydrological characteristics				
Flow regime	•	•••	•	In narrow riverbeds the wood is held back by standing vegetation with any flow conditions, In large riverbeds the wood moves more freely with high flows, when it can therefore float
Debris flow	•	•••	•	The quantity and granulometry of the sediment transported and deposited influences the chance of the wood being partially buried, blocking it, and that live wood can take root. These mechanisms are more significant when other retention mechanisms are lacking
Characteristics of the wood				
Diameter of the pieces	•	•••	•	The diameter of the pieces is only relevant in terms of favouring retention in riverbeds of intermediate width. In very narrow riverbeds even pieces with a small diameter will have difficulty in floating

	Relative size of the watercourse Small	Medium	Large	Comment
Hydrological characteristics				
Specific weight	•	•••	•	In large riverbeds, the lighter the wood and hence the more easily it floats, the more frequently hydrometric levels permitting floating may occur
Geometric complexity	•	•••	•••	In very narrow riverbeds the wood is retained in any case, even if the geometry is very simple. In medium and large riverbeds, contorted shapes and the presence of branching hinders transport downstream by the current
Length of the wood in relation to the width of the riverbed	•••	•••	•	In small and medium-sized riverbeds the length of the wood is fundamental in determining the possibility of this getting jammed at some point. In very large riverbeds the retention capacity is in any case low
Geomorphological characteristics				
Width of the active riverbed	•	•••	•	In narrow riverbeds the wood is retained in any case, in large riverbeds there are few obstacles that can retain it, whereas it is in medium-sized riverbeds that the length of the wood is decisive
Morphology of the riverbed			•••	In large riverbeds, complex morphologies with bars and sinuous channels create obstacles hindering the floating of the wood downstream

Table 2.1: Relative importance of wood characteristics and hydromorphological parameters in influencing wood containment in watercourses of different sizes (adapted from [13]).

he characteristics of the ligneous material in the riverbed depend firstly on the nature of wooded areas in the hydrographic basin, which determines the maximum diameter and length, specific weight and geometry (Gurnell et al., 2002). Conifer woods result in the introduction of very long trunks without branching and with a low specific weight into the river, with wood that therefore floats downstream more easily, whereas broad-leaved woods favour the introduction of shorter trunks with much more branching and greater weight into the river, therefore more likely to be retained.

However, once it has entered the river the wood is not transferred downstream as it is, but is rather subject to various degradation processes [13] which include: breaking and loss of branches due to rolling, abrasion by sediment, biological degradation, breaking due to impact with large boulders in the river or rock faces, absorption of water and rotting. These are all phenomena which lead to a reduction in size. With the increase in specific weight, absorption of water can also lead to the wood no longer floating, although it nevertheless continues to move downstream by rolling along the bed. In Trentino, considering the nature of the forests (in which only spruce trees can reach heights of over 30-40 m in certain favourable situations, and not on the valley floor) and the morphological characteristics of the watercourses, indicatively the rivers along the main valley floors (the Sarca in the Limarò valley, the Noce below Rocchetta, the Avisio below Predazzo and the Adige) can be considered to be "large", while the other rivers and main streams along valley floors can be categorised as "medium" and all the streams in side valleys can be categorised as "small".

2.1.2 Changes to the load of watercourses and riparian formations

In the previous section we provided a summary of the hydromorphological dynamics involving vegetation along essentially unmodified watercourses.
However, for some time the activities of man in the area have led to profound transformation of all the components in fluvial ecosystems. Consequently, the watercourses along which riparian vegetation needs to be managed have been radically transformed and have accumulated considerable pressure of anthropogenic origin over time. Some of this pressure relates directly to the watercourse and other aspects to the basin as a whole.
All pressure causing hydromorphological changes to the river system also leads to major transformation in riparian habitats. Some transformations are so profound and longstanding that one is no longer aware of them. The most dramatic transformation has been the occupation of the floodplain – which once stretched out over most of the alpine valley floors – by human activities. The consequence of this has been the almost total disappearance of riparian habitats, of which only some meagre relicts remain today. The need to defend human activities from flooding and the erosion of the terrain caused by the digression of channels has developed as a direct result of occupation of the floodplain. The combination of these factors has led to profound transformation of riverbeds and banks, making them highly artificial and meaning that the remaining wood formations along the banks are so altered and filiform that it is legitimate to ask to what extent they effectively conserve the characteristics of riparian habitats. The third fundamental pressure involved is the presence of extensive systems to draw on water for the purposes of hydropower, leading to major hydromorphological changes that also affect the riparian vegetation within the riverbed – in addition to all the aquatic biocoenoses – and the equilibrium of many of the strips of floodplain that have survived direct pressure. The fourth type of pressure is perhaps the most insidious and the least well-equipped with instruments to combat the problem: the entry of invasive alien species. These four fundamental types of pressure and the consequential impact are described in the following sections.

2.1.2.1 Utilisation of the area and intervention to reduce risk

Historically, the pressure on alpine streams was initially the result of deforestation of the mountains and subsequently stream-forestry management works designed to control the transport of debris - hyperconcentrated and debris flows – an aspect that had been dramatically accentuated by deforestation, but which represents an intrinsic characteristic of mountainous areas. Today the need to defend ourselves against this type of phenomenon is still very strong, due to the expansion of human settlement throughout the area. This significantly increases risk, although the danger has been reduced as a result of the quantitative and qualitative increase in forest coverage taking place since the Second World War and the numerous works designed to reduce risk carried out along streams threatening inhabited areas.
The presence of forest coverage along valleys and mountain streams can also lead to an increased risk, because it can contribute significantly to increasing the volume of the debris and may lead to the accumulation of debris blocking the riverbed, creating temporary basins that can suddenly break as a result of the pressure of the water, leading to very intense flooding. The method typically used to deal with these problems is the construction of a series of dams along mountain channels with inhabited areas and infrastructures downstream. In the last few years it has often been preferred to make use of solutions with less impact on the landscape, made up of ramps and steps constructed with large boulders, set up to mimic the natural step-pool morphology. Independently of the construction

solution adopted, the geomorphological effects are the same, making mobilisation of the riverbed and adjoining areas even less frequent as compared to the natural situation, and reducing the already low frequency and extent of re-colonisation by vegetation with more marked riparian characteristics.
As an alternative to direct intervention, it is currently preferred to protect areas characterised by human activities with open or debris-sorting dams, which retain the mass debris transported while allowing ordinary flows of sediment to pass.

Figure 2.12: Example of a selective dam (*Ph.* Autonomous Province of Trento's Mountain Basin Department).

Considering that in the alpine environment one of the main mechanisms leading to the entry of large wood is a result of these intense phenomena, both "management" with traditional dams and the construction of open dams lead to a drastic reduction in terms of input. The most artificial stretches of watercourse in the mountain environment are those on alluvial fans and crossing towns and villages, often delimited by vertical walls in reinforced concrete, with the bed being stabilised using dams and weirs. In these cases drastic action is taken to contain vegetation in the river bed in order to contain roughness and limit overhanging arboreal and bush vegetation in the runoff section.
In extreme cases the riverbeds on alluvial fans are reduced to simple channels running through large ditches, entirely clad in concrete, losing all their natural characteristics and any chance of vegetation establishing itself.
The evolution of forest coverage in the mountain environment has had major repercussions on the hydromorphological structure of alluvial watercourses on the valley floor. By the Second World War the mountains in Trentino had arrived at a situation with dramatically impoverished and degraded forest coverage, with extensive areas of deforestation. While the dramatic flooding in 1882 had begun an initial change in the trend for deforestation, with the adoption of extensive stream-forestry management programmes, it was only starting from the economic boom of the 1950s that forest coverage began a phase of expansion which is still underway. In the case of reduced forest coverage, the hydrological response of basins is much more intense, as is the production of sediment. This leads to the establishment of riverbeds in the valley with high energy, such as braided or transitional rivers. The increase in forest coverage reduces the response of basins, in terms of the extent of both solid and liquid flows, with consequential evolution of rivers towards morphologies with lower energy [36] [30] [31] [32].
The floodplains of watercourses along the floor of the main valleys have been extensively cultivated for centuries, and as a result the complex associated mosaic of habitats has been almost completely wiped out. Despite this, hydromorphological processes are fully active and thus flooding and erosion

of agricultural areas and inhabited areas were frequent. It has always been attempted to prevent this using bank defences of various kinds. However, it was starting from the first half of the 19th century, with renewed drive following the disastrous flooding of 1882, that more systematic intervention began, leading to the straightening and channelling of many watercourses and the construction of the first raised banks.

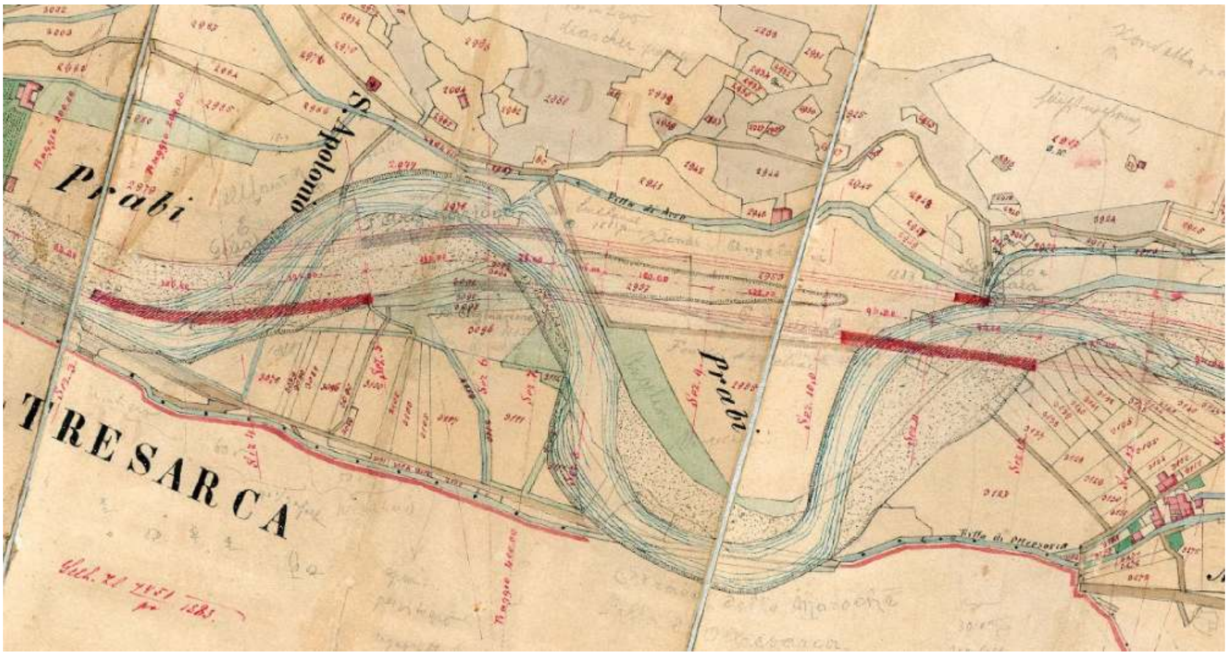


Figure 2.13: This late 19th century plan for the straightening of the River Sarco in Arco shows that the river had a transitional morphology with very accentuated bends (Source: historic archives of the Municipality of Arco).

This straightening work certainly profoundly changed the planimetric and altimetric layout of rivers on the valley floor, also leading to the need to create the first dams across rivers. However, the morphological dynamics of the river remained active and essentially unaltered, just as the equilibrium of the aquatic ecosystem remained essentially unchanged.

The resulting increased need to defend the banks from erosion and above all to minimise the occupation of land useful for agriculture led to the creation of very narrow, steep banks, with compression of the space available for riparian vegetation. In addition to this, riparian vegetation and deadwood in the river represented a source of easily accessible and promptly used firewood, hence the particularly “clean” appearance of most rivers in historic photos dating back to the first half of the 20th century.

Figure 2.14: Stretch of the River Sarca above Arco, straightened at the end of the 19th century according to the plan in Fig. 14. The almost total absence of vegetation along the banks is clear (Source: historic archives of the Municipality of Arco).

While widespread stream-forestry management works led to a drastic reduction in woody material in the hydrographic network, the channelling of riverbeds on the valley floors and their morphological simplification accelerated the progress of any material nevertheless acquired towards downstream areas.
Once the felling of trees for use as firewood halted, the vegetation once again began to develop along the banks, except for periodic cutting down aimed at limiting hydrographic risk. Intervention for the purposes of stream management has two fundamental objectives: to contain the roughness of the riverbed and to limit the quantity of large wood entering the riverbed.

Figure 2.15: Deadwood transported by the River Sarca to Lake Garda during the flooding of August 2010 (*Ph.* Autonomous Province of Trento's Mountain Basin Department).

Another fundamental form of anthropogenic pressure altering the hydromorphological equilibrium of Trentino watercourses, leaving permanent and significant signs in terms of vegetation management, was the removal of aggregates, which contributed towards the entrenchment of riverbeds, the effect of this being added to channelling and the creation of artificial lakes. The consequences are described in the subsequent section.

2.1.2.2 Utilizzo idroelettrico

Many watercourses in Trentino are subject to the effects of hydromorphological changes caused by the presence of water withdrawal works and reservoirs upstream for the purpose of hydropower.

The presence of artificial dams is capable of altering the flow regime of solids and liquids, reducing the frequency of formative flow and drastically interrupting the flow of sediment downstream. The larger the part of the basin intercepted by reservoirs, the higher the resulting impact [32]. The consequences are entrenchment and the slowing down of morphological dynamics in the river, of fundamental importance for the aquatic ecosystem.

There have thus been two successive phases in terms of the changes to hydromorphological dynamics and the entrenchment of riverbeds taking place over time: the first occurred from the end of the 19th century until the Second World War with a progressive effect, as a result of reforestation and stream-forestry management works; the second, much more rapid and with even more dramatic effects, took place starting from the 1950s as a result of the removal of aggregates and the construction of artificial lakes [36] [30] [31] [32].

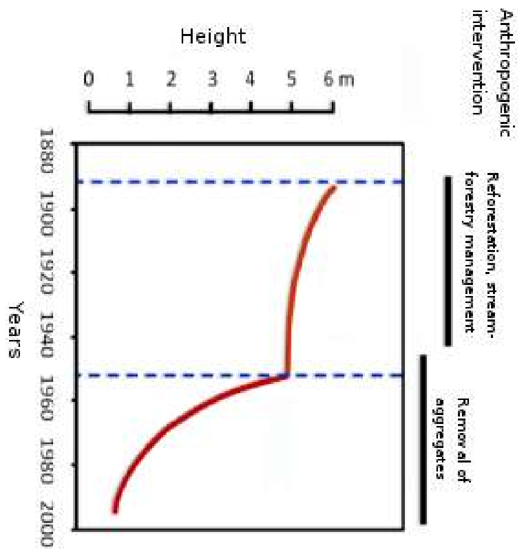


Figure 2.16: Typical progress of riverbed height over time in response to anthropogenic disturbance in around the last 100 years, observed in various Italian rivers [32].

The dynamics related to the entrenchment of the riverbed have had the most direct effects on the management and conservation of riparian vegetation. Many of the remaining floodplain areas have found themselves much higher up in relation to riverbed, losing their specific characteristics and taking on those of a terrace, becoming drier and being flooded less frequently. In the main stretches, where the floodplain has been used for human activities for some time, the banks have become higher in relation the riverbed, on many occasions leading to the collapse of old protection works. In order to limit the consumption of productive land, it has been chosen to keep the banks very steep, if necessary stabilising them with heavy works such as loose and concrete riprap and walls in reinforced concrete. The consequence has been to make the banks increasingly less suitable for colonisation by vegetation, which has gradually taken on slightly less riparian characteristics, with the entry of more mesophilous species. The combination of reduced summer flow and the lesser frequency of bankfull flow, removes the natural mechanisms contrasting evolution of the vegetation, favouring an abnormal and unnatural extension of vegetation within the riverbed. In a modified situation such as the one described, where in any case the full flow at high water is concentrated in the riverbed without any possibility of expanding over surrounding areas, the runoff section free of vegetation is considerably undersized. This leads to increased risk due to two factors:

- a considerable increase in roughness, with a resulting increase in high water runoff levels, and hence an increase in the likelihood of flooding surrounding areas;
- a strong likelihood of undercutting and uprooting the vegetation, with possible obstruction of the runoff section, in addition to the considerable cost of works to restore secure conditions after this undercutting and uprooting has taken place.

(a) Development of riparian vegetation after almost ten years without cutting down plants

(b) Vegetation knocked down and uprooted after flooding in February 2011

(c) Work to remove the vegetation knocked down following flooding

(d) The same stretch of river after the completion of works. Although lacking in vegetation, in these conditions the riverbed is closer to a state of maximum naturalness than it was before the flooding

Figure 2.17: The effect of hydromorphological changes on the development of riparian vegetation in a stretch of the River Sarca at Arco and the management consequences (*Ph.* **(a)** Giuliano Trentini; **(b)**, **(c)**, **(d)** Autonomous Province of Trento's Mountain Basin Department).

Although the vigorous vegetation developing along the riverbed may suggest highly natural conditions, it should be borne in mind that these populations are intrinsically unstable and subject to periodic destruction, and above all that this situation represents a symptom of major changes to the hydromorphological regime. The loss of riparian habitats on the floodplain cannot be compensated for by the unnatural development of vegetation along the riverbed.

2.1.2.3 Introduction of invasive alien plant species

The colonisation of riparian habitats by alien plant species is a phenomenon that can be found with ever greater frequency and that has increasingly marked characteristics as one moves from the upper stretches of the basin towards plain areas. The presence of these species, especially when they are invasive, causes problems of an ecological, economic and social nature and in terms of landscape, problems which have been increasingly recorded.
In the riparian environment these problems can be seen with the presence of invasive arboreal, bush and herbaceous species that generally form dense populations in strong competition with local vegetation, leading to simplification of the biocoenoses and a reduction in the biodiversity of ecosystems. Added to this, there are consequences in terms of management of hydrological risk, due to frequent lack of substance in terms of the root systems, rapid growth, which leads to the formation of considerable quantities of biomass, which is very dangerous in small watercourses and channels, and the formation of very dense populations made up of more "elongated" plants with a strong tendency to collapse, especially in the case of Robinia pseudacacia. The terms "invasive species" and "alien species" are not synonyms, although they are often used as such. For further information some basic definitions are given (taken from [8]):

Alien plant species : (synonyms: introduced, non-indigenous, exotic, xenophyte) plant species introduced by man, deliberately or accidentally, outside their natural distribution area;

Casual species : (synonyms: ephemeral, occasional) alien species that develop and reproduce spontaneously but do not form stable populations, which rely on the repeated introduction of new propagules by man in order to be maintained;

Naturalised species : (synonym: stabilised) alien species that form stable populations, without requiring the introduction of new propagules by man;

Invasive species : a subgroup of naturalised species capable of spreading rapidly, at considerable distances from the original source of propagules and therefore with the potential to spread over vast areas;

Locally invasive species : alien species that have been recorded as invasive only in a few stations.

The species defined as "invasive" and "alien" in the classification are significant in relation to the management of riparian vegetation.
The problem (which also extends to animal species) is so significant that it has been dealt with at European level, leading to the issuing of the Habitats Directive. Subsequently, the battle against invasive species became part of the European Union "Biodiversity Action Plan", which "recognises the need to develop a global strategy at EU level in order to reduce their impact on biodiversity in Europe".
The "Strategy on invasive alien species" policy document drawn up by the Council of Europe, which deals with the subject in terms of preventing and mitigating impact, dates back to 2011 [**?**].
In the 2005-2007 period, following an initiative by MATTM, a database of exotic vascular plants spontaneously present in Italian regions was drawn up in Italy, in the context of the "Invasive alien vascular flora in Italian regions" project. This recorded 1,023 exotic species, of which 523 naturalised, namely settled in a stable manner. 162 of these were classifiable as invasive (Celesti-Grapow, 2010). The volume contains a specific section on the Province of Trento.
In 2010 the National Biodiversity Strategy was adopted (in the context of the commitments made by Italy with the ratification of the Convention on Biological Diversity in Rio de Janeiro). This represents a tool integrating conservation needs and the sustainable use of natural resources within national policy on the sector. 15 work areas are identified in the document (e.g. Species, habitats and landscape – Protected areas – Genetic resources– Agriculture – Forests etc.) , of which no less than 6 specify invasive species as an important threat.
Some regions have passed laws on the subject: Sardinia with a number of provisions in the landscape plan, Lombardia with L.R. 10 of 31/03/2008 "Measures for the safeguarding and conservation of small fauna, flora and spontaneous vegetation", the Valle d'Aosta with the Regional Law of 7

December 2009, no. 45 “Measures for the safeguarding and conservation of alpine flora” and Piemonte with a series of regulatory references within various laws and regulations.

In almost all the aforementioned regional regulations and laws we can find the so-called “Black List”, which lists invasive species that lead or may lead to particular problems within the territory of the relevant region and as regards which the application of measures to prevent, manage, combat and contain them is necessary.

Below we list some of the most important invasive species in the riparian environment.

Ailanthus altissima (tree of heaven): one of the most common invasive species, which is by now very widespread throughout Italy, thanks to the enormous number of seeds it produces, its rapid growth and its ability to reproduce through vegetative sprouting. It colonises areas subject to degradation, such as the sides of roads, railways, courtyards and more natural environments (including riparian areas), when they are in a degraded condition.

Robinia Pseudoacacia (black locust): one of the most widespread species in Italy, used for ornamental purposes but also to control erosion and in reforestation projects. It owes its diffusion to its rapid growth and its ability to renew itself through vegetative sprouting. It is a pioneer species, thanks to its nitrogen-fixing ability, and it colonises a large number of environments not necessarily subject to degradation. Very common in riparian environments.

Ambrosia artemisiifolia : this is a rapidly expanding invasive species, much feared due to its highly allergenic pollen. It is a pioneer species capable of adapting to almost any conditions in terms of soil, temperature and humidity. It produces a large quantity of seeds, that remain vital for up to 20 years and can be transported by many carriers, although transport by man is one of the main causes of its diffusion. In the fluvial environment it colonises gravel beds and sandy and muddy deposits in an extensive manner.

Amorpha fruticosa : this is an invasive species widely present in Europe and along rivers throughout most of northern Italy. It is a thermophilous species capable of reproducing both through vegetative sprouting from fragments of branches and sexually, with the production of abundant quantities of seeds, that are transported by the water. It may become dominant in alluvial forests subject to degradation, leading to the disappearance of indigenous plant communities, and it can also invade intact alluvial forests.

Buddleja davidii : a plant that adapts to every type of soil and puts up with the cold very well. It propagates abundantly, both vegetatively (it is a stoloniferous plant) and thanks to the production of abundant quantities of seeds, which are transported by the wind. In its land of origin (North America) it is a typical riparian species, so fluvial environments are its preferred habitat, and it also colonises riparian woods and scrubland that have not degraded.

Impatiens spp : the Impatiens genus includes more than 500 species from Africa and Asia, cultivated for ornamental purposes. Some of these are among the most invasive weeds (Kashmir and Himalayan balsam etc,), also capable of developing in hostile environments, so long as they are sufficiently humid. It therefore prefers areas adjoining the banks of rivers or streams, covering the terrain completely and effectively preventing penetration by sunlight, which is fundamental for other plants.

(a) Almost pure black locust formations along the Adige to the south of Trento

(b) Terrain with a high density of Robinia pseudoacacia, with the herbaceous undergrowth dominated by Impatients sp., at the mouth of the River Avisio in the SCI of the same name

Figure 2.18: Other examples of the presence of invasive alien species along watercourses in Trentino (*Ph.* Giuliano Trentini).

Reynoutria japonica (Japanese knotweed): this is listed as one of the 100 most invasive species in Europe and one of its preferred expansion routes is represented precisely by watercourses, which transport the rhizomes. The excellent germination ability of even small parts of the rhizome leads to the species colonising all fluvial areas subject to disturbance, whether natural (erosion) or of human origin (quarries etc.), with very dense populations .

(a) Massive introduction in the final stretch of the Rio Bedù di Pelugo following reconstruction of defensive works. In the Val Rendena this species is particularly virulent

(b) In contrast the penetration into the valleys of the Avisio is just beginning. This small nucleus is situated at Molina di Fiemme along a stretch of bank almost without arboreal and bush vegetation

Figure 2.19: Images of the diffusion of Japanese knotweed *Reynoutria japonica* in Trentino (*Ph.* Giuliano Trentini).

Helianthus tuberosus (Jerusalem artichoke): a herbaceous species very similar to the sunflower, it is a species considered to be of ornamental and nutritional interest in the areas of origin (eastern parts of North America). It propagates almost exclusively vegetatively along the banks of watercourses, in riverside forests and wherever its needs for light and nutrients are satisfied. It forms dense populations, with foliage that rapidly covers the soil, hindering the development of indigenous flora. In winter the parts above ground die, leaving the soil bare and exposed to erosion, a trend which is accentuated by animals, which dig into the soil to look for the tubers.

