

Manual and Guideline of Water Assessment in Central Asia

Michael Walther,
Larissa Kogutenko & Safiya Asalbekova



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Manual and Guideline of Water Assessment in Central Asia

**Michael Walther,
Larissa Kogutenko and Safiya Asalbekova**

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1. Introduction/ Preface

About the authors



Prof. Dr. Sc. Michael Walther is the Founder and First UNESCO Chair Holder on Environmental Sciences in Eastern Central Asia at the Mongolian Academy of Sciences in Ulaanbaatar and works in the fields of Geomorphology, Climate Change, Geoecology and Natural Resource Management for more than 30 years in Central Asia, especially in Mongolia and Kazakhstan. He studied Geosciences, Biology and German Studies at the Freie University of Berlin. Beside his teaching activities at different Universities in Germany, Mongolia and Kazakhstan his special research interest is focused on environmental change in glacier-, lake- and periglacial-studies in their relation to water management issues.

For more than 10 years, I teach students on the IWRM Master's programme at the German-Kazakh University (DKU) in Almaty as part of my teaching activities. I am proud to have introduced management students to the skills they will need later in their professional lives, and I look forward to continuing to do so. I am grateful to those who supported me above all else. I would like to thank my wife and my dog Balu above all. I would be remiss if I did not also mention the presidents and rectors of the DKU, Prof. Dr. Gerlach, Dr. Kaiser, Prof. Dr. Ungvari and Prof. Dr. Rommel, who have always been committed to this endeavour. At the first years Dr. Falk Juri Knauff supports in his function as Prorector. I would be remiss if I did not acknowledge the instrumental role of Prof. Dr. Tilman Rost and his team from the Free University of Berlin. His unwavering efforts and connections with the DAAD were indispensable in making this teaching possible. At the DKU, Dr. Barbara Janusz-Pawletta, Dr. Larissa Kogutenko, Dinara Seidazimova, Symbat Dildabekova and the many committed students (in particular Safiya Asalbekova, Natalya Kim, Diana Aripkhanova, Gulsara Rahmikhudoeva and Gulzhan Zhanat) have made this field study a model of success.



Dr. Larissa Kogutenko is the coordinator of the Integrated Water Resources Management master program in Kazakh-German University. Her main research interests are monitoring of the development of the components of cryosphere in the zone of runoff formation; study of climatic conditions of runoff change; climate change in Central Asia and its impact on various ecosystems. She is an author and co-author of the series of articles on glacier degradation in Tien-Shan Mountains and other Central Asia regions. Larissa holds a master's degree in Hydrometeorology from Al-Farabi Kazakh National University (Kazakhstan) and PhD in Climate System and Climate Change in Nanjing University of Information Science and Technology (China).



MSc Safiya Asalbekova is a specialist of the Integrated Water Resources Management Project at the Kazakh-German University. She holds a Bachelor's degree in World Economics from Khorog State University and a Master's degree in Integrated Water Resources Management from the Kazakh-German University. In her Master's thesis, she worked on a project on the revitalization of *Apocynum* plant (Kendyr) technology aimed at effective land and water management. She participated in field research on the Kaskelen River, which gave her a deeper understanding of the practical aspects of aquatic ecosystem monitoring and assessment. Her professional interests include assessing the impacts of climate change and pollution on water quality and developing and implementing integrated approaches to water resources management in Central Asia.

About this Handbook

Why water monitoring and assessment are important?

Water quality assessment is one of the crucial scientific and practical analyses to identify the possibility of water consumption for different human needs and nature/ecosystem conservation for future generations. Water quality can be measured and monitored in rivers, springs, creeks, swamps, estuaries, wetlands and lakes what is called aquatic systems. Quality parameters, such as biological, chemical and physical indicators identify the combination of values that influence the composition of water. Monitoring and comparison of different water habitats (macro invertebrates) in biological monitoring provides an information of water quality and allows to make a quick assessment. Biological attributes refer to the number and types of organisms that inhabit a waterway. Chemical and Physical monitoring requires additional tools for checking the water quality and possible contaminations, which easily distinguish the certain parameters for further evaluation. Some chemical measurements actually indicate the physical presence of pollutants in water. Collected results for all categories of monitoring may give qualitative and quantitative analysis of water body. The more we monitor the water the better we will be able to recognize and prevent contamination problems. Future Water Managers must know, about what you are talking. **You can only manage something, when you are deeply informed about that, what you have to manage.**

Water quality assessment is the overall process of evaluation of the physical, chemical and biological nature of the water, whereas water quality monitoring is the collection of the relevant information. This manual concentrates on the whole assessment process, in different types of water bodies. The presence of contaminants and the characteristics of water are used to indicate the quality of water. These water quality indicators can be categorised as:

- **Biological:** invertebrates, algae
- **Chemical:** pH, dissolved oxygen, nutrients (including nitrogen and phosphorus), organic and inorganic compounds (including toxicants)
- **Physical:** temperature, turbidity and clarity, color, salinity, suspended solids, dissolved solids, odor, discharge

Measurements of these indicators can be used to determine, and monitor changes in water quality, and determine whether it is suitable for the health of the natural environment and the uses for which the water is required. And according to the Table 1 below main advantages and disadvantages of biological, physical and chemical monitoring were indicated:

Tab 1: Main advantages and disadvantages of biological, physical and chemical monitoring

Biological monitoring	Physical/Chemical monitoring
<i>Advantages</i>	
Spatial and temporal integration	Possibility of very fine temporal variations
Response to chronic, minor pollution events	Possibility of precise pollutant determination
Signal amplification (bioaccumulation, biomagnification)	Determination of pollutant fluxes
Real time studies (in-line bioassays)	Valid for all water bodies, including ground waters
Measures the physical degradation of the aquatichabitat	Standardisation possible

<i>Disadvantages</i>	
General lack of temporal sensitivity	High detection limits for many routine analyses (micro-pollutants)
Many semi-quantitative or quantitative responses possible	No time-integration for water grab samples
Standardisation difficulties	Possible sample contamination for some micro-pollutants (e.g. metals)
Not valid for pollutants' flux studies	High costs involved in surveys
Not adapted to ground waters	Limited use for continuous surveillance

This Manual is dedicated to assist the future students before the field trip, teach them how to operate with proper equipment: photometer - Aqua check, PCE-PHD1, electromagnetic flowmeter and GPS. It provides the possibility to find out what are the quality parameters they can meet during the field trip and how to calculate and analyse them.

Physical and Chemical testing allow information to be gathered about specific water quality characteristics. A variety of water quality tests can be run on fresh water – including temperature, dissolved oxygen, pH, suspended solids, phosphorus, nitrogen, chlorine, total dissolved solids, fecal coliform levels and many others. It is recommended that four core measurements be taken when doing physical/chemical testing – temperature, dissolved oxygen, pH, and conductivity. phosphorus, nitrogen, and alkalinity may be added to your list.

Water quality and environmental conditions can change throughout the day, so monitoring at approximately the same time of day is important.

! Security hint:

! If conditions are unsafe for any reason, including high water or slippery rocks, do not take samples and measure parameters.

Why IWRM students make such analyses?

In the framework of IWRM Master Program there is a special discipline called “Project Part 1 and 2”, which provides an opportunity for students to learn how to operate the main equipment, measuring chemical and physical parameters of water quality during the field trips in Kaskelen River Basin (KRB). As a second part of Project students assess the data, analyse them and finalise the report. These activities strengthen understanding of students and educate them for further development of the water quality management in Central Asian countries, as well as train them to improve the ability to monitor the water quality issue in habitable areas.

Due to our experience most of the students do not have any knowledge about nature sciences and they are „non-nature-scientists“. So it is important for them to learn some basics in Geo- and Bio-Sciences, Physics and Chemistry to have a better understanding about water and its principal characteristics in an aquatic ecosystems.

Lessons learnt during the previous field trips in Kazakhstan (2014-2024)

During the previous field trips, conducted in 2014 till 2024 master students observed the territory of Kaskelen River Basin (KRB) 25 km west of Almaty and collected the data. Field works have been usually planned for the period from late May to mid-June, and research area had been divided into upper (mountainous) and urban and rural areas. According to received results by different working groups of students in 2015 and 2016 two descriptive reports were created. The monitoring and sampling points

are clearly defined after 10 years of the study. So it was possible always to focus on the same locations. A permanent data collection of chemical and physical parameters would be desirable however could not be realized due to logistic circumstances. Nevertheless, the KRB developed to an excellent study area in order to demonstrate what Water Quality Monitoring means and makes the students familiar with different methods.

Aim of the Handbook

This guideline is intended for the study by future students before a field trip, learn how to operate with proper equipment, find out, what are the quality parameters they can meet during the fields and how to calculate and analyse them. This handbook is composed as a manual for the students how to handle the equipment, sample and analyse in the field and evaluate their monitored values leading to a report about water quality in the study area.

Content of the Manual

This manual contains three main chapters, which are presented, as follows: the first chapter is dedicated to biological water quality, parameters for its identification, description of the equipment and which activities were made while using the equipment, standards of biological parameters in Central Asia and its comparison to EU standards, including notes about outcomes and recommendations. The evaluation process of the values is described at the end of the related chapters. The second and third chapter is organised in the same way as the first one, and will be treated to the chemical and physical components of water quality assessment. The copy templates for every investigation method (Biological, Chemical and Physical) are provided at the end of each chapter too in order to be copied by the students.

About the 2nd improved and extended edition

In this second edition, the authors have placed particular emphasis on the rather low-threshold evaluation and comparison of the data as well as further information on the preparation of reports.

Analysing and calculating the data

After the field work and sampling, which in certain cases must still be analysed in the laboratory, the data must be evaluated, as the primary aim should be to obtain an objective picture of the ecological status of the water body and its environment. For reasons of traceability, this includes a description of the investigations, the equipment used and a valorisation of the measured values obtained with their maxima and minima. This is best done with the help of clear tables (e.g. Excel, Numbers etc.), which are then presented in diagrams.

Comparison of data (water standards)

The WHO has published numerous reports on water standards for drinking water with regard to chemical pollution. The standards have a global significance, but must be adapted to regional or even local characteristics. For example, national states repeatedly adjust some values with minor deviations.

Preparation of reports

The aim of reports is to put the collected data into context and, following a comparative assessment, to arrive at a qualified statement regarding

- the ecological status
- water management and utilisation modalities,
- water and nature/biotope protection, taking into account the water environment,
- the possibilities of industrial utilisation with regard to future prospects.

A report should always consist of the following chapters:

1. Introduction with a description of the assignment, the expected general objective, the geographical description of the study area/watershed with a brief geological overview, general hydrology (1), climate status (2) and, if applicable, trends with regard to air temperature and precipitation, vegetation cover (3) and forms of land use (4).

2 The description of the results of the measurement data is subdivided according to the methods of biology, chemistry and physics described here. At the end of each chapter there should ideally be a

comparison with older available data from which a trend can be derived. However, older - and methodologically comparable - data are often not available, so that water standards (e.g. drinking water standards) must be used.

3. A chapter summarising the results should conclude a comparative assessment of the work: This should then include sub-chapters such as discussion and conclusions. Conclusions are NOT a summary of the results, but contain forward-looking recommendations that must reflect an ecological, economical or infrastructural consequence. 'What will happen, if

About the 3rd improved and extended edition

The third edition of the *Manual and Guideline of Water Assessment in Central Asia* contains an improved description of individual chapters on the evaluation and validation of measurement results. Furthermore, the appendix has been expanded to include a complete list of all invertebrates found to date and their frequency, and the glossary has been revised. MSc Ms Safiya Asalbekova was able to make significant contributions to this edition thanks to her many years of experience.

Experience since the first edition has shown that the assessments of invertebrate biodiversity and the discharge measurements for the river basin are of outstanding importance. Further additions and explanations have been made to the description of the assessments. The discharge calculations have been reorganized and simplified.

List of Abbreviations/Acronyms

A	ADB	Asian Development Bank
	AWDO	Asian Water Development Outlook
C	CBO	Community based Organisation
	CDS	Collector Drainage System
D	DKU	Deutsch-Kasachische Universität
E	EA	Environmental Assessment
	EIA	Environmental Impact Assessment
	EU	European Union
	EWDF	European Water Directive Framework
F	FAO	Food & Agricultural Organisation
G	GWP	Global Water Partnership
H	HPP	Hydro Power Plant
I	IRBM	Integrated River Basin Management
	IWM	Integrated Water Management
	IWRM	Integrated Water Resource Management
K	KAP	Knowledge-Attitude-Progress
	KRB	Kaskelen River Basin
L	LPA	Local Protected Area
M	MS	Monitoring System
N	NP	National Park
	NR	Nature Reserve
P	PA	Protected Area
R	RE	Renewable Energy
S	SMART	Specific (Significant), Measurable, Accepted, Realistic, Terminated
	SPA	Strictly Protected Area
U	UN	United Nations
W	WASH	Water, Sanitation and Hygiene (UNICEF)
	WHO	World Health Organisation
	WRM	Water Resource Management

2. Biological Parameters

Biological monitoring means identifying and counting macro invertebrates. The main goal of biological monitoring is a quick assessment of both water quality and habitat. The abundance and diversity of identified macro invertebrates is an indication of overall stream quality. Macro invertebrates include aquatic insects, crustaceans, worms and molluscs that live in various stream habitats and derive their oxygen from water. They are used as indicators of stream quality. These insects and crustaceans are impacted by all the stresses that occur in a stream environment, both man-made and naturally occurring.

Advantages of macro invertebrates as a water quality indicator:

- they are affected by the physical, chemical and biological conditions of the stream;
- they can't escape pollution and show effects of short- and long-term pollution events;
- they are relatively long lived – the life cycles of some sensitive macro invertebrates range from one to several years;
- they are an important part of the food web, representing a broad range of trophic levels;
- they are abundant in most streams. Some 1st and 2nd order streams may lack fish, but they generally have macro invertebrates;
- they are a food source for many recreationally and commercially important fish;
- they are relatively easy to collect and identify with inexpensive materials;
- they are adaptable to extremes of water flow.

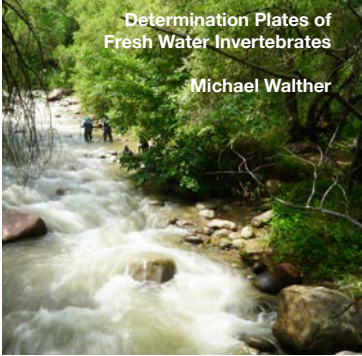
2.1 Equipment for biological Analysis

This subchapter provides a description of the equipment required for biological analysis (Table 2.1). For the qualitative biological analysis, all equipment must be carefully prepared and checked for serviceability.

Tab 2.1: Equipment list and their description

Name	Picture, photo	Brief description
Plastic jar with a magnifying glass		For collection macro invertebrates and their identification.
Samples of macro invertebrates		Collection of stream's inhabitants for water quality assessment.
Forceps		For collection of macroinvertebrates .

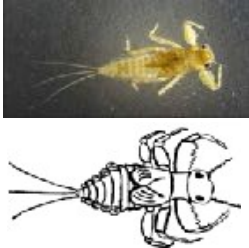
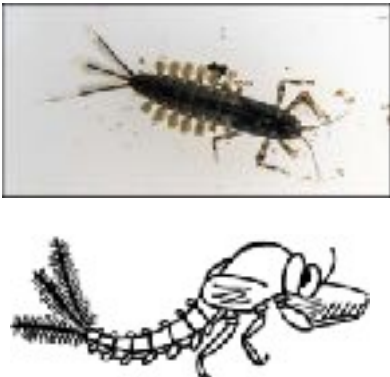
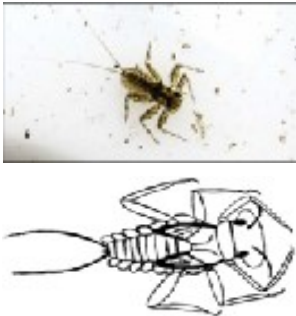
Brush		For collection of small and sensitive- skin macro invertebrates (worms, leeches and etc.).
Sorting trays		This tray is for sorting of collected macro invertebrates species, to facilitate counting and identification process.
Magnifier		For identification of small-size species.
Microscope		For identification purpose of very small species.

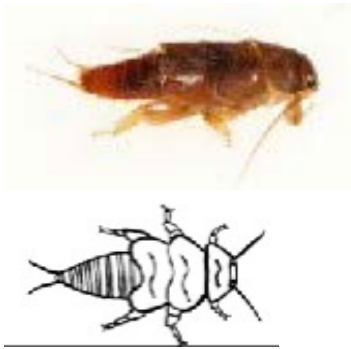
Sieve		An instrument to collect macro invertebrates.
Wader		For collection of macro invertebrates inside the streams' water.
GPS		To mark coordinate points at the selection place.
Insect identification sheets and Literature	 Determination Plates of Fresh Water Invertebrates Michael Walther unesco UNESCO Chair on Environmental Sciences in Eastern Central Asia MONGOLIAN ACADEMY OF SCIENCES 2022	It is used for classification of the types and numbers of each kind of insect.

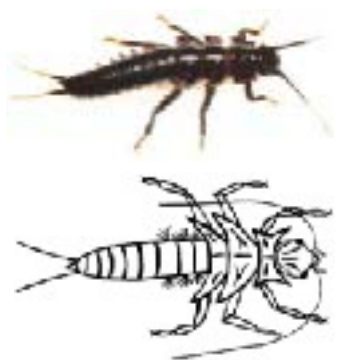
2.2 Biological Indicators

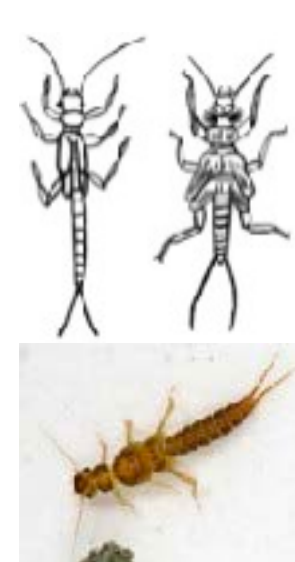
Introduction into macro Invertebrate field Identification Cards.

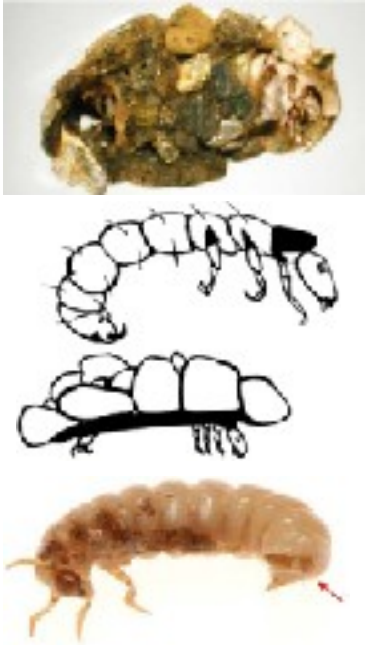
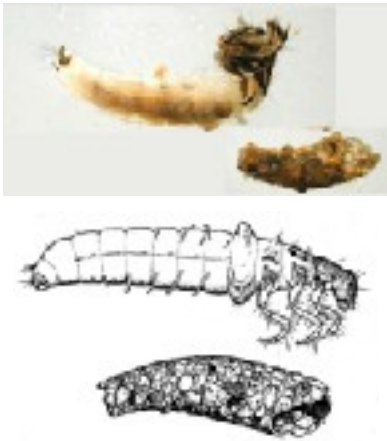
Tab 2.2: Identification of aquatic macro Invertebrates

Name	Photo/picture	Description
Most sensitive		
<u>Body-BUILDER</u> <u>Mayfly</u> Order: <i>Ephemeroptera</i> Family: <i>Ephemerellidae</i> Genus: <i>Drunella</i>		• Flat body with obvious legs; • Single set of wing pads; • Three hair-like tails at the end of the abdomen; • Small, round gills on the side of the abdomen.
<u>Brush-Legged</u> <u>Mayfly</u> Order: <i>Ephemeroptera</i> Family: <i>Isonychidae</i> <i>(Oligoneuriidae)</i> Genus: <i>Isonychia</i>		• Streamlined body, taller than wide; • Often with a "humped back" or "S-shaped" appearance when swimming; • Front legs have a double row of long hairs on the inside edge; • Single set of wing pads; • Small, round gills on the side of the abdomen; • Three feather-like tails at the end of the abdomen.
<u>Two-tailed</u> <u>flathead</u> <u>Mayfly</u> Order: <i>Ephemeroptera</i> Family: <i>Heptageniidae</i> Genus: <i>Epeorus</i>		• Extremely flat, almost translucent body, long thin legs; • Small round gills on the sides of the abdomen • Two long thin tails at the end of the abdomen (easily broken); • Single set of wing pads; • Wide flat head, obvious eyes.

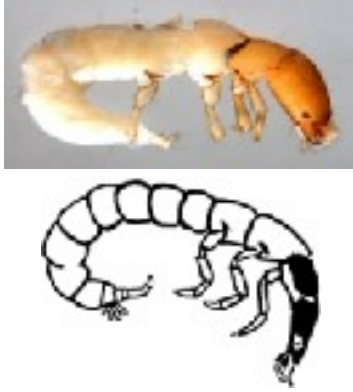
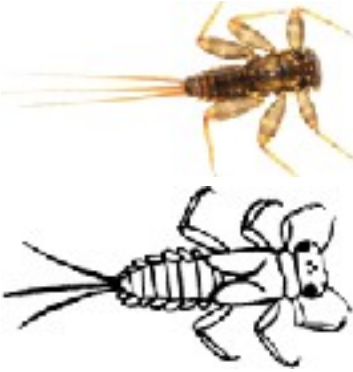
<u>Roach-like Stonefly</u> Order: <i>Plecoptera</i> Family: <i>Peltoperlidae</i> Genus: <i>All</i>		• Tear-drop shaped body with uniformly shiny brown exoskeleton; Two short tails at the end of the abdomen; • Two sets of wing pads; • No gills on the sides of the abdomen; • Commonly found on leaves.
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<u>Giant Stonefly</u> Order: <i>Plecoptera</i> Family: <i>Pteronarcyidae</i> Genus: <i>Pteronarcys</i>		• Robust body, typically dark but occasionally with white or yellow markings; • Pointed edges along the sides of the abdomen; • Two, short, tails at the end of the abdomen; • First thoracic plate is rectangular with flared edges; • Two sets of wing pads, very angular in shape; • Gill tufts on the thorax and the sides of the first three sections of the abdomen.
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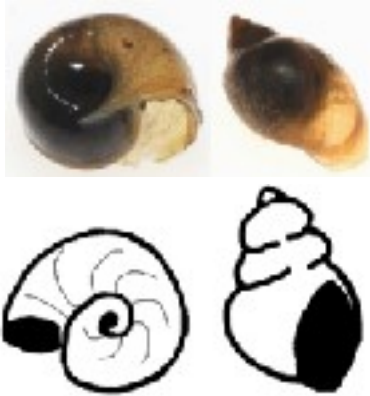
<u>Miscellaneous Small Stoneflies</u> Order: <i>Plecoptera</i>		• Two tails; • Two tarsal claws ("toes") at the end of each leg; • Dorsally flattened; • Small in size.
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<u>Saddlecase</u> <u>Maker</u> <u>Caddisfly</u> Order: <i>Trichoptera</i> Family : <i>Glossosomatidae</i> Genus: <i>Glossosoma</i>		• Small oval stone case made of sand grains and/or tiny pebbles, resembles a saddle or a turtle shell. • Case is not tube-shaped; • Underside of case has two round openings. • Larva body is maggot-like and slightly C-shaped; • Larva has a light (white to light brown) body with a dark head and legs; • End of the abdomen has an attached “butt plate’ (red arrow).
<u>Cornucopia of the</u> <u>Case</u> <u>Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Apataniidae</i> Genus: <i>Apatania</i>		• Tiny light-bodied organism; • Hunched appearance when in case; • Triangular head with dark legs; • Very small, delicate case made of sand grains; • Case of the cone-shaped of the like a Thanksgiving cornucopia.
<u>Free-living Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Rhyacophilidae</i> Genus: <i>Rhyacophila</i>		Nicknamed “Mof the ch el of then Man” • caddisfly due to its smooth, lumpy abdomen; • Six short legs near the head; • Hard tan or yellow and brown patterned head with a single thoracic plate; • Armored plate and two hooks at the end of the abdomen, somewhat loosely attached.

<u>Humpless Case Maker Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Brachycentridae</i> Genus: <i>Brachycentrus</i>		• Case constructed of thin strips of plant material assembled with a square opening; • Wider at head opening than at tail end; • Light colored body with dark head legs; • Very long legs; • No abdominal humps.
<u>Plant Case Maker Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Lepidostomatidae</i> Genus: <i>Lepidostoma</i>		• Builds a case out small, rectangular or square pieces of bark or wood (no sand grains); • Case is typically slightly wider at the head end; • Light colored body with dark head and legs; • Lateral humps present on the first
<i>Moderately Sensitive</i>		
<u>Common Netspinner Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Hydropsychidae</i> Genus: <i>All</i>		• Series of three dark plates on the dorsal side of the thorax below the head; • Fluffy gills on the underside (ventral sections of the abdomen); • Two paintbrush-like tails with hooks at the end of the abdomen; • May have a “dirty” or hairy appearance.

<u>Fingernet</u> <u>Caddisfly</u> Order: <i>Trichoptera</i> Family: <i>Philopotamidae</i> Genus: <i>All</i>		- Elongate, slender worm-like body; No gills on or along the abdomen; - Two hooks at the end of the abdomen; - Bro of theght orange head wof the th atransparent, t-shaped upper lip; - Black border along the back edge of pronotum (the plate located behind the head capsule).
<u>Three-Tailed Flat Headed Mayfly</u> Order: <i>Ephemeroptera</i> Family: <i>Heptageniidae</i> Genus: <i>Stenonema</i> and <i>Maccaffertium</i>		- Extremely flattened body; - Small, oval or square-shaped gills along the sides of the abdomen; - Three very long tails at the end of the abdomen. (Tails are fragile and can break off giving the appearance of only one or two). - Head is flat with large eyes on top; - Single set of wing pads.
<u>Water Penny Beetle</u> Order: <i>Coleoptera</i> Family: <i>Psephenidae</i> Genus: <i>Psephenus</i>		- Small, flat, disc-shaped organism; - Uniform in color; - Head and legs only visible from ventral view (i.e. from underneath).
<u>Dobsonfly</u> Order: <i>Megaloptera</i> Family: <i>Corydalidae</i> Genus: <i>Corydalus</i>		- Elongate body with a pair of long soft spine-like appendages on each section of the abdomen; - Can be extremely large (up to 4 inches); - Large pinching mouth parts; - Will bite sampling spoons and your fingers so watch out; - Two prolegs at the end of the abdomen; each with two hooks; - Tufts of fluffy gills at the base of each abdominal projection.

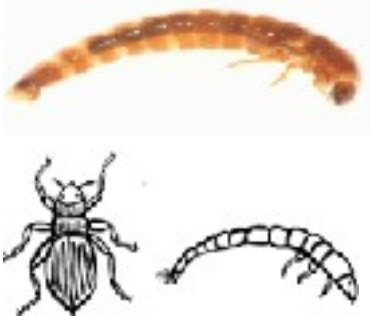
<u>Aquatic Sow Bug</u> Order: <i>Isopoda</i> Family: <i>Asellidae</i> Genus: <i>All</i>		• Body is strongly flattened from top to bottom; • Two pairs of antennae, of which one pair is significantly longer than the other pair; • Seven pairs of legs; • First pair of walking legs has enlarged ends with hinged claws; • Six pairs of short appendages on the underside of the abdomen; • The sixth pair extends behind like a pair of flat tails.
<u>Leech</u> Phylum: <i>Annelida</i> Class: <i>Clitellata</i> Sub-Class: <i>Hirudinea</i>		• Somewhat soft but muscular, flattened body with many segments and no legs; • Two distinct suction discs on the bottom of the body, one on each end; • Several small eyespots on top of first segments.
<u>Non-Biting Midge</u> Order: <i>Diptera</i> Family: <i>Chironimidae</i> Genus: <i>All</i>		• Small, very thin, wormlike body; Red or white in color; • Distinct head capsule, though very tiny; • May be found hibernating in very finely constructed cases.
<u>Black Fly</u> Order: <i>Diptera</i> Family: <i>Simuliidae</i> Genus: <i>All</i>		Bowling pin shaped body with a capsule-like head that is distinct from the thorax; Enlarged rear 1/3 of the body. Resembles the shape of a vase; There is a proleg on the bottom of the first thorax segment.

