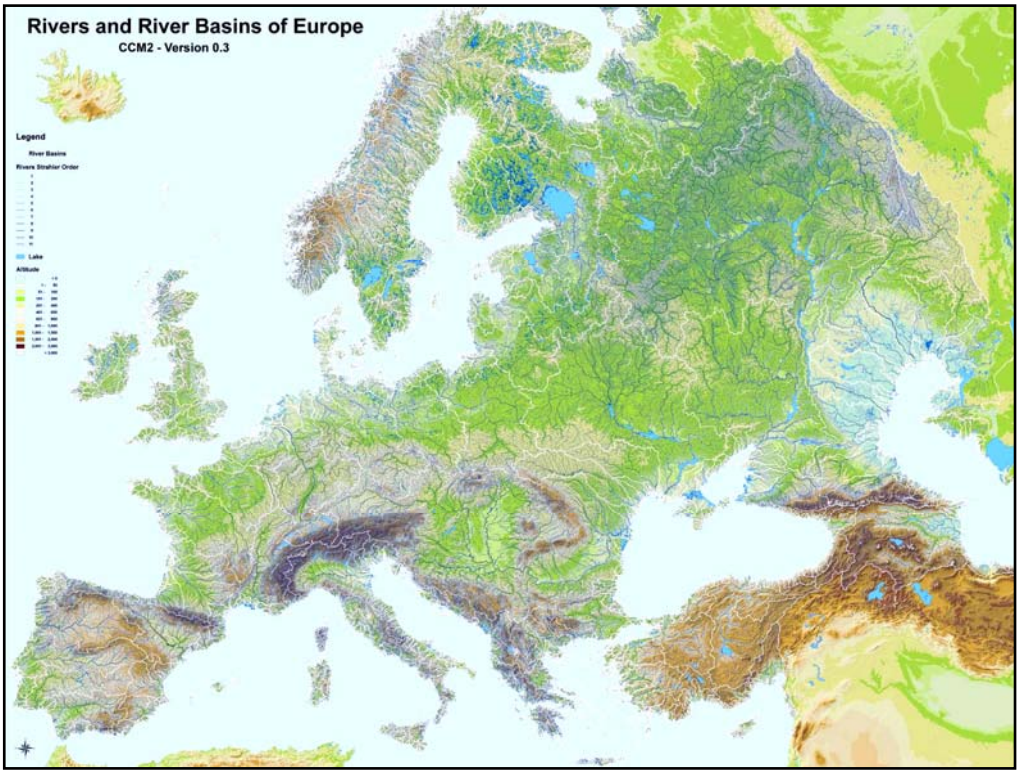
CCM River and Catchment Database

Version 2.0

Analysis Tools



Jürgen Vogt and **Stéphanie Foisneau**

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European River and Catchment Database

Version 2.0 (CCM2)

Analysis Tools

Jürgen Vogt and Stéphanie Foisneau

Table of Contents

1. Introduction

The CCM River and Catchment Database for Europe contains digital data on river networks and catchment boundaries for the entire European continent. The data are structured in a nested manner from small river reaches and their catchments to large rivers and their river basins. Different hierarchical catchment levels are linked to each other and river reaches are linked to their catchments (i.e. the area they drain) through a common identifier.

River reaches and catchments carry a set of attributes, including their Strahler Order and their Pfafstetter Hydrological Feature Code. Both attributes are fundamental for understanding and analysing the data and are briefly introduced below. Detailed descriptions of the development of the database, the underlying data and the characteristics of the database are given in Vogt *et al.* 2007.

Following this introduction we explain the theoretical concepts of Strahler ordering and of Pfafstetter coding, followed by the description of two tools, which were developed to support working with the database. The first one allows analysing upstream – downstream relationships within river networks. It is based on the Pfafstetter hydrological feature codes. The second one allows for displaying the catchment of a hydrological monitoring station by clicking on the station. This tool is specific to a set of several thousand stations from EEA's Waterbase, which have been located within the CCM River and Catchment database.

2. Theoretical Concepts

2.1. Strahler Order

The Strahler order (Strahler 1957, 1964) is based on the structure of the river network and reflects the level of each river reach in the hierarchy of the river network. Strahler ordering starts from the smallest river reaches having no tributaries, which obtain a Strahler order of one (so-called first order channels). When two first order channels join, a second order channel is formed. This second order channel extends down to the point, where it joins another second order channel. At this point a third order channel is formed, and so on. If a channel of any given order joins a channel of a higher order (e.g., a channel of order one joins a channel of order two or three) no increase in Strahler order occurs. The trunk stream of any catchment carries the highest order of the entire upstream system. The principle is illustrated for the Thames River Basin (UK) in Figure 1 below.

