SHORELINE CHANGE ANALYSIS OF VIZHINJAM COAST USING SATELLITE IMAGES

ANNUAL REPORT
(October 2017 to September 2018)

FOR

ADANI VIZHINJAM PORT PVT LIMITED

PREPARED BY

Coastal and Environmental Engineering Division

NATIONAL INSTITUTE OF OCEAN TECHNOLOGY

CHENNAI

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Report Summary

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Project		**Project No. NIOT/CEE/1301** **MoA NIOT-VISL-AVPPL dated 03.08.2017** **SO No. 5700227001 dated 15/11/2017**			
1	Draft Report	SSP/DSK	BKJ	MVR	31-October-2018
2	Final Report	SSP/DSK	BKJ	MVR	03-January-2019
3	Revised Report- I	SSP/DSK	BKJ	MVR	05-March-2019
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Executive Summary

Vizhinjam International Seaport Limited (VISL), Government of Kerala has been requested NIOT to be a part of Oceanographic / Port development related studies and nodal agency for them to suggest various studies required for port monitoring, pre, during execution and post port development, vetting of various reports submitted by different organization / institutes since 2014 as per the MOU signed by NIOT and VISL. Subsequently VISL entrusted M/s. Adani Vizhinjam Port Private Limited for developing the seaport during 2015. VISL has obtained environmental clearance from MoEF&CC during 2014. Thereafter to continue the same support from NIOT, VISL has proposed to have a tripartite MOA and the same have been signed among NIOT-VISL-AVPPL on 3rd August 2017 and valid up to 2019.

In this connection, NGT appointed Expert Committee as part of NGT Direction Compliance/Environment Compliance instructed M/S AVPPL to assess and analyze the shoreline changes over 10km either side of Vizhinjam port including Valliyathura. As the shoreline monitoring has been carried out for 40km coastline (20km on either side of the Vizhinjam port), the same has been adopted for this study to indicate high erosion and accretion zone using high resolution satellite imageries prior and after 2010.

It is also proposed to evaluate/analyze the beach profile data collected from February 2015 to September 2018 for entire 40km stretch collected at every 500m transact along with site specific analysis off Valliyathura (Service order on 5th December 2017). Accordingly NIOT has procured high resolution satellite imageries from NRSC, Hyderabad and analysis on the shoreline change assessment of Vizhinjam coast before and after 2010 has been presented in this report. This report also contains the study on shoreline change assessment of Vizhinjam coast before and after 2010, before and after 2015 and annual and seasonal shoreline change analysis for 2017-2018 using high resolution satellite images to understand the historical shoreline behaviour, situation prior and after Vizhinjam Port development and also identify the Erosion/Accretion hotspots along the 20Km either side of the Vizhinjam Port.

The procured satellite images are rectified using ground control point (GCP) from the field observed data during July 2018. The shoreline derived from the satellite image data has been validated with beach profile data and field collected shoreline data (during September 2018). Besides, high erosion and accretion zones has been compared with the earlier studies reported by various other institutes/ organizations.

The zone of high erosion and accretion derived from the high resolution satellite imageries, the decadal changes, five yearly changes and annual shoreline analysis using ArcGIS DSAS tool are also described in this report. It is noticed that high erosion being constant at Valliyathura, Punthura and Edapadu. High accretion zones are noticed at Mullur, Vizhijam and Karumkulam region. During the study period 2017-2018, a cyclone named Ockhi passed offshore of the study area that impacted the shoreline. The high wave activity which occurred during month of April 2018 also had massive impact on shoreline. The impact of Ockhi cyclone along the shoreline has been included in the monthly change analysis provided.

AVPPL/VISL has provided the monthly beach profile data collected (for the entire stretch of 40Km at 81 transect) by M/s Ocean Science and Survey, OSAS (Agency appointed by AVPPL for Shoreline Monitoring)) for the period from February 2015 to September 2018. These have been analyzed, QA and QC have been carried out and final data sets were made. These data sets have been used for analysis of beach changes on monthly, seasonally, yearly and inter-annually basis which has been included in the report. In addition, NIOT has provided a wave rider buoy and one automatic tide gauges which is deployed/ installed and periodically maintained with the help of AVVPL/VISL and the data received by NIOT are evaluated. A summary report of the data received and vetted by NIOT till date is also a part of this report.

As per the Work Order, NIOT has completed all the scope of work and submitted periodically.

- I Quarterly report, Oct.17 to Dec.17 have been submitted in the month of January 2018.
- II Quarterly report, January 2018 to March 2018 has been submitted in April 2018.
- I Half-Yearly report submitted from October 2017 to March 2018 submitted in June 2018.
- III Quarterly Report April to June 2018 has been submitted in July 2018.
- IV Quarterly report, June to September 2018 has been submitted in October 2018.
- II Half Yearly report from April 2018 to September 2018 has been submitted in October 2018.
- The final report comprising of entire one year study including high resolution satellite imageries, beach profile and other related measurement has been analyzed and reported for the period October 2017 to September 2018.

1 INTRODUCTION

Vizhinjam International Deepwater Multipurpose Seaport is an all-weather port located on the South Kerala coast. Vizhinjam International Seaport Limited (VISL), which is a fully owned company of the Government of Kerala (GoK) has been entrusted with the task of developing the seaport. The GoK has entered into a concession agreement with M/s Adani Vizhinjam Ports Private Ltd. (AVPPL) on 17th August 2015 for the development and operation of the proposed port and AVPPL commenced the construction works on 5th December 2015.

Vizhinjam International Seaport Ltd. has obtained Environmental Clearance (EC) from the Ministry of Environment, Forests & Climate Change (MoEF&CC), Government of India, for the development of the proposed Vizhinjam International Deepwater Multipurpose Seaport at Vizhinjam in Thiruvananthapuram District and the MoEF has stipulated that VISL shall carry out intensive monitoring on shoreline changes with regulatory reporting once in six months through the Regional Office, MoEF&CC.

VISL has entered into a MoU with NIOT on 19th November 2014 and NIOT has charted out a programme for intense monitoring of the shoreline changes due to the development of the proposed Project as required under the Environment Clearance issued by MoEF&CC. In continuation of the previous MoU, a tripartite MoA also has been signed between NIOT-VISL-AVPPL on 3rd August 2017 for comprehensive Shoreline Monitoring Programme from February 2016 to November 2019.

As per the meeting held on 18th August 2017 at NIOT, discussions were made on shoreline change studies to be carried out using high resolution satellite images (LISS IV and PAN: 5.8m) before and after 2010 (As per NGT MoM on 30.06.2017) and also to identify the zones of high erosion/accretion and compare the same with the earlier reports to understand the situation prior to port development. NIOT has agreed to procure the high resolution satellite imageries of the region and to carry out a separate study based on satellite imageries and monthly field measured beach profiling data, accordingly NIOT had submitted an additional study proposal to AVPPL and received the service order on 5th December 2017. This additional shoreline change study has been carried out and the report has been submitted periodically (quarterly, half yearly and yearly).

In continuation with the four quarterly report (Oct-Dec 2017, January-March 2018, April-June 2018 and July-September 2018) and two half yearly reports (Oct 2017-Mar 2018

and April-September 2018), this report compiles the results of shoreline change analysis from satellite images and beach profile analysis of 40 km coastline stretch of Vizhinjam and site specific analysis at Valliyathura.

As per NGT expert and shoreline committee meeting held on 5th February 2018, the committee suggested to incorporate high resolution satellite images available for the study area such as cartosat (1m and 2.5 m) data for shoreline change analysis. As per the suggestion of the committee, the result has been provided using analysis of high resolution satellite images.

Shoreline Change analysis using Cross shore Profile (CSP) has been done as part of the Shoreline Monitoring Programme. CSP data has been collected by AVPPL every month at 81 profile lines along a stretch of 40 Km covering the area of approximately 20 km south and 20 km north of the proposed port (For period from February 2015 to September 2018). Among the 81 locations, 40 are to the North of Vizhinjam, 40 are to the South of Vizhinjam and 1 at Vizhinjam port every 500m interval. The survey data is available from February 2015 to September 2018 for most of the locations. However, a few profiles are not available at few locations as beach profiling commenced in February 2015 for 61 locations covering approximately 30 km and later in April 2015, it was extended to 81 locations covering 40 km.

Hence, this report consists of the study on shoreline change analysis carried out over 40 km stretch keeping Vizhinjam Port as center, using high resolution satellite datasets such as Resourcesat-2A and Cartosat-1 datasets (for prior and after 2010 and prior and after port activities December 2015), beach profile analysis (2015-2018) and comparison and validation of shoreline change derived from the satellite image with the beach profile data for the period from Feb 2017 to Feb 2018.

1.1 Previous Studies on sediment transport

Studies along the Kerala coast in relation to the beach erosion dates back to late 1970's by Das et al (1966) by constructing a wave refraction diagram in the neighbourhood of Kochi Port. Various authors study the coastal erosion following the wave refraction diagrams, Wave energies and Longshore currents. Some of the significant studies include Murty and Varadachari, (1980) studied the morphological changes of the beaches at various locations along the Kerala coast and examined their stability, Shenoi (1984) has carried out a study on the littoral processes along the beaches around Cochin.

Studies on breaker wave characteristics and longshore currents/transport are relatively less when compared to erosion/accretion processes. Thomas (1988), Shahul Hameed (1988), Kurian (1988) and Harish (1988) have discussed the nearshore wave characteristics in relation to beach morphological variations at Valliyathura, Alleppey, Calicut and Tellicherry respectively. Thomas (1988) observed that the breaker period was 11 to 12s during March and April and the breaker direction was 210^0 and 225^0 except during June-August, when the direction was 230 and 240^0 at Valliyathura. Surf zone widen to around 150m during June-July and the width was practically zero during November- March. The author also measured longshore currents at six locations and found that during June - August, the direction was southerly while the direction was northerly during the other months.

Shahul Hameed (1988) analysed breaker wave data during 1981-84 and deduced the monthly averages of significant and maximum breaker wave heights, period, direction and type along Alleppey coast. Jena and Chandramohan (1997) studied the littoral characteristics off Kolachal. They found that breaking wave heights exceeded 1.5m during May to August. Width of the surf zone was wider at about 35m in June to September and November and it was less during the rest of the year.

At Valliyathura, Thomas (1988) found that the volume changes on the sub-aerial beach are systematic with slow erosion over the period from January to June, rapid erosion in June and July and recovery from August to December. The erosion coincides with the onset of the stormy, south-west monsoon. In synchrony with the erosion cycles, the beach slope is maximum during the periods of scour and then reduces as the profile recovers.

Some of the salient features that could be summarised out of the available literature with regard to the beach processes of the Kerala coast are as follows. The littoral environmental parameters show both spatial and temporal variations. The temporal variations are dictated by the monsoon regime. The spatial variations are determined by the response of the hydrodynamic forces to the geomorphic setup of the beach and inner shelf. In general it can be said that southerly longshore currents prevail during the southwest monsoon and northerly currents during the rest of the year.

In general three types of beach profiles are observed along the southwest coast: (i) a narrow beach, steep foreshore and longshore bars during the monsoon; (ii) a gently sloping beach face indicative of developing beach during the post-monsoon and (iii) a wide beach, steep foreshore and a well developed berm during pre-monsoon/ fair weather period. With inter-annual variations in the weather and differences in the strength of the monsoon, the

magnitudes of seasonal changes vary from year to year. The wave conditions and littoral environmental parameters reported in the above studies have been extensively useful in this study to compare and correlate with the profile analysis and beach volume changes.

Some of the important studies carried out related to sediment transport have been briefly summarized in Table 1.1.

Table 1.1 The sediment transport along coastal stretches of Kerala to Kanyakumari

No	Year	Paper title	Authors	Journal	Findings
1	1991	Longshore sediment transport along the Indian coast	Chandramohan and Nayak, 1991	Indian Journal of Marine Sciences	Annual net transport at the tip of Indian peninsula near Kanyakumari was negligible and west direction
2	1997	Studies on sediment transport along Kerala coast, South west coast of India.	Sajeev et al.,1997	Indian Journal of Marine Sciences	Net Transport 0.09 and 0.38* 10^6 m^3/ year along Kerala coast. At Trivendrum annual drift is towards south, however at Quilon it is towards north.
3	1997	Sediment Transport Near the Peninsular Tip of India.	Jena and Chandramohan, 1997	Second Indian National Conference on Harbour and Ocean Engineering	April 1995 to April 1996 was estimated at 0.9 *$10^6$$m^3$/year and net transport was 0.3 *10^6 m^3/year
4	2001	Littotal Transport study along West coast of India	Kunte and Walgle, 2001	Indian Journal of Marine Sciences	Gross transport of Kerala and Southwest Tamil Nadu coast is 1.5 to 2 x 10^6 m^3 per year. The highest transport is computed at Vizhinjam, Kerala with a net transport of 2.95 * 10^6 m^3 /year
5	2006	Coastal processes along the Indian coastline	Sanil et al., 2006	Current Science	Net and gross longshore sediment transport near Thiruvananthapuram is 0.99 and 1.23 Million cubic m /Year and the net transport is towards north.
6	2010	Potential littoral sediment transport along the coast of South Eastern Coast of India	Saravanan and Chandrasekar, 2010	Earth sciences Research Journal	The net and gross transport of Kanyakumari is 0.022 and 0.191x 10^6 m^3/year and the net drift is southward
7	2013	Beach dynamics of Colachel open coast, Kanyakumari Districts (SW India)	Hentry et al., 2013	Annals of Geomorphology	The net westerly transport was approximately 0.9 *10^6 m^3 per month during 2007 and 0. 3 *10^6 m^3 per month during 2008 and westerly
8	2015	Wave Refraction Pattern and Littoral Sediment Transport along the SE Tamilnadu Coast Colachel	S. Saravanan and N Chandrasekar, 2015	Journal of Coastal Research	At Colachel: the annual net transport along the beach is towards south with a magnitude of 1.2* 10^6 and 0.7*10^6 m^3/year. At Thangapatnam: Annual net drift along this beach is towards east with a value of 1.2 * 10^6 m^3/ year.

9	2015	Longshore Sediment Transport along the Coast of Kerala in Southwest India	Sheela Nair et al., 2015	8th Int. Conference on Asian and Pacific Coasts (APAC 2015)	Gross transport of Trivendrum 1.285 x 10^6 m^3/year and net transport is 0.099 x 10^6 m^3/year) and the net transport direction was predominantly towards north.
10	2017	Estimation of wave parameters projections and sea level trends along Indian coast	Jaykuamr et al 2017	India-WRIS (Water Resources Information System of India) Project report on Waves by NIO, Goa	Under the project ADB TA-8652 IND: Climate-Resilient Coastal Protection and Management Project, the estimation of wave parameters projections and sea level trends along Indian coast using Numerical modelling of waves for a period of 46 years (1970-2015). Used historical wind data from NCEP/NCAR re-analysis data. From the results, it is observed that increasing trends in significant wave height along Kerala coast from 46 years simulated wave climate
11	2018	Seasonal and interannual changes of significant wave height in shelf seas around India during 1998–2012 based on wave hindcast	V. Sanil Kumar et al., 2018	Ocean Engineering	The increase in the significant wave height on western shelf seas (~1.2m) than the eastern shelf seas (~1.0m) due to stronger influence of summer monsoon in the Arabian sea compared to Bay of Bengal have an impact on the coastal sediment transport.

2 OBJECTIVES

i) To assess the shoreline change over 40 km coastline stretch (20 km on either side) of Vizhinjam and identify the zones indicating high erosion and accretion using high resolution satellite images prior and after port activities .

ii) Beach profile analysis (Yearly, monthly and seasonal variation) from 2015 to 2018 of the entire 40 km stretch with site specific analysis of Valliyathura.

iii) Vetting of reports on oceanographic, hydrographic, bathymetric field measured data and numerical model studies provided by AVPPL/VISL.

3 METHODOLOGY & DATA USED

The methodology flowchart is shown in Figure 3.1. The shoreline change analysis has been carried out using satellite images to estimate the rate of change in terms of distance eroded or accreted and the rate of change estimated using cross shore profile in terms of area and volume. From the satellite images, shoreline has been extracted after rectification and co-registration. The shoreline change rate from 2015-2018 has been analysed and the trend has been compared with beach profile data. Digital shoreline change analysis system (DSAS) is a software application that works within the Geographic Information System (ArcGIS) software. DSAS computes rate-of-change statistics for a time series of shoreline vector data. It is also useful for computing rates of change for other boundary change conditions that incorporate a clearly-identified feature position at discrete times.

Similarly the beach profile data perpendicular to the shoreline over the period from 2015-2018 collected monthly for 40 km stretch at intervals of 500m, using RTK or total station landward up to 100m from HTL or +2m of HTL and using shallow draft boats, sled or any other suitable techniques seaward down to 10m CD.

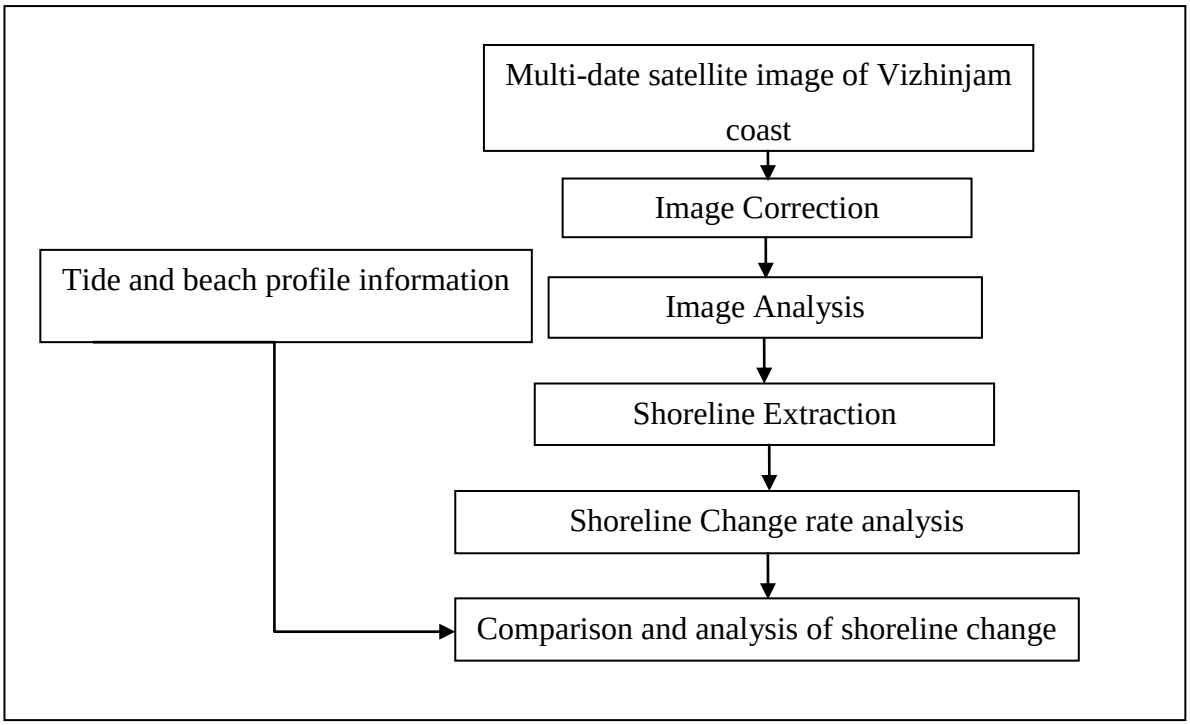


Figure 3.1 Flowchart of the methodology adopted

3.1 Shoreline change analysis from Satellite images

3.1.1 Short Term Shoreline change analysis

The end point rate (EPR) is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline (Figure 3.2). The major advantages of the EPR are the ease of computation and minimal requirement of only two shoreline dates. The major disadvantage is that in cases where more data are available, the additional information is ignored.

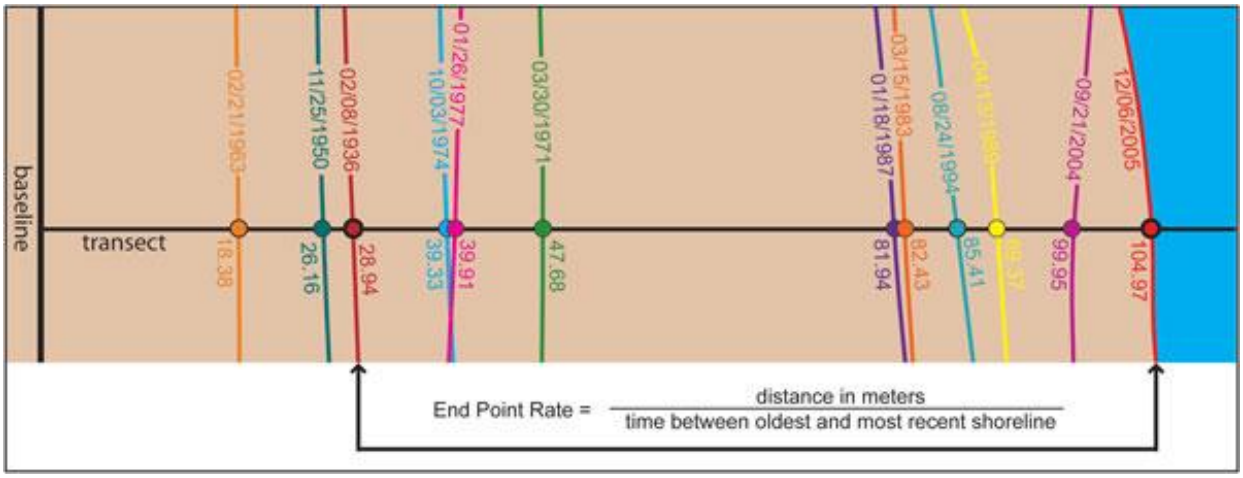


Figure 3.2 Calculation of Short Term Shoreline change analysis (Sample image source: Thieler et al., 2017)

3.1.2 Long Term Shoreline change analysis

A linear regression rate-of-change (LRR) statistic is determined by fitting a least-squares regression line to all shoreline points for a particular transect Figure 3.3. The regression line is placed so that the sum of the squared residuals (determined by squaring the offset distance of each data point from the regression line and adding the squared residuals together) is minimized. The linear regression rate is the slope of the line. However, the linear regression method is susceptible to outlier effects and also tends to underestimate the rate of change relative to other statistics.

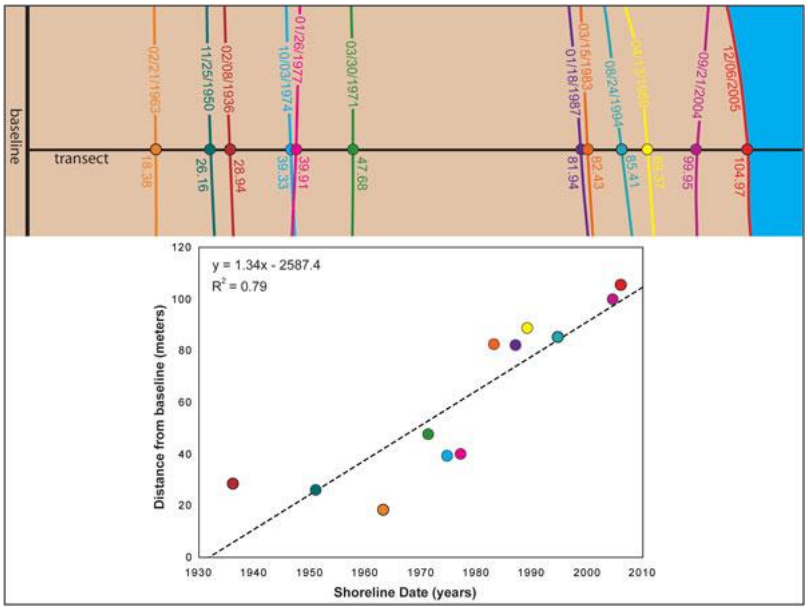


Figure 3.3 Calculation of Long Term (LRR) Shoreline change analysis (Sample image source: Thieler et al., 2017)

3.1.3 Satellite image used in shoreline change analysis

The input image has been acquired from United States of Geological Survey (USGS) for Landsat 8 OLI and from European Space Agency for Sentinel 2A MSI images to study seasonal change in shoreline since 1988 for preliminary study. The image has been co-rectified and the available data are provided in Table 3.1.

As per NGT expert, Shoreline monitoring committee recommendations, high resolution satellite images has been procured. Following are the list of image data procured from NRSC (Table 3.2). The image has been georectified using the field collected ground control points (GCP) during the field visit carried out during 3rd July 2018 to 5th July 2018 (Table 3.3).

Table 3.1 Satellite image data used for decadal shoreline change analysis

Satellite	Date	Sensor	Resolution (m)
LANDSAT	19-01-1988	TM 5	30
	12-02-1997	ETM 7	30
	21-12-2000	TM 5	30
	03-02-2008	ETM 7	30
	08-02-2010	ETM 7	30
	29-04-2013	OLI/TIRS 8	30
	26-01-2014	OLI/TIRS 8	30
	16-01-2016	OLI/TIRS 8	30
	03-02-2017	OLI/TIRS 8	30

	23-03-2017	OLI/TIRS 8	30
	18-11-2017	OLI/TIRS 8	30
	04-12-2017	OLI/TIRS 8	30
SENTINEL	14-01-2017	2B	10
	14-05-2017	2B	10

Table 3.2 Satellite image data procured from NRSC for shoreline change study

Satellite	Date	Sensor	Resolution (m)
R2A	13-02-2012	LISS4	5
	20-04-2013	LISS4	5
	02-02-2014	LISS4	5
	21-02-2015	LISS4	5
	11-03-2016	LISS4	5
	10-02-2017	LISS4	5
	17-05-2017	LISS4	5
	04-07-2017	LISS4	5
	08-10-2017	LISS4	5
IRS 1C	22-05-2000	PAN	5
	06-03-2001	PAN	5
	24-02-2003	PAN	5
	22-09-2004	PAN	5
	13-02-2005	PAN	5
C1	23-10-2005	PAN	2.5
	11-03-2007	PAN	2.5
	15-12-2010	PAN	2.5
	01-05-2011	PAN	2.5
	08-01-2012	PAN	2.5
	03-01-2015	PAN	2.5
	13-03-2016	PAN	2.5
	18-02-2018	PAN	2.5
C2	12-02-2011	PAN	1.0
	12-02-2011	PAN	1.0

Table 3.3 List of Ground Control Points collected during field visit

Name	Village/ Location	Description	GEOXT Lat	GEOXT Lon	HHGPS Lat	HHGPS Lon
0	Velli lake	Road tri junction	08°30'44.653"	76°53'30.524"	08°30'44.6"	76°53'30.6"
1	Vettukadu	Shed Near Vettucaud Church	08°29'39.874"	76°54'03.105"	08°29'39.8"	76°54'03.1"
2	Shangumukham	Road junction (near shangumukham bus stop)	08°28'51.835"	76°54'45.490"	08°28'51.8"	76°54'45.5"
3	Valliyathura	North corner of pier	08°27'46.592"	76°55'25.115"	08°27'46.5"	76°55'25.1"
4	Punthura	Opposite building of st.thomas hr. sec. school	08°26'28.653"	76°56'40.995"	08°26'28.6"	76°56'40.9"
5	Pachalloor-Vazhamuttom	Pannathura temple	08°24'56.908"	76°57'50.496"	08°24'56.9"	76°57'50.5"
6	Pachalloor-Vazhamuttom	Panathura Masjid	08°24'44.508"	76°57'57.664"	08°24'44.5"	76°57'57.7"
7	Kovalam	Kovalam Juma masjid	08°23'48.932"	76°58'23.623"	08°23'49.0"	76°58'23.5"
8	Vizhinjam harbor	Near Vizhinjam Harbor road; cross building	08°22'53.062"	76°59'00.329"	08°22'53.1"	76°59'00.4"
9	Vizhinjam harbor	Valliyapalli	08°22'44.178"	76°59'14.61"	08°22'44.2"	76°59'14.6"
10	Adimalathura	Somatheeran Adimalathura road; opposite to our lady of fatima church	08°20'59.733"	77°01'27.774"	08°20'59.7"	77°01'27.6"
11	Marthandathura	Near Marthandathurai school	08°16'45.482"	77°06'57.086"	08°16'45.5"	77°06'57.1"
12	Edapadu	Edapadu building	08°16'15.490"	77°07'36.482"	08°16'15.5"	77°07'36.6"
13	Sreevaraham	Sreevaraham temple pond (north western corner)	08°28'39.889"	76°56'25.145"	08°28'39.9"	76°56'25.2"
14	Neyatinkara	Neyatinkara-Arakannu-Marayamuttom road	08°24'23.315"	77°05'30.905"	08°24'23.3"	77°05'30.9"
15	Venganoor, Chevanthinada bus stop	Marthandam pond	08°24'06.528"	77°00'53.901"	08°24'06.5"	77°00'53.9"
16	Vizhinjam harbor	St.Marys church	08°22'41.726"	76°59'37.582"	08°22'41.7"	76°59'37.6"
17	Vizhinjam harbor	Mullor beach; poovar vizhinjam road	08°22'15.659"	77°00'30.433"	08°22'15.7"	77°00'30.5"
19	Beemapally	Road junction near Leelampally mosque and sewage farm	08°27'23.908"	76°56'09.648"	08°27'23.9"	76°56'09.6"
20	Kochuthura-Poovar	St.Andrew LP School	08°19'32.059"	77°03'25.991"	08°19'32.0"	77°03'25.9"

3.2 Beach Profile Analysis

Coastal environments are among the most changeable on the Earth's surface with many coastal changes being either circulatory in space or periodic in time. Seasonal alterations in beach profile do occur: rapid erosion during monsoon and cyclonic storms is countered, however by winter conditions that can rebuild the beach. Monitoring shoreline behaviour at regular intervals, distinguishing between cyclic and progressive change, is critical to sound shoreline management. This has recently become more significant with the potential for global warming, its attendant sea level rise and the possibility of an increase in the number of storms.

Shoreline Change analysis using Cross shore Profile (CSP) has been done as part of the Shoreline Monitoring Programme. CSP data has been collected by AVPPL every month at 81 profile lines along a stretch of 40 km covering the area of approximately 20 km south and 20 km north of the proposed port (For period between February 2015 to September 2018). Among the 81 locations, 40 are to the North of Vizhinjam, 40 are to the South of Vizhinjam and 1 at Vizhinjam port. The survey data is available from February 2015 to September 2018 for most of the locations. However, a few profiles are not available at few locations as beach profiling commenced in February 2015 for 61 locations covering approximately 30 km and later in April 2015, it was extended to 81 locations covering 40 km. The locations of the profiles are shown in Figure 3.4 and the places name in the Table 3.4.

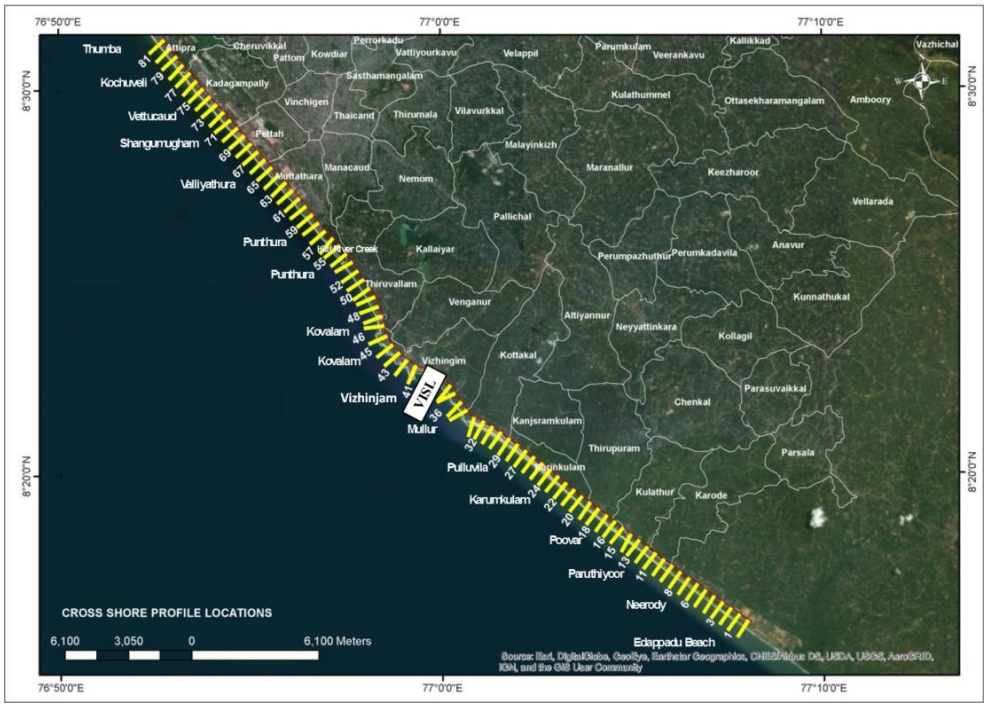


Figure 3.4 Beach Profiles lines

Table 3.4 Landmark and places names around each CSP lines

CSP NOs.	LAND MARK	LOCATION
CSP-01	CATHOLIC CRISMATIC PRAYER CENTER	EDAPPADU BEACH
CSP-02		
CSP-03		
CSP-04	ST.MARYS CHURCH	VALLAVILAY
CSP-05		
CSP-06		
CSP-07	ST.NICOLAS CHURCH	NEERODY
CSP-08		
CSP-09		
CSP-10	SREE BHADRAKALI TEMPLE	POZHIYOOR
CSP-11		
CSP-12		
CSP-13	ST.MATHEWS CHURCH	PARUTHIYOOR
CSP-14	CHURCH OF CRIST	
CSP-15	POOVAR ISLAND RESORT	POOVAR BEACH SOUTH
CSP-16		
CSP-17		
CSP-18	POZHIKARA BEACH	POOVAR
CSP-19		
CSP-20	ST.ANTONYS CHAPEL	POOVAR BEACH NORTH
CSP-21		
CSP-22	ST.ANTONYS CHURH	KARUMKULAM
CSP-23		
CSP-24		
CSP-25		
CSP-26		
CSP-27	GOTHAMBU ROAD	PULLUVILA
CSP-28		
CSP-29		
CSP-30		
CSP-31	ADIMALATHURA CATHOLIC CHURCH	ADIMALATHURA
CSP-32		
CSP-33		
CSP-34		
CSP-35	AZHIMALA TEMPLE	AZHIMALA
CSP-36	NAGAR BHAGAVATHY TEMPLE	MULLUR
CSP-37		
CSP-38	ADANI RECLAMATION AREA	ADANI PORT OFFICE VIZHINJAM
CSP-39		
CSP-40		
CSP-41	VIZHINJAM LIGHT HOUSE	KOVALAM
CSP-42		
CSP-43		
CSP-44		
CSP-45		
CSP-46		
CSP-47	SAMUDRA BEACH PARK	KOVALAM (NORTH)
CSP-48	MOSQUE	PANATHURA (SOUTH)
CSP-49		
CSP-50	PANATHURA TEMPLE	PANATHURA (NORTH)
CSP-51		
CSP-52		
CSP-53	PUNTHURA FISH MARKET	PUNTHURA
CSP-54		

CSP-55		
CSP-56		
CSP-57		
CSP-58	BEEMA PALLY	BEEMA PALLY
CSP-59		
CSP-60		
CSP-61	CHERIYATHURA SPORTS GROUND	CHERIYATHURA
CSP-62		
CSP-63	VALLIYATHURA BRIDGE	VALLIYATHURA
CSP-64		
CSP-65		
CSP-66		
CSP-67		
CSP-68	SHANGUMUGHAM BEACH	SHANGUMUGHAM (SOUTH)
CSP-69		
CSP-70	ST.PETERS CHURCH	SHANGUMUGHAM (NORTH)
CSP-71		
CSP-72	VETTUCAUD CHURCH	VETTUCAUD
CSP-73		
CSP-74		
CSP-75	VELI CHILDRENS PARK	KOCHUVELI
CSP-76		
CSP-77		
CSP-78	ST.THOMAS CHURCH	VALIYA VELI
CSP-79		
CSP-80	CHRISTIAN BROTHEREN CHURCH	THUMBA
CSP-81		

Profile surveys have been carried out as two components Viz., (1) Beach Profile surveys (land part) using RTK GPS System and (2) Nearshore Bathymetric Survey (Sea Part) using multi-beam echo sounder system. These datasets are combined, processed and transferred to NIOT for analysis.

On land side, the survey has been conducted using Real Time Kinematic (RTK) system up to 100m distance from HTL or +2m elevation w.r.t to HTL and on sea side bathymetric survey has been conducted on the profile line connecting the land survey upto 10 m depth contour which was revised to 20 m depth from September 2018. Data gaps observed at foreshore zone are corrected using suitable method.

The data received was analysed by plotting each profiles and using various software. The aim of this comprehensive exercise was to establish a base data to compare profiles with surveyed data from different location for different seasons. This data shall serve to assess the beach profile after the construction of the port at Vizhinjam in future. Difference, if any, shall be investigated further to understand impact due the port on the shoreline evolution. Profiles for different months were plotted location wise. The trends of beach profile were assessed qualitatively. A sample plot of the profile is shown in Figure 3.5.

A beach profile is defined as a set of beach levels taken at recorded distances in a straight line (Figure 3.5). It is accepted that beach profiles can only be of real use when surveys are taken over a period of time starting at exactly the same place and moving in exactly the same direction (the Origin and Orientation of the profile). SANDS software stores the beach profile surveys, to view them graphically and to analyse them to identify trends in beach levels at a location over time. The 'Beach Profile Graph' feature allows the user to graph and compare beach profiles from different/multiple locations.

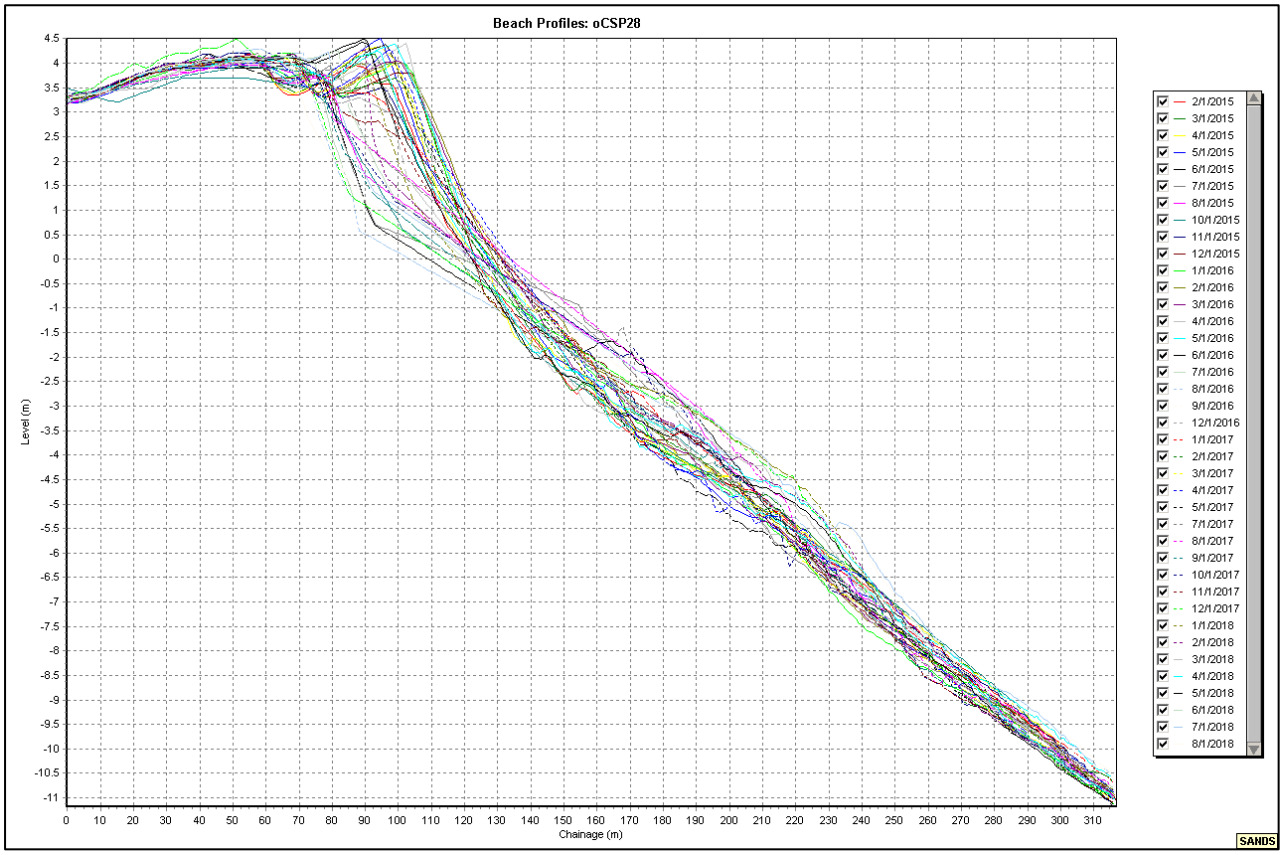


Figure 3.5 Example of beach profile graph of CSP 28 using SANDS software

It was observed during the analysis of cross shore profiles that some of the profiles appeared distorted, possibly due to some errors creeping up during the survey. These profiles are either discarded or manually corrected in respect of the earlier profiles. The profiles corresponding to the Vizhinjam Port area is completely discarded and mentioned as development zone.

The CSP data after reprocessing qualitatively and quantitatively is directly imported to SANDS for shoreline change assessment based. The following flow chart (Figure 3.6) explains the process and work flow in SANDS.

