# SEDIMENTATION RATE MONITORING REPORT - 06

## PROJECT: GULHIFALHU PORT DEVELOPMENT PROJECT PHASE 1: DREDGING, RECLAMATION AND SHORE PROTECTION

***Monitoring Period***

8th August 2020 – 24th August 2020

***Report Number***

*SedRate_1/9/2020 (Rev 1,0)*

***Client***

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# Abbreviations and Symbols

| | |
|---|---|
| π | Pi |
| cm | Centimeter |
| $cm^2$ | Square centimeter |
| EIA | Environmental Impact Assessment |
| EPA | Environmental Protection Agency |
| g | Gram |
| GPS | Global Positioning System |
| mg | Milligram |
| mg/L | Milligram per Liter |
| MMS | Maldives Meteorological Services |
| TSHD | Trailing Suction Hopper Dredger |

# 1 Introduction

## 1.1 Purpose of the report

This document provides the sedimentation rate measurements undertaken from 8th August 2020 to 24th August 2020 at reef monitoring sites prescribed in the Environmental Monitoring Plan approved by the Environmental Protection Agency (EPA) for the Phase I of Gulhifalhu Port development Project (Dredging, Reclamation and Revetment works).

This report has been prepared by CDE Consulting under a service contract with Boskalis Westminster Contracting Limited for the purpose of meeting EPA requirement for monitoring sedimentation rate at select reefs within the project impact area.

## 1.2 Major project activities during monitoring period

The following were the major project activities ongoing during this monitoring period, which could contribute to changes to natural sedimentation rate on reefs.

1. Reclamation of the south-eastern corner of Gulhifalhu.
2. Reclamation of inner lagoon of Gulhifalhu.
3. Dredging operations at the sand borrow area. Dredging operations completed on 20th August 2020.
4. Installation of temporary revetment on north and northeast side of the reclamation.
5. Preparations for installation of permanent revetment.

# 2 Methodology

**Materials**

- Sediment traps
    - Constructed from 5 cm internal diameter PVC pipe, 11.5 cm long and sealed at one end, with baffles placed in the top to prevent entry of fishes (English, Wilkinson, & Baker , 1997, p. 55).
- Iron rods

**Procedure**

- Iron rod was hammered into the substratum, so that it is vertical and firmly secured.
- Three sediment traps were then attached to the rod using cable ties. The base of the trap was kept 20 cm from the substratum, and the traps were be tied to the rod in a way that rod does not protrude above the opening of the pipes (Figure 2-1). At each monitoring site 4 sets of traps (each with three sediment traps) were installed.