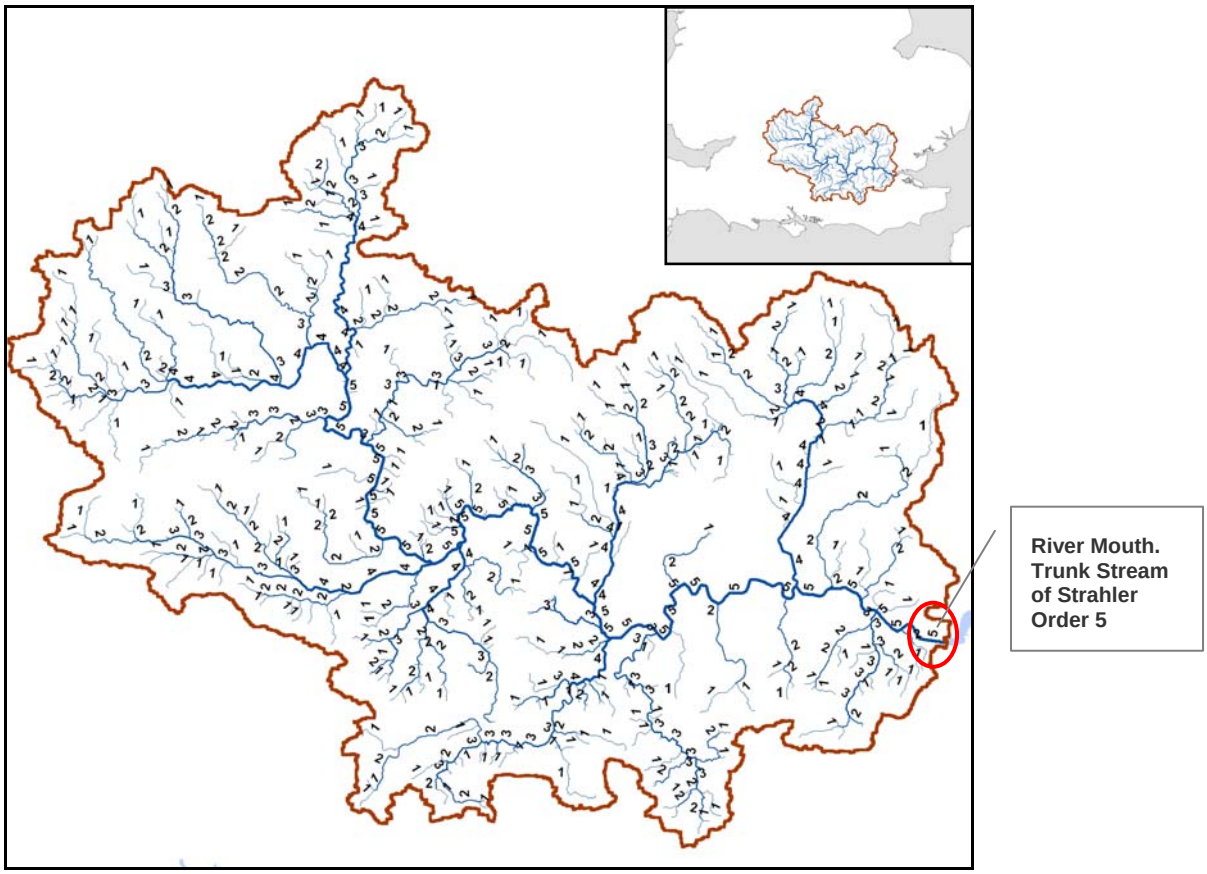


Figure 1:

Thames River Basin, UK: Principle of Strahler Ordering.

The Strahler system of a river network carries information on the dimension and complexity of a drainage network and serves as a basis for the calculation of a series of characteristics of the system (Strahler 1964). The Thames river basin as shown in figure one, for example, obtains a Strahler order of five in the CCM River and Catchment Database. The Danube River Basin in contrast reaches an order of nine due to its larger size and higher complexity.

Strahler orders are an easy way to group river reaches and catchments hierarchically. Therefore all catchments carry the Strahler order as an attribute. The principle is illustrated in Figure 2, where different levels of catchments (sub-basins) of the Thames River Basin are shown.