2.2 Conservation of habitats and riparian species

Considering that the distribution of plant species along watercourses is governed fundamentally by hydromorphological processes [?], it is easy to understand that management of vegetation aimed at reducing hydrological risk in a hydrographic network that has already been considerably modified can only influence the conservation of riparian habitats to a marginal extent. Indeed, however much attention is paid to the question, redefining management methods certainly cannot make up for the impact resulting from a radical reduction in the size of the floodplain, the artificial nature of the banks or changes in the hydromorphological regime. However, it is equally true that when other predominantly anthropogenic factors allow the persistence of spaces and hydromorphological dynamics which are sufficient for the development of the typical riparian vegetation, the ways in which the vegetation is managed can be decisive for its conservation and improvement.
Forest formations of riparian environments are described as azonal, in the sense that they are not particularly linked to biogeographical or climatic zones. Furthermore, while they are characterised by species with marked pioneer characteristics, riparian formations represent long-lasting evolutionary stages, precisely due to the cyclical repetition of the hydromorphological disturbance caused by the watercourses along which they develop, which prevents evolution towards more mature stages. The presence of eight different forest types has been recorded and described along watercourses in Trentino [35]:

- Riparian alder forest
  - Grey alder forest (*Alnus incana*)
  - Black alder forest (*Alnus glutinosa*)
- Riparian willow formations
  - Willow formations with *Salix alba*
  - Willow formations with *Salix cinerea*
  - Willow formations with *Salix eleagnos* and *Salix purpurea*
- Scots pine forest with grey alder
- Common sea-buckthorn formations (*Hippophaë rhamnoides*)
- *Myricaria germanica* formations

Grey alder forest is a formation dominated by *Alnus incana*, which settles on the banks and in the floodplain of the upper and central stretches of streams, sometimes accompanied by willow plants, *Alnus glutinosa* (in lower areas), *Frangula alnus*, *Fraxinus excelsior*, *Prunus padus* (rare) and *Ulmus minor* (mostly bushy). Riparian grey alder forest is present both in enclosed valleys in the endalpic area (in contact with European spruce forest), and along the tributaries and main watercourses of meso(es)alpic basins, where the valley floor widens. In this case it comes into contact with Salix eleagnos and Salix purpurea willow formations and with maple-ash forest of the slopes, towards which it may eventually evolve [35].
Black alder forest, dominated by Alnus glutinosa, is generally accompanied by willow, poplar and grey alder trees, and is of a strongly azonal nature. It usually establishes itself in marshy environments, on peaty soils, along watercourses at a sufficient distance from the channel to allow it not to be affected by the effects of the current. The soil is asphytic and the water flows slowly. The arboreal coverage includes Viburnum opulus, Cornus sanguinea, Frangula alnus, Sambucus nigra and Rubus ssp. [35].
Salix cinerea formations are made up of woods dominated by this species, often accompanied by a lesser presence of *Frangula alnus*. They develop on peaty, acid soils. Rarely, but significantly, *Salix cinerea* is also accompanied by Salix pentandra in more hygrophilous conditions, in the more internal environments of marshes and acidic peat bogs. The formation is linked spatially and dynamically to alder forest and sometimes to willow formations with *Salix alba*.
Salix alba formations are made up of bushy scrubland dominated by this species, often accompanied by Populus nigra. The bushy vegetation is poor and characterised by Sambucus nigra and willow and

poplar suckers. Willow formations with Salix alba are typical of the floodplain in the central and lower stretches of alluvial watercourses [35].

In willow formations with *Salix eleagnos* and *Salix purpurea* these two species form dense thickets along alpine streams from the valley floor up to 1.500 m a.s.l. and even higher, characterising the central and upper sections of watercourses, on sandy and pebbly deposits. The aquifer is temporarily close to the surface and these environments are frequently submerged by flooding and exposed to collision with rocks. In the absence of interference, the scrubland evolves towards grey alder forest and may be preceded by pioneer herbaceous vegetation or (more rarely and in internal valleys) by scrubland with common sea-buckthorn or Myricaria germanica formations. More frequently, xerothermophilous species such as the Scots pine, barberry and thyme settle in abandoned areas of the riverbed, following the lowering of the aquifer and a reduction in modifications. In this way one arrives at belts of pioneer pine formations on the riverbed or calcicolous pine forest with grey alder. Willow formations with Salix eleagnos are associated with willow formations with *Salix triandra*, which tend to substitute the former in plain environments with the progressive loss of watercourse energy. The two biocoenoses may merge and one or the other may dominate, depending on whether the watercourses show more marked torrential (*Salix eleagnos*) or plain (*Salix triandra*) characteristics [35]. In the province it is only along the River Adige that the conditions give rise to a marked prevalence of *Salix triandra* over *Salix eleagnos.*

Scrubland with common sea-buckthorn formations (*Hippophaë rhamnoides*) is typical of high energy watercourses with very coarse sediment and excellent drainage. The bushes present are the common sea-buckthorn, *Salix eleagnos* and *Salix purpurea.* With the disappearance of hydromorphological stress, evolution towards willow formations with *Salix eleagnos* and Scots pine is possible [35].

Myricaria germanica scrubland formations are typical of alluvial watercourses on the valley floor with gravelly and sandy sediment, finer and less well-drained than the sediment on which common sea-buckthorn formations establish themselves.

With a view to improvement, it would certainly be interesting to investigate which other riparian forest types could potentially be present along watercourses in Trentino, but are not present today due to changes caused by man, first of all the contraction of the fluvial belt.

As an alternative to the ecological-forestry approach, a complementary way of interpreting the situation involves the classification of habitats, introduced by the European Habitats Directive (92/43/EEC). In Trentino various Natura 2000 network sites develop along watercourses. The combination of habitats recorded within these, to which an additional habitat not currently present but which could potentially be present in more natural conditions should be added, [17] can be considered to be representative of the whole spectrum of habitats typical of Trentino watercourses.ù

In the different Natura 2000 habitat interpretation manuals drawn up at European [**?**], national [6] and provincial level [17], a clear description of the specific hydromorphological dynamics governing the existence of each individual habitat is generally lacking. We instead believe that this is essential in order to be able to explain: the reasons for the rarity of certain habitats in the current anthropogenic environment, the level of conservation or modification at sites where they exist, management methods that can best combine conservation with the reduction of hydrological risk. We summarise the relationship between habitats and e hydromorphological dynamics in Table 2 which follows, while for a detailed description of the habitats see the provincial interpretation manual.

Natura 2000 code	Name	Associated hydromorphological dynamics
3220	Alpine rivers with herbaceous vegetation	Although the names suggest that there are watercourses of radically different types leading to the presence of different habitats, it is more correct to consider that they may be present along the same watercourse within different morphological units. The hydrophytic vegetation of 3260 can clearly only be found within the water channel of the riverbed. The herbaceous vegetation of 3220 and 3270 can be found in the dry parts of the riverbed most frequently (annually) modified by flooding. The habitats with *Myricaria germanica* and *Salix eleagnos* are instead linked to high bars modified less frequently by high water. Small watercourses on the valley floor, characterised by low mobility of the riverbed, cannot create conditions suitable for the development of habitats 3220, 3230, 3240 and 3270.
3230	Alpine rivers and their ligneous vegetation with *Myricaria germanica*	
3240	Alpine rivers and their ligneous vegetation with *Salix eleagnos*	
3260	Watercourses of plain to montane levels with *Ranunculus fluitantis* and *Callitricho-Batrachion*	
3270	Rivers with muddy banks and *Chenopodion rubri p.p.* and *Bidention p.p.*	
91E0*	Alluvial forests of *Alnus glutinosa* and *Fraxinus excelsior* (*Alnopadion*, *Alnion incanae*, *Salicion albae*)	This habitat is typical of the floodplain and transitional riverside belts between the active riverbed and the neighbouring plain or slopes (channel shelf). Geomorphological dynamics, and not just hydrological conditions (usually cited) are essential for maintaining the plant formations typical of this habitat, which would evolve towards other more mature forms in the absence of periodic demolition and reconstruction. The different and multifaceted combinations that can be attributed to this habitat are distributed on the basis of the phytogeographical zones (for example grey alder forest in endalpic zones and black alder forest in esalpic zones) but also as a result of the interaction with the hydromorphological dynamics and the shape given to the floodplain by these (lower or higher zones and therefore with a different water content in the soil and different frequency/duration of flooding).
91F0	Riparian mixed forest of *Quercus robur*, *Ulmus laevis* and *Ulmus minor*, *Fraxinus excelsior* or *Fraxinus angustifolia* (*Ulmenion minoris*) along the great rivers	Without continuous rejuvenating morphological action, but with a continuing possibility of occasional flooding and a high level of soil humidity, in the main valley floors and at low altitude, habitat 91E0* evolves towards this more mature stage. It goes without saying that even after a long time the wandering of the river could once again erode and demolish these forest formations, once again sparking off plant succession, with development of habitat 91E0*..

Table 2.2: Presentation of the range of habitats typical of river corridors in Trentino and the hydromorphological dynamics governing their formation.

Mitigation of hydromorphological stress, more likely on the floor of the main valleys when the channel moves away as a result of a changing course, represents the premise for transformation of the vegetation in evolutionary phases (successional seres) gradually less linked to flooding, until climax formations are reached [35].

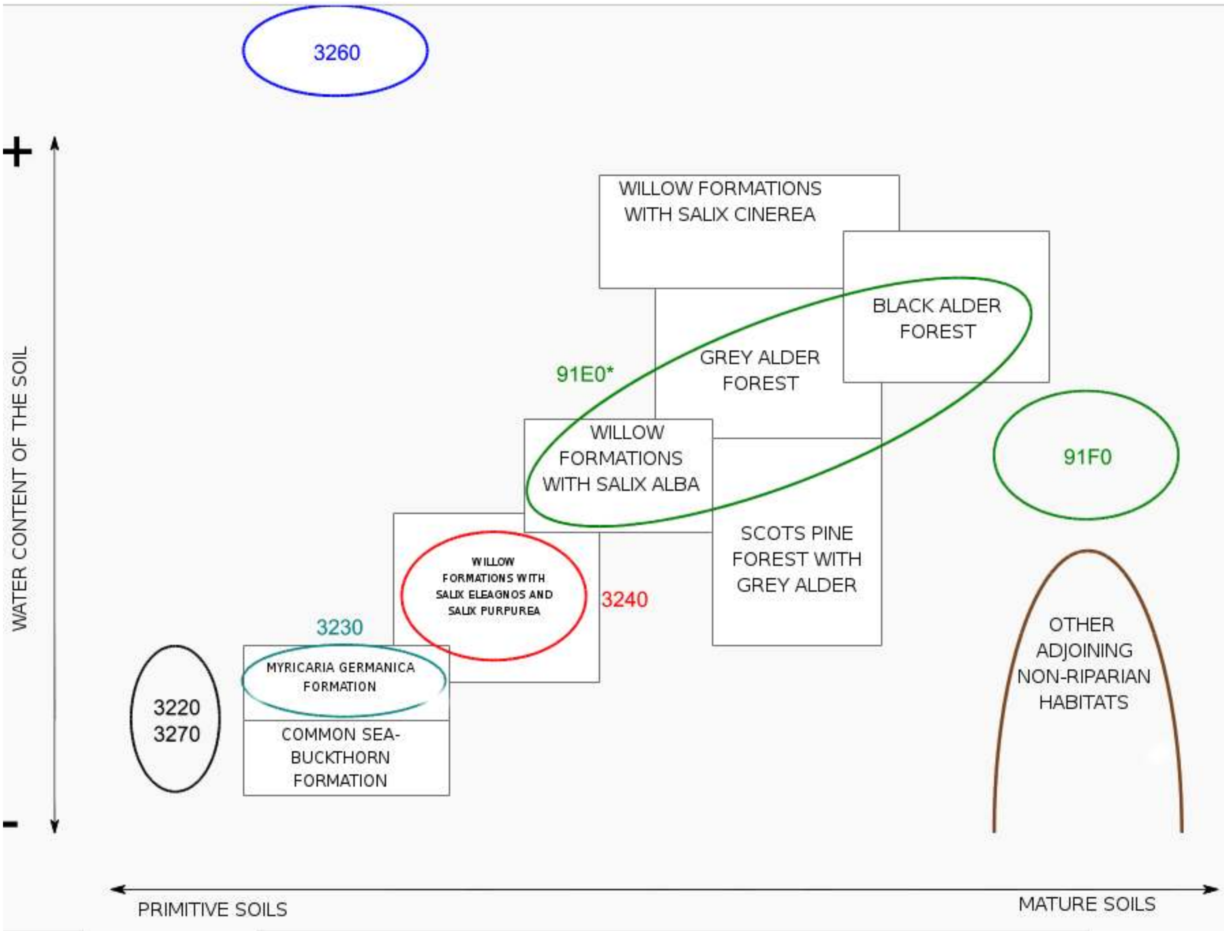


Figure 2.20: Diagram representing the relationship between forest types found in Trentino along watercourses with changing edaphic conditions (adapted from [35]) in relation to Natura 2000 habitats

The different nature and intensity of hydromorphological actions corresponds with the different morphological units on which the forest formations /habitats stand. The diagram in Fig. 22 is a reinterpretation of similar diagrams given in botanical and ecological literature [14] [21] [28] [34], with introduction of the correspondence between different flooding frequencies and the geomorphological unit, which remained an unresolved problem in the case of the authors mentioned, and between morphological units, forest types and habitats.

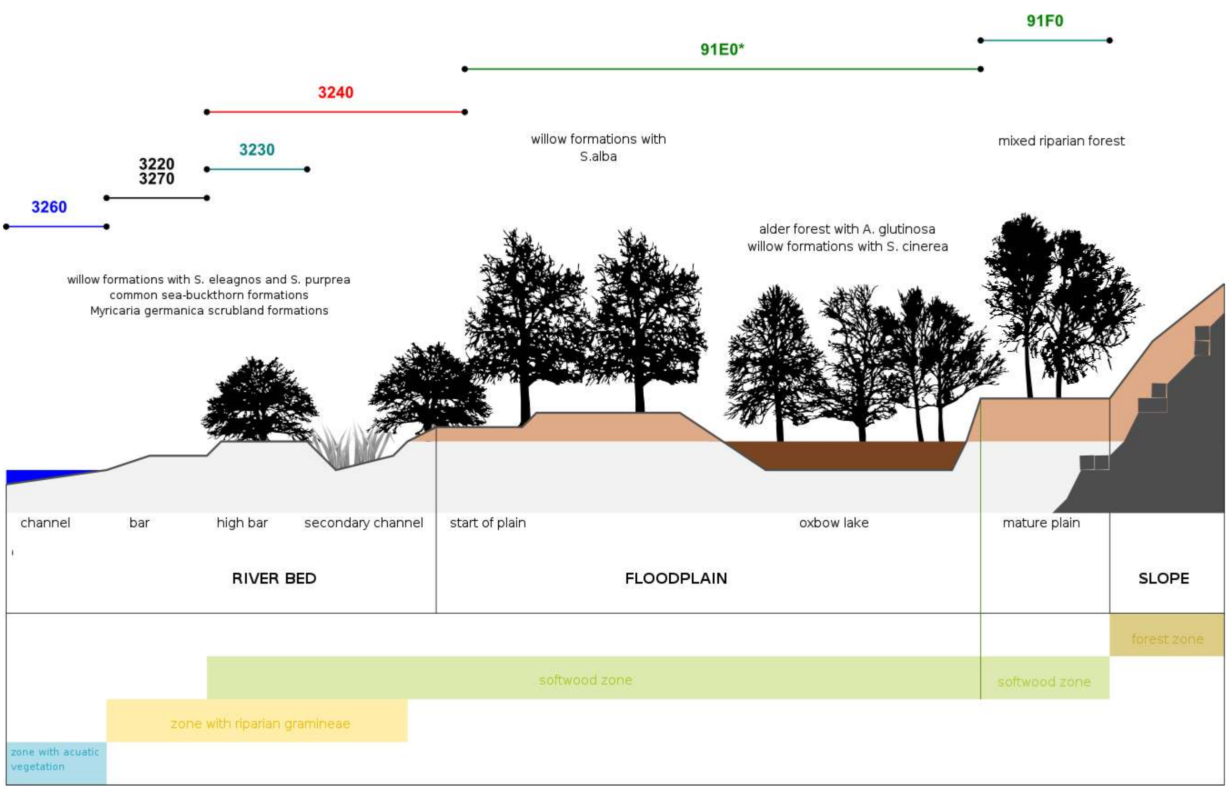


Figure 2.21: Theoretical spatial succession of plant associations in the cross-section of a watercourse on the valley floor, correspondence between morphological units, forestry types and habitats

In Italy various authors [17] [6] have highlighted that the attributing of "priority" status to some habitats according to the Habitats Directive does not always correspond with the real state of affairs, due to their distribution or for reasons related to conservation. The scenario briefly outlined in section 1.2, hence the very limited extent of the active floodplain as compared to the potential area, (a situation which is very widespread throughout Europe) certainly justifies considering habitat 91E0* as a priority. However, this same modified picture leads to the absence of the conditions necessary for the existence of other habits that are regressing rapidly in Trentino, as in other regions in the alpine area, and whose protection should be considered a priority, namely 3230 and the 91F0.

It is only along the River Adige that the hydrological regime and width of the valley floor permit the development of habitat 91F0 [17], , given that it develops in parts of the floodplain which have not been affected by the wandering of the active riverbed for a long time and thus, as a general rule, more distant from it. The changes in the river corridor that have led to the almost total disappearance of habitat 91E0* clearly affect habitat 91F0 even more seriously, given that it requires an even broader unmodified river corridor. Indeed, only two fragments of English oak woods of the plains, not yet fully mature, have been recorded: along the River Adige close to Ala and along the Noce in the provincial reserve of Rocchetta [17]. In both cases the riverbed has little lateral mobility, something which also favours the evolution of plant succession in areas very close to it.

Figure 2.22: Presence of *Myricaria germanica* in the accumulation basin of the Travignolo, just above the town of Predazzo (*Ph.* Giuliano Trentini).

In the case of Myricaria germanica, the main factor leading to regression of the population again comes from the reduction of the river corridor. The channelling and narrowing of the riverbed, alteration of the hydromorphological regime due to the presence of artificial lakes and water withdrawal upstream and the removal of aggregates from the riverbed are all pressures that gradually reduce the possibility of developing the high bars essential for the presence of these species. Indeed, in the absence of continuous natural flooding modifications due to high water, one can find the establishment of arboreal riparian willow communities related to habitat `3240`, given that Myricaria germanica is not capable of competing with the willow [22]; . However, when these upheavals are excessively frequent and intense, only herbaceous species succeed in establishing themselves. The importance of areas with Myricaria germanica is such that it represents an indicator of a good level of naturalness for streams and rivers [23] [16], and may be used as an indicator of the success of morphological improvement works [15]. . In Trentino its presence is recorded only sporadically along some stretches of the Avisio and its tributaries [22].

n most cases, the bands of vegetation surviving along the banks of Trentino watercourses have undergone so much modification that it is not appropriate to assign them to priority habitat `91E0`* [17], whereas it is mostly correct to classify what remains of more extensive willow formations in this way. However, in the latter case it is decisive to investigate whether they are found on surface areas which still have the characteristics of a floodplain or not. Indeed, formations that can be classified as `91E0`* standing on areas that have lost their nature as a floodplain are destined to evolve towards other types of habitat over time, due to the entrenchment of the riverbed and the changing hydromorphological regime. In these cases, the maintenance of habitat `91E0`* must inevitably involve the demolition of existing stands and subsequent re-establishment at a lesser height from the riverbed. This may take place gradually as a result of the action of the river, if there is still sufficient dynamism of the course and if there are no bank defences to prevent it, or due to active management measures, with levelling work in the areas concerned and subsequent reforestation.ù

The provincial reserve of Rocchetta (SCI and SPA IT3120061) provides an exhaustive example of this link between geomorphological dynamics and the conservation of riparian habitats. The part of the reserve further downstream has its origin in an artificial lake created in 1922, which then filled up rapidly due to the considerable amount of sediment carried by the Noce and its tributaries. This was followed by the construction of the artificial lakes at Mollaro and S. Giustina upstream, interception of the flows of some tributaries not affected by the dams, gravel quarries and dumping of aggregates. This complex history has today led to the presence of different morphological units, each characterised by a different link with the hydromorphological dynamics of the Noce and its tributaries, with wood formations that can be referred to habitat 91E0*. The different level of conservation of floodplain hydromorphological characteristics is directly reflected in the presence and degree of conservation of habitat 91E0* [42].

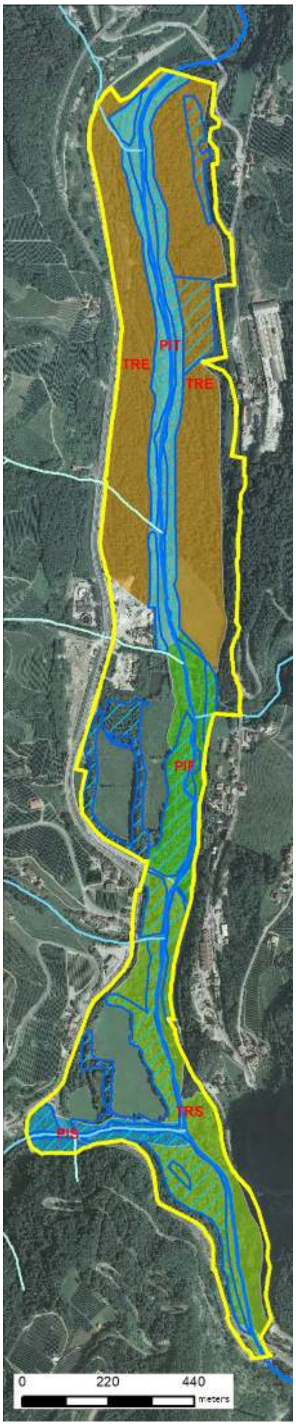


Figure 2.23: The blue hatching shows the areas in which the presence of habitat 91E0* has been recognised.

FPS – Floodplain of the Rio Sporeggio
This is the only floodplain within the SCI that can be considered to be unaltered, as the hydromorphological regime of the stream is essentially unchanged. Habitat `91E0*` is well structured and diversified in terms of specific components and age. The presence of invasive species is sporadic and controlled, taking place mainly close to infrastructures and borders with open areas.

FPF – Floodplain of the Noce along the relatively flat stretch
In the central section of the reserve, a part of the floodplain is still well linked to the hydromorphological dynamics of the Noce. The presence of the Mollaro and S. Giustina dams in the vicinity upstream leads to almost total cancellation of the hydromorphological dynamics, meaning that the floodplain has different characteristics (height above the riverbed, frequency of flooding, intensity of modification) to those that would exist in unchanged conditions along the river. The conservation of this floodplain could thus be summarised as follows: it is hydromorphologically well-balanced, with a watercourse that is significantly different to the potential situation of the Noce in the absence of hydropower dams upstream and downstream.

RTW – Recent terrace with willows
Below the railway viaduct there are large wooded areas marked by the presence of the white willow, situated on surfaces of uncertain origin, but which now certainly have the characteristics of a recent terrace. The mobility of the riverbed course is clearly inhibited and has only permitted the formation of new surface areas at a lower height at some points, subject to evolution towards a new floodplain. Given the disappearance of periodic demolition and frequent flooding, the wood stands on these terraces will very probably evolve towards habitats other than `91E0*`. The dotted red line highlights the difference in height between the beginning of the new floodplain and the previous one, which has now become a terrace.

MRT – Mature recent terrace
In the upper part of the reserve, relating to almost half of its length, there is an old floodplain on both banks that has become a terrace following entrenchment of the riverbed and changing of the hydromorphological regime, sparking off evolution of the willow formations that probably initially existed in these areas. The considerable height from the riverbed (almost three metres in the part further upstream) has meant that the stand has evolved towards a formation dominated by Scots pine, with a marked presence of robinia on the underlying plain.

FPS – Floodplain of the Noce in steep stretches
In contrast with the stretch further downstream, here the Noce has retained a significant slope and a good capacity to erode the banks, so it has succeeded in creating strips of floodplain of various widths (up to around ten metres), clearly linked to fluvial dynamics, between the riverbed and the recent terrace. Habitat `91E0*` is well structured and diversified in terms of specific components and age. The presence of invasive species is sporadic and controlled, taking place mainly close to borders with open areas and the terrace behind with Scots pine. The different slope of the riverbed, and the probably different origin, makes the formations in these bands very different from those in areas indicated as FPF and FPS areas, but this is a positive factor in terms of biodiversity.

Figure 2.24: Identification and characterisation of the main morphological units identifiable as the current or past floodplain. The dotted red line shows the accumulation basin separating the steeper stretch of the Noce upstream from the relatively flat section with the presence of the Rocchetta dam downstream (adapted from [42]).

n addition to being a potential site for important habitats in itself, the hydrographic network can also be one of the fundamental components in the ecological network of the area.
The elements making up an ecological network are: core areas, rich in biodiversity and where the species which it is wished to conserve mostly live; buffer zones, identified around the core areas to mitigate negative interference coming from the outside; ecological corridors, bands linking core areas, representing the key element in ecological networks because they allow the mobility of species and genetic exchange; stepping zones, small surface areas in a strategic position that facilitate the movement of species or host environments of particular value.
Naturally, watercourses also form a network of corridors, but their effective ability to favour the mobility of species has deteriorated considerably as a result of the changes that have taken place, as already described in section . Indeed, the full linking capacity of watercourses only exists when the integrity of the adjoining belt along the watercourses has been conserved, with all its habitats and with free manifestation of hydromorphological dynamics [46].
This situation is also confirmed in the province, where the few woods surviving along the valley floors have been identified as potentially important ecological corridors, worthy of specific protection, as well as representing areas of high natural value, [5]. Analysis of ecological connectivity carried out in the province in the context of Action A3 of the Life+ TEN Project has shown that stretches of riparian woods are becoming more fragmented and distant from one another in the Adige valley and some parts of the Sarca valley, with less variety of species. In contrast, the areas that appear to be most continuous and of highest value are: the lower stretches of the Chiese, up to the entry of the stream into Lake Idro; the central part of the Avisio in the Val di Fiemme and lower part of the Val di Cembra; some stretches of the Brenta, where there is still continuity, in a context of extensive crop cultivation and meadows, with exclusion of the part upstream, straightened and with artificial banks, close to the two lakes of Caldonazzo and Levico [5].
To effectively set up corridors for fauna along the hydrographic network it is essential to provide for the continuity of riparian forest stands [5]. However, for this purpose the narrow belt of bank vegetation that survives or can be easily re-established along lengthy stretches of Trentino watercourses may not be sufficient [46]. Thus simply re-evaluating management methods for the vegetation currently existing along watercourses, without undertaking more wide-ranging improvement works, does not ensure that these areas function adequately in terms of ecological connectivity, as in the case of the conservation of habitats and species.
The implementation of ecological corridors cannot be generic, but rather needs to designed according to the specific requirements of the relevant species in order to be truly effective [43]. Furthermore, the management policy established in these guidelines may likewise need to be adapted to the specific requirements of the relevant species. Chiroptera (bats) represent a particularly significant example of how planning choices and management policy can result in the needs of specific species or taxa emerging clearly. Bats are a significant taxonomic group, represented in Italy by at least 35 species, 20 of which are present in Trentino [29]. They are animals that have a particular preference for watercourses and that benefit significantly from the presence of continuous and structured riparian bands and wetland areas linked to environments around rivers [25]:

- Aquatic environments represent a rich hunting ground for bats, thanks also to the large numbers of insects flying over the surface, and the highest level of hunting can be recorded precisely in wetland environments with non-fragmentary and well-structured riparian vegetation.
- Bats orient themselves at night thanks to an ultrasound system. However, this system only has a range of a few metres, which is why they cannot orient themselves in open spaces. During movement between their shelters and hunting areas and between summer refuges and wintering quarters, which can be several dozen and several hundred kilometres away respectively, the presence of hedges, rows of trees, the edges of woods, ditches, watercourses and riparian vegetation is therefore essential.