<u>Snail</u> Phylum: <i>Mollusca</i> Class: <i>Gastropoda</i>		• Relatively large, globose shells with concentrically marked opercula. • Variable color, light tan to darkbrown.
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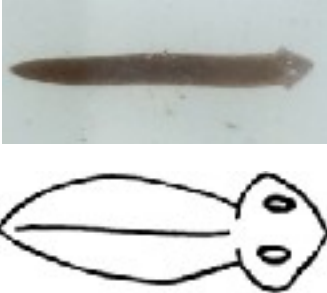
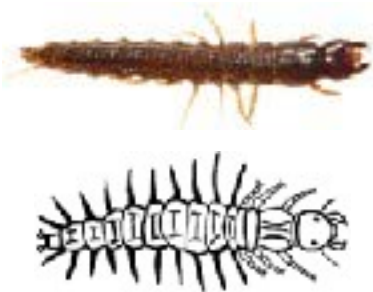
<u>Aquatic Worm</u> Phylum: <i>Annelida</i> Class: <i>Oligochaeta</i>		• Soft, long, cylindrical bodies consisting of many ring-like segments; • No suckers or eyespots.
---	--	--

Misc. Other

<u>Crayfish</u> Order: <i>Decapoda</i> Family: <i>Cambaridae</i> Genus: <i>Cambarus,</i> <i>Procambarus</i>		• Rostrum is not J shaped; • Gonopods are pipe-wrench shaped; Long, slender, curved claws; • Rostrum is J shaped w/spines; Gonopods not pipe-wrench; males with 4 hooks.
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<u>Cranefly</u> Order: <i>Diptera</i> Family: <i>Tipulidae</i> Genera: <i>Hexatoma</i> <i>, Antocha,</i> <i>Tipula</i>		• Body is cylindrical and usually stout; • Typically very soft bodied; • Head is withdrawn and not visible; • Two spiracles at the end of the abdomen surrounded by several pairs of short, fleshy lobes; • One to seven pairs of lobes that often have a fringe of hair.
<u>Riffle Beetle</u> Order: <i>Coleoptera</i> Family: <i>Elmidae</i> Genus: <i>All</i>		• Small, hard-bodied, cylindrical and slightly C shaped; • Long legs in relation to body size; • Two prominent claws on the ends of the legs.

<u>Small Minnow Mayfly</u> Order: <i>Ephemeroptera</i> Family: <i>Baetidae</i> Genus: <i>All</i>		• Small in overall size; • Three pairs of legs; legs do not have a feathery fringe of hairs; • 2-3 hair-like tails, sometimes with a shorter middle tail; • Small, round gills along the sides of the abdomen – may be difficult to see without magnification; • Elongated wing pads.
<u>Aquatic Snipe Mayfly</u> Order: <i>Diptera</i> Family: <i>Athericidae</i> Genus: <i>Atherix</i>		• Body is elongate with a pointed head end and tail-like structures at the end of the abdomen; • Series of small, paired prolegs along abdomen; • Rough appearance to the exoskeleton; • Two stout, pointed tails with a fringe of hairs at the end of the abdomen.

<u>Flatworm</u> Order: <i>Tricladida</i> Family: <i>Planariidae</i> Genus: <i>Planaria</i>		• Soft, elongate, flattened body without segmentation or legs; • Slightly triangular head with two eyespots on top.
<u>Freshwater Mussel/Clam</u> Order: <i>Unionoida</i> Family: <i>Margaritiferidae, Unionidae</i> Genus:		• Two shells connected by a strong hinge; • No distinct head; • Triangular shaped.
<u>Fishfly</u> <i>Megaloptera</i> Family: <i>Corydalidae</i> Genus: <i>Nigronia</i>		• Elongate body with a pair of long soft spine-like appendages on each section of the abdomen; • Large pinching mouth parts; • Two prolegs at the end of the abdomen, each with two hooks; • No gills at the base of the abdominal projection.
<u>Dragonfly</u> Order: <i>Odonata</i> (Suborder <i>Anisoptera</i>) Family: <i>Aeshnidae, Gomphidae</i>		• Robust body; • Three short spike-like tails; • Two sets of wing pads; • Very large eyes; • Extendable lower jaw.

2.3 Biological Standards

The basic principle behind the study of macro invertebrates is that some are more sensitive to pollution than others. Therefore, if a stream site is inhabited by organisms that can tolerate pollution and the more pollution sensitive organisms are missing a pollution problem is likely.

Stonefly nymphs' aquatic insects that are very sensitive to most pollutants cannot survive if a stream's **dissolved oxygen falls below a certain level**. If a bio survey shows that no stoneflies are present in a stream that used to support them, a hypothesis might be that dissolved oxygen has fallen to a point that keeps stoneflies from reproducing or has killed them outright.

This brings up both the advantage and disadvantage of the bio survey. The advantage of the bio survey is that it tells us very clearly when the stream ecosystem is impaired, or "sick," due to pollution or habitat loss. It is not difficult to realize that a stream full of many kinds of crawling and swimming "critters" is healthier than one without much life. The disadvantage of the bio survey, on the other hand, is that it cannot definitively tell us why certain types of creatures are present or absent.

In this case, the **absence of stoneflies** might indeed be due to low dissolved oxygen. But is the stream underoxygenated because it flows too sluggishly or because pollutants in the stream are damaging water quality by using up the oxygen? The **absence of stoneflies** might also be due to other pollutants discharged by factories or running off farmland, water **temperatures** that are too high, habitat degradation such as **excess sand or silt** on the stream bottom that has ruined stonefly sheltering areas, or other conditions. Thus, biosurvey should be accompanied by an assessment of **habitat** and **water quality** conditions in order to help explain biosurvey results.

Habitat quality categories

To identify the Habitat quality category, it is important to compare the percent similarity of your results with the range of percent similarity numbers in the stream habitat rating table to obtain the habitat quality category for your site(s) (Table 2.3). Enter the appropriate descriptive rating (excellent, good, fair, or poor) on the field data sheet. If your score falls at or near the break between habitat quality categories, use your best judgment to determine an appropriate rating.

Tab 2.3: Reference scores for sampling site comparison.

% Similarity to Reference Score	Habitat Quality Category	Attributes
>90%	Excellent	Comparable to the best situation to be expected within an ecoregion. Excellent overall habitat structure conducive to supporting healthy biological community.
75-88%	Good	Habitat structures lightly impaired. Generally, diverse in stream habitat well-developed; some degradation of riparian zone and banks; a small amount of channel alteration may be present.
60-73%	Fair	Loss of habitat compared to reference. Habitat is a major limiting factor to supporting a healthy biological community.
<58%	Poor	Severe habitat alteration at all levels.

2.4 Guidelines for Testing

When all equipment and pre-field procedures is ready, the most important part of biological analysis starts. Measurement using macro invertebrates is held by collecting stones and use of seines. The first step is the location description (weather condition, GPS coordinates, elevation, date, time, simplified method results). The next step is obtaining a sample of stream insects (stony habitat = 20 stones, 20 sieves or 10 stones and 10 sieves). Put collected macro invertebrates into a sorting pan or plastic tray. The following step is separation the insects into «looks-like» groups, using body shape, number of legs, tails, etc., as the basis for grouping. Identification the organisms within each order to family level provided using macro invertebrate identification cards (see subchapter 2.2).

<i>Pollution Sensitive Organisms – Group One Taxa</i>	<i>Somewhat Pollution Tolerant Organisms – Group Two Taxa</i>	<i>Pollution Tolerant Organisms –Group Three Taxa</i>
1) Stonefly nymph – Order Plecoptera 2) Caddisfly larva – Order Trichoptera 3) Water Penny larva – Order Coleoptera 4) Riffle Beetle – Order Coleoptera 5) Mayfly nymph – Order Ephemeroptera 6) Gilled Snail – Class Gastropoda 7) Dobsonflylarva – Hellgrammite – Family Corydalidae	1) Crayfish – Order Decapoda 2) Sowbug – Order Isopoda 3) Scud – Order Amphipoda 4) Alderfly larva – Family Sialidae 5) Fishfly larva – Family Corydalidae 6) Damselfly nymph – Suborder Zygoptera 7) Watersnipe Fly larva – Family Athericidae (Atherix) 8) Crane Fly larva – Suborder Nematocera 9) Other (aquatic) beetle larvae – Order Coleoptera 10) Dragonflynymph (Suborder Anisoptera) 11) Clam/Mussel – Class Bivalvia	1) Aquatic Worms/HorsehairWorm – Class Oligochaeta 2) Midge Fly larva – SuborderNematocera 3) Black Fly larva – Family Simuliidae 4) Leech – Order Hirudinea 5) Pouch Snail and Pond Snails – Class Gastropoda 6) Other Snails – ClassGastropoda

Tab 2.4: Subdivision of invertebrates into their sensitivity against pollution.

The Figure 2.1 illustrates the taxonomic classification scheme used to identify living organisms. In this scheme macro invertebrates are identified to the level of Order – the lowest level in taxonomic group.

Benthic macro invertebrate Classification

In order to sample the benthic macro invertebrates, physical habitat, and water quality to describe biological community condition as a result of natural and human-induced disturbance. Normally, samples are collected from riffles to characterise the benthic macro invertebrate community unless degradation is suspected in pool habitat (slow moving or eddying water). To distinguish natural versus human influence, data must be collected at reference sites and at degraded sites over a period.

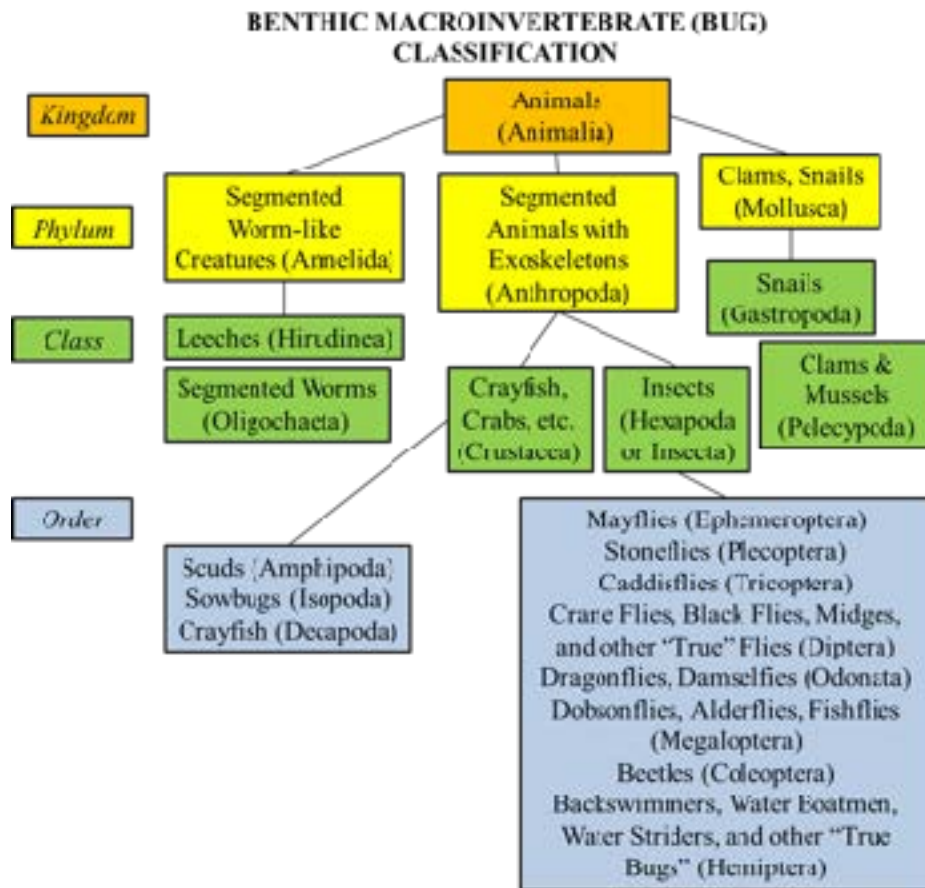


Fig. 2.1: The taxonomic classification scheme for identification living organisms.

Of time to address spatial and temporal variability. Reference sites are intended to represent relatively unimpacted or least impacted conditions. Minimally disturbed conditions reflect sites that have experienced very little historical activity that alters stream integrity. Least disturbed sites have been degraded historically, but exhibit some level of recovery. Reference sites are used to describe biological variability due to natural disturbance (e.g. precipitation, drought) (Table 2.5).

Tab 2.5: Classification of the quality of benthic macro invertebrate

<i>Classification</i>	<i>Description</i>
High	The natural behaviour of benthic macroinvertebrates
Good	An unaffected biological community
Mediocre	Several affected biological communities
Poor	Moderately affected biological community
Bad	A severely affected biological community is an extreme reaction to anthropogenic pollution.

Macro invertebrate orders and classes also are divided into 3 groups according to their pollution sensitivity: pollution sensitive, somewhat sensitive, and pollution tolerant (Table 2.4). Pollution-tolerant species do not depend upon dissolved oxygen in the water. Somewhat tolerant macro invertebrates tend to tolerate some degradation of water quality. Their abundance and diversity indicate a stream is in fair to good condition. Pollution-sensitive organisms tend to require high dissolved oxygen levels.

Tab 2.6: Analyzing invertebrate data

Observation	Analysis
High diversity, high density, many sensitive species such as stoneflies, caddisflies, and mayflies.	No problems; good water quality.
High diversity, low density of species present.	Possibly due to poor habitat conditions.
Low diversity, high density of species present.	Organic pollution (nutrient enrichment) or sedimentation; excessive algal growth resulting from nutrient enrichment.
Low diversity, low density or no macroinvertebrates but the stream appears clean.	Toxic pollution (e.g., chlorine, acids, heavy metals, oil, herbicides, insecticides); unproductive.

When present in large numbers, these macro invertebrates suggest the stream is in good condition. If these organisms were once abundant, but subsequent sampling shows a decline in numbers, it may indicate that a pollution incident occurred.

Table 2.6 can help to interpret the results by observation, but this interpretation is not enough for a full water quality analysis. It can show just an approximate picture of the river's water health.

2.5 Lessons learnt

For the future groups, there is a suggestion, firstly, to separate duties between each other for saving time and effective work: people who will be in charge of collecting stones, taking notes (description of location, weather and etc.), collecting macro invertebrates from stones, separating the insects into «look-alike» groups. The most important and difficult part is the identification of insects. All people from biological group should participate in this process. Secondly, to compare how many stones/ sieves were taken by previous groups, and decide how many stones you will take. The number of stones don't have to differ from previous years so many, for good comparison analysis. Thirdly, do not take stones from high turbulent part of stream, because of high velocity species can be washed away and you won't be able to collect them. The size of stones should not be considerable and small, medium is suitable. And, the one advice – one person should be in charge of the equipment, to prepare all instruments and check for service.

Copy Template (Field)	Macro invertebrate
-----------------------	--------------------

Copy Template (Field)	Macro invertebrate
-----------------------	--------------------

Working Group (Names)		
Date:	ID:	Altitude:
Coordinates of sampling point (UTM):		
Weather conditions:		

Water/River Conditions:

Number of stones:

Number of sieves:

Macro-Invertebrates	How many?
Total	

Copy Template (Field)

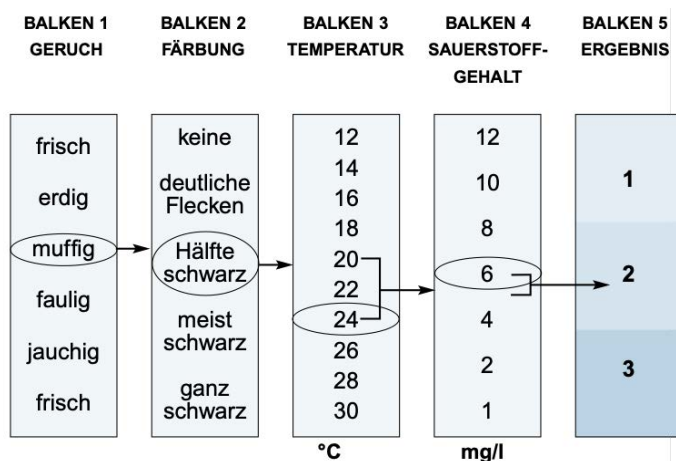
Quick Assessment

Working group (Names):		
Date:	Time:	Point:
Location: (UTM) ID:	E	N
Weather:	Altitude:	

Transpa- rency of water	Smell of water	Color of stones	Tempera- ture C°	Oxygen mg/l	Result
%	Fresh	No	8	>15(39.5)	1
	earthy		10		
	muggy		12		
	Foul-smelling	Clean spots	14	14	2
	Ichorous	Half black	16	12	
	Fresh	Mostly black	18	10	
		Total black	20	8	3
			22	6	
			24	4	
			26	2	
			>26	1	

1. Water is ok
2. Water is polluted
3. Water is seriously polluted.

Example for evaluation:



Working Group (Names)

Date:

Create own excel table according to example below and show the results by creating suitable diagrammes

Comparison of Biodiv

[illegible]

2.6 Biodiversity Calculation and Assessment

For every sample/observation site you have to use the online Biodiv Calculation and calculate Species Richness (S), Simpson's Index (D), Shannon-Wiener Index (H) and Evenness Index (E) by following the online instructions (Number of Categories = Names of Invertebrates)

<https://virtue.gmbl.se/english-content/biodiversity-calculator>

The diversity indices, their definitions and their meanings:

1. **Species richness (S)** is a measure of the number of species found in a community, in our case, on the discs. This is obtained by just counting how many different organisms are found on the discs. Although very easy to measure species richness does not tell much about the abundances and relative abundances of the species on the discs. (The more species are found on the discs, the higher is the species richness)
2. **Simpson's Index of Diversity (D)** is a measure of both richness and the relative abundances of the species on the discs. Simpson's Index is also a measure of dominance. (D is usually between 0 and 1. The closer D is to 1, the higher is the diversity)
3. **Shannon-Wiener Index (H)** is like the Simpson's Index and also measures the richness and abundances of the species. From the Shannon-Wiener Index Evenness can be calculated. (The higher H is the higher is the diversity)
4. **Evenness (E)** complements species richness in that it gives us a picture of the relative abundances of the different species represented on the discs. (E is usually between 0 and 1. The closer E is to 1, then more species in the sample are equally common, the diversity is higher)

For comparison of more than two samples you can use additional indices:

5. Jaccard Index (J) is used when comparing the species composition of two samples. This does not consider the abundances of the species but looks at how similar two samples are with regard species found. (The closer J is to 100 %, the more similar the samples are).
6. Menhinick's Index (DMn) is also a measure of species richness, which also has the same shortcomings as species richness (S). (The higher the DMn is the higher is the species richness)
7. Effective Number of Species (ENS) is a measure of true diversity with species number as its unit. It is the number of species in a community with equal abundances that would give the observed value of a diversity index, D or H. This is excellent for comparing the diversities of different samples. This corrects the non-linearity of D and H. (The higher the ESN the more diverse is a community).

What index and Why?

This depends on what questions you want answered. The indices introduced here are quite simple and will not present any problems for a high school student from grade 8 and higher to calculate. The teacher should tell the students not to be intimidated by the formulas because these are actually simpler than they seem to appear.

Species Richness: Species richness (S) is the easiest parameter to measure. It is just the number of species found. This, however, does not tell much about the structure of the community. The same is true for the Menhinicks Index (DMn). For younger students, (S) may be the easiest and fastest "quantitative" way to analyse the discs.

Species Diversity: The Simpsons (D) and Shannon-Wiener (H) indices of diversity and the Effective Number of Species (ENS) are only meaningful if used for more than one sample. These are used to compare the diversities of at least two samples. D and H are both indices and they are just that, they "indicate" only the diversity and are not true diversities in themselves. True diversity can only be

expressed with the ENS.

D and H are only linear if the species in the sample are all equally common. If the species are not equally common, it is not safe to assume that the diversity of a sample with a D or H of for example 2 is twice as diverse as a sample with D or H equal to one. In this case, it is more appropriate to calculate the ENS.

Comparing samples: If samples are to be compared D, H and ENS can be used and the Evenness (E) can tell something about the relative abundances of the species found. The Jaccard Index (J) shows how similar are the species found in two samples.

2.7 General Assessment of the data and Report Writing

The final end of every assessment is the **Assessment Report 20xx**, which includes:

1. All observed data/tables in the appendix; (who not participate: 4 students);
2. All possible evaluation forms in the text like tables;
3. A narrative Description of the assessment (Report writing)
 - 3.1. General Geology and Landscape description of the RB; differentiation and classification of morphological landscape types.
 - 3.2. Climate and characteristic weather conditions of the RB; available mean average values.
 - 3.3. Vegetation and Land Use of the RB (rough differentiation of rural and urban areas, industrial impact.
 - 3.4. General hydrological Situation of the RB (Water divide, General discharge, longitudinal profile, specific river continuum, groundwater peculiarities, water sources, waste water plants, general water use peculiarities. (Editor: xxx)
 - 3.5. Your results of the year xxxx.
 - 3.5.1. biological studies
 - 3.5.2. chemical studies
 - 3.5.3. physical studies
 - 3.6. Your comparison with the previous studies.
4. Lessons learnt, if necessary; what is/are your recommendation(s) for a sustainable water use. Regard water security, water health, water consumption and water demand specifically for the RB

2.7.1 Work Plan for Report writing

1. All field data must be **digitised** and provided either in Dropbox, Google Drive (cloud data storage) or sent by mail for everybody due to insufficient internet availability.
2. All digitised data files (Excel or Numbers) must contain **appropriate diagrams**, showing maxima, average and minima values. Statistical value “y” for calculation the increase or decrease of values must be displayed. X- and y axes must be named and the header must be inside the diagram. All diagrams should display the **lower part (503 m asl – 715 m asl), middle part (715 – 1050 m asl) and upper part (higher than 1050 m asl)**.
3. All diagrams (a representative selection is possible) should be **described** by highlighting maxima, average and minima values.
4. The results for the three investigation methods must be compared/**interpreted** with the international and regional/national standards. Which story do the measured values tells us? Is there some characteristic peculiarity in the data? An ecological behaviour should be derived on the base of Table 6.3 (in Annex).
5. The Comparison with the **field study results of the previous years** (provided in a cloud data storage) is very important in order to come to statements concerning the change of Water Quality and environmental load. The table of the previous years are provided to supplement the actual year.
6. Sharing responsibility of the introductory chapter.

2.7.2 Lessons learnt 2021

Please make sure that:

- all jpg files must be read and saved in the related separate folder;
 - the location description is placed on every field data sheet completely;
 - discharge data are not only displayed in stream velocity but to in m³ data;
 - all data sheets have to be collected by the related chief editors for Bio, Chem and Phys
- In general, the assessment of the three bundles of work (Bio, Chem, Phys) is subdivided into five main activities:
1. Digitalisation of the data in tables and design of graphs; the tables come into the chapter, Annex the graphs come into the text/narrative description.
 2. Narrative Description of the data and the graphs;
 3. Interpretation of the data according to standards;
 4. Comparison with previous data. What has changed compared with the previous years?
 5. Formulation of the summarising results, recommendations, and, if possible, conclusions.

References (...for more information)

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3. Chemical Assessment

Chemical analysis of water is used to determine the number of various substances in water that is in contact with a person for industrial and domestic purposes, or in scientific. Knowing the chemical composition of water is very important information that will help to save the health of the population and the availability of water for use in agriculture, industry, etc. Also, monitoring of chemical indicators is important for the conservation of ecosystems that are susceptible to anthropogenic influences. For various types of water, there are recommended methods of measurement, maximum permissible concentration (MPC) of contained substances, established by sanitary rules and norms named SanPIN. For each measurement method, there is a set of indicators for which water samples are examined. The analysis of water may differ: reduced water analysis, complete chemical analysis of water, or determination of individual water quality indicators.

3.1 Equipment for Chemical Analysis

The German-Kazakh University has a digital photometer for determining the exact water characteristics – Aqua-Check, developed by the German company Söll GmbH. Aqua-Check is designed for users who want to determine the basic parameters of water in an easy and fast way. The photometer helps in monitoring the most important water parameters on a regular basis. The measuring device is perfectly suited for the research and educational purposes of the Kazakh-German University.

With Aqua-Check, water analysis is carried out independently of the university's laboratory, as the photometer allows students to independently check the water quality. The Aqua-Check kit (Figure 3.1) contains the necessary equipment for measuring 8 single measurements, as well as drip tests to measure carbonate and total hardness.



Fig. 3.1: Photometer kit Aqua-Check (<http://www.aqua-check.de>).

The kit of equipment consists of several parts:

1. Photometer Aqua-Check;
2. The battery;
3. Indicators;
4. Test tubes;
5. Water bottle;
6. Mini-laboratory for test tubes;
7. Instruction

The kit contains indicators for 8 different photometric and 2 drip measurements (Figure 3.2).



Fig. 3.2: Aqua-Check indicators for tests (Foto Sajida).

3.2 Chemical Parameters

Natural waters are almost never chemically clean, since they contain various substances in a dissolved and suspended state. In the process of interaction of the hydrosphere with the atmosphere, lithosphere and biosphere, water affects various substances, forming solutions.

During the practice, undergraduates made measurements of several chemicals in the Kaskelen River (Figure. 3.3). Using the Aqua-Check photometer, a number of tests were made for fresh river water:

1. pH test (pH); Should be measured with PCE pH Meter
2. Ammoniumtest (NH_4^+);
3. Nitratetest (NO_3^-);
4. Nitritetest (NO_2^-);
5. Phosphate test (PO_4^{3-}).



Fig. 3.3: Testing with Agua-Check (Foto: Sajida).

pH TEST (pH). The hydrogen index or pH represents a logarithm of the concentration of hydrogen ions taken with the opposite sign, i.e. $\text{pH} = -\lg |\text{H}^+|$.

The pH value is determined by the quantitative ratio in water of the H^+ and OH^- ions formed during the dissociation of water. If OH^- ions in water prevail – that is $\text{pH} > 7$, then water will have an alkaline reaction,

and if the content of H^+ ions is high, $pH < 7$ is acidic. In distilled water, these ions will balance each other and the pH will be approximately equal to 7. When dissolving various chemicals, both natural and anthropogenic, in water, this balance is violated, which leads to a change in the pH level.

Depending on the pH level, the water can be conditionally divided into several groups:

1. Strongly acidic waters < 3 ;
2. Acidic waters $3 - 5$;
3. Low acidic water $5 - 6.5$;
4. Neutral water $6.5 - 7.5$;
5. Weakly alkaline water $7.5 - 8.5$;
6. Alkaline water $8.5 - 9.5$;
7. Strongly alkaline waters > 9.5 .

Depending on the pH value, the rate of chemical reactions may change, the degree of corrosive water aggressiveness, the toxicity of pollutants, and much more.

In river waters, pH is usually in the range of 6.5-8.5. At high levels ($pH > 11$), water acquires a characteristic mildness, an unpleasant smell, and can irritate the eyes and skin. Low pH < 4 can also cause unpleasant sensations. The pH also affects the life of aquatic organisms. For drinking and domestic water, the optimal pH is in the range of 6 to 9 units.