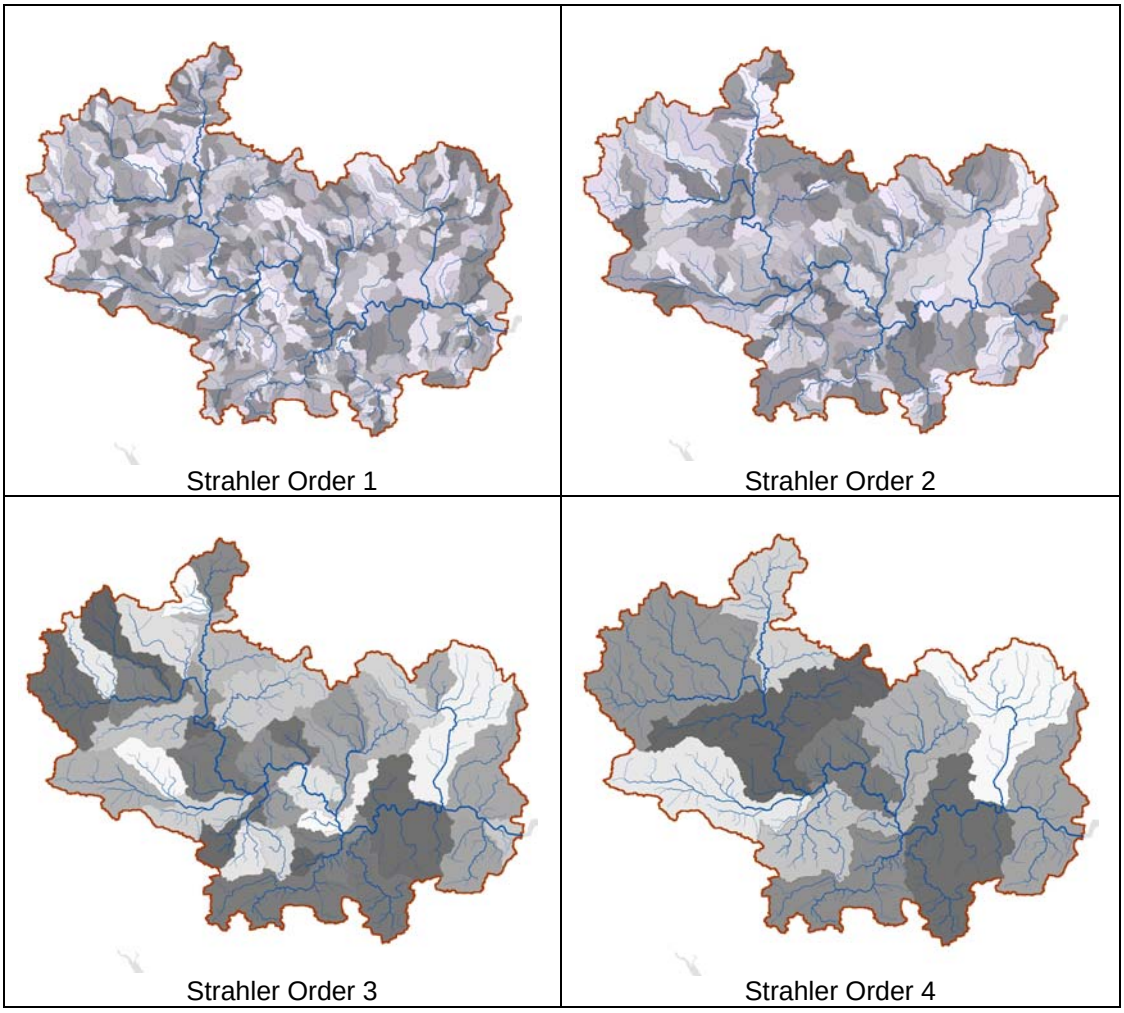


Figure 2:

Thames River Basin: Sub-basins (catchments) of Strahler Orders 1 to 4.

2.2. Pfafstetter Hydrological Feature Codes

A more complex and smart way to characterise the structure of a river network is the assignment of structured hydrological feature codes. The Pfafstetter system is an example of such a coding system that is widely used. It consists of a numbering scheme developed by Otto Pfafstetter, a Brazilian engineer (Verdin and Verdin, 1999). This system has been recommended by the GIS Working Group under the Common Implementation Strategy for the Water Framework Directive (Vogt *et al.*, 2002).

Following the Pfafstetter logic, river basins and drainage networks are tagged according to a numbering scheme based upon the topology of the drainage network <u>and</u> the size of the surface area drained. The numbering scheme is self-replicating, making it possible to provide identification numbers to the level of the smallest river reaches and sub basins. For a given location it is possible to

automatically identify all upstream sub basins, all upstream river reaches, or all downstream reaches solely from the code without the need to look at a graphical representation of the river network itself. This allows for fast queries on a database.

For assigning Pfafstetter codes first the main stem of the river network of a given river basin has to be identified. This can, for example, be done automatically, based on the flow length. Once the main stem is identified, the area drained by this river (the river basin) is subdivided into coded sub-basins and inter-basins. The four largest tributaries, according to the criterion of area drained, form sub-basins. These are assigned the numbers 2, 4, 6, and 8, in the order in which they are encountered as one goes upstream along the main stem.

Next, the inter-basins are numbered 1, 3, 5, 7, and 9, again working upstream from the mouth of the main stem. Inter-basin 1 is the area drained by the main stem between the mouth of sub-basin 2 and the mouth of the main stem. Inter-basin 3 is the area drained by the main stem between the mouths of sub-basins 2 and 4. Inter-basin 9 always consists of the headwaters area of the main stem, and by definition always drains more area than sub-basin 8 (9 being the remainder of the main stem and hence more significant than 8, a tributary). If a closed basin is encountered, it is assigned the number 0 (zero).