When watercourses cross open areas, such as pastures and cultivated land, the presence of riparian vegetation becomes even more crucial. In this situation it is enough to ensure the permanence of a narrow belt, so long as this is continuous and well-structured, complete with scrubland and arboreal layers. The continuity of this must also be ensured during management works, for example by working on alternating banks, as work to cut down vegetation taking place along lengthy stretches close to shelters can also lead to these refuges being abandoned, even in the case of selective work if this involves extensive removal. The large grassland areas characterising the floodplain of the River Adige above Trento up to the border of the province and the provincial nature reserve at the mouth of the Avisio also play a particularly important role. These are important stopping off sites for migrating fauna and can sometimes also become nesting sites [7].

2.3 Identification of management requirements

2.3.1 Identification of types of watercourse stretches

The analysis carried out in section has essentially led to the identification of seven different types of watercourse in the context of the province and in terms of the interaction between vegetation and hydromorphological dynamics:

M – Mountain streams with a very steep slope (> 8%) , characterised by a narrow riverbed in proportion to the height of vegetation on the banks and a high level of confinement within the valley; the small size and high level of confinement mean that they usually flow within forest stands, with narrow border strips of riparian vegetation, when present. The high slope means that they may be subject to the sparking off and transit of debris and hyperconcentrated flows, with the knocking down and transport of large quantities of wood and sediment downstream.

Ss – Small streams on the valley floor with a steep (< 8% e >4%) or moderate (<4% e >2%) slope characterised by a narrow riverbed in proportion to the height of vegetation on the banks, a high level of confinement within the valley and large-grained sediment of colluvial or glacial origin; the small size and high level of confinement mean that they usually flow within forest stands, with narrow border strips of riparian vegetation, when this is present.

AF– Mountain streams on alluvial fans created by the M and Ss types when they flow into the main valleys, characterised by a riverbed of from small to medium size in proportion to the height of vegetation on the banks. Even when there is no confinement the riverbed has low temporal variability. It may vary during intense events with debris and hyperconcentrated flows, also leading to sudden changes in the course of the riverbed.

T – Streams on the valley floor with a steep (< 8% e >4%) or moderate (<4% e >2%) slope , characterised by a riverbed of from medium to large size in proportion to the height of vegetation on the banks, a high level of confinement by valley slopes, scree and the alluvial fans of merging basins, but with the presence of a significant floodplain. Given the low mobility of the riverbed and the high permeability of the soil, one can frequently observe the entry of typical forest vegetation within the belts along the watercourse.

R - Semi-confined and unconfined alluvial watercourses with a riverbed that can be of medium to large size in proportion to the height of vegetation on the banks, characterised by a high level of course variability, conditioning the development of plant associations on the floodplain.

Rc – Confined alluvial watercourses , enclosed by terraces or rocky gorges, with a riverbed that can be of medium to large size in proportion to the height of vegetation on the banks. The low mobility of the riverbed and the steepness of the slopes confining the riverbed mean that the band of riparian vegetation interacting with the flows is extremely limited and that the entry of typically forest vegetation is possible.

D – Minor drainage channels on the alluvial plain , unconfined, which may also drain part of the slopes but in any case have low energy and a narrow riverbed in proportion to the height of vegetation on the banks. They may possibly flow on the floodplain of a larger watercourse. The low energy and vegetation on the banks mean that the mobility of the course is very low and therefore not capable of conditioning plant succession.
Stretches of semi-confined or unconfined alluvial watercourses, which typically develop on the floors of the main valleys, can also be encountered in the mountain environment, for example in valleys where glacial erosion has reduced the slope to modest levels (Fig. **??**).

Figure 2.25: The Travignolo in the Val Veneggia is clearly a watercourse of an alluvial nature, although it is close to the spring and when proceeding downhill subsequently acquires torrential characteristics until it meets the Avisio at Predazzo (*Ph.* Autonomous Province of Trento's Provincial Environmental Protection Agency).

Likewise, torrential watercourses, confined and with a steep slope, can also be found outside narrower valleys, for example when they carve out channels through sediment of various origin.

Figure 2.26: The Rio Carera and the Dal and Duina streams have the characteristics of confined torrential watercourses for long stretches, having carved out a furrow through the sediment of the Bleggio area.

In the context of alluvial watercourses, the interaction between the hydromorphological and vegetation dynamics of different types of riverbed (meandering, wandering, braided) does not change significantly in management terms. For this reason they have been grouped together under type R. Alluvial watercourses on the valley floor can create alluvial fans where the side valleys enter the main valley, as in the case of the Noce, the Avisio and the Fersina in the final stretch until it flows into the Adige Valley. The hydromorphological dynamics of these fans do not differ greatly from those of stretches further upstream, so in contrast with mountain streams, it was not considered necessary to identify a specific type.
There is also a network of minor drainage channels on the valley floor. Sometimes they may involve parts of the drainage basin extending to the slopes of the valley. In this case any stretches on the slopes should be attributed to the mountain streams category and those on alluvial fans to the relevant type. Only stretches below the alluvial fan should be considered as minor drainage channels, as they effectively have very different characteristics as compared to stretches further upstream.

(a) Stretch on the slopes of Monte Stivo with clear mountain stream characteristics

(b) Extensive stretch running through the agricultural area of Prato Saiano with a gentle slope, low sediment transport and helophytes in the channel, clearly attributable to the valley floor drainage channel category, although part of the basin extends up the slopes of the valley

Figure 2.27: Rio Salone at Arco (*Ph.* Autonomous Province of Trento's Provincial Environmental Protection Agency).

e include only naturally flowing watercourses in the minor drainage channel category, and not the network of artificial ditches, which has specific and unique characteristics and requirements. There is a consolidated work programme for this network, aiming to combine the reduction of risk with ecological functions and the reinforcement of ecosystem services (CIRF, 2011). The types of watercourse established in order to determine vegetation management methods in the province of Trento have also been identified by comparing notes with three more general classification systems:

- The Morphological Quality Index (MQI) [32], which is applied by assigning each stretch of the watercourse to be assessed to one of three basic categories, characterised by different hydromorphological dynamics, also in relation to the interaction with the vegetation, requiring differentiated assessment criteria;

- The relative Fluvial Functioning Index (FFI) [11], widely used in Trentino to monitor watercourses, which provides for identification of the “fluvial category” of each stretch monitored, on the basis of ecosystem, altimetric and morphological parameters;
- The Rosgen classification system (1994), which subdivides watercourses into seven main types on the basis of the morphology of the riverbed, with further detailed subdivision depending on the composition and granulometry of the riverbed sediment. It is a widely used and recognised system.

The MQI divides watercourses into two broad categories: on the one hand confined watercourses and on the other semi-confined and unconfined watercourses. Differentiated evaluation sheets are introduced for these two broad categories, given that confinement changes the way the watercourse interacts with the surrounding area, in terms of the methods of erosion/depositing of sediment and the acquisition of large items of deadwood. On this basis, the MQI assesses streams (M, Ss, S) and confined alluvial watercourses (Rc). in the same way. For the purposes of these guidelines it is instead important to adopt a more detailed subdivision, in order to take into due account the different types of risk, the local context and the ability to retain large wood, all decisive factors in terms of management. Depending on the conditions, watercourses on alluvial fans may be confined or unconfined [32].
In the case of semi-confined and unconfined watercourses, the MQI adopts different indices to assess the interaction between the riverbed and the surrounding area (the presence of erodible bands, the possibility of acquiring large wood), depending on whether the riverbed has a single channel or is made of braided or wandering channels. This is due to the fact the second group of watercourses have very wide riverbeds in relation to the width of the associated belt of land. The question is not fundamental for the purposes of management and was not therefore taken into consideration in our classification.
The subdivision introduced here can be considered a refinement of the categories identified by the relative FFI. Of the categories introduced by the FFI the following do not appear: “watercourses of the plains”, because this refers to lowland plain areas, continuing into the Veneto and Po plains in the case of Trentino watercourses and “mountain watercourses above the tree line”, because they are clearly not relevant for the purpose of these guidelines.
The subdivision of watercourses into different types proposed in these guidelines has drawn extensively on the Rosgen classification, with some modifications. Type M corresponds exactly with Rosgen’s Aa+ , both referring to debris flow transportation capacity: due precisely to this characteristic, the slope threshold was reduced from 10% to 8%, as recognised by more specific literature on this theme [38].

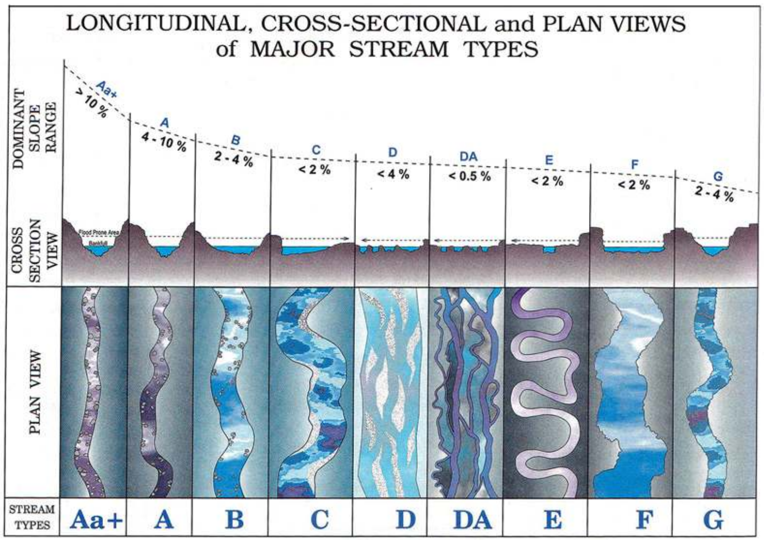


Figure 2.28: Definition of main watercourse types according to Rosgen [33], on the basis of plan view, cross-section and slope.

As in the case of the FFI categories, some types contemplated by Rosgen are not present in Trentino, such as anastomised watercourses (DA) for example.

The types of watercourse presented and described above refer to an essentially unmodified state, free of anthropogenic pressure. As seen in section , there has been substantial transformation of watercourses, the adjoining areas and the underlying river basins. The transformations made by man in the case of the different types of M, AF, Ss and S streams identified are closely linked to the environments through which they flow: forest, agricultural or inhabited areas.

In the forest environment the riverbed is mainly natural, with possible stabilisation using dams along steeper slopes and essential continuity between the riverbed and the slopes. Streams surrounded by a relatively wide band of forest vegetation, even when they flow through a mainly agricultural area, also have these characteristics.

Due to the limited frequency with which the river sediment and surrounding belts are subject to modification, it is commonly noted that types M, AF and Ss develop within forest stands, with only a sporadic presence of riparian vegetation.

(a) Rio Ribor in the Val Daone, a tributary on the right-hand bank of the Chiese, runs through beech forest

(b) Rio Val Moena, a tributary on the left-hand bank of the Avisio, runs through spruce forest

Figure 2.29: Examples of mountain streams with very steep slopes - M (*Ph.* Autonomous Province of Trento's Provincial Environmental Protection Agency).

In contrast, in the case of type S, the greater width of the riverbed and a significant presence of fine, potentially mobile sediment encourages the presence of riparian formations, which develop between the riverbed and the forest stands behind them. Although the watercourse is confined, a floodplain is present on a regular basis, and it is therefore possible to identify an adjoining area linked to the hydromorphological action of the stream. Due to the limited frequency with which the adjoining area is subject to modification by flooding, one can commonly note the spontaneous entry of vegetation typical of the surrounding forest stands (see Fig. 9 on page 13). These natural dynamics are often accentuated by the cutting down of vegetation according to forestry criteria, which tends to leave species considered to be valuable, such as the maple and the spruce, at the expense of typically riparian vegetation (see Fig. 2.30).

(a) Stretch of the Sarca in the Val Rendena where only maple trees have been left on the banks

(b) Stretch of the Avisio in the Val di Fassa, where all spruce and larch shoots and other trees have been left intact on the banks

Figure 2.30: Examples of the management of bank vegetation clearly showing the adoption of a forestry approach (*Ph.* Giuliano Trentini).

Due to this entry of forest vegetation the adjoining belt is not always immediately and unequivocally recognisable from the type of vegetation developing there, but should rather be delimited on a geomorphological basis.

Close to roads the vegetation may be interrupted as a result of intensive cutting down linked to the maintenance of erosion defence works or to the need to keep the riverbed "clean" and visible along stretches which are exploited, particularly close to inhabited areas.

(a) Depositing of alluvial sediment in a spruce wood

(b) Banks like this are a clear sign of a lack of morphological continuity and delimitation of the adjoining belt

(c) The presence of secondary channels is a very clear indicator; in this case however, the evaluation should also include the whole plain behind, stretching up to the foot of the slope, given its limited height above the riverbed and flatness, which suggests it is of alluvial origin

(d) Even anthropogenic elements such as a road can define the limit of the adjoining belt

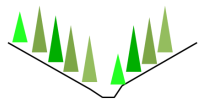
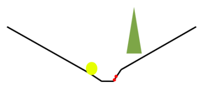
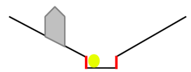
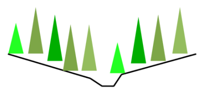
Figure 2.31: Examples of adjoining belts along streams on the valley floor - S (*Ph.* Giuliano Trentini).

In cultivated areas or pastureland the shading of the riverbed by the woods creates more favourable conditions for the establishment of riparian vegetation, even if not continuous. The absence, scarcity or low quality of riparian belts is often due to direct intervention by farmers, who see this vegetation as disturbing their crops or meadows, rather than to works designed to control hydrological risk. Even in the agricultural environment it is possible to find banks stabilised with walls in reinforced concrete, preventing the establishment of vegetation.
When crossing towns and villages, streams are sometimes channelled using walls in reinforced concrete or concrete ripraps. Although crossing areas with urban development, the dwellings and infrastructures do not necessarily reach right down to the riverbed; sometimes the streams flow through narrow strips of grassland or cultivated land without constructions.
The transformations undergone by alluvial semi-confined and unconfined watercourses are less closely linked to the environments through which they flow than the mountain streams discussed previously. This is firstly because the fundamental risk associated with these watercourses is flooding, which can expand to reach vulnerable elements at a considerable distance in flat areas. Secondly, these watercourses are also affected by the impact of hydromorphological changes taking place in the basin upstream. All alluvial watercourses, independently of the degree of confinement, may have experienced a phase of entrenchment in previous decades due to the joint effects of channelling and straightening of the riverbed, the removal of aggregates, the construction of artificial lakes upstream and the extension of forest coverage in the basin.

The first basic subdivision of alluvial semi-confined and unconfined watercourses is into contained and non-contained stretches. In non-contained stretches it is possible to find three fundamental levels of transformation, resulting from growing anthropogenic pressure on the floodplain:

- Stretches which have retained a relatively wide river corridor, within which the riverbed is free to wander, following the natural dynamics of formation and destruction of the floodplain. The external limit of the river corridor is marked by natural physical limits, such as the sides of a valley or terrace, or by anthropogenic elements, such as road embankments or bank defences. In some cases the bank defences rise up above ground level, taking on the characteristics of a raised bank.
- Entrenched stretches in which the riverbed delimited by bank defences is sufficiently wide to allow the presence of strips of floodplain or islands within it, on which bush or arboreal vegetation develops. However active the underlying dynamics are, creating bars of sediment and the alternation of pools and riffles in the riverbed at times of low water, the course is generally relatively stable over time, so the strips of floodplain and islands that exist tend to be maintained in the same position.
- Stretches in which the riverbed delimited by the bank defences includes only the active channel, due to the major contraction of the riverbed imposed by man.

In the second and third cases the banks may have different degrees of naturalness or artificiality, from banks in natural earth, to ripraps with loose boulders and sub-vertical banks with walls in n reinforced concrete or concrete ripraps. In the case of contained stretches, the fundamental distinction is the presence or absence of a floodplain between the riverbed and the raised banks.
The following table provides an overview of the various classes of watercourse identified and the types of stretches originating from these as a result of anthropogenic transformation, with the assistance of cross-sections of the types.

Type of watercourse				Type of stretch
Name	Classification			
	Confinement according to the MQI	Category according to the relative FFI	Rosgen	
M – MOUNTAIN STREAMS WITH A VERY STEEP SLOPE (>8%) Characterised by a narrow riverbed in proportion to the height of vegetation on the banks and a high level of confinement within the valley; the small size and high level of confinement mean that they usually flow within forest stands, with narrow border strips of riparian vegetation, when present. The high slope means that they may be subject to the sparking off and transit of debris and hyperconcentrated flows, with the knocking down and transport of large quantities of timber and sediment downstream.	C	Mountain watercourses below the tree line	Aa+	 M0 – Nearly natural conditions: continuous belts of riparian vegetation are not present, but the forest formations develop right up to the riverbed; possible management with dams and the occasional presence of defence works, mainly permeable  M1 – Deforestation of the banks and surrounding areas, often accompanied by simplification of bank habitats, for example due to grazing in the surrounding areas; possible management with dams and the occasional presence of defence works, mainly permeable  M2 – Riverbed channelled between mainly subvertical and impermeable banks. External areas are cultivated or with urban development
Ss – SMALL STREAMS ON THE VALLEY FLOOR with a steep (< 8% e >4%) or moderate (<4% e >2%) slope Characterised by a narrow riverbed in proportion to the height of vegetation on the banks, a high level of confinement within the valley or large-grained sediment of colluvial or glacial origin; the small size and high level of confinement mean that they usually flow within forest stands, with narrow border strips of riparian vegetation, when present.	C	Valley floor watercourses	A-B	 Ss0 – Nearly natural conditions: continuous belts of riparian vegetation are not present, but the forest formations develop right up to the riverbed; possible management with dams and the occasional presence of defence works, mainly permeable

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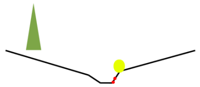
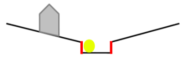
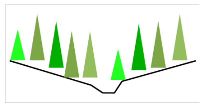
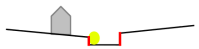
Name	Type of watercourse – Classification: Confinement according to the MQI	Type of watercourse – Classification: Category according to the relative FFI	Type of watercourse – Classification: Rosgen	Type of stretch	
					Ss1 – Deforestation of the banks and surrounding areas, often accompanied by simplification of bank habitats, for example due to grazing in the surrounding areas; possible management with dams and the occasional presence of defence works, mainly permeable
					Ss2 – Riverbed channelled between mainly subvertical and impermeable banks. External areas are cultivated or with urban development
AF– MOUNTAIN STREAMS ON ALLUVIAL FANS Created by the M and Ss types when they flow into the main valleys, characterised by a riverbed of from small to medium size in proportion to the height of vegetation on the banks. Even when there is no confinement the riverbed has low temporal variability. It may vary during intense events with debris and hyperconcentrated flows, possibly leading to sudden changes in the course of the riverbed.	C-NC	Valley floor watercourses	A-Aa+		AF0 – Nearly natural conditions: continuous belts of riparian vegetation are not present, but the forest formations develop right up to the riverbed; possible management with dams and the occasional presence of defence works, mainly permeable
					AF1 – Deforestation of the banks and surrounding areas, often accompanied by simplification of bank habitats, for example due to cultivation of the surrounding areas; possible management with dams and the occasional presence of defence works, mainly permeable
					AF2 – Riverbed channelled between mainly subvertical and impermeable banks. External areas are cultivated or with urban development

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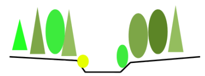
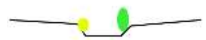
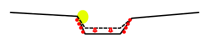
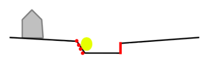
TYPE OF WATERCOURSE				TYPE OF STRETCH	
NAME	CLASSIFICATION				
	Confinement according to the MQI	Category according to the relative FFI	Rosgen		
					AF3 – Gutter in riprap or reinforced concrete
S – STREAMS ON THE VALLEY FLOOR with a steep (<8% and >4%) or moderate (<4% and >2%) slope Characterised by a riverbed of from medium to large size in proportion to the height of vegetation on the banks, a high level of confinement by valley slopes, scree and the alluvial fans of merging basins, but with the presence of a significant floodplain. Given the low mobility of the riverbed and the high permeability of the soil, one can frequently observe the entry of typical forest vegetation within the bands along the watercourse.	C	Valley floor watercourses	B		S0 – Nearly natural conditions, with the presence of a significant floodplain; frequent entry of forest species in the adjoining belt; possible management with dams and the occasional presence of defence works, mainly permeable
					S1 – Deforestation of the banks and surrounding areas, often accompanied by simplification of bank habitats, for example due to cultivation of the surrounding areas; possible management with dams and the occasional presence of defence works, mainly permeable
					S2 – As for S1, but with entrenchment of the riverbed, usually accompanied by steeper banks and greater presence of bank defence works, mainly permeable
					S3 – Riverbed channelled between mainly subvertical and impermeable banks, external areas used for cultivation or urban development

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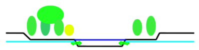
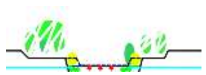
Type of watercourse				Type of stretch	
Name	Classification				
	Confinement according to the MQI	Category according to the relative FFI	Rosgen		
F – SEMI-CONFINED AND UNCONFINED ALLUVIAL WATERCOURSES With a riverbed that can be of medium to large size in proportion to the height of vegetation on the banks, characterised by a high level of course variability, conditioning the development of plant associations on the floodplain.	SC – NC with braided or wandering channels SC – NC of another type	Watercourses in the foothills	B		F0 – Nearly natural conditions, with the presence of a wooded floodplain within which the riverbed is free to wander. The extent of the floodplain may also be reduced by human use
					F1 – Presence of a floodplain within which the riverbed is free to wander. The terrain in the floodplain is mostly not wooded due to the conditions of the site or grazing or cultivation practices. The extent of the floodplain may also be reduced by human use
					F2 – The riverbed is free to wander within the confines of recent terrace, with formation of a new floodplain at lower level. The riparian wood formations on the terrace are subject to various transformations due to the hydromorphological disconnection of the riverbed
					F3 – The riverbed is free to wander within the confines of recent terrace, with formation of a new floodplain at lower level. The recent terrace is mainly destined for human activities, usually agriculture or grazing

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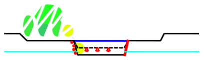
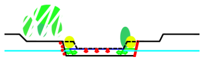
Type of watercourse				Type of stretch	
Name	Classification				
	Confinement according to the MQI	Category according to the relative FFI	Rosgen		
					F4 – Entrenched riverbed, usually with steep banks stabilised using both permeable and impermeable techniques. The original floodplain (now a terrace) is mainly destined for various anthropogenic activities. The remaining nuclei of riparian woods are subject to various transformations due to the hydromorphological disconnection of the riverbed
					F5 – Entrenched riverbed, usually with steep banks stabilised using both permeable and impermeable techniques, with a width permitting the presence of strips of new floodplain. The original floodplain (now a terrace) is mainly destined for various anthropogenic activities. The remaining nuclei of riparian woods are subject to various transformations due to the hydromorphological disconnection of the riverbed

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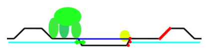
Name	**Type of watercourse**			**Type of stretch**
	Classification			
	Confinement according to the MQI	Category according to the relative FFI	Rosgen	
				 F6 – Riverbed with raised banks in direct contact with the water channel, at most with a verge that can be used for maintenance, the foot of the bank and the internal surfaces of the raised structures frequently being protected against erosion using various more or less artificial systems. At all events, the riverbeds are more or less entrenched depending on channelling
				 F7 – Riverbed with banks at a significant distance from the channel and strips of floodplain enclosed within them. It is expected that the banks of the entrenched riverbed will be protected against erosion, but there may be cases in which they are not. Floodplains are cultivated or limited to grassland, with possible residual wooded areas, which may or may not be subject to wandering of the riverbed

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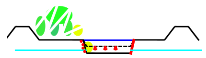
Type of watercourse				Type of stretch
Name	Classification			
	Confinement according to the MQI	Category according to the relative FFI	Rosgen	
				 F8 – Riverbed with banks and floodplain. The riverbed is mostly entrenched, with resulting steepening of the banks, frequently protected against erosion. The original floodplain (now a terrace) is mainly represented by grassland. The remaining nuclei of riparian woods are subject to various transformations due to the hydromorphological disconnection of the riverbed
Fc – CONFINED ALLUVIAL WATERCOURSES Enclosed by terraces or rocky gorges, with a riverbed that can be of medium to large size in proportion to the height of vegetation on the banks. The low mobility of the riverbed and the steepness of the slopes confining the riverbed mean that the band of riparian vegetation interacting with the flows is extremely limited and that the entry of typically forest vegetation is possible	C	Watercourses in the foothills	B-C-D	Fc0 – Nearly natural conditions, with the presence of a wooded floodplain, albeit of limited extent. There may be direct contact between the riverbed and the forest stands on the slopes Fc1 – Entrenched riverbed, with the original parts of the floodplain becoming a recent terrace. Riverbed free to wander, with the formation of a new floodplain at lower level. Possible management with weirs

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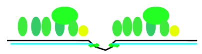
Type of watercourse				Type of stretch	
Name	Classification				
	Confinement according to the MQI	Category according to the relative FFI	Rosgen		
D - MINOR DRAINAGE CHANNELS ON THE ALLUVIAL PLAIN Unconfined, which may also drain part of the slopes but in any case have low energy and a narrow riverbed in proportion to the height of vegetation on the banks. They may possibly flow in the floodplain of a larger watercourse. The low energy and vegetation on the banks mean that mobility of the course is very low and therefore not capable of conditioning plant succession.	NC	Watercourses in the foothills	E		D0 – Nearly natural conditions, with the riverbed free to wander within a wooded area. Low dynamism of the channel; the surface over which they flow may not be their own floodplain but that of the main watercourse on the valley floor, or a terrace
					D1 – Deforestation of the banks and surrounding areas, often accompanied by simplification of bank habitats, for example due to cultivation of the surrounding areas; possible management with dams and the occasional presence of defence works, mainly permeable. The lack of shade favours the development of hydrophyte and helophyte vegetation in the riverbed.
					D2 – Riverbed channelled between mainly subvertical and impermeable banks, with external areas used for cultivation or urban development . The lack of shade favours the development of hydrophyte and helophyte vegetation in the riverbed

Table 2.3: IIdentification and description of the types of watercourses identified within the province in terms of the interaction between vegetation and hydromorphological dynamics, and related types of stretches resulting from anthropogenic transformation.