Ammonium test (NH_4^+). Ammonium ion (NH_4^+) – in natural waters accumulates when dissolved in water gas – ammonia (NH_3), formed during the biochemical decomposition of nitrogen-containing organic compounds. Dissolved ammonia enters the reservoir with surface and underground runoff, atmospheric precipitation, and also with sewage. The presence of ammonium ion in concentrations exceeding the background values indicates fresh contamination and proximity to the source of pollution (communal wastewater treatment plants, industrial waste settlers, livestock farms, manure, nitrogen fertilizer, settlements, etc.).

Nitrate test (NO_3^-) Water pollution by nitrates can be caused by both natural and anthropogenic causes. As a result of the activity of bacteria in water bodies, ammonium ions can pass into nitrate ions, in addition, during thunderstorms, a certain number of nitrates occur during electrical discharges – lightning. The main anthropogenic sources of nitrate intake into the water are discharges of domestic sewage and runoff from fields on which nitrate fertilizers are used.

The highest concentrations of nitrates are found in the waters. The increased content of nitrates in surface water bodies leads to their overgrowth, nitrogen, as a biogenic element, promotes the growth of algae and bacteria. This is called the eutrophication process. This process is very dangerous for reservoirs, since the subsequent decomposition of plant biomass will consume all the oxygen in the water, which in turn will lead to the death of the fauna of the reservoir.

Nitrates are dangerous for humans. Distinguish the primary toxicity of the nitrate ion itself; secondary, associated with the formation of a nitrite ion, and tertiary, due to the formation of nitrites and amines of nitrosamines. The lethal dose of nitrates for humans is 8-15 g. With

prolonged use of drinking water and food products containing significant amounts of nitrates, the concentration of methaemoglobin in the blood increases. The ability of the blood to transfer oxygen decreases, which leads to unfavourable consequences for the body.

Nitrite test (NO_2^-). Nitrite is an intermediate step in the chain of bacterial oxidation of ammonium to nitrates or, conversely, the reduction of nitrates to nitrogen and ammonia. Similar oxidation-reduction reactions are typical for aeration stations, water supply systems and natural waters. The greatest concentration of nitrite in water is observed in the summer, which is due to the activity of some microorganisms and algae. Nitrites can be used in the industry as preservatives and corrosion inhibitors. From sewage, they can enter open watercourses.

The increased content of nitrites indicates an intensification of decomposition processes of organic

substances under conditions of slow oxidation of NO₂⁻ to NO₃⁻, this indicates contamination of the reservoir. The content of nitrites is an important health indicator. Nitrites are much more dangerous than nitrates, therefore their content in water is controlled more strictly.

Phosphate test (PO₄³⁻). Phosphorus compounds are found in all living organisms, regulating the energy processes of cellular metabolism. Phosphorus is one of the main biogenic components that determine the productivity of the reservoir. The increase in the concentration of phosphate compounds in water disrupts biological equilibrium, leads to eutrophication of the reservoir, i.e. to a sharp increase in its biological productivity, in particular – to the “flowering” of water, contributes to the introduction of an uncharacteristic pond of flora and fauna.

Phosphate ion, like the sulfate ion, is an informative indicator of anthropogenic pollution, which is promoted by the widespread use of phosphorus fertilizers (superphosphate, etc.) and polyphosphates (as detergents). The phosphorus compounds enter the reservoir during the biological treatment of waste water.

3.3 Chemical Standards

In 1984, the World Health Organisation (WHO) issued a basic standard of quality “Guidelines for drinking water quality” on the basis of which measures are being contemplated by other States.

Tab 3.1: Comparison of the standards of chemical parameters by EPA or WHO, KZ with the results of chemical water quality monitoring in Kaskelen in 2016/17

	EPA	WHO	KAZ	Range of meanings 2016/17
Nitrate (NO₃)	10 mg/L	10 mg/L	10 mg/L	6 – 14,2 mg/L
Nitrite (NO₂)	1 mg/L	0,75 mg/L	0,75 mg/L	0,02 – 0,09 mg/L
Ammonia (NH₃)	0,5 mg/L	0,2 mg/L	0,2 mg/L	0,11 – 0,48 mg/L
Phosphate (PO₃)	0,05 mg/L	0,01 mg/L	0,01 mg/L	0,16 – 1,5 mg/L

The “Guidelines for surface water quality assessment by hydro chemical indicators” was implemented in Kazakhstan in 2012 by the Ministry of Environmental Protection and was adapted by Kazhydromet for chemical analyses. There is a Table 3.1, which represents comparison of water quality standards, provided by WHO, U.S. Environmental Protection Agency (EPA) and Ministry of Environmental Protection, as well as the results of field works in 2016 and 2017.

Nitrate and Nitrite

According to the U.S. Environmental Protection Agency (EPA) there had been established a maximum contaminant level (MCL) of 10 milligram per liter (mg/L) for nitrate as nitrogen (NO₃- N) and a MCL of 1 mg/L for nitrite as nitrogen (NO₂-N) in drinking water. ([U.S. EPA Office of Water, Drinking Water and Health Advisories](#)).

Ammonia

WHO states for domestic water supply, chronic total ammonia concentrations shall not exceed 0.5 mg/l as N at the point of intake (that is, ammonia concentrations should not exceed 0.5 mg/ l constantly over a 30-day period at the location where water enters standard treatment for drinking water).

pH

The U.S. Environmental Protection Agency (U.S. EPA) sets a secondary standard for pH levels in

drinking water: the water should be between pH 6.5 and 8.5 Secondary standards are unenforceable, but recommended, guidelines.

WHO states that waters to be used for domestic water supply should have pH values between 5.0 and 9.0 and for drinking water the range is between 6.5 and 8.0. National standards of Kazakhstan are similar to the norms presented in the Fourth edition of WHO water quality standards.

Water Quality Standards and Other Criteria Regarding Phosphorus

No national or state criteria have been established for concentrations of phosphorus compounds in water. However, to control eutrophication, the EPA makes the following recommendations: total phosphate should not exceed 0.05 mg/L (as phosphorus) in a stream at a point where it enters a lake or reservoir, and should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs (Muller and Helsel, 1999).

Phosphate levels greater than 1.0 mg/L may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed before distribution. WHO indicates PO_3 as 0.01 mg/L taken in research area.

3.4 Guidelines for chemical tests

You will be required to use two test tubes to measure a parameter. Both test tubes should be vertical and filled with tested water till the mark. The difference between reference tubes and measuring tubes is described in the following text:

The recesses/holes in the measuring device's delivered packaging are suitable for firm and steady storage.

If indicators were used already or the measured, you should perform the actions in accordance with the indicator manual before the measurement. Please ensure here that you wear safety glasses and observe the safety notes for handling hazardous substances.

Operating

Aqua-Check photometer. You should switch between the individual parameters by pressing the "Select" button. The order is as follows: Ammonia, nitrite, nitrate, phosphate, copper, silicon, chlorine, pH value. Pressing the "OK" button again confirms the selected test. After selecting and confirming the parameter to be measured, the device automatically determines the length of the measuring tube.

With the *"Please extend measuring tube!"* message the measuring tube must be carefully pulled out by hand until it engages. Pulling out further would destroy the measurement device!

With the *"Please slide in measuring tube!"* message you push the measuring tube in carefully with your hand until it stops.

Ensure that there is nothing stuck in the measurement openings. This could damage the optics.

"Ready for reference" appears when the measuring tube is in the right position.

To homogenise the test water for the measurement and to prevent air bubbles from forming on the lens, insert the measuring tube into the reference tube (tube 1) and stir the liquid lightly.

Pressing the "OK" button starts the measurement process again.

The 3 seconds wait time is announced with the *"Please wait ..."* prompt, which appears on the *"Ready for measurement" display.*

To homogenise the test water and the respective indicator for the measurement and to prevent air bubbles from forming on the lens, insert the measuring tube into the test tube (tube 2) and stir the liquid lightly

Pressing the "OK" button again starts the measurement process. The measured value is shown after three seconds.

pH Test (pH). Test preparation(<http://www.aqua-check.de>):

1. Fill both tubes up to the mark with the test water.
2. Add 12 drops of pH (R1) to one of the two tubes (test), close with the screw top lid and mix.

Measuring with AQUA-CHECK:

3. Reference measurement.
4. Test measurement.

Ammonium test (NH_4^+). Test preparation (<http://www.aqua-check.de>):

1. Fill both tubes up to the mark with the test water.
2. Put the contents of the NH_4^+ R1 ampule into one of the two tubes (test), close with the screw top lid and mix.
3. Add 1 big level measuring spoon of NH_4^+ R2 to the test, close with the screw top lid and dissolve by shaking. Leave standing for 5 minutes.
4. Add the contents of the NH_4^+ R3 ampule to the test, close with screw top lid and mix. Leave standing for 7 minutes.

Measuring with AQUA-CHECK:

5. Reference measurement.
6. Test measurement.

NITRATE TEST (NO_3^-). Test preparation(<http://www.aqua-check.de>):

1. Fill both tubes up to the mark with the test water.
2. Add 2 small level measuring spoons of NO_3^- R1 to one of the two tubes (test), close with the screw top lid and dissolve by shaking. Leave standing for 2 minutes.
3. Add 1 big level measuring spoon of NO_3^- R2 to the test, close with the screw top lid and dissolve by shaking. Measure after exactly 6 minutes reaction time.

Measuring with AQUA-CHECK:

4. Reference measurement.
5. Test measurement.

Nitrite test (NO_2^-). Test preparation (<http://www.aqua-check.de>):

1. Fill both tubes up to the mark with the test water.
2. Add 1 big level measuring spoon of NO_2^- – to one of the two tubes (test), close with the screw top lid and dissolve by shaking. Leave standing for 3 minutes.

Measuring with AQUA-CHECK:

3. Reference measurement.
4. Test measurement.

Phosphate test (PO_4^{3-}). Test preparation (<http://www.aqua-check.de>):

1. Fill both tubes up to the mark with the test water.
2. Add 9 drops of PO_4^{3-} R1 to one of the two tubes (test), close with the screw top lid and mix.
3. Add the contents of the PO_4^{3-} R2 ampule to the test, close with screw top lid and mix. Measure after exactly 5 minutes reaction time.

Measuring with AQUA-CHECK:

4. Reference measurement.
5. Test measurement.

3.5 Recommendations and Lessons learnt

You should rinse the measurement components and the lenses in particular with distilled water after every measurement. The lens can, if required, also be cleaned with a fuzz-free cloth or a cotton bud. No components must be removed for cleaning. Insert the cotton bud on the side through the cut-outs of the measuring tube and rub the lens clean on the bottom without applying pressure. The end of the transparent rod can also be cleaned.

Ensure that the measuring optics is always clean. Residue can cause measuring errors.

Please inform professor if any faults or problems occur when using the photometer, in particular in any kind of accident.

Tab 3.2: Comparison of Dissolved Oxygen (DO) characteristics in KRB

	KAZ Guidelines	2015 data	2016 data	2017 data
Classification of water pollution on dissolved oxygenindicator (mg/l)				
Normatively clean	$\geq 4,0$	<i>Environmental Monitoring</i>	<i>Environmental Monitoring</i>	<i>Environmental Monitoring</i>
Medium level of pollution	3,1 – 3,9	Urban and Rural area	Rural area	Urban and Rural area
High level of pollution	1,1 – 3,0	Rural area	Urban area	-
Extremely polluted	$\leq 1,0$	-	-	-

Working Group (Names)

Date:

Time:

Location: UTM 43T E:

N:

ID:

Altitude:

Weather:

Water/River conditions:

Parameters	Measurements
Nitrate mg/l	
Nitrite mg/l	
Ammonium mg/l	
Phosphate mg/l	

3.6 Chemical Assessment and Report writing

Here, too, it is important that the data obtained is saved immediately after the field work and the collection of the data. This is best done by digitising the observation sheets completed in the field and summarising them in a Excel table (Table 3.4). In addition to these standard measurements, other elements can be measured, but special attention should be paid to nutrients in the rivers or lakes. A digitised field table would then have to be expanded to include the corresponding columns.

The evaluation of the chemical field data cannot replace exact laboratory values and only provide an initial assessment of the chemical state of the water. However, special attention should be paid to noticeably high measured values. During the evaluation, attention should be paid to a uniform and consistent arrangement of the measured values. So, among other things, it has proven useful to arrange the sample numbers according to the altitude asl.

The graphical representation of the measured values should take place in line and bar diagrams and special anomalies should be highlighted or marked.

Once this tabular work and the graphical representation of the measurement results are done, one begins with the description of the data. This should initially be done descriptively and any particular abnormalities should be dealt with. Above all, this could be higher measured values in a certain stretch of water, such as nutrient concentrations.

The last section is devoted to the written interpretation of the values. Comparison tables should help to interpret the values. Sewage sludge ordinances, waste water regulations and drinking water assessments or international standards can be used. In section 3.3 standards of the World Health Organization have already been listed.

The final end of every assessment is the assessment report includes:

1. All observed data/tables in the appendix;
2. All possible evaluation forms in the text as tables;
3. A narrative Description of the assessment;
4. Comparison with the previous years
5. What is the message of the recent measurements?
6. Lessons learnt, if necessary

Tab 3.4 Chemical Results “*year river basin*” for Assessment (for Data safety in Excel)

Sample Nr.	Nitrate NO2 mg/l	Nitrite NO3 mg/l	Phosphate mg/l	Ammonium mg/l	pH

References and further information sources

<https://www.intechopen.com/chapters/69568>

<https://www.onlinebiologynotes.com/chemical-parameters-of-water-quality-chemical-characteristics-of-water/>

<http://wgbis.ces.iisc.ernet.in/energy/monograph1/Methpage1.html>

Walther, M. et al. 2016: Water Quality & Security Assessment of Kaskelen River Basin. – unpubl. Report 2015 – 2016.

Walther, M. et al. 2017: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2017.

Walther, M. et al. 2018: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2018.

Walther, M. et al. 2019: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2019.

Walther, M. et al. 2021: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2021.

Walther, M. et al. 2022: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2022.

Walther, M. et al. 2023: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2023.

Walther, M. et al. 2024: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2024.

4. Physical Tests and their Assessment

Water is a unique binary inorganic compound with the chemical formula H_2O . Under normal conditions, it is a clear liquid that does not have color (with a small thickness of the layer), smell and taste. However, water like any other substance is subject to external changes. To identify the quality of water there is a physical analysis described in the following sub-chapter.

4.1 Equipment for Physical Analysis

The German company “PCE Instruments” is working on very important things – industrial measurement products, which help to better understand and optimize processes and offers ready-made industrial measurement technologies for complex tasks of modern developments



Fig. 4.1: Multiparameter Tester of PCE – PHD 1.

That will help achieve maximum reliability. One of their products is the Tester PCE-PHD 1, designed to measure the physical parameters of water (Figure 4.1).

PCE-PHD 1 Multifunction pH Meter is a portable, easy-to-use measuring device with multiple capabilities for inspecting water quality. Offering extraordinary precision at an affordable price, the Multifunction pH Meter is used for laboratory and in situ testing of the pH value, redox, conductivity, salt content, oxygen level and temperature of water. Three-point calibration and automatic temperature compensation guarantee a high level of accuracy even with variable temperature measurements. The specifications of the measured parameters, including their units, accuracy are presented in Table 4.1.

PCE-PHD 1 comes with both a pH electrode and a conductivity electrode. Additional electrodes are available for purchase separately, as is an optional mains adapter for power and a software kit with an RS-232 cable. PCE-PHD 1 acts as a real-time data logger. All values can be stored directly on the included SD card in Microsoft Excel format or transferred to a PC by means of the RS-232 port. Thus, no additional software is required for evaluation of the data.

Highlights:

- Automatic calibration
- Low battery indication
- Adjustable measurement rate
- Manual or automatic temperature compensation
- Compatibility with SD cards up to 16 GB
- Electrodes for pH and conductivity
- BNC connector.

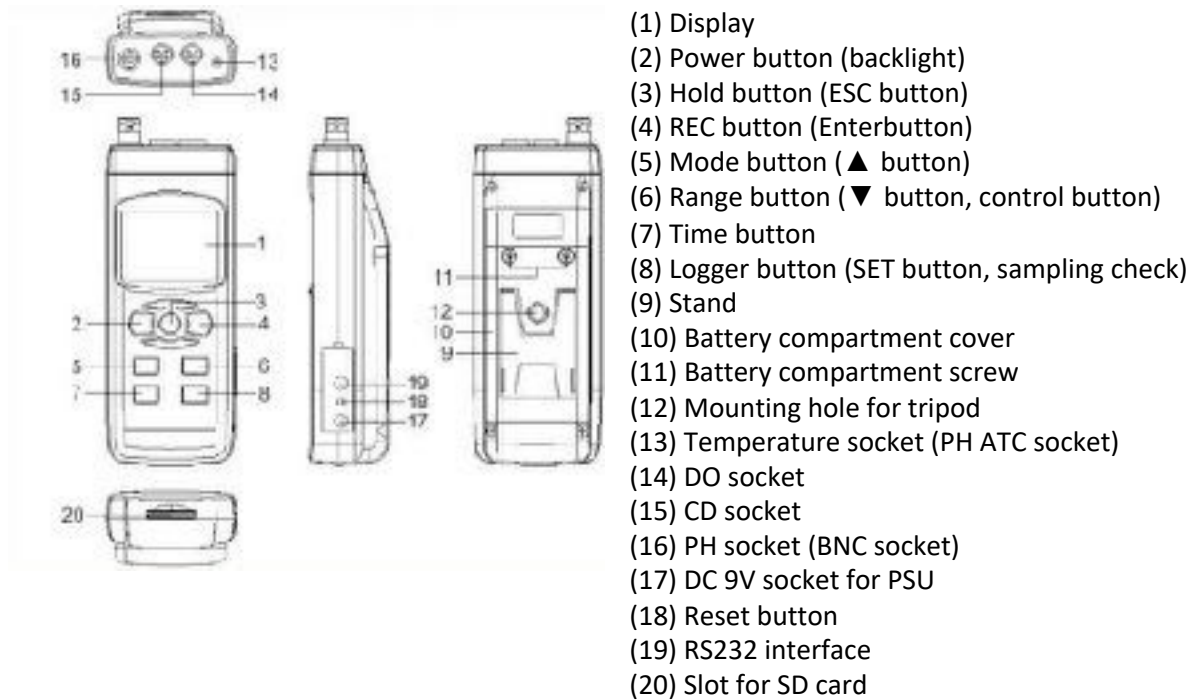


Fig. 4.2: Device structure.

General specifications:

Measurement rate	1 second up to 9 hours
Display	LCD
Memory	SD card up to 16 GB (2 GB card included)
Interface	RS-232
Software	Optional
Powersupply	6 x 1.5 V AA batteries (optional power adapter)
Operatingconditions	0 ... +50 °C / < 85 % RH
Dimensions	177 mm x 68 mm x 45 mm / 7.0 in x 2.7 in x 1.8 in
Weight	490 g / 1.1 lbs

Tab 4.1: Specification of measured parameters.

pH measurement

Measurement range	0 ... 14.0 pH
Resolution	0.01 pH
Accuracy	±0.02 pH + 2 digits
Calibration	3 points (pH 4, pH 7, and pH 10)
Temperature compensation	Automatic with additional temperature sensor (0 ... 60 °C / 32 °F ... 140 °F) or manual (0 ... 100 °C / 32 °F ... 212 °F)
Conductivity	
Measurement range	0 ... 200 µS/cm, 0.2 ... 2.0 mS/cm, 2 ... 20.0 mS/cm, 20 ... 200 mS/cm
Resolution	0.01 µS/cm, 0.001 mS/cm, 0.01 mS/cm, 0.1 mS/cm
Accuracy	±2 % of the measurement range + 1 digit
Calibration	1413 mS/cm
Temperature compensation	Automatic (0 ... 60 °C / 32 °F ... 140 °F)
Total dissolved solids (TDS)	
Measurement range	0 ... 132 ppm, 132 ... 1320 ppm, 1320 ... 13200 ppm, 13200 ... 132000 ppm
Resolution	0.1 ppm, 1 ppm, 10 ppm, 100 ppm
Accuracy	±2 % of the measurement range + 1 digit
Temperature compensation	Automatic (0 ... 60 °C / 32 °F ... 140 °F)
Salt content	
Measurement range	0 ... 12 % (of weight)
Resolution	0.1 %
Accuracy	±0.5 % of the measurement range
Temperature compensation	Automatic (0 ... 60 °C / 32 °F ... 140 °F)
Oxygen	
Measurement range	0 ... 20 mg/l (in water), 0 ... 100 % (in air), 0 ... 50 °C / 32 °F ... 122 °F
Resolution	0.1 mg/l, 0.1 %, 0.1 °C

Accuracy	± 0.4 mg/l, ± 0.7 %, ± 0.8 °C
Calibration	In the air
Temperature compensatio	Automatic (0 ... 50 °C / 32 °F ... 122 °F)
Temperature	
Measurement range	0 ... 60 °C / 32 °F ... 140 °F
Resolution	0.1 °C
Accuracy	± 0.8 °C
Temperature compensation	Automatic (0 ... 60 °C / 32 °F ... 140 °F)

4.2 Physical Parameters

pH (potential of hydrogen) – a numeric scale used to specify the acidity or basicity of an aqueous solution. It is approximately the negative of the base 10 logarithm of the molar concentration, measured in units of moles per liter, of hydrogen ions. More precisely it is the negative of the base 10 logarithm of the activity of the hydrogen ion. Solutions with a pH less than 7 are acidic and solutions with a pH greater than 7 are basic. Pure water is neutral, at pH 7 (25 °C), being neither an acid nor a base. Contrary to popular belief, the pH value can be less than 0 or greater than 14 for very strong acids and bases respectively.

The pH scale is traceable to a set of standard solutions whose pH is established by international agreement. Primary pH standard values are determined using a concentration cell with transference, by measuring the potential difference between a hydrogen electrode and a standard electrode such as the silver chloride electrode. The pH of aqueous solutions can be measured with a glass electrode and a pH meter, or an indicator.

Conductivity (or specific conductance) of an electrolyte solution – a measure of its ability to conduct electricity. The SI unit of conductivity is siemens per meter (S/m). **However, we use principally $\mu\text{S}/\text{cm}$ of measurement for electrical conductivity.** Measured in Siemens [S] or millisiemens [mS] or microsiemens [μS] per meter [m] or centimeter [cm]. Millisiemens per meter [mS/m] or microsiemens per centimeter [$\mu\text{S}/\text{cm}$] are commonly used. Conversion: $10 \mu\text{S}/\text{cm} = 1 \text{ mS}/\text{m}$. The conductivity of water depends heavily on its purity: highly pure, distilled water has a conductivity of around 0.055 to $20 \mu\text{S}/\text{cm}$, while German tap water has a conductivity of **300 to $800 \mu\text{S}/\text{cm}$** and seawater even has a conductivity of $56,000 \mu\text{S}/\text{cm}$ (or $56 \text{ mS}/\text{cm}$). Conductivity increases with the concentration of dissolved ions, i.e., the more salts or minerals there are in the water.

Conductivity measurements are used in routinely in many industrial and environmental applications as a fast, inexpensive and reliable way of measuring the ionic content in a solution. For example, the measurement of product conductivity is a typical way to monitor and continuously trend the performance of water purification systems.

In many cases, conductivity is linked directly to the total dissolved solids (T.D.S.). High quality deionized water has a conductivity of about $5.5 \mu\text{S}/\text{m}$, typical drinking water in the range of 5– $50 \mu\text{S}/\text{m}$, while sea water about $5 \text{ S}/\text{m}$ (i.e., sea water's conductivity is one million times higher than that of deionized water).

Total dissolved solids (TDS) - a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro- granular (colloidal sol) suspended form.

Generally, the operational definition is that the solids must be small enough to survive filtration through a filter with two-micrometer (nominal size, or smaller) pores. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. The principal application of TDS is in the study of water quality for streams, rivers and lakes.

Although TDS is not generally considered a primary pollutant (e.g. it is not deemed to be associated with health effects) it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants.

Salinity is the saltiness or amount of salt dissolved in a body of water. Salinity is an important factor in determining many aspects of the chemistry of natural waters and of biological processes within it, and is a thermodynamic state variable that, along with temperature and pressure, governs physical characteristics like the density and heat capacity of the water.

Dissolved oxygen refers to the level of free, non-compound oxygen present in water or other liquids. It is an important parameter in assessing water quality because of its influence on the organisms living within a body of water. In limnology (the study of lakes), dissolved oxygen is an essential factor second only to water itself. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality.

Non-compound oxygen, or free oxygen (O_2), is oxygen that is not bonded to any other element. Dissolved oxygen is the presence of these free O_2 molecules within water. The bonded oxygen molecule in water (H_2O) is in a compound and does not count toward dissolved oxygen levels. One can imagine that free oxygen molecules dissolve in water much the way salt or sugar does when it is stirred. Measured in % or mg per liter.

Temperature is a physical quantity expressing the subjective perceptions of hot and cold. Temperature is measured with a thermometer, historically calibrated in various temperature scales and units of measurement. The most commonly used scales are the Celsius scale, denoted in $^{\circ}C$ (informally, *degrees centigrade*), the Fahrenheit scale ($^{\circ}F$), and the Kelvin scale. The kelvin (K) is the unit of temperature in the International System of Units (SI), in which temperature is one of the seven fundamental base units.

4.3 Physical Standards

The tightening of pollution monitoring and assessment, which were launched by the Stockholm conference in 1972 to establish a global system of environmental monitoring (GSEM), were further developed in the UN conference on environment and sustainable development (Rio de Janeiro, 1992) as a natural phenomenon or a control and subsequent improvement of an ecological situation there.

These postulates are reflected in the law of the Republic of Kazakhstan named “About environmental protection” adopted in August 1997, where several articles are devoted monitoring of the environment of the country, including water bodies.

Monitoring and assessment of surface water in Kazakhstan were adopted in “Guidelines for surface water quality assessment by hydrochemical indicators” in 2012. These guidelines defines the basic provisions on the organisation of surface water quality complex assessment and contain the rules for doing calculations based on officially submitted data (Kazhydromet , 2012).

According to the main physical characteristics, which were analysed during the field work from 2015 to 2017, was created a comparative table between Kazakh National Standards (2012) and measured results (Table 3.1).

Hardness

Hardness varies greatly due to differences in geology, there aren't general standards for hardness. The

hardness of water can naturally range from zero to hundreds of milligrams per liter (or parts per million). Water with a total hardness in the range of 0 to 60 mg/L are termed soft; from 60 to 120 mg/L moderately hard; from 120 to 180 mg/L hard; and above 180 mg/L very hard. If water is very hard, water softeners may be required to avoid deposits forming on fixtures.

Alkalinity

Alkalinity varies greatly due to differences in geology, there aren't general standards for alkalinity. Levels of 20-200 mg/L are typical of fresh water. A total alkalinity level of 100-200 mg/L will stabilize the pH level in a stream. Levels below 10 mg/L indicate that the system is poorly buffered, and is very susceptible to changes in pH from natural and human-caused sources.

Conductivity (SC)

Generally, there aren't regulatory levels for SC. Instead, the concentration of Total Dissolved solids (TDS) is often regulated. However, SC is an easily-obtained parameter that is a good indicator of the number of dissolved solids in water, and thus can be used to detect contaminants in water.

Pure water would theoretically have an SC value of zero $\mu\text{S/cm}$ at 25° C; however, this water is very difficult to produce. Distilled or deionized water has an SC of at least 1 $\mu\text{S/cm}$. Rain water can have an SC value higher than distilled water, because it dissolves gases from the air and also particles of dust or other airborne material. Sea water has an SC of approximately 50,000 $\mu\text{S/cm}$, caused by the large number of dissolved salts it contains. The conductivity of water depends heavily on its purity: highly pure, distilled water has a conductivity of around 0.055 to 20 $\mu\text{S/cm}$, while German tap water has a conductivity of **300 to 800 $\mu\text{S/cm}$** and seawater even has a conductivity of 56,000 $\mu\text{S/cm}$ (or 56 mS/cm). Conductivity increases with the concentration of dissolved ions, i.e., the more salts or minerals there are in the water.