It should be noted that the river reaches along the main stem are identified by the inter-basin codes. Ultimately, the inter-basin codes define the full river network. They also identify the areas that drain in a diffused manner into that network. This system is then iteratively repeated for the sub-basins and inter-basins down to the level of the smallest river reaches. Due to its characteristics the Pfafstetter system allows to add more detail as more information becomes available, without necessarily disrupting the higher level codes.

Figure 3 demonstrates the principle of Pfafstetter coding. The resulting coding for the Thames River basin is shown in Figures 4 and 5.

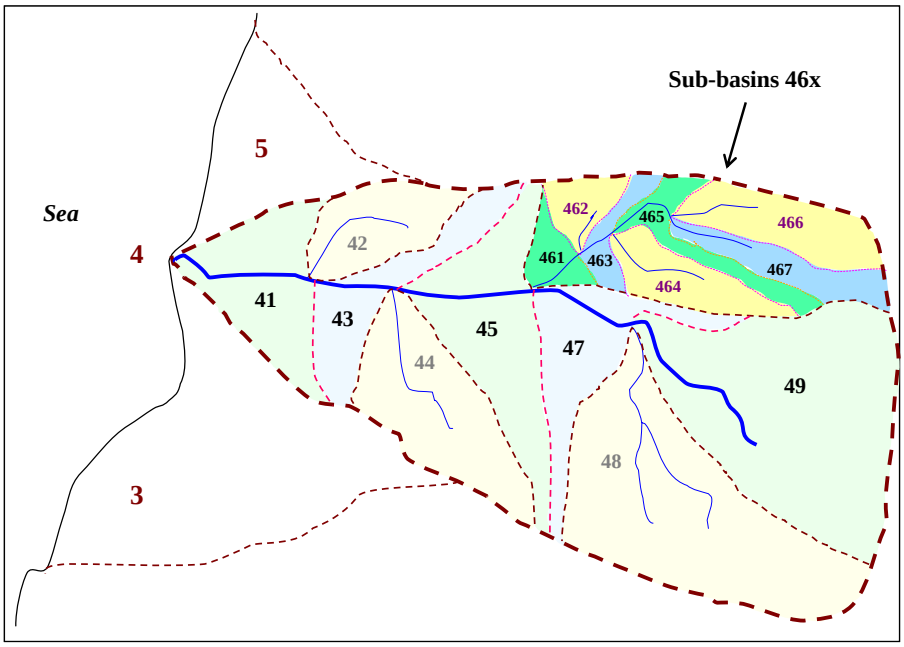


Figure 3:

Principle of Pfafstetter Coding for a Hypothetical River Basin with Code 4.

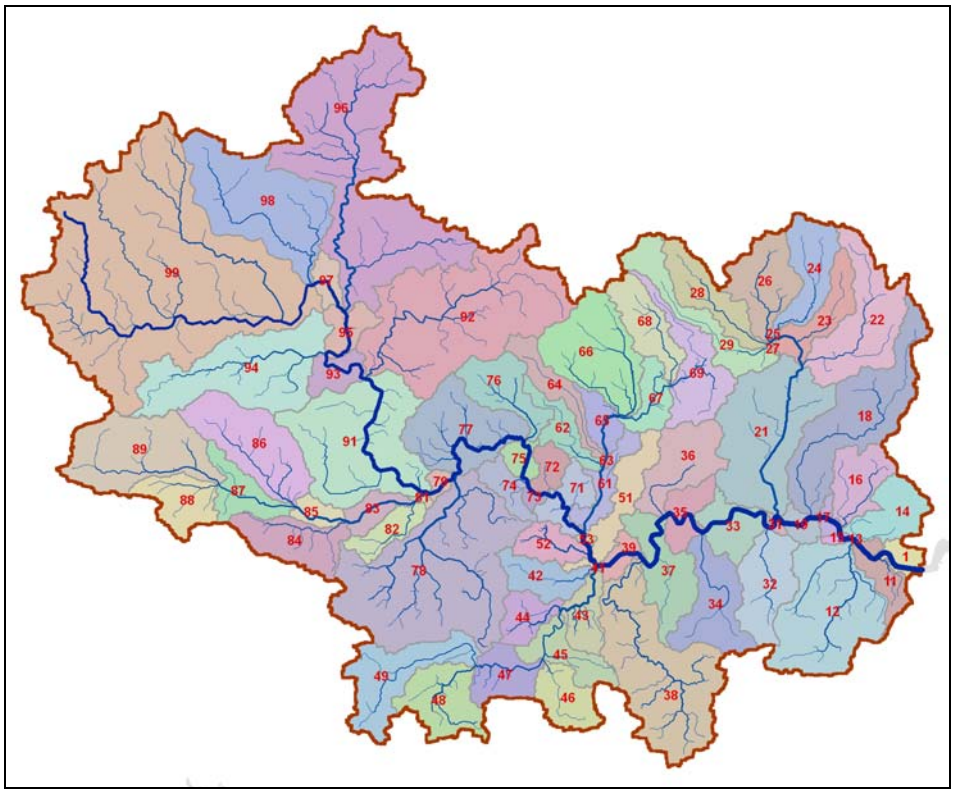


Figure 4:

Thames River Basin: Pfafstetter Codes of Level 2.