2.3.2 3.2 Identification of management categories for streams

Problems relating to hydrological and environmental risk in relation to the different types of streams are discussed in an systematic and comparative manner below, focussing particularly on the role played by vegetation and vegetation dynamics. This analysis has led to the grouping of these types of stretch into uniform categories in terms of management requirements.
Type M and Ss streams mostly flow through natural and wooded environments (M0, Ss0), or occasionally through cultivated areas or pastureland (M1, Ss1), while even more rarely there may be direct interference with infrastructures or inhabited areas justifying channelling of the riverbed (M2, Ss2). Work to "manage" streams using dams and riprap bank defences may also be present along type M0, Ss0, M1 and Ss1 stretches.
Given that historically settlements have preferably developed on alluvial fans, type AF0 stretches are rare, whereas types AF1 and AF2 are much more frequent. In relatively frequent cases the need to protect settlements and the infrastructure system has led to the development of artificial riverbeds following major works, and these watercourses are described as type AF3.

(a) The Larganza stream at Roncegno, the breadth and specific hydrological regime allowing the growth of dense vegetation, type AF2

(b) Gutter along the Rio Val Averta in the Val di Fiemme, type AF3

Figure 2.32: Examples of mountain streams on alluvial fans - AF (*Ph.* Giuliano Trentini).

For types M0, M1, Ss0, Ss1, AF0 and AF1 the high level of natural roughness of the material in the channel and the low local risk associated with flooding (which should definitely be preserved) mean that the roughness created by the vegetation on the banks is not significant. In contrast, the marked regularity of the section and the small grain size of the riverbed sediment along stretches of types M2, Ss2 and AF2, caused by the construction of dams, makes an increase in roughness by the vegetation more significant.
The lack of shade from forest formations along stretches of types M1, M2, Ss1, Ss2, AF1 and AF2 creates favourable conditions for the development of dense vegetation on the banks. When the sections have been reconstructed in order to contain flows with high return times, the hydrological regime is a fundamental factor in determining the development of the vegetation in the riverbed. If the flow is high in times of low water, with large parts of the riverbed under water, and there are frequent episodes of flooding capable of affecting the bed sediment of the whole section, there is little spontaneous development of ligneous vegetation. On the other hand, watercourses with very wide riverbeds, only partly under water during the summer and with rare episodes of very intense flooding, favour the establishment of extensive and dense bush and tree formations, with consequential management problems.
In an urban environment with types M2, Ss2, AF2 and S2, local authorities sometimes raise questions related to landscape or "attractiveness" and urge the adoption of forms of management that may be in conflict with objectives related to ecological functions (cutting down of all vegetation, maintaining only grassland areas) and security (preference for maintaining tall trees, giving the idea

of a town park, rather than scrubland vegetation, which may give some people the idea of abandonment and untidiness).

Figure 2.33: The Larganza stream at Roncegno, subject to riverbed improvement works between the embankment walls, ensuring the formation of a low water channel and accompanying riparian vegetation along it (which needs to grow further). Considering that the spontaneous situation would be similar to Fig. 2.32(a), this approach would appear to be a good compromise between different needs (*Ph.* Giuliano Trentini).

The absence of local risks and the substantial continuity of forest stands, also across the riverbed, means that for stretches of types M0, Ss0 and AF0 it is not worthwhile or appropriate to adopt a hydrological-environmental approach to the management of vegetation. In these cases forest coverage is instead more appropriately managed according to the principle of "protection forest", in line with the provisions of the provincial law on forests and nature protection (L.P. 11/2007). The tendency for the establishment of forest species is a critical factor in terms of risk along streams on the valley floor in the S0 forest environment, but also in the agricultural S1 environment, where remnants of riparian formations occasionally persist, as during exceptional episodes of flooding the trees may be knocked down and carried along by the current. This is potentially dangerous for inhabited areas further downstream, above all in the case of long spruce and larch trunks. Streams are characterised by a high interchange between riverbed and aquifer flows. As a result, stretches flowing in an agricultural environment, usually types M1, Ss1, AF1 and S1, are a critical part of the hydrographic network, due to the entry of nutrients and contaminants into the system. Thus the continuity and abundance of the bank vegetation belt should be preserved and restored as a priority. On the basis of these considerations, the 14 types of stream stretches can be brought together in just 5 management categories, as illustrated in Fig. 35. While different, the stretches gathered together within the same category have similar problems, which can be dealt with using the same management approach. Given their specific nature, gutters on alluvial fans (type AF3) have not been included in any of the management categories in these guidelines, not because these works do not require any intervention in terms of vegetation, but rather because this intervention is aimed at maintaining the works and eradicating vegetation, to avoid root systems interrupting them.

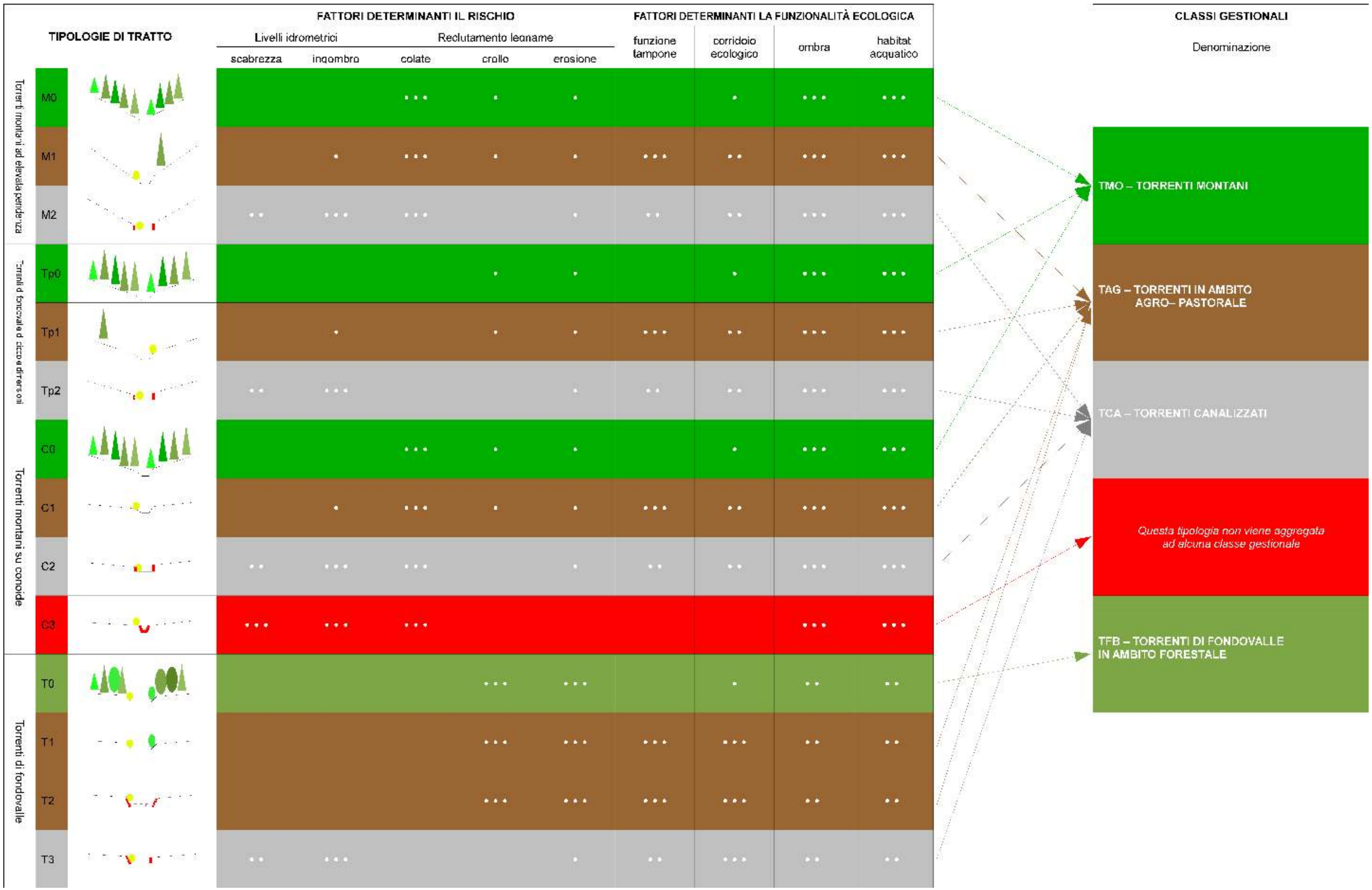


Figure 2.34: Identification of management categories related to streams.

2.3.3 3.3 Identification of management categories for alluvial watercourses

Problems relating to hydrological and environmental risk in relation to the different types of alluvial watercourse stretches are discussed in a systematic and comparative manner below, focussing particularly on the role played by vegetation and vegetation dynamics. This analysis has led to the grouping of these types of stretch into uniform categories in terms of management requirements.
The fundamental risk associated with alluvial watercourses R, Rc and D is flooding, which can be translated into a significant risk only for watercourses R and D. In confined stretches it is advisable to maintain a high flooding capacity, in order to contribute to flood lamination. The presence of bridges with closely planted pillars in the riverbed is a factor increasing risk, leading to situations that are made more serious by the floating of large wood, mainly coming from mountain stretches, but which may also originate in stretches along the valley.
Type R0 and Rc0 stretches represent those of greatest value in terms of conservation, where there is the greatest presence or potential for habitat `91E0` (in any case limited by the reduced width of the river corridor and the hydromorphological changes taking place in the underlying river basin). Most of these stretches, but not all, are included within provincial or local nature reserves and some have been identified as SCIs and SPAs. Stretches R2 and Rc1 are also of high value in terms of conservation, because although the surface areas subject to erosion by the wandering of the river cannot be considered as a floodplain but rather as a recent terrace, with consequential degrading of priority habitat `91E0`, following spontaneous evolution a floodplain will nevertheless be formed. R1 and R3 stretches in Trentino can be found in upper, unconfined parts of the hydrographic network (see Fig. 25 on page 33), flowing in surface areas with pastureland.
From a management point of view, types R0, R1, R2, R3, Rc0, Rc1 and D0 have similar problems. The local risk of flooding is clearly very low or non-existent, an essential premise which has allowed the conservation of these areas, while their high environmental value must be the fundamental consideration governing their management. It is necessary to bear in mind the potential increase in risk for areas further downstream that may result from the introduction of large wood into the channel following erosion of wooded surface areas. In the case of confined stretches, difficulty in gaining access may sometimes make direct management works inconvenient or not feasible. As an alternative, structural works may be adopted, such as construction of selective dams trapping trunks at the outlets of confined stretches of streams.
Types R4 and R5 are normally associated with high risk, as they have to convey large flows within restricted channels, usually with limited or inexistent safety barriers. When the neighbouring areas have undergone urban development there is thus potentially a very high risk. The influence of bank vegetation on runoff capacity is closely related to the breadth of the channel, so in broad channels (width ratio > 10) it can certainly be said that the roughness of the banks, and hence the type of vegetation present on them, is of practically no influence, whereas in very narrow sections the obstruction created by foliage in the runoff section may also be associated with the significant role of the roughness of the banks.
In R4 stretches, the riverbed delimited by the bank defences allows only the presence of the channel and eventual bars of sediment. With an essentially unaltered hydrological regime this is spontaneously translated into a limited presence of vegetation in the riverbed, given that the vegetation is largely in the water even at low water and the emerging bars of sediment are continuously shaken up by ordinary episodes of flooding. In general, the highly artificial nature of the slopes means that vegetation does not develop on these, except sporadically. However, there are situations with less artificial banks and the presence of narrow belts of vegetation. In the event of significant modifications to the hydrological regime, with a reduction in low water flow and the frequency of formative flood events (namely with a significant part of the underlying basin concerned by withdrawal works without release and dams), ligneous vegetation tends to colonise large parts of the riverbed (see section), increasing the management burden in order to combat this tendency.
The presence of vegetation on the strips of floodplain typical of R5 stretches requires further management attention. However, these stretches must be dealt with bearing in mind that if strips of floodplain have been able to develop spontaneously, this is because in these sections of the channel the speed of the current is considerably slower as compared to other areas, so with less hydrodynamic

stress and a lower contribution to the runoff capacity of high water flows. The decisive factor in determining risk is therefore the possibility that the active riverbed has, or lacks, to wander across the plain, with resulting demolition of parts of the floodplain and the introduction of large wood into the channel, which can increase risk in stretches further downstream. On the other hand, the strips of floodplain alongside R5 stretches, when they cover a certain area, are of high environmental value, often recognised and protected by assigning them with the status of a local nature reserve. These are not generally subject to extensive erosion, given that the riverbed is usually restricted upstream and downstream, limiting the opportunities for wandering over the plain. R5 stretches also have similar problems to those already described for R4 in the event of major hydromorphological changes. As regards contained stretches R6, R7 and R8, it should be borne in mind that to minimise construction costs and land occupation, at the time the sections were designed with minimum levels of roughness, namely with an almost total absence of arboreal and bush vegetation and with all the dry surface areas maintained as grasslands. This situation, even with a revised attitude and awareness involving recognition of the fundamental role of riparian vegetation, does not leave space for its reintroduction on a large scale. Raised banks have specific problems linked to the need to guarantee their functioning over time. This means ensuring that they are geotechnically stable (in short that they are not subject to collapse and landslides), watertight (namely that at high water levels the water cannot filter through them, which could lead to the collapse of the embankment, with a resulting sudden outflow of water towards the surrounding areas) and that the performance of the works can be monitored continuously and with ease. This combination of needs inevitably makes it impossible to maintain significant arboreal and bush vegetation on the slopes of raised banks, either on the side of the river or on the other side. This is because the root system of the plants interrupts the uniformity of the terrain in depth, creating ideal infiltration routes, above all when plants die and rot. The coverage created by the foliage makes inspection more difficult and can encourage animals to settle there, digging underground burrows. While in general the root systems of plants have a stabilising effect in terms of possible collapse and landslides of the embankments, when a tree falls over, this can lead to the detachment of whole clods of earth from the raised bank, thus sparking off phenomena that could lead to the collapse of the raised bank. Although the situation described may be unlikely, the associated risk is so high that it absolutely must be prevented.

Minor drainage channels are represented by watercourses on a very slight gradient, with small, compact channels. The trunks and more rarely the foliage of vegetation growing on their banks interact with the current. The low energy of these watercourses usually means that the root systems of bank vegetation are adequate for ensuring the stability of the banks. In stretches D1 and D2, the lack of shading for the riverbed can favour the development of dense helophyte vegetation, with considerable problems in terms of the increase in roughness and obstruction of the bed.

On the basis of these considerations, the 14 types of alluvial watercourses can be gathered together in just 6 management categories, as illustrated in Fig. 36. While different, the stretches gathered together within the same category have similar problems, which can be dealt with using the same management approach.

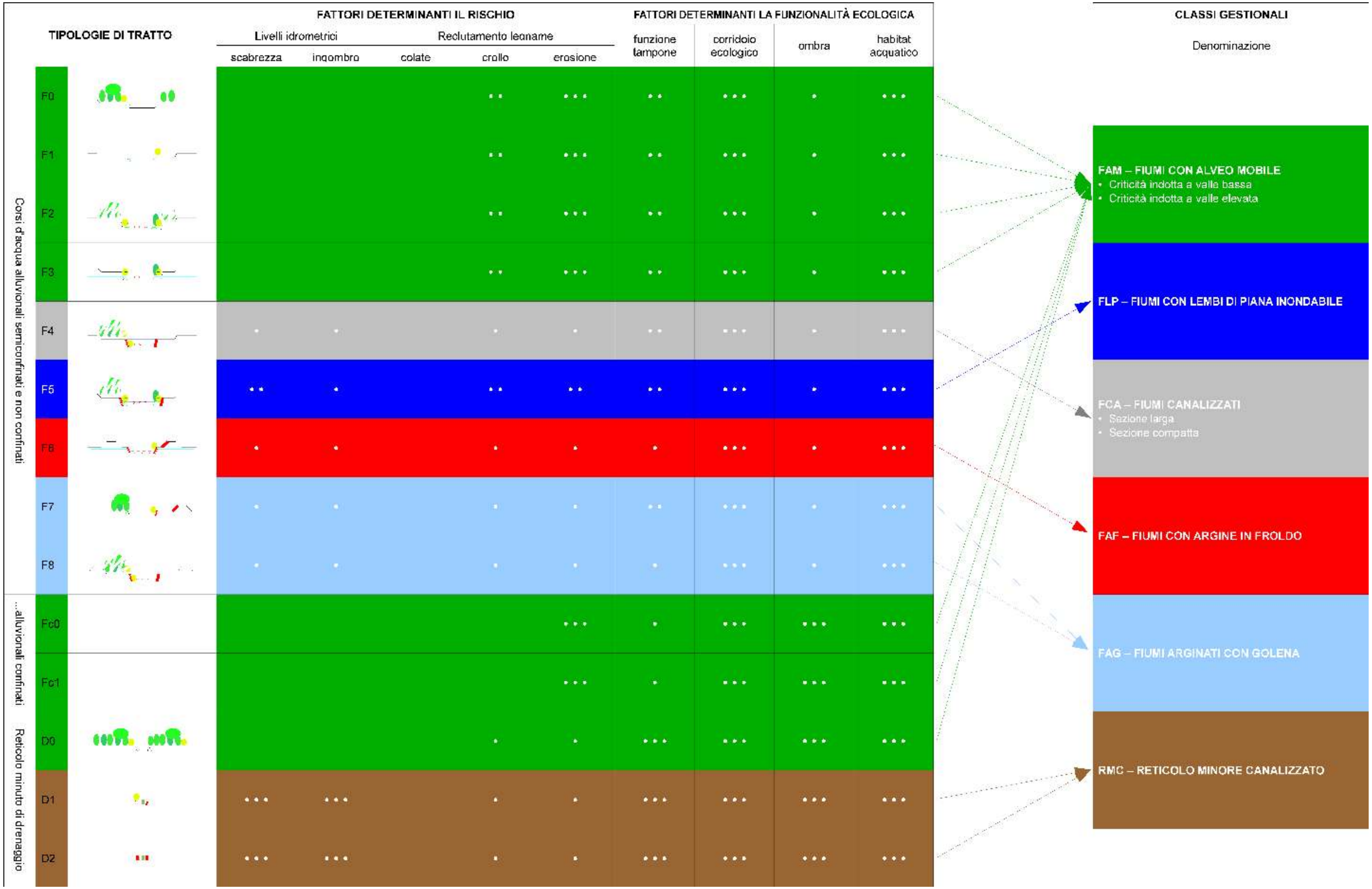


Figure 2.35: Identification of management categories related to alluvial watercourses.

3 Parte II: Guidelines for the management of vegetation along watercourses

3.1 5 General considerations

Ten categories of watercourse stretches have been identified on the basis of the analysis carried out in the first part of this document, each of which is characterised by specific management requirements in terms of vegetation. These categories are:

MOS - Mountain streams : very steep to moderate slope, with a riverbed highly confined by the furrow of the valley and of limited size in relation to the height of the surrounding forest coverage, with no flood plain. There are no continuous belts of riparian vegetation, while the forest stands on the slopes stretch down to the riverbed. Possible presence of stabilisation works such as dams and weirs across the watercourse and less frequent presence of riprap bank defences or embankment walls. Rare streams on alluvial fans in forest environments should be included in this category.

VFS - Streams on the valley floor in forest environments : steep to moderate slope, confined riverbed of medium to large size in proportion to the height of vegetation on the banks, with the presence of a significant flood plain and the possibility of continuous and wide belts of riparian vegetation forming.

AGS - Streams in agricultural environments : very steep to moderate slope, both in side valleys and on alluvial fans and the main valley floors, flowing through cultivated areas or pastureland, with no belt of bank vegetation or a very scattered presence. Frequent presence of stabilisation works such as dams and weirs across the watercourse, above all in the case of alluvial fans and steep lateral valleys, less frequent presence of riprap bank defences or embankment walls. The absence, scarcity and low quality of belts of riparian vegetation can often be linked to direct intervention by farmers, who see this vegetation as disturbing their crops or meadows, rather than to works designed to control hydrological risk.

CHS - Channelled streams : streams in the mountains, on the valley floor or on alluvial fans crossing inhabited areas, with a very steep to moderate slope, highly artificial nature of the riverbed, with embankment walls in reinforced concrete or concrete ripraps and sometimes numerous dams. Although crossing areas with urban development, the dwellings and infrastructures do not necessarily reach right down to the riverbed. Sometimes these streams, although of a very artificial nature, flow through narrow strips of grassland or cultivated land without constructions. The level of artificiality can be very varied, and consequently the vegetation present within the riverbed may also be very varied, going from streams characterised by relatively wide riverbeds with a low gradient and only the banks constructed artificially to very narrow channels on alluvial fans, with a series of dams, but with the bed still made up of loose sediment.

RMB - Rivers with mobile bed : rare stretches of alluvial watercourses, confined and unconfined, along which a relatively wide river corridor has been conserved, within which the riverbed is free to wander, following the natural dynamics of formation and demolition of the floodplain.

RSF - Rivers with strips of floodplain : stretches of alluvial watercourse, around which parts of the floodplain remain, but also stretches in which the channel delimited by the two banks is sufficiently wide to permit the presence of strips of floodplain or islands within it, on which bush or arboreal vegetation develops. In both cases, however active the dynamics of the underlying forms are, creating bars of sediment and the alternation of pools and riffles in the riverbed at times of low water, the course of the riverbed is generally relatively stable over time, with less likelihood of the floodplain being demolished.

CHR - Channelled rivers : stretches of channelled alluvial watercourse, in which the riverbed delimited by the banks only permits the presence of the active channel, completely under water or with sediment bars emerging. The banks are mostly steep and protected from erosion by walls in reinforced concrete or ripraps with loose or cemented rocks, rarely permeable, and there is a lack of continuity in terms of bank vegetation.

RBW - Rivers with banks in direct contact with the water : stretches of alluvial watercourse with raised banks in direct contact with the water, at most with a verge that can be used for maintenance, with the foot of the bank and the internal surfaces of the raised banks frequently being protected against erosion using various more or less impermeable systems. Occasional presence of sparse bush vegetation, of limited size due to repeated cutting down, sometimes also along the embankments of the raised banks.

CRF – Contained rivers with floodplain : stretches of alluvial watercourse with raised banks situated closer or further back in relation to the banks, so with the presence of a floodplain subject to periodic flooding. Only the active channel is present within the channel delimited by the banks. The vegetation cover of the floodplain is very variable, with certain areas being used for haymaking and vegetable growing and others essentially abandoned. These may be subjected to work cutting down riparian vegetation for safety reasons, resulting in the creation of an alternation of surfaces with herbaceous vegetation and others with more or less extensive and structured arboreal and bush vegetation, that sometimes extends to the embankments of the raised banks. The height of the floodplain as compared to the riverbed is such that it does not have the usual hydromorphological characteristics of a floodplain.

MDC - Minor drainage channels : minor drainage channels of the alluvial plain, with a compact and regular cross-section, typically trapezoidal, flowing through cultivated lands and built up areas, with banks in earth, riprap or reinforced concrete walls.

An information sheet has been drawn up for each of these categories of watercourse stretches, describing the main characteristics and the landscape features potentially acquired by the vegetation along the banks or within the adjoining area, in order to arrive at the best possible compromise between the need to improve the ecological state and conservation of habitats and species on the one hand and the reduction of hydrological risk on the other. Each management sheet is structured as follows:

DESCRIPTIVE SECTION AND FRAMEWORK **Description of the main characteristics** , allowing the selection of the most appropriate management sheet for each stretch of watercourse, with the support of photographs of four typical situations distributed throughout the province, if possible representing the different types of stretch included in the category.

- **Description of the most relevant questions** regarding the conservation of habitats and species, with the assistance of cross-sections of types, illustrating Natura 2000 habitats potentially present in natural conditions, the presence of which is still possible given the modified situation in which intervention takes place.
- **Description of problems in terms of hydrological risk** , locally and downstream, and to what extent and through which mechanisms the vegetation can have a positive or negative influence on the level of risk.
- **Evaluation of aspects useful for establishing the planning of management works** , particularly in relation to the frequency of intervention.

OPERATIONAL SECTION , describing the methods of intervention. For some management categories two different types of intervention are presented and hence the section is repeated:

First of all the [management objectives] that it is intended to pursue are specified, providing indications explained in more detail in subsequent sections. With the assistance of cross-sections of types the specific morphological units to which the management directions relate are also described and located.

Management methods are described using a table showing the methods of intervention for different types of vegetation in the morphological units described and located in the previous section.

Other operational indications that cannot be included in the table are presented in a separate section, usually regarding specific problems related to work on site, methods for approaching specific situations or questions regarding the control of invasive alien species.