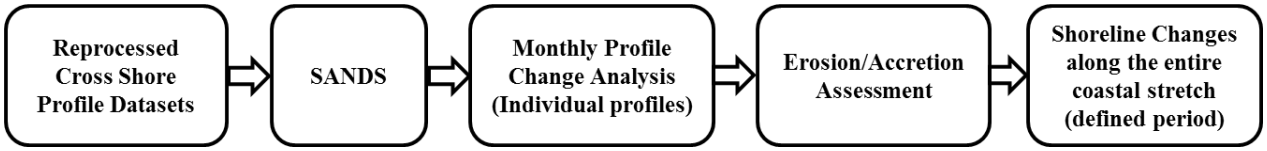


Figure 3.6 Work Flow in SANDS

3.3 Analyzing Beach Profiles in SANDS

SANDS allow for any number of beach profiles survey records to be stored at each profile location. This means that over a period of years, it will accumulate a valuable resource for determining the stability and long term trends in beach levels. The two main Beach Profile Analyses are: Profile Analysis by Level and Profile Analysis by Chainage.

3.3.1 Profile Analysis by Level

Profile analysis 'by Level' is one of two methods of analysing beach profiles (the other being Profile Analysis by Chainage). The difference between the two is that this process analyses the changes in the chainage at which certain levels occur whilst the other analyses changes in level at certain chainages (Figure 3.7). In other words, this analysis looks at horizontal strips of the profile.

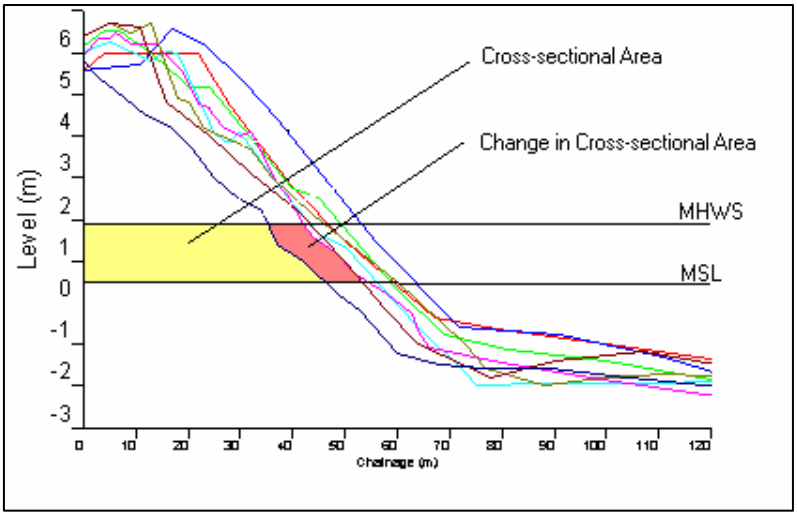


Figure 3.7 Profile Analysis by Level

3.3.2 Profile Analysis by Chainage

Profile analysis 'by Chainage' is one of two methods of analysing beach profiles (the other being Profile Analysis by Level). The difference between the two is that this process analyses the changes in level at certain chainages whilst the other analyses changes in the

chainage of certain levels. In other words, this analysis looks at vertical strips of the profile (Figure 3.8).

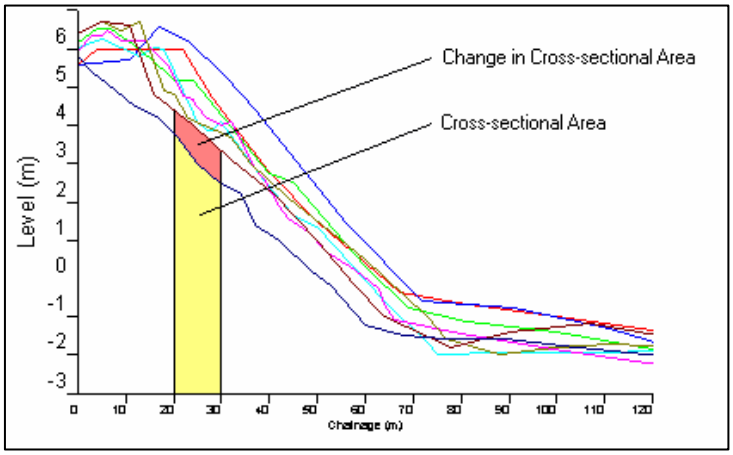


Figure 3.8 Profile Analysis by Chainage

Based on the above methods SANDS calculate the profile changes and then it calculates volumes of pre-defined areas. It also enables to group together all beach profile locations and analyse the volumes of these units. SANDS calculate the Profile Accretion / Erosion through a direct comparison between profiles over the period of comparison and allow the results to be displayed within a GIS-style plan-view format to give striking visual results.

4 RESULTS AND ANALYSIS

In the present study, the shoreline rate of change statistics from time series of multiple shoreline positions of 40 km coastal stretch of south Kerala coast (20 km either side of Vizhinjam Port) has been taken in to account for shoreline calculation using satellite images. Total 4341 transects were generated with 10m spacing along the shoreline. The length of one transect (Cross shore) was 500m. The shoreline change rate results show variation of NNW – SSE coast configuration. The result from the shoreline change analysis carried out for 2000-2018 using LRR method and annual variation for the year 2015-2016, 2016-2017, 2017-18 using EPR method has been described. An overall shoreline change analysis using moderate resolution images such as Landsat and Sentinel for the years 1988 to 2017 is also analysed.

As a part of NGT direction, the shoreline change analysis has been carried out for the year 2000-2010, 2010-2018, 2000-2018 using high resolution LISS 4 (5m) and PAN (2.5m) images to study the changes before and after 2010. Further, the shoreline change analysis has been carried out for the years 2000-2005, 2005-2010, 2010-2015, 2015-2018 to study the immediate changes prior and after port commencement activity (December 2015).

Based on the rate of change over the period, shoreline change has been categorized into 5 classes (NCSCM, 2014). They are high accretion (>5m/year), moderate accretion (5-1m/year), stable coast (1 to -1m/year), moderate erosion (-1 to -5m/year), high erosion (<-5m/year).

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch has been presented as Inter-annual, seasonal and monthly changes in the beach volume for a period from February 2015 to September 2018 in section 4.2.

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch has been presented as Inter-annual, seasonal and monthly changes in the beach volume for a period from February 2015 to September 2018. Monthly beach volume changes has been assessed by comparing month to month profiles while the seasonal changes is the total monthly volume changes for the particular season i.e. cumulative sum of changes in a season.

The annual beach changes assessment is the total changes takes place every month in a particular year with respect to the data available. The inter-annual beach assessment is a year to year comparison of beach profiles. We have considered the data collected in February/March month of every year (months and year in concurrence with the satellite image analysis) for the inter-annual change assessment.

The erosion and accretion are highlighted with red and green fill in the charts for better understanding. The results presented in the charts are also presented in the tables.

4.1 Results for Shoreline Change Analysis from Satellite images

4.1.1 Results for Shoreline Change 2000-2018

Using high resolution (PAN 2.5m and LISS-IV 5m) satellite images, the result has been processed since 2000 to 2018. Figure 4.1 shows the shoreline map. High erosion can be noticed at Edapadu (-6.54 m/year), Valliyathura (-3.04 m/year) and Punthura (Killi river creek) (-8.12 m/year) and accretion is noticed at Karumkulam (1.74 m/year) and Poovar (2.2 m/year). Further section 4.1.2 and 4.1.3 discusses the shoreline condition prior and after 2010. Since the satellite image coverage for the entire 40km stretch is not possible with higher resolution images, few transects to the extreme north could not be analyzed for the years 2000-2018, 2000-2010, 2010-2018. Hence shoreline change map shows few transects with null values (Figure 4.1 to 4.3).

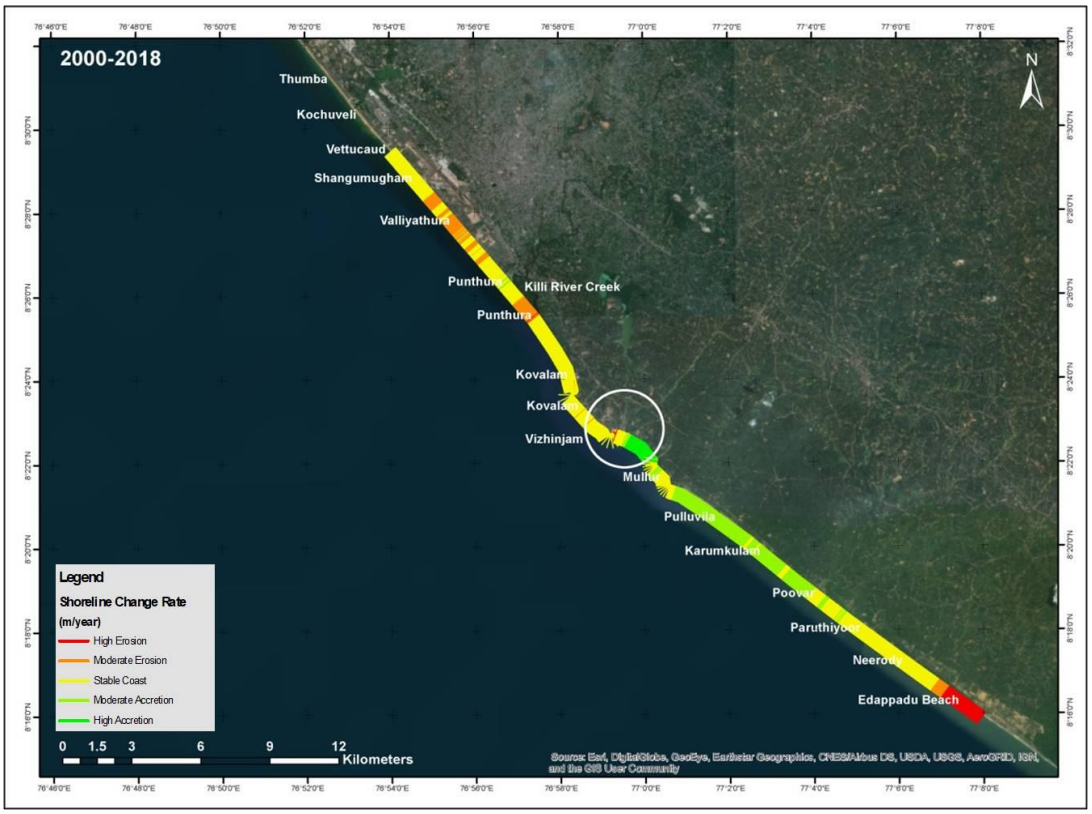


Figure 4.1 Shoreline Change Map May 2000- Feb 2018

4.1.2 Results for Shoreline Change 2000-2010

The study has been carried out prior to the port activity (before 2010) using high resolution satellite images. From the shoreline change map shown in Figure 4.2, the high erosion has been noticed to the north of Vizhinjam at Valliyathura and Punthura and accretion to the south of Vizhinjam at Karumkulam and Paruthiyoor.

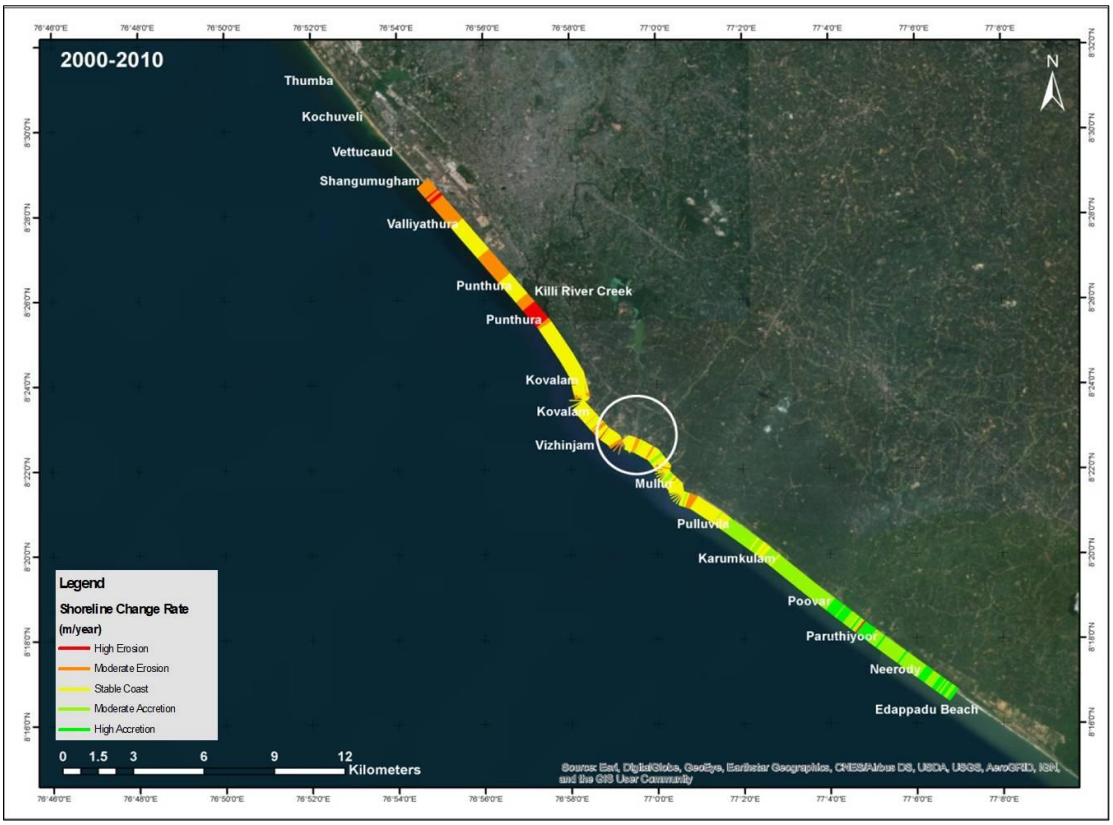


Figure 4.2 Shoreline Change Map May 2000- Dec 2010

4.1.3 Results for Shoreline Change 2010- 2018

The rate of change of shoreline has been calculated using high resolution satellite data is shown in Figure 4.3. The overall shoreline change map indicates the accretion to the south of Vizhinjam at Pulluvila, Karumkulam and erosion at Killi river creek (Punthura), Valliyathura to the north and Edapadu to the south.

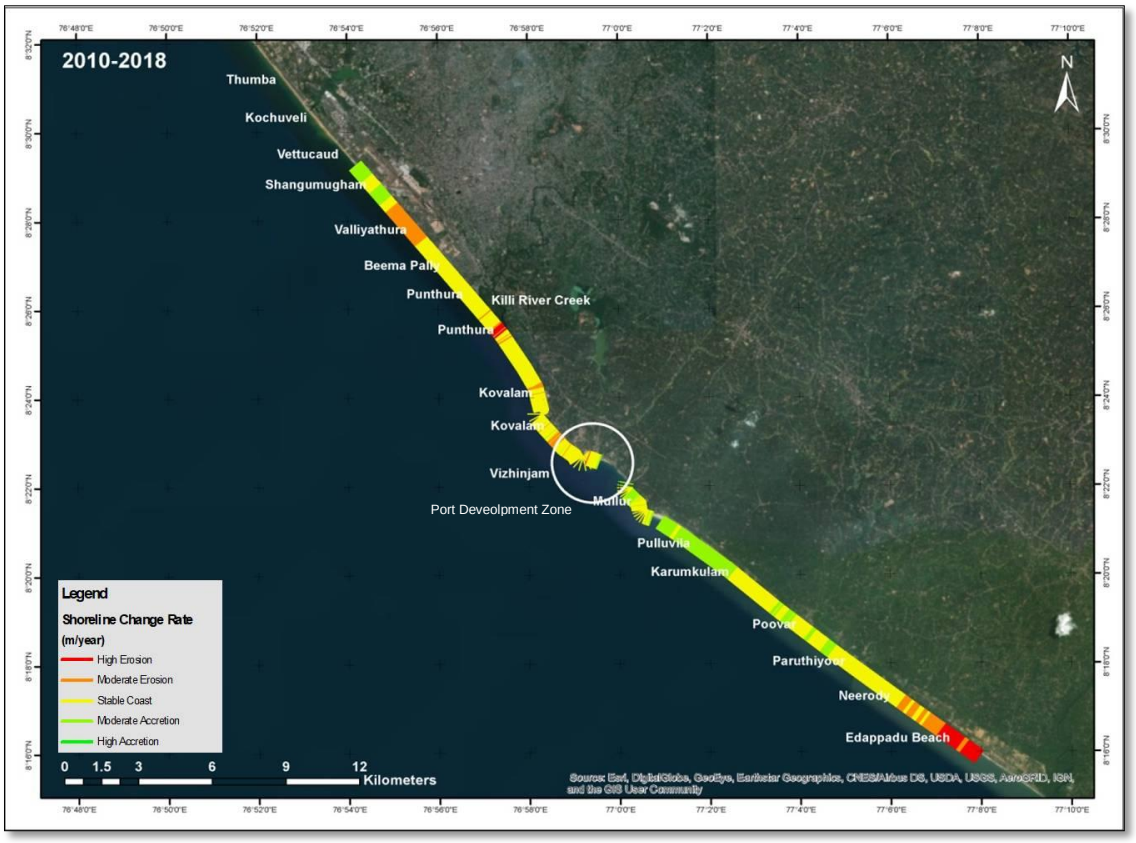


Figure 4.3 Shoreline Change Map Dec 2010- Feb 2018

4.1.4 Results for Shoreline Change 2000-2005, 2005-2010, 2010-2015, 2015-2018

As per the NGT requirement 10 km at either side of the proposed VISL has been analysed with high resolution satellite image. Besides we also attempt to study upto a maximum possible extent to cover the baseline of 43 km with limitations and availability of high resolution data coverage. Figure 4.4 - 4.7 depicts the shoreline change rate for the period 2000-2005, 2005-2010, 2010-2015 and 2015-2018 respectively. It may be noted that the high erosion constantly occurs at north of Vizhinjam at Valliyathura and Punthura (Killi river creek) region and at extreme south at Paruthiyoor and Edapadu region. Similarly, high accretion is noted at Vizhinjam and Karumkulam villages.

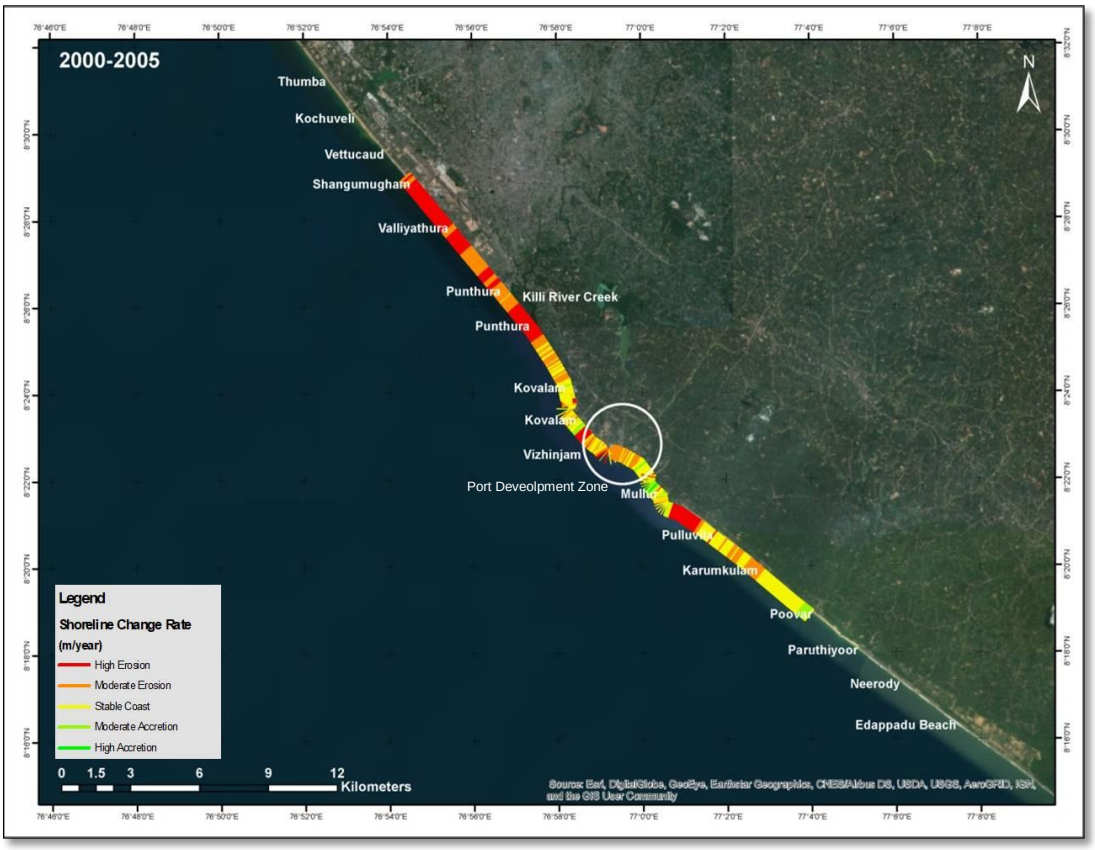


Figure 4.4 Shoreline Change Map May 2000- Feb 2005

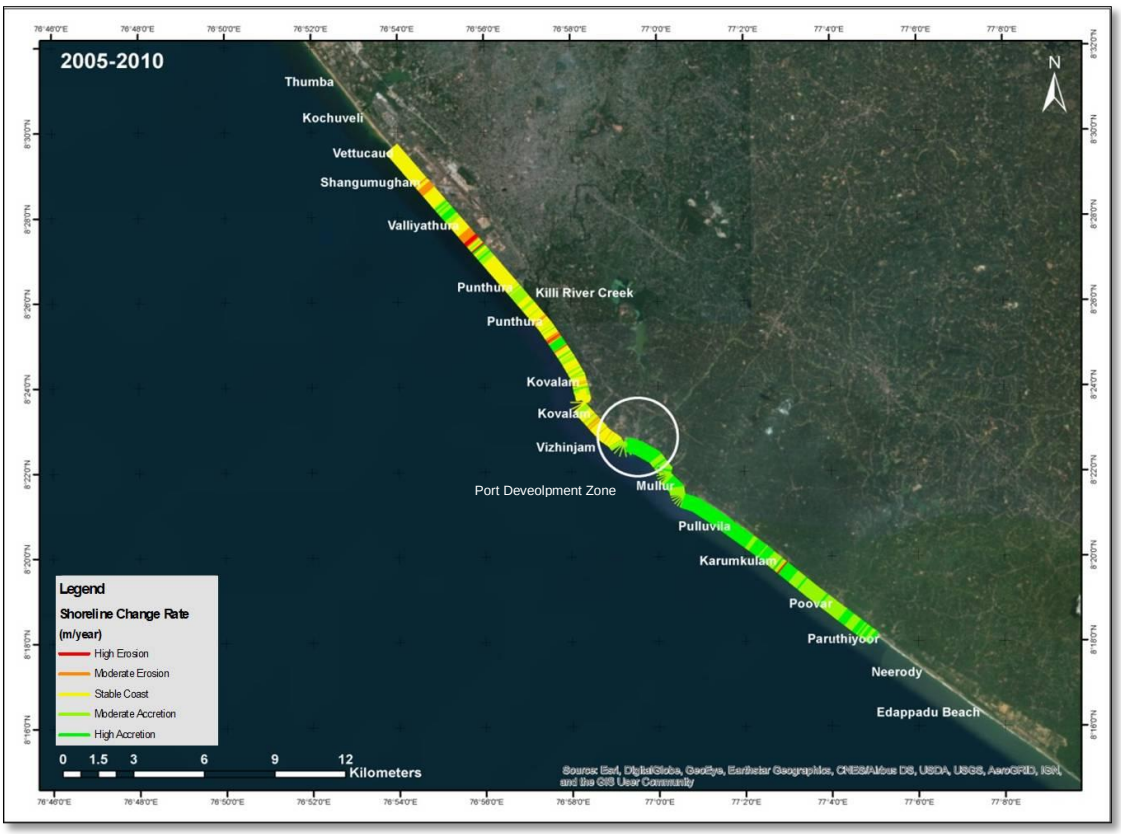


Figure 4.5 Shoreline Change Map Feb 2005- Dec 2010

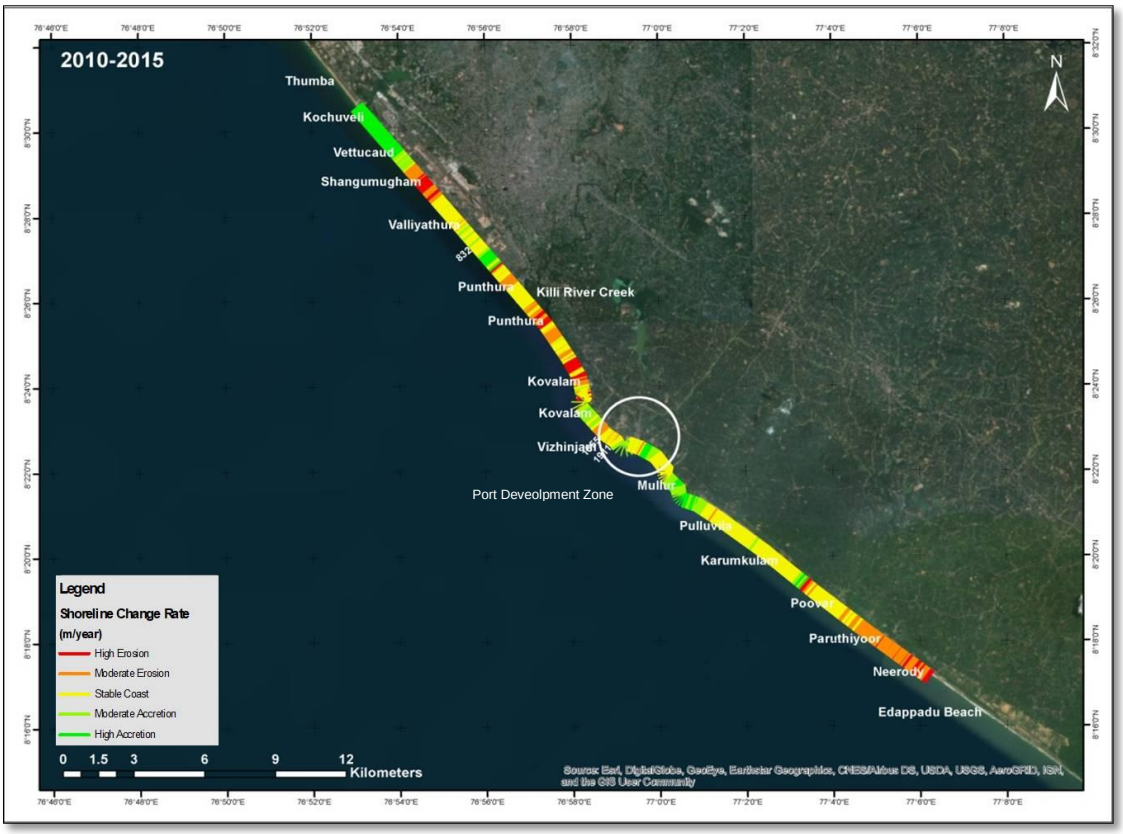


Figure 4.6 Shoreline Change Map Dec 2010- Jan 2015

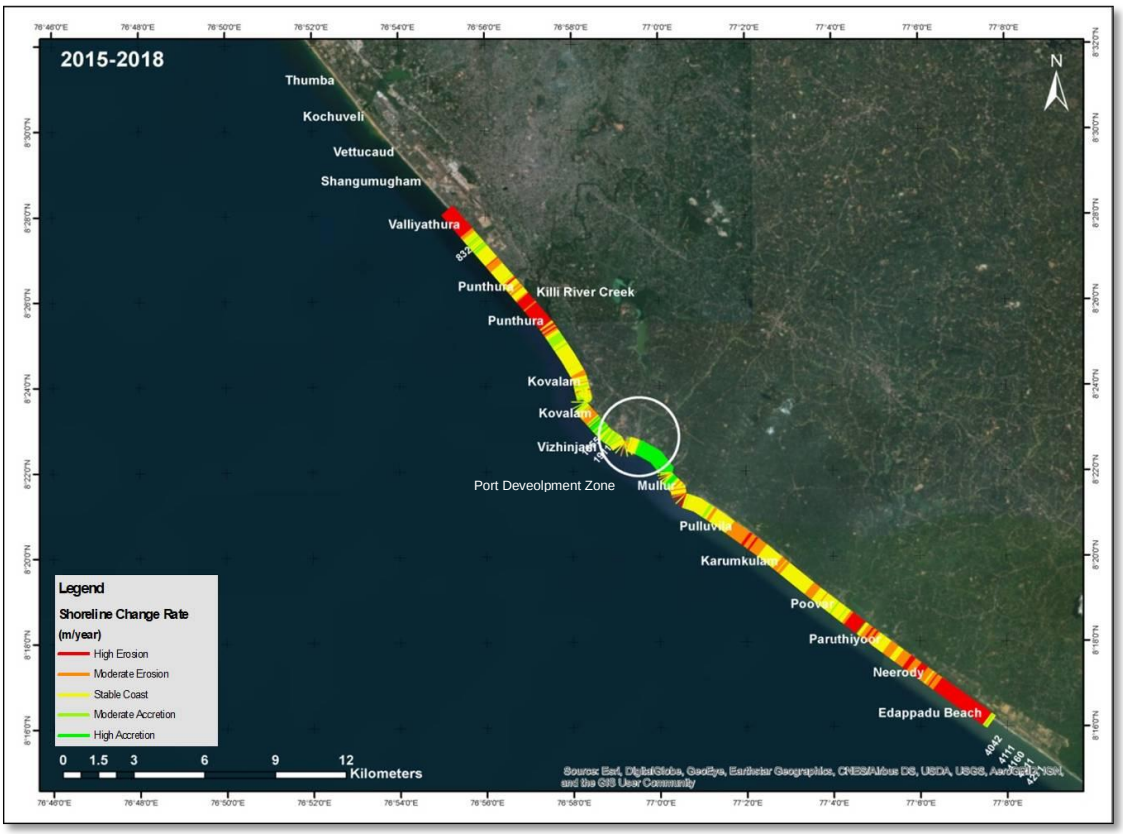


Figure 4.7 Shoreline Change Map Jan 2015- Feb2018

4.1.5 Annual shoreline change study 2015-2018

4.1.5.1 Annual Shoreline Movement 2015-2016

The satellite image data of 2.5m resolution of Jan 2015 and Mar 2016 has been considered for analysis. The shoreline change result for the year 2015-2016 (Figure 4.8) shows high erosion at Valliyathura and also to the south of Vizhinjam at Paruthiyoor and high accretion at Kovalam.

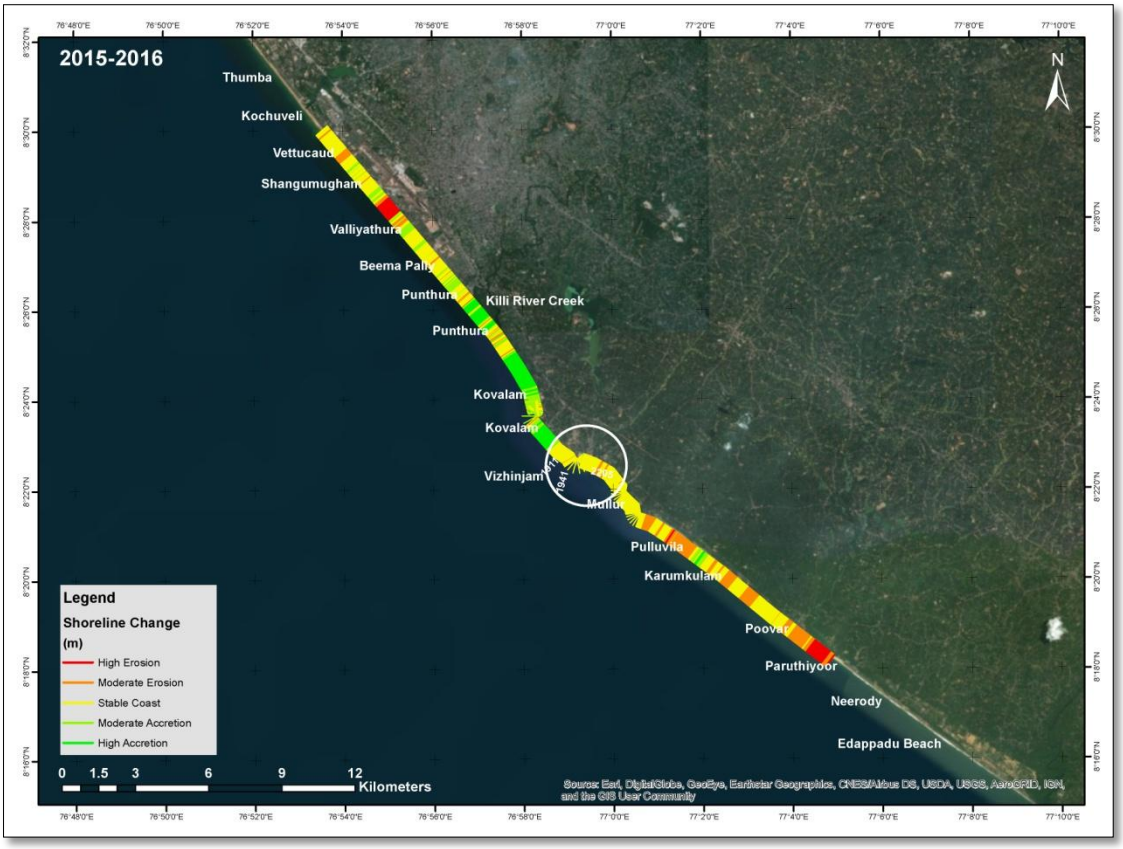


Figure 4.8 Shoreline Change Map Jan 2015- Mar 2016

4.1.5.2 Annual Shoreline Movement 2016-2017

The satellite image data of 2.5m resolution (Mar 2016) and 5m resolution (Feb 2017) has been considered for analysis. The shoreline change result for the year 2016-2017 (Figure 4.9) shows that erosion is seen at Punthura (Killi river creek) and accretion is noted to the south of Vizhinjam.

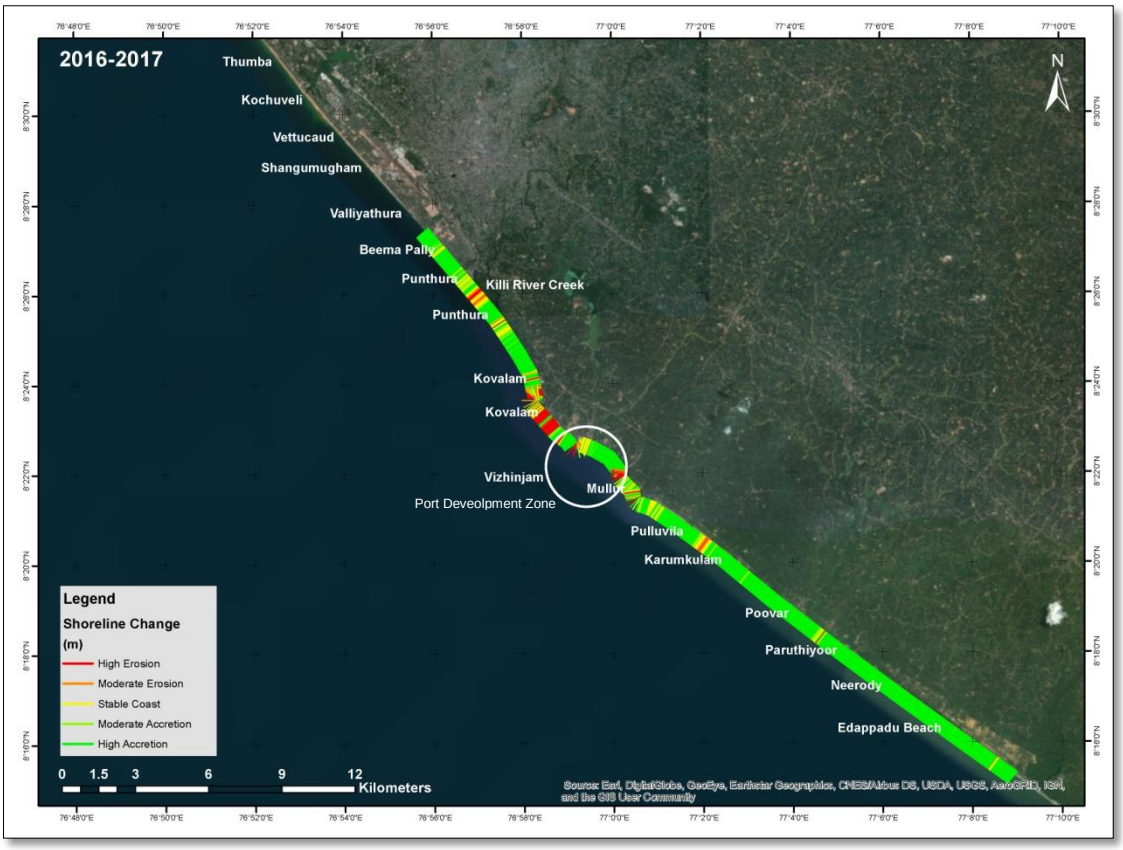


Figure 4.9 Shoreline Change Map Mar 2016- Feb 2017

4.1.5.3 Annual Shoreline Movement 2017-2018

The satellite image data of 5m resolution (Feb 2017) and 2.5m resolution (Feb 2018) has been considered for analysis. The shoreline change result for the year 2017-2018 (Figure 4.10) shows that erosion is seen to the north of Vizhinjam at the region of Valliyathura, Killi river creek, south Punthura and North Punthura and also to the south of Vizhinjam at Pulluvila and Karumkulam region. Few transects to the extreme north are not presently considered for analysis due to lack of high resolution data at the particular region. This annual shoreline change result for the year 2017-2018 has been compared and validated with the beach profile analysis after clarification from the field team of AVPPL/VISL & OSAS on data review meeting held at NIOT.

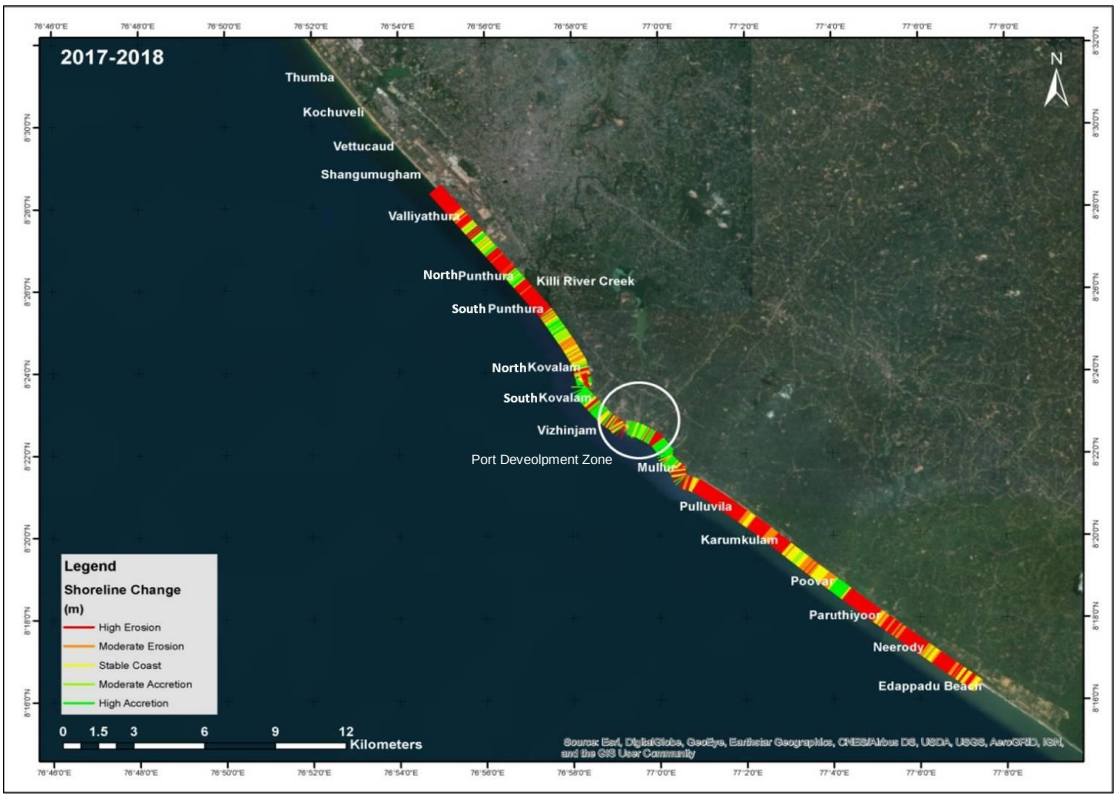


Figure 4.10 Shoreline Change Map Feb 2017- Feb 2018

4.1.6 Seasonal Shoreline change analysis 2017-2018

For the study on seasonal change of the shoreline, the year 2017-2018 has been considered due to the availability of the high resolution satellite data representing every seasons. In this section the results from the three seasons (Fair weather period, south west monsoon, and north east monsoon) has been described.

4.1.6.1 Fair Weather Period (FWP)

For the fair weather period, the data from Feb 2017 and May 2017 has been used to assess the change in the shoreline. The net shoreline change between the above said months has been provided in the Figure 4.11. High erosion is noted at Valliyathura, Punthura and Edapadu.

