FACTS ABOUT

An Information Update from the IADC

TURBIDITY & DREDGING

WHAT IS TURBIDITY?

Turbidity is an optical quality of water and describes how clear or transparent the water is. It describes the degree to which water contains particles that cause cloudiness or muddiness resulting in the disturbance of sunlight. Water is turbid – that is cloudy, opaque or thick – when it contains suspended silt. If turbidity is low, sunlight shines through the water in a straight line down to the waterbed. When turbidity increases it changes the direction of the light, so that the light scatters, illuminating the particles in the water, much the way a ray of sunlight illuminates specks of dust in the air. The cloudier the water, the greater the turbidity. The further sunlight penetrates the water, the higher the water clarity and the lower the turbidity.

WHAT CAUSES TURBIDITY?

Turbidity is a natural phenomenon that occurs in bodies of water, be it oceans, lakes or rivers. Turbidity is not itself a pollutant, but indicates how much sediment and organic matter are in the water. High turbidity may be caused by a high content of fine sediments or organic particles. Or by low concentrations of material with a high light absorption. A major source of turbidity in the open waters of many lakes and rivers is typically phytoplankton. Closer to the shore, particulates may also include clays and silts from shoreline erosion, re-suspended bed sediments and organic detritus from streams. Bottom-feeding fish like carp can stir up sediments on the bed and increase the cloudiness of the water as can the excessive growth of algae.

Turbidity also occurs in oceans. Like lakes, highly turbid ocean waters have a large number of particulates like sediments and phytoplankton which reduce the visibility of the water. In addition, turbidity can also be caused by human activities. These anthropogenic causes may originate from wastewater discharges to beam trawling, propeller wash resulting from shipping as well as re-suspension caused by dredging.

IS TURBIDITY UNUSUAL?

Not at all. Turbidity is a background quality in all bodies of water. Natural events such as storms, heavy rains and floods can increase the degree of turbidity. These events create fast running water that can carry more particles and larger-sized sediment, which in turn can pick up sand, silt, clay and organic particles from the land and carry them to surface water thus affecting turbidity. After a hurricane makes landfall, for instance, an increase in turbidity can be seen as a result of sediments that have been re-suspended from the shallow beds. In near-shore areas, some turbidity may also come from sediments eroded from beaches as well as from sediment-laden river plumes.

WHAT ARE TOTAL SUSPENDED SOLIDS (TSS)?

