SEDIMENTATION RATE MONITORING REPORT - 16

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

Monitoring Period

26th December 2020 – 10th January 2020

Report Number

SedRate_2/1/2021(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 26th December to 10th January 2021 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

Sedimentation rate monitoring at select reefs around the project site commenced on 30th May 2020. Since then monitoring has been carried out for 15 rounds in reclamation site, and for 6 rounds in the sites near the dredging area.

Table 1-1 provides major project activities that were undertaken over rounds.

Table 1-1: Major project activities over the sedimentation monitoring periods

Round		Period	Project Activities (simplified)
Reclamation Site	**Dredging Site**		
1	Baseline[1]	30/05/2020 – 15/06/2020	Bund construction
2	1	13/06/2020 – 01/07/2020	Bund construction, dredging and reclamation
3	2	27/06/2020 – 13/07/2020	Bund construction, dredging and reclamation
4	3	11/07/2020 – 28/07/2020	Dredging and reclamation
5	4	26/07/2020 – 10/08/2020	Dredging and reclamation
6	5	08/08/2020 – 24/08/2020	Dredging and reclamation
7	6	22/08/2020 – 08/09/2020	Revetment works
8	-	05/09/2020 – 20/09/2020	Revetment works
9	-	19/09/2020 – 04/10/2020	Revetment works
10	-	03/10/2020 – 18/10/2020	Revetment works
11	-	17/10/2020 – 1/11/2020	Revetment works
12	-	31/10/2020 – 15/11/2020	Revetment works
13	-	14/11/2020 – 29/11/2020	Revetment works
14	-	28/11/2020 – 13/12/2020	Revetment works
15	-	12/12/2020 – 27/12/2020	Revetment works

[1] *As dredging operations did not start during this period baseline measurements were taken at monitoring sites T-21, T-23, and T-24 near the proposed sand borrow site. The baseline values reported for T-19, T-20 and T-22 are sedimentation rates recorded in the EIA for this project.*

Round		Period	Project Activities (simplified)
Reclamation Site	**Dredging Site**		
16	-	26/12/2020 – 10/01/2021	Revetment works

The major project activity that was ongoing during this monitoring period, which could contribute to changes to natural sedimentation rate on reefs was installation of temporary revetment (geotubes at the northern section of the reclamation).

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.

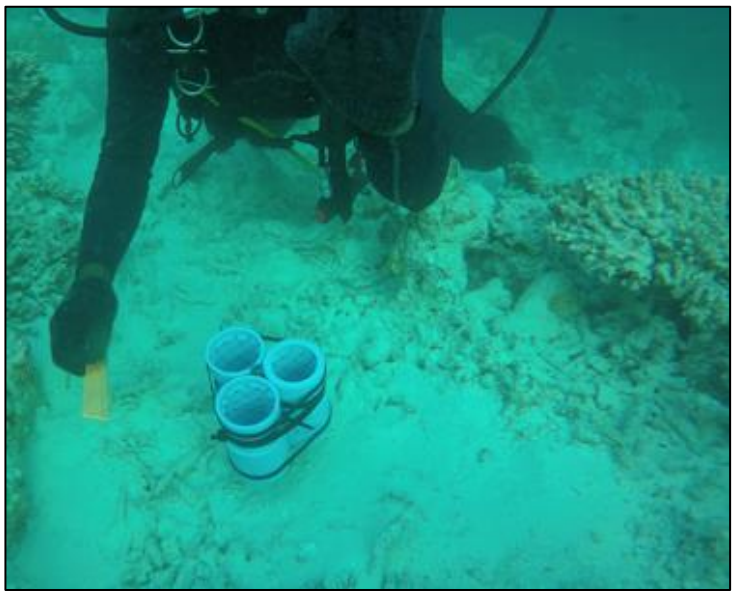


Figure 2-1: Sedimentation trap installed for sedimentation rate monitoring

- 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).

Dredging operations were completed on 20th August 2020, and no project related works were ongoing near the sand borrow area during this monitoring period. Hence no sedimentation rate monitoring was carried at sites near the sand borrow area during this period.