Total Dissolved Solids

The U.S. Environmental Protection Agency (U.S. EPA) sets a secondary standard of 500 mg/l TDS in drinking water (<http://www.epa.gov/safewater/mcl.html>). Secondary standards are unenforceable, but recommended, guidelines for contaminants that may cause cosmetic or aesthetic effects in drinking water. High TDS concentrations can produce laxative effects and can give an unpleasant mineral taste to water. It is also unsuitable for many industrial applications.

Temperature

Colorado Department of Public Health and Environment-Water Quality Control Division (CDPHE-WQCD) regulations (5 CCR 1002-31) state that waters classified as "Class 1 Cold Water Aquatic Life" should never have temperatures exceeding 20° C, while waters classified as "Class 1 Warm Water Aquatic Life" should never have temperatures exceeding 30° C (<http://www.cdphe.state.co.us/cdphe/reg.asp#wqreg>). These regulations also state that temperature for these classes shall maintain a normal pattern of diurnal and seasonal fluctuations with no abrupt changes and shall have no increases in temperature of a magnitude, rate, and duration deemed harmful to the resident aquatic life. Generally, a maximum 3° C increase over a minimum of a 4-hr period, lasting 12 hrs maximum, is deemed acceptable. Temperature preferences among aquatic species vary widely, but all species tolerate slow, seasonal changes better than rapid changes.

4.4 Guidelines for Physical Tests

1. Switch on the meter by pushing and holding the power button (2) for a few seconds. (Pushing and holding the button again for more than two seconds switches off the device.)
2. You can choose from four modes. After pushing the mode button (5), the display will show the following options in sequence (Table 4.2):

Table 4.2: Abbreviation of the physical parameters, measured by PHD1

PH	pH (ORP) measurement
Do	Dissolved oxygen measurement
Cd	conductivity, TDS measurement
SALt	salt measurement

pH MEASUREMENT



Note: The default settings of the meter are: displayed unit = pH temperature unit = °C manual temperature compensation (when the probe is not connected) automatic power off deactivated sampling time of the data logger = 2 seconds.



CAUTION: When first using the probe along with the meter, urgently **calibrate before starting** with the measurement.

pH measurement (manual temperature compensation):

1. Switch on the device.
2. Select the "PH" measurement mode.
3. Put the plug of the probe into the BNC socket (16).
4. Adapt the temperature manually to the temperature of the solution to be measured.
5. Hold the handle of the probe and dip the complete probe head into the solution.
6. Stir slightly.
7. The display will show the pH value and the set temperature value.

pH measurement (automatic temperature compensation – ATC):

1. Switch on the device.
2. Select the "PH" measurement mode.
3. Insert the plug of the probe into the BNC socket (16).
4. Insert the plug of the temperature probe into the temperature socket (13).
5. Hold the handles of the probes and dip the complete probe heads into the solution.
6. Stir slightly.
7. The display will show the pH value and the measured temperature value.



Note: When the pH probe is not in use, the probe head must be in the protective bottle.

pH CALIBRATION

Background:

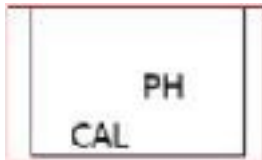
An ideal pH electrode generates a voltage value of zero millivolts when the pH value is seven. The device was calibrated with signals which indicate this optimum value at an ambient temperature of 25 °C. Not all electrodes come up to these optimum values. That is why a calibration must be carried out before first use. Additionally, occasional calibrations of a used probe makes sense in order to ensure precise measurements.

For calibration, a pH electrode and a pH standard solution are necessary.

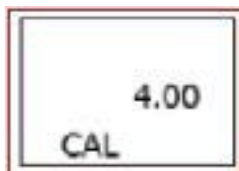
To carry out a pH calibration:

1. Put the plug of the pH probe into the BNC socket (16).

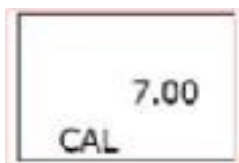
2. Switch on the device.
3. Select the "PH" measurement mode.
4. Adapt the temperature manually to the temperature of the standard solution or put the plug of the temperature probe into the temperature socket (13). If you want to use the temperature probe, you must dip it into the standard solution.
5. Dip the tip of the pH probe into the standard solution.
6. Stir slightly.
7. The display will show the pH value and the set / measured temperature value.
8. Push the REC button and the Hold button at the same time until the following is displayed:



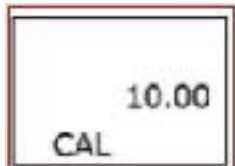
9. Use the arrow buttons to choose one of the following indications:



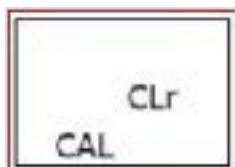
for calibration by means of a solution with a pH value of 4



for calibration by means of a solution with a pH value of 7



for calibration by means of a solution with a pH value of 10



for deleting the existing calibration

10. By pushing the Enter button, you can finish the calibration.



Calibration Solution pH4, pH7 and pH10.
pH electrodes drift over time, causing measurement errors. To ensure high accuracy, we recommend regular calibration of pH meters.
pH 4, pH 7 and pH 10
Dosing with certificate
Various sizes can be selected
Manufacturer: PCE Instruments

Fig. 4.3: Calibration Solution pH4 and pH7 and pH10.



Storage solution for pH electrodes: -500ml storage solution 3 mol / l in a standard bottle
 Manufacturer: [PCE Instruments](https://www.pce-instruments.com)

Fig. 4.4: Electrode Storage Solution 3mol / l.



Fig. 4.5: REDOX- Test Solution HI 7021L (Manufacturer: Hanna Instruments Deutschland GmbH)



Note: You should make at least a two-point calibration (i. e. pH 7 and pH 4 calibration or pH 7 and pH 10 calibration). First calibrate with pH7 and afterwards with pH 4 / pH10. Between the processes, clean the electrode with distilled water. Carry out the two-point calibration at least twice.

CONDUCTIVITY MEASUREMENT



Note: The default settings of the meter are:

displayed unit = μS , mS

temperature unit = $^{\circ}\text{C}$

temperature compensation factor = 2 % per $^{\circ}\text{C}$

automatic range selection automatic power off deactivated sampling time of the data logger = 2 seconds



CAUTION: When first using the probe along with the meter, urgently **calibrate before starting** with the measurement.

To measure conductivity:

1. Put the plug of the conductivity probe into the CD socket (15)
2. Switch on the device.
3. Select the "Cd" measurement mode.
4. Hold the handle of the probe and dip the complete probe head into the solution.
5. Shake the probe to make sure that the air bubble escapes from the probe head.
6. The display will show the conductivity value and the measured temperature value.

Manual range selection

Automatic range selection is set as default for measuring conductivity, but by means of the Range button you can switch between the two ranges.

Zero adjustment

When the probe is not in the solution to be measured and the display still does not indicate “Zero“, you can force “Zero“ to be displayed by pushing the zero button (5) for at least 10 seconds.

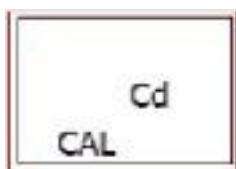
Note: Zero adjustment is only possible in the range of 200 μS and with a deviation of $< 2 \mu\text{S}$.

CONDUCTIVITY CALIBRATION

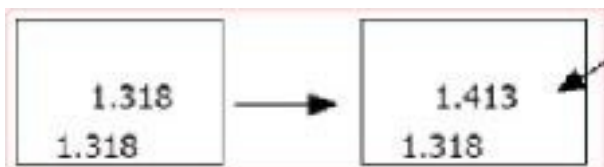
For calibration, a conductivity standard solution is necessary, e. g. 1.413mS standard solution for a measurement range of 2 mS, 80 μS standard solution for a measurement range of 200 μS and 12.88 mS for a measurement range of 20mS.

To carry out a conductivity calibration:

- 1.Put the plug of the conductivity probe into the CD socket (15)
- 2.Switch on the device.
- 3.Select the “Cd” measurement mode.
- 4.Hold the handle of the probe and dip the complete probe head into the solution.
- 5.Shake the probe to make sure that the air bubble escapes from the probe head.
- 6.The display will show the conductivity value.
- 7.Push the REC button and the Hold button at the same time until the following is displayed:



- 8.Push the Enter button. The measurement value will be shown on the upper and on lower sides of the display.
- 9.Use the arrow buttons to set the upper value exactly to the value of the standard solution.



value of the standard solution

10. Push the Enter button so that the data is saved and the calibration is finished



Conductivity solution 500 ml; 1413 μS / cm;
Potassium chloride 0.01 mol / l in a dosing bottle with a certificate
Manufacturer: PCE Instruments

Fig. 4.6: Potassium Chloride Conductivity Solution 1413 μS / cm



Note: If you only want to carry out a one-point calibration, it is sufficient to calibrate the measurement range of 2mS. If you make a calibration with several points, you must first calibrate the range of 2 mS and afterward the other ranges.

TDS MEASUREMENT



Note: The procedure is as that in conductivity measurement. The only difference is that the unit must be switched from $\mu\text{S}/\text{mS}$ to ppm.

SALT CONTENT MEASUREMENT

To measure the salt content:

1. Put the plug of the conductivity probe into the CD socket (15)
2. Switch on the device.
3. Select the "SALT" measurement mode.
4. Hold the handle of the probe and dip the complete probe head into the solution.
5. Shake the probe to make sure that the air bubble escapes from the probe head.
6. The display will show the salt content in % (1 % is equivalent to 10 g/kg).

CALIBRATION OF THE SALT CONTENT MEASUREMENT



Note: If you have already carried out a calibration of the conductivity measurement, a calibration of the salt content measurement is not necessary.

DISSOLVED OXYGEN MEASUREMENT



CAUTION: When first using the probe along with the meter, urgently **calibrate before starting** with the measurement. In order to ensure exact measurements, **it is recommended** to carry out a calibration before every measurement.

To measure dissolved oxygen:

1. Put the plug of the oxygen probe into the DO socket (14).
2. Switch on the device.
3. Select the "do" measurement mode.
4. Hold the handle of the probe and dip the probe head at least 10 cm deep into the solution to be measured so that the probe takes over the temperature of the liquid, which enables automatic temperature compensation. If the difference in temperature between the probe and the solution is only a few degrees, a few minutes for temperature compensation are sufficient.
5. For the measurement, it is enough to dip the tip of the probe into the liquid. However, the flow velocity of the medium must be at least 0.2 – 0.3 m/s. This can also be achieved by shaking the probe.
6. The display will show the value of dissolved oxygen in mg/l as well as the temperature of the solution.
7. Clean the probe with ordinary tap water after each series of measurements.



Note: Under laboratory conditions it is recommended to use a blender or stirrer to ensure a consistent flow velocity. In this way, the diffusion of ambient air oxygen into the solution can be reduced to the minimum.

ATMOSPHERIC OXYGEN CONTENT MEASUREMENT

When the device is in "do" mode, push the control key (6) in order to switch from mg/l to %O₂. The atmospheric oxygen content is now displayed as a reference value.

CALIBRATION OF THE ATMOSPHERIC OXYGEN CONTENT MEASUREMENT

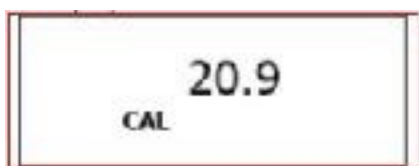


CAUTION: To ensure the best possible calibration result, make sure that the calibration

is carried out in a well-ventilated environment. The volume share of oxygen in the ambient air is normally 20.9 %. That is why this value serves as the reference value.

To carry out an oxygen calibration:

1. Put the plug of the oxygen probe into the DO socket (14) .
2. Switch on the device.
3. Select the “do” measurement mode.
4. Use the control key (6) to switch from mg/l to %O₂.
5. Wait until the measurement value has stabilised. This will take at least five minutes.
6. Push the REC button and the Hold button at the same time until the following is displayed (for example):



7. Push the Enter button. The device counts from 30 to 0, then returns to normal measuring operation and finishes the calibration. The calibration process takes 30 seconds.

Maintenance of the oxygen probe

First use of the probe

In order to keep the probe in good condition from the beginning, first fill the electrolyte of the probe.

After longer use of the probe

Whenever an exact device calibration fails or no stable measurement value can be determined, check whether the level of electrolytes in the probe head is too low or whether the membrane is dirty (in case the probe contains a membrane).

Background information on a probe with a membrane in the measurement head:

This is a thin membrane made of Teflon® which can be found in the probe tip. Oxygen molecules can pass through the membrane whereas the substantially bigger molecules contained in the electrolyte cannot. This feature enables the oxygen to spread out in the electrolyte of the probe and its concentration can be measured.

To fill the electrolyte

1. Unscrew the probe head (3).
2. Remove the old electrolyte from the probe head.
3. Put the new electrolyte (OXEL-3) into the probe head.
4. Screw the probe head back together with the case.



Note: When the probe is not in use, the probe head must be in the protective bottle.



- (1) Case
- (2) Temperature sensor
- (3) Probe head

Fig. 4.7: Oxygen probe OXPB – 11.

4.5 Lessons learnt and Recommendations

In order to improve the efficiency and quality of the field work, recommendations were drawn up, which are based on previous field experience (Table 4.3).

Tab 4.3: Recommendations for improvement the efficiency and quality of the field work

What	Why
Mobile table	In order to make sure the safety (from water and damage) and accuracy of the equipments, a mobile table is needed to be taken.
Wader /rubber boot	Since the group was waiting for free waders and it took much time, it is recommended to take more than one pair of wader to make measurements inside the river stream.
Stopwatch	Also, it would be good to use a stopwatch (device) instead of using the smartphone for timing. That was a big risk of dropping phone into the water.
Gloves and towel	When working with equipment and switching adapters, often hands became dirty and the equipment needs to be cleaned as well. In this regard, gloves and towel are needed.
Review of reports from the previous years	Before starting the field work, it is necessary to familiarize with the results of the previous measurements (Report) in order to adopt a unified methodology and to avoid writing an incorrect report.

Copy template Physical Assessment of Water Quality

Date:

Time:

Working Group (Names):

Location: UTM

E:

N:

Altitude:

Weather:

Water/River conditions:

ID:

Parameters	Measurements
Temperature C °	
Oxygen content mg/l	
Oxygen saturation %	
Biochemical Oxygen demand mg/l BSD	
pH	
Conductivity <u>µS/cm</u>	

4.6 Electromagnetic Flow Meter

4.6.1 Electromagnetic velocity meter MGG/KL-DCB

The series electromagnetic velocity meter MGG/KL-DCB (Figure 4.8) is a portable instrument for measuring flow velocity/rate. It is suitable for agricultural irrigation, hydrological monitoring, river flow monitoring, and urban water monitoring. Low power consumption design and full digital signal processing technology make the measurement more stable and reliable. Wide range and high accuracy.



Fig. 4.8: MGG/KL-DCB Portable Electromagnetic Flow Meter

Working principle.

The MGG/KL-DCB portable electromagnetic velocity/flow meter operates based on Faraday's law of electromagnetic induction. When a conductive liquid flows perpendicularly through an alternating magnetic field in the measuring pipe, it generates an induced electromotive force. Electrodes installed orthogonally to the pipe axis and magnetic field lines detect this force, which should be directly proportional to the flow rate. This signal is then amplified and converted into a standard DC output (0 ~ 10 mA, 4 ~ 20 mA) or frequency output (0 ~ 5 kHz), representing the flow velocity.

The velocity equation:

$E = KBVDV$ (K is induced electric potential magnification);

E- Induced potential (V);

V- Mean velocity when the fluid crosses the electrode surface in the range.

B - Magnetic induction intensity;

D - Induction electric potential spacing.

Structure.

The instrument structure is divided into three parts: an electromagnetic velocity sensor (the III-model includes a level sensor), a flow display, and a wading rod (or suspension wire).

Flow display terminals

It is used to connect the electromagnetic sensor. The outgoing line of the electromagnetic velocity sensor has a completed coupler plug (Figure 4.9).

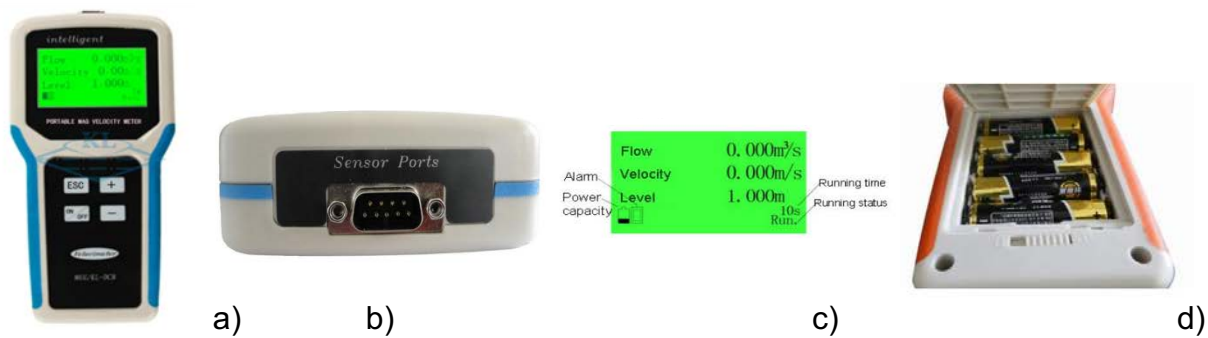


Fig. 4.9: Flow display terminals: a) flow display, b) display port, c) display interface, d) battery, and communication port

Note: Please insert the plug directly and tighten the screws.

Velocity sensor

The velocity sensor consists of a velocity sensor and a tail cable (Figure 4.10) .

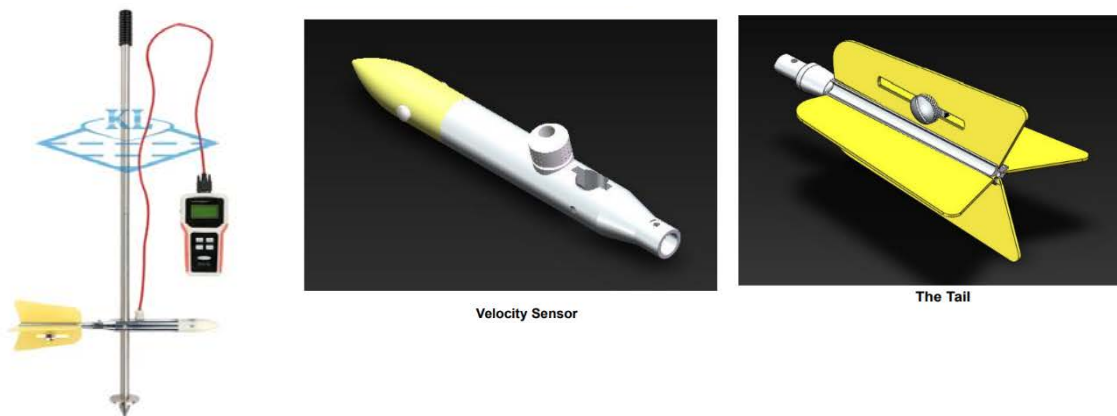


Fig. 4.10: Velocity sensor parts

Note: Please connect the display gantry with the velocity sensor as shown in Figure 4.10.

Measurement Instruction for Flowmeter

Installing and configuring the flow meter.

Step 1: Mounting, Secure the flowmeter to the measurement site with an iron rod or rope, ensuring vertical stability with an attached weight.

Step 2: Connections

Connect the sensor cables to the appropriate connectors on the flowmeter, strictly following the flowmeter wiring diagram. Follow Figure 4.10.

Step 3: Initialize and configure the device. Power up the device and open its configuration interface. Enter the required parameters, including units of measurement, calibration factors, and all specific settings. All necessary parameters are included in Table 4.4.

Tab 4.4: Parameter details of Flow Meter

Parameters	SET/Unit	Description
Calibration		This menu will be automatically calibrated on 01H 60S;

Level Adjust m 00,000 (River width)	0~20.000m	Measuring height. The height from the velocity sensor to the channel bottom (<i>Necessary setting</i>);
Flow Height m 00.000 (River Depth)	0~20.000m	The height of the channel from the surface to the bottom (<i>Necessary setting</i>);
Bottom Width m 00,000	0~20.000m	The width of the channel bottom at the water surface (<i>Necessary setting</i>);
Slope Grade	00.000	Side wall. The factor of the side wall, which means the aspect ratio of the trapezoid sidewall (<i>Necessary $\alpha=B/H$</i>);
Sens Margin	m 00,000	Edge distance: The distance from the velocity sensor to the channel side. (<i>Necessary setting</i>);
Damping 10	0~60	Long measurement filtering time can improve the stability of the flow display and the 7-signal output. Short measurement filtering time shows a fast corresponding speed.
Flow Unit m ³ /s 0	0=m ³ /s; 1=m ³ /h	Instantaneous flow divides m ³ /s and m ³ /h;
Velo Decimal m/s 1	m/s 1	The display of the converter is 3-digit for choice according to the need.
Running Time 10s 1	1 (10s)	The velocity meter will send average data within a certain period to display. This is the measurement period. Setting 0 means manual set measurement control time (Long measurement period can improve stability of velocity display and signal output. It is used for pulsating flow measurement field. Short measurement period means fast corresponding speed uses, for instance, velocity measurement);
Stop Time 10s 1	1 (10s)	The interval between two measurements is 0~900s;
Records ID xxxx	0~999	This parameter is for the serial number, which can be input by the user. It is used for recognizing value properties. The value number auto adds 1 every time.
Records No xxx	0~999	This parameter is used for historical data inquiry of value through page turning to judge value property.
Auto Off 1	0=off, 1=on	1 is a Time-limited model (1800s auto shutdown), 60s auto shutdown without any operation. 0 is a continuous working model;
Light on 0	0=off, 1=on	0 is the auto backlight shutdown when a faulty operation. 1 is keep running.

Note: For flow measurement, you must enter the river measurement parameters from the table above, which are determined as a necessary setting. These parameters will be calculated before they are added to the display.

To ensure compliance with established hydrometric standards, the sensor is calibrated using the one-point method. This technique involves positioning the velocity sensor at 60% (0.6*h) of the total water depth from the surface (i.e., 0.6 times the depth), a practice widely recognized for providing a reliable approximation of the mean velocity in a vertical profile, particularly in shallow streams and under routine field conditions.

Velocity distribution line within the velocity of vertical distribution and vertical direction of the water depth (Table 4.5)

Tab 4.5: Recommendation of measurement points due to water surface width.

Water width(m)	Vertical number
>0 and <0.5	3-4
>0.5 and <1	4-5
>1 and <3	5-8
>3 and <5	8-10
>5 and <10	10-20
>10	>20

Note: Velocity sensor position: Please point the measuring head upstream and ensure the velocity sensor is parallel to the flow direction. Waiting a moment for the stable running of the sensor, then resending the data. Avoid the primary interference signal input and eliminate the electrode oxide film interference.

Slope Grade/side wall calculation. In the context of trapezoidal channel design, the **aspect ratio**—often denoted as α —is defined as the ratio of the channel's bottom width (B) to its flow depth (H): [Academia](#)

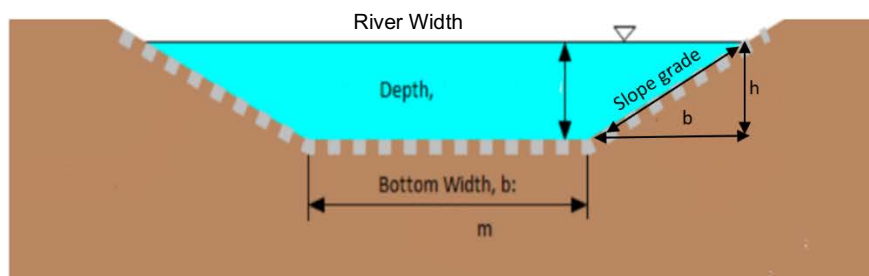


Fig. 4.11: Slope grade

Step 4: Start Data Input

- Hold the  quadrat button to initiate data entry mode.
- Navigate and Modify Settings. Press the quadrat button to cycle through display screens or modify settings.
- Data Input. Use the triangle  up/down  buttons to adjust values as needed.
- Save or Exit. Hold the quadrat button to save the entered data and use the  EXIT to return to the previous menu.

After all parameter settings are completed, long-press “EXIT” for 6 seconds. The program returns to the normal measuring status (it will automatically return to the normal measuring status if there is no operation).

Copy template
Electromagnetic Flow Meter

Working Group (Names):

 Water/River conditions:
 extrem high, high, normal, low
 UTM Zone

 Date:
 Time:

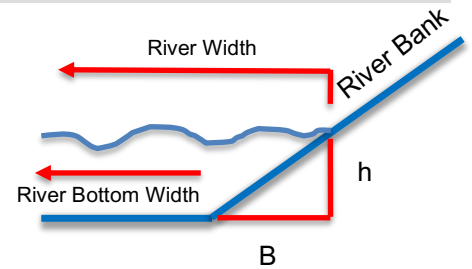
Northing:

Weather:

Easting:

ID: KAS

Altitude:



River width of the water surface:	m	The water surface from one river bank to the opposite bank
River Bottom width:	m	Bottom width: The width of the channel bottom
Slope Grade ($K_R = B : h$) Inclination factor K_R		Side wall: The factor of the side wall, which means the aspect ratio of the trapezoid side wall ($K_R = B/H$)

Point No. Measure 3 x	Flow in m^3/sec	Velocity in m/sec	Level/Water Depth m	Edge Distance (Sens margin) The distance from the velocity sensor to the river bank m	Sensor height (Level adjust): Measuring height: The height from the velocity sensor to the channel bottom ($0.6 \cdot h$)
1a					
1b					
1c					
2a					
2b					
2c					
3a					
3b					
3c					
4a					
4b					
4c					
5a					
5b					
5c					

If needed, continue on a separate sheet.

4.6.2 How to calculate the discharge at one measurement point?

Water discharge, also known as flow or discharge rate, is the volume of water passing through a specific point over a fixed period. In open channels like streams, rivers, and ditches, it may also be called surface flow or stream discharge. It's typically measured in cubic meters per second (m³/s) or cubic feet per second (cfs).

When calculating flow at a single measurement point in a stream or river, the velocity-area method is commonly used. The principle is as follows:

$$Q = v \cdot A$$

Where:

- **Q** = discharge (m³/s)
- **A** = cross-sectional area of flow (m²)
- **V** = average velocity of flow (m/s)

Step 1. Determine the width (w) and depth (d) of the stream at the measurement point. Divide the cross section into several vertical segments (subareas) as it shown in the Figure 4, calculate the area of each segment, and sum them:

$$A_{\text{total}} = \sum_{i=1}^n (w_i \times d_i)$$

Step 2. With a current meter, measure the velocity at different depths. The average velocity is usually measured at 0.6 of the total depth.

Step 3. Calculate the discharge (Q). After getting the values of A and V, substitute them into the formula:

$$Q = A \times V_{\text{avg}}$$

At the site of measurement, a cross-section is identified as a conceptual line crossing the stream perpendicular to the flow direction. This cross-section is divided into smaller sections (also known as subareas, profiles, or partial sections) of known width at which velocity is measured (Figure 4.12). The USGS recommends using between twenty-five to thirty subsections, but as a general rule, subsections should ideally contain less than 5 percent of the total discharge of the cross-section and not more than 10 percent.