The sheet concludes with a section providing certain minimum [improvement proposals] particularly significant for the specific management category, designed to increase the functioning of the fluvial ecosystem or the expression of ecosystem services.

3.2 6 Management guidelines

The following pages provide some directions of a general nature to be adopted when carrying out silvicultural work on riparian vegetation. These guidelines are the result of bibliographical research, the technical directions contained in plans and other guidelines and the experience gained in the field.

A) Structural characteristics of riparian vegetation . The works must have the objective of establishing and maintaining diversified formations for each specific component and structure, in relation to the stretch concerned. On the basis of the relevant context, the correct approach will permit the conservation of a riparian formation with a complex structure and wealth of flora, with a comprehensive sequence of natural-like formations. The broader the belt of vegetation, the more this will be complex.

B) Selectiveness of intervention . Differentiated management methods must be established for each morphological unit of the watercourse (bank, floodplain, sediment bars with vegetation etc.). Within each unit, it is necessary to intervene with selective cutting down in line with the specific hydromorphological dynamics and stress, the structure and vigour of existing populations, the risks related to conditions locally and downstream, and the general conservation requirements of the site. Work to cut down vegetation must be planned by considering what needs to be cut down, rather than what needs to be left, preferably with frequent intervention.

C) Intervention guided by monitoring . In the case of less vigorous populations such as those in mountain areas, of high value in natural terms and for fauna, or characterised by difficulties in terms of access, it is preferable to substitute regular works with periodic monitoring, if necessary to be repeated after very intense episodes of flooding, with which to promptly identify and control the individual critical elements requiring management intervention.

D) Discontinuity of stretches involved in intervention . In order to minimise the disturbance to the fluvial ecosystem, it is preferable to intervene: on alternate banks in the case of larger watercourses, in other cases leaving parts of the riverbed undisturbed between two stretches subject to intervention. The length of the stretches in which work takes place must be assessed in proportion to the width of the riverbed. Specific and ascertained ecological connectivity requirements may make it necessary to intervene on alternate banks even in the case of smaller watercourses. This need for discontinuity is not applicable in the case of work involving limited removal or for the recovery of riparian vegetation after a long period of abandon, when safety considerations mean that it is not advisable to wait any further.

E) Management of large wood along watercourses . It should be aimed to retain the largest possible amount of deadwood along watercourses, both on the ground and in the riverbed, given its importance for the diversification of habitats and as a form of support for the presence of numerous species of fauna. To limit the hydrological risk associated with floating wood in narrow sections of streams or where there are bridges with closely planted pillars in the riverbed, it is necessary to act by:

- favouring and increasing the capacity to retain timber in stretches upstream of the problem areas, when this does not lead to increased risk at local level;
- preventing the entry of wood into the riverbed in the stretches (upstream) closest to problem area;
- managing belts of riparian vegetation and woods close to the hydrographic network in such a way as to select the type of wood potentially introduced on the basis of the hydromorphological characteristics of the riverbeds. The presence of spruce and larch trees, which by their nature are transformed into cylinders with a low specific weight without branches, therefore difficult to retain and floating easily, even if they are of considerable length [13], should always be discouraged in adjoining areas.

Four alternative approaches to dealing with the material deposited on the riverbed are possible: leaving it as it is, cutting up on site, moving from the active riverbed towards floodplain areas, removal. The treatment method should be decided on the basis of the likelihood and rapidity with which the material can possibly reach problem areas further downstream, in conditions that may represent an effective factor in terms of increasing risk:

- elements that can be easily retained, due to their shape and size in relation to the characteristics of the riverbed (see section in), should preferably be left as they are;
- in the case of elements that might well be transported downstream, it is preferable to cut them up into sections around 1-2 m long, keeping the stumps linked to part of the trunk, and retaining short branch stumps. In this way the possibility of the elements being retained by irregularities in the riverbed and their ability to create microhabitats is not completely eliminated. At the same time they are less likely to accumulate at bridge pillars or get stuck in narrow sections of the stream;
- the removal of ligneous material should be considered when large amounts are present, as may take place in streams following debris flows in one of the tributaries or landslides in gullies, in alluvial watercourses following the erosion of extensive wooded areas and in channelled stretches, and in any other cases in which it is believed that there are specific problems increasing risk.

F) Minimising the impact of site work . When planning work, special care must be paid to minimising the impact of site work, above all for intervention concerning areas of high natural value. Particular attention must also be paid to establishing and locating a rational system of routes to the site. The bush clearing methods most suitable for minimising disturbance to the specific ecological characteristics of the site must be selected.

G) Carrying out of works with the supervision of specialist personnel . The fragility of the riparian ecosystem and the many needs it is necessary to bear in mind mean that intervention to cut down vegetation should always be supervised by specialist technical staff who should initially explain the methods of intervention to the work team, on the basis of the measures established in these guidelines, and subsequently check that the work carried out effectively complies with the indications given. This point is particularly important in the event of work carried out by local authorities or the private sector via competitive tender or licence.

H) Planning of intervention . The choice of the period in which to carry out work related to vegetation is not uniform, but as also established in the Piano Generale di Utilizzazione delle Acque Pubbliche (PGUAP- General Plan for the Use of Public Waters), should be carried out on the basis of technical, natural and socioeconomic requirements. In general, the period of vegetative rest should be preferred, which also coincides with the period of minimum disturbance to fauna and the different plant species. When it is believed that the carrying out of work will make it necessary for vehicles and workers to enter the water, this general criterion should be reconsidered with greater attention, due to possible disturbance to the reproduction of salmonidae, which takes place in the same period.

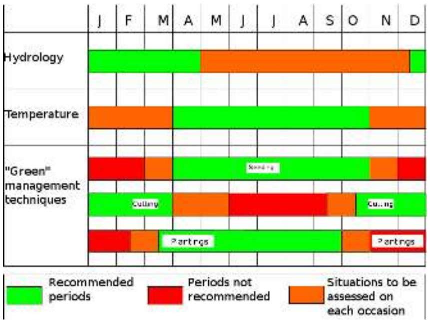


Figure 3.1: (a)

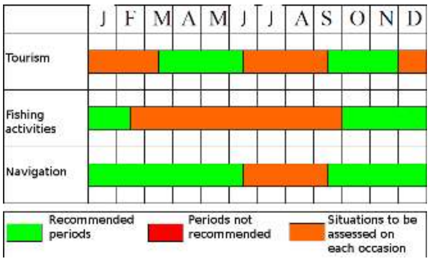


Figure 3.2: (b)

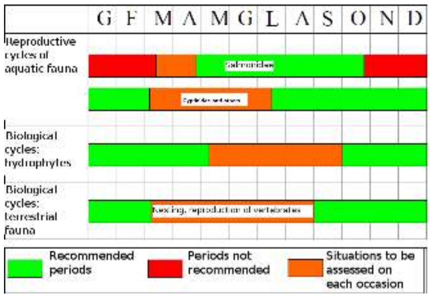


Figure 3.3: (c)

Figure 3.4: Calendar for work along watercourses on the basis of (a) technical, (b) socioeconomic (c) natural requirements [1].

Specifically, as regards work to cut down and maintain vegetation, reference should be made to the periods when work is prohibited, as established by DGP no. 1660/2012, which is binding for work carried out within Natura 2000 sites.

Intervention	Altitude < 1.000 metri	Altitude > 1.000 metri
At all sites	15/03 – 15/07	31/03 – 31/07
In the presence of heron nesting colonies	1/02 – 30/06	
In the event of entry in the riverbed	1/10 – 31/03	

Table 3.1: Periods to be avoided when carrying out work to cut down and maintain vegetation along watercourses.

As a general rule, these periods of time are also considered to be binding for intervention within local nature reserves

I) Maintenance of stream management structures and works . Walls, dams, weirs, banks and many other structures are seriously damaged by the root systems of vegetation growing on them or close by. Other works, such as systems of dams and accumulation areas, have been specially designed to encourage the depositing of sediment, on which riparian formations, also of a valuable nature, may establish themselves between one outlet point and the next. In all these cases, the need to preserve the integrity and functioning of the works is a priority as compared to any other objectives of an environmental nature. When planning and managing larger accumulation areas and at sites of greater natural interest, given the rarity of large spaces without human activities along the valley floors, a multifunctional approach should be adopted, making it possible to combine the objective of reducing risk, for which purpose the area was established, with the establishment of riparian wood formations within it, in the parts most rarely subject to the depositing of sediment. In the presence of valuable and sporadic species on sediment that must be removed, if the characteristics of the species so permit (as in the case of Myricaria germanica), the possibility of proceeding with transplanting or the collection of cuttings in order to propagate the species at other points along the hydrographic network should be evaluated, before carrying out works.

J) Safeguarding of sporadic species and species of high natural value . When determining work to cut down vegetation, priority should always be given to leaving sporadic species and species of high natural value.

K) Combating invasive alien plant species . The elimination of a species from an area is an objective which is practically impossible (except in the case of prompt intervention in small areas) and consequently the strategies that can be adopted must include management and control measures rather than criteria based on techniques used in agriculture. Intervention using chemical products should therefore be avoided, due both to the lack of efficacy and the clear environmental damage caused, whereas indirect or direct action to manage and control invasive flora should be taken, implemented in different ways depending on the context and the problems it is necessary to deal with. In general, indirect methods include all operational techniques and methods aimed at environmental recovery and all measures of a preventive nature designed to avoid the propagation and establishment of invasive species, such as:

- paying particular attention to not leaving extensive areas of bare earth after carrying out any type of work;
- avoiding excessive deforestation and coppicing, or the planting of bushes and trees without carrying out regular maintenance in terms of mowing and bush clearing;
- it has been observed that the entry of invasive alien species is more unlikely in the presence of active hydromorphological processes, and that a restoration of these processes when they have been compromised can represent an effective tool in combating such species [18]. However, when using the reactivation of hydromorphological processes as tool for combating invasive vegetation, it is necessary to take care not simply to move the problems further downstream (by favouring the entry of the propagules of the invasive species into the current) [44] [3].

Direct intervention to combat invasive species can be implemented in more localised environments (due to costs and the complexity of the work), when the infestation is serious, and should be implemented using different techniques and methods according to the type of invasive species, the context and the possibilities in terms of intervention:

- manual removal, essentially to combat invasive herbaceous species;
- bush clearing, to be carried out several times during the spring and summer, always seeking to prevent the plants from flowering (especially in the case of herbaceous species), with the objective of reducing the ability to grow new rhizomes and rootstock and preventing dissemination;
- cutting down of trees with subsequent maintenance as described previously;
- girdling of trunks, namely elimination of a strip of bark of at least 15 cm around the trunk, cutting into the trunk up to the xylem, to be carried out in the phase of vegetative regrowth, with the plant being left to die standing.

In all cases, in order to be truly effective the work described above cannot take place without intervention designed to improve the structure of riparian forest formations, through the planting of local species contrasting the establishment of heliophilous invasive plants, for example.

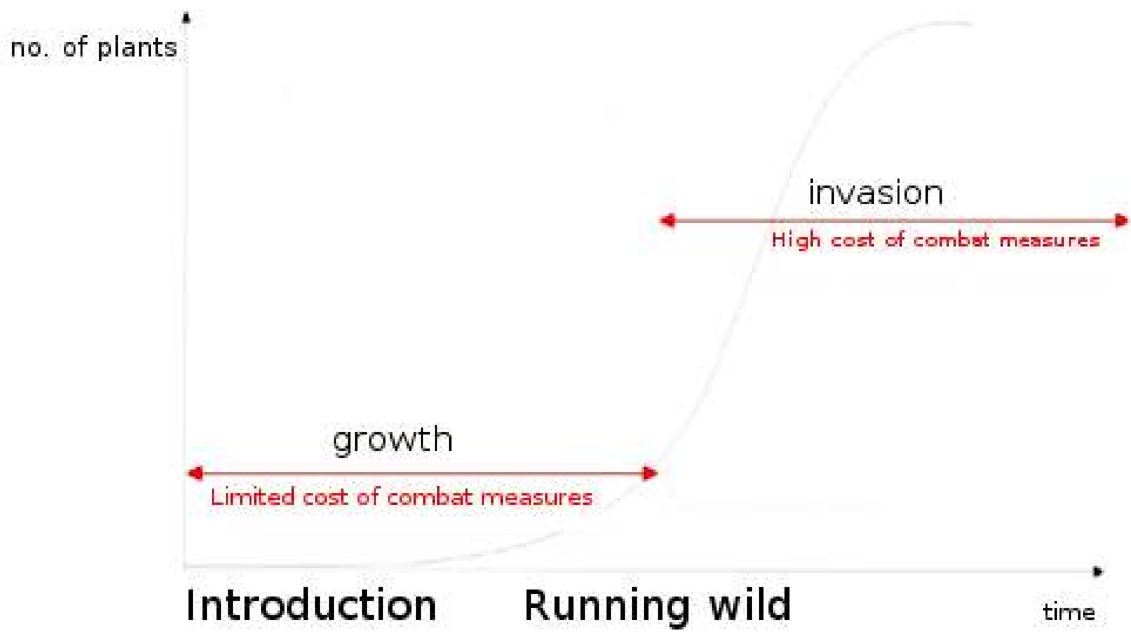


Figure 3.5: It is cheaper to combat spread in the initial phases of colonisation[44].

In the context of ordinary management of riparian vegetation it is possible to implement progressive but effective measures directed at arboreal species (Robinia pseudoacacia and Ailanthus altissima) without a significant increase in costs, by intervening with selective felling. Overall, the management methods established in these guidelines aim to establish more widespread, stable and better structured riparian populations. In this context they represent an effective indirect measure for combating all invasive species. Some general guidelines regarding intervention in relation to the black locust in the context of the ordinary management of vegetation could be as follows:

- With sparse trees: felling of only dominated or non-dominated plants (healthy and deteriorating) whose rootstock is strongly shaded by local species; leaving healthy and vigorous plants, but also declining plants so that they spontaneously reach the end of their life cycle with the contemporary death of the rootstock. The coppicing of these plants in conditions without shading inevitably leads to reinvigoration of the rootstock and to many new offshoots from the root system.
- With widespread populations: felling of only dominated plants, leaving all local species (arboreal and bushy); the scope is to reinvigorate the stand dominated by local species, while at the same time allowing the black locust plants to age naturally, avoiding reinvigoration and growth as a result of cutting.
- Leaving mature individual black locust trees to age naturally is not always compatible with hydrological management requirements. In all cases when felling is required, action must therefore be taken to contrast the consolidation of the numerous suckers that will emerge from the root system by repeated bush clearing during the growing season, in order to impoverish the rootstock.

When it is wished to take active action against other invasive species, the main limiting factor is cost, and it is therefore necessary to establish certain priorities:

- monitoring of the diffusion of invasive species in the area and action to hinder their penetration into valleys where they are not yet present;
- implementing control plans in the context of provincial and local nature reserves and Natura 2000 sites as a priority, above all if characterised by invasive processes still in their early stages.

Along the banks of watercourses on the valley floor it is often possible to find the presence of alien species that it has been suggested should be progressively eliminated, although they are not of an invasive nature (*Acer negundo*, *Salix babilonica*, *Ligustrum japonicum* etc...), in order to safeguard the integrity of the flora and the riparian landscape.

L) Grazing in the area adjoining watercourses . The transit of herds along the banks is permitted. In grassland areas, widespread grazing without dietary supplements between July and the end of the winter can be considered not only compatible but also desirable. Intensive or persistent grazing should instead be avoided, along with manuring within arboreal and bush formations on floodplains, along the banks and above all on embankment works, due to the resulting damage.

M) Use of biomass removed in riparian habitats . Any use of the biomass removed during felling operations, for energy production for example, is secondary as compared to needs related to reducing hydrological risk, conservation, improvement of the ecological state of watercourses and preservation of species and habitats. This means that all works must be planned and conducted according to these guidelines and that only the resulting biomass can be exploited for energy or in other ways.

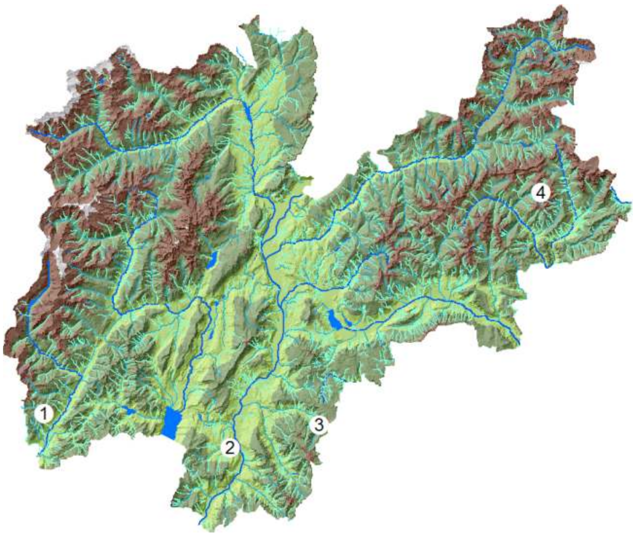
In the areas of greatest environmental value, the establishment of wood hauling procedures is a priority, in order to minimise site impact on species and habitats and only secondarily to increase the economic yield of the biomass removed.

3.3 Specific management directions for each category

3.3.1 MOS: Mountain streams

Stretches of streams in forest environments, characterised by narrow riverbeds in proportion to the height of vegetation on the banks, so essentially with continuity of forest coverage across the riverbed. High level of confinement within the valley; moderate to very steep slope.
Types of stretches included in this management category:

- Steep mountain streams: M0
- Small streams on the valley floor: Ss0
- Mountain streams on alluvial fans: AF0



Present in a uniform manner throughout the province.

(a) 1: Rio Sorino (type Ss0), tributary on the right-hand bank of the River Chiese, at an altitude of 1,200 m a.s.l. (*Ph.* APPA).

(b) 2: Rio Sorna (type M0), tributary on the right-hand bank of the River Adige, at an altitude of 240 m a.s.l. (*Ph.* APPA).

(c) 3: Leno di Terragnolo (type Ss0), tributary on the left-hand bank of the River Adige, at an altitude of 890 m. a.s.l., with a border of riparian shrubs (ash and goat willow) in succession with local non riparian arboreal formations (beech, spruce) (*Ph.* APPA).

(d) 4: Rio Val Sorda (type M0), on the left-hand bank of the Vanoi stream, at an altitude of 1,600 m a.s.l. (*Ph.* APPA).

3.3.1.1 Conservation of habitat and species

Although there is essentially continuous forest vegetation, there may also be riparian vegetation present, creating ecotonal conditions and greater overall biodiversity. When it develops it should naturally be promoted and safeguarded.
As the context is essentially natural, the role of these stretches of stream as ecological corridors is generally not particularly significant.

3.3.1.2 Hydrological risk

The main risk associated with streams included in this management category is linked to hyperconcentrated and debris flows, the effects of which may be significantly intensified by the transport of large trees downstream. The possibility of accumulating trunks forming dams, which then give way suddenly to the pressure of water building up further upstream, leading to violent flooding and possibly also evolving towards hyperconcentrated and debris flows, is also particularly significant and requires attention.
These phenomena are sparked off and take place along steep mountain streams (M0), whereas alluvial fans (AF0) and less steep streams (Ss0) represent areas for the invasion and depositing of sediment mobilised further upstream.
The risk is only significant when inhabited areas are inundated, so no risk is associated with possible inundation of areas along M0 and AF0 stretches.

3.3.1.3 Planning of intervention

The management of vegetation along these streams should be planned within the context of management of the overall forest stand through which they flow.
In specific situations that could increase risk, it may be necessary to carry out stream and environmental management works outside the context of programmed intervention, for example in the case of trees falling over due to snow, accumulating along the riverbed, or wood dragged downhill by avalanches or landslides on the slopes.

3.3.1.4 Management objectives

Management of forest coverage on the slopes complying with the principles of “protection forest” should be adopted along streams included in this category, in line with the provisions of the provincial law on forests and nature protection (L.P. 11/2007).

3.3.1.5 Management methods

Introduce types of forest cultivation in which stability prevails over strictly productive aspects, with greater representation of broad-leaved trees as compared to conifers, avoiding the presence of large trees (shorter harvest cycles or lower cultivation heights), preferring more stable trees, also in the case of thinning. Clearly this does not mean eliminating or altering the nature of the woods, but rather careful examination of stream conditions in order to establish particular stretches or points that could be dangerous, and specific consideration of hydromorphological dynamics when dealing with the woods in question (AA. VV., 2005). In particular, it is necessary to discriminate between stretches where debris flows may be sparked off and make their way downstream and stretches where the sediment mobilised can be deposited.
More specifically, it is necessary to provide for the removal of potentially unstable plants along the riverbed. Trees and wood present in the riverbed or immediate vicinity represent a problem, as they may be transported downstream by the current in the case of a sudden increase in flow due to intense precipitation or the sparking off of debris flows, leading to obstruction of narrower sections, such as bridges, rocky promontories and bends. These blockages can then in their turn cause flooding or erosion of the banks. However, this must not be translated into uniform and widespread removal of the vegetation present along the banks. Selective cutting down operations should instead be provided

for in order to encourage stable and flexible vegetation, usually of a riparian or in any case hygrophilous nature, to protect the bank. A stable forest population prevents erosion. The populations along these streams are generally difficult to reach, so wood hauling is not necessarily required, but only the setting up and concentration of wood in areas not subject to the runoff of floodwater, even with high return times [1]. According to L.P. 11/2007, the Forest and Mountain Plans have the task of identifying protection forest and determining the silvicultural policy to be adopted.

3.3.1.6 Other instructions for intervention

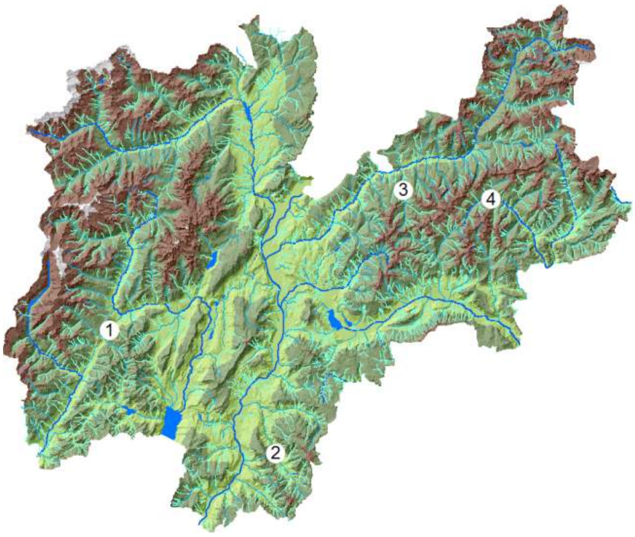
There are none for this category.

3.3.1.7 Improvement proposals

There are none for this category.

3.3.2 VFS: Streams on the valley floor in forest environments

Stretches of streams in forest environments, characterised by riverbeds of medium to large size in proportion to the height of vegetation on the banks, a high level of confinement by valley slopes, scree and the alluvial fans of confluent basins, but with the presence of a significant floodplain. Moderate to steep slope.
The occasional presence of "management" works with weirs and bank defences is possible, above all close to roads.
This management category includes only the S0 type of stretch for streams on the valley floor.



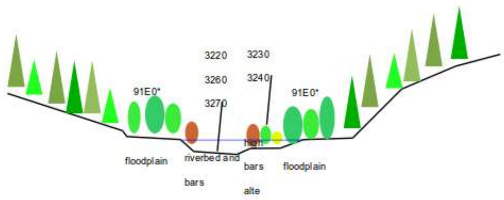
Present in a uniform manner throughout the province.

(a) 1: The Duina, a tributary on the right-hand bank of the Sarca, stabilised using weirs alone (*Ph.* APPA).

(b) 2: A stretch of Rio Cadino, a tributary on the left-hand bank of the Avisio, in the valley of the same name, running along the road embankment (*Ph.* APPA).

(c) 3: A stretch of the Leno di Vallarsa marked by the presence of a floodplain; one can note erosion of the plain, with arboreal vegetation that has fallen over (*Ph.* APPA).

(d) 4: The Vanoi stream (*Ph.* APPA).



3.3.2.1 Conservation of habitat and species

The watercourse is essentially in a natural state.
The following habitats could potentially develop: 3260 in the riverbed, 3220 and 3240 on the bars,3230 (very rare) and 3240 on high bars, 91E0* in the floodplain.

3.3.2.2 Hydrological risk

Streams included in this management category may be associated with risks linked to flooding and erosion of the banks.
The naturally high roughness of the riverbed and the broad shallow shape of the bed means that vegetation along the banks and in the floodplain has little influence in terms of determining runoff capacity. The bush vegetation on the bars may be more significant.
Overflowing along these stretches contributes towards reducing the danger and risk for stretches further downstream and is not generally associated with any local risk, so in these cases it should not be prevented.
Erosion of the banks and the edges of islands, along with modification of bars covered with bush vegetation, takes place naturally along any watercourse in its natural state, and so long as these processes do not threaten infrastructures and constructions, or the stability of the slopes, they should be left to run their course. These stretches are also the first to receive the large quantities of sediment and fallen trees that may be mobilised by avalanches, landslides and mass transport along the tributaries. The introduction of large wood through these mechanisms should be controlled on the basis of the impact it may have in terms of causing a significant increase in risk for stretches further downstream.
Due to the limited frequency with which the adjoining land is subject to modification by flooding, one can commonly note the spontaneous entry of vegetation typical of the surrounding forest stands, not infrequently causing the almost total disappearance of riparian vegetation. These natural dynamics intensify all the problems associated with the introduction of large wood and should therefore be contrasted.