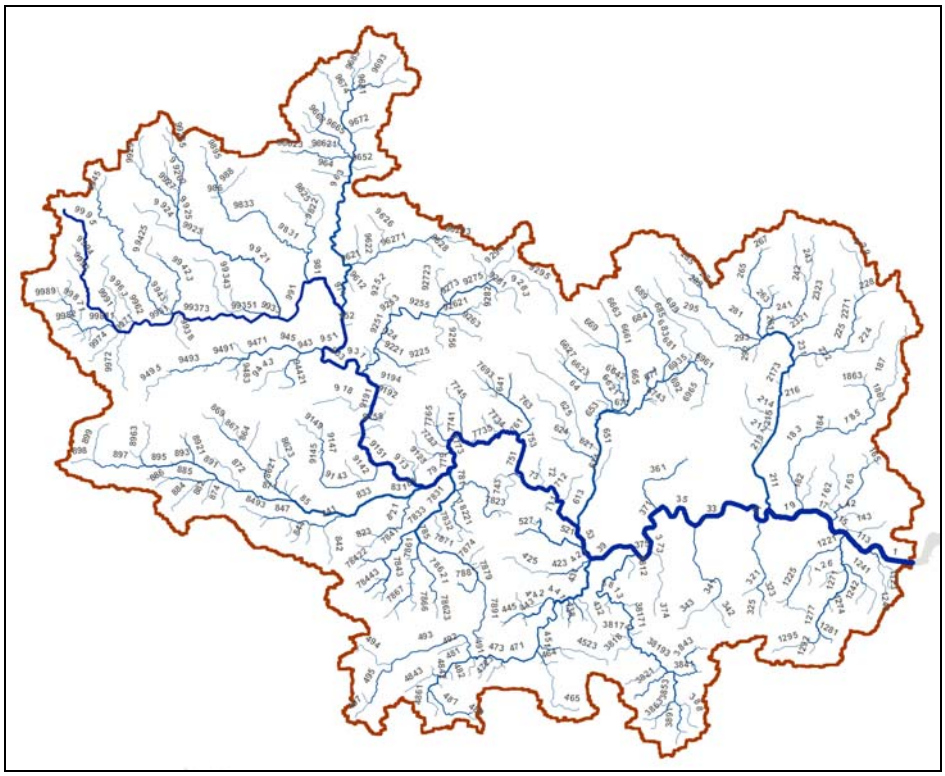


Figure 5:

Thames River Basin: Full Pfafstetter Codes.

Once Pfafstetter codes are assigned, they can be used to analyse upstream-downstream relationships within a river network and its sub-basins. The analysis is based on simple larger-smaller and odd-even comparisons of the individual digits of the code. An example is given in Figure 6.