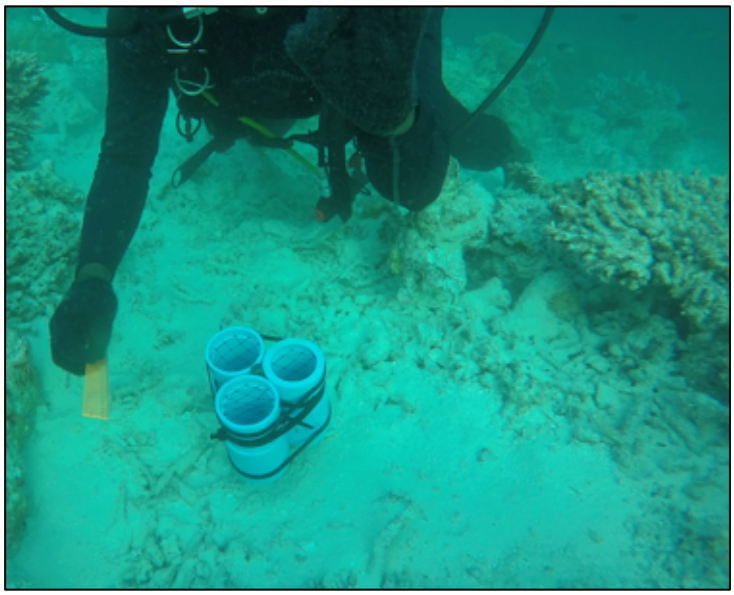


**Figure 2-1: Sedimentation trap installed for sedimentation rate monitoring**

- The traps were to be left for over a fourteen-day period and retrieved. On occasions when the weather did not permit this, traps were retrieved the earliest when the weather permitted.
- The traps were sealed prior to removal from the rod, to prevent loss of any material.
- The sample were dried in an oven (at 60 °C) and weighed to the nearest milligram.
- Sedimentation rate is calculated as mg of sediment per $cm^2$ per day, using the following formula, where Sediment Weight is average dry weight of the sediment samples, and "r" is radius of the trap opening.

$$Sedimentation\ Rate = \frac{Sediment\ Weight}{Number\ of\ day \times \pi r^2}$$

# 3 Monitoring Sites

Sedimentation rate monitoring is required at a total 14 sites in the approved Environmental Monitoring Plan for the project. This include 8 sites at/or near the reclamation site (T-2, T-4, T-6, T-7, T-8, T-9, T-10 and T-11) and 6 sites near the sand borrow area (T-19, T-20, T21, T-22, T-23 and T-24).

GPS coordinates and depth of the sedimentation rate monitoring sites are provided in Table 3-1 and location map is provided in Figure 3-1.

**Table 3-1: GPS coordinates and depth of sedimentation rate monitoring sites**

| Trap ID | Description | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|
| T-2 | Gulhifalhu (N) | 4.18785° | 73.4684° | 2.5 m |
| T-4 | Gulhifalhu (NE) | 4.182291° | 73.475565° | 3 m |

| Trap ID | Description | Latitude | Longitude | Depth (m) |
|---|---|---|---|---|
| T-6 | Gulhifalhu (SE) | 4.172121° | 73.478178° | 5 m |
| T-7 | Gulhifalhu (SE) | 4.172238° | 73.474390° | 5 m |
| T-8 | Gulhifalhu (S) | 4.17332° | 73.467003° | 5 m |
| T-9 | Gulhifalhu (S) | 4.174529° | 73.461196° | 3.3 m |
| T-10 | Gulhifalhu (SW) | 4.176124° | 73.454658° | 5 m |
| T-11 | Villingili (NW) | 4.176084° | 73.483121° | 10 m |
| T-19 | Feydhoo Finolhu (SW) | 4.211618° | 73.481556° | 3 m |
| T-20 | Olhuhaa (S) | 4.217497° | 73.458640° | 2.5 m |
| T-21 | Bangau (S) | 4.222450° | 73.429949° | 2.7 m |
| T-22 | Kurumba (W) | 4.226931° | 73.517007° | 2.5 m |
| T-23 | Dhiyaneru (SW) | 4.231697° | 73.471358° | 2.5 m |
| T-24 | Kandinmafalhu (SW) | 4.238414° | 73.457170° | 2.5 m |


**Figure 3-1: Sedimentation Rate Monitoring Sites**

# 4 Results

The trigger value set by EPA for the maximum daily sedimentation rate is 15 mg/cm$^2$/day (Environmental Protection Agency, N.D.).

Three out of the five monitoring sites at Gulhifalhu recorded average sedimentation rates above the trigger value. Sedimentation rate recorded at Villingili monitoring site was well below the trigger value. All sites around the dredging site recorded sedimentation rates below the trigger value except at one location.

In addition to the dredging and reclamation works, there are several natural factors that can influence sedimentation rate, this includes wave condition (Storlazzi, Ogston, Bothner, Field, & Presto, 2004), speed and direction of current flow and weather condition (Otaño-Cruz, Montañez-Acuña, Torres-López, Hernández-Figueroa, & Edwin A. Hernández-Delgado, 2017).

Figure 4-1, Figure 4-2 and Figure 4-3 summarizes wind and rainfall data collected by Maldives Meteorological Services (MMS) at Hulhulé Met Station during this monitoring period.