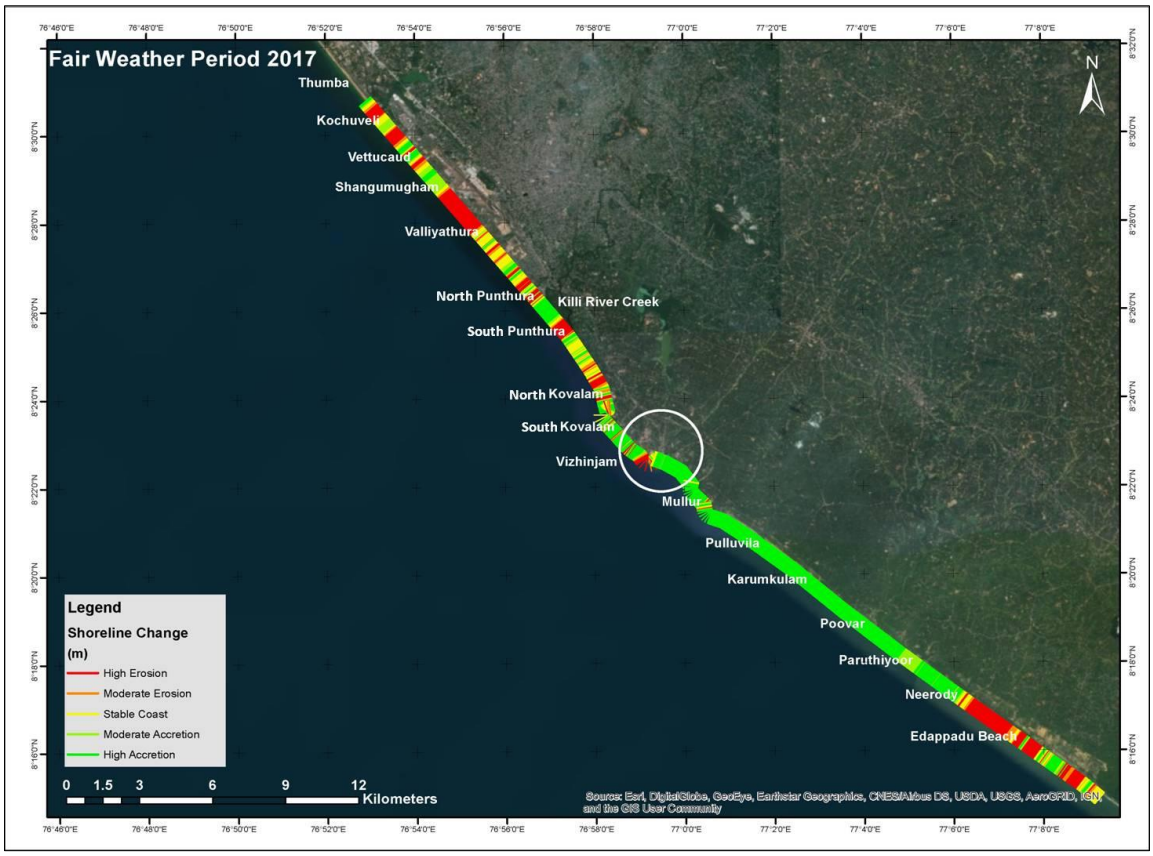


Figure 4.11 Shoreline Change Map for Fair weather period 2017

4.1.6.2 North East Monsoon (NEM)

For the North east monsoon season, the data from October 2017 and Feb 2018 has been used to assess the change in shoreline. The net shoreline change for the north east monsoon season has been provided in the Figure 4.12. High erosion is noted at Valliyathura, Punthura, Pullavila, Paruthiyoor, Neerody and Edapadu beach during north east monsoon season. It is to be noted that this season have also faced Ockhi cyclone during the months of 30th November- 1st December 2017 along Kerala coast.

4.1.6.3 South West Monsoon (SWM)

For the South west monsoon season, the data from May 2017 to July 2017 has been used to assess the change in shoreline. The net shoreline change for the south west monsoon season has been provided in the Figure 4.13. During south west monsoon season, almost entire coast faces erosion attributed to high wave activity.

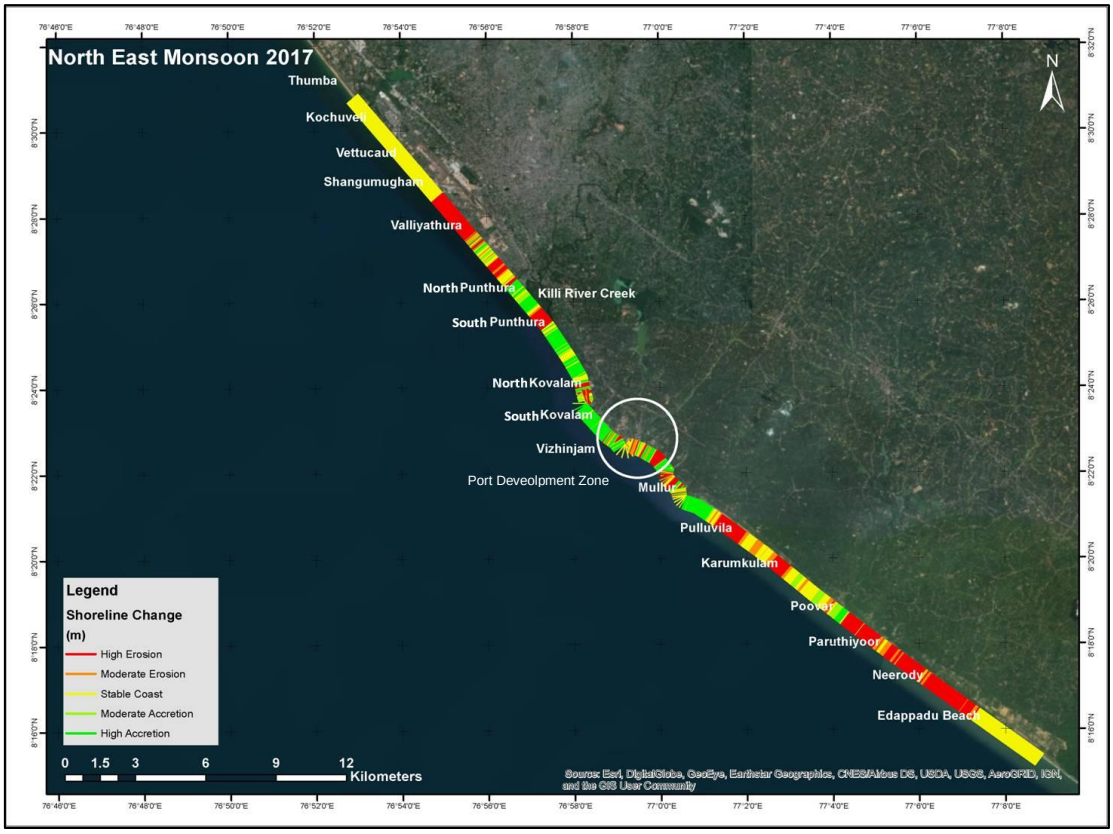


Figure 4.12 Shoreline Change Map for North East Monsoon 2017

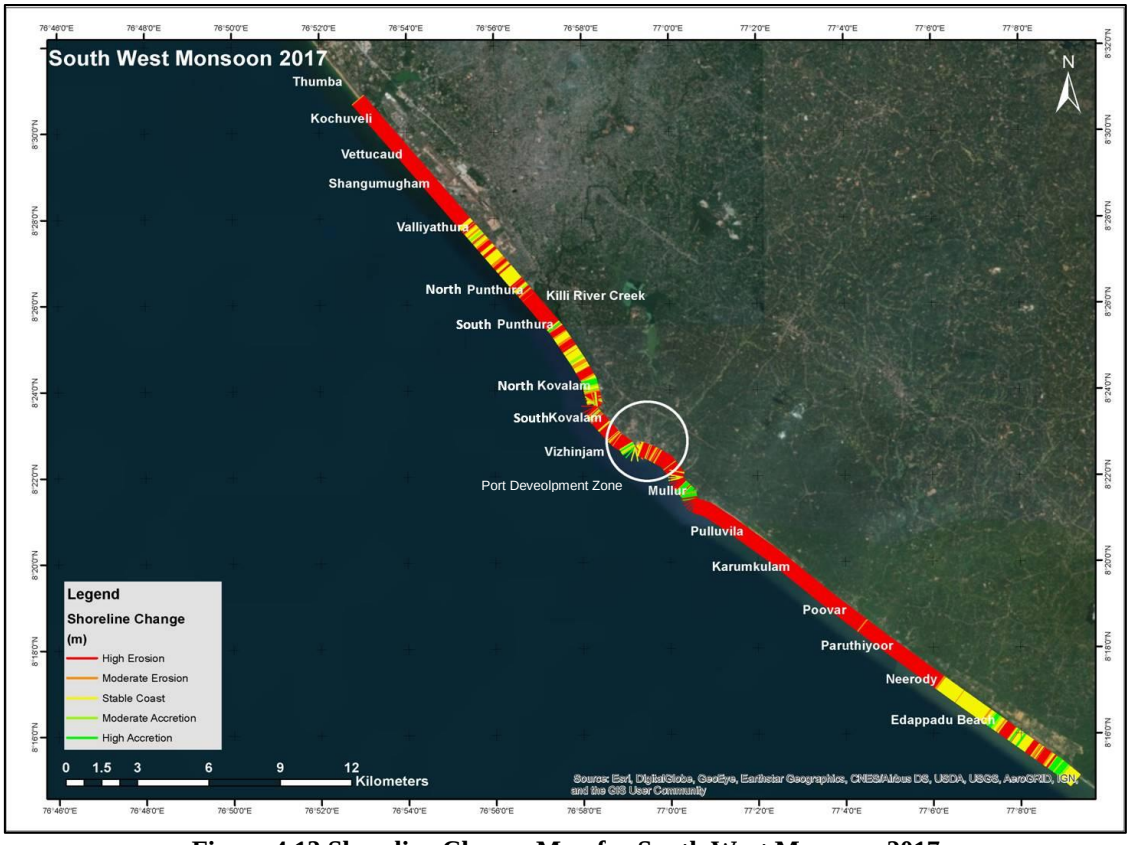


Figure 4.13 Shoreline Change Map for South West Monsoon 2017

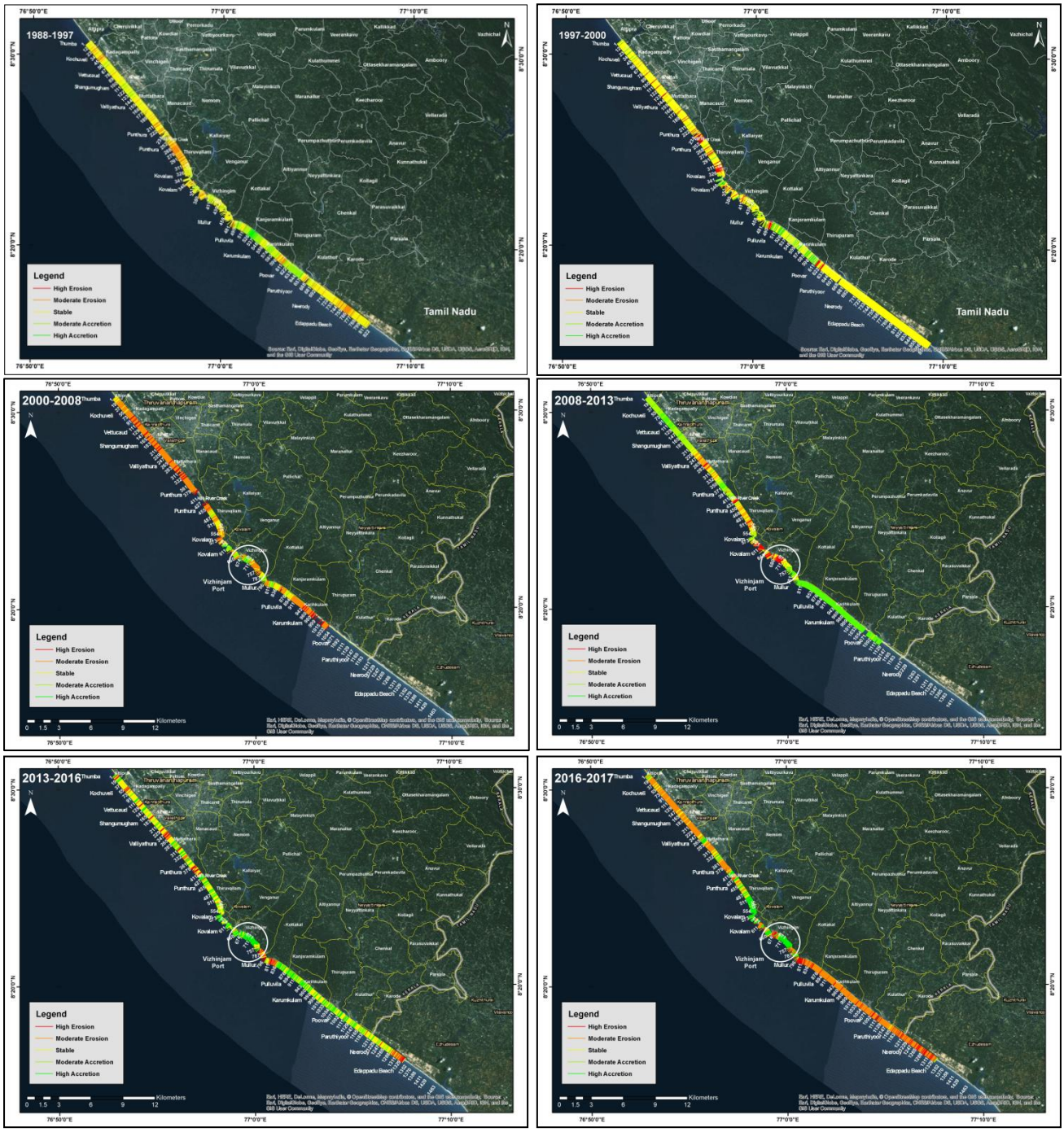


Figure 4.14 Shoreline change over the years 1988 to 2017.

The zone of erosion derived from the moderate resolution (30~10m) satellite images from 1988-2017 (shown in Figure 4.14) are Valliyathura, Punthura and Edapadu and high accretion at Karumkulam and Poovar.

4.1.7 Zones of high erosion and high accretion

From the results from various analysis carried out for the period from 1988-2017 using moderate resolution (30~10m) satellite images and from 2000-2018 using high resolution (5~1m) satellite images, the zones of high erosion has been derived such as Valliyathura,

Punthura and Edapadu. High accretion zones are Kottakal, Poovar and Karumkulam regions. The zones of high erosion and accretion has been compared with the previous report by various institutions, has been listed in Table 4.1. It can be noted that the various organizations have reported the same spots of erosion and accretion for the respective period of years. Noujas and Thomas, 2015 have reported the erosion hotspots along the south west coast of India which includes Valliyathura and Punthura.

Table 4.1 Zones of High erosion and accretion identified by other institutions

Institute/ Organisation	NCSCM (2010)	INCOIS (2012)	SAC (2014)	NCCR (2016)	NIOT (present study)
Shoreline Change Analysis studies	• Over the period of 38 years from 1972 to 2010. • USGS Digital Shoreline Analysis System (DSAS) software in ArcGIS.	• Landsat TM and IRS P6 LISS III over the period from 1992-2011 has been considered. • Shoreline change rate were estimated during the period of 1992-2011 using DSAS tool.	• HWL of 1989-91 and HWL of 2004-2006 have been considered to derive the areas under erosion and accretion. • Field checks were carried out and based on field observations, corrections were incorporated.	• Landsat TM, ETM+, IRS P5 PAN, IRS P6 LISS III, Resoursesat LISS IV over the period from 1990-2016 has been used. • Shoreline change rate were estimated during the period of 1990-2016 using DSAS tool.	• From 1988-2017 Landsat, Sentinel images. • USGS Digital Shoreline Analysis System (DSAS) software in ArcGIS.
Analysis of Results (Quantitative/ Qualitative)	The results were categorized into eight classes of zones of erosion/accretion such as: High accretion, medium accretion, low accretion, stable coast, low erosion, medium erosion, high erosion and artificial coast.	The change rates were classified as : high erosion (<-5m/year), Low erosion (-2--5m/year), no change (erosion and accretion up to 2m/year), low accretion (2-5m/year) and high accretion (>5m/year)	Hotspots were identified based on the magnitude of shoreline dynamics. Recent satellite images (2011-2012) were acquired and analyzed.	The change rate was categorized as follows: High erosion (<-5.0) Moderate Erosion (-5.0 to -3.0) Low Erosion (-3.0 to -0.5) Stable coast (-0.5 to 0.5) Low Accretion (0.2 to 3.0) Moderate Accretion (3.0 to 5.0) High Accretion (>5.0)	The change rates were classified as: High accretion (>5m/year), moderate accretion (5-1m/year), stable coast (1to -1m/year), moderate erosion (-1 to -5m/year), high erosion (<-5m/year).
Zones of High Erosion	Valliyathura beach	Between Valliyathura and Punthura- a stretch of 5 Km. (Muthala Pozhi) **1992-1997**- Narakattara (Killi) **1997-2001**-	Valliyathura, Thirvallam	Punthura, Valliyathura	Valliyathura, Punthura, Edapadu **2000-20010**- Punthura (Killi river creek) and Valliyathura

		Valliyathura **2001-2006**-Between Narakattara and Kovalam **2006-2011**-Narakattara (Killi)			**2010-2018**-Shangumukham, Valliyathura and Punthura, Neerody to Edapadu
Zones of High Accretion	Poovar	Poovar, Kovalam, Adimalathura,	Puliyakudi, Poovar	Karumkulam, Kochuthura	Karumkulam, Kottakal and Poovar

4.1.8 Location specific Analysis

Location specific analysis has been done before and after 2010, for every five year period from 2000 and seasonal changes 2017-2018 for the two erosion hotspots on the north of VISL – Valliyathura (as per NGT committee suggestion) and Punthura has been carried out and described in detail.

4.1.8.1 Location specific analysis of Valliyathura

The location of the shoreline along Valliyathura at the specific distance from the constant baseline since the year 2000 has been presented in the Figure 4.15 to 4.17. The analysis of distance from the baseline before and after 2010 has been shown in Figure 4.15. It can be noticed that Valliyathura has been facing eroding trend since 2000.

10 year period may not be sufficient to bring a view on shoreline change, hence five yearly change since 2000 to 2018 has been analyzed and shown in Figure 4.16. It is noticed that 2000-2005 has been facing severe erosion trend, 2005-2010 have slight accreting trend and 2010-2015 have nearly stable trend and in 2015-2018 has been facing eroding trend similar to 2000-2005. A study carried out by Neelima et al., 2017 on shoreline variation along south west coast of India indicates erosion from 1989-2011at Valliyathura and Punthura.

Short term change analysis has been carried out to get an idea about how the changes within a year can happen. Hence, seasonal change analysis for the year Feb 2017- Feb 2018 has been done as shown in Figure 4.17. On an average, Valliyathura has been facing erosion in all the seasons. However, the period Feb 2017- Feb 2018 has faced various issues like Ockhi cyclone during 30 November-1 December 2017 and high wave activities during 2018.

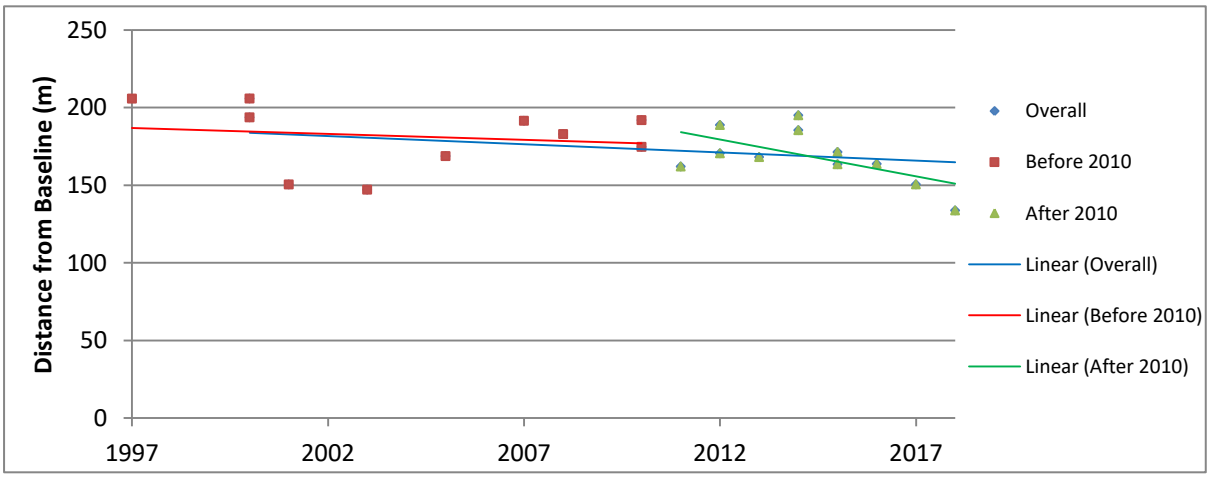


Figure 4.15 Trend of erosion along Valliyathura before and after 2010.

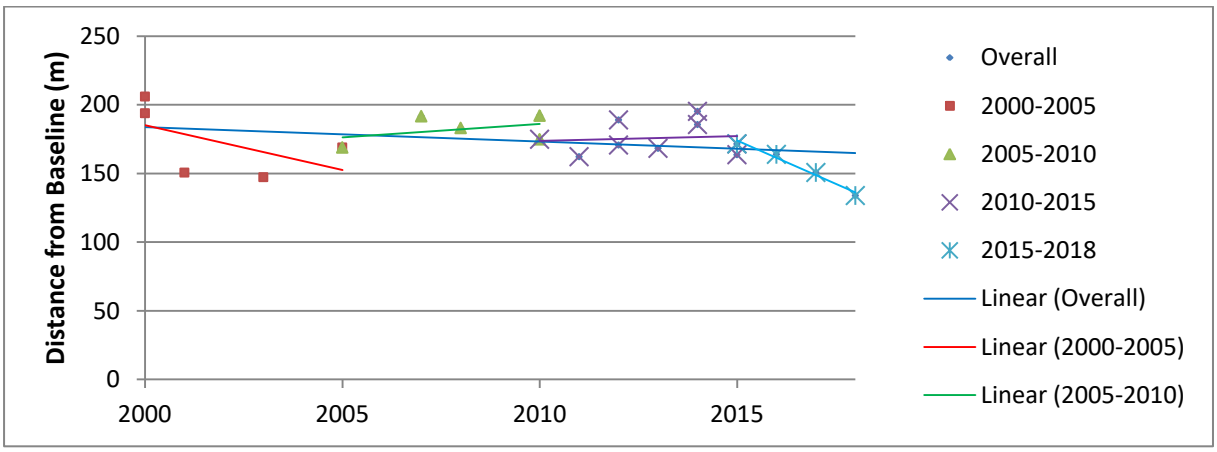


Figure 4.16 Trend of erosion along Valliyathura since 2000 of 5 year interval.

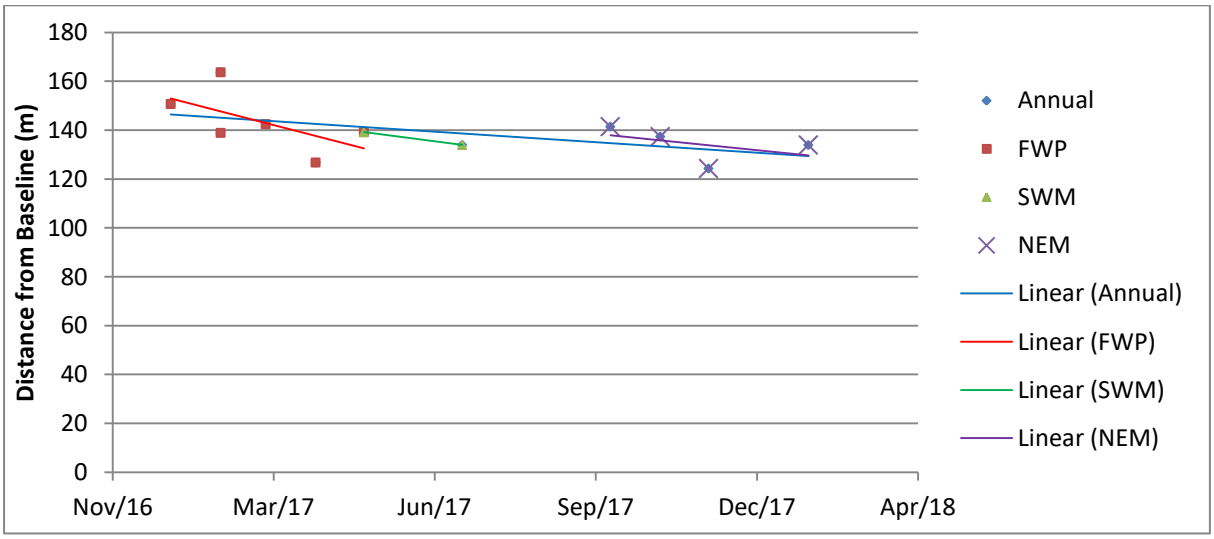


Figure 4.17 Seasonal trend of erosion along Valliyathura Feb 2017- Feb 2018.

4.1.8.2 Location specific analysis of Punthura

Punthura is one of the sites that face erosion along the north of Vizhinjam. Killi river creek is part of Punthura. The analysis of distance from the baseline at Punthura before and after 2010 has been shown in Figure 4.18. It can be noticed that Punthura has been facing eroding trend since 2000 and analysis shows erosion before 2010 and after 2010.

Ten year period may not be suffice to bring a view on shoreline change, hence Five yearly change from 2000 to 2018 has been analyzed and shown in Figure 4.19. It can be noticed that 2000-2005 has been facing erosion trend, 2005-2010 has been facing accretion trend, 2010-2015 have been facing stable trend with slight erosion and in 2015-2018 has been facing eroding trend similar to 2000-2005.

Short term change analysis has to be considered to get an idea about how the changes within a year can happen. Hence, seasonal change analysis for the year Feb 2017- Feb 2018 has been done as shown in Figure 4.20. On an average, Punthura has been facing erosion in a year. Fair weather period shows accreting trend whereas both south west and north east monsoon season shows eroding trend. However, the period Feb 2017- Feb 2018 has faced various issues like Ockhi cyclone during 30th November- 1st December 2017 and high wave activities during 2018.

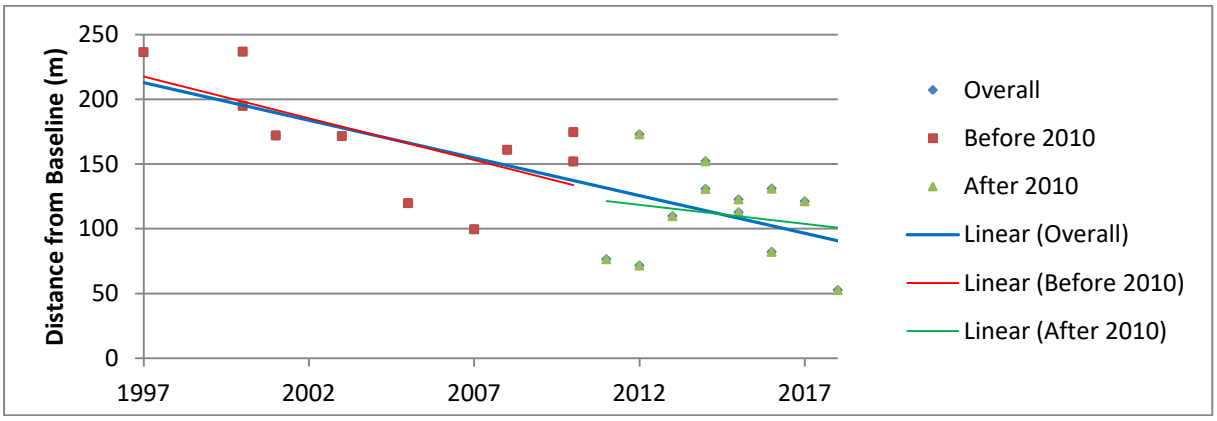


Figure 4.18 Trend of erosion along Punthura before and after 2010.

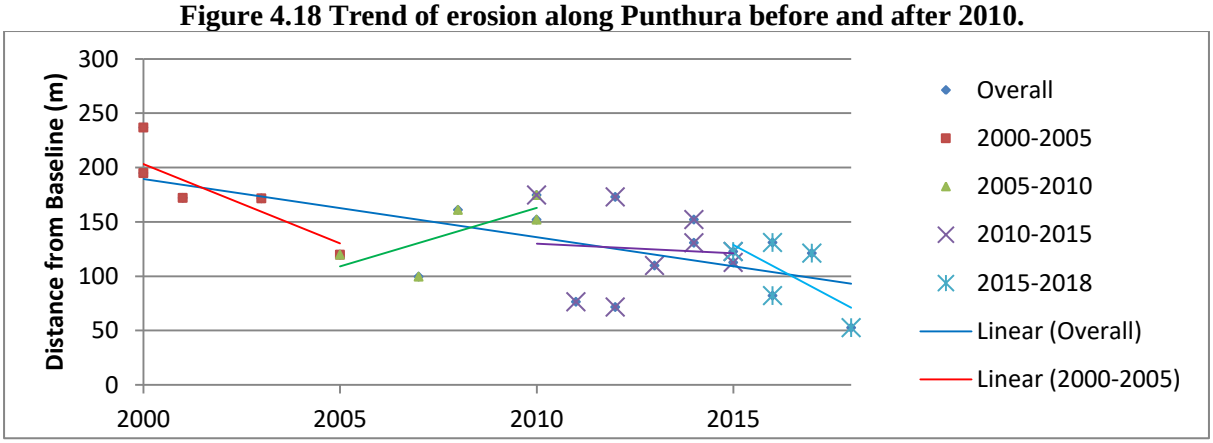


Figure 4.19 Trend of erosion along Punthura since 2000 of 5 year interval.

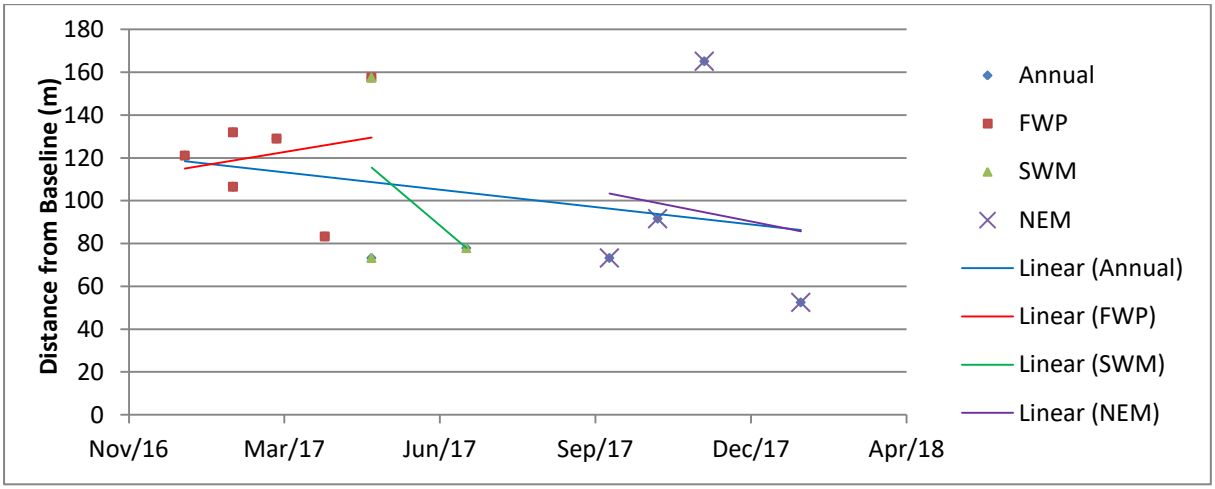


Figure 4.20 Seasonal trend of erosion along Punthura Feb 2017- Feb 2018.

4.2 Results from Beach Profile Analysis

The observations from the beach profile analysis done using SANDS for the entire 40 km stretch is presented as monthly, seasonal, annual and Inter-annual changes in the beach volume for a period from February 2015 to September 2018. The beach profile data consist of both foreshore and offshore profiles. Monthly beach volume changes have been assessed by comparing month to month profiles. The seasonal change is the total monthly volume changes for the particular season i.e. cumulative sum of changes in a season. The annual beach changes assessment is the sum of total changes takes place every month in a particular calendar year that is limited to the monthly data available or used for the analysis. The inter-annual beach assessment is a year to year comparison of beach profiles. We have considered the data collected in February month, every year (months and year in concurrence with the satellite image analysis) for the inter-annual change assessment.

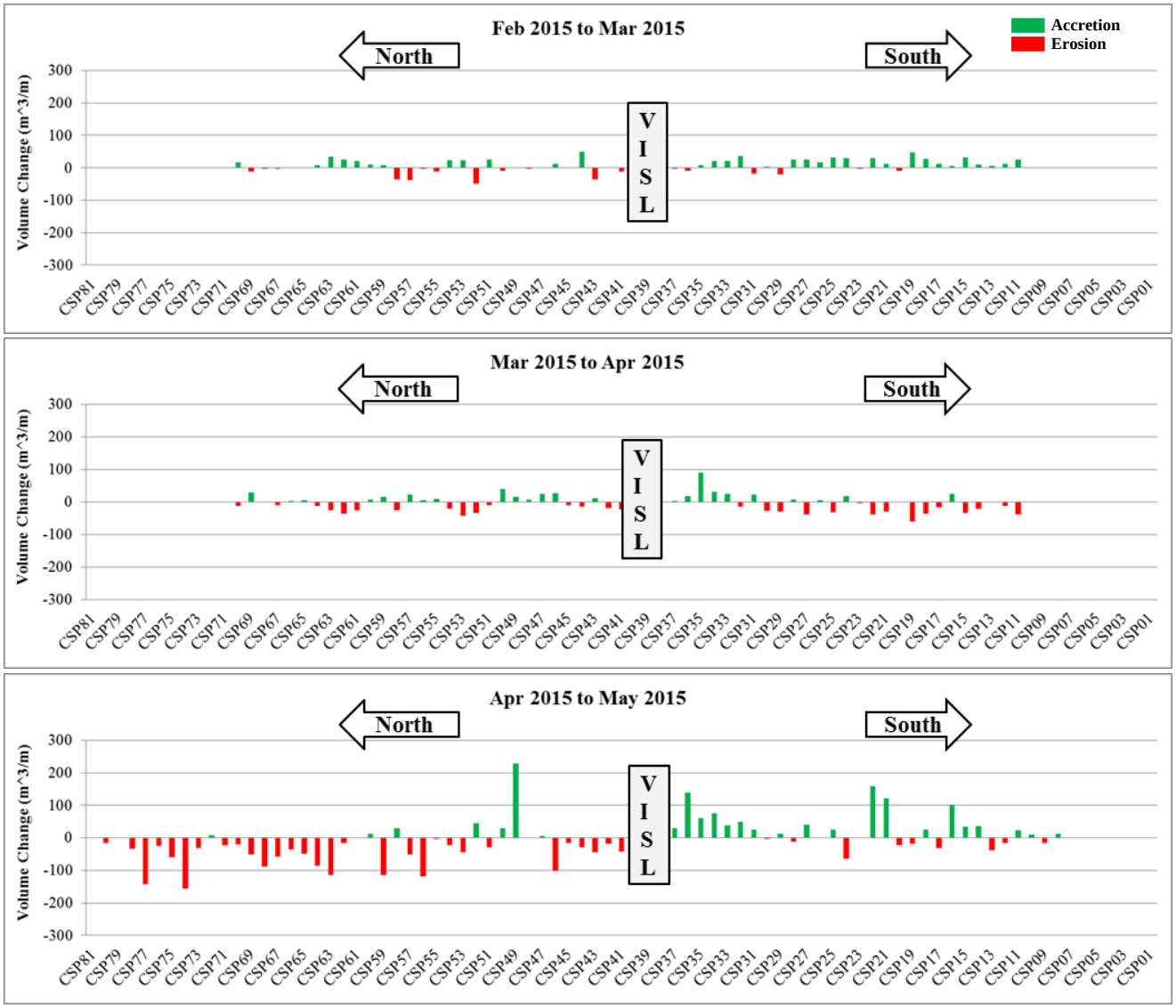
4.2.1 Monthly Beach Profile Variation

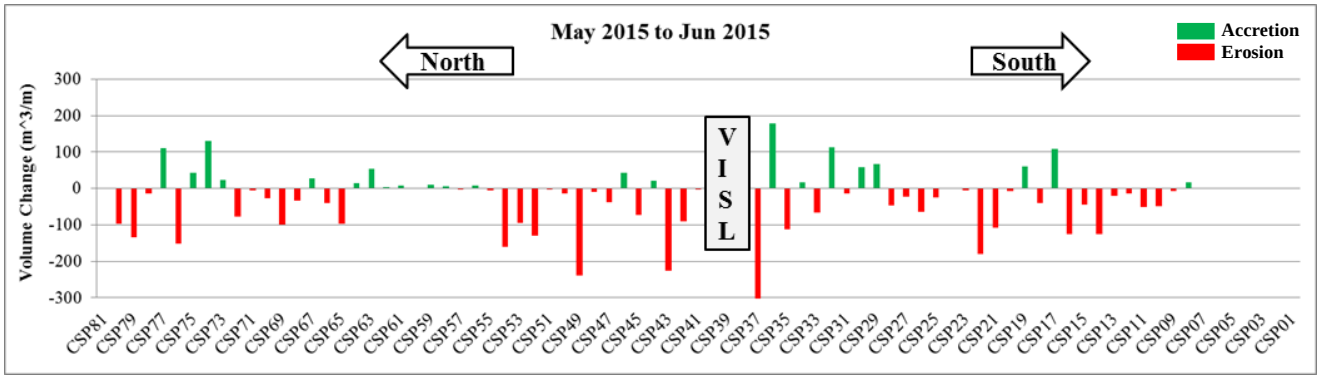
Monthly change in the beach volume is represented in this section for every year based on the month to month comparison of measured profiles. The monthly beach volume changes assessment is useful to understand synoptic / grave oceanic and atmospheric processes that affect the beach.

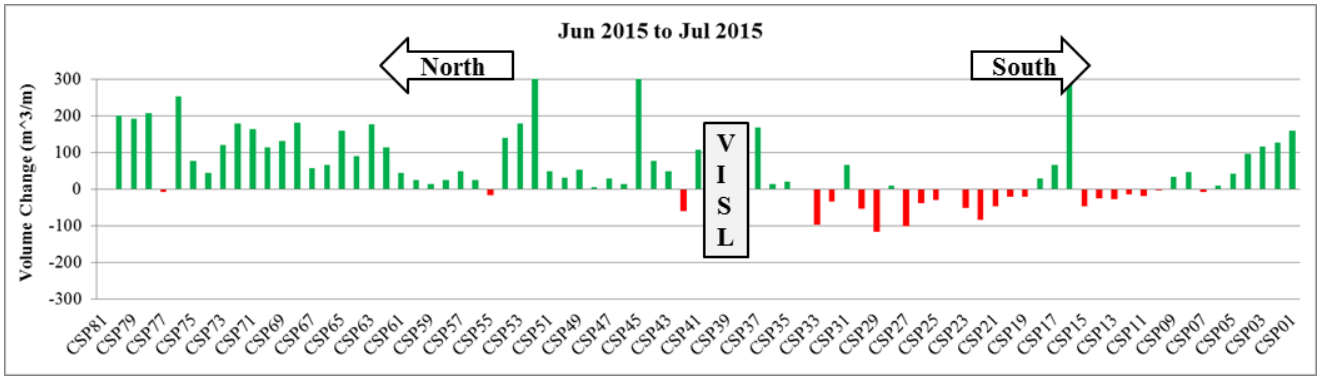
4.2.1.1 Monthly Beach Volume variations in the year 2015

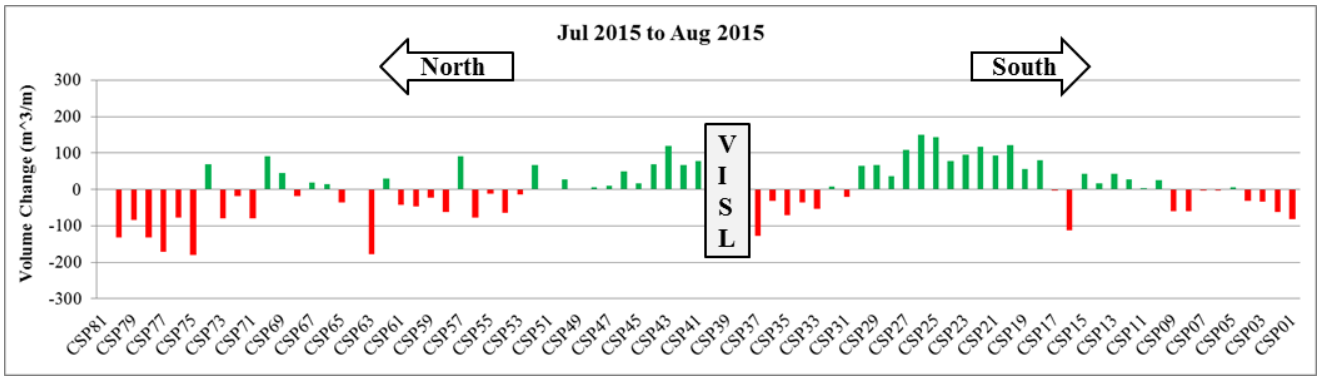
The profile measured during the month of September 2015 was totally discarded from the analysis as part of data quality control. Data was not collected at transects CSP 01 to CSP

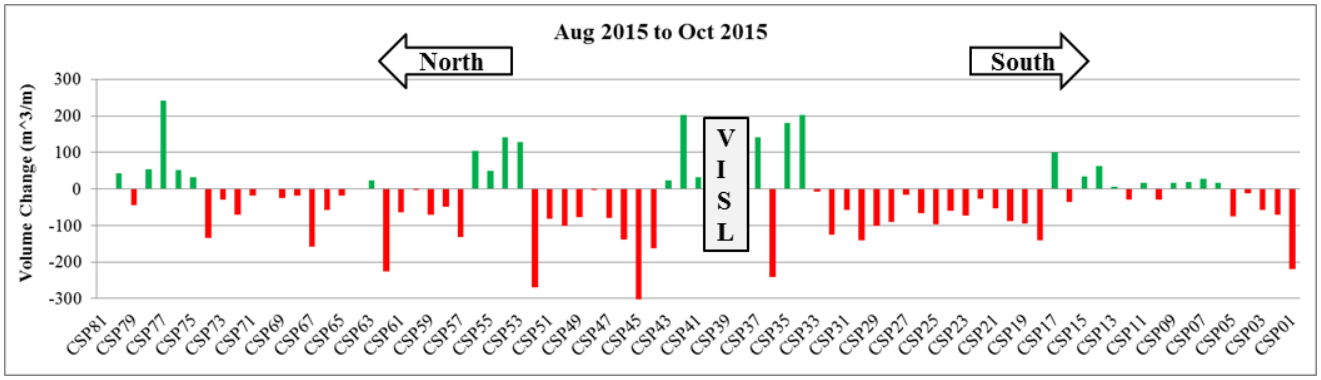
10 and CSP 72 to CSP 81 during the month of February and March 2015. During the year 2015 the coast was found to have an alternative erosion and accretion trend almost at all profile transect and found to have a stable beach with more accretion in intra-annual scenario. The more erosion was found during the month of May to June and August to October 2015. More accretion was found during the month of July to August and November to December 2015. The beach regained well to its position during the month of November and December 2015. The beach volume change between each month is given in the Figure 4.21 and Table 4.2.