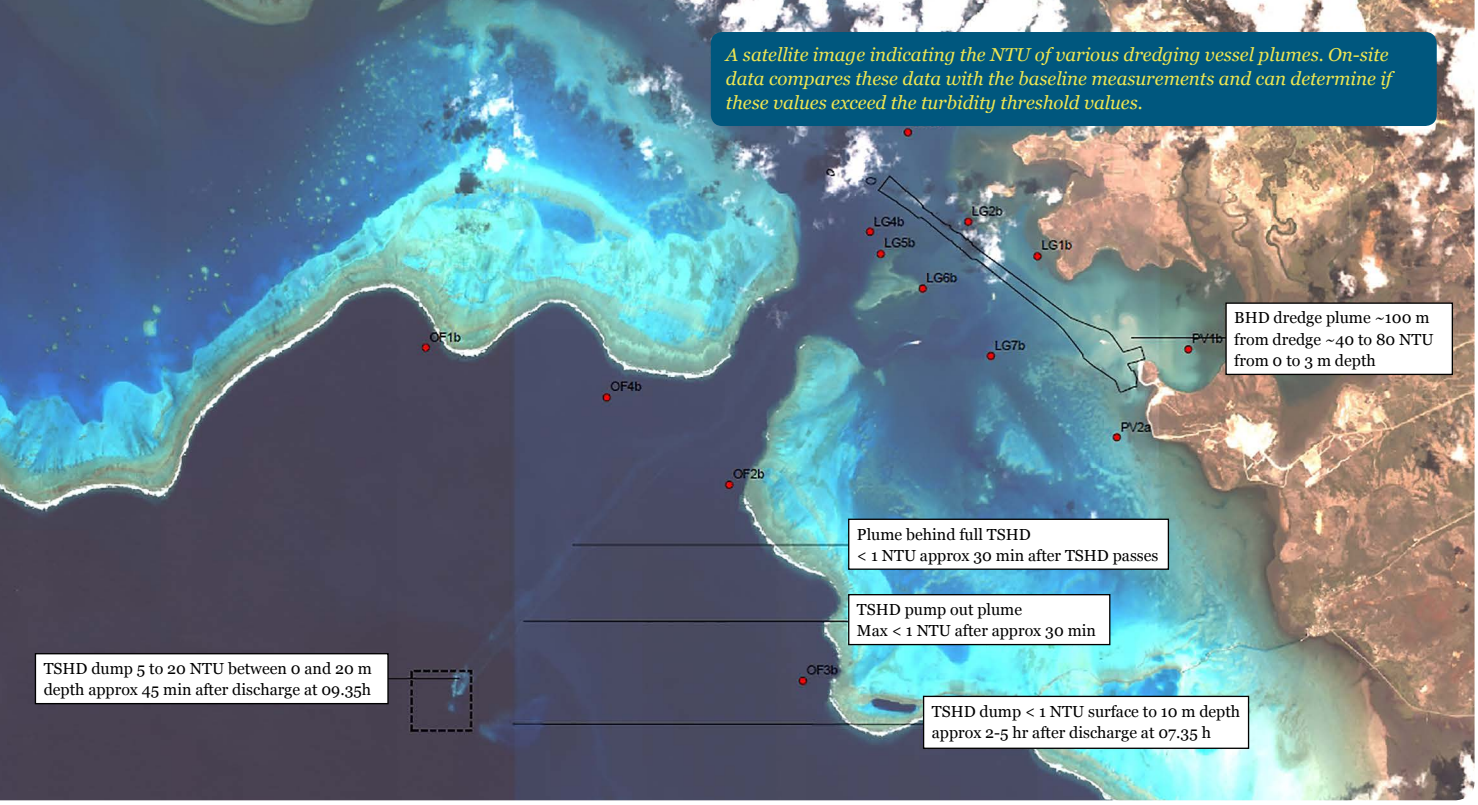
Suspended matter such as clay, silt and organic matter, as well as plankton and other microscopic organisms interfere with the passage of light through the water and thus cause turbidity. Taken together all these 'particles' are known as the total suspended solids (TSS). The greater the amount of TSS in the water, the murkier it appears, and the higher the measured turbidity.

ARE TURBIDITY AND TSS THE SAME?

Although total suspended solids or TSS affect turbidity, turbidity is not the same as TSS. TSS is a measurement of the dry-weight mass of non-dissolved solids which are suspended in the water. These are measured as the solids suspended per unit volume of water and are expressed as mg/l. Both organic (such as algae, zooplankton and detritus) and inorganic (clay, silt and sand) solids are included in TSS.

Turbidity refers to the optical or visual properties of water and is not a measurement of the concentration of suspended sediments. Turbidity is affected by TSS, but is also determined by the shape of particles, size distribution, refractive index, color and absorption spectra. For a specific location and specific sediment properties, simultaneously measuring

Above: A "curtain" made of air bubbles creates a barrier that limits the sediments in the turbid water at the dredging site from dispersing into more sensitive areas.



A satellite image indicating the NTU of various dredging vessel plumes. On-site data compares these data with the baseline measurements and can determine if these values exceed the turbidity threshold values.

turbidity and TSS will normally result in a good correlation between TSS and turbidity.

HOW IS TURBIDITY MEASURED?

Since turbidity is an optical property of water, it is measured by optical units such as Jackson Turbidity Units (JTU) or Nephelometric Turbidity Units (NTU). The two units are similar although not completely equal. Turbidity can be measured using either electronic turbidity meters, a turbidity tube or a Secchi disc. Various electronic turbidity meters are available and they are very accurate for measuring low turbidity, less than 5 NTU. A turbidity tube has a simple, sturdy design but is less precise when measuring very low turbidity. A Secchi disc is typically an opaque, white or black and white disc mounted on a pole or line and lowered into the water. It gauges the transparency of water by measuring the depth (Secchi depth) at which the disc is no longer visible from the surface. Although this is a straightforward, inexpensive means of measuring, it is only as accurate as the person who is using it.