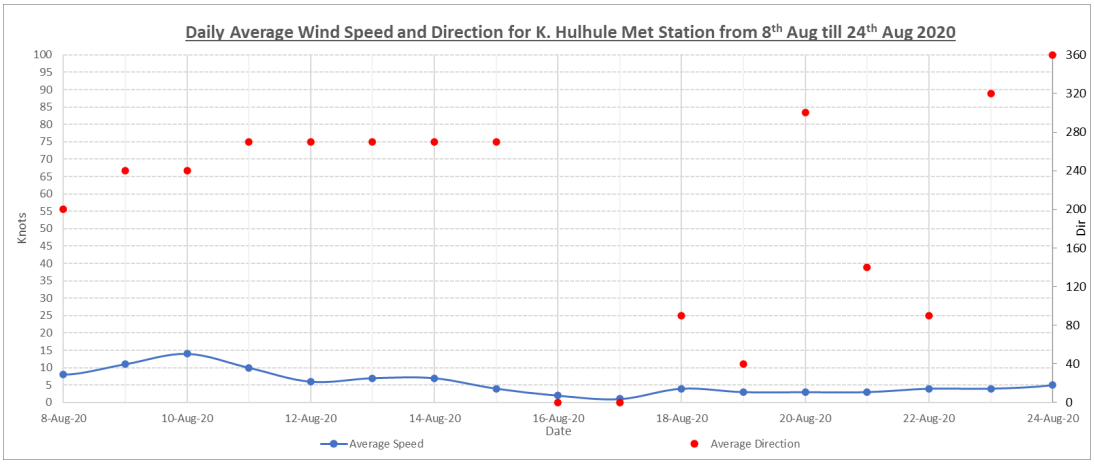



**Figure 4-1: Daily Average wind speed and direction for K. Hulhulé Met Station from 8th August till 24th August 2020**

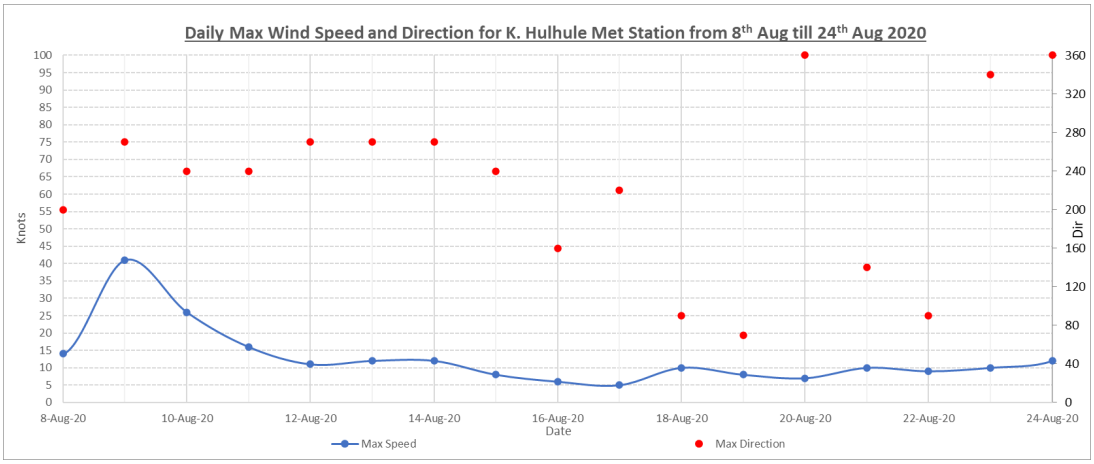



**Figure 4-2: Daily Max wind speed and direction for K. Hulhulé Met Station from 8th August till 24th August 2020**

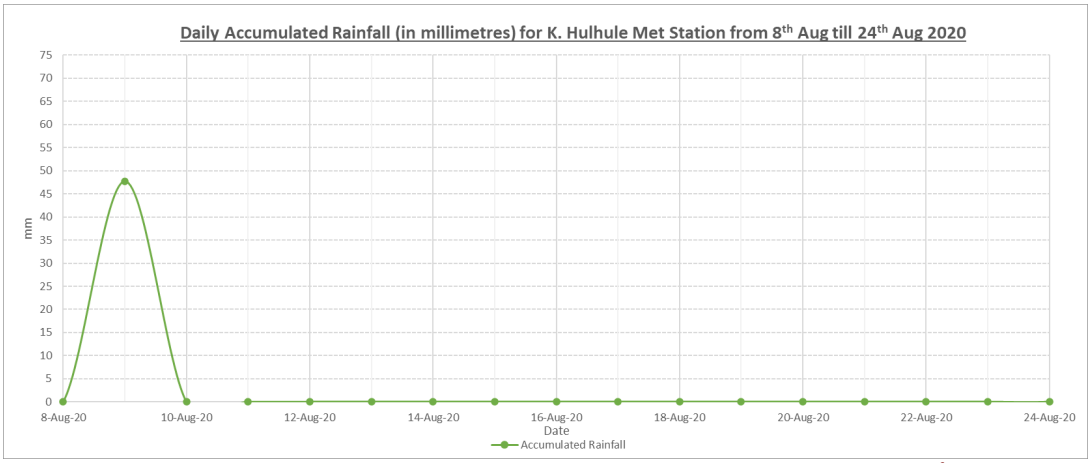



**Figure 4-3: Daily accumulated rainfall (in millimeters) for K. Hulhulé Met Station from 8th August till 24th August 2020**

## 4.1 Reclamation Site

Table 4-1 provides the average sedimentation rates recorded at monitoring sites in Gulhifalhu reclamation site and neighboring Villingili reef during this period. Figure 4-4 provides a comparison of average sedimentation rates recorded at these sites during baseline and subsequent monitoring rounds.

The highest sedimentation rate recorded at Gulhifalhu reef was at T-4 located on the north eastern side (59.33 mg/cm$^2$/day), erosion of the bunds at the site is likely cause for the elevated sedimentation rate at this site.

T-2 showed the next highest sedimentation rate at 41.99 mg/cm$^2$/day located on the northern side of the island. Reclamation works on the northern side reef is likely cause of the high sedimentation rate recorded at this site.