May 2015 to Jun 2015
Accretion
Erosion
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Jun 2015 to Jul 2015
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Jul 2015 to Aug 2015
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Aug 2015 to Oct 2015
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01

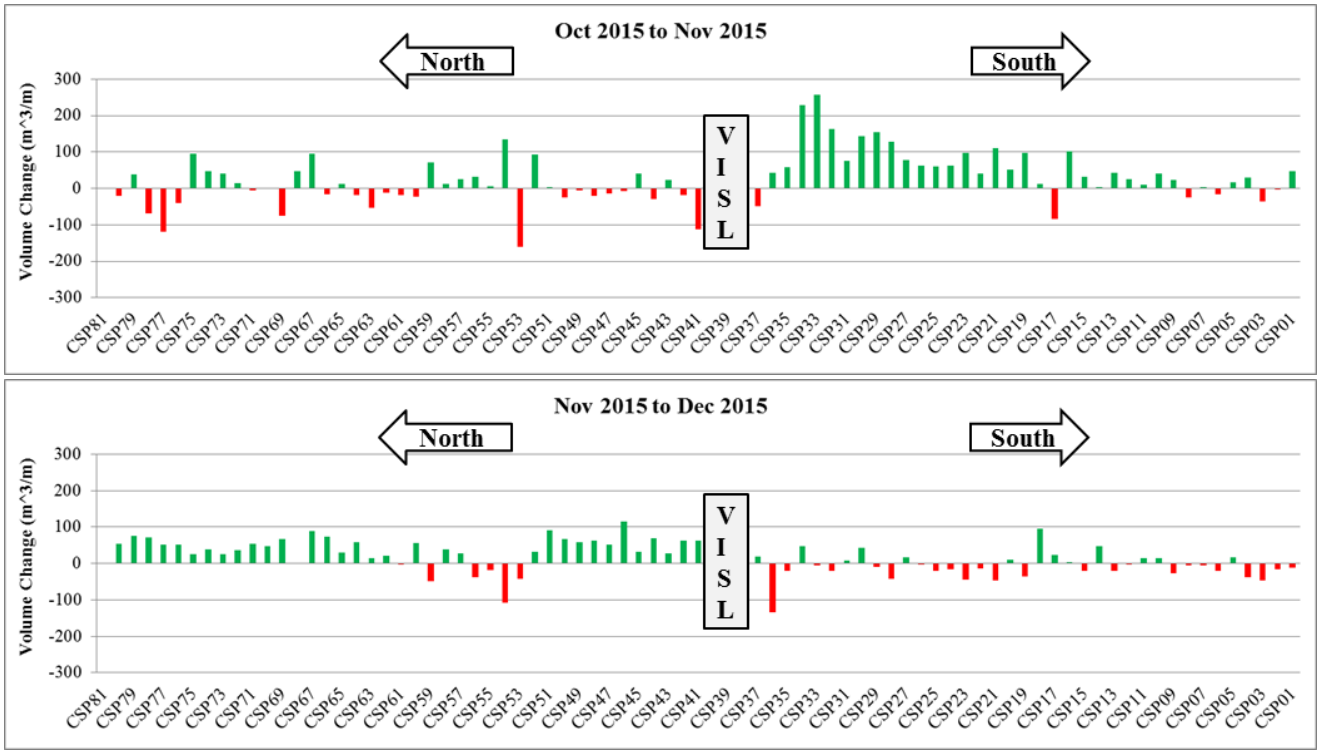


Figure 4.21 Monthly Beach Volume Changes during the year 2015 in m^3/m

NOTE: The red color indicates erosion and green color indicates accretion in the graphs and figures provided. The negative values indicate erosion and the positive values indicate accretion in the Tables provided.

Table 4.2 Monthly Beach Volume Changes during the year 2015 in m^3/m

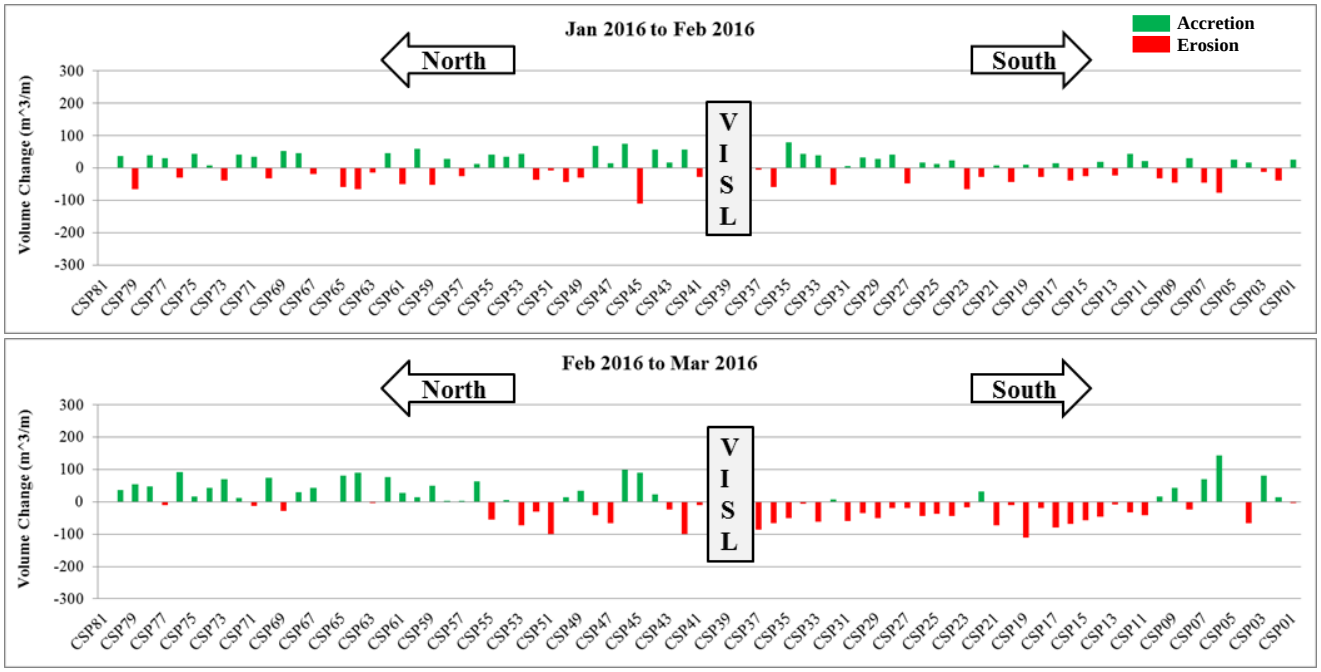
Locations	Profiling Period									
	Feb '15 – Mar '15	Mar '15 – Apr'15	Apr'15 – May '15	May'15 – Jun '15	Jun '15 – Jul '15	Jul'15 – Aug '15	Aug'15 – Oct '15	Oct'15 – Nov '15	Nov'15 – Dec '15	Total
CSP01					159.64	-81.61	-218.97	46.4	-12.55	-107.09
CSP02					127.18	-62.63	-71.38	-1.79	-15.98	-24.6
CSP03					115.48	-34.67	-57.93	-35.33	-45.88	-58.33
CSP04			-		96.29	-31.51	-11.82	29.44	-38.24	44.16
CSP05					42.24	6.71	-74.13	17.67	16.61	9.1
CSP06					8.96	-2.74	17.2	-17.12	-19.58	-13.28
CSP07					-8.67	-1.39	27.56	2.51	-5.79	14.22
CSP08			12.67	16.9	46.4	-59.33	18.89	-25.91	-6.2	3.42
CSP09		-	-15.04	-6.6	33.31	-58.84	17.4	24.08	-26.9	-32.59
CSP10			9.61	-48.55	-3.21	25.48	-30.27	39.62	15.42	8.1
CSP11	24.76	-37.49	23.29	-50.63	-18.15	4.17	16.33	10.96	14.71	-12.05
CSP12	11.34	-12.42	-17.14	-13.66	-13.37	28.14	-28.91	24.74	-3	-24.28
CSP13	5.47	-1.62	-37.14	-21.44	-28.23	42.06	6.02	42.43	-20.3	-12.75
CSP14	11.08	-19.94	37.26	-126.22	-24.9	16.19	62.84	3.06	47.19	6.56
CSP15	31.19	-34.91	33.38	-45.18	-46.3	43.27	34.31	31.91	-19.65	28.02
CSP16	4.84	24.24	99.86	-124.93	290.78	-111.57	-36.78	100.95	2.81	250.2
CSP17	11.71	-16.44	-31.84	107.45	66.22	-3.47	99.35	-84.73	22.94	171.19
CSP18	27.32	-35.88	24.4	-39.56	28.22	79.57	-141.23	12.4	95.56	50.8
CSP19	47.9	-59.89	-17.68	60.97	-20.41	56.21	-95.08	97.64	-36.08	33.58

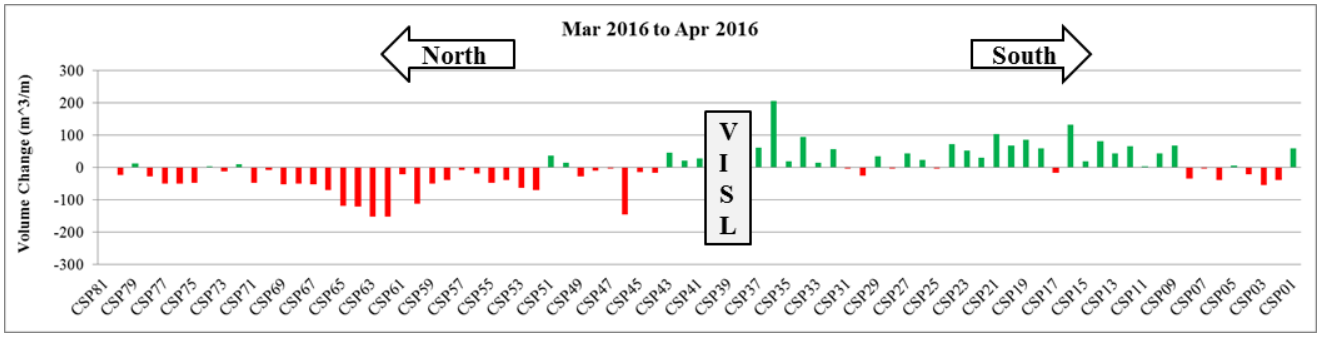
CSP20	-8.5	-1.51	-21.88	-6.31	-20.56	121.7	-88.34	52.04	10.2	36.84
CSP21	12.71	-30.46	121.31	-107.27	-47.37	93.94	-54.21	111.5	-47.53	52.62
CSP22	30.58	-38.33	157.65	-180.28	-84.95	117.13	-28.04	41.56	-13.63	1.69
CSP23	-0.77	-3	1.51	-5.9	-50.64	94.79	-72.73	98.31	-43.9	17.67
CSP24	28.74	18.19	-65.03	-		77.87	-59.4	63.61	-16.28	47.7
CSP25	31.63	-32.81	25.12	-25.31	-28.84	142.43	-97.85	60.99	-19.42	55.94
CSP26	16.3	4.92	2.25	-64.13	-38.68	149.76	-66.33	63.3	-2.84	64.55
CSP27	25.27	-38.21	41.74	-21.94	-101.8	107.85	-16	77.31	16.67	90.89
CSP28	25	7.45	-12.2	-46.92	8.72	36.48	-91.03	128.4	-42.42	13.48
CSP29	-19.52	-29.01	12.11	67.97	-116.53	67.22	-101	154.81	-9.27	26.78
CSP30	2.59	-27.2	-1.78	58.78	-52.83	64.81	-140.23	143.47	42.94	90.55
CSP31	-18.55	22.44	25.71	-13.24	65.52	-21.04	-57.1	76.68	8.48	88.9
CSP32	36.33	-13.82	50.42	112.57	-34.79	8.87	-125.8	163.94	-21.05	176.67
CSP33	20.88	25.03	37.96	-65.82	-97.69	-52.99	-8.43	257.41	-5.66	110.69
CSP34	21.31	30.41	75.49	15.92	-2.26	-34.91	202.33	229.04	47.2	584.53
CSP35	8.83	90.45	60.35	-111.98	20.87	-70.54	179.86	58.05	-20.36	215.53
CSP36	-8.84	17.78	138.83	177.82	13.54	-30.75	-241.03	42.06	-133.42	-24.01
CSP37	-0.52	0.63	29.63	-310.83	167.56	-128.01	140.8	-48.6	19.36	-129.98
CSP38	**Port Area**									
CSP39										
CSP40										
CSP41	-12.76	-22.73	-42.75	-0.76	108.33	76.94	32.37	-111.68	62.36	89.32
CSP42	1.39	-19.2	-19.11	-90.72	-61.2	67.76	203.43	-17.77	61.85	126.43
CSP43	-35.58	12.29	-44.78	-226.09	47.71	120.07	24.23	24.15	27.61	-50.39
CSP44	49.81	-15.35	-30.1	20.53	77.55	70.02	-162.85	-29.71	69.3	49.2
CSP45	1.78	-10.65	-16.48	-72.71	347.5	16.54	-314.57	40.88	31.6	23.89
CSP46	13.29	27.41	-101.13	42.4	13.08	49.43	-138.32	-6.51	115.56	15.21
CSP47	2.42	24.32	4.79	-38.93	28.66	11.12	-78.88	-13.97	50.65	-9.82
CSP48	-3.95	7.2	2.16	-9.81	4.21	5.16	-1.45	-20.55	63.07	46.04
CSP49	0.44	15.12	227.67	-238.06	52.75	1.93	-77.81	-6.17	57.85	33.72
CSP50	-9.25	39.64	30.09	-13.15	31.48	27.51	-101.17	-25.07	67.37	47.45
CSP51	25.05	-9.79	-29.64	-2.47	48.19	0.4	-81.88	4.26	90.33	44.45
CSP52	-47.91	-33.75	44.27	-130.67	327.2	67.05	-270.18	93.3	32.83	82.14
CSP53	24.06	-42.69	-45.34	-95.2	178.35	-14.21	127.45	-160.67	-42.52	-70.77
CSP54	23.84	-20.42	-23.03	-159.89	140.84	-64.51	141.47	134.17	-108.47	64
CSP55	-12.14	8.52	-0.22	-4.8	-16.18	-10.84	49.01	6.71	-18.32	1.74
CSP56	-0.82	5.09	-119.17	6.96	23.82	-77.86	103.72	32.71	-38.72	-64.27
CSP57	-37.47	22.76	-50.59	-3.97	47.77	91.86	-131.16	24.94	28.57	-7.29
CSP58	-35.81	-25.54	29.66	4.64	25.85	-62.43	-47.87	12.06	38.86	-60.58
CSP59	8.15	16.3	-114.63	9.06	13.76	-22.61	-70	70.23	-48.48	-138.22
CSP60	10.14	6.4	11.96	1.4	24.04	-46.52	-3.36	-21.69	56.26	38.63
CSP61	20.94	-24.2	2.07	8.37	44.01	-41.89	-63.86	-17.25	-3.37	-75.18
CSP62	25.05	-36.21	-15.52	3.13	114.77	29.24	-226.02	-12.81	21.61	-96.76
CSP63	33.76	-25.36	-113.89	53.4	178.09	-176.86	22.21	-52.5	14.24	-66.91
CSP64	6.9	-13.15	-86.13	13.62	90.14	-		-18.42	57.55	50.51
CSP65	2.08	5.01	-49.32	-97.07	160.58	-35.09	-17.56	11.3	29.3	9.23
CSP66	2.02	1.86	-36.49	-39.77	65.92	13.73	-56.83	-15.78	73.7	8.36
CSP67	-4.01	-10.56	-57.42	27.73	56.59	18.97	-158.34	96.11	88.09	57.16
CSP68	-3.16	-2.13	-88.48	-33.02	181.38	-18.55	-18.59	48.23	-	65.68
CSP69	-11.93	28.79	-51.31	-99.5	131.66	46.02	-23.85	-74.24	67.33	12.97
CSP70	17.62	-11.2	-21.24	-27.39	114.14	90.48	-		48.32	210.73
CSP71	-		-23.09	-5.23	164.17	-78.69	-18.18	-4.22	53.23	87.99
CSP72			8.27	-78.25	179.27	-17.78	-69.93	14.89	36.41	72.88
CSP73			-31.42	22.91	119.84	-80.03	-29.62	39.77	25.91	67.36
CSP74			-156.11	129.28	45.11	69.21	-133.19	47.74	37.42	39.46

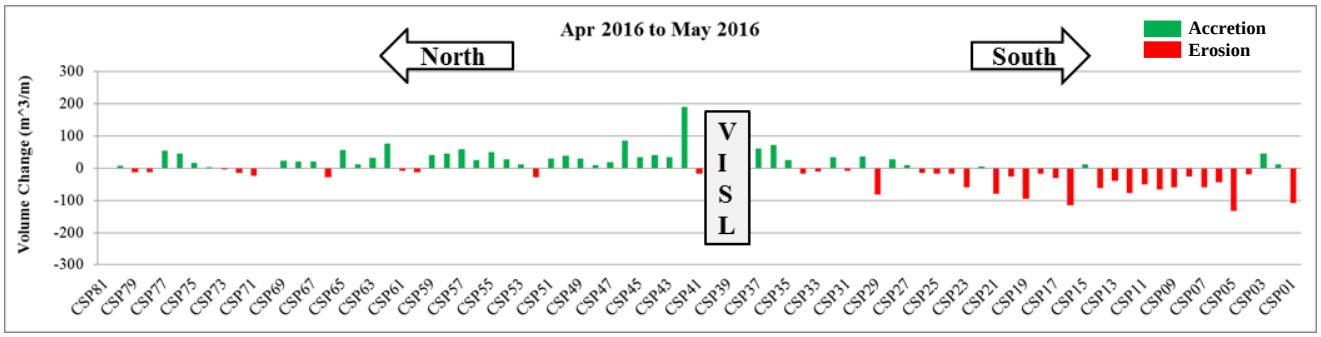
CSP75		-59.11	43.7	76.96	-179.95	33	94.7	26.47	35.77
CSP76		-25.58	-151.88	254.15	-77.26	51.55	-40.36	51.72	62.34
CSP77		-143.39	110.31	-8.88	-170.77	240.91	-118.33	51.13	-39.02
CSP78		-34.59	-14.04	208.07	-131.66	53.96	-67.68	72.27	86.33
CSP79		0.19	-133.3	192.66	-84.26	-43.58	38.9	75.02	45.63
CSP80		-16.21	-97.11	200.95	-132.06	42.11	-20.63	53.54	30.59
CSP81	-								0
(-) indicates Erosion **(+) indicates Accretion** **- Data not used for analysis**									

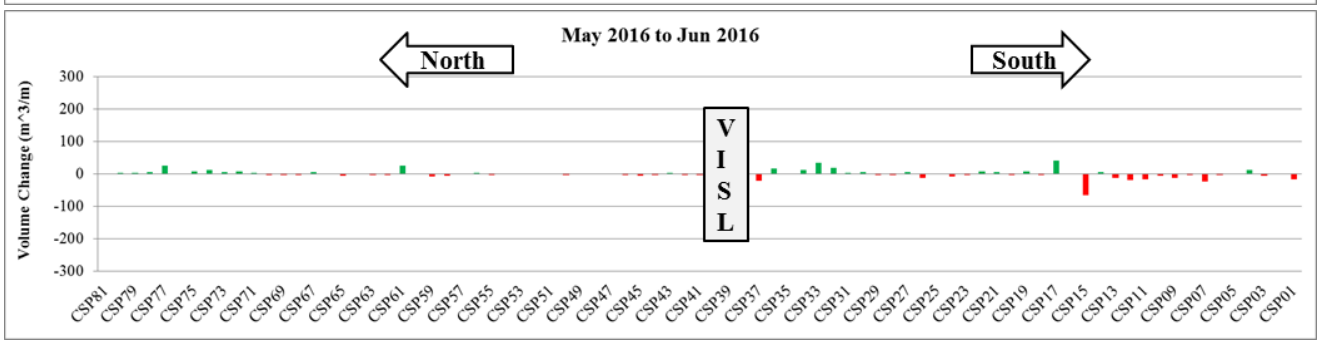
4.2.1.2 Monthly Beach Volume variations in the year 2016

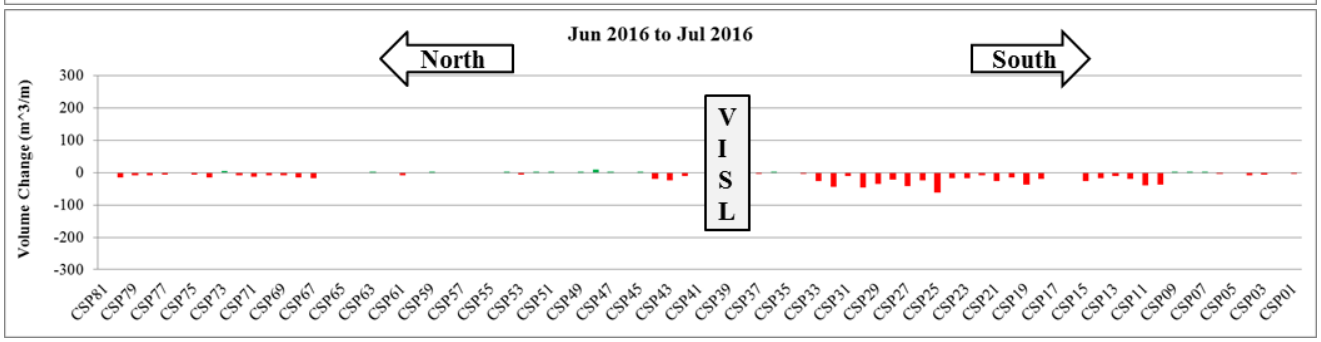
During the year 2016 the coast was found to have an alternative erosion and accretion trend at all profile transect and at few stretches particularly near Kovalam beach (CSP 45 to CSP 52) and Valliyathura (CSP 60 to CSP 66 except CSP 62) the beach shows net erosion during 2016. The northern part of the coast between CSP 67 to CSP 80 (Table 4.3) shows net accretion. During the month between September 2016 and November 2016 the beaches exhibit accretion (Figure 4.22). The beach got reclaimed which was lost to monsoon waves during these months. The erosion was found to be more during the month of June 2016 (Figure 4.22). The beach regained well to its position during the end of the year at most of the profiles lines except at Kovalam beach (CSP 45 to CSP 52). The beach volume change between each month was given in the Figure 4.22 and Table 4.3.

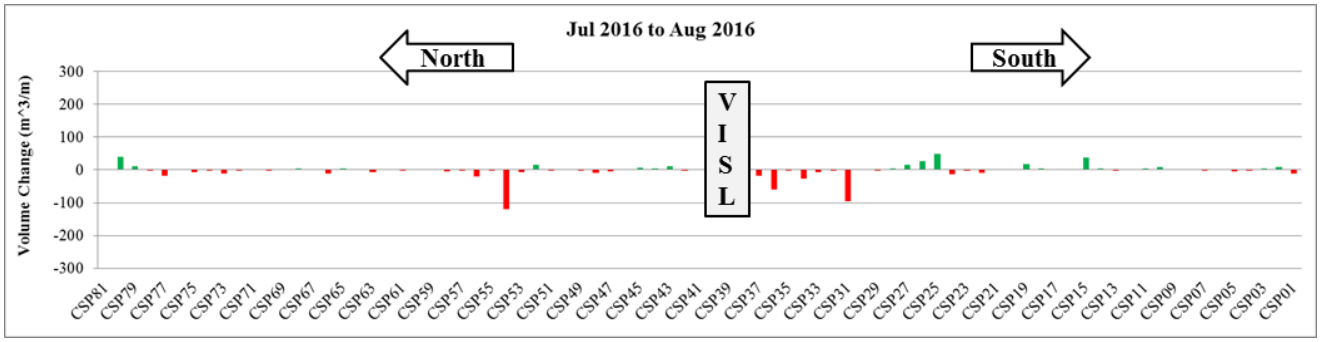



Mar 2016 to Apr 2016
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Apr 2016 to May 2016
Accretion
Erosion
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


May 2016 to Jun 2016
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Jun 2016 to Jul 2016
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Jul 2016 to Aug 2016
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01

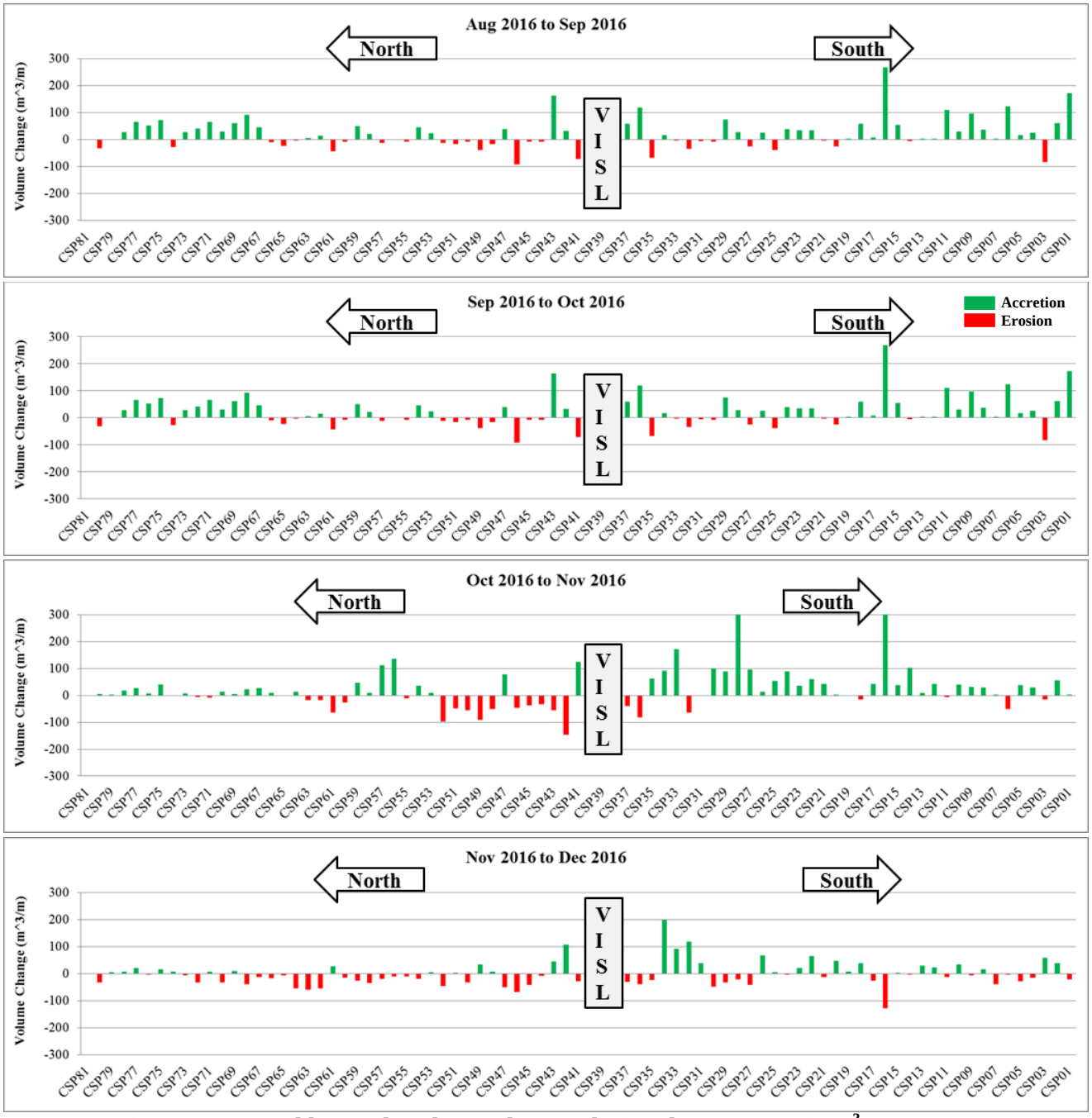


Figure 4.22 Monthly Beach Volume Changes during the year 2016 in m^3/m

Table 4.3 Monthly Beach Volume Changes during the year 2016 in m^3/m

Locations	Profiling Period											
	Jan '16 - Feb '16	Feb '16 – Mar '16	Mar '16 – Apr'16	Apr'16 – May '16	May'16 – Jun '16	Jun '16 - Jul'16	Jul'16 – Aug '16	Aug'16 – Sep '16	Sep'16 – Oct '16	Oct'16 – Nov '16	Nov'16 – Dec '16	Total
CSP01	25.84	-	59.36	-108.55	-15.17	-3.01	-11.1	171.95	-88.47	2.93	-19.79	13.99
CSP02	-38.31	14.9	-38.52	11.37	-		8.57	60.84	57.82	55.06	39.28	171.01
CSP03	-12.1	79.76	-54.81	44.07	-4.29	-5.57	4.74	-83.63	-85.3	-15.57	58.4	-74.3
CSP04	15.21	-66.06	-19.8	-18.69	12.05	-7.5	-1.74	25.76	-85.01	29.28	-14.33	-130.83
CSP05	25.04	-1.83	5.84	-133.55	1.41	-1.47	-4.4	16.17	-37.96	38.27	-26.46	-118.94
CSP06	-77.76	143.06	-38.22	-44.29	-0.23	-4.07	0.26	124.16	13.3	-51.66	-0.5	64.05
CSP07	-46.9	69.28	-2.54	-59.11	-23.67	0.15	-1.34	4.84	-15.22	2.76	-38.91	-110.66
CSP08	30.17	-23.23	-33.18	-26.23	-1	0.8	1.49	36.58	-118.51	30.44	16.45	-86.22
CSP09	-45.14	43.6	67.88	-59.1	-11.55	0.31	0.58	96.44	-66.03	31.18	-3.94	54.23

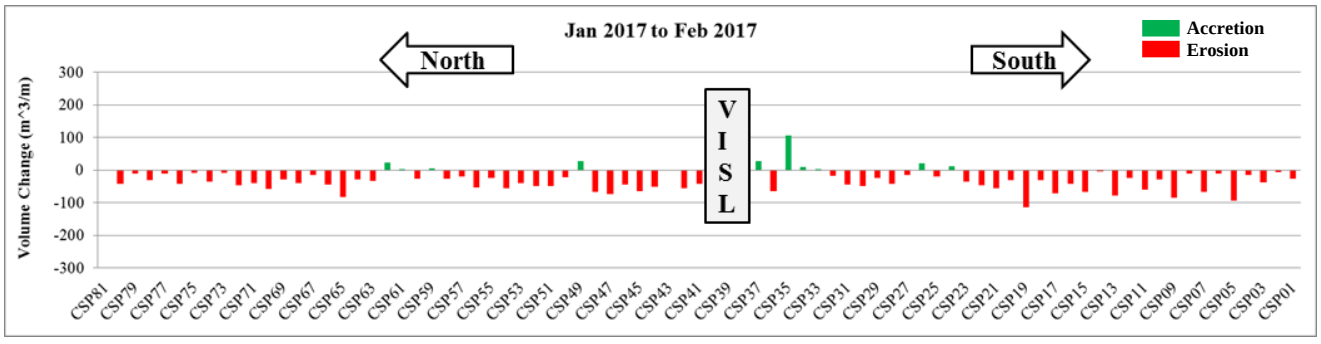
CSP10	-32.49	16.51	44.13	-65.82	-4.81	-36.71	8.74	30.94	11.04	40.17	35.57	47.27
CSP11	20.61	-42.88	3.59	-49.85	-15.87	-40.32	4.01	110.19	48.07	-5.26	-10.65	21.64
CSP12	43.87	-32.97	66.55	-77	-18.07	-20.03	2.95	3.56	4.61	43.31	24.66	41.44
CSP13	-24.78	-9.44	44.7	-40.28	-12.55	-10.92	-0.92	2.94	71.38	9.49	31.03	60.65
CSP14	19.07	-46.05	81.06	-62.39	6.72	-18.34	3.38	-4.9	11.62	103.59	-0.24	93.52
CSP15	-26.11	-56.9	18.4	12.57	-65.39	-25.76	37.14	55.29	12.24	37.26	4.22	2.96
CSP16	-39.28	-67.97	133.6	-115.05	-			267.98	-128.6	355.27	-127.01	278.94
CSP17	14.27	-80.21	-17.23	-30.49	41.82	-		7.8	-7.2	41.9	-24.92	-54.26
CSP18	-27.72	-20.34	59.99	-18.13	-1.12	-18.85	5.44	59.84	-20.78	-14.42	39.56	43.47
CSP19	8.86	-109.85	86.87	-96.01	8.13	-38.03	17.46	3.08	16.44	-2.34	9.16	-96.23
CSP20	-44.79	-11	67.36	-25.77	-2.44	-16.03	0.22	-24.18	34.42	3.51	48.05	29.35
CSP21	7.79	-73.85	104.92	-79.16	6.39	-26.06	3.01	-2.85	17.59	43.58	-11.75	-10.39
CSP22	-28.74	30.71	31.16	5.83	9.19	-8.83	-8.8	34.26	37.84	60.58	66.43	229.63
CSP23	-65.69	-16.69	53.35	-59.66	-3.08	-16.74	-1.96	34.48	28.13	37.17	20.89	10.2
CSP24	22.07	-44.13	71.91	-17.1	-7.08	-16.8	-14.43	39.36	-20.48	89.72	-0.83	102.21
CSP25	11.31	-36.7	-0.94	-17.09	0.19	-60.99	49.44	-38.48	6.41	53.33	4.99	-28.53
CSP26	16.33	-44.7	24.25	-14.1	-11.35	-23.83	27.14	25.32	-1.32	13.44	69.13	80.31
CSP27	-47.29	-19.51	44.74	10.08	4.97	-41.54	15.12	-25.02	-11.54	96.99	-40.57	-13.57
CSP28	41.2	-18.57	-3.22	28.15	-0.31	-22.52	5.14	27.72	-378.77	467.63	-20.22	126.23
CSP29	27.53	-49.77	34.47	-81.21	-1.54	-35.04	-1.89	75.76	-37.52	88.53	-31.47	-12.15
CSP30	32.83	-34.34	-25.39	36.45	6.8	-45.84	2.92	-8.27	-9.66	100.36	-47.52	8.34
CSP31	6.1	-59.13	-2.94	-8.56	3.74	-9.7	-94.98	-4.12	32.76	-2.29	39.87	-99.25
CSP32	-53.15	6.53	57.11	33.99	20.4	-42.96	-2.54	-33.1	23.61	-64.3	118.7	64.29
CSP33	38.11	-61.77	16.07	-10.8	34.09	-26.51	-5.66	-1.67	-71.25	172.79	92.56	175.96
CSP34	44.04	-7.29	94.88	-17.02	12.38	-3.81	-27.25	17.85	-3.76	92.82	200.42	403.26
CSP35	78.72	-50.74	18.85	24.6	0	0	-2.18	-66.86	36.44	63.54	-23.58	78.79
CSP36	-60.06	-66.09	205.91	72.54	16.84	1.98	-60.64	118.68	-140.2	-82.15	-39.31	-32.5
CSP37	-5.27	-87.43	62.1	60.55	-20.08	-3.48	-18.03	58.33	88.89	-39.32	-28.75	67.51
CSP38	**Port Area**											
CSP39												
CSP40												
CSP41	-27.92	-10.2	27.3	-17.16	-0.42	-0.8	2.4	-71.45	-71.59	125.75	-27.65	-71.74
CSP42	56.42	-99.5	22.46	190.37	-0.41	-10.8	-2.44	33.63	213.58	-146.81	107.21	363.71
CSP43	16.17	-24.46	45.66	34.73	4.31	-23.74	11.03	162.79	47.41	-55.29	45.73	264.34
CSP44	56.73	22.86	-16.66	40.76	-0.54	-19.37	3.79	-6.4	47.04	-32.32	-7.96	87.93
CSP45	-111.42	89.65	-13.6	34.54	-5.91	0.33	6.25	-7.87	-39.27	-36.89	-40.98	-125.17
CSP46	75.17	97.6	-145.14	86.14	-0.09	-		-92.34	29.19	-46	-68.28	-63.75
CSP47	14.03	-67.12	-0.11	19.17	0.71	1.31	-3.84	39.55	-40.92	77.91	-49.63	-8.94
CSP48	67.65	-42.29	-8.47	10.47	1.14	8.34	-9.78	-15.9	30.93	-50.27	8.09	-0.09
CSP49	-30.92	34.19	-26.58	29.84	0.81	3.11	-3.17	-39.12	34.47	-91.64	34.27	-54.74
CSP50	-44.24	14.12	15.51	37.6	-2.41	-0.53	3.08	-6.77	-68.79	-55.38	-31.31	-139.12
CSP51	-7.84	-100.72	37.43	29.73	1.57	2.02	-3.07	-17.1	-47.39	-49.03	3.53	-150.87
CSP52	-36.24	-29.68	-68.92	-29.31	1.26	3.48	16.11	-11.21	19.73	-97.31	-46.13	-278.22
CSP53	43.54	-72.55	-62.31	12.69	2.41	-7.03	-5.74	23.76	99.24	10.4	5.89	50.3
CSP54	33.97	4.56	-38.51	26.64	0.08	0.17	-118.91	47.05	212.35	35.78	-18.54	184.64
CSP55	41.74	-55.45	-47.92	49.21	-1.85	-0.28	-0.14	-6.23	74.13	-11.73	-9.01	32.47
CSP56	11.94	62.72	-17.89	24.21	4.26	-0.95	-19.72	-		136.86	-10.51	190.92
CSP57	-26.64	0.2	-7.24	59.09	0.17	-0.06	-2.63	-12.41	-5.48	112.52	-17.33	100.19
CSP58	28	2.38	-37.92	45.13	-5.06	-1.67	-3.81	20.68	31	10.06	-34.95	53.84
CSP59	-53.72	49.68	-50.1	41.32	-6.37	0.44	0.31	50.93	-3.46	47.26	-24.2	52.09
CSP60	59.48	12.94	-112.67	-12.78	0.44	-0.81	0.02	-6.46	17.87	-25.71	-14.02	-81.7
CSP61	-51.38	26.41	-20.22	-8.62	25.41	-8.37	-1.38	-43.42	39.37	-64.24	28.32	-78.12
CSP62	45.02	76.25	-151.93	77.12	-1.23	-0.95	0.48	14.11	20.72	-16.9	-52.84	9.85
CSP63	-14.15	-4.26	-152.66	31.78	-1.39	3.28	-6.08	5.95	81.03	-16.74	-58.74	-131.98
CSP64	-65.91	88.83	-120.87	11.74	-			-0.86	74.26	13.94	-53.7	-52.57
CSP65	-60.44	81.16	-117.7	55.56	-5.88	-0.83	4.01	-22.49	64.04	-1.29	-5.05	-8.91

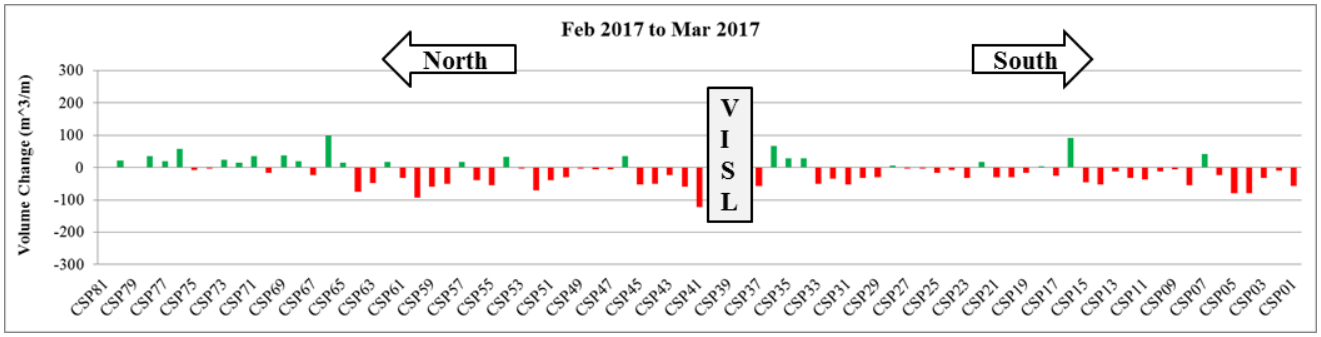
CSP66	-	-2.51	-70.01	-28.35	0.25	-1.43	-11.04	-9.65	95.26	8.92	-15.52	-34.08
CSP67	-19.53	43.66	-51.78	21.48	5.71	-18.23	0.89	46.08	8.53	26.22	-10.78	52.25
CSP68	45.85	29.32	-48.91	19.69	-2.62	-16.18	4.76	93.73	66.13	22.62	-37.29	177.1
CSP69	50.85	-28.39	-50.91	22.83	-1.14	-9.43	2.98	60.76	80.24	5.38	11.04	144.21
CSP70	-32.96	73.02	-8.13	-0.12	-3	-8.77	-2.98	30.67	94.74	13.73	-30.72	125.48
CSP71	34.97	-12.14	-47.77	-23.32	3.39	-13.2	1.81	65.32	19.13	-9.08	8.07	27.18
CSP72	39.77	11.06	9.53	-14.34	7.55	-8.25	-0.49	41.17	80.67	-6.32	-30.9	129.45
CSP73	-39.25	69.11	-12.75	-3.26	6.68	5.2	-10.6	29.02	61.37	7.93	-5.49	107.96
CSP74	7.53	43.39	4.7	1.24	13.84	-15.23	-2.29	-26.72	82.66	-0.72	7.61	116.01
CSP75	43.76	15.85	-47.71	15.14	8.88	-6.93	-7.45	72.9	56.57	39.9	16.37	207.28
CSP76	-31.54	92.26	-48.99	46.06	-		2.79	51.91	93.97	7.15	-1.49	212.12
CSP77	29.03	-11.54	-48.79	53.53	26.89	-7.03	-18.14	65.19	53.52	26.63	21.71	191
CSP78	39.62	46.66	-28.13	-13.16	5.79	-9.52	-3.19	27.39	83.47	17.61	8.27	174.81
CSP79	-66.41	54.95	12.94	-12.62	2.92	-8.47	10.37	2.32	74.1	2.14	5.96	78.2
CSP80	36.09	36.84	-22.32	6.62	4.5	-15.43	39.64	-30.8	85.69	4.79	-30.81	114.81
CSP81	-											