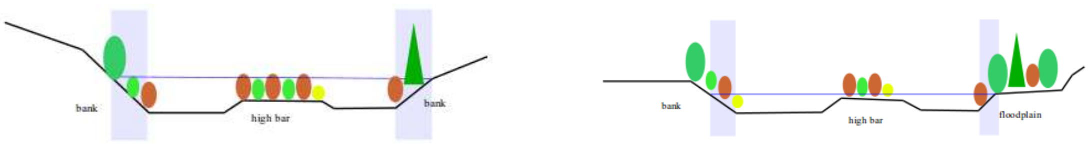
3.3.2.3 Planning of intervention

As a general rule, not all stretches included in this category require intervention in terms of vegetation management. It is only necessary to intervene along stretches associated with a local risk, usually due to the presence of roads and bridges, or along those that may be the cause of a significant increase in risk for stretches further downstream, due to the transport of large wood. In the latter case, a possible guiding principle is that the stretch of stream taking on significance in terms of management regards the whole section along which a trunk falling into the riverbed from the banks would cover when floating up to the problem area further downstream in the context of a single episode of flooding. When evaluating which stretches of watercourse require programmed management it is also necessary to bear in mind the presence of lakes, artificial reservoirs or other situations downstream that could trap large wood or reduce its size to non critical levels.
In order to minimise the extent and drastic nature of cutting operations, periodic monitoring should be provided for to identify problems and organise targeted management work. The following table showing methods of intervention can also act as a check list, in order to verify the presence of situations requiring intervention. The frequency of work depends strongly on seasonal conditions: the

greater the vigour of the vegetation the more frequent and assiduous the monitoring and intervention will need to be.

3.3.2.4 Management objectives

To promote the permanence of a continuous belt of riparian vegetation over time, covering all the areas which are shown to have a more direct relationship with the stream environment in geomorphological terms, in standard conditions and during exceptional episodes of flooding, causing modification and mobilisation of the sediment present and potentially uprooting the vegetation growing on it.



\ Bankfulll ▭ Part of the bankfull exposed to runoff from bankfull flow

3.3.2.5 Management methods

	Active channel	Bars	Part of the bank exposed to bankfull flow	Upper part of the bank	Back of floodplan areas
Herbaceous vegetation	Respect and do not remove, especially helophyte vegetation				
Bush vegetation of limited size		Cut down any species of trees eventually present	Give preference to the presence of bushy species	Silvicultural management for natural purposes	Silvicultural management for natural purposes
Arboreal bush vegetation (D > 4-10 cm)		"	"	"	"
Medium-sized trees (D < 30 cm)		"	"	"	"
Large trees (D > 30 cm)		Cut down			
Unstable, deteriorating, ageing and dead plants still standing		Cut down and treat as deadwood	•*Small plants*: leave •*Large plants*: cut down and treat as deadwood		Leave standing if evaluation establishes that they cannot fall down on frequented areas and roads
Deadwood of considerable size	Treat according to section E) in the "Management Guidelines"		Leave on the ground whole, unless very bulky		
Large forest species, with attention for conifers	Cut down independently of the size and discourage their establishment				

3.3.2.6 Other instructions for intervention

- The intervention must be extended not only to riparian vegetation, but to all vegetation present in the adjoining belt, to be identified according to the criteria presented in section .

- If the cutting down of forest species leads to sparse coverage or even to the exposure of bare earth over large areas, it is necessary to provide for reforestation in order to prevent the entry of invasive species.
- Wood which it has been specifically decided not to leave on site must be immediately transported to an area not subject to flooding.

3.3.2.7 Improvement proposals

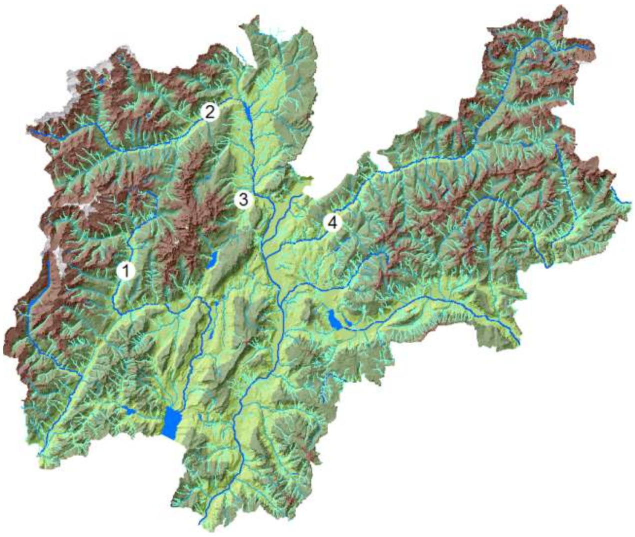
There are none for this category.

3.3.3 AGS: Streams in agricultural environments

Stretches of streams flowing through cultivated areas or pastureland, characterised by a moderate to very steep slope. Bank vegetation absent or present in a very interrupted manner; frequent presence of stabilisation works such as dams and weirs across the watercourse; less frequent presence of riprap bank defences or embankment walls.
Types of stretch included in this management category:

- Steep mountain streams: M1
- Small streams on the valley floor: Ss1
- Mountain streams on alluvial fans: AF1
- Streams on the valley floor: S1, S2

The absence, scarcity and low quality of belts of riparian vegetation is often due to direct intervention by farmers, who see this vegetation as disturbing their crops or meadows, rather than to works designed to control hydrological risk.



Present in a uniform manner throughout the province.

(a) 1: The River Sarca in the Val Rendena (type S1), without bank vegetation and close to fodder crops, certainly subject to the spreading of sewage and therefore an important source of nutrients (*Ph.* Giuliano Trentini).

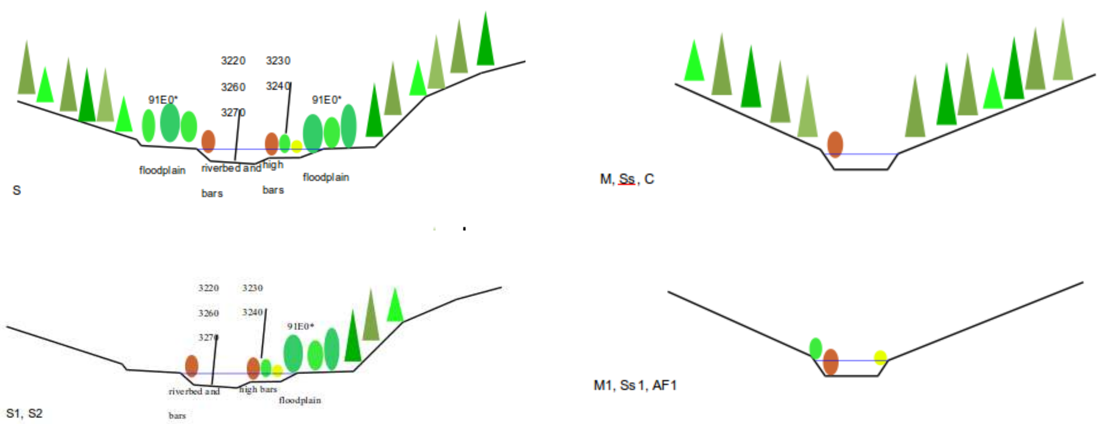
(b) 2: The Noce stream in the Val di Non (type S1). The bank is bare, also as a result of the construction of a very steep riprap slope (*Ph.* APPA).

(a) 3: Rio Sporeggio (type M1) a tributary on the right-hand bank of the Noce (*Ph.* APPA).

(b) 4: Rio di Regnana (type M1) a tributary on the left-hand bank of the Avisio (*Ph.* Giuliano Trentini).

3.3.3.1 Conservation of habitat and species

Natural riverbed **Modified riverbed**



This management category includes both streams on the valley floor (T), with the presence of a significant alluvial plain and the possible development of continuous, broad belts of riparian vegetation, and streams in the mountains and on alluvial fans, where riparian vegetation is naturally present in a limited and scattered manner (M, C, Ss), dominated by surrounding forest stands.
The following habitats can potentially develop along streams on the valley floor: `3260` in the riverbed, `3220` and `3240` on bars, `3230` (very rare) and `3240` on high bars and `91E0*` on the floodplain. None of these habitats are present along the other streams, although there may be a sporadic presence of typical species.
Crop cultivation or grazing on the valley floor has led to deforestation of most of the floodplain and the remaining valley floor areas. Sporadic and limited bank vegetation survives, sometimes with strips of habitat `91E0*`, of great value both in terms of conservation and due to its role as an ecological corridor. The disappearance of forest shading along the riverbeds of smaller watercourses makes the presence of more continuous and significant riparian vegetation possible.
Independently of the composition of the flora, the belts of bank vegetation cannot be assigned to any of the habitats described in any of the types of stretch, due to their limited extent and lack of the characteristic hydromorphological dynamics.
In the event of entrenchment of the riverbed (S2 stretches) uncultivated floodplains may have lost their specific hydromorphological characteristics. These floodplain areas are nevertheless of considerable interest due to their role as ecological corridors.

The high interchange between stream riverbed and aquifer flows makes these stretches flowing in an agricultural environment particularly significant and critical, due to the entry of nutrients and contaminants into the hydrographic network.

3.3.3.2 Hydrological risk

Streams included in this management category may be associated with risks linked to flooding (M1, Ss1, AF1, S1, S2), debris flows (M1, AF1) and erosion of the banks (all).
The risk of flooding takes on different characteristics and the role of the vegetation is different along the various types of stream:

- the naturally high roughness of the riverbed and the broad shallow shape of the bed along streams on the valley floor (S1, S2), means that vegetation along the banks and in the floodplain has little influence. The bush vegetation on the bars may be more significant.
- streams in mountains and alluvial fans, along with narrow streams on the valley floor (M1, AF1, Ss1) have compact river beds, so the vegetation may have a significant role in determining the roughness of the riverbed, above all if management works have made it more regular. Obstruction of the section by foliage may also have a significant role.

Overflowing along these stretches contributes towards reducing the danger and risk for stretches further downstream. For this reason intervention must only be directed at reducing roughness, and hence flooding, in the case of effective local risk (usually low or absent).
The maintaining of dense, flexible bank vegetation favours the stability of the banks and helps to prevent the sparking off of erosion.
The danger of flooding can be accentuated by the presence of large wood in the riverbed. By deviating the flow, the wood may also favour the development of bank erosion. Wood floating along these stretches or directly introduced from the banks may float downstream, potentially increasing the risk of flooding.
Steep stretches (M, C) may be subject to debris and hyperconcentrated flows. For this reason, it is recommended to keep bank vegetation flexible and of limited size, so that the vegetation can better resist hydrodynamic stress and break up into small pieces in the event that material ends up in the channel.
In stretches at lower altitude (as an indication $< 1{,}000$ m a.s.l.) the presence of Salix alba and Popolus nigra is possible. Given the considerable size that may be reached by these species, it is advisable to limit their presence, in favour of bushy willow formations along the foot of the bank and on surface areas most exposed to hydrodynamic stress from high water flows. More generally, for the same reason, the entry of large typical forest species should be discouraged in the adjoining area, particularly in the case of conifers, in favour of bushy riparian species.

3.3.3.3 Planning of intervention

n steep stretches with a narrow river bed, as the vegetation needs to be kept flexible, it is preferable to intervene regularly, in line with the effective vigour of the vegetation, with operations designed to ensure that the trunks of plants directly affected by the current have a diameter of less than 10 cm.
When the vegetation is less vigorous and Salix alba and Popolus nigra are not present, due to the high altitude and site conditions, it is possible to carry out periodic monitoring instead of intervening regularly, ordering prompt intervention to deal with any specific problems that may arise on the basis of the monitoring.
To ensure the continuing role of the ecological corridor and minimise the impact on the aquatic ecosystem, work to cut down vegetation along smaller watercourses must be carried out along alternate stretches of limited size. Along larger watercourses it is preferable to proceed along alternate banks.

3.3.3.4 Management objectives

The presence of a continuous belt of riparian vegetation along both banks must be aimed for, ensuring the connection with wooded areas stretching up to the watercourse and with the riparian belts of tributaries and receiving waters.
Along any stretches of impermeable bank defences (such as walls in reinforced concrete or concrete ripraps), and therefore unsuitable for the establishment of vegetation, it should nevertheless be aimed to encourage the presence of bush vegetation at the foot of the bank defences, and secondly or additionally beyond the edge of the bank. By interacting directly with hydromorphological dynamics, vegetation at the foot of the bank has a wide range of functions (albeit limited), whereas vegetation beyond the edge of the bank at least offers shade to the riverbed, providing direct input in terms of organic substances, and may have a buffer effect.

Figure 3.6: \ Bankfulll Part of the bankfull exposed to runoff from bankfull flow

3.3.3.5 Management methods

EDGE OF THE ACTIVE CHANNEL : parts of the banks and edges of floodplain areas in direct contact with the active channel, without intervening floodplain and high bars with willow formations;

UPPER PART OF THE BANK : sections not concerned by ordinary flooding, above the bankfull level;

FLOODABLE AREAS : wooded areas subject to flooding along the riverbed, both with and without floodplain characteristics.

	Active channel	Bars	Part of the bank exposed to bankfull flow	Upper part of the bank	Back of floodplan areas
Herbaceous vegetation	Respect and do not remove, especially halophyte vegetation				
Bush vegetation of limited size		Cut down any species of trees that may be present	Leave	Leave	Silvicultural management for natural purposes
Arboreal bush vegetation (D > 4-10 cm)		"	•Narrow section: cut down •Wide section: give preference to bushy species	Cut down In the case of high banks leave a few trees in the highest parts subject to less stress	"
Medium-sized trees (D < 30 cm)		"	"	"	"
Large trees (D > 30 cm)		Cut down			

Continued from previous page

	Active channel	Bars	Part of the bank exposed to bankfull flow	Upper part of the bank	Back of floodplan areas
Unstable, deteriorating, ageing and dead plants still standing		Cut down and treat as deadwood	Knock down and ensure that the uprooted stumps do not represent possible sources of instability or erosion	Leave standing if evaluation concludes that they cannot fall down into the riverbed or neighbouring areas	"
Deadwood of considerable size	Treat according to section E) in the "Management Guidelines"		Leave on the ground whole, unless very bulky		
Large forest species, with attention for conifers	Cut down independently of the size and discourage their establishment				

3.3.3.6 Other instructions for intervention

- The establishment of a belt of riparian vegetation must be encouraged along stretches of bank without arboreal and bush vegetation, or where it is excessively sparse due to human intervention, with a prevalence of bushy species in the areas closest to the active channel. This may also take place through reforestation work.
- Wood which it has been specifically decided not to leave in the adjoining area must be immediately transported to an area not subject to flooding.
- The presence of any *Myricaria germanica* on bars must be safeguarded, and given its rarity encouraged, by cutting down all the surrounding bush vegetation

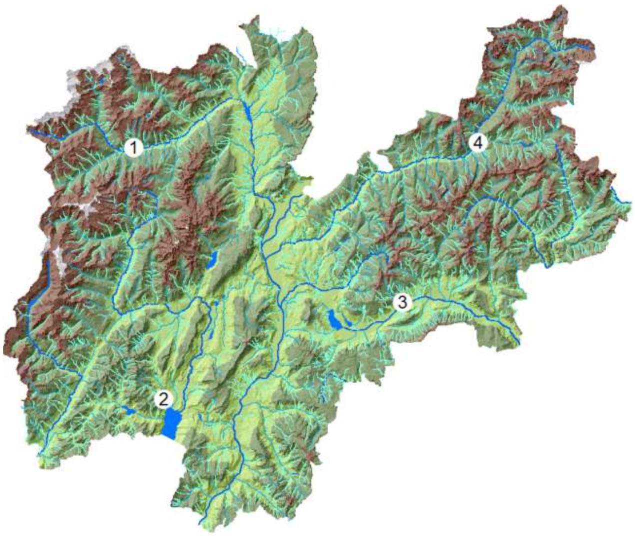
3.3.3.7 Improvement proposals

As a priority, aim to implement the provisions of paragraph 4, article 9 of LP 11/2007 in these parts of the hydrographic network, setting up wooded buffer zones, that also extend beyond the specific context of the banks, capable of intercepting the nutrients carried by surface and subsurface outflows (fertilisation of arable and vegetable crops, spreading of sewage on forage meadows, grazing of livestock) and by the spraying of pesticides (particularly to treat vineyards and fruit orchards). The extent of these should be evaluated individually, however as an indication a minimum overall width of 5 m can be taken as a reference, keeping a strip of perennial grasslands around 3-4 m wide between the wooded and cultivated areas, to act as a trap for sediment. In the case of stretches with vertical or sub-vertical banks in reinforced concrete or concrete ripraps, decisions should be made with a view to possibly substituting the existing stabilisation works with others based on permeable ripraps and with less steep banks, allowing the establishment of a belt of riparian vegetation.
Recognising the need to increase diversification of the aquatic habitat, it is possible to mimic the action that would normally be carried out by naturally transported large wood in the riverbed, positioning and anchoring dead trunks, according to methods widely explored and tested, as described in various handbooks [24] [45].

3.3.4 CHS: Channelled streams

Stretches of streams on alluvial fans or crossing inhabited areas, characterised by a moderate to steep slope and a highly artificial riverbed, with embankment walls in reinforced concrete or concrete ripraps and sometimes numerous dams.
Types of stretch included in this management category:

- Steep mountain streams: M2
- Small streams on the valley floor: Ss2
- Mountain streams on alluvial fans: AF2
- Streams on the valley floor: S3



Present in a uniform manner throughout the province.

(a) 1: Corda stream downstream of Castello (type AF2). The narrow channel leads to the whole riverbed remaining permanently under water. The altitude at almost 1,000 m a.s.l. means that only occasional vegetation develops spontaneously in the river bed (*Ph.* APPA).

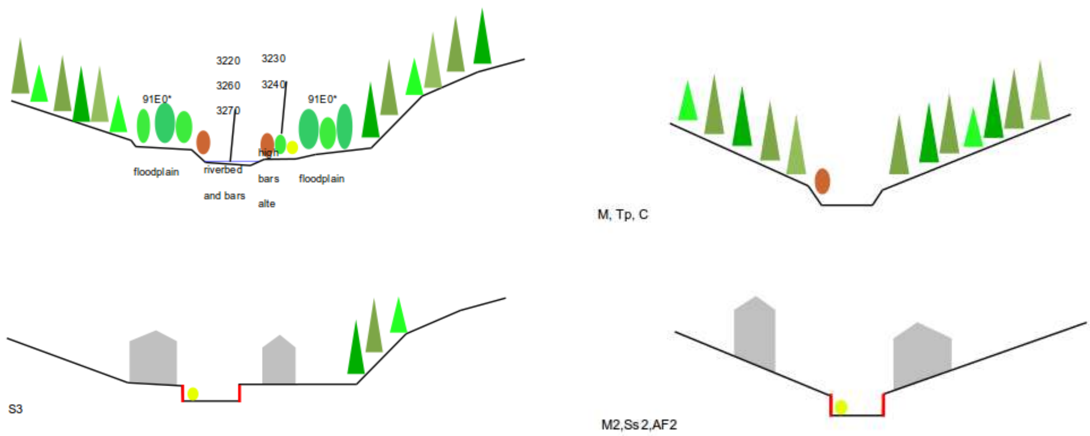
(b) 2: Albola stream at Riva del Garda (type M2) (*Ph.* APPA).

(a) 3: Larganza stream at Roncegno (type AF2). The wide bed and particular hydrological regime permit the growth of thick vegetation (*Ph.* Giuliano Trentini).

(b) 4: Travignolo stream at Predazzo (type S3), with only a limited band of willow bushes on the banks, kept under control by frequent cutting operations (*Ph.* Giuliano Trentini).

3.3.4.1 Conservation of habitat and species

Natural riverbed **Modified riverbed**



The highly artificial nature of the channels inevitably means that the ecological value is low, to the extent that they can represent an element interrupting ecological continuity between stretches further upstream and downstream.
It is not possible for any of the typical habitats to become established.
Given the urban environment, local authorities sometimes raise questions related to landscape or "attractiveness" and urge the adoption of forms of management that may be in conflict with objectives related to ecological functions (cutting down of all vegetation, maintaining only grassland areas) and security (preference for maintaining tall trees, giving the idea of a town park, rather than scrubland vegetation, which may give some people the idea of abandonment and untidiness).

3.3.4.2 Hydrological risk

The risk associated with these stretches is often very high, as they must channel significant flows through narrow areas, with limited or inexistent security measures, and there may be hyperconcentrated and debris flows in stretches on alluvial fans or at the mouth of side valleys. Vegetation has a fundamental role in determining runoff capacity, by increasing roughness and obstructing the runoff section.

In the case of local bottlenecks, very narrow runoff sections and bridges crossing the watercourse, large wood carried by high waters can be significant factor in increasing risk.
The hydrological regime affects the presence of vegetation in the riverbed. When the flow is high even in low water conditions, with large parts of the riverbed under water and flooding episodes capable of modifying the sediment on the bed of the whole section taking place frequently, there is little development of ligneous vegetation. In contrast, sections with very wide riverbeds, only partly in contact with water during the summer, and rare episodes of intense flooding, encourage the establishment of extensive and dense arboreal and bush formations. The latter situation is typically found on alluvial fans.

3.3.4.3 Planning of intervention

It is recommended to intervene regularly and frequently in order to ensure the vegetation remains at a young and flexible stage.

3.3.4.4 Management objectives

The reduction of hydrological risk prevails over any other needs.
The highly artificial nature allows the presence of very little or no vegetation in the riverbed. For this reason the minimal natural elements surviving should be conserved, both in terms of the presence of non-ligneous vegetation and the morphological diversification of the riverbed (also thanks to the presence of deadwood).

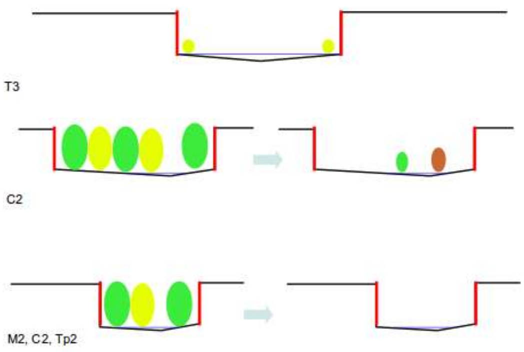


Figure 3.7: \ Bankfulll ▪ Part of the bankfull exposed to runoff from bankfull flow

3.3.4.5 Management methods

PERMEABLE BANK : bank in natural sediment or at most stabilised with loose rocks, allowing the establishment of vegetation

IMPERMEABLE BANK : embankment wall in reinforced concrete or concrete riprap

	Riverbed	Permeable bank	Impermeable bank
Herbaceous vegetation	Respect and do not remove, especially halophyte vegetation	Respect and do not remove, especially halophyte vegetation	Maintain the structure by removing all vegetation that may possibly damage it over time
Bush vegetation of limited size	Cut down	Cut down	"
Arboreal bush vegetation (D > 4-10 cm)	They should not establish themselves spontaneously, if necessary cut down	"	"
Alberi (D > 30 cm)	"	Do not permit development	"
Alberi di prima grandezza	"	"	"
Unstable, deteriorating, ageing and dead plants still standing	Cut down		
Deadwood of considerable size	Treat according to section E) in the “Management Guidelines“		

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	Riverbed	Permeable bank	Impermeable bank
Large forest species, with attention for conifers	They should not establish themselves spontaneously, if necessary cut down		

3.3.4.6 Other instructions for intervention

- The drastic coppicing made necessary in these situations is a factor increasing the risk of invasive species entering the area. This must be carefully monitored and immediately combated if the situation should arise.
- Very wide riverbeds, with a big gap between standard flows and those that must be safely conveyed in the event of occasional and intense episodes of flooding require more targeted management, given that in these cases the tendency is to arrive at total colonisation by vegetation. These dynamics must be obstructed. In such cases it is necessary to take action to keep most of the riverbed free of vegetation, maintaining at least a belt of bushy riparian vegetation along the low water channel, with possible grasslands in the remaining part of the riverbed.
- Controlling the development of the vegetation may make it necessary to uproot stumps.

3.3.4.7 Improvement proposals

In wider riverbeds, where only a small part is under water in standard conditions, it is possible to provide for morphological improvement works on the riverbed, in order to keep the low water flow concentrated and favour the variability of the hydraulic head and speeds similar to those taking place naturally.

3.3.5 RMB: Rivers with mobile riverbed

Rare stretches of alluvial watercourse conserving a relatively wide river corridor, within which the riverbed is free to wander, with natural dynamics leading to the formation and destruction of the floodplain.
The external limit of the river corridor is marked by natural physical limits, such as the edge of the valley or a terrace, or by anthropogenic elements, such as road embankments or bank defences. In some cases the bank defences rise up above ground level, taking on the characteristics of a raised bank.
Stretches of alluvial watercourse confined by the slopes of the valley, where the lack lateral mobility permitted by the slopes is nevertheless natural and may give rise to the same problems present along unconfined stretches, are also included in this management category.
Types of stretch included in this management category:

- Unconfined and semi-confined alluvial watercourses: R0, R1, R2, R3
- Confined alluvial watercourses: Rc0, Rc1
- Minor drainage channels of the alluvial plain: D0

This type can mainly be found along the lower part of the River Brenta, but also occasionally along the River Sarca and the Noce and Fersina streams
Stretches of confined alluvial watercourses can be encountered along the River Sarca and the Noce, Avisio, Fersina and Vanoi streams

(a) 1: River Sarca at Busa di Tione (type R1) (*Ph.* Associazione Pescatori Alto Sarca).

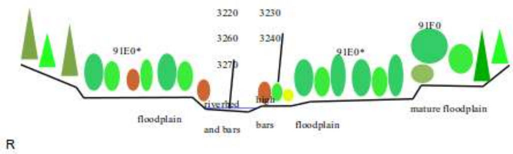
(b) 2: Floodplain at the convergence of the Noce (type R2) and the Sporeggio (type R0), within the "Rocchetta" provincial nature reserve and SCI (*Ph.* Giuliano Trentini).

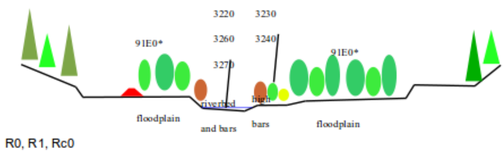
(a) 3: Fersina stream in the “Molini Dorigoni” local reserve (type Rc1) (*Ph.* Giuliano Trentini).

(b) 4: River Brenta (type R0) upstream of the “Fontanazzo” provincial nature reserve and SCI (*Ph.* Giuliano Trentini).