Sedimentation rate recorded at T-6 located on the south eastern side of Gulhifalhu reef recorded values above the trigger value. Reclamation work was undertaken at this site during this period and is likely cause of elevated sedimentation rate recorded.

The traps placed at T-7 and T-9 recorded sedimentation rate of 9.13 mg/cm$^2$/day and 3.32 mg/cm$^2$/day respectively, both readings below the trigger value.

Sedimentation rate recorded at Villingili monitoring site was 3.35 mg/cm$^2$/day, well below the trigger value.

**Table 4-1: Average sedimentation rate recorded at Gulhifalhu and Villingili**

| Trap ID | Installation Date | Retrieval Date | Average Sedimentation Rate (mg/cm$^2$/day) | ±Standard Error |
|---|---|---|---|---|
| T-2 | 12-Aug-2020 | 23-Aug-2020 | 41.99 | 3.92 |
| T-4 | 9-Aug-2020 | 23-Aug-2020 | 59.33 | 2.70 |
| T-6 | 8-Aug-2020 | 23-Aug-2020 | 29.16 | 2.48 |
| T-7 | 8-Aug-2020 | 23-Aug-2020 | 9.13 | 1.65 |
| T-9 | 9-Aug-2020 | 22-Aug-2020 | 3.32 | 0.57 |
| T-11 | 8-Aug-2020 | 22-Aug-2020 | 3.35 | 0.95 |

## 4.2 Dredging Site

Table 4-2 provides the average sedimentation rates recorded at monitoring sites near the sand borrow area during this monitoring period. Figure 4-5 shows a comparison of sedimentation rates recorded at these sites during baseline and subsequent monitoring rounds.

Except at T-20 located on the southern side of Olhuhaa, all other monitoring sites around the sand borrow area recorded sedimentations well below the trigger value.