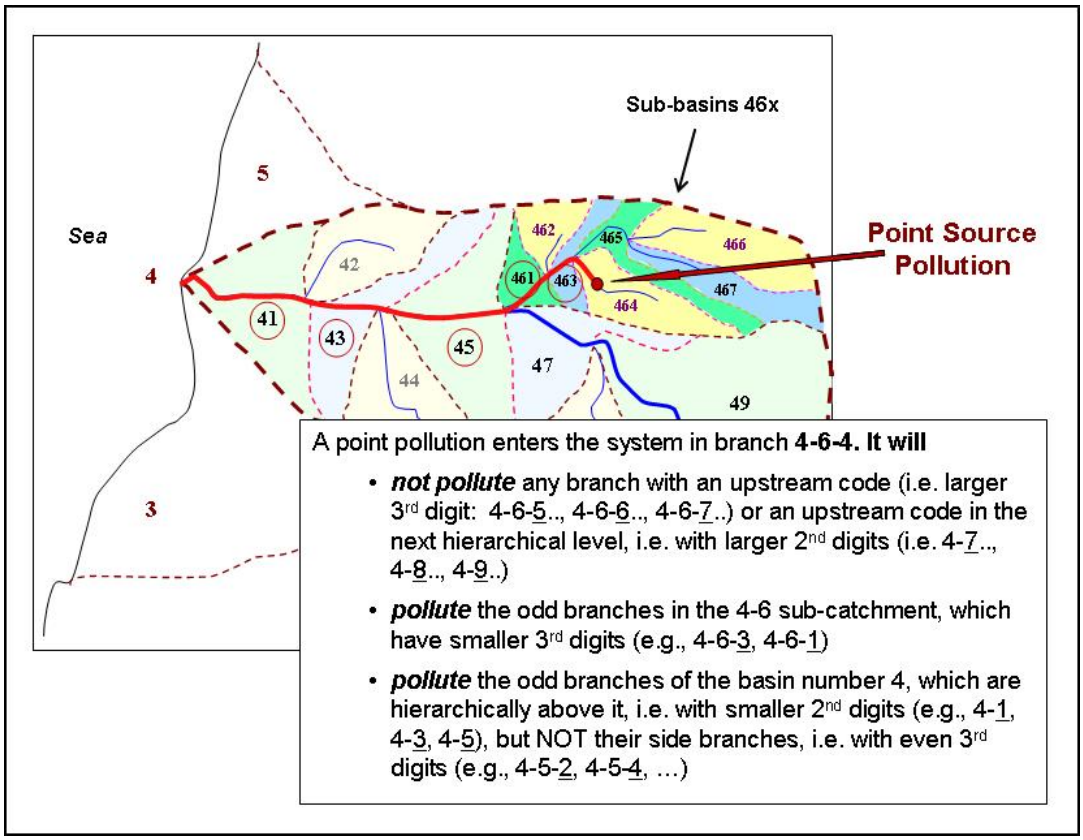


Figure 6:

Example of Analysing Pfafstetter Codes.

Figure 6 illustrates the concept for identifying river stretches affected by a point source pollution entering the system in the branch with code 464. Note that the code is not to be understood as a number (i.e. fourhundertsixtyfour) but that the individual digits of the code have to be considered (i.e. four-six-four). In the example a point source pollution enters the drainage system at branch 4-6-4 of a hypothetical river basin with code 4. By simple larger-smaller and odd-even comparisons of the different digits, potentially polluted stretches can easily be identified. Detailed explanations are given in the figure. The same applies for the identification of upstream river stretches and their catchments. An example for the latter case would be the identification of potential source areas for a pollution measured at a given point in the system.

The simplicity of the code and the fact that it implicitly encodes the topology of the system allows for the development of automatic queries on a database without even displaying the river system graphically.

3. Analysis Tools

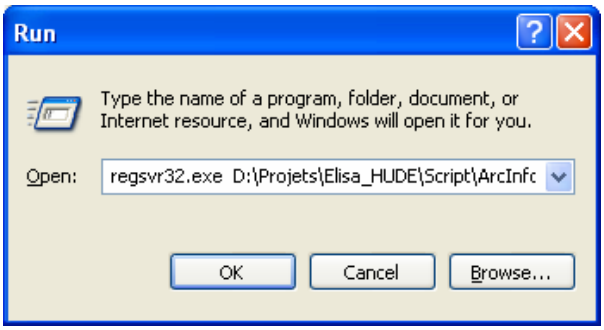
The tools described below have been developed in Visual Basic and are delivered in the form of Dynamic Link Libraries (DLL). Each DLL needs to be registered with the operating system and declared in ArcGIS. After that, the tools will be usable as an extension to ArcGIS.

3.1. Installing the Tools

3.1.1. Registering the Tools

Before using a tool, it needs first to be registered:

1. Save the DLL in a directory of your choice.
2. Open the Windows **Start menu** and launch the **Run window**.
3. Type *regsvr32.exe <Your Path> <DLL Name>*:



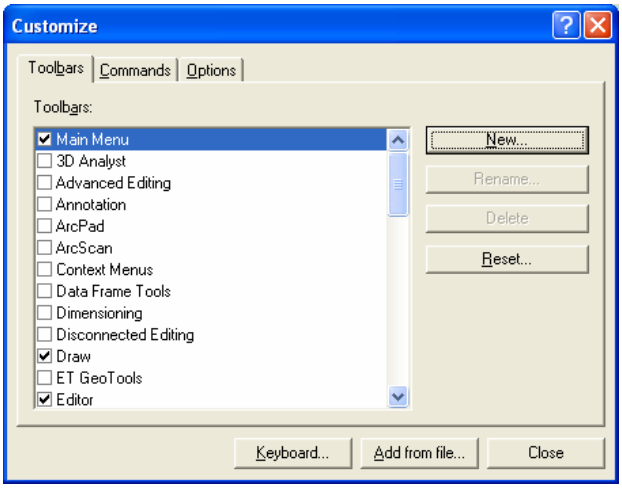
4. Click OK.

The following window should appear to indicate that the registration was successful.