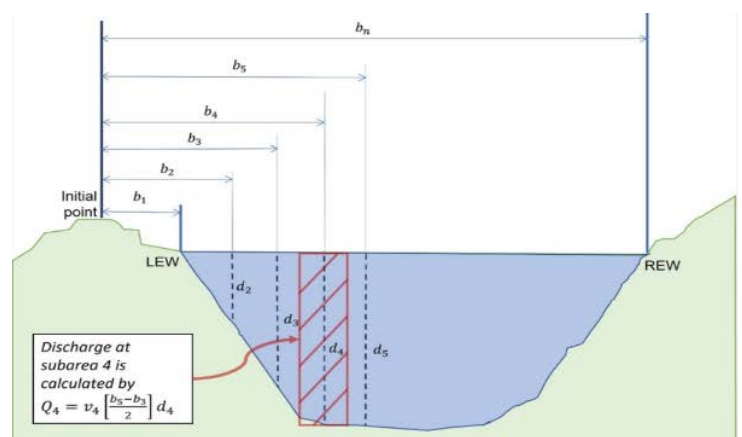
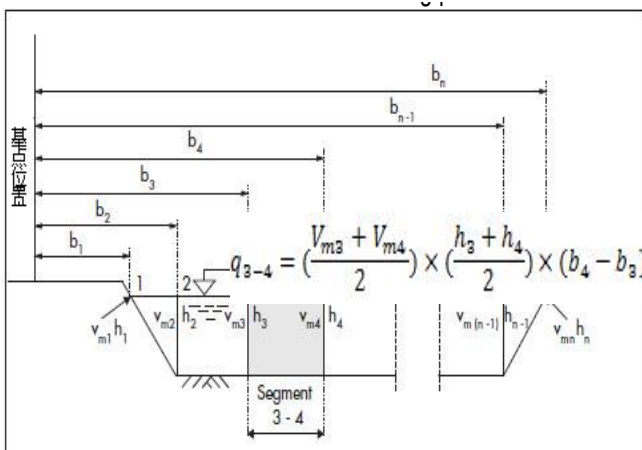


Fig. 4.12: Flow calculation between the measuring point line.

Regarding Figure 4.12, the partial discharge for any subarea is calculated as follows:

$$Q_i = v_i \left[\frac{(b_i - b_{i-1})}{2} + \frac{(b_{i+1} - b_i)}{2} \right] d_i \quad \text{or} \\ = v_i \left[\frac{b_{i+1} - b_{i-1}}{2} \right] d_i$$

Where Q_i is the discharge through subarea i , v_i is the mean velocity at location i , b_i is the distance from the initial point to each location i , b_{i-1} is the distance from the initial point to the preceding location, b_{i+1} is the distance from the initial point to the next location, and d_i is the depth of water at each location i . Distances and depths should be measured in meters, keeping consistent units (US customary or metric) for all parameters. The total discharge is the sum of the discharges in all subareas.

4.7 Report on Physical Assessment

Here, too, it is important that the data obtained is saved immediately after the field work and the collection of the data. This is best done by digitising the observation sheets completed in the field and summarising them in a table (Excel). In addition to these standard measurements, other parameters can be measured, but special attention should be paid to Oxygen in the rivers or lakes. A digitised field table would then have to be expanded to include the corresponding columns.

The evaluation of the physical field data cannot replace exact laboratory values (e.g. for Oxygen content) and only provide an initial assessment of the physical recent state of the water. However, special attention should be paid to noticeably high measured values. During the evaluation, attention should be paid to a uniform and consistent arrangement of the measured values. So, among other things, it has proven useful to arrange the sample numbers according to the altitude asl.

The graphical representation of the measured values should take place in line and bar diagrams and special anomalies should be highlighted or marked.

Once this tabular work and the graphical representation of the measurement results are done, one begins with the description of the data. This should initially be done descriptively and any particular abnormalities should be dealt with. Above all, this could be higher measured values in a certain section of the river course, such as discharge or water temperature.

The last section is devoted to the written interpretation of the values. Comparison tables should help to interpret the values. In section 4.3 regional standards have already been listed and described.

Calculation of the measured discharge

How to calculate the discharge at the sampling point based on the measurements?

Step 1: Copy the hand written data of the field measurements into Table 4.6. (Excel)

Tab 4.6: Table of data safety for discharge measurements (for table calculation, Excel)

Point Nr.	Flow in m ³ /sec	Velocity in m/sec	Level/Water Depth m	Edge Distance The distance from velocity sensor to river bank m
1a				
1b				
1c				
2a				
2b				
2c				
3a				
3b				
3c				
4a				
4b				
4c				
5a				
5b				
5c				

5. Final instruction for Report writing

ASK ChatGPT: Key components of a water assessment report:

- **Inventory (*Introduction*):** A list of water sources, meters, and water-using equipment.
- **Data Collection (*Field class*):** Gathering and analyzing information from various sources, including water bills, utility data, and on-site monitoring.
- **Analysis (*Data backup and results*):** A review of the collected data to understand water usage patterns, assess quality (e.g., pH levels), and identify potential risks or areas for efficiency.
- **Risk Assessment (*Conclusions-1*):** Identifying potential contaminants, assessing their impact, and determining the vulnerability of a water source to contamination.
- **Recommendations (*Conclusions-2*):** The report's findings are used to develop an action plan for improving efficiency, protecting a source water area, or planning for future water needs.

The final end of every assessment is the assessment report, which includes:

1. All observed field data/tables in the annex;
2. All possible evaluation forms in the text as tables;
The enumeration of figures and data follow the enumeration of the single chapters:
 1. Introduction;
 2. Biological monitoring; Fig. 2.1:, Tab. 2.1:, 2.2:, 2.3:, 2.4:, 2.5:, 2.6:
 3. Chemical Monitoring; Fig. 3.1:, 3.2:, 3.3:, Tab. 3.1:, Tab. 3.2:, Tab 3.3:,
 4. Physical Monitoring; Fig. 4.1:, 4.2:, 4.3:, 4.4:, 4.5:, 4.6:, 4.7:, 4.8:, 4.9:, 4.10:, 4.11:, 4.12:, Tab. 4.1:, 4.2:, 4.3:, 4.4:, 4.5:, 4.6:, 4.7:,
3. A narrative Description of the assessment;
The authors must explain or describe the course of the curves in the diagrams; present the maximum and minimum values; and explain the results of the surveys in a concluding chapter; Comparison with standard values (see Manual).
4. Comparison with previous data
What changes can be seen in the individual measurements? Are there improvements and/or deteriorations in the three methods used? What is the message of the measurements?
5. Conclusions
The chapter do NOT repeat the results. What conclusions or consequences can be drawn from results A, B, and C for the present and the future, and what solutions could be proposed? Are there any potential risks that could threaten water quality?

How to write a conclusion

To link results to conclusions, summarize the results, use them to answer the original research question or thesis, and then draw conclusions based on the analysis of the results. Establish a clear connection between the results and your conclusions by supporting your argument with evidence and interpreting the results in the context of the theoretical framework.

Steps for linking results and conclusions:

1. Recall the research question/thesis: Begin the conclusion by concisely restating the

original question or thesis to remind the reader of the main objective of the paper.

2. Summarize the results: Briefly summarize the most important results of your analysis. Use the results as evidence to support your conclusion.

3. Make the connection: Explain how your results answer the research question or confirm the thesis. Argue for the "correctness" of your considerations and show how your analysis leads to your conclusion.

4. Interpret the results: Explain the significance of your results in the context of the theoretical framework. Discuss what the results mean and what implications they have.

5. Draw conclusions: Formulate the final conclusions based on your results. This may include:

1. Confirmation or refutation of the hypothesis.

2. A conclusion that summarizes the key statements.

3. An outlook for future research or recommendations for action.

6. Use logical connecting words: Use phrases that clarify the transition from the results to the conclusion, such as "consequently," "therefore," or "accordingly."

Example (simplified):

- Result: By surveying 100 people, we found that 80% of them prefer a certain sport.

- Conclusion: This suggests that the sport is very popular among the surveyed population group. Consequently, we can conclude that promoting this sport would lead to greater participation.

To link results to conclusions, you need to interpret the significance of your results, place them in a broader context, and show how they answer your original question. This is usually done in the discussion section of a scientific paper.

Concerning Kaskelen River Basin

How is the Water Quality of Kaskelen River Basin to be estimated? Bad or Good?

We assume that the water quality is excellent and that it is also available in large quantities in future.

To find an answer to this we use (Methods)

What is the connection between the study question and the results? Are your results correct? Explain strength and weaknesses

Why are the results significant? Discuss the general meaning!

Are your key statements of your hypothesis confirmed or rejected?

Formulate recommendation for future management strategies. What must be improved? Is everything OK? Use logical connecting words: Use phrases that clarify the transition from the results to the conclusion, such as "consequently," "therefore," or "accordingly."

Important General Remark

Each group should prepare their own contribution to the subchapter "Conclusion". The editor will collect and edit this in the "Conclusion"

References and further information sources:

<http://www.epa.gov/safewater/mcl.html>).

<http://www.fao.org/3/x5624e/x5624e05.htm>

<https://www.ag.ndsu.edu/publications/environment-natural-resources/drinking-water-quality-testing-and-interpreting-your-results>

Walther, M. et al. 2016: Water Quality & Security Assessment of Kaskelen River Basin. - unpubl. Report 2014 - 2016.

Walther, M. et al. 2017: Water Quality & Security Assessment of Kaskelen River Basin. - unpubl. Report 2014 - 2017.

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Walther, M. et al. 2023: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2023.

Walther, M. et al. 2024: Water Quality Assessment of Kaskelen River Basin, - unpubl. Report 2024.

6. Annex

6.1 Glossary

A

Algae	Simple plants which do not grow true roots, stems, or leaves and live mainly in water, providing food for the food chain.
acid	a substance that has a pH of less than 7, which is neutral. Specifically, an acid has more free hydrogen ions (H ⁺) than hydroxyl ions (OH ⁻).
alkaline	sometimes water or soils contain an amount of alkali (strongly basic) substances sufficient to raise the pH value above 7.0 and be harmful to the growth of crops.
Alkalinity	the capacity of water for neutralizing an acid solution.
Alluvium	deposits of clay, silt, sand, gravel, or other particulate material that has been deposited by a stream or other body of running water in a streambed, on a flood plain, on a delta, or at the base of a mountain.
Aquaculture	farming of plants and animals that live in water, such as fish, shellfish, and algae.
Aquifer	a geologic formation(s) that is water bearing. A geological formation or structure that stores and/or transmits water, such as to wells and springs. Use of the term is usually restricted to those water-bearing formations capable of yielding water in sufficient quantity to constitute a usable supply for people's uses.
artesian water	groundwater that is under pressure when tapped by a well and is able to rise above the level at which it is first encountered. It may or may not flow out at ground level. The pressure in such an aquifer commonly is called artesian pressure, and the formation containing artesian water is an artesian aquifer or confined aquifer.
artificial recharge	an process where water is put back into groundwater storage from surface-water supplies such as irrigation, or induced infiltration from streams or wells.
Atmosphere	layers of gases which surround the Earth. Although the atmosphere may not be a great storehouse of water, it is the superhighway used to move water around the globe.

B

base	a substance that has a pH of more than 7, which is neutral. A base has less free hydrogen ions (H ⁺) than hydroxyl ions (OH ⁻).
base flow	sustained flow of a stream in the absence of direct runoff. It includes natural and human-induced streamflows. Natural base flow is sustained largely by groundwater discharges.
Basin	an area of land that drains all the streams and rainfall to a common outlet such as the outflow of a reservoir, mouth of a bay, or any point along a stream channel.
Bay	a body of water that is partly surrounded by land and partly surrounded by another body of water.
Bedrock	the solid rock beneath the soil and superficial rock. A general term for solid rock that lies beneath soil, loose sediments, or other unconsolidated material.
Biodiversity -	The number of different species of organisms in a particular environment.
Biological assessment	Assessing water quality by determining the diversity, abundance, and kinds of organisms that inhabit the stream.
Brook	a small stream

C

capillary action	the means by which liquid moves through the porous spaces in a solid, such as soil, plant roots, and the capillary blood vessels in our bodies due to the forces of adhesion, cohesion, and surface tension. Capillary action is essential in carrying substances and nutrients from one place to another in plants and animals.
Chemical assessment	Assessing water quality by performing various chemical tests to characterise the chemical composition of the water
commercial water use	water used for motels, hotels, restaurants, office buildings, other commercial facilities, and institutions. Water for commercial uses comes both from public-supplied sources, such as a county water department, and self-supplied sources, such as local wells.

Condensation	the process of water vapor in the air turning into liquid water. Water drops on the outside of a cold glass of water are condensed water. Condensation is the opposite process of evaporation.
consumptive use	that part of water withdrawn that is evaporated, transpired by plants, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the immediate water environment. Also referred to as water consumed.
conveyance loss	water that is lost in transit from a pipe, canal, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a groundwater source and be available for further use.
Creek	a natural stream of water normally smaller than and often tributary to a river.
Culvert	A closed passageway (such as a pipe) under roadways and embankments which drains surface water.

D

Desalination	the removal of salts from saline water to provide freshwater. This method is becoming a more popular way of providing freshwater to populations.
Desertification	Type of land degradation in which a relatively dry land region becomes increasingly arid, typically losing its bodies of water as well as vegetation and wildlife.
Discharge	the volume of water that passes a given location within a given period of time. Usually expressed in cubic feet per second.
domestic water use	water used for household purposes, such as drinking, food preparation, bathing, washing clothes, dishes, and dogs, flushing toilets, and watering lawns and gardens. About 85% of domestic water is delivered to homes by a public-supply facility, such as a county water department. About 15% of the Nation's population supply their own water, mainly from wells.
drainage basin	land area where precipitation runs off into streams, rivers, lakes, and reservoirs. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large drainage basins, like the area that drains into the Mississippi River contain thousands of smaller drainage basins. Also called a "watershed."

drawdown	a lowering of the groundwater surface caused by pumping.
drip irrigation	a common irrigation method where pipes or tubes filled with water slowly drip onto crops. Drip irrigation is a low-pressure method of irrigation and less water is lost to evaporation than high-pressure spray irrigation.
Drought	a period of drier-than-normal conditions that results in water-related problems.
Dump	A land site where trash is left exposed in a way which does not protect the environment.

E

Effluent:	An out-flowing branch of a main stream or lake; waste material (i.e., liquid industrial refuse, sewage) discharged into the environment.
Erosion	The wearing away of land by wind or water.
Estuary	a place where fresh and salt water mix, such as a bay, salt marsh, or where a river enters an ocean.
Evaporation	the process of liquid water becoming water vapor, including vaporization from water surfaces, land surfaces, and snow fields, but not from leaf surfaces. See transpiration
Evapotranspiration	the sum of evaporation and transpiration.
Evenness (E)	A measure of how similar the abundances of different species are in the community.

F

Flood	An overflow of water onto lands that are used or usable by man and not normally covered by water. Floods have two essential characteristics: The inundation of land is temporary; and the land is adjacent to and inundated by overflow from a river, stream, lake, or ocean.
flood stage	The elevation at which overflow of the natural banks of a stream or body of water begins in the reach or area in which the elevation is measured.
Floodplain	A low area of land, surrounding streams or rivers, which holds the overflow of water during a flood.

Floodway	The channel of a river or stream and the parts of the floodplain adjoining the channel that are reasonably required to efficiently carry and discharge the flood water or flood flow of a river or stream.
Flow	The direction of movement of a stream or river.
flowing well/spring	a well or spring that taps groundwater under pressure so that water rises without pumping. If the water rises above the surface, it is known as a flowing well.
freshwater, fresh water	water that contains less than 1,000 milligrams per liter (mg/L) of dissolved solids; generally, more than 500 mg/L of dissolved solids is undesirable for drinking and many industrial uses.

G

Groundwater	(1) water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturate zone is called the water table. (2) Water stored underground in rock crevices and in the pores of geologic materials that make up the Earth's crust.
gaging station, gauging station	a site on a stream, lake, reservoir or other body of water where observations and hydrologic data are obtained. The U.S. Geological Survey measures stream discharge at gaging stations.
Glacier	--a huge mass of ice, formed on land by the compaction and recrystallization of snow, that moves very slowly downslope or outward due to its own weight.
Greywater	--wastewater from clothes washing machines, showers, bathtubs, hand washing, lavatories and sinks.
groundwater recharge	--inflow of water to a groundwater reservoir from the surface. Infiltration of precipitation and its movement to the water table is one form of natural recharge. Also, the volume of water added by this process.

H

Hardness	a water-quality indication of the concentration of alkaline salts in water, mainly calcium and magnesium. If the water you use is "hard" then more soap, detergent or shampoo is necessary to raise a lather.
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Headwater(s)	(1) the source and upper reaches of a stream; also the upper reaches of a reservoir. (2) the water upstream from a structure or point on a stream. (3) the small streams that come together to form a river. Also may be thought of as any and all parts of a river basin except the mainstream river and main tributaries.
hydroelectric power water use	the use of water in the generation of electricity at plants where the turbine generators are driven by falling water.
hydrologic cycle	the cyclic transfer of water vapor from the Earth's surface via evapotranspiration into the atmosphere, from the atmosphere via precipitation back to earth, and through runoff into streams, rivers, and lakes, and ultimately into the oceans.

I

Ice	water in it's solid state. Water turns to ice at 32 degrees Fahrenheit.
industrial water use	water used for industrial purposes in such industries as steel, chemical, paper, and petroleum refining. Nationally, water for industrial uses comes mainly (80%) from self-supplied sources, such as a local wells or withdrawal points in a river, but some water comes from public-supplied sources, such as the county/city water department.
Infiltration	flow of water from the land surface into the subsurface.
injection well	refers to a well constructed for the purpose of injecting treated wastewater directly into the ground. Wastewater is generally forced (pumped) into the well for dispersal or storage into a designated aquifer. Injection wells are generally drilled into aquifers that don't deliver drinking water, unused aquifers, or below freshwater levels.
Irrigation	the controlled application of water for agricultural purposes through manmade systems to supply water requirements not satisfied by rainfall. Here's a quick look at some types of irrigation systems.
irrigation water use	water application on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands, such as parks and golf courses.

L

Lake	where surface-water runoff (and maybe some groundwater seepage) have accumulated in a low spot, relative to the surrounding countryside.
Leaching	The process where materials in the soil (such as nutrients and pesticide chemicals) are washed into lower layers of soil or are dissolved and carried away by water.
lentic waters	ponds or lakes (standing water).
Levee	a natural or manmade earthen barrier along the edge of a stream, lake, or river. Land alongside rivers can be protected from flooding by levees.
livestock water use	water used for livestock watering, feed lots, dairy operations, fish farming, and other on-farm needs.
lotic waters	flowing waters, as in streams and rivers.

M

Marsh	a primarily grassy area where water covers the ground most of the time. A marsh may be prone to flooding during wet seasons.
maximum contaminant level (MCL)	the designation given by the U.S. Environmental Protection Agency (EPA) to water-quality standards promulgated under the Safe Drinking Water Act. The MCL is the greatest amount of a contaminant that can be present in drinking water without causing a risk to human health.
milligrams per liter (mg/l)	a unit of the concentration of a constituent in water or wastewater. It represents 0.001 gram of a constituent in 1 liter of water. It is approximately equal to one part per million (PPM).
mining water use	water use during quarrying rocks and extracting minerals from the land.
Monitoring	To watch and care for a stream on a regular basis.
municipal water system	a water system that has at least five service connections or which regularly serves 25 individuals for 60 days; also called a public water system

N

Non-point source pollution	pollution discharged over a wide land area, not from one specific location. These are forms of diffuse pollution caused by sediment, nutrients, organic and toxic substances originating from land-use activities, which are carried to lakes and streams by surface runoff. Non-point source pollution is contamination that occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants, such as nutrients and pesticides.
Nutrient	Substance which is necessary for growth of all living things (i.e., oxygen, nitrogen, and carbon)

O

Ocean	Earth's largest bodies of water are called oceans. They divide Earth's continents and contain saline water.
organic matter	plant and animal residues, or substances made by living organisms. All are based upon carbon compounds.
Osmosis	the movement of water molecules through a thin membrane. The osmosis process occurs in our bodies and is also one method of desalinating saline water.
Outfall	the place where a sewer, drain, or stream discharges; the outlet or structure through which reclaimed water or treated effluent is finally discharged to a receiving water body.
oxygen demand	the need for molecular oxygen to meet the needs of biological and chemical processes in water. Even though very little oxygen will dissolve in water, it is extremely important in biological and chemical processes.

P

particle size	the diameter, in millimeters, of suspended sediment or bed material. Particle-size classifications are: [1] Clay—0.00024-0.004 millimeters (mm); [2] Silt—0.004-0.062 mm; [3] Sand—0.062-2.0 mm; and [4] Gravel—2.0-64.0 mm.
parts per million	the number of "parts" by weight of a substance per million parts of water. This

	unit is commonly used to represent pollutant concentrations.
Pathogen	a disease-producing agent; usually applied to a living organism. Generally, any viruses, bacteria, or fungi that cause disease.
peak flow	the maximum instantaneous discharge of a stream or river at a given location. It usually occurs at or near the time of maximum stage.
per capita use	the average amount of water used per person during a standard time period, generally per day.
Percentile	The value below which a given percentage of observations in a group of observations fall. For example, the 20th percentile is the value below which 20 percent of the observations may be found.
Percolation	(1) The movement of water through the openings in rock or soil. (2) the entrance of a portion of the streamflow into the channel materials to contribute to groundwater replenishment.
Permeability	the ability of a material to allow the passage of a liquid, such as water through rocks. Permeable materials, such as gravel and sand, allow water to move quickly through them, whereas impermeable material, such as clay, don't allow water to flow freely.
Pesticide	A chemical that kills insects and rodents.
pH	a measure of the relative acidity or alkalinity of water. Water with a pH of 7 is neutral; lower pH levels indicate increasing acidity, while pH levels higher than 7 indicate increasingly basic solutions.
Physical assessment	Assessing water quality by the appearance and/or odor of a sample including discharge and stream velocity.
Point source pollution	A type of pollution that can be tracked down to an easily noticeable cause, such as discharge pipes and people putting chemicals and trash into water.
point-source pollution	water pollution coming from a single point, such as a sewage-outflow pipe.
Pollutant	Something that makes land, water, and air dirty and unhealthy
Pollution	The presence of waste that makes the world around us dirty and contaminated.

polychlorinated biphenyls (PCBs)	a group of synthetic, toxic industrial chemical compounds once used in making paint and electrical transformers, which are chemically inert and not biodegradable. PCBs were frequently found in industrial wastes, and subsequently found their way into surface and groundwaters. As a result of their persistence, they tend to accumulate in the environment. In terms of streams and rivers, PCBs are drawn to sediment, to which they attach and can remain virtually indefinitely. Although virtually banned in 1979 with the passage of the Toxic Substances Control Act, they continue to appear in the flesh of fish and other animals.
Pond-riffle	In a stream or river, areas of deep slow-moving water (pools) or areas of shallow fast-moving water; synonym: Riffle-Pool sequence
Porosity	a measure of the water-bearing capacity of subsurface rock. With respect to water movement, it is not just the total magnitude of porosity that is important, but the size of the voids and the extent to which they are interconnected, as the pores in a formation may be open, or interconnected, or closed and isolated. For example, clay may have a very high porosity with respect to potential water content, but it constitutes a poor medium as an aquifer because the pores are usually so small.
potable water	water of a quality suitable for drinking.
potentiometric surface/piezometric surface	-he imaginary line where a given reservoir of fluid will "equalize out to" if allowed to flow; a potentiometric surface is based on hydraulic principles.
precipitation	rain, snow, hail, sleet, dew, and frost.
primary wastewater treatment	the first stage of the wastewater-treatment process where mechanical methods, such as filters and scrapers, are used to remove pollutants. Solid material in sewage also settles out in this process.
public supply	water withdrawn by public governments and agencies, such as a county water department, and by private companies that is then delivered to users. Public suppliers provide water for domestic, commercial, thermoelectric power, industrial, and public water users. Most people's household water is delivered by a public water supplier. The systems have at least 15 service connections (such as households, businesses, or schools) or regularly serve at least 25 individuals daily for at least 60 days out of the year.
public water use	water supplied from a public-water supply and used for such purposes as firefighting, street washing, and municipal parks and swimming pools.

R

rating curve	A drawn curve showing the relation between gage height and discharge of a stream at a given gaging station.
Recharge	water added to an aquifer. For instance, rainfall that seeps into the ground.
reclaimed wastewater	wastewater-treatment plant effluent that has been diverted for beneficial uses such as irrigation, industry, or thermoelectric cooling instead of being released to a natural waterway or aquifer.
recycled water	water that is used more than one time before it passes back into the natural hydrologic system.
Reforestation	To renew the woods by planting trees
Renewable natural resource	Natural resource which can replenish with the passage of time, either through biological reproduction or other natural processes.
Reservoir	a pond, lake, or basin, either natural or artificial, for the storage, regulation, and control of water.
return flow	(1) That part of a diverted flow that is not consumptively used and returned to its original source or another body of water. (2) (Irrigation) Drainage water from irrigated farmlands that re-enters the water system to be used further downstream.
reverse osmosis	(1) (Desalination) The process of removing salts from water using a membrane. With reverse osmosis, the product water passes through a fine membrane that the salts are unable to pass through, while the salt waste (brine) is removed and disposed. This process differs from electrodialysis, where the salts are extracted from the feedwater by using a membrane with an electrical current to separate the ions. The positive ions go through one membrane, while the negative ions flow through a different membrane, leaving the end product of freshwater. (2) (Water Quality) An advanced method of water or wastewater treatment that relies on a semi-permeable membrane to separate waters from pollutants. An external force is used to reverse the normal osmotic process resulting in the solvent moving from a solution of higher concentration to one of lower concentration.
Riffle	A shallow area of water with a fast current.

riparian water rights	the rights of an owner whose land abuts water. They differ from state to state and often depend on whether the water is a river, lake, or ocean. The doctrine of riparian rights is an old one, having its origins in English common law. Specifically, persons who own land adjacent to a stream have the right to make reasonable use of the stream. Riparian users of a stream share the streamflow among themselves, and the concept of priority of use (Prior Appropriation Doctrine) is not applicable. Riparian rights cannot be sold or transferred for use on nonriparian land.
river	A natural stream of water of considerable volume, larger than a brook or creek.
River basin	River basin is larger body of water, characterized by all runoff being conveyed to the same outlet
River mouth	Part of river where stream flows into a larger water body
River stream	Large natural stream of water emptying into an ocean, lake or other body of water
Riverbed	Bottom and side walls of a river that confines the normal water flow
Runoff	Water, including rain and snow, which is not absorbed into the ground, instead it flows across the land and eventually runs into streams and rivers; runoff can pick up pollutants from the air and land, carrying them into the stream.
Runoff	(1) That part of the precipitation, snow melt, or irrigation water that appears in uncontrolled surface streams, rivers, drains or sewers. Runoff may be classified according to speed of appearance after rainfall or melting snow as direct runoff or base runoff, and according to source as surface runoff, storm interflow, or groundwater runoff. (2) The total discharge described in (1), above, during a specified period of time. (3) Also defined as the depth to which a drainage area would be covered if all of the runoff for a given period of time were uniformly distributed over it.