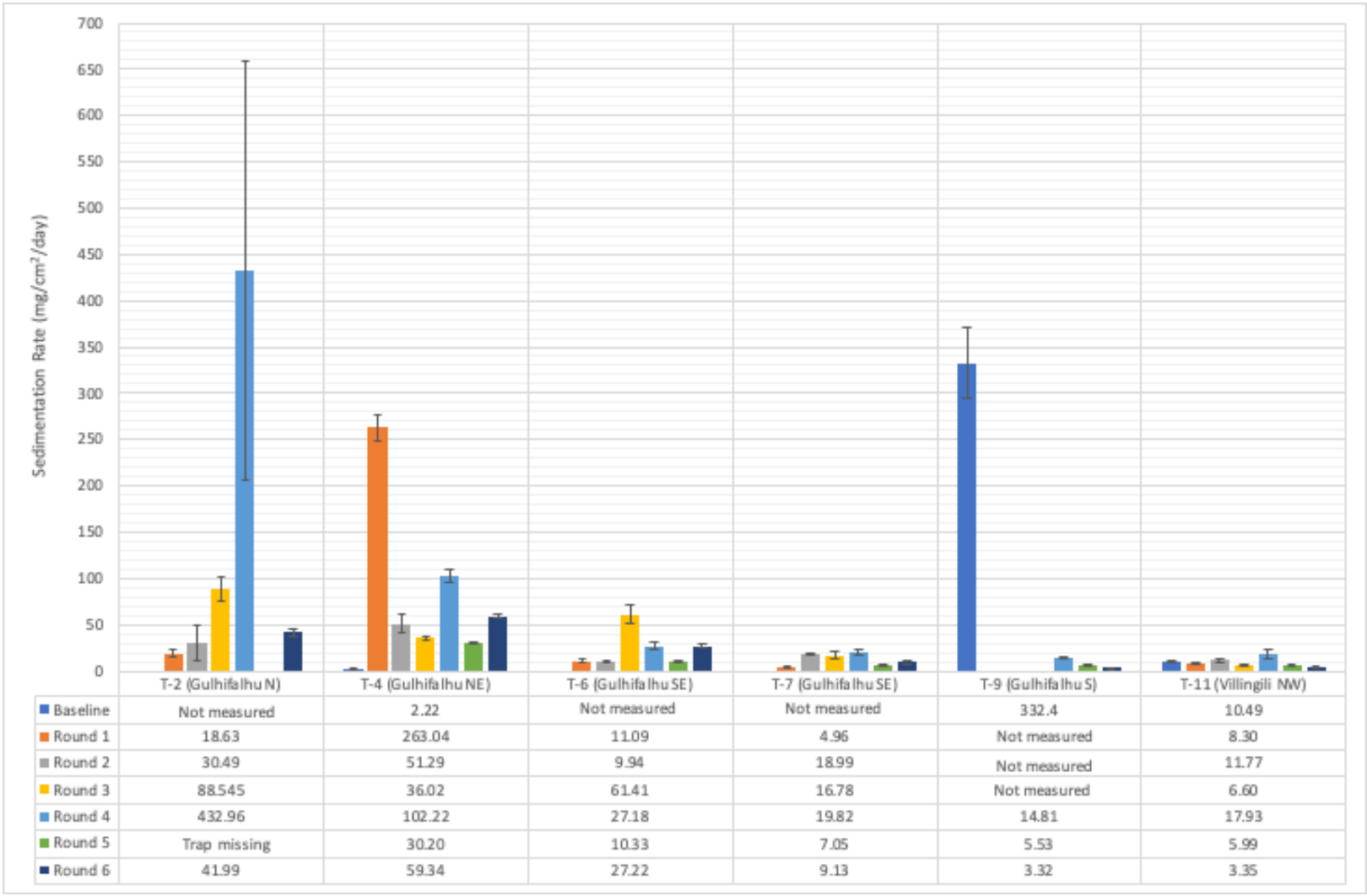
Sedimentation rate recorded at T-20 was significantly lower (57.34 mg/cm$^2$/day) than the previous monitoring period (206.04 mg/cm$^2$/day). As stated in the previous monitoring report, Olhuhaa is a large sea mount with top exclusively made up of sand, disturbances to the seabed by wave action may result in significant increase in sedimentation on the reef.