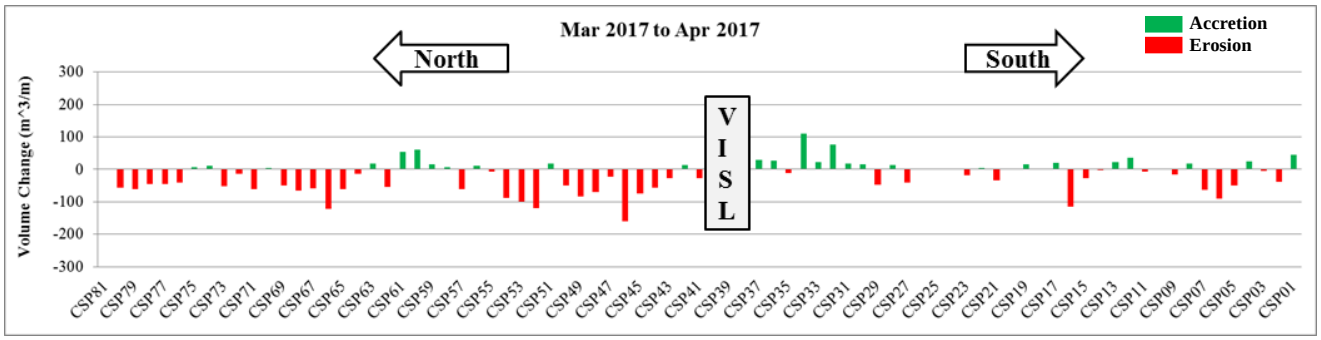
(-) indicates Erosion **(+) indicates Accretion**
- Data not used for analysis

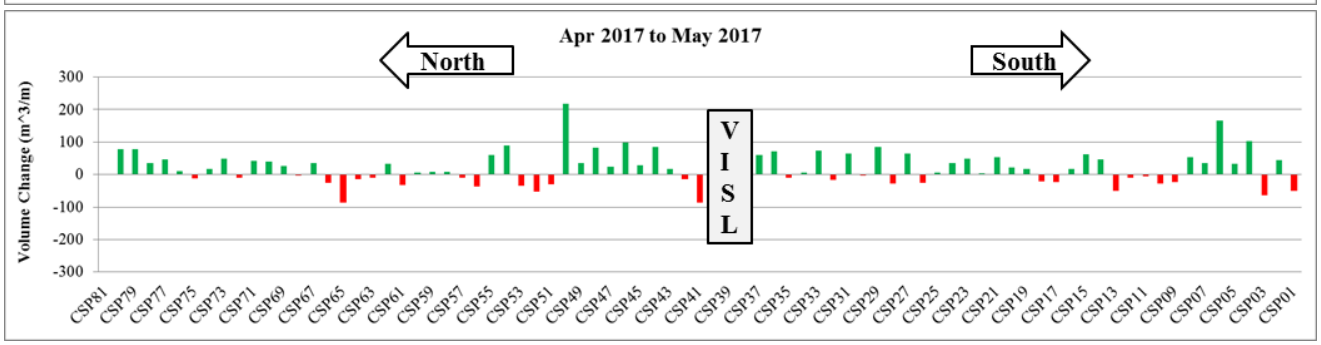
4.2.2 Monthly Beach Volume variations in the year 2017

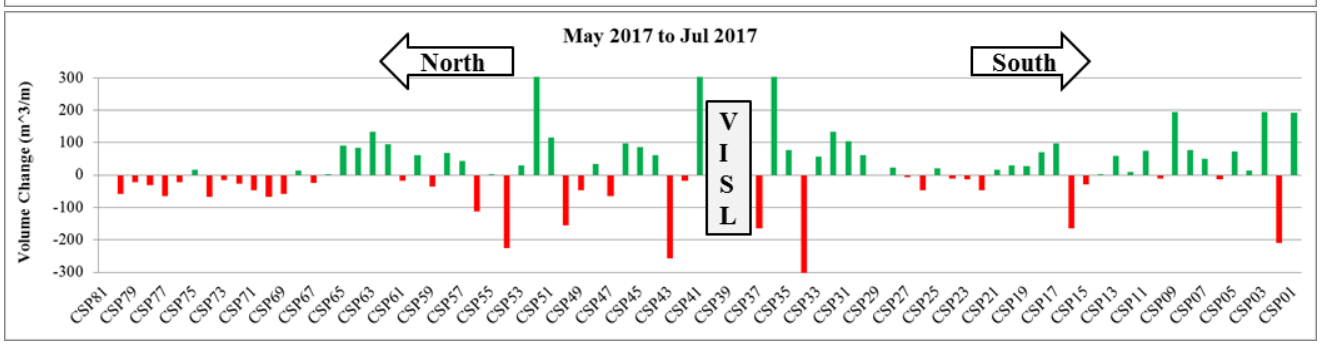
The profile measured during the month of June 2017 was totally discarded from the analysis. For December 2017 foreshore profile data was not available and only offshore data was considered for analysis. During the year 2017 significant amount of erosion was observed as most of the coastal stretch shows net erosion (Table 4.4). The month of January and February 2017 shows erosion at most of the coastal stretch and this scenario continues till March 2017 (Figure 4.23). During the month between April and June 2017 few beach stretches (for example CSP 44 to CSP 50) regained it beach (Table 4.4). Again at the onset of monsoon the beach shows erosion during the month of July to September 2017. The south of Poovar (CSP 09 to CSP 16) and north of Valliyathura had more net (CSP 63 to CSP 72) erosion rate and beach formation was found to be very low throughout the year (Table 4.4). The beach volume change between each month was given in the Figure 4.23 and Table 4.4.

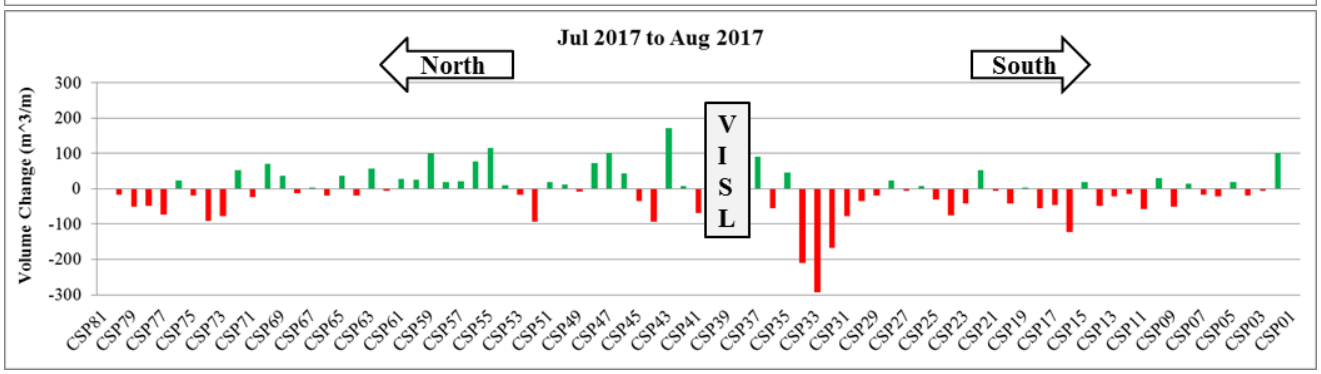



Feb 2017 to Mar 2017
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Mar 2017 to Apr 2017
Accretion
Erosion
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Apr 2017 to May 2017
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


May 2017 to Jul 2017
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Jul 2017 to Aug 2017
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01

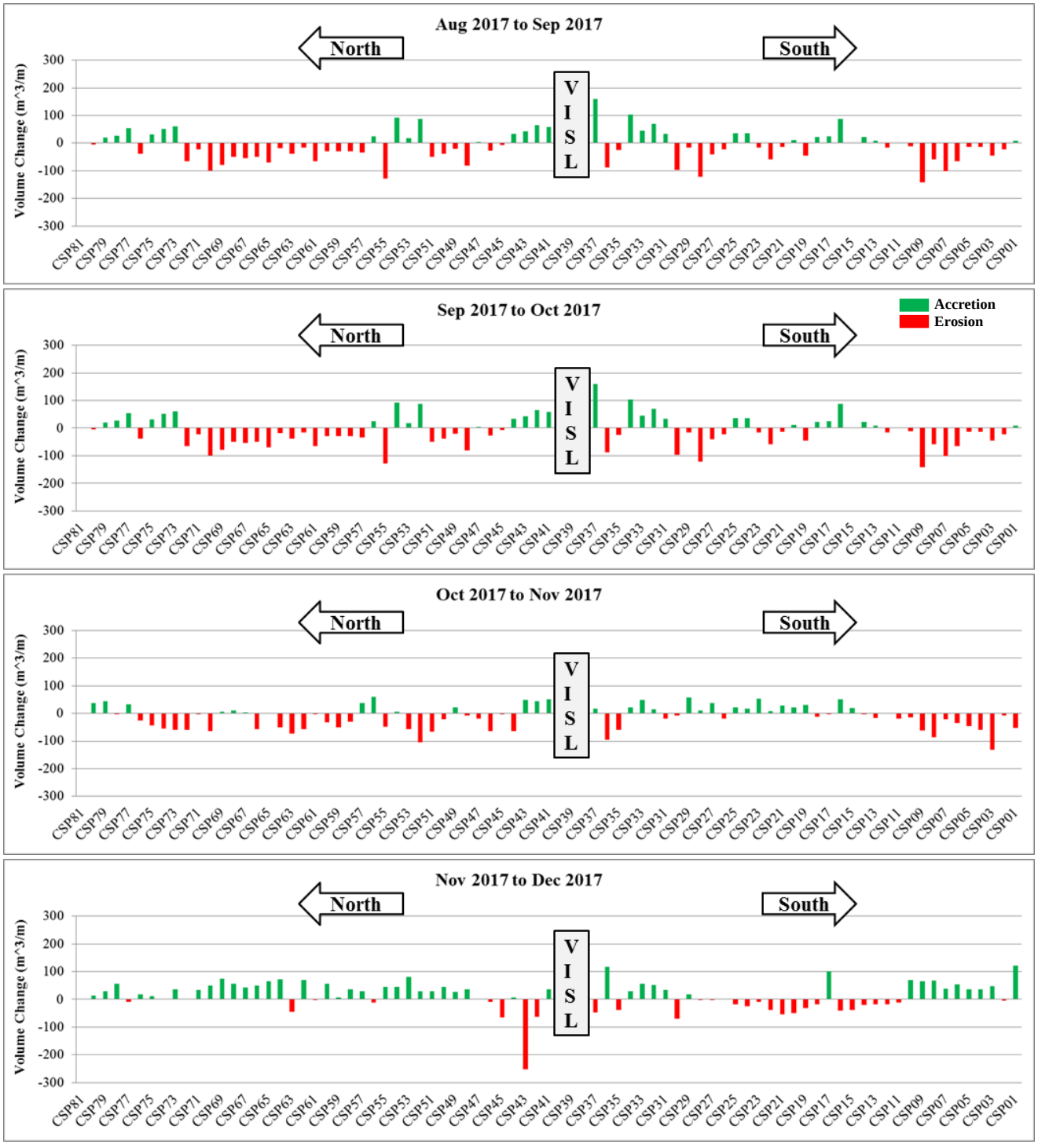


Figure 4.23 Monthly Beach Volume Changes during the year 2017 in m^3/m

The total monthly changes in the beach profiles at all transect shows higher erosion during the month of January 2017 and accretion during April 2017. The impact of severe cyclonic storm Ockhi that occurred during the end of November and the beginning of December 2017 has large impact on the beach but the sediment lost to the beach could be traced in the offshore profile lines thus it could be inferred that cross shore sediment

movement was limited to 12m contour depth during the period of cyclone. This can be seen clearly in the analysis results presented in Table 4.4.

Table 4.4 Monthly Beach Volume Changes during the year 2017 in m^3/m

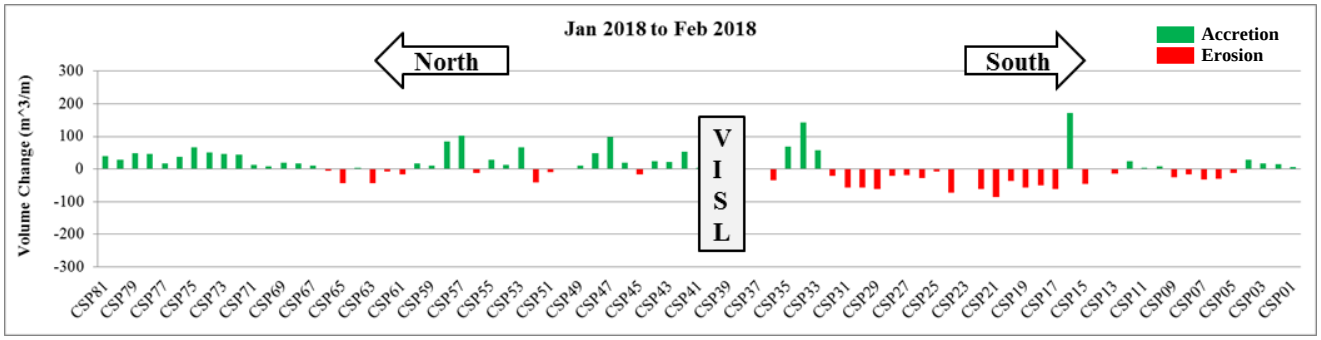
Locations	Profiling Period										
	Jan '17 - Feb '17	Feb '17 – Mar '17	Mar '17 – Apr'17	Apr'17 – May '17	May'17 – Jul '17	Jul'17 – Aug '17	Aug'17 – Sep '17	Sep'17 – Oct '17	Oct'17 – Nov '17	Nov'17 – Dec '17	Total
CSP01	-26.17	-57.76	45.96	-50.57	191.9	-1.13	10.09	-83.46	-52.77	122.28	98.37
CSP02	-6.21	-10.28	-37.8	43.29	-210.28	100.92	-23.4	41.79	-7.82	-4.43	-114.22
CSP03	-38.28	-31.52	-5.37	-64.91	195.67	-4.88	-46.12	-34.11	-131.68	48.08	-113.12
CSP04	-14.45	-78.76	24.97	102.84	13.04	-18.65	-13.26	-22.43	-59.15	35.66	-30.19
CSP05	-94.63	-80.79	-49.39	33.6	73.76	17.8	-13.66	-29.42	-45.29	35.37	-152.65
CSP06	-10.24	-23.96	-90.06	165.15	-13.15	-21.35	-64.89	-14.11	-33.63	53.3	-52.94
CSP07	-65.91	41.95	-62	34.96	49.1	-16.9	-100.71	42.75	-20.07	39.16	-57.67
CSP08	-11.67	-56.02	18.18	52.47	77.82	14.56	-59.55	-2.42	-85.96	67.2	14.61
CSP09	-83.92	-4.51	-15.58	-22.79	194.44	-50.69	-141.98	46.84	-61.63	65.89	-73.93
CSP10	-28.03	-11.93	0.88	-26.76	-9.69	30.43	-11.28	-9.86	-14.58	69.22	-11.6
CSP11	-60.05	-37.47	-6.77	-5.86	74.43	-56.74	1.01	9	-18.66	-12.34	-113.45
CSP12	-24.9	-32.81	36.24	-10.54	10.26	-15.55	-15.49	13.69	-	-18.88	-57.98
CSP13	-78.24	-13.05	21.62	-49.75	58.57	-20.7	8.01	-11.16	-16.06	-18.98	-119.74
CSP14	-3.67	-52.39	-1.99	47.06	2.8	-48.96	21.89	16.54	-3.36	-20.86	-42.94
CSP15	-65.85	-46.61	-26.72	62.22	-27.87	18.27	0	-48.62	19.48	-38.19	-153.89
CSP16	-42.13	90.82	-113.93	17.7	-164.73	-122.24	88.13	-83.8	50.74	-40.82	-320.26
CSP17	-71.74	-26.1	20.08	-22.66	97.37	-46.9	24.49	-28.81	-0.88	101.64	46.49
CSP18	-30.18	3.78	1.12	-20.62	71.15	-55.39	21.83	16.15	-12.42	-18.6	-23.18
CSP19	-113.59	-17.07	15.89	17.79	27.13	2.92	-46.02	34.03	30.09	-31.08	-79.91
CSP20	-30.02	-29.8	1.8	22.21	29.9	-41.21	11.95	10.13	20.98	-49.17	-53.23
CSP21	-55.31	-29.91	-34.53	52.94	17.2	-6.74	-13.43	-33.23	28.71	-54.48	-128.78
CSP22	-47.08	16.58	5.33	4.6	-47.61	51.85	-58.58	28.77	7.33	-39.05	-77.86
CSP23	-34.33	-33.43	-17.93	48.46	-12.61	-41.81	-15.3	2.67	52.66	-9.76	-61.38
CSP24	11.61	-6.98	2.64	35.06	-11.54	-76.05	35.97	26.23	16.31	-24.51	8.74
CSP25	-19.91	-17.3	1.36	6.15	21.83	-29.53	35.97	-36.47	20.93	-17.06	-34.03
CSP26	21.59	-3.75	2.01	-25.49	-46.07	7.05	-22.66	15.24	-19.12	2.55	-68.65
CSP27	-16.29	-1.75	-41.3	65.29	-6.18	-6.18	-40.28	-33.82	37.66	-1.16	-44.01
CSP28	-41.35	5.77	13.5	-26.81	22.8	23.77	-121.04	62.55	11.16	-0.44	-50.09
CSP29	-23.32	-29.67	-46.51	84.56	-0.54	-19.77	-15.69	-42.91	56.9	17.1	-19.85
CSP30	-49.34	-31.77	15.85	-1.08	60.5	-35.75	-96.9	81.79	-6.62	-69.95	-133.27
CSP31	-43.94	-53.55	16.91	64.72	103.63	-77.97	33.42	-25.87	-19.98	33.25	30.62
CSP32	-16.94	-34.14	76.53	-15.95	133.25	-166.43	69.36	-76.49	15.43	52.75	37.37
CSP33	0.71	-50.56	23.02	73.94	57.09	-292.14	45.62	46.94	47.66	56.13	8.41
CSP34	9.51	28.17	111.08	5.02	-363.97	-210.04	103.05	180.56	21.47	29.54	-85.61
CSP35	106.38	28.47	-11.65	-10.66	76.76	44.84	-25.24	8.41	-59.18	-38.07	120.06
CSP36	-64.07	66.45	27.05	70.89	394.65	-55.71	-88.2	-232.8	-95.96	117.16	139.46
CSP37	28.05	-57.67	30.19	60.26	-164.23	91.51	158.75	-3.46	16.89	-46.38	113.91
CSP38	**Port Area**										
CSP39											
CSP40											
CSP41	-41.75	-123.6	-26.39	-87.13	379.94	-67.62	59.42	-178.87	51.03	35.36	0.39
CSP42	-56.32	-59.51	12.45	-14.18	-17.67	7.26	64.72	72.59	45.07	-64.05	-9.64
CSP43	-	-22.26	-27.06	17.68	-256.4	171.52	42.96	97.33	48.42	-252.34	-180.15
CSP44	-50.35	-50.61	-56.85	84.63	61.62	-93.02	32.98	-13.91	-64.33	6.04	-143.8
CSP45	-63.65	-53.73	-74.8	28.2	87.35	-35.6	-5.81	-40.48	-1.66	-65.73	-225.91
CSP46	-44.24	35.79	-159.85	98.56	97.93	44.53	-26.14	-67.06	-62.88	-9.69	-93.05
CSP47	-72.93	-4.36	-21.6	24.96	-63.9	102.51	5.11	29.88	-18.57	1.61	-17.29

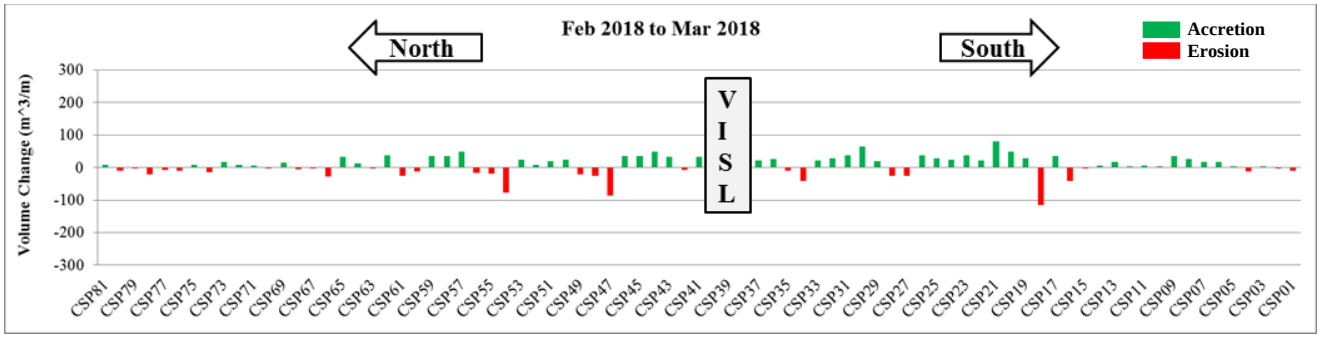
CSP48	-67.89	-5.61	-69.86	82.5	34.81	73.71	-80.27	-23.56	-7.48	35.94	-27.71
CSP49	26.64	-1.41	-83	34.12	-47.49	-8.95	-21.26	-26.06	22.38	26.99	-78.04
CSP50	-21.05	-29.36	-49.5	217.13	-155.65	12.67	-38.02	-31.94	-21.91	44.44	-73.19
CSP51	-49.48	-38.05	17.04	-31.09	114.74	18.24	-49.15	-31.2	-65.85	29.28	-85.52
CSP52	-49.08	-71.52	-119.54	-52.94	510.01	-93.2	88.12	-52.15	-103.5	28.87	85.07
CSP53	-39.27	-1.48	-98.48	-34.55	30.4	-16.63	17.87	52.52	-57.39	80.82	-66.19
CSP54	-56.27	33.53	-87.49	88.3	-224.91	9.43	91.4	63.87	6.37	45.36	-30.41
CSP55	-24.79	-53.87	-6.51	59.09	1.4	116.42	-129.09	86	-48.62	45.57	45.6
CSP56	-54.13	-40.12	10.79	-35.79	-112.87	76.35	24.73	-102.55	59.15	-12.06	-186.5
CSP57	-18.94	16.8	-60.51	-10.36	44.05	21.96	-32.94	-123.51	37.98	29.72	-95.75
CSP58	-26.81	-49.6	7.03	8.45	68.8	18.92	-28.53	-45.94	-30.38	36.55	-41.51
CSP59	4.98	-59.52	15.61	7.87	-36.27	99.44	-30.21	-7.05	-49.37	6.05	-48.47
CSP60	-27.11	-94.03	61.19	4.81	61.91	25.15	-28.65	-13.81	-31.26	55.78	13.98
CSP61	0.84	-31.77	54.72	-31.59	-18.2	28.93	-65.99	76.09	-1.19	-1.46	10.38
CSP62	23.31	18.26	-53.12	34.01	95.92	-4.97	-16.8	-52.98	-56.09	70.74	58.28
CSP63	-34	-47.55	17.85	-9.5	134.17	56.18	-38.16	7.12	-73.12	-44.15	-31.16
CSP64	-29.47	-75.09	-13.49	-14.96	84.59	-19.69	-17.35	30.55	-50.61	71.72	-33.8
CSP65	-82.68	15.01	-60.39	-86.17	91.36	35.92	-68.82	-2.97	1.22	64.69	-92.83
CSP66	-44.5	98.74	-121.6	-24.73	1.56	-20.3	-49.45	65.07	-56.09	49.88	-101.42
CSP67	-14.58	-24.06	-57.72	35.22	-25.02	0.19	-54.3	18.39	4.31	43.09	-74.48
CSP68	-40.6	20.42	-66.36	-1.62	14.2	-12.59	-49.45	-19.23	9.89	56.17	-89.17
CSP69	-28.66	38.59	-49.52	25.13	-57.16	36.69	-78.57	33.41	5.88	73.15	-1.06
CSP70	-57.48	-17.14	4.52	38.75	-67.47	71.09	-98.13	89.55	-64.64	49.35	-51.6
CSP71	-39.83	35.72	-60.4	41.89	-46.09	-22.82	-23.23	22.98	-3.91	34.26	-61.43
CSP72	-46.01	15.61	-12.99	-10.84	-27.69	53.64	-65.41	61.4	-59.61		-91.9
CSP73	-7.98	23.81	-52.22	48.87	-15.49	-78.14	59.71	66.8	-59.48	35.26	21.14
CSP74	-35.26	-2.23	10.32	17.67	-67.07	-92.21	51.4	113.14	-55.06	2.83	-56.47
CSP75	-7.87	-8.08	7.13	-11.1	17.01	-18.87	32.39	75.67	-43.85	11.77	54.2
CSP76	-42.75	58.45	-41.02	10.19	-22.24	24.41	-38.44	51.18	-25.34	17.52	-8.04
CSP77	-10.36	19.84	-43.98	46.44	-64.17	-73.73	53.4	4.46	34.09	-8.93	-42.94
CSP78	-30.4	34.93	-45.56	35.19	-30.81	-48.43	27.96	7.41	-2.36	55.89	3.82
CSP79	-10.52	1.73	-59.91	78.92	-21.51	-50.91	21.15	-20.02	44.92	29.89	13.74
CSP80	-43.1	22.58	-55.85	78.35	-58.48	-16.63	-4.54	4.66	38.01	13.68	-21.32
CSP81	-										

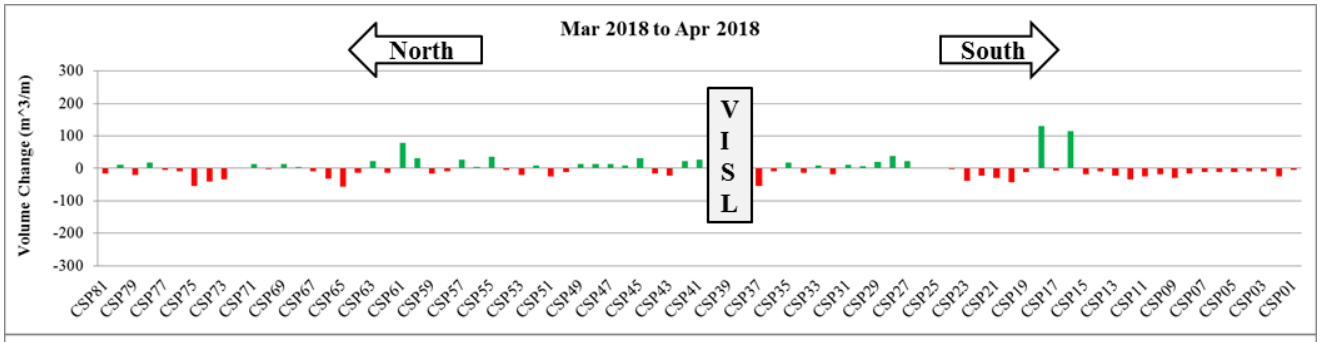
(-) indicates Erosion **(+) indicates Accretion**
- Data not used for analysis

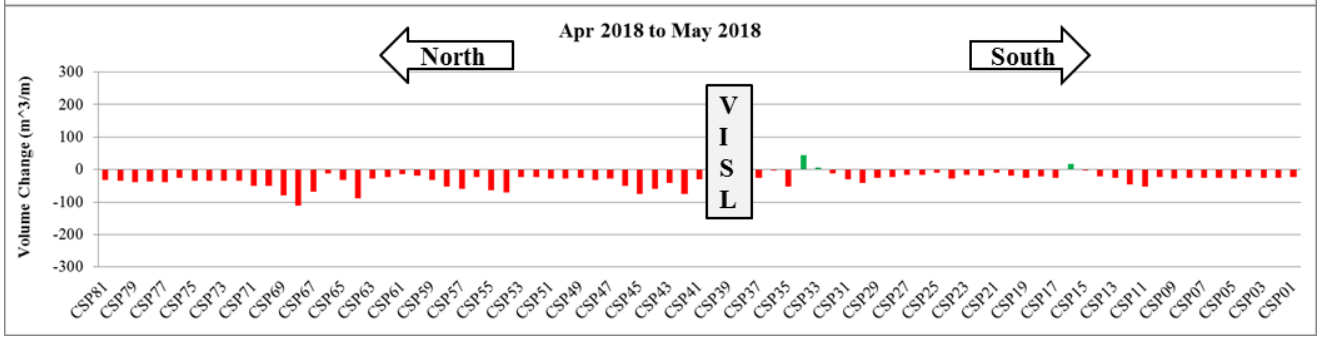
4.2.2.1 Monthly Beach Volume variations in the year 2018

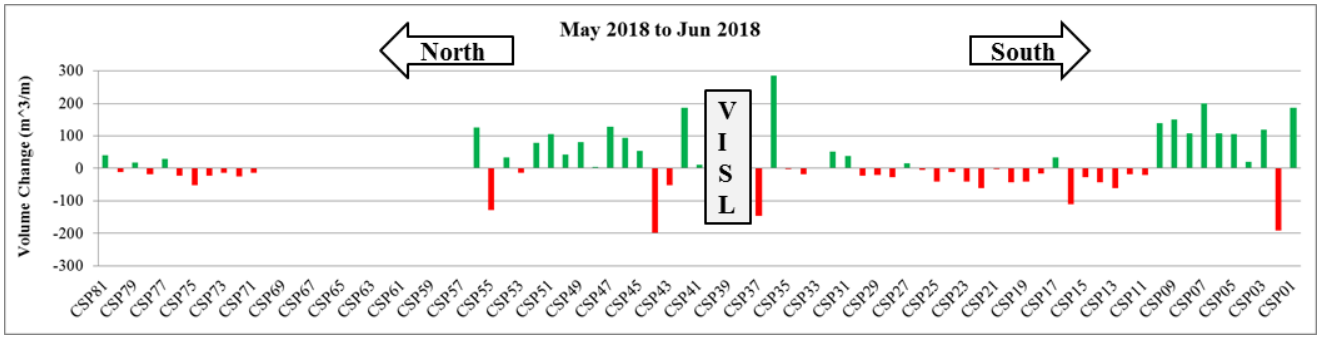
During the year 2018 (January to September 2018) beach formation was found at the north part of the Vizhinjam (CSP 67 to CSP 81) during the month of January to February 2018. The high wave activity that occurred during the month of April 2018 had an impact on beach and almost all profiles expect three (CSP 16, CSP 33 and CSP 34) underwent severe erosion (Table 4.5 and Figure 4.24). Again during the month of July to September 2018 the beach found to have net erosion. There was also a significant beach accretion during the month of May – July 2018. The beach volume change between each month was given in the Figure 4.24 and Table 4.5.


Jan 2018 to Feb 2018
North
South
Accretion
Erosion
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Feb 2018 to Mar 2018
North
South
Accretion
Erosion
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Mar 2018 to Apr 2018
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


Apr 2018 to May 2018
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01


May 2018 to Jun 2018
North
South
VISL
Volume Change (m^3/m)
300
200
100
0
-100
-200
-300
CSP81 CSP79 CSP77 CSP75 CSP73 CSP71 CSP69 CSP67 CSP65 CSP63 CSP61 CSP59 CSP57 CSP55 CSP53 CSP51 CSP49 CSP47 CSP45 CSP43 CSP41 CSP39 CSP37 CSP35 CSP33 CSP31 CSP29 CSP27 CSP25 CSP23 CSP21 CSP19 CSP17 CSP15 CSP13 CSP11 CSP09 CSP07 CSP05 CSP03 CSP01

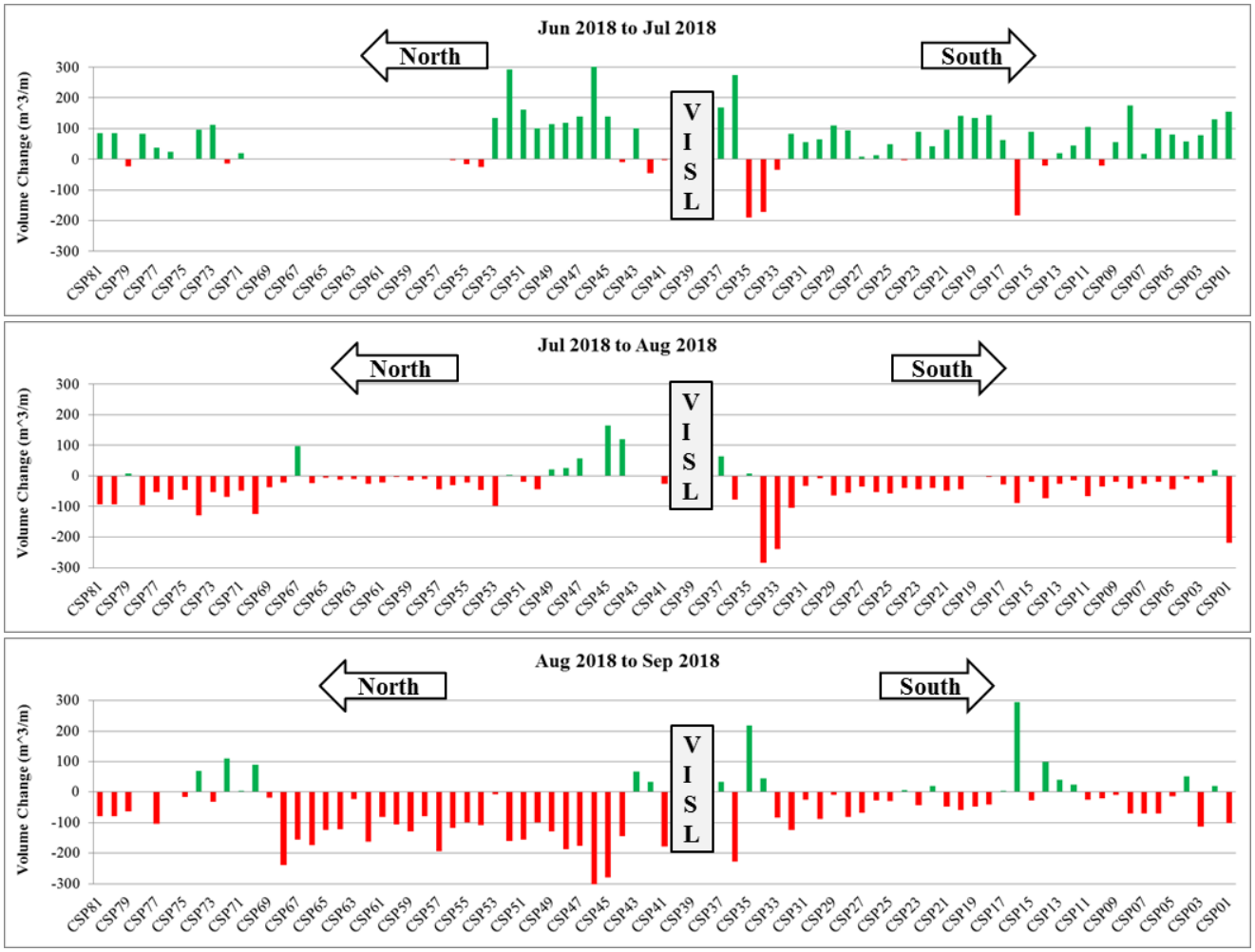


Figure 4.24 Monthly Beach Volume Changes during the year 2018 in m^3/m

Table 4.5 Monthly Beach Volume Changes during the year 2018 in m^3/m

Locations	Profiling Period								
	Jan '18 - Feb '18	Feb '18 – Mar '18	Mar '18 – Apr'18	Apr'18 – May '18	May'18 – Jun '18	Jun '18 - Jul'18	Jul'18 – Aug '18	Aug'18 – Sep '18	Total
CSP01	5.23	-10.95	-4.73	-24.19	186.6	153.72	-219.65	-100.58	-14.55
CSP02	15.85	-0.29	-25.5	-26.1	-190.9	129.84	19.71	20.36	-57.03
CSP03	17.75	4.12	-8.69	-26.25	120.1	77.73	-22.46	-111.86	50.44
CSP04	28.12	-12.68	-9.11	-23.68	21.02	58.16	-11.26	52.77	103.34
CSP05	-13.05	4.49	-12.3	-27.11	106.39	80.98	-43.09	-13.04	83.27
CSP06	-30.72	16.36	-11.52	-26.48	107.12	99.82	-20.11	-68.99	65.48
CSP07	-31.15	17.94	-11.51	-25.72	199.39	16.85	-25.84	-70.74	69.22
CSP08	-17.19	26.37	-16.13	-25.13	107.03	175.92	-42.8	-68.76	139.31
CSP09	-26.33	35.25	-30.16	-28.88	150.7	55.44	-18.96	-9.13	127.93
CSP10	8.23	4.77	-19	-24.07	138.89	-22.2	-35.71	-20.75	30.16
CSP11	3.19	5.74	-24.47	-53.64	-19.49	105.19	-67.56	-23.74	-74.78
CSP12	23.65	4.2	-33.52	-46.56	-18.74	44.56	-14.44	24.48	-16.37
CSP13	-14.27	17.21	-22.25	-25.55	-61.55	19.27	-26.92	39.5	-74.56
CSP14	1.17	5.85	-9.47	-20.52	-43.86	-21.18	-72.5	99.14	-61.37
CSP15	-46.76	-0.3	-17.14	-2.22	-27.87	88.36	-19.95	-26.76	-52.64
CSP16	172.51	-40.33	114.15	17.6	-109.62	-183.37	-88.86	295.56	177.64
CSP17	-60.95	35.04	-6.19	-24.61	34.13	63.2	-28.2	5.08	17.5
CSP18	-50.46	-116	130.58	-22.01	-16.59	142.76	-3.08	-40.67	24.53

CSP19	-56.29	29.15	-10.43	-26.39	-41.52	134.58	-2.45	-48.07	-21.42
CSP20	-36.43	49.7	-42.04	-17.83	-42.9	142.1	-43.15	-57.94	-48.49
CSP21	-85.3	80.58	-29.35	-10.8	-3.26	96.97	-48.68	-47.55	-47.39
CSP22	-60.51	22.71	-21.71	-18.7	-60.33	42.72	-39.1	19.51	-115.41
CSP23	0.72	38.35	-37.89	-15.81	-39.59	89.42	-44.16	-42.82	-51.78
CSP24	-71.88	23.85	-2.23	-28.92	-11.63	-1.8	-40.41	7.13	-125.89
CSP25	-6.84	29.22	1.52	-9.76	-39.38	48.76	-56.37	-28.48	-61.33
CSP26	-28.57	37.96	0.88	-15.76	-3.8	11.94	-52.92	-26.9	-77.17
CSP27	-18.6	-25.51	22.21	-15.77	15.16	8.8	-34.14	-68.14	-115.99
CSP28	-20.88	-25.15	38.56	-24.28	-27.72	93.01	-56.3	-81.61	-104.37
CSP29	-61.23	20.1	20.91	-25.84	-20.1	108.56	-64.12	-9.03	-30.75
CSP30	-58.01	65.22	5.69	-40.28	-21.97	64.99	-8.87	-88	-81.23
CSP31	-57.67	36.52	10.42	-29.72	39.05	55.55	-33.73	-24.02	-3.6
CSP32	-20.36	28.21	-18.37	-11.53	51.04	83.33	-104.47	-124.11	-116.26
CSP33	56.63	21.73	8.46	5.85	0.91	-35.63	-239.61	-82.78	-264.44
CSP34	142.48	-40.8	-13.17	43.24	-17.11	-171.73	-285.37	44.27	-298.19
CSP35	69.12	-10.51	17.25	-52.84	-1.69	-190.02	7.77	218.43	57.51
CSP36	-33.98	25.73	-9.67	-1.11	285.29	273.22	-76.61	-227.3	235.57
CSP37	2.18	21.3	-53.89	-25.72	-145.28	167.6	64.02	33.16	63.37
CSP38	**Port Area**								
CSP39									
CSP40									
CSP41	3.25	33.73	27.42	-30.99	11.76	19	13.14	-100.94	-23.63
CSP42	53.8	-7.51	22.35	-75.34	185.76	2.25	0.74	-216.87	-34.82
CSP43	22.6	34.08	-21.78	-41.43	-50.76	-43.15	0	28.18	-72.26
CSP44	24.89	48.71	-16.27	-60.12	-197.02	95.83	0	65.7	-38.28
CSP45	-16.17	34.69	32.14	-75.49	53.32	-9.86	139.12	-142.11	15.64
CSP46	20.19	34.59	8.18	-51.2	95.52	140.77	162.24	-276.22	134.07
CSP47	98.97	-85.8	12.94	-27.21	127.12	372.47	-19.02	-318.77	160.7
CSP48	47.89	-24.52	12.49	-32.39	5.31	133.99	52.08	-159.96	34.89
CSP49	11.39	-21.92	12.66	-26.33	81.69	114.28	20.73	-127.98	64.52
CSP50	2.11	23.91	-10.47	-28.29	41.85	99.69	-43.57	-98.85	-13.62
CSP51	-10.61	19.93	-24.02	-27.59	106.54	160.98	-19.64	-154.8	50.79
CSP52	-41.45	8.6	9.72	-22.9	79.11	292.13	1.48	-159.89	166.8
CSP53	65.96	23.23	-19.85	-23.39	-12.53	135.23	-98.46	-5.78	64.41
CSP54	13.54	-76.36	-4.99	-70.61	32.7	-25.21	-47.08	-108.04	-286.05
CSP55	28.06	-18.85	34.96	-62.81	-128.02	-17.05	-20.82	-99.74	-284.27
CSP56	-11.48	-15.94	5.19	-22.66	125.88	-1.33	-30.83	-117.85	-69.02
CSP57	102.16	48.72	27.63	-58.83			-44.8	-193.58	-118.7
CSP58	85.22	34.24	-9.52	-52.39			-10.79	-78.25	-31.49
CSP59	11.1	36.14	-15.56	-32.23			-15.21	-128.69	-144.45
CSP60	17.51	-12.13	32.38	-18.09			-2.61	-106.55	-89.49
CSP61	-17.63	-26.67	79.22	-14.66			-20.57	-81.69	-82
CSP62	-7.69	37.78	-13.72	-23.63			-26.48	-161.37	-195.11
CSP63	-44.16	-4.02	21.7	-27.1			-9.73	-22.43	-85.74
CSP64	3.91	13.4	-12.53	-88.77	-		-13.06	-120.74	-217.79
CSP65	-44.41	32.25	-56.83	-32.96			-4.86	-123.48	-230.29
CSP66	-4.8	-28.56	-32.14	-11.1			-24.73	-173.38	-274.71
CSP67	9.93	-0.96	-9.7	-68.62			98.38	-156	-126.97
CSP68	16.62	-5.69	4.32	-111.87			-22.59	-238.04	-357.25
CSP69	19.5	14.06	13.36	-80.44			-22.36	-234.25	-290.13
CSP70	9.25	-3.86	-1.91	-51.53			-37.71	-16.33	-102.09
CSP71	12.87	5.5	13.19	-50.78	-14.61	-32.55	-128.48	90.36	-104.5
CSP72	45.05	7.51	1.39	-35.54	-24.9	16.78	-44.74	5.86	-28.59
CSP73	45.22	16.3	-33.2	-34.5	-14.03	-15.74	-67.89	109.83	5.99

CSP74	51.75	-14.38	-40.54	-34.72	-21.64	115.62	-55.88	-31.31	-31.1
CSP75	66.65	8.96	-54.44	-34.63	-51.13	96.73	-129.69	71.76	-25.79
CSP76	38.01	-10.15	-9.56	-26.59	-21.69	1.2	-45.4	-15.04	-89.22
CSP77	17.44	-8.27	-3.67	-40.08	30.19	23.11	-76.35	1.3	-56.33
CSP78	46.03	-21.34	18.6	-36	-17.98	41.57	-57.19	-104.46	-130.77
CSP79	47.51	-2.05	-20.49	-38.67	17.39	81.87	-94.31	1.66	-7.09
CSP80	28.7	-9.65	10.98	-33.55	-11.13	-23.8	9.42	-61.66	-90.69
CSP81	39.45	8.94	-16.57	-32.14	40.97	84.61	-93.09	-79.63	-47.46
(-) indicates Erosion (+) indicates Accretion **- Data not used for analysis**									

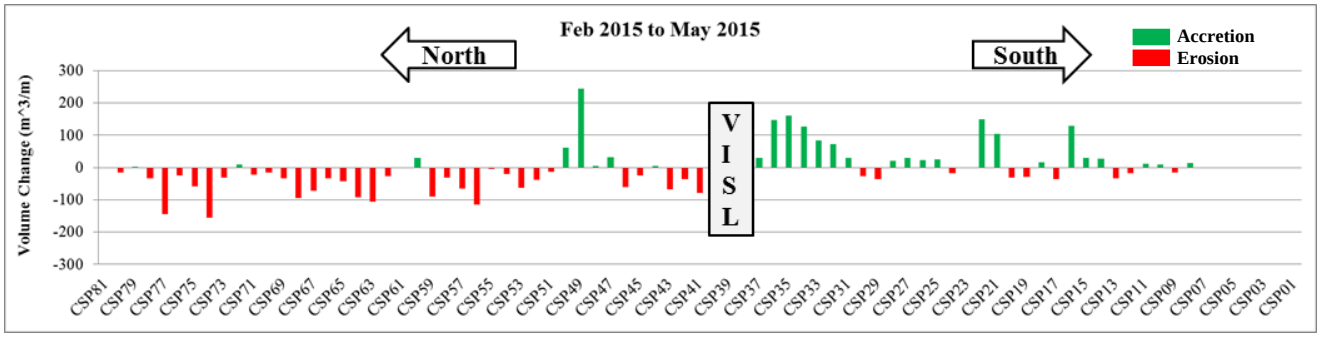
There was a considerable amount of beach formation during the month of May to July 2018. The month of July records the highest accretion rate in the year followed by immediate erosion during the month of August 2018. The periodic high wave activity has affect on beach formation.