S

saline water	water that contains significant amounts of dissolved solids. Here are our parameters for saline water: Fresh water - Less than 1,000 parts per million (ppm) Slightly saline water - From 1,000 ppm to 3,000 ppm Moderately saline water - From 3,000 ppm to 10,000 ppm Highly saline water - From 10,000 ppm to 35,000 ppm
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Salt index	Measure of the salt concentration; the process is salinisation
Sea	a body of water that is smaller than an ocean and usually located where the land and ocean meet.
secondary wastewater treatment	treatment (following primary wastewater treatment) involving the biological process of reducing suspended, colloidal, and dissolved organic matter in effluent from primary treatment systems and which generally removes 80 to 95 percent of the Biochemical Oxygen Demand (BOD) and suspended matter. Secondary wastewater treatment may be accomplished by biological or chemical-physical methods. Activated sludge and trickling filters are two of the most common means of secondary treatment. It is accomplished by bringing together waste, bacteria, and oxygen in trickling filters or in the activated sludge process. This treatment removes floating and settleable solids and about 90 percent of the oxygen-demanding substances and suspended solids. Disinfection is the final stage of secondary treatment.
Sediment	Soil, sand, and materials washed from land into waterways. Synonym: deposit
Sediment	usually applied to material in suspension in water or recently deposited from suspension. In the plural the word is applied to all kinds of deposits from the waters of streams, lakes, or seas.
sedimentary rock	rock formed of sediment, and specifically: (1) sandstone and shale, formed of fragments of other rock transported from their sources and deposited in water; and (2) rocks formed by or from secretions of organisms, such as most limestone. Many sedimentary rocks show distinct layering, which is the result of different types of sediment being deposited in succession.
Sedimentation	When soil particles (sediment) settle to the bottom of a waterway or lake.
sedimentation tanks	wastewater tanks in which floating wastes are skimmed off and settled solids are removed for disposal.
Seepage	(1) The slow movement of water through small cracks, pores, Interstices, etc., of a material into or out of a body of surface or subsurface water. (2) The loss of water by infiltration into the soil from a canal, ditches, laterals, watercourse, reservoir, storage facilities, or other body of water, or from a field.
self-supplied water	water withdrawn from a surface- or groundwater source by a user rather than being obtained from a public supply. An example would be homeowners getting their water from their own well.

septic tank	a tank used to detain domestic wastes to allow the settling of solids prior to distribution to a leach field for soil absorption. Septic tanks are used when a sewer line is not available to carry them to a treatment plant. A settling tank in which settled sludge is in immediate contact with sewage flowing through the tank, and wherein solids are decomposed by anaerobic bacterial action.
settling pond (water quality)	an open lagoon into which wastewater contaminated with solid pollutants is placed and allowed to stand. The solid pollutants suspended in the water sink to the bottom of the lagoon and the liquid is allowed to overflow out of the enclosure.
sewage treatment plant	a facility designed to receive the wastewater from domestic sources and to remove materials that damage water quality and threaten public health and safety when discharged into receiving streams or bodies of water. The substances removed are classified into four basic areas: [1] greases and fats; [2] solids from human waste and other sources; [3] dissolved pollutants from human waste and decomposition products; and [4] dangerous microorganisms. Most facilities employ a combination of mechanical removal steps and bacterial decomposition to achieve the desired results. Chlorine is often added to discharges from the plants to reduce the danger of spreading disease by the release of pathogenic bacteria.
Sewer	a system of underground pipes that collect and deliver wastewater to treatment facilities or streams.
Shannon-Winner-Index	This diversity measure came from information theory and measures the order (or disorder) observed within a particular system. In ecological studies, this order is characterized by the number of individuals observed for each species in the sample plot (e.g., biofilm on a plexiglass disc).
Simpson's index (D)	The probability that two randomly selected individuals in the community belong to the same category (e.g., species).
Simpson's index of diversity (1 - D)	The probability that two randomly selected individuals in a community belong to different categories (e.g., species).
Simpson's reciprocal index (1/D)	The number of equally common categories (e.g., species) that will produce the observed Simpson's index.
sinkhole	a depression in the Earth's surface caused by dissolving of underlying limestone, salt, or gypsum. Drainage is provided through underground channels that may be enlarged by the collapse of a cavern roof.

Slumping	Sections of soil with or without vegetation that have come loose and slipped into the stream.
Snow	precipitation in the form of ice crystals. Snow forms when the air temperature is at or below 32 degrees Fahrenheit.
Soil erosion	Naturally and human impacted process that affects all landforms by destroying the surface soil and subsurface layers.
solute	a substance that is dissolved in another substance, thus forming a solution.
solution	a mixture of a solvent and a solute. In some solutions, such as sugar water, the substances mix so thoroughly that the solute cannot be seen. But in other solutions, such as water mixed with dye, the solution is visibly changed.
solvent	a substance that dissolves other substances, thus forming a solution. Water dissolves more substances than any other, and is known as the "universal solvent".
Species Richness	The number of different species found in a particular environment.
spray irrigation	a common irrigation method where water is shot from high-pressure sprayers onto crops. Because water is shot high into the air onto crops, some water is lost to evaporation.
Spring	a water body formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water.
Stage	the water level above some arbitrary point in the river and is commonly measured in feet.
Stagnation	When there is little water movement and pollutants are trapped in the same area for a long period of time.
steam	water in a gas state. See vapor
storm sewer	a sewer that carries only surface runoff, street wash, and snow melt from the land. In a separate sewer system, storm sewers are completely separate from those that carry domestic and commercial wastewater (sanitary sewers).
stream	a general term for a body of flowing water; natural water course containing water at least part of the year. In hydrology, it is generally applied to the water

	flowing in a natural channel as distinct from a canal.
streamflow	the water discharge that occurs in a natural channel. A more general term than runoff, streamflow may be applied to discharge whether or not it is affected by diversion or regulation.
subsidence	a dropping of the land surface as a result of groundwater being pumped. Cracks and fissures can appear in the land. Subsidence is virtually an irreversible process.
Surface runoff	Surface runoff is the water flow that occurs when the soil is infiltrated to full capacity and excess water from rain, meltwater, or other sources flows over the land. This is a major component of the water cycle, and the primary agent in water erosion.
surface tension	the attraction of molecules to each other on a liquid's surface. Thus, a barrier is created between the air and the liquid.
surface water	water that is on the Earth's surface, such as in a stream, river, lake, or reservoir.
suspended sediment	very fine soil particles that remain in suspension in water for a considerable period of time without contact with the bottom. Such material remains in suspension due to the upward components of turbulence and currents and/or by suspension.
suspended solids	solids that are not in true solution and that can be removed by filtration. Such suspended solids usually contribute directly to turbidity. Defined in waste management, these are small particles of solid pollutants that resist separation by conventional methods.
suspended-sediment concentration	the ratio of the mass of dry sediment in a water-sediment mixture to the mass of the water-sediment mixture. Typically expressed in milligrams of dry sediment per liter of water-sediment mixture.
suspended-sediment discharge	the quantity of suspended sediment passing a point in a stream over a specified period of time. When expressed in tons per day, it is computed by multiplying water discharge (in cubic feet per second) by the suspended-sediment concentration (in milligrams per liter) and by the factor 0.0027.

Sustainability	In ecology, sustainability is how biological systems endure and remain diverse and productive. Long-lived and healthy wetlands and forests are examples of sustainable biological systems. More recent accounts have broadened the idea of sustainability to include social wellbeing, resilience and adaptation across four domains: ecology, economics, politics and culture.
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T

Toxic Substance	Poisonous matter (either chemical or natural, which causes sickness, disease, and/or death to plants or animals).
tertiary wastewater treatment	selected biological, physical, and chemical separation processes to remove organic and inorganic substances that resist conventional treatment practices; the additional treatment of effluent beyond that of primary and secondary treatment methods to obtain a very high quality of effluent. The complete wastewater treatment process typically involves a three-phase process: (1) First, in the primary wastewater treatment process, which incorporates physical aspects, untreated water is passed through a series of screens to remove solid wastes; (2) Second, in the secondary wastewater treatment process, typically involving biological and chemical processes, screened wastewater is then passed a series of holding and aeration tanks and ponds; and (3) Third, the tertiary wastewater treatment process consists of flocculation basins, clarifiers, filters, and chlorine basins or ozone or ultraviolet radiation processes.
thermal pollution	a reduction in water quality caused by increasing its temperature, often due to disposal of waste heat from industrial or power generation processes. Thermally polluted water can harm the environment because plants and animals can have a hard time adapting to it.
thermoelectric power water use	water used in the process of the generation of thermoelectric power. Power plants that burn coal and oil are examples of thermoelectric-power facilities.
Transmissibility (groundwater)	the capacity of a rock to transmit water under pressure. The coefficient of transmissibility is the rate of flow of water, at the prevailing water temperature, in gallons per day, through a vertical strip of the aquifer one foot wide, extending the full saturated height of the aquifer under a hydraulic gradient of 100-percent. A hydraulic gradient of 100-percent means a one foot drop in head in one foot of flow distance.
Transpiration	process by which water that is absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface, such as leaf pores. See evapotranspiration.

Tributary	a smaller river or stream that flows into a larger river or stream. Usually, a number of smaller tributaries merge to form a river.
Turbidity	the amount of solid particles that are suspended in water and that cause light rays shining through the water to scatter. Thus, turbidity makes the water cloudy or even opaque in extreme cases. Turbidity is measured in nephelometric turbidity units (NTU).

U

Undercutting	A type of erosion which occurs when fine soils are swept away by the action of the stream, especially around curves; the result is an unstable overhang.
unsaturated zone	the zone immediately below the land surface where the pores contain both water and air, but are not totally saturated with water. These zones differ from an aquifer, where the pores are saturated with water.

V

vapor	created when a substance (such as water) is in a gas state. Particles of the substance will be suspended or diffused in the air. See evaporation

W

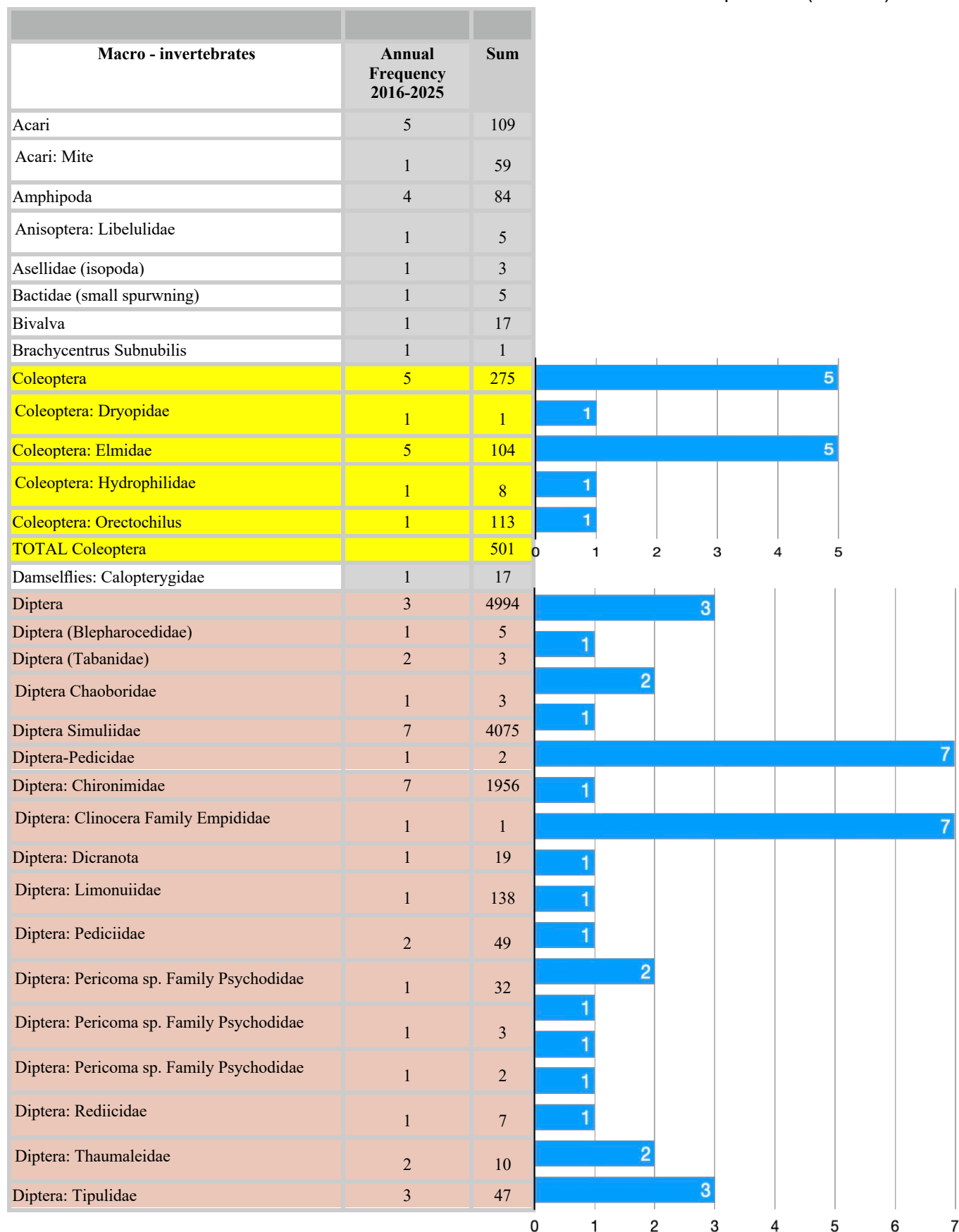
Wastewater	water that has been used in homes, industries, and businesses that is not for reuse unless it is treated.
wastewater-treatment return flow	water returned to the environment by wastewater-treatment facilities.
water cycle	the circuit of water movement from the oceans to the atmosphere and to the Earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transportation.
water quality	a term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.
water table	The upper level of groundwater.
water treatment	The process of Keeping and making water after usage

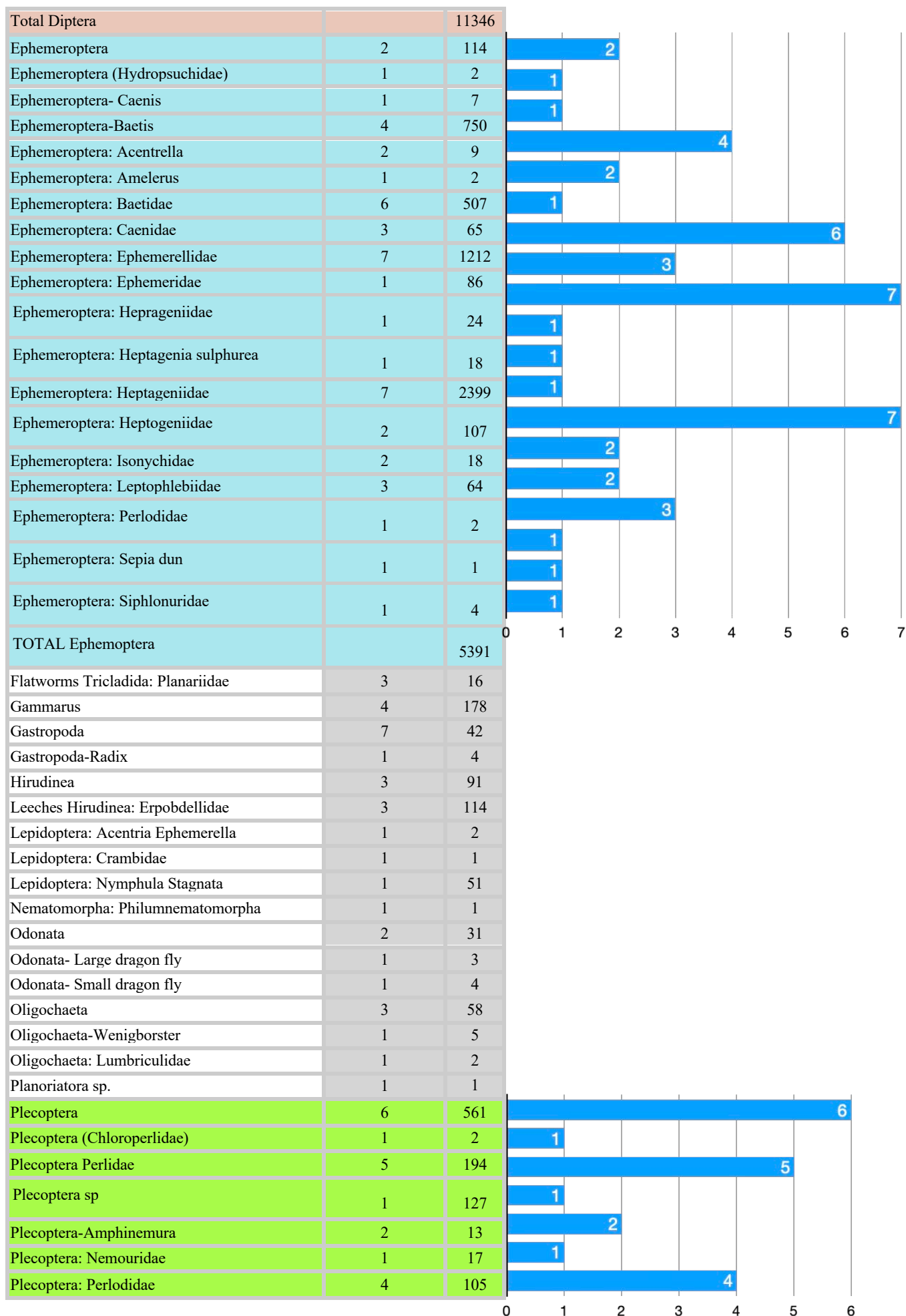
water use	water that is used for a specific purpose, such as for domestic use, irrigation, or industrial processing. Water use pertains to human's interaction with and influence on the hydrologic cycle, and includes elements, such as water withdrawal from surface- and groundwater sources, water delivery to homes and businesses, consumptive use of water, water released from wastewater-treatment plants, water returned to the environment, and instream uses, such as using water to produce hydroelectric power.
water year	a continuous 12-month period selected to present data relative to hydrologic or meteorological phenomena during which a complete annual hydrologic cycle normally occurs. The water year used by the U.S. Geological Survey runs from October 1 through September 30, and is designated by the year in which it ends.
watershed	the land area that drains water to a particular stream, river, or lake. It is a land feature that can be identified by tracing a line along the highest elevations between two areas on a map, often a ridge. Large watersheds, like the Mississippi River basin contain thousands of smaller watersheds.
watershed management	is an approach which plans natural resource management and rural development (= overall goals of watershed management) on the level of watersheds (= planning unit) Management of water resources (e.g., rainwater harvesting); Management of soil resources (soil conservation); Management of human resources (qualification of resource managers and users, etc.). Land management (land use planning, for example); Pasture management (area closure, for example); Crop yield management (e.g., storage management, marketing); Livestock management (e.g., marketing, dairy production); Rural energy management (e.g., decentralised use of renewable energy resources); Vegetation/biomass management (reforestation, agroforestry, etc.); Farm and off-farm activities adding value (e.g., creation of infrastructure)
watershed planning	attempts to balance socio-economic, political and environmental objectives (Brady 1996, Randolph 2003 quoted in: Butler 2003)
Waterway	A natural or man-made place for water to run through (such as a river, stream, creek, or channel).
Weathering	Weathering describes the breaking down or dissolving of rocks and minerals on the surface of the Earth. Water, ice, acids, salts, plants, animals, and changes in temperature are all agents of weathering.

Well (water)	an artificial excavation put down by any method for the purposes of withdrawing water from the underground aquifers. A bored, drilled, or driven shaft, or a dug hole whose depth is greater than the largest surface dimension and whose purpose is to reach undergroundwater supplies or oil, or to store or bury fluids below ground.
Wetland	An area of land that is regularly wet or flooded, such as a marsh or swamp
Withdrawal	water removed from a ground- or surface-water source for use.

6.2 List of Invertebrates of Kaskelen River Basin, Kazakhstan, and their frequency and abundance

Annual Frequencies (9 Years)





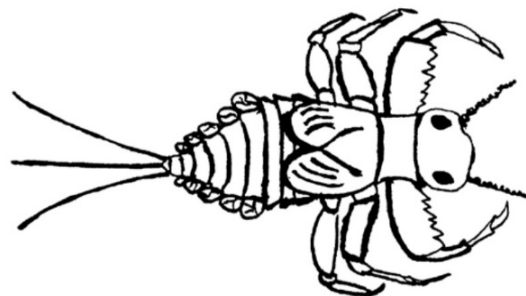
TOTAL Plecoptera		1019	
Prostoma Graecensa	1	12	
Radix (snake)	1	2	
Scuds Amphipoda	1	5	
Snail: Mollusca	2	171	
Stonefly: Perlidae	1	256	1
Stonefly: Perlodidae	2	153	2
Trichoptera	4	5308	4
Trichoptera / later Brachycentrus subnubilus	1	52	1
Trichoptera-Rhyacophila	4	644	4
Trichoptera: acapebus fuscipes	1	16	1
Trichoptera: Apataniidae	1	144	1
Trichoptera: Brachycentridae	7	2115	1
Trichoptera: Drusus annulatus	1	15	7
Trichoptera: Glossosomatidae	6	5188	1
Trichoptera: Goeridae	1	123	6
Trichoptera: Hydropsychidae	3	1515	1
Trichoptera: Hydroptilaineoides	1	4	3
Trichoptera: Lepidostomatidae	1	66	1
Trichoptera: Leptoceridae	7	2422	1
Trichoptera: Nemouridae	1	4	1
Trichoptera: Orthotrichia costalis	1	1	7
Trichoptera: Osmylus fulvicephalus larvae	1	1	1
Trichoptera: Pericoma sp. Family Psychodidae	1	2	1
Trichoptera: Perlidae	1	134	1
Trichoptera: Perlodidae	2	55	1
Trichoptera: Psychomyiidae	1	43	2
Trichoptera: Pteronarcyidae	1	2	1
Trichoptera: Rhyacophila sp	5	370	1
Trichoptera: Rhyacophilidae	2	1801	5
Trichoptera: Thyacophilidae	1	26	2
Trichoptera: Limnephilidae	2	130	1
TOTAL Trichoptera		20590	2
Tricladia	3	23	
Triclodida (Planariidae)	1	4	
Triclodida (Planeridat)	2	6	
Tridadida (Dugesia Lugubris)	1	1	
Tridadida (Dugesia)	1	4	
Tridadida (Planaria)	1	7	
Turbellaria	5	125	
Turbellaria: Planarian	1	55	

6.3 Complementary Information about Invertebrate Determination

Most Sensitive

Body-Builder Mayfly

Most Sensitive **1**



KEY FEATURES



- ☐ The first section of the front legs look like muscular biceps being flexed.
- ☐ Front legs have a serrated edge.



- ☐ Flat body with obvious legs.
- ☐ Single set of wing pads.
- ☐ Three hair-like tails at the end of the abdomen.
- ☐ Small, round gills on the side of the abdomen

Taxonomic Information

Order: Ephemeroptera
Family: Ephemerellidae
Genus: *Drunella*

Ecological Information

Tolerance Value = 0
Feeding Group = Scraper
Stream Habitat = On rocks or coarse organic substrates

Key Behaviors

- This mayfly nymph will crawl among leaves, stones, and other debris in the tray.
- Occasionally *Drunella* may swim by slowly undulating back and forth.

Important Notes

This organism can be confused with other members of the Ephemerellidae family. The distinguishing characteristic of *Drunella* is the enlarged front legs, each with a serrated margin along the front edge. These mayfly can be very abundant under appropriate conditions, however they typically emerge in the spring and are therefore uncommon in RBV samples.

Size and Color

Size: 6-15 mm
Color: Tan to dark brown, legs may have orange or yellow bands



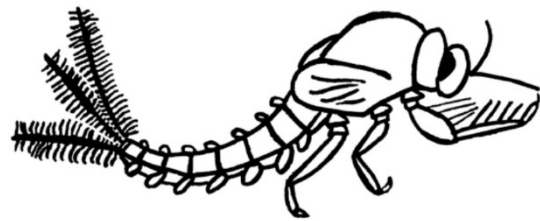
Photographs courtesy of (top to bottom): Kelsey Quartuccio/CT DEEP; Kelsey Quartuccio/CT DEEP; Jake Renkert/The Marvelwood School

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Brush-Legged Mayfly

Most Sensitive **2**



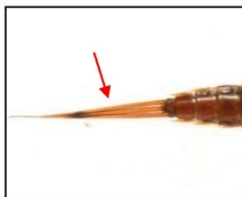
KEY FEATURES



- ☐ Streamlined body, taller than wide.
- ☐ Often with a “humped back” or “S-shaped” appearance when swimming.



- ☐ Front legs have a double row of long hairs on the inside edge.
- ☐ Single set of wing pads.
- ☐ Small, round gills on the side of the abdomen.



- ☐ Three feather-like tails at the end of the abdomen.

Taxonomic Information

Order: Ephemeroptera
Family: Isonychidae (Oligoneuriidae)
Genus: *Isonychia*

Ecological Information

Tolerance Value = 2
Feeding Group = Collector-Filterer
Stream Habitat = Moderate to fast flows, rock surfaces

Key Behaviors

- This mayfly nymph is an extremely strong swimmer. It swims by undulating back and forth very rapidly.
- This mayfly will often stand on rocks, leaves and sticks.

Identification Notes

There is only one genera (*Isonychia*) of Isonychidae in Connecticut. *Isonychia*, often called “Minnow Mayflies” by experienced volunteers, are very strong swimmers. The three tails are made up of a series of fine hairs that act like an oar on a boat, propelling the mayfly through the water. No other mayfly has a double row of fine hairs on the front legs.

Size and Color

Size: 8-17 mm
Color: Light brown to dark brown body, sometimes with yellow or white markings



Photographs courtesy of (top to bottom): Kelsey Quartuccio/CT DEEP; Jake Renkert/The Marvelwood School; NY DEC Biomonitoring Unit; Jake Renkert/The Marvelwood School

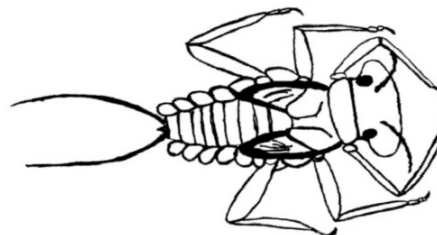
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Two-Tailed Flathead Mayfly

Most Sensitive

3



KEY FEATURES



- ☐ Extremely flat, almost translucent body, long thin legs.



- ☐ Small round gills on the sides of the abdomen.
- ☐ Two Long thin tails at the end of the abdomen (easily broken)



- ☐ Single set of wing pads.
- ☐ Wide flat head, obvious eyes.

Taxonomic Information

Order: Ephemeroptera
Family: Heptageniidae
Genus: *Epeorus*

Ecological Information

Tolerance Value = 0
Feeding Group = Scraper
Stream Habitat = Cobble and organic substrates

Key Behaviors

- This mayfly nymph crawls very fast on the surface of stones.
- Will move quickly in the tray and try to hide under any leaves or sticks present.
- *Epeorus* may try to swim by wiggling side to side.

Important Notes

The best way to find *Epeorus* is to carefully 'wash off' cobbles in the net before kicking. When present, these mayflies will scurry along the surface of the rock. Because of the body color and shape, they can be very difficult to spot. *Epeorus* can be extremely abundant when conditions are appropriate.

Size and Color

Size: 2-10 mm
Color: Tan to dark brown, sometimes with lighter gills and markings on the legs and head.



Photographs courtesy of (top to bottom): Kelsey Quartuccio / CT DEEP; DEEP files, author unknown; NY DEC Biomonitoring Unit; DEEP files, author unknown

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Roach-Like Stonefly

Most
Sensitive

4



KEY FEATURES



- ☐ Tear-drop shaped body with a uniformly shiny brown exoskeleton.
- ☐ Two short tails at the end of the abdomen.



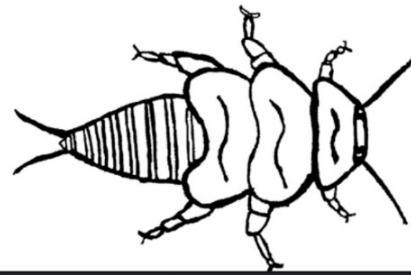
- ☐ Two sets of wing pads.



- ☐ No gills on the sides of the abdomen.



- ☐ Commonly found on leaves



Taxonomic Information

Order: Plecoptera
Family: Peltoperlidae
Genus: All

Ecological Information

Tolerance Value = 0
Feeding Group = Shredder
Stream Habitat = In and on coarse organic substrates

Key Behaviors

- This stonefly nymph is commonly found crawling in and amongst leaf packs in riffle areas. To locate, peel apart leaves in any packs present!
- Typically not observed swimming in the tray.