Slight elevation in sedimentation rate was recorded at the monitoring site in Kurumba (T-22). However the sedimentation rate recorded was well below the trigger value.

Similar to T-20, significant reduction in sedimentation rate was observed at T-19, T-21, and T-23. Compared to the previous monitoring period no significant change in sedimentation rate was recorded at T-24

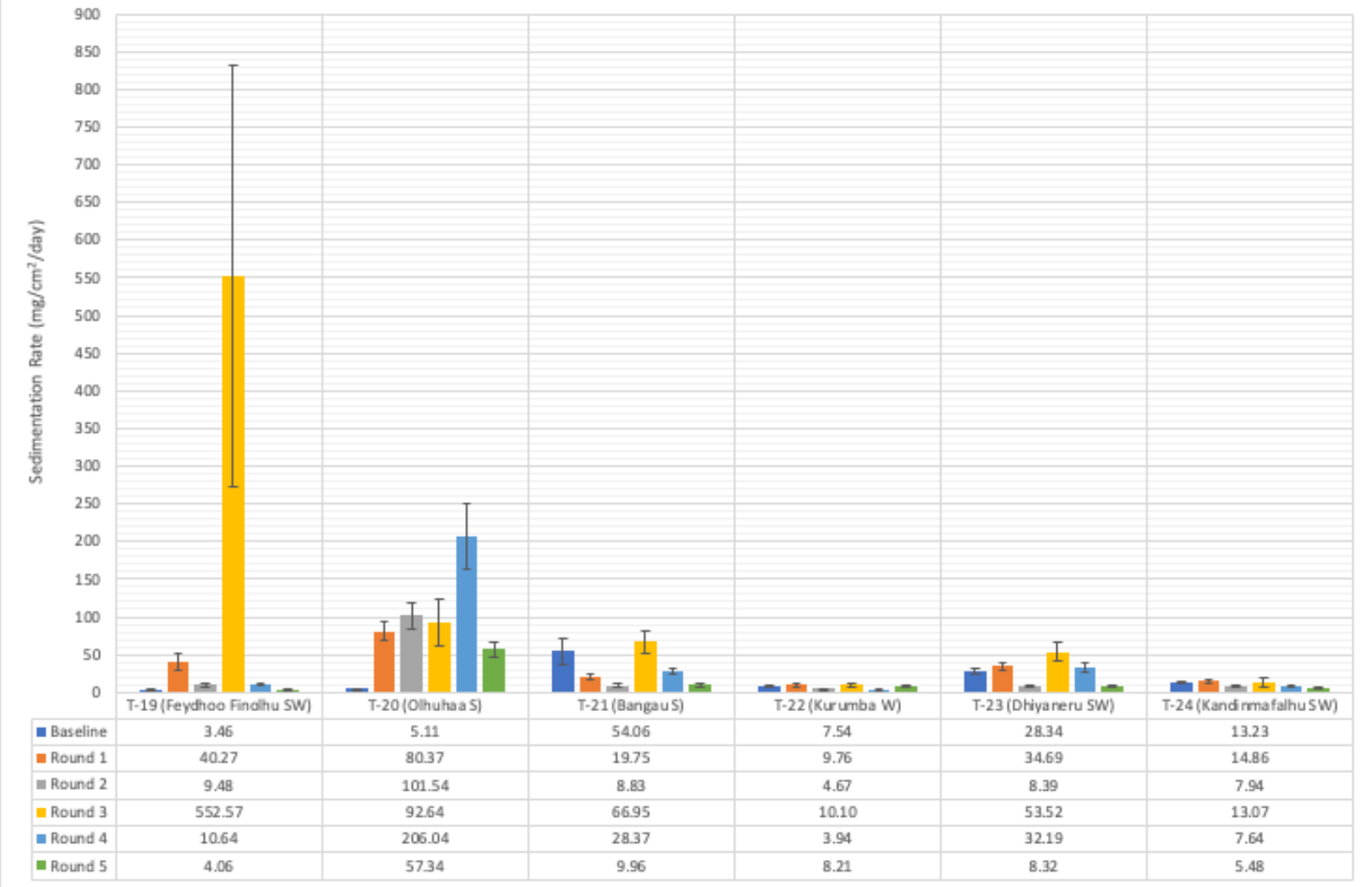
**Table 4-2: Sedimentation rate measurement near sand borrow area**