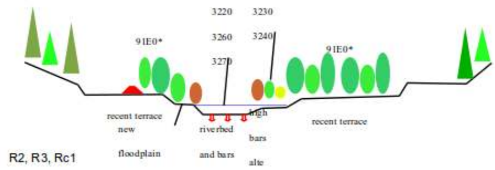
3.3.5.1 Conservation of habitat and species

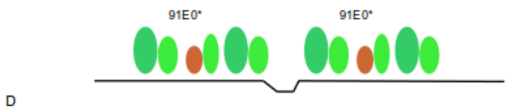
Natural riverbed

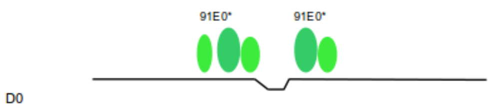




Modified riverbed







This management category includes all stretches of alluvial watercourses flowing within a wider or narrower belt on the plain, wooded or unwooded, with banks unprotected against erosion and therefore liable to erosion following the wandering of the riverbed. It also includes cases in which this plain area does not currently have the characteristics of a floodplain, but rather those of a recent terrace, due to entrenchment of the riverbed or other anthropogenic disturbance,.

These are the stretches in which priority habitat `91E0*` is best able to establish itself, due to the opportunities offered by the limited width of the river corridor and hydromorphological pressure in the hydrographic basin. Given their rarity and very high value in ecological and conservation terms, most of these stretches are subject to protection within the province and are included in local or

provincial nature reserves, SCIs or SPAs. In any case, given their extreme interest, any stretches which are not subject to protection measures should be treated with the same attention.
The forest types present in habitat 91E0* vary on the basis of the site conditions.
The following habitats may also potentially develop: 3260 in the riverbed, 3220 and 3270 on the bars, 3230 (very rare) and 3240 on the high bars. In general, appropriate conditions (space) for the development of habitat 91R0 are not present.
Forest stands in the adjoining band today classifiable as 91E0*, given the composition of the arboreal formations, and those present in areas which have lost their floodplain characteristics due to entrenchment of the riverbed and modifications to the hydromorphological regime, are destined to evolve towards other types of habitat over time. In these cases, maintaining habitat 91E0* must inevitably involve the demolition of existing stands and subsequent re-establishment at a lesser height from the riverbed. This may take place gradually as a result of the action of the river, if there is still sufficient dynamism of the course and there are no bank defences to prevent it, or due to active management measures, with levelling work in the areas concerned and their subsequent reforestation.
The high level of naturalness in these stretches means that they represent very important features of the ecological network in the province. They are among the areas of greatest interest for the nesting of migrating birds in the province of Trento.

3.3.5.2 Hydrological risk

In terms of management, the biggest problem is linked to the mobility of the riverbed and the consequential progressive demolition of parts of the floodplain. The very fact that it is possible to maintain these extensive surface areas of riparian woods shows that the issue of roughness is not relevant.
The local risk associated with these stretches is moderate or inexistent.
The wandering course of the riverbed is associated with the introduction of large wood into the channel during flooding. The wood introduced may increase hydrological risk downstream to a different extent:

Moderate or inexistent increase in risk , for example due to the presence downstream of lakes, artificial reservoirs or other works that can trap large wood, or as a result of low dynamism, associated with a small number of trees in the channel, or in contrast because the dynamism is so high that most of the material in the cannel is of limited size.

Major increase in risk , when the elements above are absent and wood of considerable size can still easily reach narrow sections or bridges with pillars in the riverbed.

3.3.5.3 Planning of intervention

In order to establish management methods, it is first of all necessary to establish to what extent the risk downstream is increased as a result of the introduction of wood. To do this it is essential to evaluate frequency and the size of the material introduced, identify the type and distance from the problem areas and see whether there are any situations in the middle favouring the retaining or deterioration of ligneous material.

- on site surveys of the type of vegetation present;
- observation of the evolution of the active riverbed using a series of historic aerial photographs, making it possible to assess the speed of changes and therefore the extent of the wooded belt that one might expect to be demolished during the course of a season [**?**];
- periodic mapping of geomorphological dynamics in order to better understand how the active riverbed tends to evolve, starting from a given situation, and consequently which parts of the woods will be demolished during subsequent episodes of flooding [37].

Extensive felling, even of a selective nature, extended uncritically to large parts of the wooded area should always be avoided, regardless of evaluation of the parts that will effectively be potentially subject to erosion, unless it is specifically designed for the purposes of conservation.

3.3.5.4 Management objectives

The problems caused downstream are considered to be major when there are critical sections just downstream of the stretch, where the deadwood introduced may arrive in large quantities and of considerable size, and in any other cases when it is evaluated that the introduction of large wood to the riverbed cannot be permitted.
It is necessary to identify the parts on the edges of riparian woods that could be expected to be eroded during forthcoming episodes of flooding (typically the external side of bends in the active riverbed), where it is necessary to provide for periodic selective coppicing of arboreal species only, with a frequency ensuring that the diameter at the base is not over 10 cm.

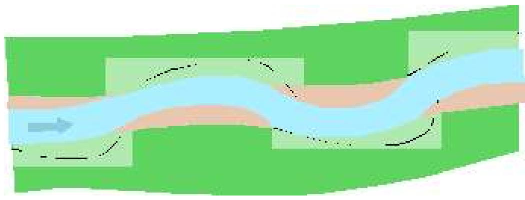


Figure 3.8: Selective cutting down of arboreal vegetation only in areas which have been evaluated as potentially subject to erosion in the course of forthcoming episodes of flooding (pale green areas). \ Evoluzione planimetrica attesa dell'alveo attivo. The black line shows the expected evolution in the course of the active riverbed

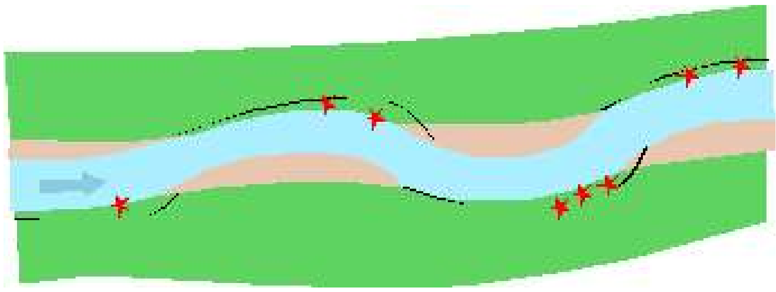
3.3.5.5 Management methods

	Active riverbed and bard	Islands	Banks and surfaces potentially subject to erosion	Floodplain
Herbaceous vegetation	Respect and do not remove, especially halophyte vegetation			
Bush vegetation of limited size	Leave	Leave	Leave	Only carry out intervention for conservation purposes
Arboreal bush vegetation (D > 4-10 cm)	Cut down	"	Cut down	"
Medium-sized trees (D < 30 cm)	They should not develop spontaneously, if necessary cut down	Leave occasional plants in the innermost area of the island	"	"
Medium-sized trees (D > 30 cm)	"	Cut down	"	"
Unstable, deteriorating, ageing and dead plants still standing	"	Knock down and treat as deadwood of considerable size	"	"
Deadwood of considerable size	To be evaluated on the basis of each individual case, deciding whether to remove or treat according to section E) in the "Management Guidelines""			

3.3.5.6 Other instructions for intervention

In sites of high environmental value with large long-established trees, when it is has been concluded that free evolution cannot be permitted, the option to be pursued should always be selective felling of individual trees about to enter the riverbed, with monitoring based on the degree of hydrological risk linked to this. Assiduous monitoring does not mean at fixed intervals, but rather after each episode of flooding over the threshold necessary for morphological evolution to take place.

In stretches characterised by a low level of risk it is essentially possible to permit free evolution, intervening only with felling designed to conserve the habitats.



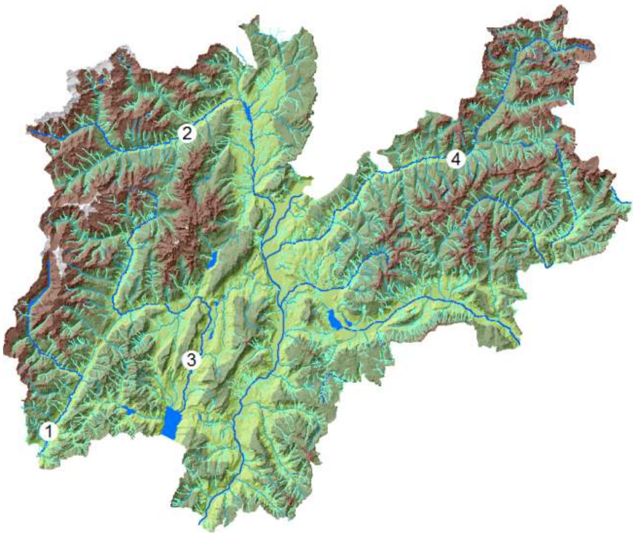
3.3.5.7 Improvement proposals

Any intervention that could favour the erosion of terraces and their transformation into a floodplain is useful, above all in situations where the alluvial plain area that could potentially be eroded is very extensive, but does not have all the characteristics of a floodplain, due to hydromorphological modifications: removal of bank defences that are no longer necessary, removal of terrace banks in order to favour their erosion, levelling work to lower the height of the terrace to the level of the floodplain, with subsequent reforestation.
On recent terraces which are not expected to be affected by the wandering of the active riverbed for a long time, it is necessary to evaluate which of two alternative routes to pursue:

- guiding the vegetation towards more mature stands;
- bringing the terrace back to the floodplain stage.

3.3.6 RSF: Rivers with strips of floodplain

Stretches of alluvial watercourse in which the riverbed delimited by the two banks is sufficiently wide to permit the presence of strips of floodplain or islands, on which bush or arboreal vegetation develops.
However active the underlying dynamics are, creating bars of sediment and the alternation of pools and riffles in the riverbed at times of low water, the course of the riverbed is generally relatively stable over time, so the floodplain and existing islands tend to remain in the same position.
The banks are usually steep and protected from erosion by walls in reinforced concrete or loose rock or concrete ripraps. On rare occasions the banks are made up of loose natural sediment.
This management category includes only the R5 type of stretch of alluvial watercourses on the valley floor.



The types of stretches included in this management category can be found along the main watercourses on the valley floor: Chiese, Sarca, Noce, Adige, Avisio, Brenta

(a) 1: Chiese stream at Darzo (type R5). This part of the floodplain justified the setting up of the "Darzo" local nature reserve (*Ph.* APPA).

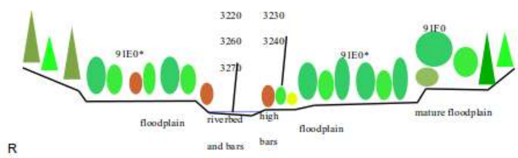
(b) 2: River Sarca at Dro (type R5), with a floodplain populated by poplars, now small and slender (*Ph.* Giuliano Trentini).

(a) 3: Noce stream (type R5), with a floodplain populated by alder forest with grey alders and the common ash, justifying the setting up of the "Ontaneta di Croviana" SCI (*Ph.* APPA).

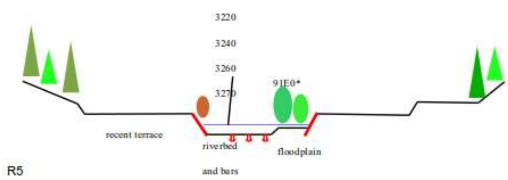
(b) 4: River Avisio at Ziano (type R5). This part of the floodplain justified the setting up of the "Panchià" local nature reserve (*Ph.* APPA).

3.3.6.1 Conservation of habitat and species

Natural riverbed



Modified riverbed



Although the environment has been modified, the chance for the active riverbed to interact with the floodplain, albeit of limited size, encourages biodiversity and should therefore be safeguarded and promoted as much as possible, within the context of the need to contain the risk of flooding.
In general, the highly artificial nature of the banks, also the result of entrenchment of the riverbed, means that vegetation does not develop on them, except sporadically, but there are situations with less artificial banks and the presence of narrow belts of vegetation. Despite the limitations of the bank defences and the limited size of the strips of floodplain, the riverbed can in any case have a natural appearance.
The following habitats can potentially develop along these stretches: 3260 in the riverbed, 3220 and 3240 on the bars, 91E0* on the floodplain.
The limited width of the riverbed does not usually allow the formation of the intermediate high bars necessary for the establishment of *Myricaria germanicae*, and hence habitat 3230.
The belts of vegetation along the banks, when present, cannot be referred to any of the habitats, as a result of excessive hydromorphological modification and the limited extent of the formations.
The interest in terms of conservation is such that stretches with more extensive belts are sometimes protected by setting up local nature reserves.

3.3.6.2 Hydrological risk

In most cases the riverbed is entrenched and therefore capable of containing high water flows with long return times. The risk associated with these stretches is usually high, as they have to channel very high flows into the riverbed delimited by the banks, with security measures that are usually very limited or absent. It follows that the risk is consequently very high when the surrounding areas have undergone urban development.
The presence of strips of floodplain means that a certain care is required in terms of management. They should be dealt with bearing in mind that these strips of floodplain have been able to develop spontaneously because in these sections of the channel the speed of the current is considerably slower as compared to other areas, with less hydrodynamic stress and a lower contribution to the runoff capacity of high water flows.
In the event of significant modifications to the hydrological regime, with a reduction in low water flow and the frequency of formative flood events (namely with a significant part of the underlying basin concerned by withdrawal works without release and dams), vegetation tends to colonise large parts of the riverbed, thus leading to increasing management demands.

3.3.6.3 Planning of intervention

Intervention should preferably carried out regularly, in line with the effective vigour of the vegetation, maintaining the vegetation at a young and flexible stage, in direct contact with the current.
To ensure the permanence and role of the ecological corridor and to minimise the impact on the aquatic ecosystem, it is advisable to proceed with the cutting down of the vegetation on alternate banks.

3.3.6.4 Management objectives

Consolidation of the controlled presence of riparian vegetation on strips of floodplain is considered to be a priority, pursuing appropriate development of the bank vegetation with the purpose of creating a continuous border of trees and bushes. The possibility of creating this belt of continuous vegetation depends on how artificial the banks are, going from cases in which the banks are natural (rare) or stabilised with permeable riprap and boulder techniques, meaning that vegetation is effectively present, to other situations in which the defences are impermeable to vegetation, in which case it is necessary to aim to establish a scrubland belt at the foot of the bank, with the main role of masking and mitigating the impact of the works in terms of landscape.

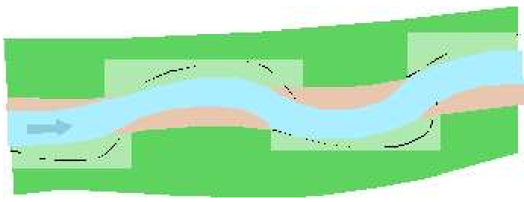


Figure 3.9: \ Bankfull (flooding with T=2-3 anni). ■ Edge interfacing with the channel

3.3.6.5 Management methods

UPPER PART OF THE BANK : parts not concerned by ordinary flooding, above the bankfull level

EDGE OF THE FLOODPLAIN : belt assessed as being potentially subject to erosion

	Active riverbed (channel and bars)	Permeable bank in direct contact with the active riverbed	Edge of floodplain	Floodplain and bank behind it
Herbaceous vegetation	Respect and do not remove, especially halophyte vegetation			
Bush vegetation of limited size	Leave	Leave	Leave	Leave
Arboreal bush vegetation (D > 4-10 cm)	Cut down	Cut down	Cut down	Cut down
Medium-sized trees (D < 30 cm)	They should not develop spontaneously, if necessary cut down	Maintain only sporadically and on the highest part of the bank	Cut down	Leave increasing proportions depending on the increase in the extent and natural value of the strip of floodplain in relation to hydrological risk
Medium-sized trees (D > 30 cm)	"	"	"	"
Unstable, deteriorating, ageing and dead plants still standing	"	Remove	Remove	Leave plants for which there are adequate guarantees that they cannot end up in the channel or spark off erosion of the bank, due to their position and size
Deadwood of considerable size	Treat according to section E) in the “Management Guidelines”			

3.3.6.6 Other instructions for intervention

In stretches where modification of the hydromorphological regime favours colonisation of extensive areas of the riverbed by riparian vegetation, management must be more intense and assiduous. The development of vegetation does not take place in a regular manner, being strongly conditioned by seasonal flows, so very rainy winters with frequent high flow levels capable of modifying the sediment on the riverbed, and high flows in the summer keeping extensive sections of the riverbed under water prevent the establishment and development of this vegetation, which is instead favoured by years with little rain. For this reason it is not possible to establish specific intervals for intervention. It is rather recommended to proceed with operations to cut down vegetation on every occasion that the presence of large surface areas is noted (usually along the edge of the water), with natural reproduction of willow and poplar trees and plants reaching a height of 100-150 cm (which means they are around two years old, namely two years in which there have not been conditions of sufficient intensity and duration to contrast this development).
If islands are present, these should be treated in the same way as the floodplain, distinguishing the edges which are potentially liable to erosion from the more stable internal area. The presence of large trees should be evaluated on each occasion, on the basis of the extent of the island and the stability noted over time, also in the case of very high flows.

3.3.6.7 Improvement proposals

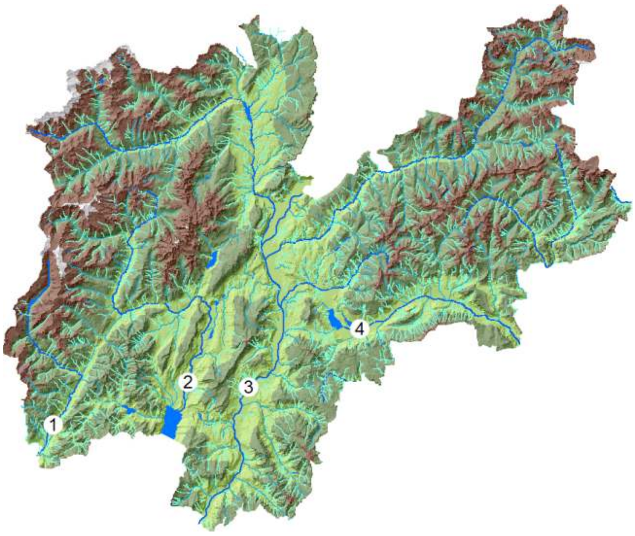
The minimum improvement proposals that can be made for this type of stretch involve expanding the belt of riverside vegetation, according to the provisions of paragraph 4, article 9 of LP 11/2007.This can be carried out in different ways:

- Whenever it is necessary to carry out work on the banks to reduce steepness, by pushing back the edge of the bank. Less steep slopes are intrinsically more stable and require less artificial defensive works to protect against erosion. The combination of these factors allows the establishment of belts of bank vegetation with better structure and of higher ecological value. In this way ecological connectivity between the riverbed and the surrounding area is also increased.
- There are various situations in which state-owned water resources extend significantly beyond the margins of the current riverbed. It is therefore possible to consider exploiting these areas, interrupting the licences granted in order to extend the areas of woodland.

It is important to underline that in the case of entrenched watercourses, any wood formations beyond the edge of the bank will find themselves on the terrace, and therefore not in hygrophilous conditions permitting the establishment of riparian formations, but rather in forest stands made up of oak, hornbeam and elm trees. The consequence of this situation is that these belts will certainly be of value in terms of ecology and landscape, but will have little effect as a buffer zone, due to low interaction of the root systems with sub-surface and aquifer flows. In this context, it is possible to consider lowering the level of these areas to bring them down to the level of the floodplain before reforestation, in order to increase the spectrum of ecosystem services provided by them and expand more strictly riparian formations.
Recognising the need to increase the diversification of aquatic habitat, it is possible to mimic the action that would normally be carried out by naturally transported large wood in the riverbed, positioning and anchoring dead trunks, according to methods widely explored and tested, as described in various handbooks [24] [45].

3.3.7 CHR: Channelled rivers

Stretches of alluvial watercourse with major narrowing and channelling of the riverbed carried out by man, permitting only the presence of the active riverbed between the two banks. The banks are usually steep and protected against erosion by walls in reinforced concrete or loose rock or concrete ripraps. On rare occasions the banks are made up of loose natural sediment.
This management category includes only the R4 type of stretch of alluvial watercourses on the valley floor.



The types of stretch included in this management category can be found along the main watercourses on the valley floor: Chiese, Sarca, Noce, Adige, Avisio, Brenta

(a) 1: Chiese stream at Storo. The hydromorphological regime has been significantly modified (*Ph.* APPA).

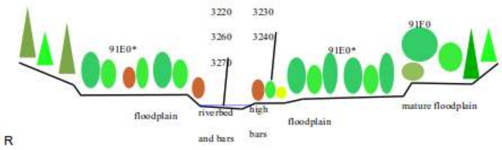
(b) 2: River Sarca in the town of Arco. This stretch is affected by the modification of the hydromorphological regime caused by the Ponte Pià dam further upstream (*Ph.* Giuliano Trentini).

(a) 3: River Adige at Villa Lagarina, where the banks, which are not impermeable, are in direct contact with agricultural areas. Although the hydromorphological regime has been seriously modified, the riverbed is always completely under water (*Ph.* Giuliano Trentini).

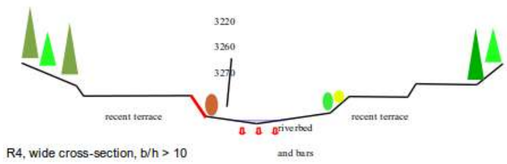
(b) 4: River Brenta, channelled at Borgo Valsugana. The bank defences allow only sparse and sporadic vegetation, preferably at the foot (*Ph.* APPA).

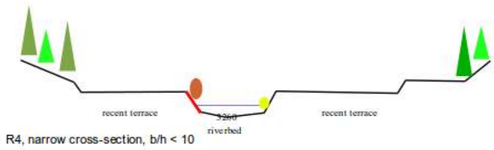
3.3.7.1 Conservation of habitat and species

Natural riverbed



Modified riverbed





In general, the highly artificial nature of the banks, also the result of entrenchment of the riverbed, means that vegetation does not develop on them, except sporadically, but there are situations with less artificial banks and the presence of narrow belts of vegetation.

The following habitats can potentially develop along these stretches: 3260 in the riverbed, 3220 and 3270 on the bars.

The limited width of the riverbed does not usually allow the formation of the intermediate high bars necessary for the establishment of Myricaria germanicae, and hence of habitats 3230 and 3240.

The belts of vegetation along the banks, when present, cannot be referred to any of the habitats, as a result of excessive hydromorphological modification and the limited extent of the formations.

3.3.7.2 Hydrological risk

In most cases the riverbed is entrenched and therefore capable of containing high water flows with long return times. The risk associated with these stretches is usually high, as they have to channel very high flows into the riverbed delimited by the banks, with security measures that are usually very limited or absent. It follows that the risk is consequently very high when the surrounding areas have undergone urban development.

The presence of strips of floodplain means that a certain care is required in terms of management. They should be dealt with bearing in mind that these strips of floodplain have been able to develop spontaneously because in these sections of the channel the speed of the current is considerably slower as compared to other areas, with less hydrodynamic stress and a lower contribution to the runoff capacity of high water flows.
In the event of significant modifications to the hydrological regime, with a reduction in low water flow and in the frequency of formative flood events (namely with a significant part of the underlying basin concerned by withdrawal works without release and dams), vegetation tends to colonise large parts of the riverbed, thus leading to increasing management demands.

3.3.7.3 Planning of intervention

Intervention should preferably carried out regularly, in line with the effective vigour of the vegetation, maintaining the vegetation at a young and flexible stage, in direct contact with the current.
To ensure the permanence and role of the ecological corridor and to minimise the impact on the aquatic ecosystem, work to cut down vegetation along smaller watercourses must be carried out along alternate stretches of limited size. Along larger watercourses it is preferable to proceed along alternate banks

3.3.7.4 Management objectives

- Aim for the establishment and maintenance of a continuous belt of vegetation on the banks or at the foot of the banks. In the event that the banks are of a very artificial nature (walls in reinforced concrete or concrete ripraps) this also has the role of masking and mitigating the impact on the landscape.
- In the river bed the hydromorphological dynamics should spontaneously ensure only a sporadic and ephemeral presence of small ligneous vegetation, only rarely requiring intervention.
- Given how seriously the ecological state has been compromised, any minimal natural elements surviving should be conserved, both in terms of the presence of non-ligneous vegetation and the morphological diversification of the riverbed (also thanks to the presence of deadwood), leading to a greater presence of micro-habitats.

3.3.7.5 Management methods

	Banks in permeable materials	Banks impermeable to vegetation	Riverbed
Herbaceous vegetation	Respect and do not remove, especially halophyte vegetation		Respect and do not remove, especially halophyte vegetation
Bush vegetation of limited size	Leave	If the river bed has large areas not under water, establish a belt even a single row wide at the foot of the bank, coppicing arboreal bush vegetation with a D > 4-10 cm cm	Leave
Arboreal bush vegetation (D > 4-10 cm)	Cut down	"	Cut down
Medium-sized trees (D < 30 cm)	Maintain only sporadically and on the highest part of the bank	Cut down	They should not develop spontaneously, if necessary cut down
Large trees (D > 30 cm)	"	"	"

Continued from previous page

	Banks in permeable materials	Banks impermeable to vegetation	Riverbed
Unstable, deteriorating, ageing and dead plants still standing	Remove		"
Deadwood of considerable size	Treat according to section E) in the "Management Guidelines"		

3.3.7.6 Other instructions for intervention

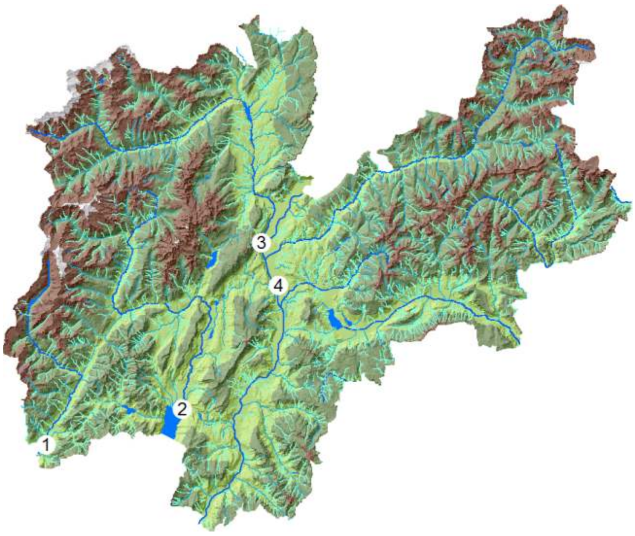
In stretches where modification of the hydromorphological regime favours colonisation of extensive areas of the riverbed by riparian vegetation, management must be more intense and assiduous. The development of the vegetation does not take place in a regular manner, being strongly conditioned by seasonal flows, so very rainy winters with frequent high flow levels capable of modifying the sediment on the riverbed, and high flows in the summer keeping extensive sections of the riverbed under water prevent the establishment and development of this vegetation, which is instead favoured by years with little rain. For this reason it is not possible to establish specific intervals for intervention. It is rather recommended to proceed with operations to cut down vegetation on every occasion that the presence of large surface areas is noted (usually along the edge of the water), with natural reproduction of willow and poplar trees and plants reaching a height of 100-150 cm (which means they are around two years old, namely two years in which there have not been conditions of sufficient intensity and duration to contrast this development).
In the event of narrow sections, the quantity of vegetation that can establish itself on the banks should be commensurate with the admissible roughness. In general, the vegetation on the lower part of the bank should remain bushy and flexible, limiting medium-sized and large trees to the upper part of the banks, so that their foliage does not interfere with runoff flows but still shades the river bed.