WHAT IS AN NTU?

Nowadays turbidity is commonly measured by a nephelometer in Nephelometric Turbidity Units or NTU. The nephelometer measures the clarity of the water and NTU represent the average volume of particles scattered over a defined angular range. Both particle size and concentration of suspended solids as well as dissolved solids can affect this reading. NTU can be translated into mg/l through a correlation based on simultaneously taken water samples.

WHY IS TURBIDITY IMPORTANT?

Since a certain degree of turbidity occurs naturally, many marine species are accustomed to variability in turbidity and can survive for a reasonable length of time with reduced sunlight. A significant increase in turbidity from the background values, however, can disrupt the natural environment and hinder the growth of flora and fauna. When sunlight is blocked from penetrating through the water, high concentrations of particulate matter will modify light penetration, causing shallow lakes and bays to fill in faster and smother benthic habitats. This impacts both underwater organisms and their eggs.

In addition, when sunlight penetration is significantly reduced, photosynthesis is also reduced. This in turn lowers the daytime release of oxygen into the water, which reduces plant productivity in the waterbed. Without sunlight, marine flora like seaweed and bay grasses cannot continue photosynthesis. Reduced light penetration also has a sensory impact by preventing various organisms from seeing their food, their preys and predators, their mates and offspring. This is true whether increased turbidity is caused by natural or anthropomorphic events.

DOES INCREASED TURBIDITY IMPACT HUMAN LIFE?

Turbidity can impact water quality with subsequent health and hygiene repercussions. For that reason, turbidity is one of the many water quality criteria that will be measured during a dredging operation. Turbidity itself is not a major health concern – the water is not necessarily contaminated – but high turbidity can interfere with disinfection and provide a medium for the growth of microbes and bacteria. If water is contaminated then highly turbid water which drifts to other areas can be cause for concern.

DOES DREDGING CAUSE TURBIDITY?

Besides naturally occurring events like storms, river flows, waves and activities like fishing, shipping and dredging operations also cause turbidity. To be more accurate, dredging can cause 'extra' turbidity. Environmental impact assessments and continuous monitoring will help evaluate how much extra turbidity is too much. To do this, turbidity fluctuations in the natural, background environment should be determined as part of an environmental baseline study.

WHAT IS A BASELINE STUDY?

A baseline study is usually part of an Environmental Management Plan (EMP) and is carried out prior to a

Turbidity plumes are caused by all dredging vessels: left, the plume from a trailing suction hopper dredger; right, from a backhoe.

dredging operation. At this time, the marine species and their habitats which may be sensitive to (large) fluctuations in turbidity should be identified. During the execution of the project, turbidity must then be carefully monitored by measuring light penetration and water clarity. Generally speaking there are three variables that are usually considered: the nature of the waterbed in the area to be dredged; the nature of the surface water in and around the area to be dredged; and the dredging technique and type of dredger that is being used.

CAN TURBIDITY BE CONTROLLED TO PROTECT THE MARINE ENVIRONMENT?

Yes, and consequently dredging companies and environmental scientists spend a great deal of attention to when, where and how dredging takes place. Whilst weather events which cause increased turbidity are beyond human control, human interventions like dredging can be, and in general are, planned to minimise disturbances.

Turbidity must be measured in relationship to the natural background levels and the season in which dredging is scheduled. In some environments turbidity is naturally high. Organisms in these waters have adapted to higher turbidity levels. Other water habitats have much clearer (less turbid) water and any change to light penetration will adversely affect the underwater species. In these environments dredging is often limited or avoided entirely during spawning season to protect marine life. Often special dredging technologies are implemented which minimise turbidity or, as in the case of silt or bubble curtains, limit sediment from spreading beyond a designated area. Mangroves, coral reefs and oyster beds are particularly sensitive to turbidity and TSS and often require special attention. In some instances, coral can be transplanted to a safer environment before dredging starts and replanted when work is finished.