4.2.3 Seasonal Beach Profile Variation

Seasonal variation has been analyzed as Fair weather period (Feb-May), Monsoon (Jun – Sep) and Post – Monsoon (Oct-Jan) for each year. The results have been presented to depict the total changes that occur in a particular season by analyzing profiles between each month in a season. In this way the seasonal variation in beach variation due to varying seasons can be inferred.

4.2.3.1 Seasonal Beach Volume variations during the year 2015-16

The beach during the fair weather period shows erosion trend while the monsoon and post monsoon season shows accretion at most of the profiles (Figure 4.25 and Table 4.6). The northern part of the Vizhinjam port area exhibits alternative phases of erosion and accretion with predominant beach formation seasonally during 2015-16. The southern part of the beach stretch (CSP 18 to CSP 35) shows more beach formation during the pre and post monsoon for the year 2015-16.



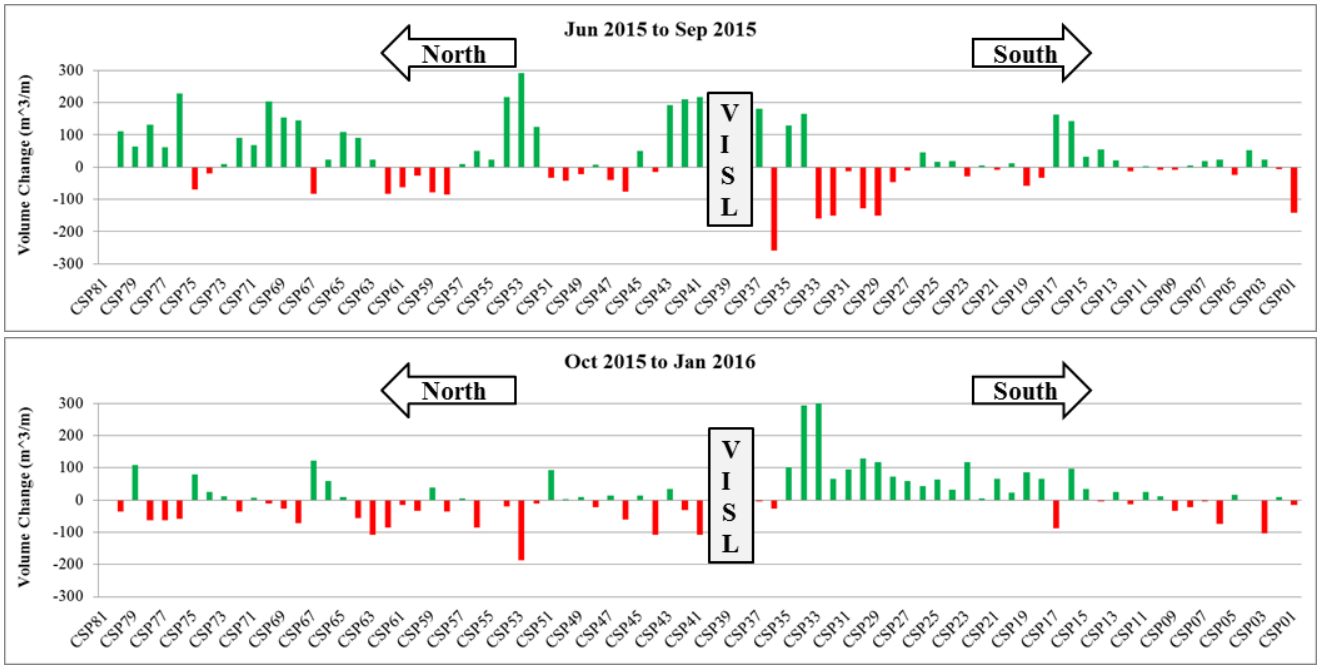


Figure 4.25 Seasonal Beach Volume Changes during the year 2015-16 in m^3/m

Table 4.6 Seasonal Beach Volume Changes during the year 2015-16 in m^3/m

Location	Feb 2015 to May 2015	Jun 2015 to Sep 2015	Oct 2015 to Jan 2016	Total
CSP01	-	-140.94	-15.09	-156.03
CSP02		-6.83	8.87	2.04
CSP03		22.88	-104.2	-81.32
CSP04		52.96	-2.53	50.43
CSP05		-25.18	16.82	-8.36
CSP06		23.42	-73.2	-49.78
CSP07		17.5	-4.25	13.25
CSP08	12.67	5.96	-22.29	-3.66
CSP09	-15.04	-8.13	-32.46	-55.63
CSP10	9.61	-8	10.69	12.3
CSP11	10.56	2.35	24.66	37.57
CSP12	-18.22	-14.14	-12.28	-44.64
CSP13	-33.29	19.85	25	11.56
CSP14	28.4	54.13	-4.74	77.79
CSP15	29.66	31.28	35.25	96.19
CSP16	128.94	142.43	97.33	368.7
CSP17	-36.57	162.1	-87.73	37.8
CSP18	15.84	-33.44	65.53	47.93
CSP19	-29.67	-59.28	86.37	-2.58
CSP20	-31.89	12.8	23.24	4.15
CSP21	103.56	-7.64	65.28	161.2
CSP22	149.9	4.14	4.3	158.34
CSP23	-2.26	-28.58	118.6	87.76
CSP24	-18.1	18.47	32.82	33.19
CSP25	23.94	15.74	64.65	104.33
CSP26	23.47	44.75	44.29	112.51
CSP27	28.8	-9.95	60.21	79.06
CSP28	20.25	-45.83	72.63	47.05
CSP29	-36.42	-150.31	118.18	-68.55
CSP30	-26.39	-128.25	128.47	-26.17
CSP31	29.6	-12.62	94.42	111.4

CSP32	72.93	-151.72	66.93	-11.86
CSP33	83.87	-159.11	300.68	225.44
CSP34	127.21	165.16	293.61	585.98
CSP35	159.63	130.19	103	392.82
CSP36	147.77	-258.24	-27.17	-137.64
CSP37	29.74	180.35	-3.87	206.22
CSP38	**Port Area**			
CSP39				
CSP40				
CSP41	-78.24	217.64	-106.88	32.52
CSP42	-36.92	209.99	-31.77	141.3
CSP43	-68.07	192.01	33.28	157.22
CSP44	4.36	-15.28	-107.78	-118.7
CSP45	-25.35	49.47	14.44	38.56
CSP46	-60.43	-75.81	-59.78	-196.02
CSP47	31.53	-39.1	13.56	5.99
CSP48	5.41	7.92	-22.03	-8.7
CSP49	243.23	-23.13	8.76	228.86
CSP50	60.48	-42.18	1.45	19.75
CSP51	-14.38	-33.29	93.2	45.53
CSP52	-37.39	124.07	-10.15	76.53
CSP53	-63.97	291.59	-186.26	41.36
CSP54	-19.61	217.8	-19.76	178.43
CSP55	-3.84	21.99	-0.43	17.72
CSP56	-114.9	49.68	-85.38	-150.6
CSP57	-65.3	8.47	5.5	-51.33
CSP58	-31.69	-84.45	-35	-151.14
CSP59	-90.18	-78.85	38.76	-130.27
CSP60	28.5	-25.84	-32.98	-30.32
CSP61	-1.19	-61.74	-15.01	-77.94
CSP62	-26.68	-82.01	-84.99	-193.68
CSP63	-105.49	23.44	-108.26	-190.31
CSP64	-92.38	90.14	-56.02	-58.26
CSP65	-42.23	107.93	8.53	74.23
CSP66	-32.61	22.82	58.56	48.77
CSP67	-71.99	-82.78	122.47	-32.3
CSP68	-93.77	144.24	-71.99	-21.52
CSP69	-34.45	153.83	-25.85	93.53
CSP70	-14.82	204.62	-10.26	179.54
CSP71	-23.09	67.3	7.98	52.19
CSP72	8.27	91.56	-35.72	64.11
CSP73	-31.42	10.19	10.97	-10.26
CSP74	-156.11	-18.87	24.42	-150.56
CSP75	-59.11	-69.99	78.98	-50.12
CSP76	-25.58	228.44	-59.21	143.65
CSP77	-143.39	61.26	-63.57	-145.7
CSP78	-34.59	130.37	-63.43	32.35
CSP79	0.19	64.82	108.46	173.47
CSP80	-16.21	111	-34.62	60.17
CSP81	-			
(-) indicates Erosion (+) indicates Accretion **- Data not used for analysis**				

4.2.3.2 Seasonal Beach Volume variations during the year 2016-17

The fair weather period season in the year 2016 shows erosive trend while the monsoon and post monsoon analysis indicate net beach formation (Table 4.7 and Figure 4.26). Beach formation was more during the post monsoon season in the year 2016-17.

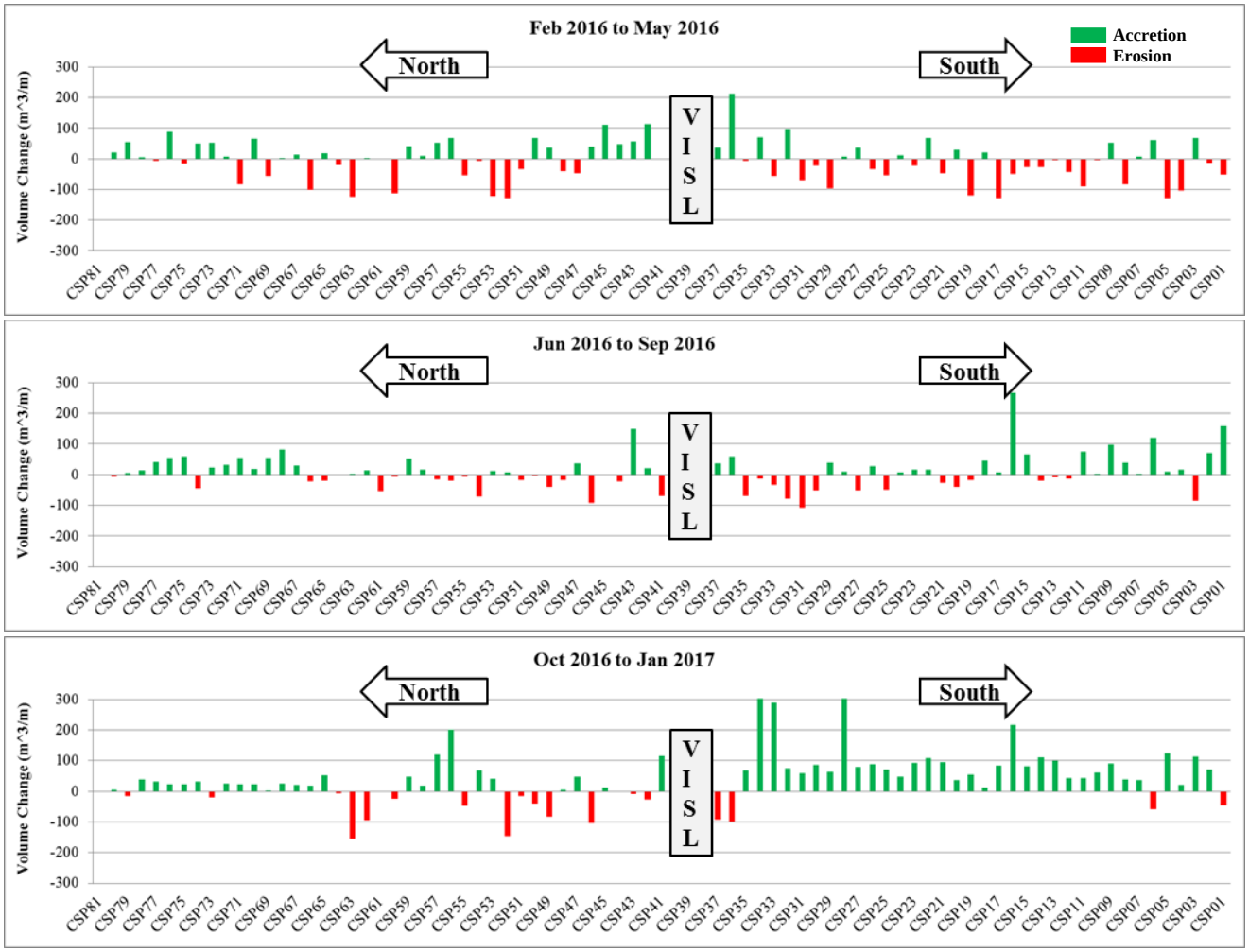


Figure 4.26 Seasonal Beach Volume Changes during the year 2016-17 in m^3/m

Table 4.7 Seasonal Beach Volume Changes during the year 2016-17 in m^3/m

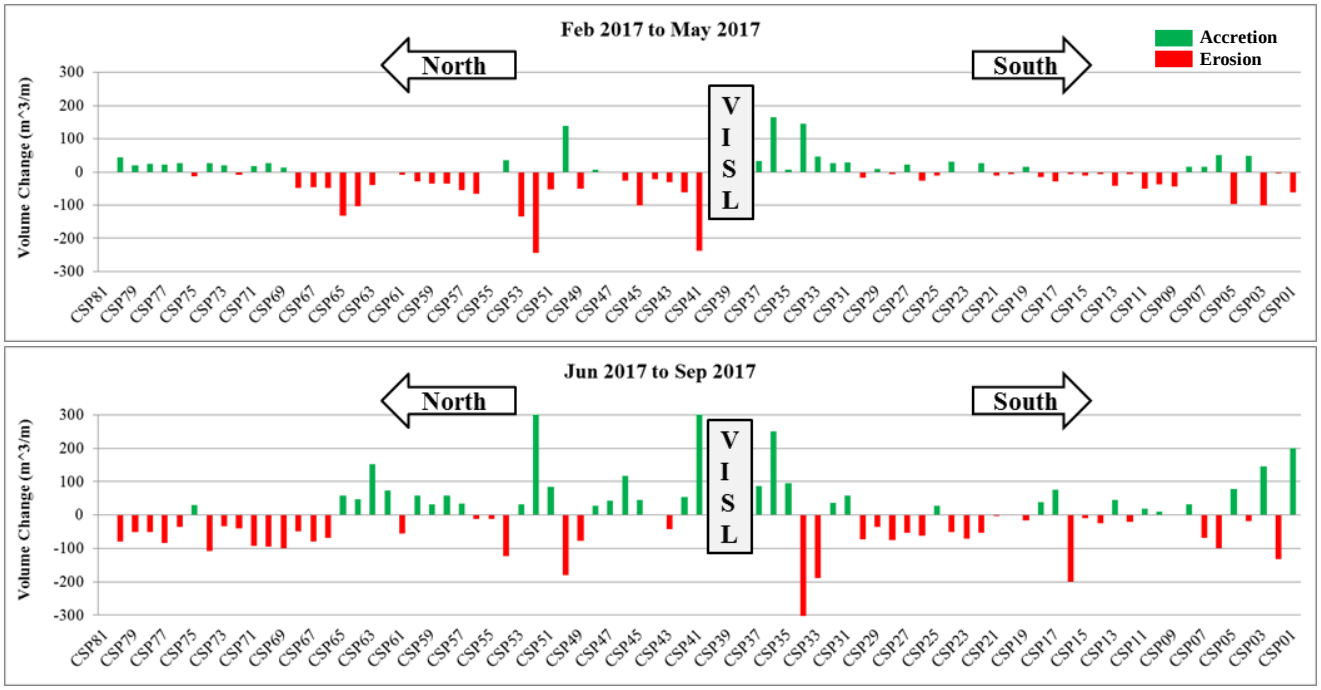
Location	Feb 2016 to May 2016	Jun 2016 to Sep 2016	Oct 2016 to Jan 2017	Total
CSP01	-52.38	157.84	-45.61	59.85
CSP02	-12.25	69.41	70.31	127.47
CSP03	69.02	-84.46	113.99	98.55
CSP04	-104.55	16.52	21.35	-66.68
CSP05	-129.54	10.3	124.72	5.48
CSP06	60.55	120.35	-57.5	123.4
CSP07	7.63	3.65	37.46	48.74
CSP08	-82.64	38.87	39.05	-4.72
CSP09	52.38	97.33	91.01	240.72
CSP10	-5.18	2.97	60.99	58.78
CSP11	-89.14	73.88	43.67	28.41

CSP12	-43.42	-13.52	43.22	-13.72
CSP13	-5.02	-8.9	100.1	86.18
CSP14	-27.38	-19.86	110.32	63.08
CSP15	-25.93	66.67	82.34	123.08
CSP16	-49.42	267.98	217.15	435.71
CSP17	-127.93	7.8	83.9	-36.23
CSP18	21.52	46.43	11.71	79.66
CSP19	-118.99	-17.49	54.76	-81.72
CSP20	30.59	-39.99	37.03	27.63
CSP21	-48.09	-25.9	95.59	21.6
CSP22	67.7	16.63	107.96	192.29
CSP23	-23	15.78	92.38	85.16
CSP24	10.68	8.13	47.6	66.41
CSP25	-54.73	-50.03	69.68	-35.08
CSP26	-34.55	28.63	88.85	82.93
CSP27	35.31	-51.44	79.71	63.58
CSP28	6.36	10.34	461.64	478.34
CSP29	-96.51	38.83	63.2	5.52
CSP30	-23.28	-51.19	87.24	12.77
CSP31	-70.63	-108.8	59.94	-119.49
CSP32	97.63	-78.6	74.2	93.23
CSP33	-56.5	-33.84	288.46	198.12
CSP34	70.57	-13.21	366.58	423.94
CSP35	-7.29	-69.04	67.55	-8.78
CSP36	212.36	60.02	-98.77	173.61
CSP37	35.22	36.82	-91.28	-19.24
CSP38	**Port Area**			
CSP39				
CSP40				
CSP41	-0.06	-69.85	115.88	45.97
CSP42	113.33	20.39	-26.99	106.73
CSP43	55.93	150.08	-9.56	196.45
CSP44	46.96	-21.98	-0.52	24.46
CSP45	110.59	-1.29	12.7	122
CSP46	38.6	-92.34	-103.94	-157.68
CSP47	-48.06	37.02	48.42	37.38
CSP48	-40.29	-17.34	4.47	-53.16
CSP49	37.45	-39.18	-83.74	-85.47
CSP50	67.23	-4.22	-39.05	23.96
CSP51	-33.56	-18.15	-14.98	-66.69
CSP52	-127.91	8.38	-146.65	-266.18
CSP53	-122.17	10.99	40.84	-70.34
CSP54	-7.31	-71.69	68.29	-10.71
CSP55	-54.16	-6.65	-46.76	-107.57
CSP56	69.04	-20.67	201.7	250.07
CSP57	52.05	-15.1	121.24	158.19
CSP58	9.59	15.2	19.64	44.43
CSP59	40.9	51.68	47.06	139.64
CSP60	-112.51	-7.25	-24.82	-144.58
CSP61	-2.43	-53.17	-1.45	-57.05
CSP62	1.44	13.64	-95	-79.92
CSP63	-125.14	3.15	-155.35	-277.34
CSP64	-20.3	-0.86	-5.25	-26.41
CSP65	19.02	-19.31	53.27	52.98
CSP66	-100.87	-22.12	19.33	-103.66
CSP67	13.36	28.74	21.68	63.78
CSP68	0.1	82.31	24.3	106.71
CSP69	-56.47	54.31	0.07	-2.09

CSP70	64.77	18.92	22	105.69
CSP71	-83.23	53.93	23.87	-5.43
CSP72	6.25	32.43	26.03	64.71
CSP73	53.1	23.62	-19.48	57.24
CSP74	49.33	-44.24	31.91	37
CSP75	-16.72	58.52	22.25	64.05
CSP76	89.33	54.7	23.81	167.84
CSP77	-6.8	40.02	32.96	66.18
CSP78	5.37	14.68	38.28	58.33
CSP79	55.27	4.22	-14.29	45.2
CSP80	21.14	-6.59	5.44	19.99
CSP81	-			
(-) indicates Erosion (+) indicates Accretion **- Data not used for analysis**				

4.2.3.3 Seasonal Beach Volume variations during the year 2017-18

All the seasons in the year 2017-18 exhibits net erosion. The rate of erosion was high during the pre – monsoon and low during the post – monsoon season in the year 2017-18 (Table 4.8 and Figure 4.27). The northern part of the coast (CSP 67 to CSP 80) eroded severely during the fair weather period. Southern part of the coast (CSP 09 to CSP 34) has net erosion during the post – monsoon season of the year 2017-18.



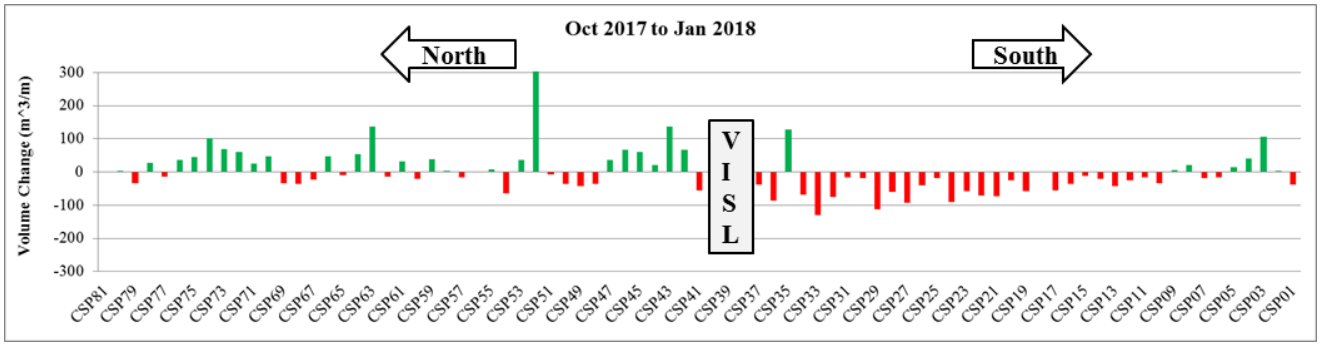


Figure 4.27 Seasonal Beach Volume Changes during the year 2017-18 in m^3/m

Table 4.8 Seasonal Beach Volume Changes during the year 2017-18 in m^3/m

Location	Feb 2017 to May 2017	Jun 2017 to Sep 2017	Oct 2017 to Jan 2018	Total
CSP01	-62.37	200.86	-38.5	99.99
CSP02	-4.79	-132.76	3.28	-134.27
CSP03	-101.8	144.67	105.31	148.18
CSP04	49.05	-18.87	40.78	70.96
CSP05	-96.58	77.9	15.01	-3.67
CSP06	51.13	-99.39	-16.97	-65.23
CSP07	14.91	-68.51	-19.13	-72.73
CSP08	14.63	32.83	20.77	68.23
CSP09	-42.88	1.77	5.74	-35.37
CSP10	-37.81	9.46	-33.7	-62.05
CSP11	-50.1	18.7	-15.93	-47.33
CSP12	-7.11	-20.78	-24.7	-52.59
CSP13	-41.18	45.88	-43.28	-38.58
CSP14	-7.32	-24.27	-19.45	-51.04
CSP15	-11.11	-9.6	-11.79	-32.5
CSP16	-5.41	-198.84	-36.17	-240.42
CSP17	-28.68	74.96	-55.69	-9.41
CSP18	-15.72	37.59	1.21	23.08
CSP19	16.61	-15.97	-57.73	-57.09
CSP20	-5.79	0.64	-25.23	-30.38
CSP21	-11.5	-2.97	-73.47	-87.94
CSP22	26.51	-54.34	-70.54	-98.37
CSP23	-2.9	-69.72	-58.29	-130.91
CSP24	30.72	-51.62	-91	-111.9
CSP25	-9.79	28.27	-17.56	0.92
CSP26	-27.23	-61.68	-39.23	-128.14
CSP27	22.24	-52.64	-93.08	-123.48
CSP28	-7.54	-74.47	-59.49	-141.5
CSP29	8.38	-36	-111.91	-139.53
CSP30	-17	-72.15	-18.28	-107.43
CSP31	28.08	59.08	-16.42	70.74
CSP32	26.44	36.18	-75.9	-13.28
CSP33	46.4	-189.43	-130.08	-273.11
CSP34	144.27	-470.96	-68.95	-395.64
CSP35	6.16	96.36	127.04	229.56
CSP36	164.39	250.74	-86.68	328.45
CSP37	32.78	86.03	-37.11	81.7
CSP38	**Port Area**			
CSP39				
CSP40				
CSP41	-237.12	371.74	-55.4	79.22

CSP42	-61.24	54.31	67.17	60.24
CSP43	-31.64	-41.92	137.81	64.25
CSP44	-22.83	1.58	19.98	-1.27
CSP45	-100.33	45.94	59.41	5.02
CSP46	-25.5	116.32	67.25	158.07
CSP47	-1	43.72	36.35	79.07
CSP48	7.03	28.25	-35.38	-0.1
CSP49	-50.29	-77.7	-41.98	-169.97
CSP50	138.27	-181	-34.86	-77.59
CSP51	-52.1	83.83	-6.97	24.76
CSP52	-244	504.93	307.63	568.56
CSP53	-134.51	31.64	36.81	-66.06
CSP54	34.34	-124.08	-64.39	-154.13
CSP55	-1.29	-11.27	8.17	-4.39
CSP56	-65.12	-11.79	0.69	-76.22
CSP57	-54.07	33.07	-15.93	-36.93
CSP58	-34.12	59.19	4.55	29.62
CSP59	-36.04	32.96	39.01	35.93
CSP60	-28.03	58.41	-20.36	10.02
CSP61	-8.64	-55.26	30.85	-33.05
CSP62	-0.85	74.15	-13.38	59.92
CSP63	-39.2	152.19	137.39	250.38
CSP64	-103.54	47.55	54.36	-1.63
CSP65	-131.55	58.46	-10.01	-83.1
CSP66	-47.59	-68.19	46.85	-68.93
CSP67	-46.56	-79.13	-22.92	-148.61
CSP68	-47.56	-47.84	-35.75	-131.15
CSP69	14.2	-99.04	-33.05	-117.89
CSP70	26.13	-94.51	47.58	-20.8
CSP71	17.21	-92.14	25.05	-49.88
CSP72	-8.22	-39.46	59.61	11.93
CSP73	20.46	-33.92	69.79	56.33
CSP74	25.76	-107.88	101.88	19.76
CSP75	-12.05	30.53	44.52	63
CSP76	27.62	-36.27	35.33	26.68
CSP77	22.3	-84.5	-12.89	-75.09
CSP78	24.56	-51.28	27.62	0.9
CSP79	20.74	-51.27	-33.26	-63.79
CSP80	45.08	-79.65	2.9	-31.67
CSP81	**No Valid data**			0
(-) indicates Erosion (+) indicates Accretion **- Data not used for analysis**				

4.2.3.4 Seasonal Beach Volume variations during the year 2018-19

During the year 2018-19, fair weather period season exhibits net erosion were most of the coastal stretches underwent erosion (Table 4.9 and Figure 4.28). The Monsoon season also shows erosion which was less compared to fair weather period and some beaches (CSP 11 to CSP 23) have beach formation.

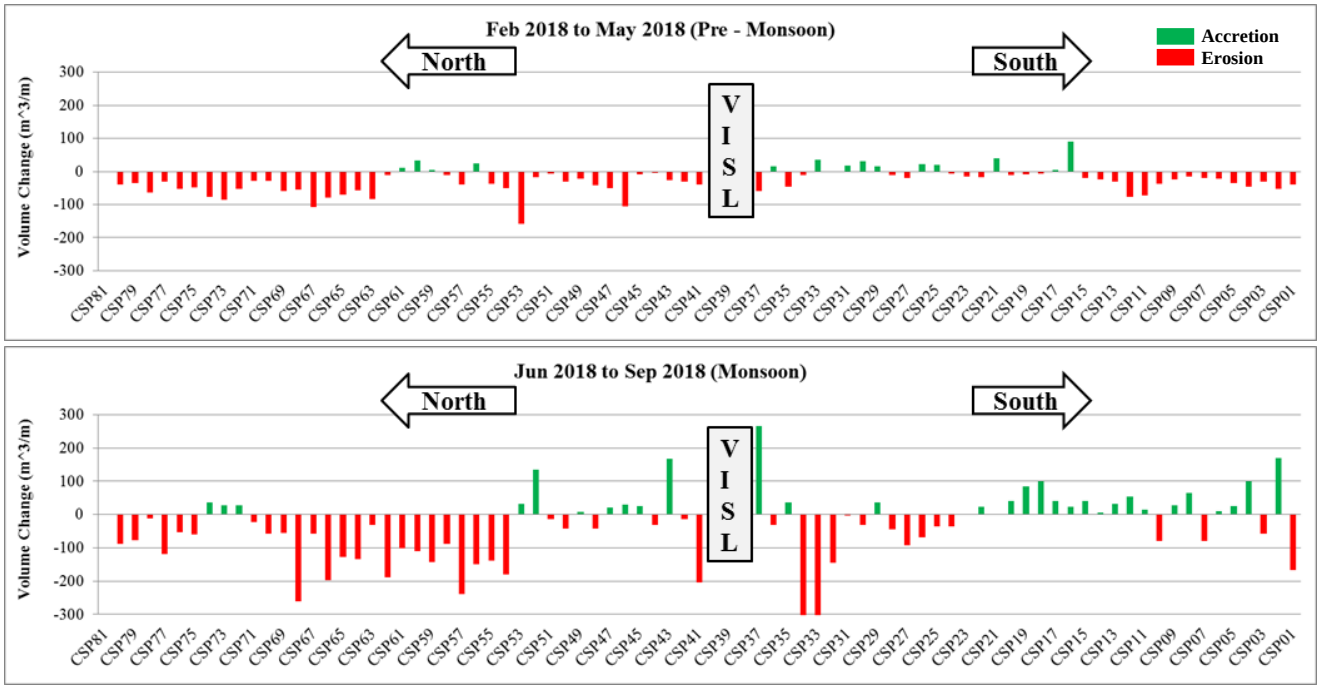


Figure 4.28 Seasonal Beach Volume Changes during the year 2018-19 in m^3/m

Table 4.9 Seasonal Beach Volume Changes during the year 2018-19 in m^3/m

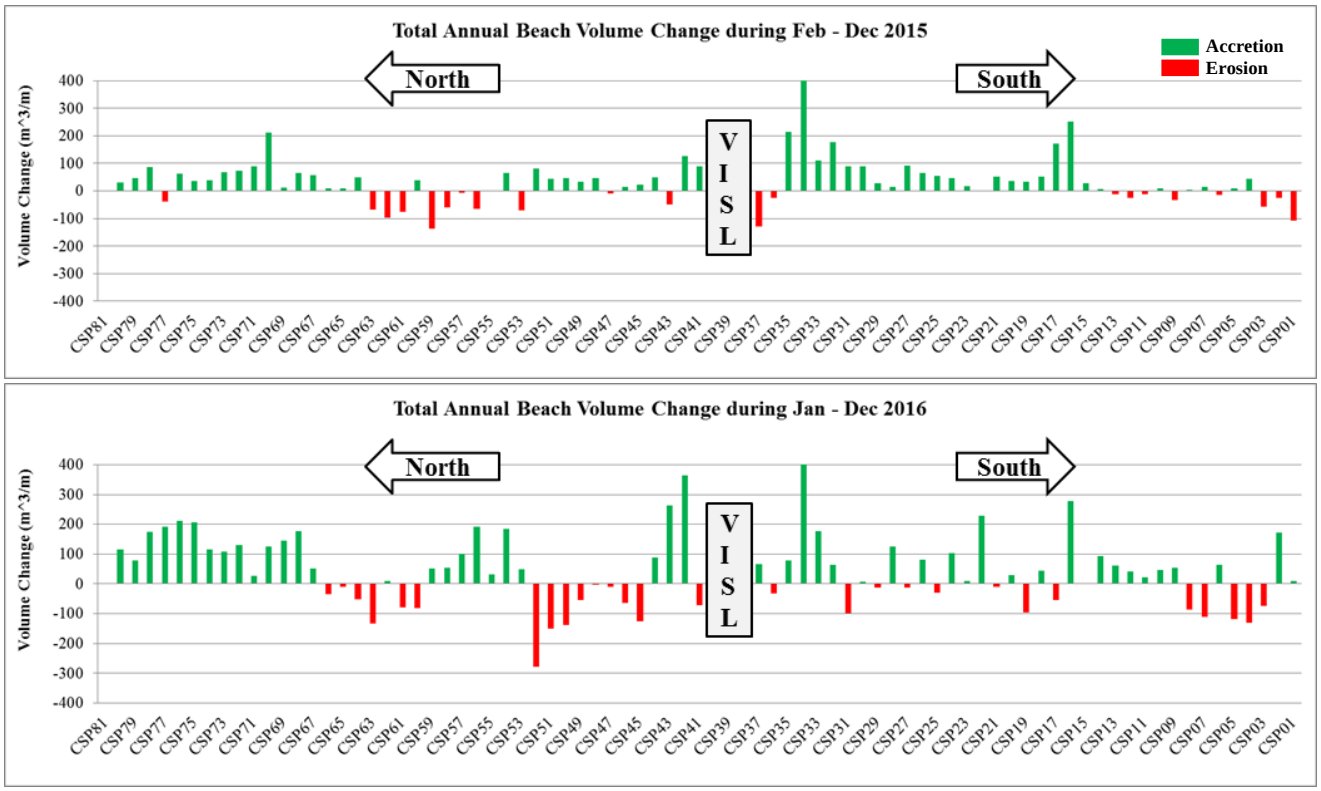
Location	Feb 2018 to May 2018	Jun 2018 to Sep 2018	Total
CSP01	-39.87	-166.51	-206.38
CSP02	-51.89	169.91	118.02
CSP03	-30.82	-56.59	-87.41
CSP04	-45.47	99.67	54.2
CSP05	-34.92	24.85	-10.07
CSP06	-21.64	10.72	-10.92
CSP07	-19.29	-79.73	-99.02
CSP08	-14.89	64.36	49.47
CSP09	-23.79	27.35	3.56
CSP10	-38.3	-78.66	-116.96
CSP11	-72.37	13.89	-58.48
CSP12	-75.88	54.6	-21.28
CSP13	-30.59	31.85	1.26
CSP14	-24.14	5.46	-18.68
CSP15	-19.66	41.65	21.99
CSP16	91.42	23.33	114.75
CSP17	4.24	40.08	44.32
CSP18	-7.43	99.01	91.58
CSP19	-7.67	84.06	76.39
CSP20	-10.17	41.01	30.84
CSP21	40.43	0.74	41.17
CSP22	-17.7	23.13	5.43
CSP23	-15.35	2.44	-12.91
CSP24	-7.3	-35.08	-42.38
CSP25	20.98	-36.09	-15.11
CSP26	23.08	-67.88	-44.8
CSP27	-19.07	-93.48	-112.55
CSP28	-10.87	-44.9	-55.77
CSP29	15.17	35.41	50.58
CSP30	30.63	-31.88	-1.25

CSP31	17.22	-2.2	15.02
CSP32	-1.69	-145.25	-146.94
CSP33	36.04	-358.02	-321.98
CSP34	-10.73	-412.83	-423.56
CSP35	-46.1	36.18	-9.92
CSP36	14.95	-30.69	-15.74
CSP37	-58.31	264.78	206.47
CSP38	**Port Area**		
CSP39			
CSP40			
CSP41	-38.69	-203.34	-242.03
CSP42	-31.11	-13.07	-44.18
CSP43	-26.03	167.24	141.21
CSP44	-3.16	-32.08	-35.24
CSP45	-9.4	25.52	16.12
CSP46	-104.93	29.06	-75.87
CSP47	-50.51	20.3	-30.21
CSP48	-41.78	-41.7	-83.48
CSP49	-21.14	7.03	-14.11
CSP50	-30.74	-42.73	-73.47
CSP51	-5.86	-13.46	-19.32
CSP52	-17.8	133.72	115.92
CSP53	-158.01	30.99	-127.02
CSP54	-50.87	-180.33	-231.2
CSP55	-36.21	-137.61	-173.82
CSP56	23.44	-148.68	-125.24
CSP57	-38.81	-238.38	-277.19
CSP58	-10.97	-89.04	-100.01
CSP59	3.45	-143.9	-140.45
CSP60	33.99	-109.16	-75.17
CSP61	11.18	-102.26	-91.08
CSP62	-9.88	-187.85	-197.73
CSP63	-82.91	-32.16	-115.07
CSP64	-57.1	-133.8	-190.9
CSP65	-70.98	-128.34	-199.32
CSP66	-79.99	-198.11	-278.1
CSP67	-107.76	-57.62	-165.38
CSP68	-55.53	-260.63	-316.16
CSP69	-58.33	-54.97	-113.3
CSP70	-28.67	-57.17	-85.84
CSP71	-28.44	-23.01	-51.45
CSP72	-52.75	26.71	-26.04
CSP73	-86.73	27.23	-59.5
CSP74	-76.3	36.72	-39.58
CSP75	-47.69	-59.95	-107.64
CSP76	-53.27	-53.99	-107.26
CSP77	-31.3	-118.43	-149.73
CSP78	-64.15	-12.66	-76.81
CSP79	-34.26	-78.12	-112.38
CSP80	-39.77	-88.12	-127.89
CSP81	-		
(-) indicates Erosion (+) indicates Accretion **- Data not used for analysis**			

4.2.4 Annual Changes in the Beach Profile

The total change in the year is presented in this section i.e. the total cumulative monthly changes during the calendar year based on the available data. This enables to understand the beach variations that happen in a year.