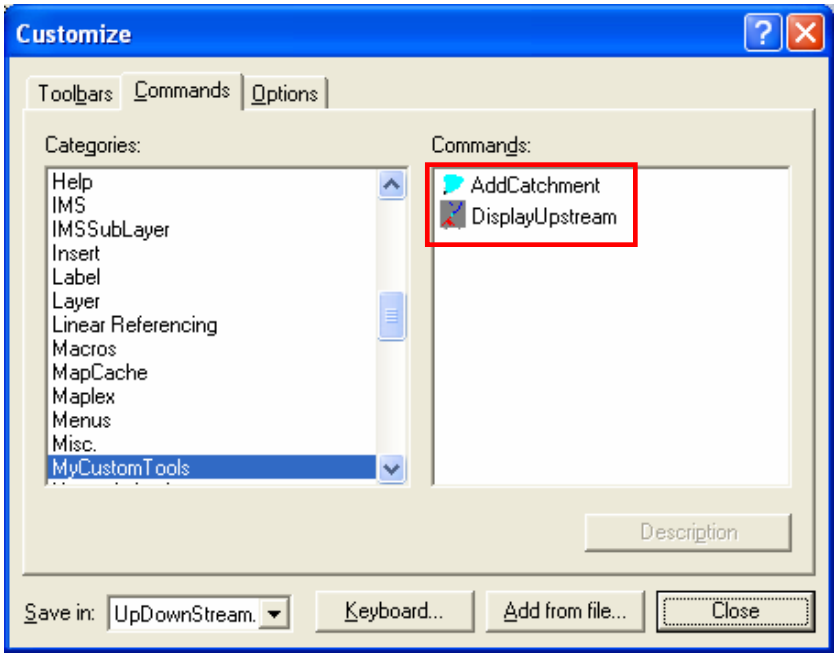
3.1.2. Declaring the Tools in ArcGIS

The second step consists in declaring the tool in ArcGIS.

1. Open the **Tools menu** and then the **Customize dialog**.
2. Select an existing toolbar or optionally click on **New** to define your personal toolbar.



3. Under the Commands tab, click on **Add from file** and select the Tool to be declared.



4. Drag the tool into an existing or your personal toolbar.
5. If the corresponding toolbar is activated, the tool icon should now be visible in ArcGIS.

3.2. Uninstalling the Tools

In case you want to uninstall a tool, use the un-register command

1. Open the Windows **Start menu** and launch the **Run window**.
2. Type *regsvr32.exe /u <Your Path> <DLL Name>*:

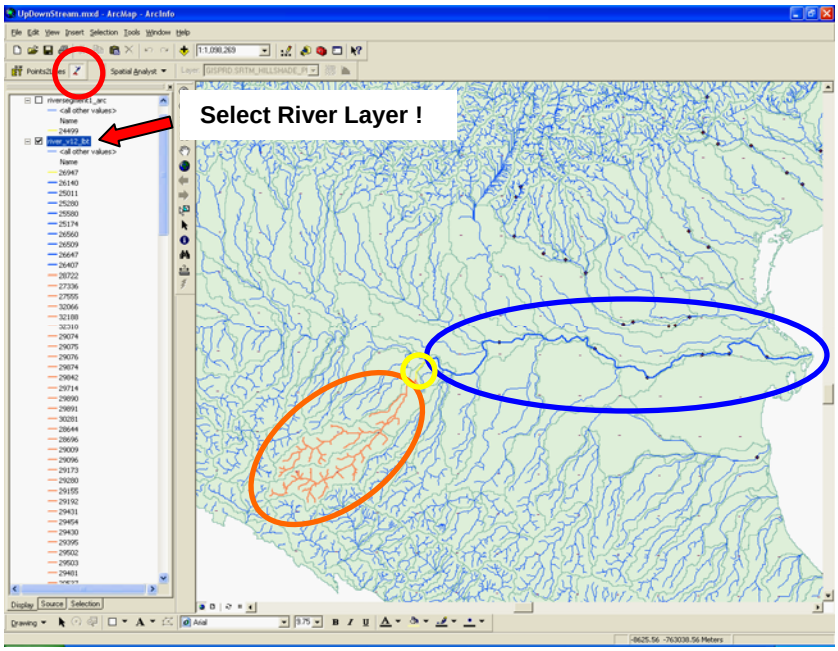
3.3. Upstream – Downstream Analysis Tool

The **DisplayUpstreamDownstream** GIS Tool allows to identify and to display both the upstream and the downstream river segments with respect to a selected segment of a river. The purpose of this tool is to rapidly identify river stretches that can be affected by a pollution entering the river network in the selected river segment and/or to identify the potential source area of a pollution measured in the selected river segment.

3.3.1. How to Use the Tool

1. In the ArcGIS Layers list, select the river layer for which you want to display the upstream and the downstream rivers.
2. Click on the tool icon  .
3. Click on one river segment you want to study.

All upstream rivers will display in orange, the downstream river stretches in thick blue and the selected river stretch itself in yellow.



3.3.2. Error Messages

In case you did not select a river layer layer, the following error message will appear.

If the selected river theme doesn't have the Pfafstetter information, the following error message will appear.