IS TURBIDITY CAUSED BY DREDGING HARMFUL?

Increased silt concentrations during dredging and sand extraction can have a negative effect on marine fauna and flora. Therefore research into the effects of turbidity must be done on a case-by-case basis. Especially since sometimes observations can be counter-intuitive. A short but very high impact from a dredging activity may cause mortality, but not always. Sometimes dredging that causes very high levels of turbidity for a shorter period of time can be less invasive and less of a problem for marine life than dredging more slowly and creating longer-lasting, lower level turbidity. The question about turbidity which arises when dredging is "To what level?". This emphasises the necessity for accurate baseline studies as well as adequate in-situ measuring and monitoring throughout the dredging operations.

WHAT KINDS OF DREDGERS CAUSE TURBIDITY?

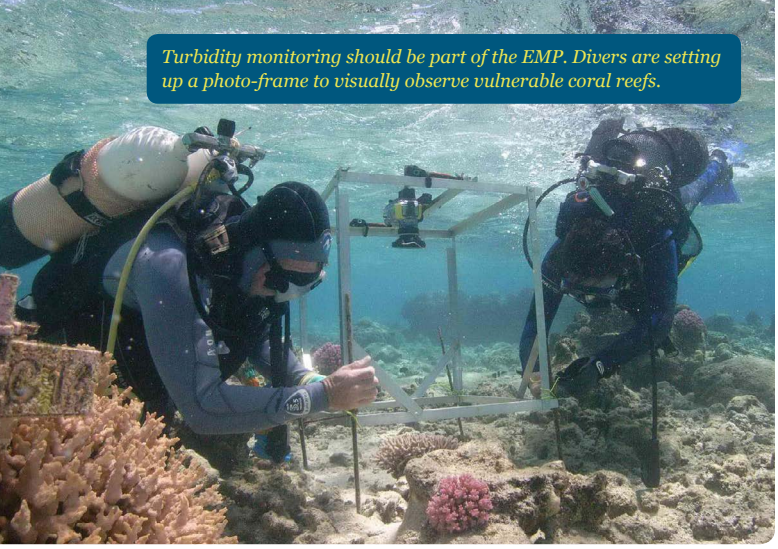
All types of dredgers cause some turbidity during excavation as well as during the flow of sediments from the hoppers and barges. The 'plumes' seen behind dredgers are evidence of this. The plumes arising from trailing suction hopper dredgers are caused by the discharge (or "overflow") of sediment-laden water from the hopper (usually through the hull of the dredger but sometimes over the ship-sides) which can form surface or near bed plumes. Disturbance by the draghead and erosion from propeller wash also play a role.

HOW IS TURBIDITY EVALUATED DURING DREDGING?

Turbidity seen in the above-mentioned plumes can easily be measured in the field on site. For the sake of accuracy turbidity during dredging operations should be and can be measured on a weekly, daily, hourly or even continuous basis depending on the locality. Turbidity measurements are then an immediate and reliable indicator of marine conditions – unlike testing water for other physical or chemical properties for which samples must be sent to laboratories.

The focus of monitoring investigation programmes should be to establish accurate, real-time measurements of the average natural background turbidity at the site prior to dredging and then determine the characteristic increase of the averaged turbidity during dredging. The comparison of these two gives insight into any significant changes caused by dredging and helps to quantify the potential impacts.

A telemetry buoy anchored near a working area. Collected data are transmitted by a radio modem inside the buoy to a receiver station and compared with the EMP turbidity threshold values.



Turbidity monitoring should be part of the EMP. Divers are setting up a photo-frame to visually observe vulnerable coral reefs.

CAN TURBIDITY BE ELIMINATED DURING DREDGING?

Probably not entirely. Limiting turbidity during a dredging project is of course possible and monitoring turbidity carefully so that it is more controllable and therefore acceptable is a high priority. A thoroughly thought-out EMP can help foresee challenges and allow for the development of innovative methods to help mitigate impacts. In this way sensitive environments can be protected.