The annual beach volume variation shows that during the year 2015 and 2016 many coastal stretch found to have net accretion (beaches between CSP 15 and CSP 35) and net erosion at very few stretches (beaches between CSP 49 and CSP 63) (Figure 4.29 and Table 4.10). During the year 2017 the rate of erosion was found to be higher and beach formation was limited to few profile transects (example CSP35 to CSP37). In the year 2018 few stretches shows accretion (CSP 03 to CSP 10, CSP 35 to CSP 37, CSP 46 to CSP 52) and the stretches along the north of Panathura to north of Shangumugham(CSP 54 to CSP 80) was under severe threat of erosion.



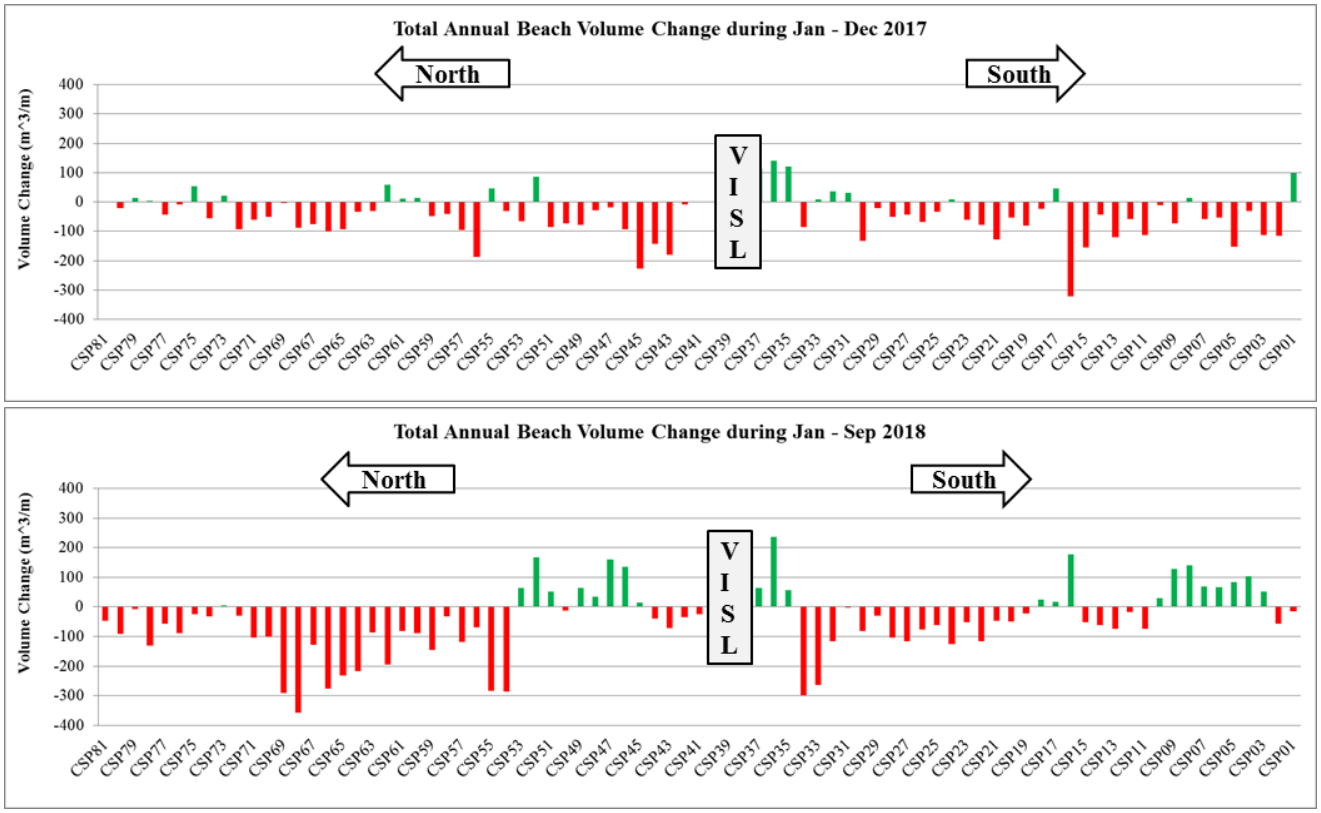


Figure 4.29 Annual Beach Volume Changes during the period between 2015 and 2018 in m^3/m

Table 4.10 Annual Beach Volume Changes during the period between 2015 and 2018 in m^3/m

Location	2015 (Feb-Dec)	2016 (Jan– Dec)	2017 (Jan– Dec)	2018 (Jan-Sep)	Total
CSP01	-107.09	10.8	98.37	-14.55	-12.47
CSP02	-24.6	171.01	-114.22	-57.03	-24.84
CSP03	-58.33	-74.3	-113.12	50.44	-195.31
CSP04	44.16	-130.83	-30.19	103.34	-13.52
CSP05	9.1	-118.94	-152.65	83.27	-179.22
CSP06	-13.28	64.05	-52.94	65.48	63.31
CSP07	14.22	-110.66	-57.67	69.22	-84.89
CSP08	3.42	-86.22	14.61	139.31	71.12
CSP09	-32.59	54.23	-73.93	127.93	75.64
CSP10	8.1	47.27	-11.6	30.16	73.93
CSP11	-12.05	21.64	-113.45	-74.78	-178.64
CSP12	-24.28	41.44	-57.98	-16.37	-57.19
CSP13	-12.75	60.65	-119.74	-74.56	-146.4
CSP14	6.56	93.52	-42.94	-61.37	-4.23
CSP15	28.02	2.96	-153.89	-52.64	-175.55
CSP16	250.2	278.94	-320.26	177.64	386.52
CSP17	171.19	-54.26	46.49	17.5	180.92
CSP18	50.8	43.47	-23.18	24.53	95.62
CSP19	33.58	-96.23	-79.91	-21.42	-163.98
CSP20	36.84	29.35	-53.23	-48.49	-35.53
CSP21	52.62	-10.39	-128.78	-47.39	-133.94
CSP22	1.69	229.63	-77.86	-115.41	38.05
CSP23	17.67	10.2	-61.38	-51.78	-85.29
CSP24	47.7	102.21	8.74	-125.89	32.76
CSP25	55.94	-28.53	-34.03	-61.33	-67.95

CSP26	64.55	80.31	-68.65	-77.17	-0.96
CSP27	90.89	-13.57	-44.01	-115.99	-82.68
CSP28	13.48	126.23	-50.09	-104.37	-14.75
CSP29	26.78	-12.15	-19.85	-30.75	-35.97
CSP30	90.55	8.34	-133.27	-81.23	-115.61
CSP31	88.9	-99.25	30.62	-3.6	16.67
CSP32	176.67	64.29	37.37	-116.26	162.07
CSP33	110.69	175.96	8.41	-264.44	30.62
CSP34	584.53	403.26	-85.61	-298.19	603.99
CSP35	215.53	78.79	120.06	57.51	471.89
CSP36	-24.01	-32.5	139.46	235.57	318.52
CSP37	-129.98	67.51	113.91	63.37	114.81
CSP38	**Port Area**				
CSP39					
CSP40					
CSP41	89.32	-71.74	0.39	-23.63	-5.66
CSP42	126.43	363.71	-9.64	-34.82	445.68
CSP43	-50.39	264.34	-180.15	-72.26	-38.46
CSP44	49.2	87.93	-143.8	-38.28	-44.95
CSP45	23.89	-125.17	-225.91	15.64	-311.55
CSP46	15.21	-63.75	-93.05	134.07	-7.52
CSP47	-9.82	-8.94	-17.29	160.7	124.65
CSP48	46.04	-0.09	-27.71	34.89	53.13
CSP49	33.72	-54.74	-78.04	64.52	-34.54
CSP50	47.45	-139.12	-73.19	-13.62	-178.48
CSP51	44.45	-150.87	-85.52	50.79	-141.15
CSP52	82.14	-278.22	85.07	166.8	55.79
CSP53	-70.77	50.3	-66.19	64.41	-22.25
CSP54	64	184.64	-30.41	-286.05	-67.82
CSP55	1.74	32.47	45.6	-284.27	-204.46
CSP56	-64.27	190.92	-186.5	-69.02	-128.87
CSP57	-7.29	100.19	-95.75	-118.7	-121.55
CSP58	-60.58	53.84	-41.51	-31.49	-79.74
CSP59	-138.22	52.09	-48.47	-144.45	-279.05
CSP60	38.63	-81.7	13.98	-89.49	-118.58
CSP61	-75.18	-78.12	10.38	-82	-224.92
CSP62	-96.76	9.85	58.28	-195.11	-223.74
CSP63	-66.91	-131.98	-31.16	-85.74	-315.79
CSP64	50.51	-52.57	-33.8	-217.79	-253.65
CSP65	9.23	-8.91	-92.83	-230.29	-322.8
CSP66	8.36	-34.08	-101.42	-274.71	-401.85
CSP67	57.16	52.25	-74.48	-126.97	-92.04
CSP68	65.68	177.1	-89.17	-357.25	-203.64
CSP69	12.97	144.21	-1.06	-290.13	-134.01
CSP70	210.73	125.48	-51.6	-102.09	182.52
CSP71	87.99	27.18	-61.43	-104.5	-50.76
CSP72	72.88	129.45	-91.9	-28.59	81.84
CSP73	67.36	107.96	21.14	5.99	202.45
CSP74	39.46	116.01	-56.47	-31.1	67.9
CSP75	35.77	207.28	54.2	-25.79	271.46
CSP76	62.34	212.12	-8.04	-89.22	177.2
CSP77	-39.02	191	-42.94	-56.33	52.71
CSP78	86.33	174.81	3.82	-130.77	134.19
CSP79	45.63	78.2	13.74	-7.09	130.48
CSP80	30.59	114.81	-21.32	-90.69	33.39
CSP81	-			-47.46	-47.46

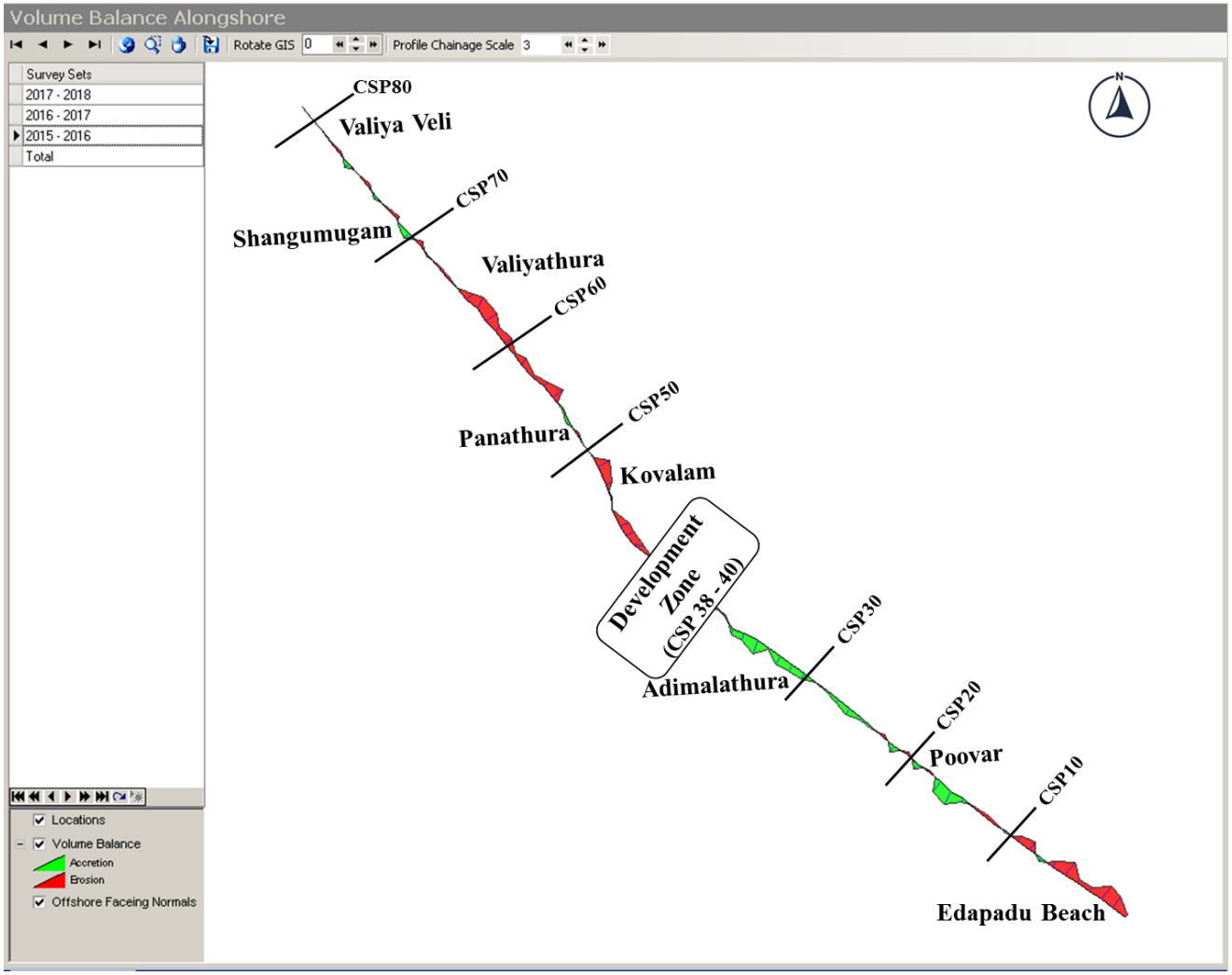
(-) indicates Erosion (+) indicates Accretion
- Data not used for analysis

4.2.5 Inter-annual Changes in the Beach Profile

The entire northern stretch except few beaches (North of Vizhinjam) (CSP 45 to CSP80) and extreme south (CSP1 to CSP10) of coastline shows erosional trend, however immediate south of port to CSP 15 shows depositional trend in the inter-annual scenario. Figure 4.33 depicts the total change in beach volume of all profiles (CSP 1 to CSP 81) for the 4 years period.

The inter-annual beach volume analysis shows, erosion at Valliyathura, Poonthura and Edapadu and there is deposition in beach along few south stretches of Vizhinjam along Mullur to Poovar (Figure 4.30 and Table 4.11) between 2015-2016. The entire coast faces less erosion and high accretion in 2016-2017 compared to the previous year. (Figure 4.31). During the period 2017-2018, there is decrease in beach volume in many part of the coastal stretch attributed to Ockhi cyclone during 30 November- 1 December 2017. (Figure 4.32).

The four years change in beach volume is depicted in Figure 4.33 and Table 4.11 respectively. There was net accretion along the southern part of the beach (CSP 13 to CSP 43 except CSP 01 to CSP 12 that has net erosion) and net erosion along the northern part of the beach (CSP 45 to CSP 75) during February 2015 to February 2018.



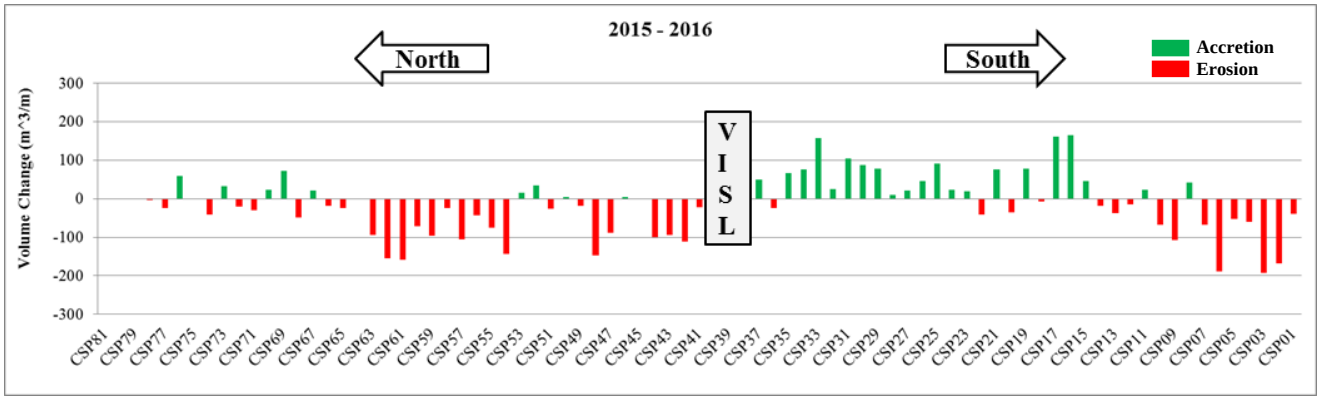
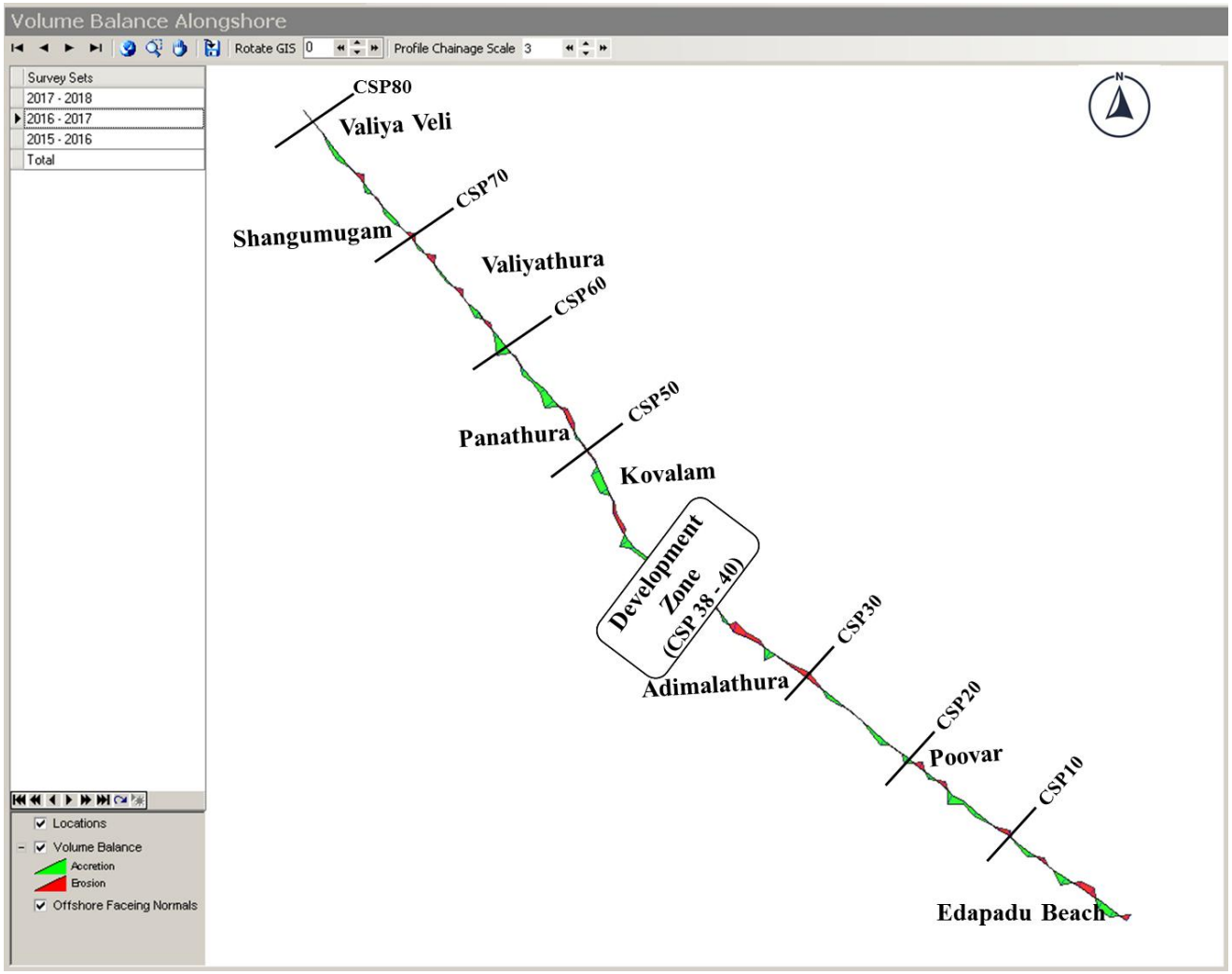


Figure 4.30 Inter-annual Beach Volume Changes from 2015 to 2016 in m^3/m



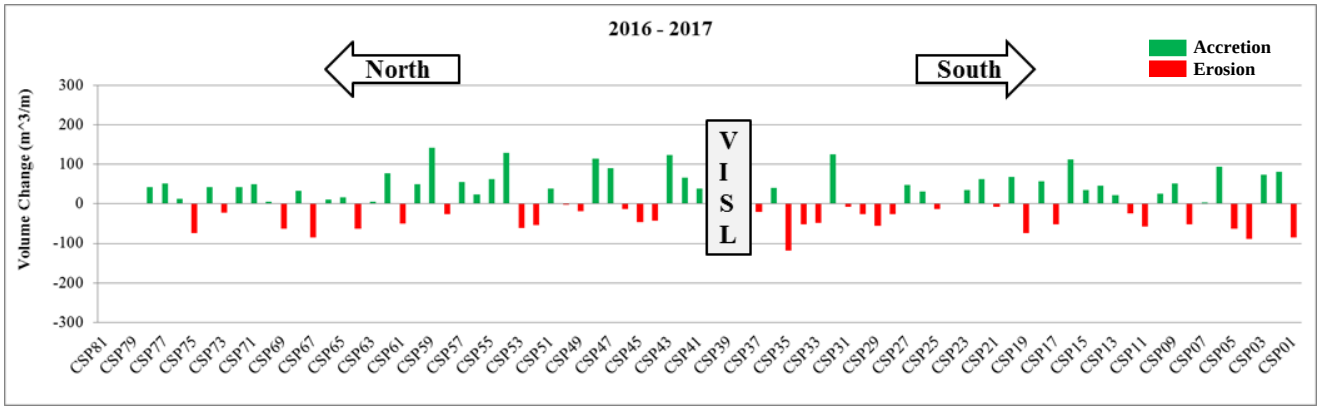
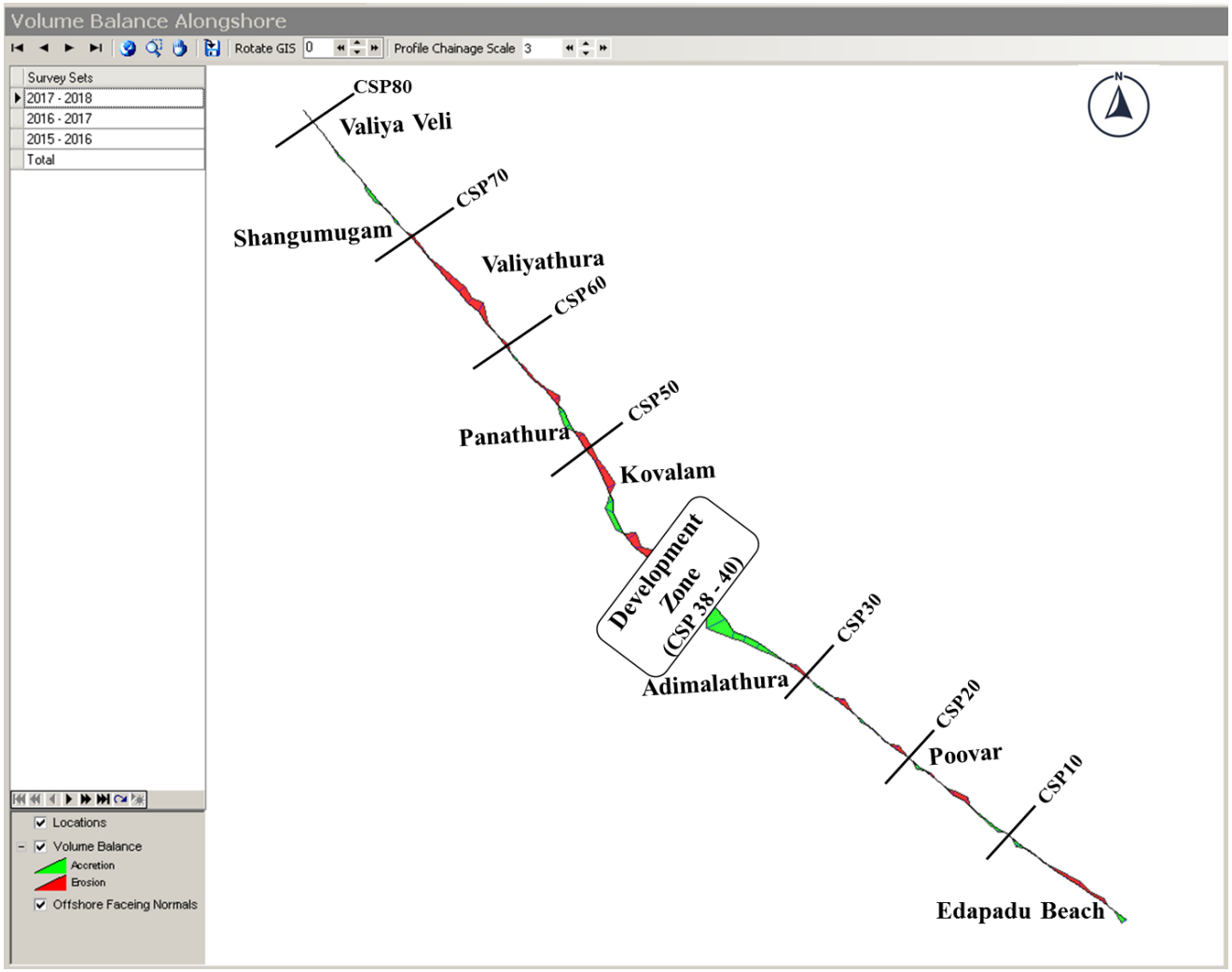


Figure 4.31 Inter-annual Beach Volume Changes from 2016 to 2017 in m^3/m



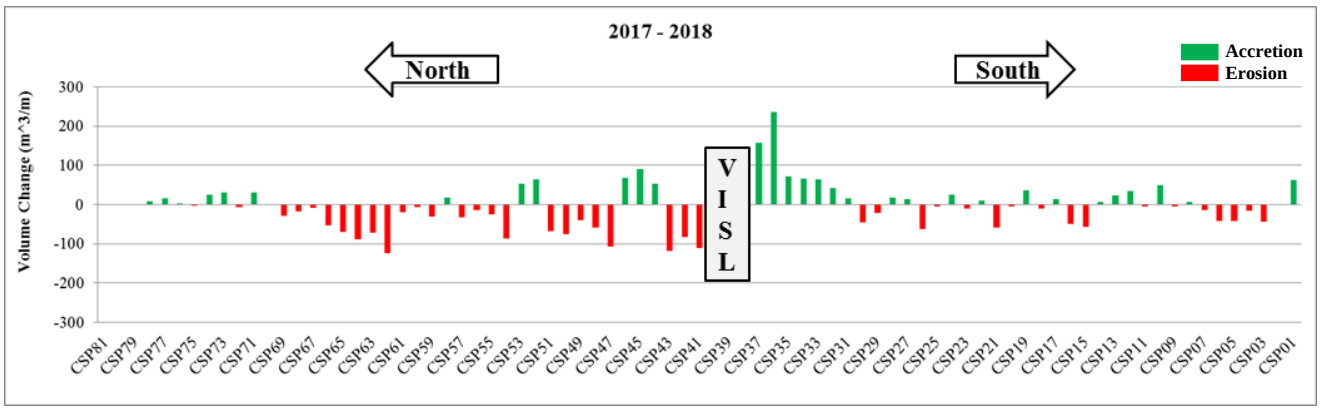
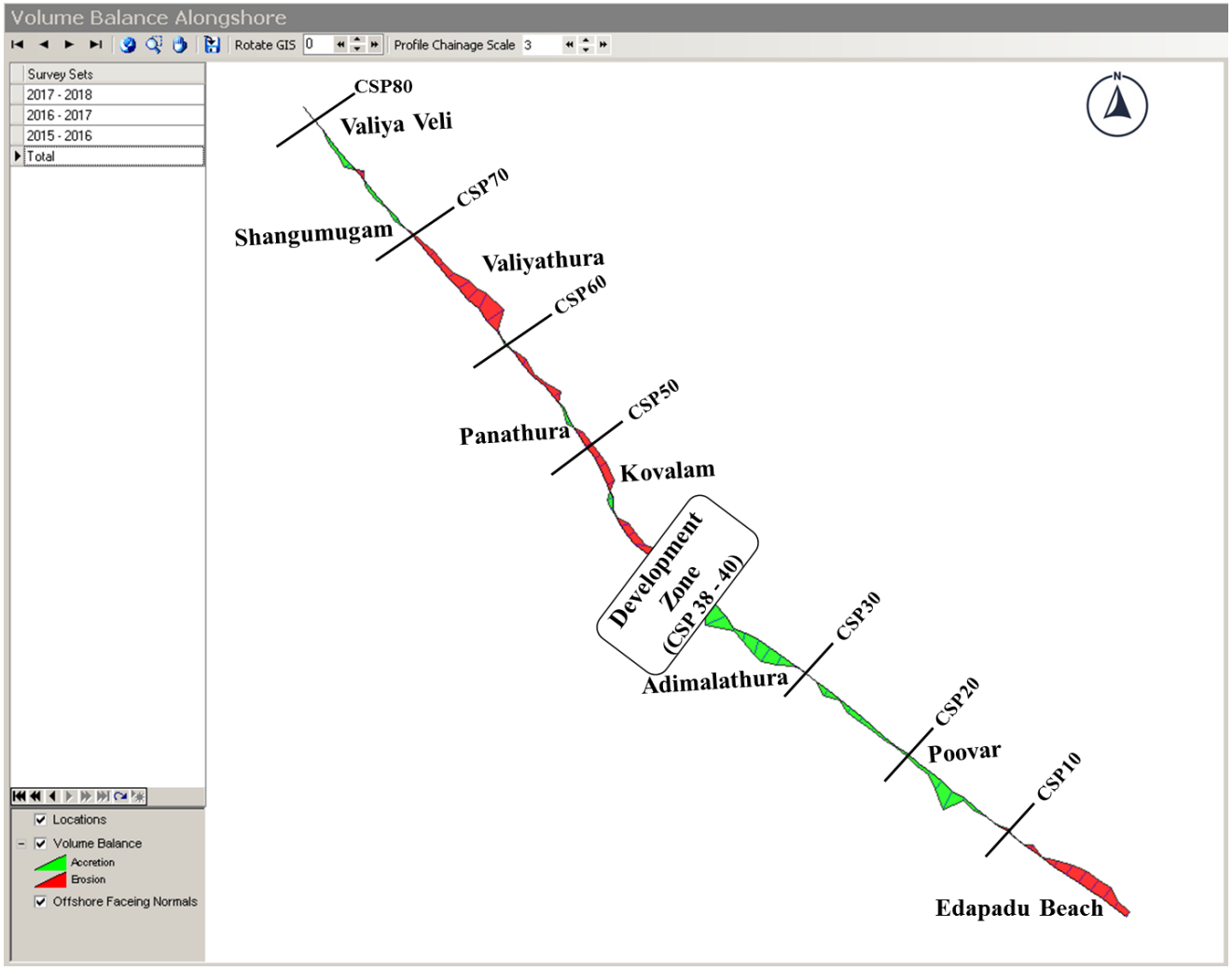


Figure 4.32 Inter-annual Beach Volume Changes from 2017 to 2018 in m^3/m



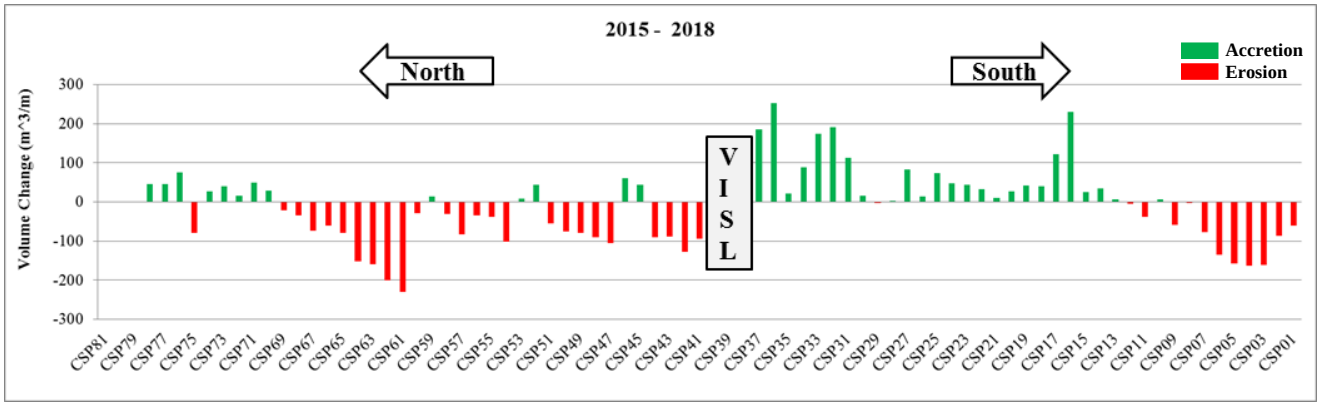


Figure 4.33 Total Beach Volume Changes in Inter-annual scenario from 2015 to 2018 in m^3/m

Table 4.11 Inter-annual Beach Volume Changes between 2015 and 2018 in m^3/m

Location	Feb 2015 –Mar 2016			Mar 2016 – Feb 2017			Feb 2017 – Feb 2018			Feb 2015 – Feb 2018 (Total)		
	Accretion	Erosion	Total	Accretion	Erosion	Total	Accretion	Erosion	Total	Accretion	Erosion	Total
CSP01	56.44	-95.22	**-38.78**	10.27	-95.21	**-84.94**	84.22	-20.93	**63.29**	150.93	-211.36	**-60.43**
CSP02	14.33	-181.64	**-167.31**	125.08	-43.87	**81.21**	30.57	-30.51	**0.07**	169.98	-256.02	**-86.03**
CSP03	11.43	-203.92	**-192.49**	92.77	-18.32	**74.45**	17.71	-60.49	**-42.78**	121.91	-282.73	**-160.82**
CSP04	32.04	-91.27	**-59.23**	14.93	-103.24	**-88.31**	16.13	-31.23	**-15.1**	63.1	-225.74	**-162.64**
CSP05	11.86	-64	**-52.14**	18.61	-81.96	**-63.35**	4.84	-47.42	**-42.58**	35.31	-193.38	**-158.07**
CSP06	0.68	-188.64	**-187.96**	106.86	-12.1	**94.75**	10.4	-51.77	**-41.37**	117.94	-252.51	**-134.58**
CSP07	1.81	-69.91	**-68.1**	36.18	-32.76	**3.42**	30.68	-43.61	**-12.94**	68.67	-146.28	**-77.62**
CSP08	55.57	-12.99	**42.58**	11.54	-62.74	**-51.21**	24.01	-17.13	**6.87**	91.12	-92.86	**-1.76**
CSP09	2.89	-110.34	**-107.45**	69.96	-17.87	**52.08**	23.46	-27.12	**-3.65**	96.31	-155.33	**-59.02**
CSP10	7.74	-76.34	**-68.6**	42.28	-16.54	**25.74**	58.95	-9.61	**49.34**	108.97	-102.49	**6.48**
CSP11	40.3	-16.7	**23.6**	16.26	-74.15	**-57.89**	54.31	-58.33	**-4.03**	110.87	-149.18	**-38.32**
CSP12	22	-36.24	**-14.24**	21.97	-45.59	**-23.61**	77.56	-43.73	**33.83**	121.53	-125.56	**-4.02**
CSP13	22.93	-60.37	**-37.44**	43.12	-20.93	**22.19**	66.21	-43.68	**22.53**	132.26	-124.98	**7.28**
CSP14	23.48	-42.2	**-18.72**	64.83	-18.42	**46.41**	63.98	-57.16	**6.81**	152.29	-117.78	**34.5**
CSP15	80.01	-33.63	**46.37**	61.44	-27.01	**34.43**	64	-119.91	**-55.91**	205.45	-180.55	**24.89**
CSP16	216.86	-50.95	**165.91**	174.7	-61.3	**113.4**	33.92	-82.51	**-48.59**	425.48	-194.76	**230.72**
CSP17	233.3	-72.55	**160.75**	88.52	-140.61	**-52.09**	115.48	-101.12	**14.36**	437.3	-314.28	**123.02**
CSP18	56.67	-64.54	**-7.88**	70.92	-12.86	**58.07**	59.13	-68.7	**-9.57**	186.72	-146.1	**40.62**
CSP19	96.17	-17.21	**78.96**	9.63	-83.04	**-73.4**	85.4	-48.61	**36.79**	191.2	-148.86	**42.35**
CSP20	33.3	-68.8	**-35.5**	79.9	-12.03	**67.87**	60.75	-65.47	**-4.72**	173.95	-146.3	**27.65**
CSP21	84.27	-7.91	**76.35**	34.94	-42.9	**-7.96**	44.06	-102.96	**-58.9**	163.27	-153.77	**9.49**
CSP22	22.91	-63.61	**-40.7**	75.53	-13.53	**62**	70.55	-59.23	**11.32**	168.99	-136.37	**32.62**
CSP23	52.85	-32.99	**19.86**	56.32	-21.55	**34.76**	43.83	-53.9	**-10.07**	153	-108.44	**44.55**
CSP24	43.24	-20.96	**22.29**	25.53	-24.92	**0.61**	77.77	-52.88	**24.89**	146.54	-98.76	**47.79**
CSP25	103.78	-12.14	**91.64**	16.85	-30.7	**-13.85**	63.04	-67.67	**-4.63**	183.67	-110.51	**73.16**
CSP26	102.4	-56.35	**46.05**	39.59	-9	**30.6**	51.56	-113.16	**-61.6**	193.55	-178.51	**15.05**
CSP27	49.38	-28.43	**20.95**	54.46	-7.42	**47.03**	78.64	-64.25	**14.39**	182.48	-100.1	**82.37**
CSP28	59.47	-49.93	**9.55**	23.39	-48.57	**-25.18**	68.42	-50.22	**18.2**	151.28	-148.72	**2.57**
CSP29	100.51	-22.51	**78**	12.18	-68.44	**-56.26**	46.01	-68.11	**-22.1**	158.7	-159.06	**-0.36**
CSP30	108.43	-21.06	**87.38**	22.79	-48.6	**-25.81**	62.22	-108.31	**-46.1**	193.44	-177.97	**15.47**
CSP31	115.2	-10.05	**105.16**	34.62	-42.54	**-7.92**	102.01	-86.12	**15.89**	251.83	-138.71	**113.13**
CSP32	78.02	-52.23	**25.79**	143.54	-18.94	**124.6**	119.8	-78.25	**41.55**	341.36	-149.42	**191.94**
CSP33	187.83	-31.11	**156.73**	25.45	-73.17	**-47.71**	138.68	-73.95	**64.73**	351.96	-178.23	**173.75**
CSP34	130.86	-54.78	**76.08**	41.3	-93.36	**-52.06**	128.59	-63.15	**65.43**	300.75	-211.29	**89.45**
CSP35	80.94	-14.27	**66.67**	1.91	-119.81	**-117.91**	110.98	-38.46	**72.53**	193.83	-172.54	**21.29**
CSP36	20.01	-44.22	**-24.22**	62.44	-21.98	**40.46**	258.28	-22.29	**235.99**	340.73	-88.49	**252.23**
CSP37	70.82	-21.94	**48.87**	26.41	-47.26	**-20.84**	160.33	-2.62	**157.71**	257.56	-71.82	**185.74**
CSP38	**Port Area**											
CSP39												
CSP40												
CSP41	30.67	-48.91	**-31.62**	8.83	-75.64	**-66.81**	229.24	-1.04	**228.2**	112.74	-206.32	**-93.58**
CSP42	18.8	-10.86	**48.36**	12.84	-160.14	**-147.3**	325.58	-5.49	**320.09**	134	-261.71	**-127.71**
CSP43	12.66	-10.48	**50.67**	16.56	-57.79	**-41.24**	94.3	-27.75	**66.56**	156.41	-244.48	**-88.06**
CSP44	9.75	-25.08	**-8.66**	22.22	-38.2	**-15.98**	90.38	-88.64	**1.73**	155.93	-246.77	**-90.83**
CSP45	33.37	-106.59	**-93.19**	14.09	-101.49	**-87.4**	123.76	-3.95	**119.82**	207.91	-163.72	**44.18**
CSP46	55.73	-72.48	**-57.15**	26.48	-66.17	**-39.69**	73.81	-38.08	**35.72**	153.36	-93.47	**59.9**
CSP47	1.69	-144.81	**-143.32**	3.77	-113.19	**-109.42**	96.8	-7.55	**89.25**	115.56	-220.17	**-104.62**
CSP48	2.38	-74.79	**-67.32**	24.72	-31.08	**-6.35**	117.71	-24.34	**93.37**	152.72	-243.59	**-90.87**
CSP49	14.58	-70.85	**-48.01**	6.68	-56.38	**-49.7**	133.52	-10.93	**122.6**	37.03	-115.25	**-78.23**
CSP50	36.25	-83.81	**-81.67**	21.12	-26.32	**-5.2**	57.5	-72.47	**-14.97**	221.7	-296.1	**-74.38**
CSP51	41.66	-117.8	**-116.23**	23.05	-38.24	**-15.19**	99.17	-75.96	**23.22**	182.17	-237.11	**-54.95**

CSP52	54.88	-104.1	**-94.3**	47.05	-12.23	**34.82**	32.26	-32.98	**-0.72**	191.22	-147.14	**44.08**
CSP53	27.02	-138.82	**-106.14**	22.58	-204.76	**-182.19**	290.14	-92.76	**197.38**	116.51	-108.56	**7.97**
CSP54	0.83	-175.04	**-136.21**	70.36	-29.07	**41.3**	99.07	-155.99	**-56.91**	184.38	-286.5	**-102.13**
CSP55	2.57	-35.83	**3.96**	8.71	-76.19	**-67.48**	171.01	-49.33	**121.69**	121.35	-159.59	**-38.24**
CSP56	7.03	-72.43	**-71.56**	8.79	-26.53	**-17.75**	116.4	-21.82	**94.58**	69.62	-103.11	**-33.5**
CSP57	0.06	-101.63	**-95.67**	50.72	-10.37	**40.35**	64.64	-45	**19.64**	105.7	-188.65	**-82.96**
CSP58	10.03	-87.11	**-84.55**	38.17	-13.22	**24.95**	59.36	-27.18	**32.18**	47.94	-79.26	**-31.32**
CSP59	2.62	-79.47	**-77.67**	37.69	-19.06	**18.63**	64.57	-16.8	**47.77**	182.42	-167.79	**14.63**
CSP60	7.09	-108.15	**-107.46**	30.38	-23.38	**7**	92.41	-53.86	**38.55**	108.89	-137.88	**-29**
CSP61	2.65	-113.64	**-113.63**	45.1	-11.23	**33.88**	106.51	-3.51	**103**	32.83	-262.81	**-229.98**
CSP62	1.03	-124.14	**-111.16**	195.54	-17.99	**177.55**	31.55	-70	**-38.45**	112.22	-312.88	**-200.65**
CSP63	2.04	-142.74	**-141.84**	100.4	-12.09	**88.31**	92.66	-50.53	**42.12**	66.8	-226	**-159.21**
CSP64	27.25	-336.29	**-336.23**	98.28	-12.19	**86.09**	66.51	-55.11	**11.4**	80.4	-231.75	**-151.36**
CSP65	17.47	-189.75	**-187.54**	37.94	-27.19	**10.74**	46.47	-101.2	**-54.73**	95.28	-173.38	**-78.11**
CSP66	15.37	-136.22	**-133.98**	34.91	-37.56	**-2.65**	77.48	-162.01	**-84.53**	115.91	-176.5	**-60.58**
CSP67	32.05	-75.88	**-72.54**	28.91	-44.31	**-15.39**	64.78	-139.52	**-74.74**	108.45	-181.62	**-73.18**
CSP68	9.87	-55.54	**-45.52**	20.74	-74.36	**-53.62**	87.38	-77.48	**9.9**	141.34	-174.83	**-33.49**
CSP69	77.65	-48.82	**-42.88**	30.96	-42.5	**-11.54**	85.88	-66.63	**19.25**	154.51	-174.87	**-20.36**
CSP70	43.49	-62.17	**-56.98**	28.57	-46.86	**-18.28**	87.71	-92.5	**-4.78**	145.89	-116.92	**28.97**
CSP71	16.36	-7.91	**28.37**	10.54	-71.88	**-61.33**	93.26	-81.55	**11.71**	180.6	-130.45	**50.16**
CSP72	15.45	-14.02	**20.8**	30.52	-60.12	**-29.6**	98.7	-100.21	**-1.51**	141.5	-125.18	**16.31**
CSP73	46.11	-7.93	**41.86**	22.85	-33.57	**-10.71**	67.93	-87.73	**-19.8**	152.03	-112.26	**39.77**
CSP74	19.95	-5.74	**30.35**	12.59	-54.54	**-41.95**	77.09	-69.77	**7.32**	177.53	-149.53	**28**
CSP75	55.18	-6.6	**38**	37.59	-32.84	**4.74**	57.56	-120.92	**-63.36**	184.72	-262.79	**-78.07**
CSP76	75.68	-18.81	**9.15**	38.15	-32.48	**5.67**	98.94	-89.84	**9.11**	196.1	-120.78	**75.33**
CSP77	4.63	-21.5	**-0.45**	45.39	-25.36	**20.04**	85.69	-89.98	**-4.29**	174.52	-129.51	**45.01**
CSP78	20.12	-104.05	**-71.29**	51.78	-99.29	**-47.52**	103.19	-68.46	**34.73**	153.75	-107.52	**46.22**
CSP79	**Data not included for analysis**											
CSP80												
CSP81												
(-) indicates Erosion **(+) indicates Accretion** **- Data not used for analysis**												

4.2.6 Observations from Beach profiles at Valliyathura 2015-2018

Beach profile analysis has been carried out for the Valliyathura site as per NGT requirement. The beach profiles (CSP 63 to CSP 65) near Valliyathura village has been analysed and presented. CSP 63 is situated to the south of Valliyathura pier, CSP 64 adjacent to Valliyathura pier and CSP 65 to the north of Valliyathura Pier in a distance of about 500m each.