GPS coordinates and depth of all 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
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

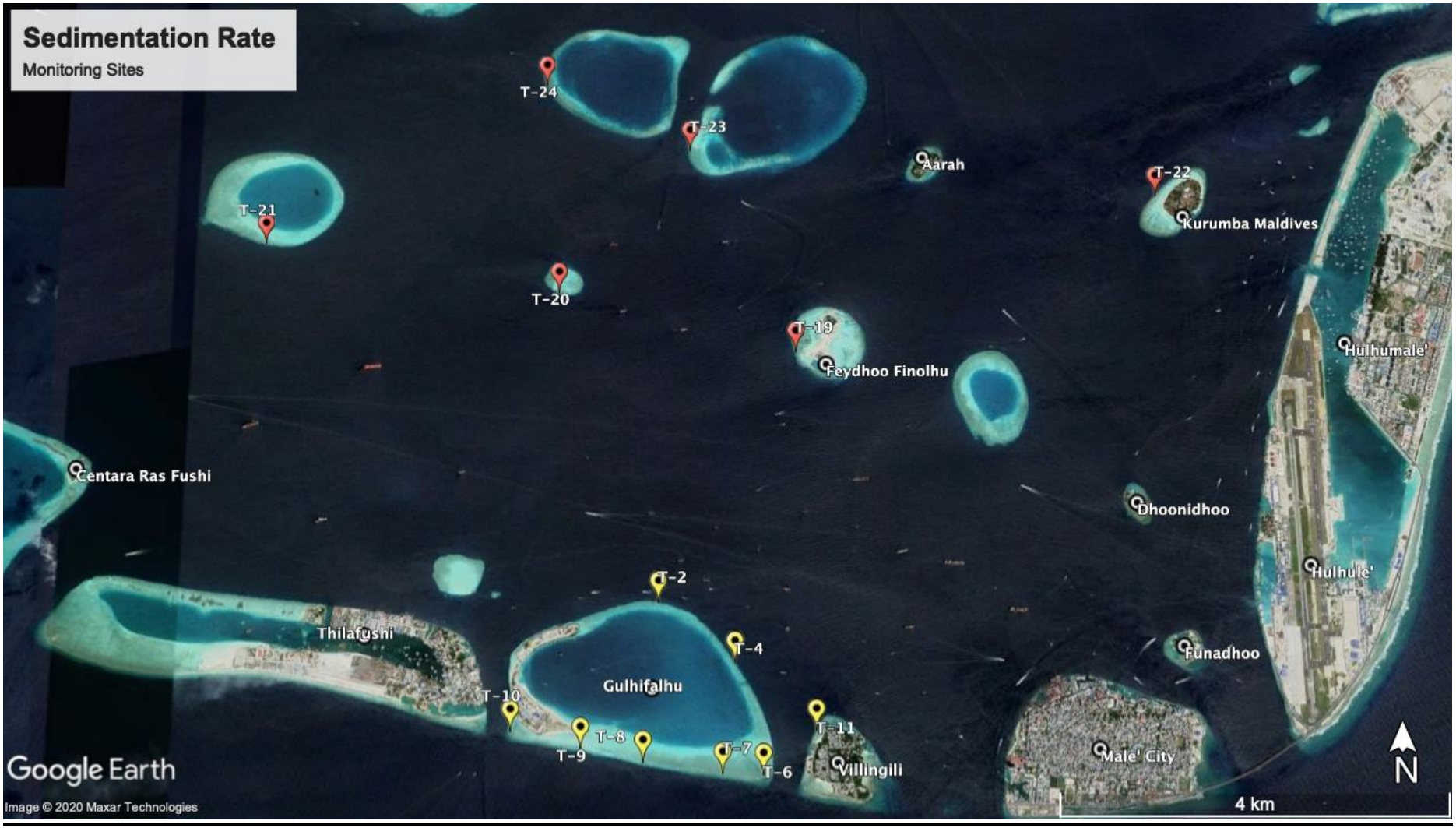


Figure 3-1: Sedimentation Rate Monitoring Sites

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.).

Four out of six monitoring sites at Gulhifalhu recorded average sedimentation rates above the trigger value

In addition to the reclamation and coastal 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).

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 4-1 provides 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-2 located on the north side (159.07 mg/cm^2/day) which is far above the trigger value. T-4, T-6 and T-7 also showed values above the trigger value.

As stated earlier heavy rainfall, thunderstorm, and rough seas during this period in combination with erosion of the reclaimed area and ongoing revetment works may have contributed to the high sedimentation rates at these sites.

The remaining two monitoring sites T-9 (S) in Gulhifalhu and T-11 in Villingili recorded sedimentation rates well below the trigger value.