WHAT STUDIES ARE BEING CONDUCTED TO MONITOR TURBIDITY?

Several in-depth studies have been carried out regarding the application of remote sensing, transport modelling and data-model integration (DMI) techniques for monitoring the environmental effects of dredging and disposal. Telemetry buoys and satellite images add to the data available to determine any values exceeding those specified in the EMP. A long-term aim is to develop an improved monitoring system that combines optical remote-sensing data, dynamic plume spreading model results, in-situ turbidity and actual dredging data in order to provide near real-time information on the extent (location and dimensions) and concentrations of the total suspended solids in a dredging or disposal plume.

WHAT ARE THE LONG-TERM EFFECTS OF TURBIDITY?

Turbidity is only one factor influencing a dredging project – albeit a very visible one. Its impacts must be considered in the totality of the economic and social need for the dredging operation. Each local situation must be evaluated individually. Multi-criteria analyses of a dredging project are necessary to evaluate whether the level of turbidity which may result is acceptable or can be made acceptable by mitigating methods.

On the other hand, although dredging can lead to an elevation in turbidity, recent research indicates that this elevation often subsides rather rapidly – within a few hours – especially where currents are strong. As a result, turbidity is often temporary and of short duration. The long-term effects are generally less dramatic than is commonly believed. Still, the public's perception of turbidity, as well as national and international regulation of turbidity, has encouraged dredging companies and environmental scientists to increase their efforts to reduce human-induced turbidity.

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FOR FURTHER READING AND INFORMATION

Anchor Environmental CA, L.P. (2003). "Literature Review of Effects of Resuspended Sediments due to Dredging Operations". (Prepared for Los Angeles, CA, Sediments Task Force, June).

Borst, W. and Vellinga, T. (2012). "The Monitoring Programme for the Maasvlakte 2 Construction at the Port of Rotterdam". Terra et Aqua, nr 129, December.

Borst, W., Vellinga, T. and van Tongeren, O. (2013). "The Monitoring Programme for the Maasvlakte 2 Construction at the Port of Rotterdam – Part II". Terra et Aqua, nr 130, March.

Bray, R.N. (Editor) (2008). Environmental Aspects of Dredging. IADC-CEDA-Taylor & Francis, The Netherlands.

EPA. (2012). Water: Monitoring & Assessment. 5.5: Turbidity.

John, S.A., Challinor, S.L., Simpson, M., Burt, T.N. and Spearman, J. (2000). "Scoping the assessment of sediment plumes from dredging" (C547). CIRIA, UK.

Kramer, A. and Kenny, I. (2012). "Coral Relocation: A Mitigation Tool for Dredging and Reclamation Works at the Cruise Ship Terminal in Jamaica". Terra et Aqua, nr. 128, September.

Moulaert, I. and Schiettecatte, W. (2012). "Dredging in New Caledonia at a UNESCO-IUCN World Heritage Site with Care for Nature". Terra et Aqua, nr. 126. March.

Pennekamp, Joh.G.S., Epskamp, R.J.C., Rosebrand, W.F., Mullié, A., Wessel, G.L., Arts, T., and Deibel, I.K. (1996). "Turbidity Caused by Dredging; Viewed in Perspective." Terra et Aqua, nr. 64, September, pp. 10-17.

Pennekamp, J.G.S. and Quaak, M.P. (1990). "Impact on the Environment of Turbidity Caused by Dredging". *Terra et Aqua*, nr. 42, April, pp. 10-20.

Spearman, J., de Heer, A., Aarninkhof, S. and van Koningsveld, M. (2011). "Validation of the Tass System for Predicting the Environmental Effects of Trailing Suction Hopper Dredgers". Terra et Aqua, nr. 125, December.

Taelman, E. (2009). "Saadiyat Island Tourist Development Project: Dredging in an Ecologically Sensitive Area." Terra et Aqua, nr. 116, September.

Facts About is presented by the International Association of Dredging Companies whose members offer the highest quality and professionalism in dredging and maritime construction. The information presented here is part of an on-going effort to support clients and others in understanding the fundamental principles of dredging and maritime construction.

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