| Trap ID | Installation Date | Retrieval Date | Average Sedimentation Rate (mg/cm$^2$/day) | ±Standard Error |
|---|---|---|---|---|
| T-19 | 9-Aug-2020 | 22-Aug-2020 | 4.06 | 0.49 |
| T-20 | 9-Aug-2020 | 23-Aug-2020 | 57.34 | 10.10 |
| T-21 | 10-Aug-2020 | 23-Aug-2020 | 9.96 | 2.25 |
| T-22 | 10-Aug-2020 | 24-Aug-2020 | 8.21 | 1.69 |
| T-23 | 10-Aug-2020 | 23-Aug-2020 | 8.32 | 1.51 |
| T-24 | 10-Aug-2020 | 23-Aug-2020 | 5.48 | 0.39 |




| | T-2 (Gulhifalhu N) | T-4 (Gulhifalhu NE) | T-6 (Gulhifalhu SE) | T-7 (Gulhifalhu SE) | T-9 (Gulhifalhu S) | T-11 (Villingili NW) |
|---|---|---|---|---|---|---|
| Baseline | Not measured | 2.22 | Not measured | Not measured | 332.4 | 10.49 |
| Round 1 | 18.63 | 263.04 | 11.09 | 4.96 | Not measured | 8.30 |
| Round 2 | 30.49 | 51.29 | 9.94 | 18.99 | Not measured | 11.77 |
| Round 3 | 88.545 | 36.02 | 61.41 | 16.78 | Not measured | 6.60 |
| Round 4 | 432.96 | 102.22 | 27.18 | 19.82 | 14.81 | 17.93 |
| Round 5 | Trap missing | 30.20 | 10.33 | 7.05 | 5.53 | 5.99 |
| Round 6 | 41.99 | 59.34 | 27.22 | 9.13 | 3.32 | 3.35 |

**Figure 4-4: Comparison of average sedimentation rates recorded at monitoring sites in Gulhifalhu and Villingili**




| | T-19 (Feydhoo Finolhu SW) | T-20 (Olhuhaa S) | T-21 (Bangau S) | T-22 (Kurumba W) | T-23 (Dhiyaneru SW) | T-24 (Kandirmafalhu SW) |
|---|---|---|---|---|---|---|
| Baseline | 3.46 | 5.11 | 54.06 | 7.54 | 28.34 | 13.23 |
| Round 1 | 40.27 | 80.37 | 19.75 | 9.76 | 34.69 | 14.86 |
| Round 2 | 9.48 | 101.54 | 8.83 | 4.67 | 8.39 | 7.94 |
| Round 3 | 552.57 | 92.64 | 66.95 | 10.10 | 53.52 | 13.07 |
| Round 4 | 10.64 | 206.04 | 28.37 | 3.94 | 32.19 | 7.64 |
| Round 5 | 4.06 | 57.34 | 9.96 | 8.21 | 8.32 | 5.48 |

**Figure 4-5: Comparison of average sedimentation rate at monitoring sites near dredging site**

# References

English, S., Wilkinson, C., & Baker , V. (1997). *Survey manual for tropical marine resources* (2nd Edition ed.). Townsville, Australia : Australian Institute of Marine Science .

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