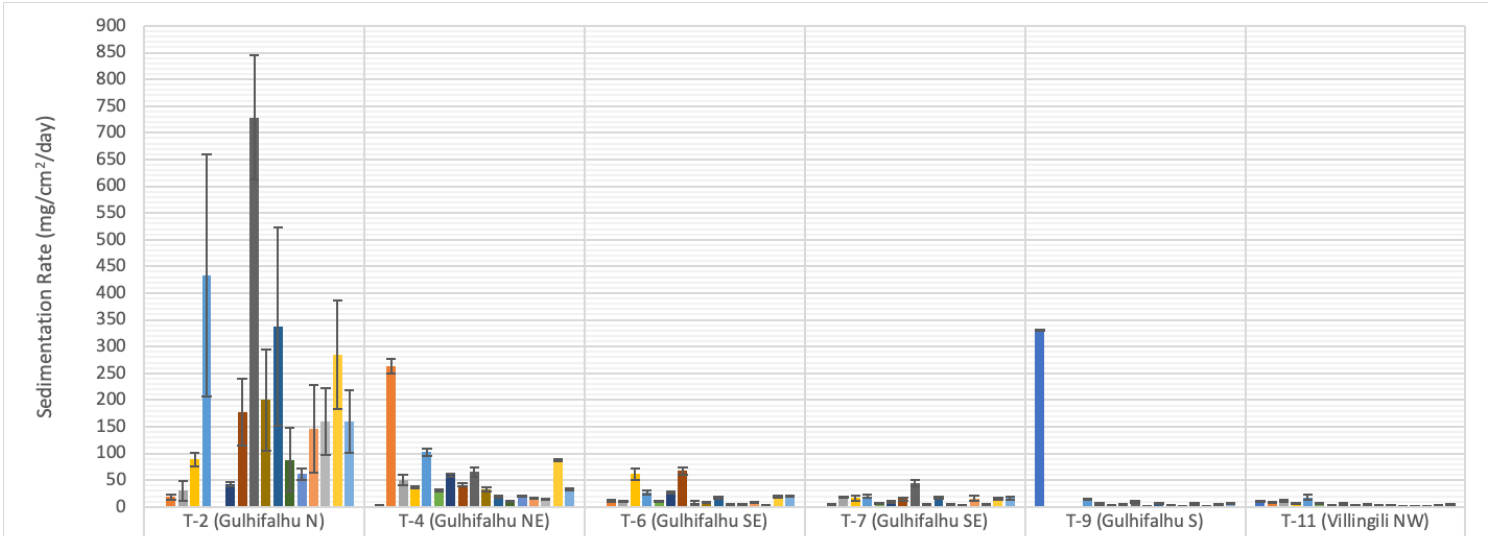
Table 4-1: Average sedimentation rate recorded at Gulhifalhu and Villingili

Trap ID	Installation Date	Retrieval Date	Average Sedimentation Rate (mg/cm^2/day)	±Standard Error
T-2	27-Dec-2020	10-Jan-2021	159.07	58.64
T-4	27-Dec-2020	10-Jan-2021	33.09	2.43
T-6	26-Dec-2020	09-Jan-2020	20.05	1.18
T-7	26-Dec-2020	09-Jan-2020	16.33	3.03
T-9	26-Dec-2020	09-Jan-2020	6.09	0.59
T-11	27-Dec-2020	10-Jan-2021	5.13	0.88