3.3.3. Known Limitations and Areas of on-going Development

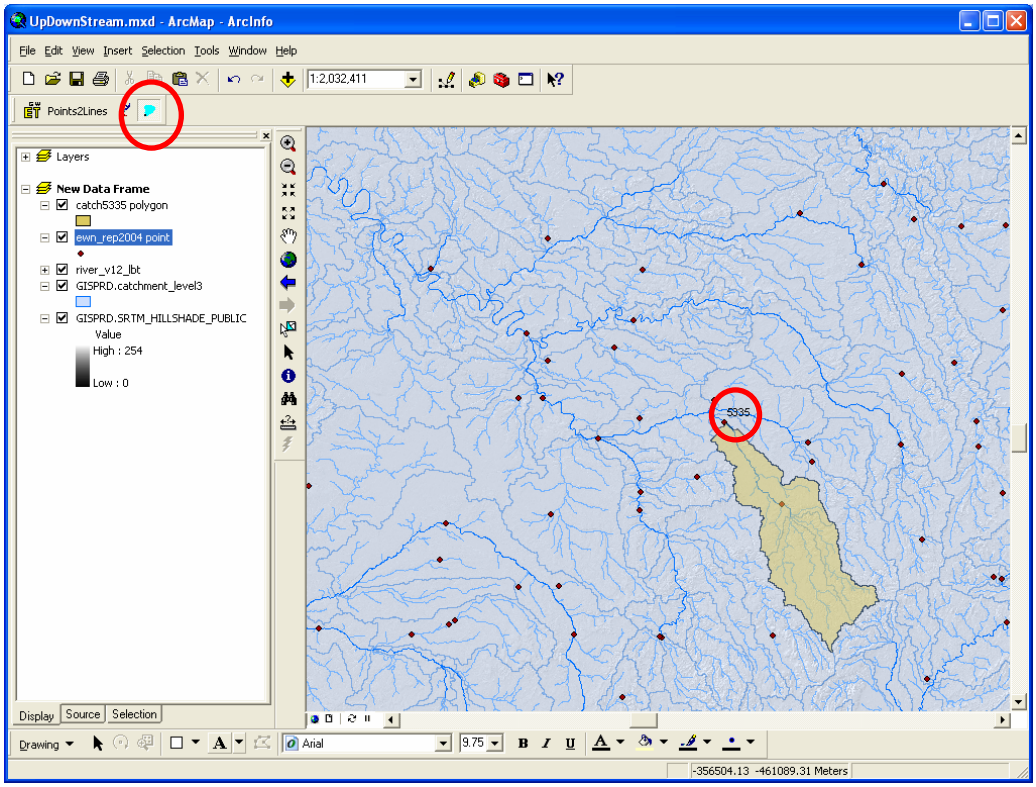
The current Upstream/Downstream tool is a prototype developed with data from the CCM River and Catchment database, version 1.2. It will need to be tested with and adapted to the upcoming version 2.0 of the database, which will contain Pfafstetter codes amended by unique identifiers for all European river basins and coastal waters.

3.4. Station Catchment Tool

The **AddCatchment** GIS Tool allows loading the catchment of a selected measurement station into the ArcGIS project.

3.4.1. How to Use the Tool

1. Select the station layer in the layers list.
2. Click on the tool icon  .
3. Click on a station for which you want to load and display its corresponding catchment.



4. The catchment of the station will be loaded and displayed. At the same time the station will be labelled with its station code (STATCODE).

3.4.2. Error Messages

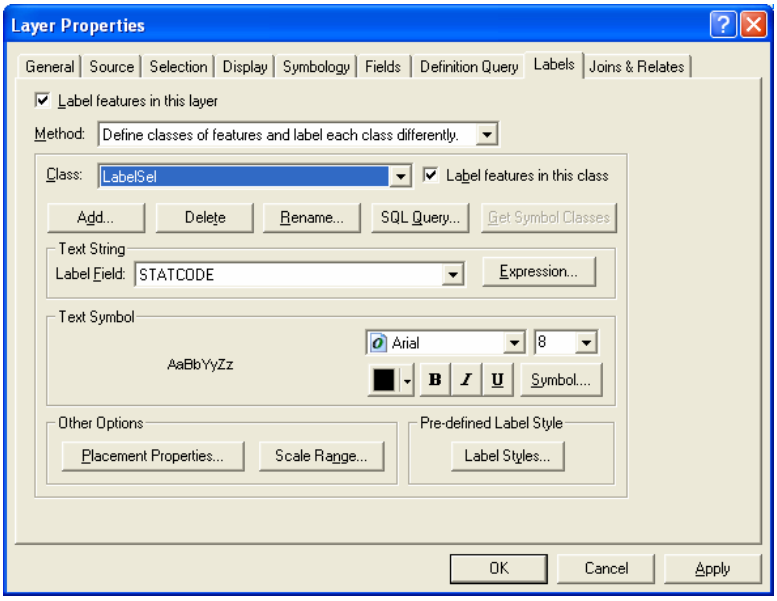
In case you did not select a station layer in the layers list, the following error message will appear:

If the selected station layer does not point to the EEA Eurowaternet Stations positioned on the CCM River network, the following error message will appear:

3.4.3. How to Suppress the Labels

To suppress the station label created by the tool:

1. Open the **Properties Window** of the station layer
2. Open the **Labels** Tab
3. Select the “LabelSel” and delete it.



3.4.4. Known limitations and areas of on-going development

The current AddCatchment tool is a prototype developed with data from the CCM River and Catchment database, version 1.2. It will need to be tested with and adapted to the upcoming version 2.0 of the database. Currently the tool works with station and catchment data stored on path \agrienv\elisa\database\ eurowaternet2004, which contains the measurement stations for the stations stored in the EEA-Waterbase 2004 and their corresponding catchments.

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