Important Notes

Peltoperlids are very intolerant of environmental stresses. Its characteristic inverted tear drop shape, short tails, and head which is broadly joined to the thorax, differentiate the Roach-Like Stonefly from other stoneflies.

Size and Color

Size: 6-11 mm
Color: Light to dark brown, uniform



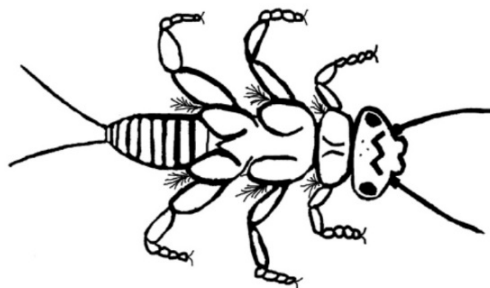
All photographs courtesy of Jake Renkert / The Marvelwood School

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Common Stonefly

Most Sensitive **5A**



KEY FEATURES



- ☐ Flat body with obvious, segmented legs. Some specimens (not all) have a tortoise-shell pattern on the head and thorax.
- ☐ Two long tails at the end of the abdomen.



- ☐ Two sets of wing pads



- ☐ Rounded thoracic plate



- ☐ Gill tufts resembling armpit hairs at the base of each leg.

Taxonomic Information

Order: Plecoptera
Family: Perlidae
Genus: All

Ecological Information

Tolerance Value = 1
Feeding Group = Predator
Stream Habitat = Burrowed in substrate

Key Behaviors

- Very active crawler, highly mobile. (Watch out – they will crawl out of your ice cube trays!)
- May hide on like colored objects in the tray.
- May be observed doing “push-ups” in the tray. (This helps circulate water over their gills.)

Important Notes

When present in a sample, this organism will crawl out of the debris. Don't be confused by size or color - often different sizes will be collected at the same site and coloration can vary quite a bit between organisms. Darker and/or larger versions of common stoneflies are often misidentified as the Giant Stonefly (see panel 5B).

Size and Color

Size: 8-30 mm
Color: Variable. Light yellowish, brown to very dark, some with a tortoise-shell pattern.



All photographs courtesy of Joshua Fusaro/ The Marvelwood School

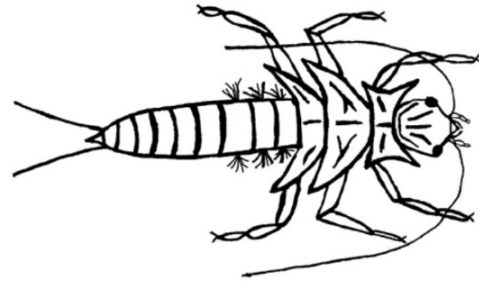
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Giant Stonefly

Most
Sensitive

5B



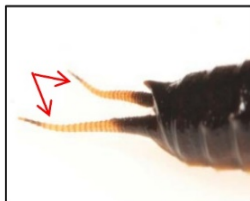
KEY FEATURES



- ☐ Robust body, typically dark but occasionally with white or yellow markings.



- ☐ Pointed edges along the sides of the abdomen.



- ☐ Two, short tails at the end of the abdomen.



- ☐ First thoracic plate is rectangular with flared edges
- ☐ Two sets of wing pads, very angular in shape.



- ☐ Gill tufts on the thorax and the sides of the first three sections of the abdomen.

Taxonomic Information

Order: Plecoptera
Family: Pteronarcyidae
Genus: *Pteronarcys*

Ecological Information

Tolerance Value = 0
Feeding Group = Shredder
Stream Habitat = Fast flowing, high-gradient riffles

Key Behaviors

- This stonefly nymph is not very active. If it moves at all, it will crawl very slowly around the tray.
- May curl into a C-shape and pretend to be dead when disturbed.

Important Notes

Pteronarcys is often confused with the Common Stonefly (Panel 5A) as both can grow to be quite big. The Giant Stonefly is distinguished easily by its relatively sluggish activity level and more armored appearance. Don't be fooled by size – all giant stoneflies must start out small! Typically, only a few Pteronarcyidae are collected at any site when conditions are appropriate.

Size and Color

Size: 35-50 mm
Color: Brown to black, sometimes with white or yellow tail tips



Photographs courtesy of Joshua Fusaro/ The Marvelwood School

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Miscellaneous Small Stoneflies

Most Sensitive

5C

SMALL STONEFLY FAMILIES



Small Winter Stoneflies¹ (*Capniidae*)

- Often dark
- Legs short
- Abdomen slightly wider at middle



Green Stoneflies¹ (*Chloroperlidae*)

- No distinctive color patterns
- Tails shorter than the abdomen is long



Rolled-winged Stoneflies² (*Leuctridae*)

- Long, slender body
- Short legs
- Abdomen same width along length



Nemourid Stoneflies¹ (*Nemouridae*)

- Long legs (tips extend to the tip of the abdomen or beyond)



Perlodid Stoneflies³ (*Perlodidae*)

- Very similar to the Common Stonefly but without gill tufts near the base of the legs



Winter Stoneflies (*Taeniopterygidae*)⁴

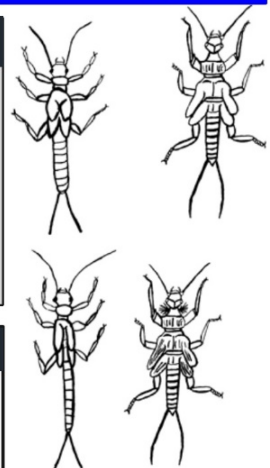
- Wing pads form a distinct triangle
- Typically only present in late November RBV samples

Photographs courtesy of: ¹Donald S. Chandler – www.discoverlife.org; ²Author unknown; ³Unknown – <http://aquaticinsectsofcentralvirginia.blogspot.com>; ⁴Jake Renkert – The Marvelwood School

General Identification

The following characteristics are universally true of the stonefly families at left:

- Two tails
- Two tarsal claws ('toes') at the end of each leg
- Dorsally flattened
- Small in size



Taxonomic Information

Order: Plecoptera
Family: See families at left
Genus: All within families at left

Ecological Information

Tolerance Value = See below
Feeding Group = See below
Stream Habitat = Fast moving water, under rocks/debris

	Tolerance Value	Feeding Group
<i>Capniidae</i>	1	Shredder
<i>Chloroperlidae</i>	1	Predator
<i>Leuctridae</i>	0	Shredder
<i>Nemouridae</i>	2	Shredder
<i>Perlodidae</i>	2	Predator
<i>Taeniopterygidae</i>	2	Shredder

Important Notes

All stoneflies are intolerant of organic pollutants and therefore indicate high water quality.

Size and Color

Size: 4-10 mm average (*Taeniopterygidae* can reach up to 15 mm))
Color: Variable. Many light brown or cream colored



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Saddlecase Maker Caddisfly

Most Sensitive

6A



KEY FEATURES

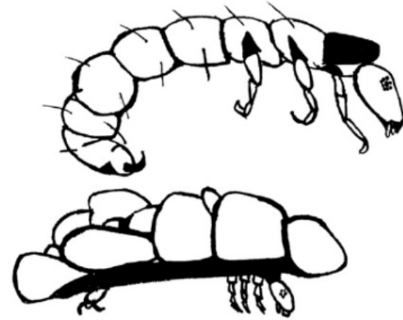


- ☐ Small oval stone case made of sand grains and/or tiny pebbles, resembles a saddle or a turtle shell. (Case is NOT tube-shaped.)
- ☐ Underside of case has two round openings.



- ☐ Larva body is maggot-like and slightly C-shaped.
- ☐ Larva has a light (white to light brown) body with a dark head and legs.
- ☐ End of the abdomen has an attached 'butt plate' (red arrow)

Photographs courtesy of (top to bottom): NY DEC Biomonitoring Unit; Kelsey Quartuccio/CT DEEP; Jake Renkert/The Marvelwood School



Taxonomic Information

Order: Trichoptera
Family: Glossosomatidae
Genus: *Glossosoma*

Ecological Information

Tolerance Value = 0
Feeding Group = Scraper
Stream Habitat = Exposed upper surfaces of rocks

Key Behaviors

- This caddisfly larva is often attached to the surface of rocks in fast current.
- *Glossosoma* may not move at all while in the tray. If it does, it will crawl very slowly along the bottom of the tray.

Important Notes

Glossosoma is often confused with other small stone case building caddisflies. Unlike other caddisfly cases, the *Glossosoma* case is not tube shaped but rather resembles a turtle shell with only a thin 'strap' of pebbles holding the case around the organism. Keep an eye out for both the case and the organism in your tray as the two are easily separated.

Size and Color

Size: 3-10 mm
Color: White to light brown, with dark head, legs and butt plate



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Cornucopia-Case Caddisfly

Most
Sensitive

6B



KEY FEATURES



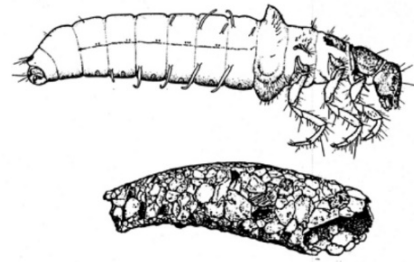
- ☐ Tiny light-bodied organism
- ☐ Hunched appearance when in case.
- ☐ Triangular head with dark legs.
- ☐ Very small, delicate case made of sand grains
- ☐ Case is cone-shaped like a Thanksgiving cornucopia.



Don't be Fooled by This Imposter!



- ☐ The Strong Case-Maker Caddisfly (Odontoceridae) also makes a case of small grains of sand. To tell the two apart, inspect the case closely. Odontoceridae cases are very difficult to break apart and are the same width at both ends. In comparison, the Apatania case is quite small (see above), more easily broken apart, and noticeably wider at the opening than at the other end.



Taxonomic Information

Order: Trichoptera
Family: Apataniidae
Genus: *Apatania*

Ecological Information

Tolerance Value = 3
Feeding Group = Scraper
Stream Habitat = Fast flowing, shallow riffles

Key Behaviors

- This caddisfly larva is tiny and therefore easily overlooked, however if you watch your tray closely you may see a tiny sand horn walking around the bottom!
- Resembles a tiny hermit crab in that it drags its case along as it walks.

Important Notes

This organism is commonly confused with other stone case building caddisflies including *Glossosoma*. The easiest distinguishing characteristic is that that *Apatania* is VERY tiny, typically smaller than the width of your pinky nail. This caddisfly can be abundant under appropriate conditions. Look very carefully in your trays for these tiny caddisfly larvae!

Size and Color

Size: 2-6 mm
Color: Light colored body with dark head



Photographs courtesy of (top to bottom): NY DEC Biomonitoring Unit; Jake Renkert/The Marvelwood School; DEEP file photo, author unknown

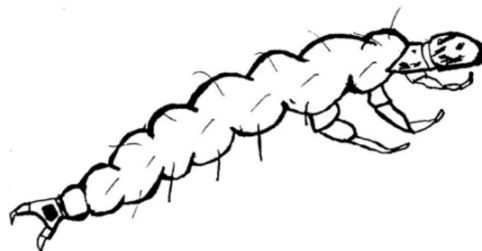
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Free-Living Caddisfly

Most Sensitive

7



KEY FEATURES



- ☐ Nicknamed "Michelin Man" caddisfly due to its smooth, lumpy abdomen
- ☐ Six short legs near the head



- ☐ Hard tan or yellow and brown patterned head with a single thoracic plate.



- ☐ Armored plate and two hooks at the end of the abdomen, somewhat loosely attached



Taxonomic Information

Order: Trichoptera
Family: Rhyacophilidae
Genus: *Rhyacophila*

Ecological Information

Tolerance Value = 0
Feeding Group = Predator
Stream Habitat = Fast flowing, high-gradient riffles

Key Behaviors

- Clings very well to the net.
- Moderately active organism; will crawl or wiggle in the tray.
- Will try to hide under objects.

Important Notes

Rhyacophila is called the 'free-living' caddisfly because larvae of this genus do not build a case until they are about to pupate. (At which point they will build a loosely constructed stone shelter.) This organism is often found among aquatic mosses. A key field characteristic is the bright green or lavender abdominal coloring.

Size and Color

Size: 10-30 mm
Color: Variable. White, green, purple



Photographs courtesy of (top to bottom): Jake Renkert/The Marvelwood School;): Jake Renkert/The Marvelwood School; NY DEC Biomonitoring Unit; Jake Renkert/The Marvelwood School; Jake Renkert/The Marvelwood School

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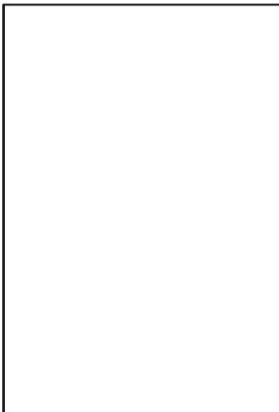
Humpless Case Maker Caddisfly

Most
Sensitive

8A



KEY FEATURES



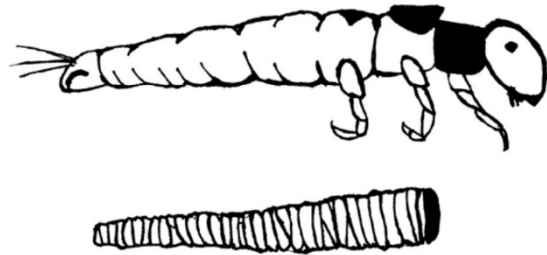
Case Construction:

- ☐ Case constructed of thin strips of plant material assembled with a square opening.
- ☐ Wider at head opening than at tail end.



Macroinvertebrate Features:

- ☐ Light colored body with dark head and legs.
- ☐ Very long legs
- ☐ No abdominal humps.



Taxonomic Information

Order: Trichoptera
Family: Brachycentridae
Genus: *Brachycentrus*

Ecological Information

Tolerance Value = 1
Feeding Group = Shredder
Stream Habitat = Upper surfaces of rocks

Key Behaviors

- Typically *Brachycentrus* does not move in the tray. If it does move, it will carry its case with it as it slowly crawls along.

Important Notes

This caddisfly can be very abundant under the appropriate conditions. Look carefully for *Brachycentrus* when the sample contains old leaves, sticks or bark. The cases may be attached to sticks, leaves or larger rocks.

Size and Color

Size: 10-17 mm
Color: Light body with dark head and legs



All photographs courtesy of Jake Renkert/The Marvelwood School

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Plant Case Maker Caddisfly

Most
Sensitive

8B



KEY FEATURES



Case Construction:

- ☐ Builds a case out of small, rectangular or square pieces of bark or wood (no sand grains).
- ☐ Case is typically slightly wider at the head end.

Macroinvertebrate Features:

- ☐ Light colored body with dark head and legs.
- ☐ Lateral humps present on the first section of the abdomen.



Photographs courtesy of (top to bottom): Jake Renkert/The Marvelwood School; NY DEC Biomonitoring Unit; Jake Renkert/The Marvelwood School



Taxonomic Information

Order: Trichoptera
Family: Lepidostomatidae
Genus: *Lepidostoma*

Ecological Information

Tolerance Value = 1
Feeding Group = Shredder
Stream Habitat = Accumulated plant debris on bottom

Key Behaviors

- Typically does not move in the tray. If it does move, will carry its case with it as it slowly crawls.

Important Notes

This caddisfly can be very abundant under the appropriate conditions, particularly in forested areas. Look carefully for *Lepidostoma* when the sample contains old leaves, sticks or bark. The cases may be attached to sticks, leaves or larger rocks.

Size and Color

Size: 7-15 mm
Color: Light body with dark head and legs



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Moderate Sensitive

Common Netspinner Caddisfly

Moderately
Sensitive

9



KEY FEATURES



- ❑ Series of three dark plates on the dorsal side of the thorax below the head.



- ❑ Fluffy gills on the underside (ventral sections) of the abdomen.



- ❑ Two paintbrush-like tails with hooks at the end of the abdomen.
- ❑ May have a 'dirty' or hairy appearance



Photographs courtesy of (top to bottom): NY DEC Biomonitoring unit; The Marvelwood School & Kent Conservation Commission RBV Program; Jake Renkert / The Marvelwood School; Becky Martorelli / Quinnipiac River Watershed Association; Jake Renkert / The Marvelwood School

Taxonomic Information

Order: Trichoptera
Family: Hydropsychidae
Genus: All

Ecological Information

Tolerance Value = 4
Feeding Group = Collector-filterer
Stream Habitat = Rock surfaces, woody debris, plants

Key Behaviors

- Extremely active, wiggles violently back and forth
- Gregarious, will form clumps of 2-4 in the tray
- May cling strongly to the net!

Important Notes

Hydropsychidae is probably one of the most common organisms encountered during benthic sampling. These can be extremely abundant under appropriate conditions. Because some are greenish in color they may be confused as *Rhyacophila* (Panel 7). Hydropsychidae have a dark plate above each pair of legs & fluffy gills on the underside of the abdomen, *Rhyacophila* does not.

Size and Color

Size: 13-18 mm
Color: Light brown to black, sometimes with green tint



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Fingernet Caddisfly

Moderately
Sensitive

10



KEY FEATURES



- ☐ Elongate, slender worm-like body.
- ☐ No gills on or along the abdomen.
- ☐ Two hooks at the end of the abdomen.



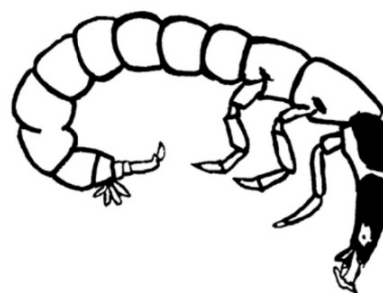
- ☐ Bright orange head with a transparent, t-shaped upper lip.



- ☐ Black border along the back edge of pronotum (the plate located behind the head capsule.)



Photographs courtesy of (top to bottom): NY DEC Biomonitoring unit; The Marvelwood School/Kent Conservation Commission RBV program; The Marvelwood School/Kent Conservation Commission RBV program; The Marvelwood School/Kent Conservation Commission RBV program; Jake Renkert / The Marvelwood School



Taxonomic Information

Order: Trichoptera
Family: Philopotamidae
Genus: *All*

Ecological Information

Tolerance Value = 3
Feeding Group = Collector-filterer
Stream Habitat = Undersides of rocks in high gradient

Key Behaviors

- Extremely active, wiggles violently back and forth.
- Gregarious, will form clumps of 2-4 in the tray.
- Very active, will crawl around the bottom of the tray.

Important Notes

Philopotamidae is a very common organism encountered during RBV sampling, and can be extremely abundant under appropriate conditions.

Size and Color

Size: 13-17 mm
Color: Yellow-orange, bright yellow, beige, white, or transparent



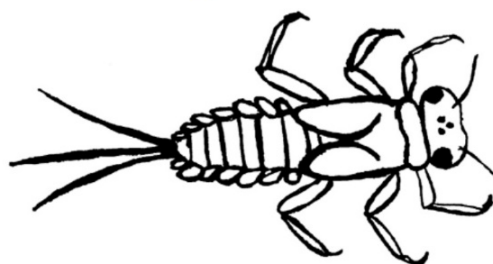
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Three-Tailed Flat Headed Mayfly

Moderately
Sensitive

11



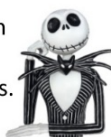
KEY FEATURES



- ☐ Extremely flattened body.
- ☐ Small, oval or square-shaped gills along the sides of the abdomen.
- ☐ Three very long tails at the end of the abdomen. (Tails are fragile and can break off giving the appearance of only one or two.)



- ☐ Head is flat with large eyes on top.
- ☐ Resembles 'Jack Skellington' from Nightmare Before Christmas.



- ☐ Single set of wing pads.

Taxonomic Information

Order: Ephemeroptera
Family: Heptageniidae
Genus: *Stenonema* and *Maccaffertium*

Ecological Information

Tolerance Value = 4
Feeding Group = Scraper
Stream Habitat = On/underneath cobbles and organics

Key Behaviors

- Very mobile; can move and swim fast when in water.
- Doesn't move well in the net
- It will try to hide on any flat dark colored object like stones, leaves, and other invertebrates

Important Notes

Very common across Connecticut. Flat headed mayflies can be found by slowly lifting the cobbles out of the water. They may run to the other side of the rock. Be careful not to confuse this organism with the two-tailed version (*Epeorus*/Panel 3); the legs, gills, and tails of the flat headed mayfly tend to break off during the collection process.

Size and Color

Size: 5-20 mm
Color: Light golden brown to dark brown, often with spots or stripes on the legs and body



Photographs courtesy of Jake Renkert / The Marvelwood School

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Water Penny Beetle

Moderately
Sensitive

12



KEY FEATURES



- ☐ Small, flat, disc-shaped organism.
- ☐ Uniform in color
- ☐ Head and legs only visible from ventral view (i.e. from underneath)

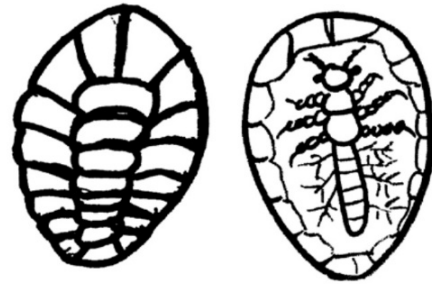


Don't be Fooled by This Imposter!



- ☐ Often confused with the False Water Penny (*Eubriidae*). *Eubriidae* is more ovoid in shape and has a serrated or more jagged outer edge.

Photographs courtesy of (top to bottom): Jake Renkert / The Marvelwood School (top three); Meghan Lally/CT DEEP; The Marvelwood School/Kent Conservation Commission RBV program; The



Taxonomic Information

Order: Coleoptera
Family: Psephenidae
Genus: *Psephenus*

Ecological Information

Tolerance Value = 4
Feeding Group = Scraper
Stream Habitat = Attached to rocks in fast flows

Key Behaviors

- Cling very well to rocks and smooth surfaces such as the sorting tray (see image at left)
- May glide along the bottom of the tray
- May curl up when disturbed

Important Notes

Water penny beetle larvae are common in RBV samples, but can be very hard to locate in the field due to their cryptic nature. Look very closely at any cobbles in your sample area; water penny beetle larva will adhere strongly to rock surfaces. They are very distinctive due to their penny like shape and coloration. These organisms can be locally abundant when conditions are appropriate.

Size and Color

Size: 3-10 mm
Color: Uniform in color. Ranges from golden to dark brown.



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Dobsonfly

Moderately
Sensitive

13A



KEY FEATURES



- ☐ Elongate body with a pair of long soft spine-like appendages on each section of the abdomen.
- ☐ Can be extremely large (up to 4 inches)



- ☐ Large pinching mouth parts.
- ☐ Will bite sampling spoons and your fingers so watch out!



- ☐ Two prolegs at the end of the abdomen, each with two hooks.



- ☐ Tufts of fluffy gills at the base of each abdominal projection.

Taxonomic Information

Order: Megaloptera
Family: Corydalidae
Genus: *Corydalis*

Ecological Information

Tolerance Value = 6
Feeding Group = Predator
Stream Habitat = Under loosely embedded stones

Key Behaviors

- Very mobile, will be very active crawling or wiggling in the tray
- Will curl their abdomen around your finger if picked up
- May cling to the net
- May pinch! Use caution when handling!

Important Notes

Dobsonflies are very common in RBV samples. These macroinvertebrates are sometimes called "Hellgrammites" by fishermen and are a trout favorite! *Corydalis* is often confused with *Nigronia* (Panel 13B). The Dobsonfly can be distinguished by its larger size, darker brown color, and the presence of fluffy gill tufts on the underside of the abdomen.

Size and Color

Size: 25-90 mm
Color: Variable. Brown to nearly black

Photographs courtesy of Jake Renkert / The Marvelwood School

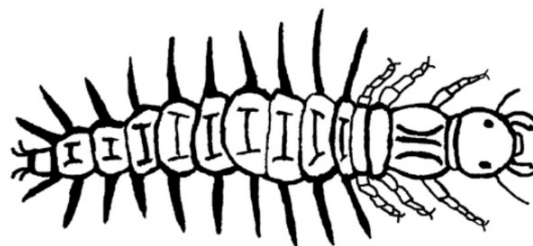
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Fishfly

Moderately
Sensitive

13B



KEY FEATURES



- ☐ Elongate body with a pair of long soft spine-like appendages on each section of the abdomen.



- ☐ Large pinching mouth parts.



- ☐ Two prolegs at the end of the abdomen, each with two hooks.



- ☐ No gills at the base of the abdominal projection.

Taxonomic Information

Order: Megaloptera
Family: Corydalidae
Genus: *Nigronia*

Ecological Information

Tolerance Value = 4
Feeding Group = Predator
Stream Habitat = Under loosely embedded stones

Key Behaviors

- Very mobile, will be very active crawling or wiggling in the tray
- Will curl their abdomen around your finger if picked up
- May cling to the net
- **May pinch! Use caution when handling!**

Important Notes

Very common in RBV samples. *Nigronia* is often confused with *Corydalus* (Panel 13A). The fishfly can be distinguished by its smaller size, more reddish color, and absence of fluffy gill tufts on the underside of the abdomen.

Size and Color

Size: 25-50 mm
Color: Variable. Light brown to reddish orange.



All photographs courtesy of Jake Renkert / The Marvelwood School

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Dragonfly

Moderately
Sensitive

14A

General Identification

The following characteristics are universally true of the dragonfly families below:

- Robust body
- Three short spike-like tails
- Two sets of wing pads
- Very large eyes
- Extendable lower jaw



DRAGONFLY FAMILIES



- ❑ **Darter Dragonfly**
(*Aeshnidae*)
- Very common
 - Usually very dark and almost black
 - Elongate body with small thin legs



- ❑ **Biddie Dragonfly**
(*Cordulergastridae*)
- Somewhat common
 - Light brown; robust, hairy appearance
 - Deeply rounded labium extends out almost half the length of the body



- ❑ **Club Tail Dragonfly**
(*Gomphidae*)
- Very common
 - Short antennae similar in shape to a Q-tip
 - Adapted for burrowing into the substrate to wait for prey



- ❑ **Common Skimmer Dragonfly** (*Libellulidae*)
- Rare – prefers ponds and wetlands

Taxonomic Information

Order: Odonata (Suborder Anisoptera)
Family: All families at left
Genus: All genera within families at left

Ecological Information

Tolerance Value = See below
Feeding Group = See below
Stream Habitat = Typically among rocks and vegetation, or burrowed in soft substrate

	Tolerance Value	Feeding Group
<i>Aeshnidae</i>	3	Predator
<i>Cordulergastridae</i>	3	Predator
<i>Gomphidae</i>	1	Predator
<i>Libellulidae</i>	9	Predator

Important Notes

Dragonfly nymphs can be very common when conditions are appropriate. They are very mobile and move with jet propulsion or by walking. There are several types of dragonflies found in riffle areas, however the majority of species live in slow moving or standing water.

Size and Color

Size: 8-42mm
Color: Variable. Light brown to nearly black



All photographs courtesy of Jake Renkert / The Marvelwood School

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Damselfly

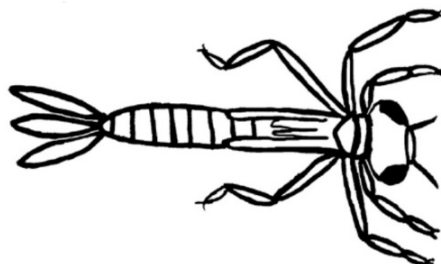
Moderately
Sensitive

14B

General Identification

The following characteristics are universally true of the damselfly families below:

- Slender, delicate body with long legs.
- Three long feather-like caudal gills at the end of the abdomen that resemble tails.
- Two sets of wing pads.
- Very large eyes and extendable lower jaw.