4.2 Dredging Site

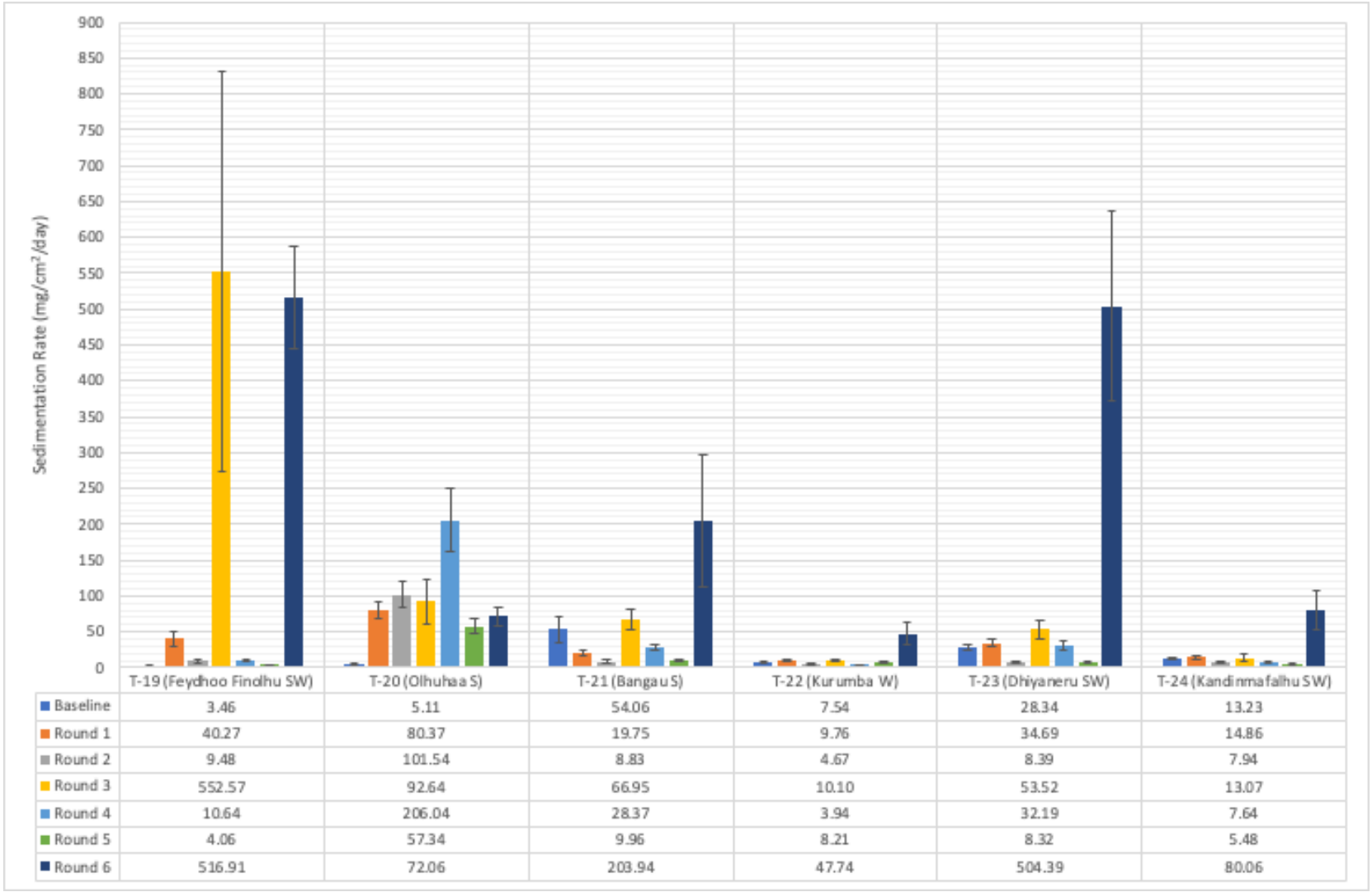
Figure 4-2 provides comparison of sedimentation rates recorded at monitoring sites around the sand borrow area during baseline and subsequent monitoring rounds.

As dredging operations were completed on 20th August 2020, monitoring works were also discontinued after Round 6.



	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	88.55	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
Round 7	177.75	41.32	67.04	14.85	4.24	5.19
Round 8	728.32	65.12	8.42	44.75	9.47	3.50
Round 9	200.04	32.69	8.84	5.01	2.16	4.80
Round 10	337.60	19.31	16.62	17.08	6.08	2.45
Round 11	88.31	10.22	5.33	4.43	2.52	2.34
Round 12	61.77	19.43	4.31	4.13	1.61	1.52
Round 13	146.29	16.47	8.64	15.54	5.28	1.47
Round 14	159.76	13.50	3.40	4.35	1.79	1.56
Round 15	285.03	87.46	19.11	15.36	5.58	3.51
Round 16	159.07	33.09	20.05	16.33	6.09	5.13

Figure 4-1: Comparison of average sedimentation rates recorded at monitoring sites in Gulhifalhu and Villingili



	T-19 (Feydhoo Findhu SW)	T-20 (Olhuhaa S)	T-21 (Bangau S)	T-22 (Kurumba W)	T-23 (Dhiyaneru SW)	T-24 (Kandinmafalhu 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
Round 6	516.91	72.06	203.94	47.74	504.39	80.06

Figure 4-2: 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 .

Environmental Protection Agency. (N.D.). *EIA data collection guidelines* .

Storlazzi, C. D., Ogston, A. S., Bothner, M. H., Field, M. E., & Presto, M. K. (2004). Wave- and tidally-driven flowand sediment flux across a fringing coral reef: Southern Molokai, Hawaii. *Continental Shelf Research*, 1397–1419.

Otaño-Cruz, A., Montañez-Acuña, A. A., Torres-López, V., Hernández-Figueroa, E. M., & Edwin A. Hernández-Delgado, E. A. (2017). Effects of Changing Weather, Oceanographic Conditions, and Land Uses on Spatio-Temporal Variation of Sedimentation Dynamics along Near-Shore Coral Reefs. *Front. Mar. Sci.* doi:doi: 10.3389/fmars.2017.00249