3.3.7.7 Improvement proposals

Minimum improvement proposals can only be made for stretches outside inhabited areas, where the possibility of substituting the most artificial bank defences with others based on permeable ripraps and less steep banks should be considered, allowing the establishment of a belt of riparian vegetation.

3.3.8 RBW: Rivers with banks in direct contact with the water

Stretches of alluvial watercourse with raised banks in direct contact with the water, at most with a verge that can be used for maintenance, frequently with the foot of the bank and the internal surfaces of the raised structures protected against erosion using ripraps or concrete slabs.
Occasional presence of sparse ligneous vegetation of limited size, due to repeated cutting operations, sometimes also on the embankments of raised banks.
Due to the entrenchment of the riverbed the banks are usually very steep.
This management category includes only the R6 type of stretch of alluvial watercourses along the valley floor.



The presence of raised banks can be noted extensively along the Adige , the Noce downstream of Rocchetta and some stretches of the River Sarca in the lower Sarca valley, the Chiese close to Lake Idro and the River Brenta. The stretches in this category are mostly but not exclusively located in urban environments.

(a) 1: Chiese stream in the Storo valley. The presence of raised banks has not prevented the development of a narrow belt of vegetation (*Ph.* APPA).

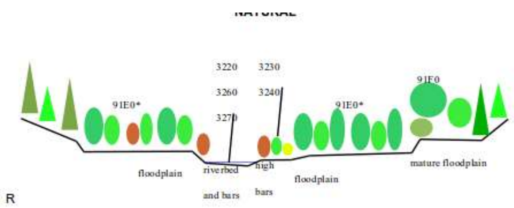
(b) 2: River Sarca at Torbole. It is possible to note the riprap at the foot of the banks and the service track, protected with a slab of reinforced concrete (*Ph.* Giuliano Trentini).

(a) 3: Noce stream at San Michele all'Adige. The presence of raised banks has not prevented the development of a narrow belt of vegetation (*Ph.* APPA).

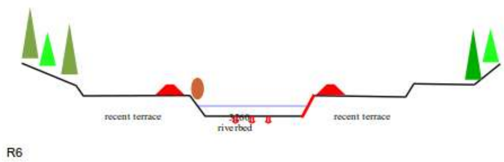
(b) 4: River Adige at Trento. One can observe the internal face of the raised bank, protected by a slab of reinforced concrete, and the presence of a few bushes (*Ph.* APPA).

3.3.8.1 Conservation of habitat and species

Natural riverbed



Modified riverbed



In general the highly artificial nature of the banks, also the result of entrenchment of the riverbed, means that vegetation does not develop on them, except sporadically, but there are situations with less artificial banks and the presence of narrow belts of vegetation.
The belts of vegetation along the banks, when present, cannot be referred to any of the habitats, as a result of excessive hydromorphological modification and the limited extent of the formations.

3.3.8.2 Hydrological risk

The risk of flooding associated with these stretches is generally high.
In order to minimise construction costs and land occupation, at the time the sections were designed with minimum levels of roughness, namely with an almost total absence of arboreal and bush vegetation and with all the dry surface areas maintained as grasslands. This situation, even with a revised attitude and awareness involving recognition of the fundamental role of riparian vegetation, may not leave space for its reintroduction on a large scale.
There are major limitations to the possibility of maintaining any arboreal and bush vegetation along the embankments, on the side towards the river or the other side of the banks, due to the need to ensure both the efficacy of the works and to allow continuous monitoring.

3.3.8.3 Planning of intervention

All stretches with embankments require management and regular monitoring.
When the nature of the banks does not prevent the establishment of arboreal bush vegetation, evaluation of the hydrological characteristics will determine how extensive this belt may be and consequently the frequency of intervention. The frequency of intervention must be evaluated on the basis of vigour and populations, in order to ensure that the vegetation remains young and flexible . Work to cut down vegetation must be carried out along alternate stretches of the banks.

3.3.8.4 Management objectives

- The establishment of a continuous belt of willow bushes should be aimed for. In the event that the presence of bushes is only considered to be compatible with safety requirements along one bank, it is preferable to provide for formations on alternating banks, with the length of the stretches being equivalent to the width of the riverbed.
- All the surfaces of the raised banks and a wide belt on both sides (river and land) should be maintained as grasslands, with only a sporadic presence of bushes.

3.3.8.5 Management methods

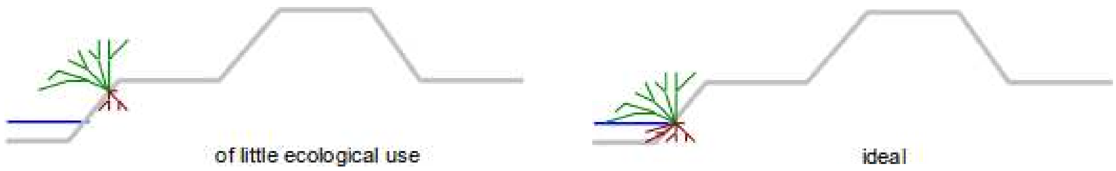
	Raised bank including the belt at the foot on both sides	**Impermeable bank**	**Permeable bank**	**Riverbed**
Herbaceous vegetation	Late mowing once a year, preferably not to be carried out before July along stretches of naturalistic significance		Respect and do not remove, especially halophyte vegetation	
Bush vegetation of limited size	Leave only sparse bush formations, to be kept at a young and flexible stage, with restricted foliage	Combat the establishment of ligneous vegetation on rigid defence works	Leave and encourage the establishment of a continuous belt at the foot of the bank	
Arboreal bush vegetation (D > 4-10 cm)	"	"	Cut down	Cut down
Medium-sized trees (D < 30 cm)	Cut down	"	"	They should not develop spontaneously, if necessary cut down
Large trees (D > 30 cm)	"	"	"	"
Unstable, deteriorating, ageing and dead plants still standing	"	"	"	"
Deadwood of considerable size	Remove	To be evaluated on the basis of each individual case, deciding whether to remove or treat according to section E) in the “Management Guidelines”		

3.3.8.6 Other instructions for intervention

Unless there is a specific need to contain hydrological risk, if there is no belt of bushes along the banks active measures should be taken to establish one, by planting cuttings.

It is advisable to retain the presence of irregularities along the foot of the bank, such as trapped ligneous waste, projecting stumps, large branches lying in the water (only the shoots of these should be cut) and local accumulations of sediment, as they represent important habitats for fish , aquatic and macrobenthic fauna.

Difficulties in gaining access (due to the steepness of the bank) and the uniformity of formations makes extensive cutting down to the ground of existing vegetation necessary.
Material resulting from cutting must be removed immediately.
The real benefit for the aquatic ecosystem takes place when the bushes establish themselves at the foot of the bank, so that the foliage touches the water and the root system extends within it (a behaviour typical of the willow), creating local diversification of the flow. This provides favourable conditions for sheltering ichthyofauna and habitats for macrobenthic fauna.



When drastic cutting down of vegetation is necessary, this represents a factor increasing the risk of invasive species entering the area. This must be carefully monitored and immediately combated should it take place. For this reason it is advisable to also provide for selective cutting down of invasive species along stretches of the riparian belt where coppicing is not provided for.
In the event that use is made of the verge, more frequent mowing must be limited exclusively to areas effectively subject to traffic.

3.3.8.7 Improvement proposals

There are none for this category.

3.3.9 CRF: Contained rivers with floodplains

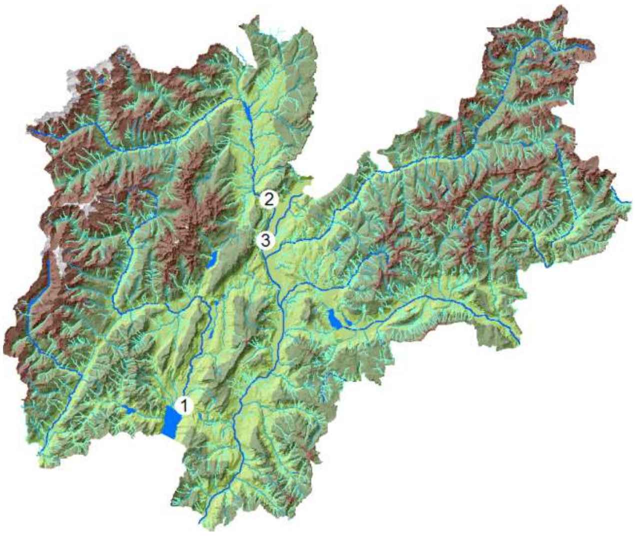
Stretches of alluvial watercourse with raised banks to the rear of the banks and hence with the possible presence of floodplains subject to periodic flooding.

Due to entrenchment of the riverbed, the height of the floodplain areas as compared to the riverbed is such that they frequently do not have the usual characteristics of a floodplain.

The vegetation cover of the floodplain is very variable, with haymaking and vegetable growing being permitted in certain areas and others being essentially abandoned and subject to work to cut down riparian vegetation for safety reasons, resulting in the creation of an alternation of surfaces with herbaceous vegetation and others with more or less extensive and structured arboreal and bush vegetation, sometimes extending to the embankments of the raised banks.

Due to the entrenchment of the riverbed the banks are usually very steep.

This management category includes the R7 and R8 types of stretch of alluvial watercourses on the valley floor.



The presence of raised banks can be noted extensively along the Adige , the Noce downstream of Rocchetta and some stretches of the River Sarca in the lower Sarca valley, the Chiese close to Lake Idro and the River Brenta.

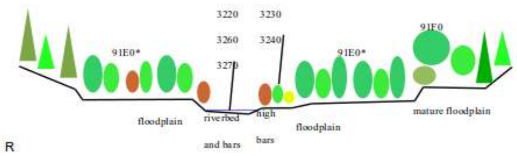
(a) 1: River Sarca at Torbole (type R8). In this case only the right-hand side is contained by a bank. The bank is very close to the riverbed, but despite this the floodplain is permanently wooded (*Ph.* Giuliano Trentini).

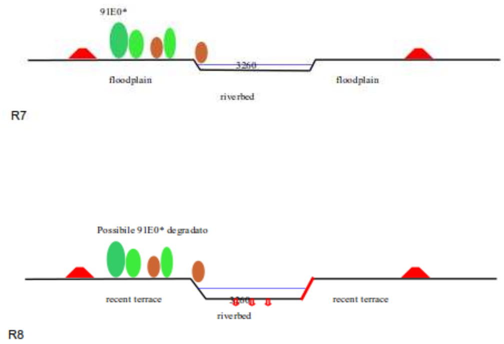
(b) 2: Noce stream at Mezzolombardo (type R7). The floodplain is only just above the riverbed, thus potentially having the typical characteristics of a floodplain. The surface is however maintained as grasslands with a few trees (*Ph.* Giuliano Trentini).

3: River Adige at Zambana (type R8), with a floodplain covered by grassland, a very steep but wooded bank and occasional bushes also on the raised bank (*Ph.* Giuliano Trentini)

3.3.9.1 Conservation of habitat and species

Natural riverbed **Modified riverbed**





In general, the highly artificial nature of the banks, also the result of entrenchment of the riverbed, means that vegetation does not develop on them, except sporadically, but there are situations with less artificial banks and the presence of narrow belts of vegetation.
The belts of vegetation along the banks, when present, cannot be referred to any of the habitats, as a result of excessive hydromorphological modification and the limited extent of the formations.
The raised banks situated well back from the riverbed also keep other anthropogenic pressure at a distance. Floodplains along the main watercourses, along the River Adige in particular, have an important role as a stopping off site for migrating birds and if appropriately managed, can also become nesting sites.
The height of the floodplain in relation to the riverbed is usually such that this does not have the typical hydromorphological characteristics of a floodplain and thus, even if wooded, it does not have the characteristics necessary for habitat `91E0*`.
These floodplain areas, even when maintained as grasslands, are significant in relation to fauna as they represent stopping off and sometimes nesting sites for important species of migrating birdlife.

3.3.9.2 Hydrological risk

The risk of flooding associated with these stretches is generally high.
In order to minimise construction costs and land occupation, at the time the sections were designed with minimum levels of roughness, namely with an almost total absence of arboreal and bush

vegetation and with all the dry surface areas maintained as grasslands. This situation, even with a revised attitude and awareness involving recognition of the fundamental role of riparian vegetation, may not leave space for its reintroduction on a large scale.
There are major limitations to the possibility of maintaining any arboreal and bush vegetation along the embankments, on the side towards the river or the other side of the banks, due to the need both to ensure the efficacy of the works and to allow continuous monitoring.

3.3.9.3 Planning of intervention

All stretches contained within banks embankments require management and regular monitoring. When the nature of the banks does not prevent the establishment of arboreal bush vegetation, evaluation of the hydrological characteristics will determine how extensive this belt may be and consequently the frequency of intervention. The frequency of intervention must be evaluated on the basis of vigour and populations, in order to ensure that the vegetation remains young and flexible .
As a guideline, intervention on the wooded parts of floodplains should take place at longer intervals as compared to the frequency determined for the banks, to ensure that mature plants can develop, maintenance being limited to the elimination of dead, deteriorating or dangerous plants, as a result of their position or lack of stability.
Work to cut down vegetation must be carried out along alternate stretches of the banks.

3.3.9.4 Management objectives

Am to ensure a belt of vegetation that is as continuous as possible along the banks, with foliage frequently touching the water and root systems extending within it, creating local diversification of the flow. On the flood plain area carry out work to ensure the formation and maintenance of a wooded belt of arboreal bush vegetation, as uneven-aged as possible, with tree coverage being maintained sufficiently sparse to allow correct stratification with bush and grassland vegetation..
Maintain the whole of the surface area of the raised bank and a wide belt on both sides (river and land) as grasslands, with only a sporadic presence of bushes.

3.3.9.5 Management methods

	Raised bank including belt at the foot on both sides	**Grassy floodplain**	**Wooded floodplain**	**Bank**	**Riverbed**
Herbaceous vegetation	Late mowing once a year, not to be carried out before July		Late mowing once a year, not to be carried out before July	Respect and do not remove, especially halophyte vegetation	
Bush vegetation of limited size	Leave only sparse bush formations, to be kept at a young and flexible stage, with restricted foliage		Leave	Leave and encourage establishment of a continuous belt at the foot	Leave, if the hydrological conditions so permit
Arboreal bush vegetation (D > 4-10 cm)	"		"	Cut down	Cut down

Continued from previous page

	Raised bank including belt at the foot on both sides	Grassy floodplain	Wooded floodplain	Bank	Riverbed
Medium-sized trees (D $<$ 30 cm)	Cut down	Leave occasional trees	The presence of large trees should be encouraged, although this presence will tend to be greater in wide wooded floodplains and more scattered and sporadic in very narrow floodplains	Cut down	They should not develop spontaneously, if necessary cut down
Large trees (D $>$ 30 cm)	Cut down	"	"	"	"
Unstable, deteriorating, ageing and dead plants still standing	Cut down	Cut down	"	"	"
Deadwood of considerable size	Remove		To be evaluated on the basis of each individual case, deciding whether to remove or treat according to section E) in the “Management Guidelines”		

3.3.9.6 Other instructions for intervention

It is advisable to retain the presence of irregularities along the foot of the bank, such as trapped ligneous waste, projecting stumps, large branches lying in the water (only the shoots of these should be cut) and local accumulations of sediment, as they represent important habitats for fish , aquatic and macrobenthic fauna.
Material resulting from cutting operations on the bank must be moved away from the bank immediately.
In phases to convert floodplains and raised banks it is necessary to provide for:

- cutting of shoots from stumps several times a year in areas which it is wished to maintain as grasslands;
- stump-grinding, which may significantly limit the vigour of new shoots, reducing conversion times and simplifying subsequent activities to cut down vegetation;
- cutting before first flowering, when invasive herbaceous species are present.

In conversion phases on the banks:

- care must be taken not to encourage more vigorous species, generally represented by trees and invasive plants;
- in order to avoid invasive species gaining the upper hand, in the initial phase it may be appropriate to leave most of the bushes (even if ageing) so that the stumps resulting from the cutting down of trees and alien plants are shaded and dominated.

3.3.9.7 Improvement proposals

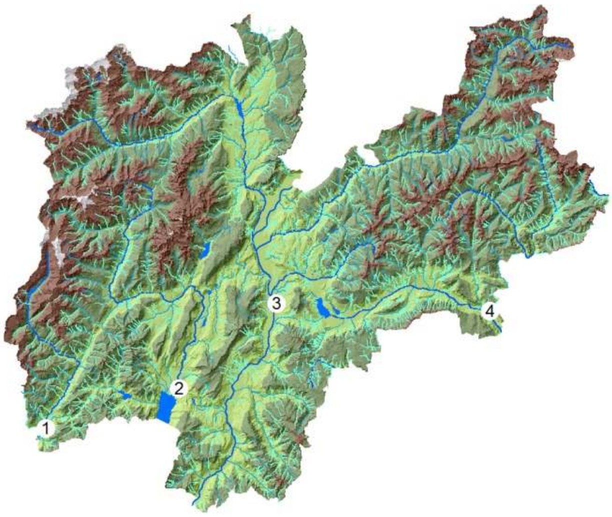
In all cases with floodplains wider than the 3 metres minimum necessary for the service track, it is appropriate to aim to reduce the slope of the bank, in order to make it more stable from the geotechnical point of view and at the same time to permit the development of riparian formations

with better structure, more stable and stabilising, reducing ecological discontinuity between aquatic and terrestrial environments and making management work easier.
The site conditions of each part of the floodplain should be considered in the context of improvement, with careful consideration of the fact that entrenchment of the riverbed and deposits on the floodplain may have led to the disappearance of the hygrophilous conditions necessary for the establishment of riparian formations. In the absence of these hygrophilous conditions there are two possible alternatives in terms of intervention:

- Aiming for the establishment of more mesophilous formations with hornbeam, elm and English oak trees, except for a narrow belt along the bank, where more typically riparian vegetation should be established. Given the greater correspondence with the effective edaphic conditions, regardless of the vicinity of the riverbed, this choice will make it possible to have a more healthy and stable population, hence of greater ecological value and with safer interaction in the event of high water runoff.
- Reducing the height of the floodplain in relation to the riverbed with appropriate levelling work, in order to provide conditions closer to those on a standard floodplain, recreating the hygrophilous conditions necessary for the development of truly riparian formations. This type of intervention also has the advantage of increasing the volume of the alluvial area of the riverbed, with a resulting increase (albeit marginal) in flood lamination capacity, increasing the buffer effect in relation to nutrients carried by subsurface flow and favouring the retention of large wood floating in the channel.

3.3.10 RMC: Reticolo minore canalizzato

Minor drainage channels of the alluvial plain flowing in agricultural or urban environments. They have small, compact channels.
They are characterised by deforestation of the banks and surrounding areas, a simplified, often very regular and prismatic riverbed and the frequent presence of permeable bank defences and embankment walls in reinforced concrete.
The little arboreal and bush vegetation present mainly develops on the edge of the bank and does not interfere with high water runoff. The lack of shade encourages the development of hydrophyte and helophyte vegetation in the riverbed.
This management category includes the D0 and D1 types of stretch of minor drainage channels of the alluvial plain.



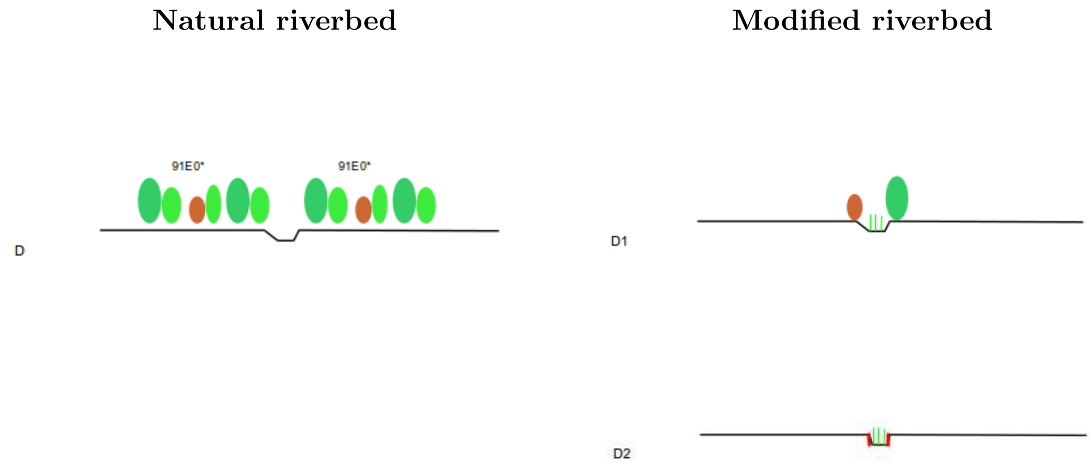
On the valley floors of the main provincial watercourses: Adige, Sarca, Chiese, Brenta.

(a) 1: Rio Lora just before it flows into the Chiese stream (type D1) (*Ph.* APPA).

(b) 2: Rio Salone at Arco, just before it flows into the Sarca (type D2) (*Ph.* Giuliano Trentini).

(c) 3: Rio di Val Negra at Trento (type D2) (*Ph.* APPA).

3.3.10.1 Conservation of habitat and species



The belts of vegetation along the banks, when present, cannot be referred to any of the habitats, as a result of excessive hydromorphological modification and the limited extent of the formations.
These watercourses usually drain the stratum and collect surface runoff during precipitation. They are therefore particularly relevant and critical, due to the entry of nutrients and contaminants of urban and agricultural origin into the hydrographic network.
The hydrophyte and helophyte vegetation favours biophysical water purification processes in the riverbed.
They can have an important role in ecological connectivity.

3.3.10.2 Hydrological risk

There is a risk of flooding associated with this category. Given the small size of the watercourses and the magnitude of the events the risk is never high in absolute terms, but the associated risk may be high if urban and not only agricultural areas are concerned.
The hydrophyte and helophyte vegetation that may develop in the riverbed can significantly reduce the runoff capacity of the channel and favour filling in, creating the conditions for the depositing of sediment transported by the current.
The arboreal and bush vegetation along the banks does not usually interfere greatly with flow runoff and mainly establishes itself on the edge of the bank. In effect, the rarity of this vegetation on the banks is mostly due to interference with neighbouring crops and not to needs related to hydrological safety.
The shading of the riverbed caused by the presence wooded belts on the banks strongly limits the development of vegetation in the riverbed and thus reduces the risk and the need for maintenance.

3.3.10.3 Planning of intervention

In the event of intense development of helophytes in the riverbed it may be necessary to carry out mowing several times a year. Intervention can otherwise take place at longer intervals, as the vegetation does not directly interfere with the flows in the riverbed.

3.3.10.4 Management objectives

Promote the establishment and continuing permanence of a continuous belt of vegetation on at least one of the two banks, preferably the southerly one. Control the development of hydrophyte and helophyte vegetation, minimising the impact on the aquatic ecosystem and biodiversity

3.3.10.5 Management methods

	Bank	Riverbed
Herbaceous vegetation	Periodic mowing, preferably on alternate banks	Periodic mowing of the part emerging from the water alone
Bush vegetation of limited size	Cultivation of a wooded belt, by selective cutting or on alternate banks. Only intervene in the context of hydrological safety in the case of plants obstructing flow runoff	They should not develop, if necessary cut down
Arboreal bush vegetation (D > 4-10 cm)	"	"
Medium-sized trees (D < 30 cm)	"	"
Large trees (D > 30 cm)	"	"
Unstable, deteriorating, ageing and dead plants still standing	Remove	
Deadwood of considerable size	"	

3.3.10.6 Other instructions for intervention

Per questa tipologia non ce ne sono

3.3.10.7 Improvement proposals

As a priority, aim to implement the provisions of paragraph 4, article 9 of LP 11/2007 in these parts of the hydrographic network, setting up wooded buffer zones along the watercourse, capable of intercepting the nutrients carried by surface and subsurface outflows (fertilisation of arable and vegetable crops, spreading of sewage on forage meadows, grazing of livestock) and by the spraying of pesticides (particularly to treat vineyards and fruit orchards). The extent of these buffer zones should be evaluated individually, however as an indication a minimum overall width of 5 m can be taken as a reference, keeping a strip of perennial grasslands around 3-4 m wide between the wooded and cultivated areas, to act as a trap for sediments. For stretches with vertical or sub-vertical banks in reinforced concrete or concrete ripraps, decisions should be made with a view to possibly substituting the existing stabilisation works with others based on permeable ripraps and with less steep banks, allowing the establishment of a belt of riparian vegetation.

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