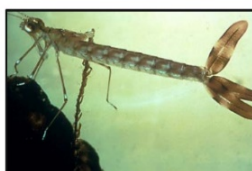
DAMSELFLY FAMILIES



- ☐ **Broad Winged Damselfly**
(*Calopterygidae*)
- First antennae segment is very long, almost half the length of the antenna
 - Uncommon in RBV samples; prefers low gradient habitat



- ☐ **Narrow Winged Damselfly**
(*Coenagrionidae*)
- Two-toned gills at end of abdomen
 - Occasionally in RBV samples; prefers rocks and vegetation in moderate to slow flowing waters



- ☐ **Spread Winged Damselfly** (*Lestidae*)
- Lower lip (labium) is long and slender
 - Gills at end of abdomen are very dark and thick
 - Rare in RBV samples; prefers thick vegetation in very slow flows

Photographs courtesy of Jake Renkert (top); NY DEC (middle); DEEP files, author unknown (bottom)

Taxonomic Information

Order: Odonata (Suborder Zygoptera)
Family: All families at left
Genus: All genera within families at left

Ecological Information

Tolerance Value = See below
Feeding Group = See below
Stream Habitat = Slow or standing water, on vegetation

	Tolerance Value	Feeding Group
<i>Calopterygidae</i>	5	Predator
<i>Coenagrionidae</i>	9	Predator
<i>Lestidae</i>	9	Predator

Important Notes

These larvae are very active and will move by wiggling side to side.

Damselflies are rare in riffle areas; the majority of species live in slow moving or standing water. If you find a lot of damselflies in your sample check that you are in the right habitat for the RBV program.

Size and Color

Size: 13-50mm
Color: Variable. Yellow to dark brown.
Sometimes with patterns.

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Least Sensitive

Scud

Least
Sensitive

15



KEY FEATURES



- ☐ Body strongly flattened from side to side.
- ☐ Two pairs of antennae are about the same length.



- ☐ Seven pairs of walking legs.
- ☐ The first two pairs of legs have hinged claws.

Taxonomic Information

Order: Amphipoda
Family: All
Genus: All

Ecological Information

Tolerance Value = 6
Feeding Group = Collector-gatherer
Stream Habitat = In and on organic substrate, slow flows

Key Behaviors

- Can swim very rapidly on their sides when disturbed; also called "side swimmers"
- Turn bleach white when preserved

Important Notes

Common in CT streams, but less likely in RBV samples due to their preference for slower flows and lower gradients. They are typically found in areas of loose substrate and prefer cool, shallow streams and the backwaters of larger rivers. Most are omnivorous and feed in organic debris that accumulate in the stream margins. Scuds are an important food source for fish.

Size and Color

Size: 5-20 mm
Color: White to gray



Photographs courtesy of (top to bottom): Jake Renkert / The Marvelwood School (top); Becky Martorelli / Quinnipiac River Watershed Coalition; Kelsey Quartuccio / CT DEEP

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Aquatic Sow Bug

Least
Sensitive

16



KEY FEATURES



- ☐ Body is strongly flattened from top to bottom.



- ☐ Two pairs of antennae, of which one pair is significantly longer than the other pair.



- ☐ Seven pairs of legs.
- ☐ First pair of walking legs has enlarged ends with hinged claws.



- ☐ Six pairs of short appendages on the underside of the abdomen. The sixth pair extends behind like a pair of flat tails.

Taxonomic Information

Order: Isopoda
Family: Asellidae
Genus: All

Ecological Information

Tolerance Value = 8
Feeding Group = Collector-gatherer
Stream Habitat = In and on substrate, slow flows

Key Behaviors

- Crawl slowly amongst the debris.
- Sow bugs will avoid light by hiding under leaves or other debris.
- Turn gray when preserved

Important Notes

Aquatic sow bugs prefer darker, slower, shallow habitats; they are not typically found in high quality riffles and therefore are rare in RBV samples. Sow bugs are an important food source for fish in low gradient CT streams.

Size and Color

Size: 5-20 mm
Color: Medium to dark gray is most common but can also be blackish or brownish



Photographs courtesy of: Jake Renkert / The Marvelwood School

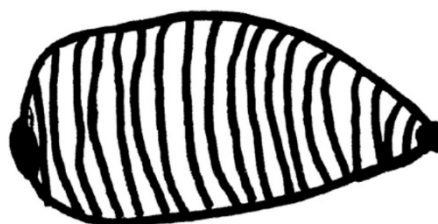
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Leech

Least
Sensitive

17



KEY FEATURES



- ❑ Somewhat soft but muscular, flattened body with many segments and no legs.
- ❑ Two distinct suction discs on the bottom of the body, one on each end.
- ❑ Several small eyespots on top of first segments.



Taxonomic Information

Phylum: Annelida
Class: Clitellata
Sub-Class: Hirudinea

Ecological Information

Tolerance Value = 10
Feeding Group = Predator
Stream Habitat = Slow or standing water, among debris

Key Behaviors

- Leeches will stick to the bottom of the tray and move like inch worms
- Tend to curl up when preserved

Important Notes

Leeches are rare in RBV samples due to their preference for slow flows. They feed on the blood of a host organism by using a drill-like rasping tongue to penetrate the skin. The leech injects hirudin, a chemical which prevents the blood from clotting. Some leeches are used in medical practice to remove the build-up of blood and body fluids in bruised or surgically reattached appendages or tissues.

Size and Color

Size: 4-450 mm
Color: Tan, brown, gray or black sometimes with colored patterns



Photographs courtesy of Jake Renkert / The Marvelwood School (top two); and NY DEC Biomonitoring Unit (bottom)

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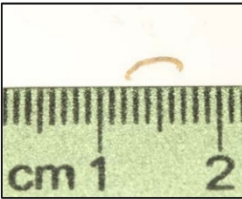
Non-Biting Midge

Least
Sensitive

18



KEY FEATURES



- ☐ Small, very thin, wormlike body
- ☐ Red or white in color



- ☐ Distinct head capsule, though very tiny



- ☐ May be found hiding in very finely constructed cases

Taxonomic Information

Order: Diptera
Family: Chironimidae
Genus: All

Ecological Information

Tolerance Value = 6 (White) or 8 (Red)
Feeding Group = Collector-gatherer
Stream Habitat = On substrate in all flow types

Key Behaviors

- Midges swim by violent side to side wiggling
- Red midges turn white when preserved.

Important Notes

Look carefully for midge larvae, they are common but extremely small! There are approximately 100 different genera of midges in Connecticut. These can be divided into two main groups: the white and red midges. The color in the red midges comes from a hemoglobin-like compound which allows the midge to survive in very low oxygen levels.

Size and Color

Size: 5-25 mm
Color: White (clear to cream) or red



Photographs courtesy of: Jake Renkert / The Marvelwood School (top three); and NY DEC (bottom)

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Black Fly

Least
Sensitive

19



KEY FEATURES



- ❑ Bowling pin shaped body with a capsule-like head that is distinct from the thorax.
- ❑ Enlarged rear one-third of the body. Resembles the shape of a vase.
- ❑ There is a proleg on the bottom of the first thorax segment..



Taxonomic Information

Order: Diptera
Family: Simuliidae
Genus: All

Ecological Information

Tolerance Value = 6
Feeding Group = Collector-filterer
Stream Habitat = Attached to rocks in riffle areas

Key Behaviors

- Black flies will attach to the bottom of the tray
- Move like inch-worms

Important Notes

Black fly larvae are common in RBV samples, but are relatively small so may be easily overlooked.

Black fly larvae have a ring of small hooks at the back end of the abdomen that enables them to adhere to a rock and not be swept away by the current. They use a brush-like structure to filter fine organic matter from the water column.

Size and Color

Size: 5-10 mm
Color: Whitish-gray



Photographs courtesy of (top to bottom): Jake Renkert / The Marvelwood School; The Marvelwood School/Kent Conservation Commission Local RBV program;); Jake Renkert / The Marvelwood School

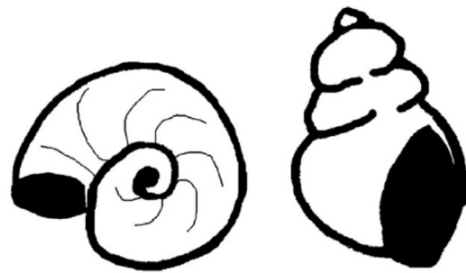
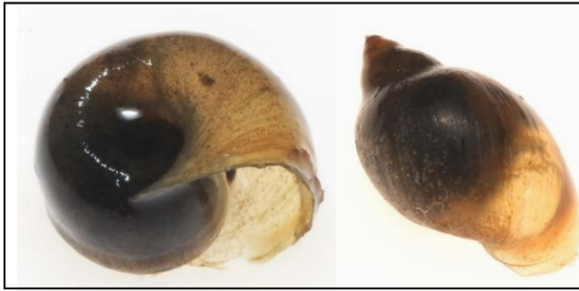
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Snail

Least
Sensitive

20



KEY FEATURES

☐ Gilled Snails

Subclass: Prosobranchia

- Breathe by absorbing dissolved oxygen from the water through gills
- Sensitive to pollution; indicative of high water quality

☐ Lunged Snails

Subclass: Pulmonata

- Take in oxygen from the air into an internal lung-like structure
- Can tolerate low dissolved oxygen levels



☐ Chinese Mystery Snail (*Bellamya chinensis*)

☒ Invasive!

- ☐ Relatively large, globose shells with concentrically marked opercula

Taxonomic Information

Phylum: Mollusca
Class: Gastropoda

Ecological Information

Tolerance Value = Variable
Feeding Group = Scraper
Stream Habitat = On rock surfaces and finer sediments

Key Behaviors

- May glide along the bottom of the tray or cling to tray walls

Important Notes

Freshwater snails in CT are most commonly located below ponds and in wetlands areas and are therefore relatively uncommon in RBV samples. There are two major groups of snails in CT – 'right handed' and 'left handed'; they can be differentiated by facing the snail toward you and determining the direction to which the snail opens at the bottom.

Size and Color

Size: 3-60 mm
Color: Variable. Light tan to dark brown.

Photographs courtesy of: Jake Renkert / The Marvelwood School (top); USGS / Wikipedia.org (bottom)

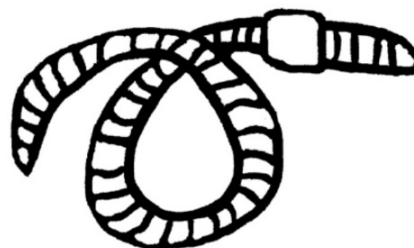
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Aquatic Worm

Least
Sensitive

21



KEY FEATURES



- ☐ Soft, long, cylindrical bodies consisting of many ring-like segments
- ☐ No suckers or eyespots



Taxonomic Information

Phylum: Annelida
Class: Oligochaeta

Ecological Information

Tolerance Value = 8
Feeding Group = Collector-gatherer
Stream Habitat = In and on fine substrate

Key Behaviors

- May wiggle or curl in a 'knot' while in the tray

Important Notes

Aquatic earthworms can be found in any flows, but prefer slower flows and are therefore not common in RBV samples. Aquatic earthworms, especially tubifex worms, can live in extremely polluted water with very low dissolved oxygen levels. Often, severely impacted streams will have large populations of these worms.

Size and Color

Size: 1-30 mm avg. (up to 150 mm)
Color: Variable, but typically white or reddish.



Above photographs courtesy of Jake Renkert / The Marvelwood School

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Miscellaneous Other

CAMBARUS SPECIES IN CT



- ❑ **Common Crayfish**
(*Cambarus bartonii*)
- Native, rare (western CT)
- No depression on large claw
- 1 row of tubercles
- Lower part of gonopod 'pipe' longer than the top part



- ❑ **Robust Crayfish**
(*Cambarus robustus*)
- Introduced, common (Statewide)
- Deep depression on outer margin of large claw
- Pipe-wrench shaped gonopods of equal length
- 2 rows of tubercles

PROCAMBARUS SPECIES IN CT



- ❑ **White River Crayfish**
(*Procambarus acutus*)
- Introduced, common (eastern CT)
- No spikes on inside margin of claws
- Brown mottled color
- Areola open

General Identification

Cambarus crayfish species:

- Rostrum is not "J" shaped
- Gonopods are pipe-wrench shaped

Procambarus crayfish species:

- Long, slender, curved claws
- Rostrum is "J" shaped w/ spines
- Gonopods not pipe-wrench; males with 4 hooks



Taxonomic Information

Order: Decapoda
Family: Cambaridae
Genus: Cambarus, Procambarus

Ecological Information

Tolerance Value = 6
Feeding Group = Gatherer, collector
Stream Habitat = All flows, shallows (1-2m) burrowed in substrate or under rocks

Important Notes

Crayfish resemble small lobsters. They have a hard exoskeleton, long "nose"; large eyes; 5 pairs of walking legs; flipper at end of tail; and large claws. When disturbed in the water, crayfish use their "flipper" to quickly scoot backwards through the water.

DO NOT INCLUDE CRAYFISH IN YOUR VOUCHER COLLECTION; photograph any crayfish found and return them alive to the stream from which you collected them.

Size and Color

Size: 10-150mm
Color: Usually brownish green but ranges from blackish to red/orange, often speckled

Above photographs courtesy of Robert Jacobs / CT DEEP Inland Fisheries Division

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Crayfish

Misc. Other

22B

ORCONECTES SPECIES IN CT



- ❑ **Spiny Cheek Crayfish**
(*Orconectes limosus*)
 - Native, common (Statewide)
 - Spiny cheeks! (Can feel if rub finger along side of head)
 - Claw tips are orange with a black band



- ❑ **Rusty Crayfish**
(*Orconectes rusticus*)
 - **Invasive!** Common in western CT
 - Rusty colored patch near tail above legs
 - Claw tips orange with black band
 - No spines on cheeks



- ❑ **Virile or Northern Crayfish** (*Orconectes virilis*)
 - Occasional, statewide
 - Blue claws with prominent white bumps
 - Pair of dark tail spots
 - Scissor-like gonopods
 - No spines on cheeks



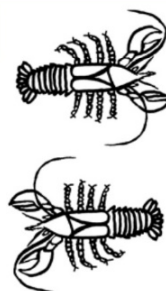
- ❑ **Ringed Crayfish**
(*Orconectes neglectus*)
 - Introduced, Rare (Hudson drainage)
 - Heavy black banding
 - Claw tips orange with black "racing stripe"
 - No spines on cheeks

Above photographs courtesy of Robert Jacobs / CT DEEP Inland Fisheries Division

General Identification

The following characteristics are universally true of the Orconectes crayfish species in CT:

- Rostrum is "J" shaped and spines present
- Gonopods are not pipe-wrench like in shape



Taxonomic Information

Order: Decapoda
Family: Cambaridae
Genus: Orconectes

Ecological Information

Tolerance Value = 6
Feeding Group = Gatherer, collector
Stream Habitat = All flows, shallows (1-2m) burrowed in substrate or under rocks

Important Notes

Crayfish are the largest stream invertebrates and can be extremely numerous under appropriate conditions. Crayfish are tolerant of most pollution and environmental stress (temperature, pH, alkalinity). Although, they bioaccumulate some metals (mercury); crayfish tissue samples can be used to detect contamination.

DO NOT INCLUDE CRAYFISH IN YOUR VOUCHER COLLECTION; photograph any crayfish found and return them alive to the stream from which you collected them.

Size and Color

Size: 10-150mm
Color: Usually brownish green but ranges from blackish to red/orange, often speckled

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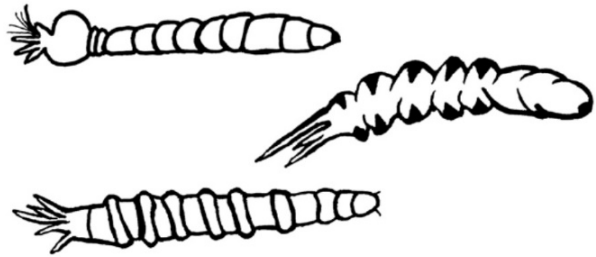


KEY FEATURES

The following characteristics are universally true of crane fly:

- ☐ Body is cylindrical and usually stout.
- ☐ Typically very soft bodied.
- ☐ Head is withdrawn and not visible.
- ☐ Two spiracles at the end of the abdomen surrounded by several pairs of short, fleshy lobes.
- ☐ One to seven pairs of lobes that often have a fringe of hair.

Above photographs courtesy Jake Renkert / The Marvelwood School



Taxonomic Information

Order: Diptera
Family: Tipulidae
Genera: Hexatoma, Antocha, Tipula

Ecological Information

Tolerance Value = 3
Feeding Group = Shredder
Stream Habitat = Burrowed in substrate and leaf packs

Key Behaviors

- Often found in leaf packs within sample

Important Notes

Craneflies are common in RBV samples. All crane flies have what appear to be tails, however they are respiratory organs. Most crane fly larvae are very large at around 2 inches long. Some species have a bulb-like structure near the tails, while others have dark areas on the top and bottom of the abdomen.

Size and Color

Size: 5-25 mm average (up to 100 mm)
Color: Tan to White.



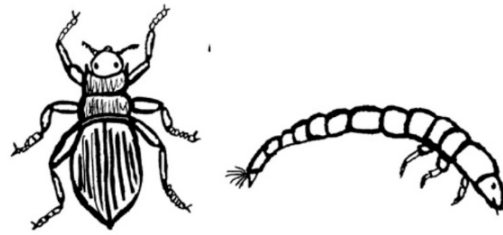
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Riffle Beetle

Misc. Other

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KEY FEATURES (Larva)



- ☐ Small, hard-bodied, cylindrical and slightly "C" shaped



- ☐ Long legs in relation to body size.



- ☐ Two prominent claws on the ends of the legs.

KEY FEATURES (Adult)



- ☐ Small, dark brown or black beetles.

Taxonomic Information

Order: Coleoptera
Family: Elmidae
Genus: All

Ecological Information

Tolerance Value = 4
Feeding Group = Scraper
Stream Habitat = On organic substrate in riffles

Key Behaviors

- Larval form is relatively inactive, but adult riffle beetles will crawl around the sorting tray.

Important Notes

Riffle Beetles are common in RBV samples. *Elmidae* is one of the very few benthic macroinvertebrates who remain aquatic in both its larval and adult stages.

Size and Color

Size: 5-15 mm (Larva)
Color: Brown



Above photographs courtesy of (top to bottom): Jake Renkert / The Marvelwood School); NY DEC Biomonitoring Unit; Jake Renkert / The Marvelwood School); Jake Renkert / The Marvelwood School); NY DEC Biomonitoring Unit

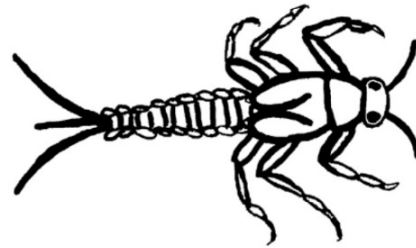
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Small Minnow Mayfly

Misc. Other

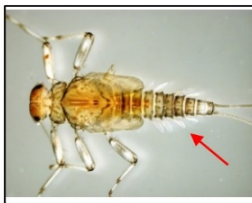
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KEY FEATURES



- ☐ Small in overall size.
- ☐ Three pairs of legs; legs do not have a feathery fringe of hairs
- ☐ 2-3 hair-like tails, sometimes with a shorter middle tail



- ☐ Small, round gills along the sides of the abdomen – may be difficult to see without magnification
- ☐ Elongated wing pads



Taxonomic Information

Order: Ephemeroptera
Family: Baetidae
Genus: All

Ecological Information

Tolerance Value = 4
Feeding Group = Collector-gatherer
Stream Habitat = On and in rocky substrates

Key Behaviors

- Swim very well and will quickly swim in short bursts from one hiding spot to another in the tray

Important Notes

Baetidae are common in RBV samples, however due to their small size they are often easily missed when sampling. Baetidae is commonly confused with Isonychidae (Panel 2). Baetidae can be differentiated by its smaller size and lack of fine hairs along the inside edge of the front legs. (Some genera of Baetidae may also appear to only have two tails.)

Size and Color

Size: 3-12 mm
Color: Light brown



Above photographs courtesy of (top to bottom): NY DEC Biomonitoring Unit; Kelsey Quartuccio / CT DEEP; NY DEC Biomonitoring Unit; CT DEEP files, author unknown

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Aquatic Snipe Fly

Misc. Other

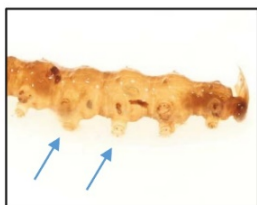
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KEY FEATURES



- ☐ Body is elongate with a pointed head end and tail-like structures at the end of the abdomen.



- ☐ Series of small, paired prolegs along abdomen
- ☐ Rough appearance to the exoskeleton.



- ☐ Two stout, pointed tails with a fringe of hairs at the end of the abdomen

Above photographs courtesy of (top to bottom) Kelsey Quartuccio / CT DEEP; Becky Martorelli / Quinnipiac River Watershed Association; Jake Renkert / The Marvelwood School; and Kelsey Quartuccio / CT DEEP



Taxonomic Information

Order: Diptera
Family: Athericidae
Genus: *Atherix*

Ecological Information

Tolerance Value = 2
Feeding Group = Predator
Stream Habitat = Buried in the substrate in fast flows

Key Behaviors

- No unique behaviors; may be observed crawling in tray

Important Notes

Atherix is relatively rare in RBV samples. They are piercer-predators that prey on midge and mayfly larvae.

Size and Color

Size: 10-20 mm
Color: Golden brown to dark brown

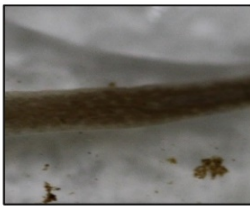


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KEY FEATURES



- ☐ Soft, elongate, flattened body without segmentation or legs



- ☐ Slightly triangular head with two eyespots on top. (Resemble a cross-eyed, unsegmented leech)



Taxonomic Information

Order: Tricladida
Family: Planariidae
Genus: *Planaria*

Ecological Information

Tolerance Value = 4
Feeding Group = Predator
Stream Habitat = On rocky substrate

Key Behaviors

- Planaria are able to 'glide' by beating microscopic cilia along a film of mucus.
- Tend to curl up when preserved

Important Notes

Although flatworms occur in a wide variety of habitats, they are rarely collected in RBV samples. When a large number of planarians are present in a collection, the site is most likely affected by organic pollution. Flatworms are heavily studied due to their regenerative capacity; when split lengthwise or crosswise they will regenerate into two genetically identical individuals!

Size and Color

Size: 5-20 mm
Color: Gray, brown or black on top, sometimes with spots or pattern; light on bottom

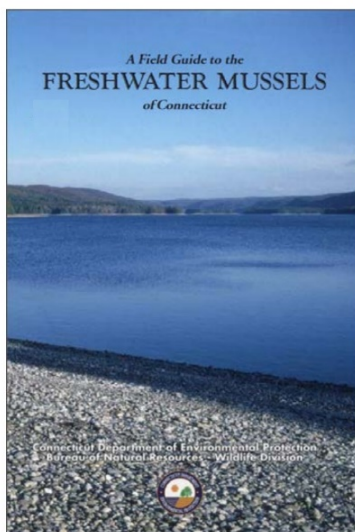
Above photographs courtesy of Meghan Lally / CT DEEP (top);
Becky Martorelli / Quinnipiac River Watershed Association
(bottom two)

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FRESHWATER MUSSELS IN CONNECTICUT

Refer to the CT DEEP publication "A Field Guide to the Freshwater Mussels of Connecticut" for identification details.



To download a PDF version visit:
www.ct.gov/deep/lib/deep/wildlife/pdf_files/nongame/fwmusl.pdf

General Identification

The following characteristics are universally true of the freshwater mussels in CT:

- Two shells connected by a strong hinge
- No distinct head



Taxonomic Information

Order: Unionoida
 Family: Margaritiferidae, Unionidae
 Genus: See Field Guide

Ecological Information

Tolerance Value = 7
 Feeding Group = Collector-filterer
 Stream Habitat = Buried in substrate, slower flows

Key Behaviors

- Live on stream bottom, typically partially buried

Important Notes

Almost all kinds of mussels are sensitive to pollution and environmental stress. In Connecticut, 6 of the 12 native freshwater mussel species are listed as special concern, threatened, or endangered.

To avoid accidentally injuring a listed species, please **DO NOT DISTURB OR HANDLE LIVE MUSSELS** observed at your RBV monitoring location. **Photograph live mussels only; if empty shells are found, turn these in to your coordinator with your voucher.**

Size and Color

Size: Variable (refer to guide)
 Color: Variable (refer to guide)

INTRODUCED MUSSELS IN CONNECTICUT



- ❑ **Zebra Mussel**
 (*Dreissena polymorpha*)
- Small (< 1 inch)
 - Triangular shaped
 - Distinct black or gray stripes
 - Strongly adheres to surfaces



- ❑ **Asian Clam**
 (*Corbicula fluminea*)
- Small (0.5-.75 inches wide)
 - Triangular shaped
 - Yellowish, light brown or black

Photographs courtesy of Dave Brenner, Michigan Sea Grant (top) and USGS, author unknown (bottom)

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6.4 Ecological Sensitivity and Tolerance towards Pollution

Order	Family	Tolerance value	Ecological sensitivity
Ephemeroptera	Ephemerellidae	1	Most sensitive
Ephemeroptera	Oligoneuriidae	2	Most sensitive
Ephemeroptera	Heptagenidae	0	Most sensitive
Plecoptera	Peltoperlidae	0	Most sensitive
Plecoptera	Perlidae	1	Most sensitive
Plecoptera	Pteronarcyidae	0	Most sensitive
Plecoptera	Capniidae	1	Most sensitive
Plecoptera	Chloroperlidae	1	Most sensitive
Plecoptera	Leuctridae	0	Most sensitive
Plecoptera	Nemouridae	2	Most sensitive
Plecoptera	Perlodidae	2	Most sensitive
Plecoptera	Taeniopterygidae	2	Most sensitive
Trichoptera	Glossosomatidae	0	Most sensitive
Trichoptera	Apataniidae	3	Most sensitive
Trichoptera	Rhyacophilidae	0	Most sensitive
Trichoptera	Brachycentridae	1	Most sensitive
Trichoptera	Lepidostomatidae	1	Most sensitive
Trichoptera	Hydropsychidae	4	Moderately sensitive
Trichoptera	Philopotamidae	3	Moderately sensitive
Ephemeroptera	Heptageniidae	4	Moderately sensitive
Coleoptera	Psephenidae	4	Moderately sensitive
Megaoptera	Corydalidae	6	Moderately sensitive
Megaoptera	Corydalidae <i>Nigronia</i>	4	Moderately sensitive
Odonata	Aeshnidae	3	Moderately sensitive
Odonata	Cordulidae	3	Moderately sensitive
Odonata	Gomphidae	1	Moderately sensitive
Odonata	Libellulidae	9	Moderately sensitive
Odonata (Zygoptera)	Calopterygidae	5	Moderately sensitive
Odonata (Zygoptera)	Coenagrionidae	9	Moderately sensitive
Odonata (Zygoptera)	Lestidae	9	Moderately sensitive
Amphipoda	All families	6	Least sensitive
Isopoda	Asellidae	8	Least sensitive
Annelida	Clitellata	10	Least sensitive
Diptera	Chironomidae (white)	6	Least sensitive
Diptera	Chironomidae (red)	8	Least sensitive
Diptera	Simuliidae	6	Least sensitive
Phylum: Annelida	Oligochaeta	8	Least sensitive
Decapoda	Cambaridae <i>Cambarus</i>	6	Miscellaneous Other

Decapoda	Cambaridae <i>Oronectes</i>	6	Miscellaneous Other
Diptera	Tipulidae	3	Miscellaneous Other
Coleoptera	Elmidae	4	Miscellaneous Other
Ephemeroptera	Baetidae	4	Miscellaneous Other
Diptera	Athericidae	2	Miscellaneous Other
Tricardia	Planariidae	4	Miscellaneous Other
Unionoida	Unionidae	7	Miscellaneous Other