4.2.6.1 Annual trend in beach profile:

The annual beach profile analysis around Valliyathura shows net erosion during 2016 to 2018 at all the three profiles (CSP 63 to CSP65) (Figure 4.34 and Table 4.10). CSP 64 and CSP 65 show net accretion during 2015. There was net erosion in all the profiles during the period February 2015 to September 2018 (Table 4.10).

Figure 4.34 Annual beach profile trend for the profiles CSP 63 to CSP 65.

4.2.6.2 Monthly and seasonal trend in beach profile:

The beach profile analysis from February 2015 to September 2018 was presented in the Figure 4.35. Monthly beach volume variation at Valliyathura shows that during the months of March – April and April – May there is significant erosion. During the month of September – October accretion was observed.

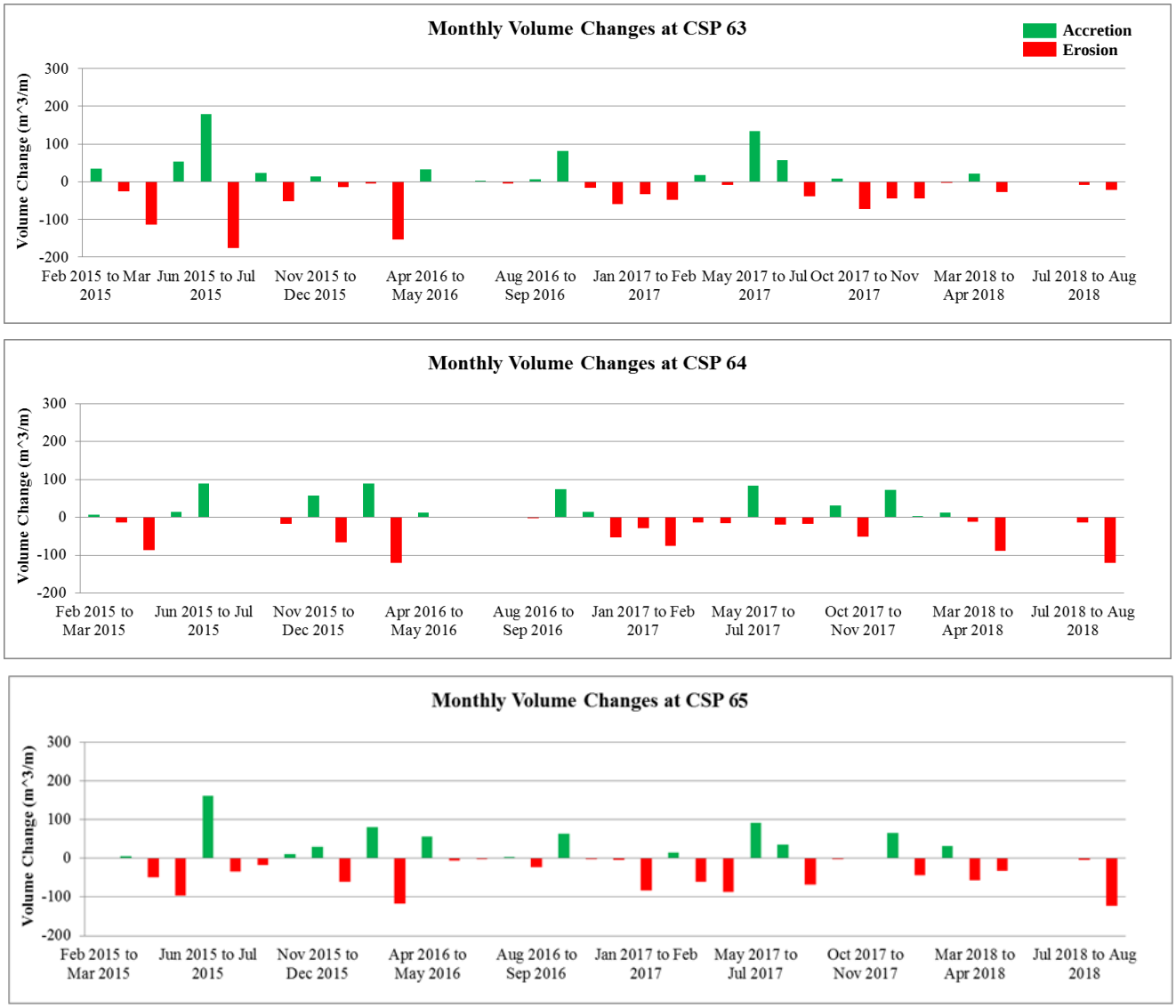


Figure 4.35 Monthly beach profile trend for the profiles CSP 63 to CSP 65.

4.2.6.3 Seasonal trend in beach profile:

Figure 4.36 Seasonal beach profile trend for the profiles CSP 63 to CSP 65

The seasonal beach volume (Figure 4.36) shows erosion during February to May and accretion in the month of September. In monsoon season the beach lost during the months of June, July and August is completely recovered during the month of September. The post-monsoon season has erosion and accretion.

It can be inferred that there is net erosion along the Valliyathura segment (CSP 63 to CSP 65) in the annual scenario that requires immediate and long term mitigation measures.

4.3 Validation and Comparison of results

For the validation of the results from the shoreline derived from the satellite images (LISS 4 and LANDSAT), the beach profile data of February 2017 has been used. The average error between LANDSAT derived shoreline is -11.8m and for LISS 4 data, the error is -1.5m. Figure 4.37 shows the beach profile data and shoreline extracted from the satellite

images (Landsat-30m and LISS IV-5m) data with respect to baseline parallel to the coast (transects with rocky/ irregular coast to the baseline has not been considered). The error in extracting the shoreline from satellite images reduces with respect to the spatial resolution of the satellite images. The result from the two analysis (high resolution satellite image and beach profile data) shows concurrence. The difference in the shoreline distance along the transects south of Vizhinjam port is due to the fact that the beach profile data has been collected at different time and date whereas the satellite image captures the entire coast at a single time and date.

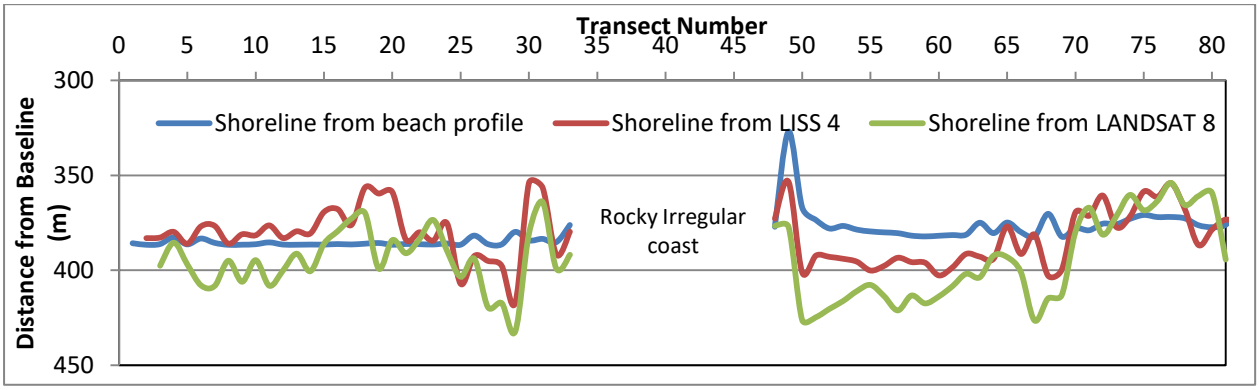


Figure 4.37 Baseline distance of Shoreline derived from satellite images (5m and 30 m spatial resolution) and shoreline from beach profile for February 2017.

Similarly, the validation of the result has been carried out using the shoreline data collected from 40km (20km from either side of the port) stretch of Vizhinjam port, using both handheld GPS (HHGPS) and Differential GPS (DGPS) on Sep 2018 (Figure 4.38). The field data has been compared with shoreline derived from Beach profile and Satellite Imagery is shown in Figure 4.39. With the higher resolution satellite images, the field shoreline exactly matches with the shoreline derived from the satellite images whereas shoreline derived from the beach profile matches only at every 500m.

A comparison of the shoreline change for the year 2017-2018 using satellite image and the beach profile data has been provided in the Figure 4.40 and the regression graph has been provided in Figure 4.41. The comparison shows that the change assessed from both the methods shows correlation regression of 0.81. The minor deviation at transects 68 to 71 and 75 in the shoreline change in the south of Vizhinjam port (Figure 4.40) is due to the fact that the shoreline extracted from the beach profile after linear interpolation of the profile at inaccessible region.

Figure 4.38 Shoreline data collected using DGPS and Handheld GPS

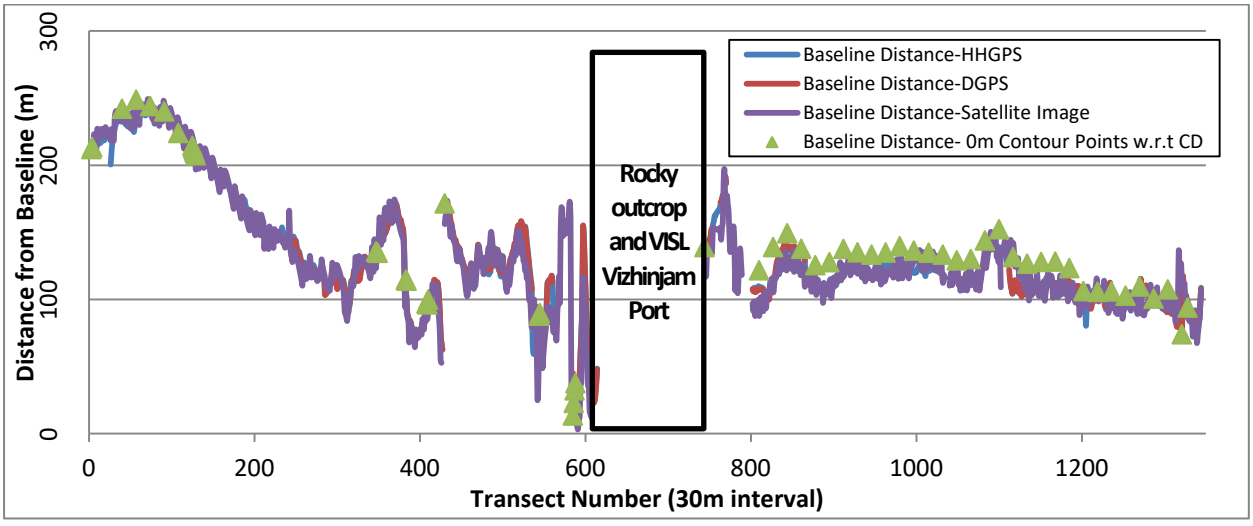


Figure 4.39 Comparison of Shoreline data from satellite image and beach profile data with field shoreline

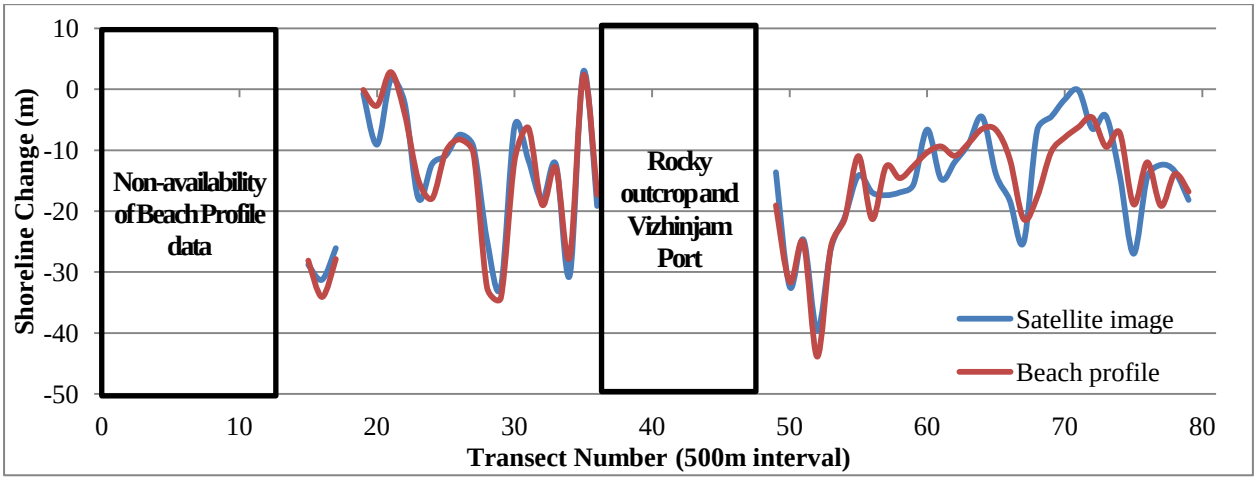


Figure 4.40 Comparison of shoreline change Feb 2017- Feb 2018 from satellite image and beach profile data

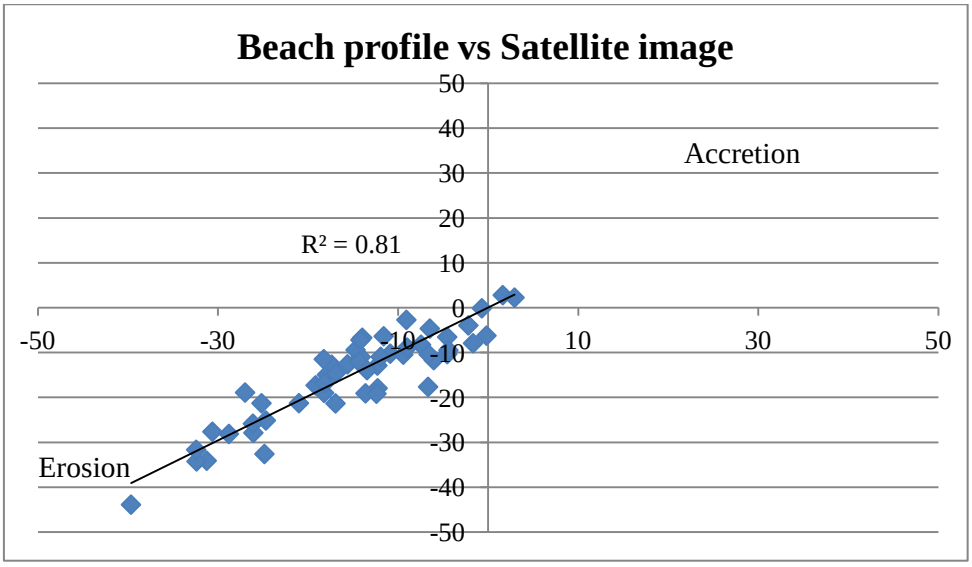


Figure 4.41 Correlation regression between satellite image and beach profile data at each transects.

The derived zones of high erosion and accretion have been compared with the spots mentioned in the various reports as provided in Table 4.1. A recent report on National Assessment of Shoreline changes along Indian coast for the period 1990-2016 by National Centre for Coastal Research (previously Integrated Coastal and Marine Area Management Project Directorate) under Ministry of Earth Sciences has been published in the year 2018. They have used the satellite data of spatial resolution ranging from 30m to 5.8m for the shoreline change analysis. Valliyathura, Punthura has been a spot of high erosion in the overall results. The shoreline change map of Kerala coast is provided in Figure 4.42 from the NCCR report.

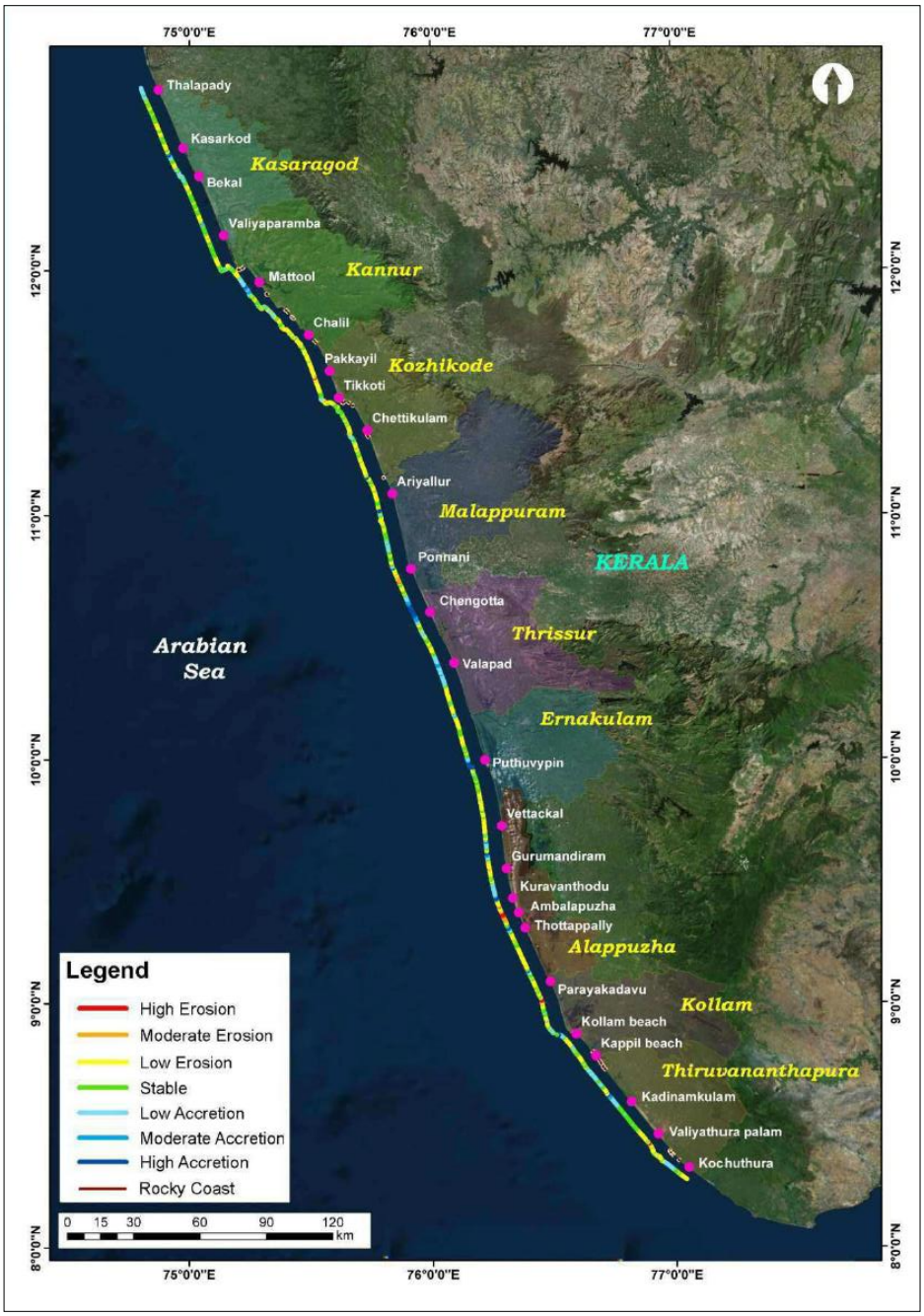


Figure 4.42 Shoreline change map of Kerala coat (Source: NCCR).

The Google earth images of the zones of high erosion and accretion has been provided in the Figure 4.43 to 4.46 and the field photos (from the field visit carried out during the month of July and September 2018) of those locations are shown in Figure 4.47 to 4.50.

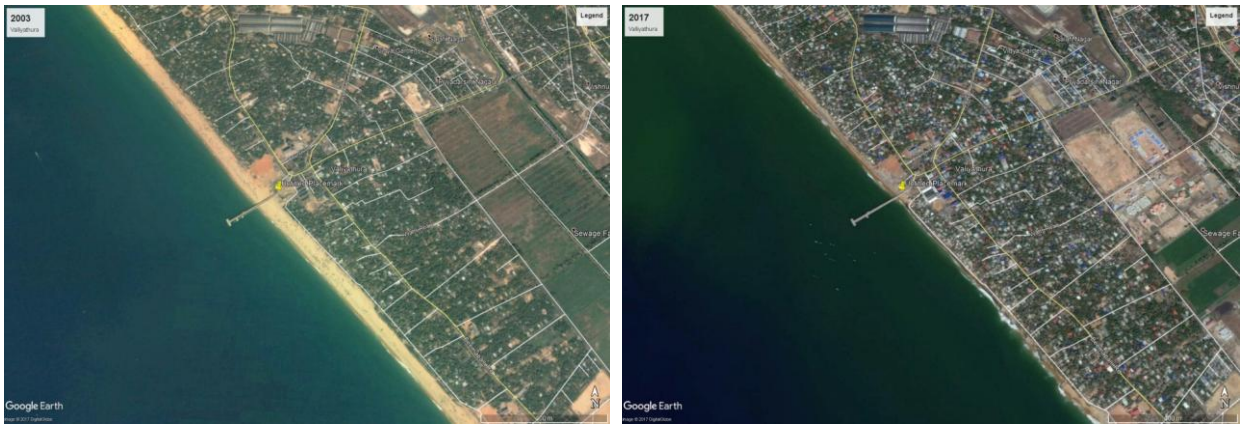


Figure 4.43 Valliyathura during 2003 and 2017

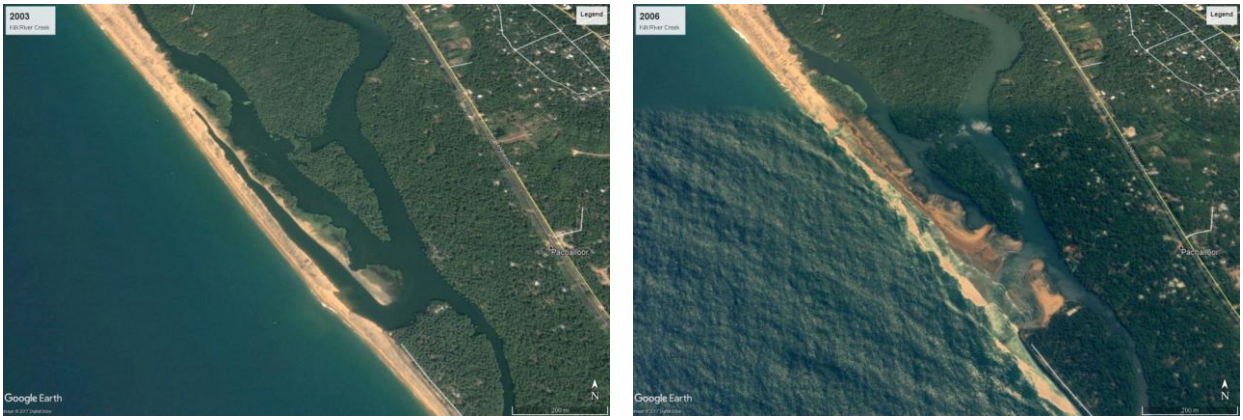


Figure 4.44 Killi river creak (Punthura) during 2003 and 2006

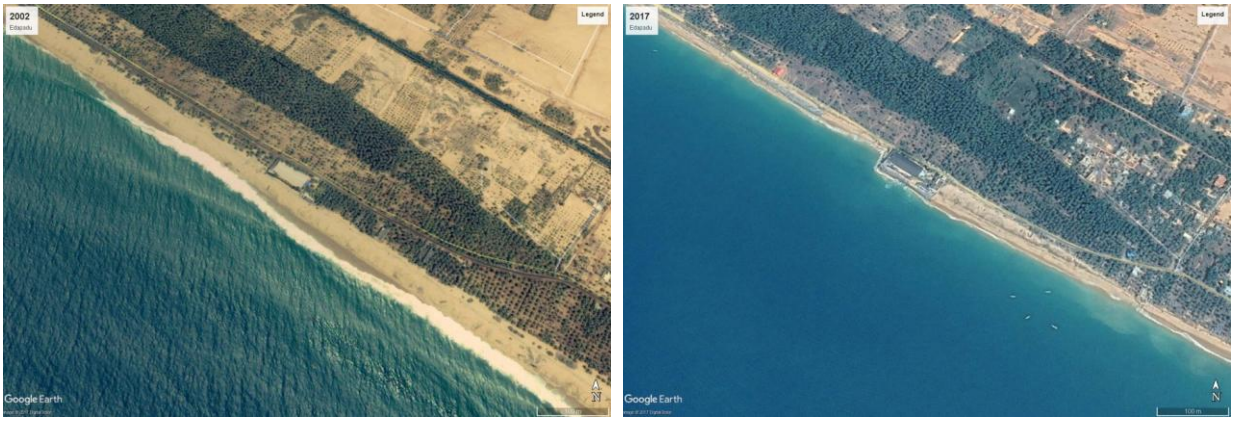


Figure 4.45 Edapadu of Tamilnadu during 2002 and 2017

Figure 4.46 Vizhinjam Port region during 2016, 2017 and 2018

Figure 4.47. Erosion along the Edapadu beach (south of Vizhinjam)

Figure 4.48. Erosion near Valliyathura pier

Figure 4.49 Combination of Sea and Groins at Punthura

Figure 4.50 Poovar River

5 VETTING OF REPORTS/ DATA

NIOT as a committee member involved in study plan design for VISL proposed shoreline monitoring during October 2012. An automatic tide gauge has been installed at Vizhinjam fishing harbour during December 2012 and vetting of Reports on field measured oceanographic and hydrographic data was done during March 2013. Vetting of report on qualifying the survey procedures and methodology for project execution and plan for oceanographic data collection including shoreline monitoring has been done during December 2014. The sequence of events is provided in Table 5.1.

Periodical (monthly, seasonal and yearly) reports on field data quality check and advise on water quality, sediments, shoreline monitoring, etc. are scrutinized by NIOT. The data received from AVPPL/VISL for the years 2015, 2016, 2017 and 2018 are listed in tables 5.2-5.5. Sediment samples were collected at the cross-shore profile locations seasonally. Water

quality (turbidity, TSS and salinity being carried out at 4 locations, two each north and south of Vizhinjam port).

Oceanographic and bathymetric data till September 2018 has been received (Table 5.5) and vetting of Reports on oceanographic and bathymetric data collection for assessment of Shoreline changes has been completed till August 2018. Recently a vetting of tide data report to be submitted to National Hydrographic Office (NHO), Dehradun has been completed.

Table 5.1 Sequence of events

SNo.	Description of work	Date
1.	VISL has entered into a MoU with NIOT	19th November 2014
2.	Wave Rider Buoy (WRB) was deployed with the help of VISL and appointed agencies	February, 2015
3.	The vetting of Shoreline Modelling Report prepared by L&TIEL based on the field data collected under this programme including Shoreline Monitoring	February 2015 to February 2018
4.	The final discussion among all stake holder meeting conducted at NIOT	18th August 2017
5.	New studies related to field data collection programme and numerical Modelling suggested to AVPPL as per their request for 2017-2018	December 2017
6.	Dr. Jena attended and presented the shoreline change work carried out using satellite images at KCZMA meeting	5th February 2018
7.	Vetting of Reports on oceanographic and bathymetric data collection for assessment of Shoreline changes has been completed till August 2018	September 2018

Table 5.2 Data status for 2015

Sl no.	Parameters	Pre monsoon (Feb-May)				SW Monsoon (June- September)				Post monmsoon (October-January)			
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	✓ (15 Feb to 15 march, 2015)				✓ (15 July to 15 August, 2015)				✓ (15 Jan to 12 Feb., 2016)			
5	Bathymetry	✓				✓				✓			
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	River bathymetry (7 locations)	×	×	×	×	✓				×	×	×	×
8	Water sample (Turbidity, TSS, Salinity and temp)	×	✓	×	×	✓	✓	×	×	×	×	×	✓
9	Grain size(81 locations at 500 m distance)	✓(one time)				✓(one time)				✓(one time)			
10	LEO (81 locations at 500 m distance)	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
11	River discharge	×	×	×	×	×	×	×	×	×	×	×	×

N. B.	✓= Available	×= Non available

Sl no	River locations
1	Chovara River
2	Gangayattumkara Canal
3	Karimpallickara Stream
4	Mullur Stream
5	Poovar River
6	Thiruvallam River
7	Veli River

Sl no	ADCP locations
1	Mullor
2	Pachaloor
3	poovar
4	Vizhnjam

Report status	
Pre monsoon	Available
Monsoon	Available
Post Monsoon	Available

Table 5.3 Data status for 2016

Sl no.	Parameters	Pre monsoon (Feb-May)				SW Monsoon (June- September)				Post monmsoon (October-January)				Feb.,2017
1	Wave (1 location)	✓	✓	✓	✓	Incois wave data	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	✓ (20 April to 20 May, 2016)				✓ (15 August to a5 September, 2016)				×				×
5	Bathymetry	✓				×				✓				
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
7	River bathymetry (7 locations)	×	×	×	×	✓ (Sept., 2016)				×	×	×	×	×
8	Water sample (Turbidity, TSS, Salinity and temp)	×	✓	×	×	×	×	✓	×	×	✓	✓	✓	✓
9	Grain size(81 locations at 500 m distance)	×				✓ (July, 2016)				✓ (October, 2016)				✓
10	LEO (81 locations at 500 m distance)	×	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓

N. B.	✓ = Available	× = Non available

Sl no	River locations
1	Chovara River
2	Gangayattumkara Canal
3	Karimpallickara Stream
4	Mullur Stream
5	Poovar River
6	Thiruvallam River
7	Veli River

Sl no	ADCP locations
1	Mullor
2	Pachaloor
3	poovar
4	Vlzhnjam

Report status	
Pre monsoon	NA
Monsoon	NA
Post Monsoon	NA

Table 5.4 Data status for 2017

Sl no.	Parameters	Pre monsoon (Feb-May)				SW Monsoon (June- September)				Post monmsoon (October-January)			
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth	✓				✓				✓ (January - February 2018)			
5	Bathymetry	✓ (June)								✓ (November)			
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Turbidity	✓	✓	✓	✓	✓	✓	✓	x	✓	✓	✓	✓
7	River bathymetry (7 locations)	✓											
8	Water sample (TSS, Salinity and temp)	✓ (April, 2017)				✓ (October)							
9	Grain size(81 locations at 500 m distance)	✓ (January)				✓ (August, 2016)							
10	LEO (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

N. B.	✓ = Available	× = Non available

Sl no	River locations
1	Chovara River
2	Gangayattumkara Canal
3	Karimpallickara Stream
4	Mullur Stream
5	Poovar River
6	Thiruvallam River
7	Veli River

Sl no	ADCP locations
1	Mullor
2	Pachaloor
3	poovar
4	Vlzhnjam

Report status	
Pre monsoon	NA
Monsoon	NA
Post Monsoon	NA

Table 5.5 Data Status as on September 2018

Sno.	Parameters	Pre monsoon (Feb-May)				SW Monsoon (June- September)			
1	Wave (1 location)	✓	✓	✓	✓	✓	✓	✓	✓
2	Tide (1 location)	✓	✓	✓	✓	✓	✓	✓	✓
3	Met (1 location)	✓	✓	✓	✓	✓	✓	✓	✓
4	ADCP (4 locations) at 20 m water depth		✓ (May 2018)			✓ (August 2018)			
5	Bathymetry		✓ (April 2018)				x		
6	Beach Profile (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓
	Turbidity	✓	✓	✓	✓	✓	✓	✓	✓
7	River bathymetry (7 locations)		x			✓ (July 2018)			
8	Water sample (TSS, Salinity and temp)		✓ (May, 2018)			✓ (August 2018)			
9	Grain size(81 locations at 500 m distance)	✓ (Beach Sediment sample and Grab Sample - March 2018)				✓ (Beach Sediment Sample - June 2018)			
10	LEO (81 locations at 500 m distance)	✓	✓	✓	✓	✓	✓	✓	✓

5.1 Methodology adopted for verifying various parameters are provided below

The calibrated pressure sensor was installed at Vizhinjam port. The Vizhinjam tide gauge data has been connected to bench mark near jetty and the data were observed with respect to chart datum. NIOT has checked the consistency of water level by installing radar level sensor near to the existing tide gauge. The periodically check by manual measurement logs are also verified and the difference matched well between the acceptable limit. The observed tide data are checked thoroughly and removed the flag suspicious data like spikes.

The beach profile data quality check has been carried out based on the quantity of the data received against the temporary bench mark and beach profile comparison with the earlier data sets. The data set has been discarded from the analysis based on the following criteria:

1. No simultaneous offshore profile data with onshore profile observed less than +1 m contour.
2. More than 50% spatial profile deviation from the previous month data with respective to x and y coordinates
3. Data set which has less than 4 data points
4. The cross sectional profiles survey has been carried out using RTK method. The NIOT team members visited site during RTK survey and checked the base station and rover setup during survey. The consistency of position and level before starting the survey and after finishing survey has been check during survey.

Initial data quality analysis has been done based on the above criteria. When two of the above points are noticed in all the profile data in a month, the data of that particular month has been discarded.

Sudden unrealistic changes/Spikes observed in the profile level arising due to some reasons are carefully examined and removed before the analysis. Further to normalize the gaps in a single profile bilinear interpolation has been carried out to fill the data gaps and uniform 1 meter interval profile data has been generated. Shoreline and Nearshore Data System (SANDS) that was used in the analysis has its own Data Quality procedure which will not allow the system to proceed and analyze the data but ends up with error. Sands have an option to edit/omit the profile data that contains error and or not qualitatively passed. All profiles are manually checked before entering the data in to SANDS.

The calibration of multi-beam echo sounder commonly referred as patch test. It is required to indentify the offsets which would be applied to the data in order to compensate any misalignment in various sensors used. The offsets from vessel reference point, DGPS antenna and transducer was measured and entered into the acquisition software with in-situ measurement of sound velocity profiler. The initial multi-beam survey was carried out without taking the cross lines, after 1st survey NIOT has insisted to AVVPL for carrying out the crossline survey as per the IHO standards for multi-beam survey. The NIOT team has checked patch test and other offsets for bathymetry survey.

TSS was analysis data provided was verified using the protocol prescribed by the American Public Health Association (APHA) 21st Edition 2540 D and also validated using available data. Turbidity was measured using turbidity meter as per APHA protocol. The instrument was calibrated using formazin / factory calibrated standard.

The ADCP current data analyzed using standard oceanographic methods and analysis techniques provided by the client software. These includes standard visualization techniques, pre and post calibration at lab, time-series and statistical methods and numerical analysis. The ADCP quality control checks, correlation test, false target rejection test and error velocity test.

The data copied at buoy internal memory was downloaded at the end of retrieval and verified against the real-time data for any missing part. Wave data was processed using the manufacturer’s software package after downloading to the field PC. Wave parameters like

Significant wave height, period, maximum wave height and wave direction was tabulated against time. Data gaps, Spikes or improbable data was verified and removed. As the present used directional wave rider buoy is working based on the GPS principle, hence calibration of the buoy is not required.

Grab samples analysis report checked whether i) Grain size analysis is carried out as per IS 2720 PART IV, ii) Grain size distribution chart and table are provided as per IS 2720 PART IV, Appendix A, iii) Soil classification is carried out as per IS 1498 and iv) D50 values and location are provided for each sample. Also duplicate set of few samples are collected and analysed at NIOT Geotechnical laboratory for cross verification of results submitted.

6 CONCLUSION

NIOT has carried out shoreline analysis using high resolution satellite images and analysis of beach profile data. Apart from that NIOT has also vetted / reviewed project proposals, field measured data and reports on various oceanographic data related to port development and monitoring, installation and maintenance of automatic tide gauge & WRB including shoreline monitoring studies.

The zones of High erosion and accretion have been derived from the high resolution satellite images for the year 2000 to 2018. Valliyathura, Punthura and Edapadu have been identified as zones of high erosion, whereas Kottakal, Poovar and Karumkulam regions are identified as zones of high accretion. This was also compared with the previous studies carried out by premier institutions such SAC, INCOIS, NCSCM and NCCR.

Beach profile analysis for the entire 40 km stretch has been carried out monthly, seasonal, annual and inter-annual including changes in the beach volume. The monthly analysis shows that the beach undergoes erosion during the months of March to August and beach formation from September to February every year with varying magnitude. The seasonal analysis shows fair weather period (February to May) and Monsoon (June to September) exhibits severe erosion, while Post Monsoon (October to January) exhibits deposition. The annual variation of the total beach volume indicates erosion during the year 2017 and 2018 along the 40 km stretch. The inter- annual scenario from 2015 - 2018 (months and year in concurrence with the satellite image analysis) indicates similar trend of more erosion and less accretion pattern along 40 km stretch for the years 2015-2016, 2017-2018 except that more accretion and less erosion was noticed during 2016-2017.

The most of the beach along the 40 km stretch underwent erosion during the year 2017, which are partially recovered during the post monsoon (December 2017 to February 2018. The beaches between Edapadu and Paruthiyoor (CSP 1 to CSP 15), Kovalam to Punthura (CSP 44 to CSP 55) and Valliyathura to Vettucaud (CSP 63 to CSP 75) are experiencing net erosion despite seasonal deposition. The region between Adimalathura and Mullur (CSP 31 to CSP 37 up to VISL Port region) shows accretion.

Analyses of beach profiles with specific reference to Valliyathura (north of Vizhinjam) coast are cyclic and changes seasonally. Erosion is noticed during Fair weather period (February-May) and Monsoon (June to September) and deposition during Post monsoon period (October to January). Valliyathura region is presently undergoing severe erosion. Similarly the location specific analysis using satellite images at Valliyathura also indicates net erosion from 2015 to 2018. Historical trend analysis with respect to shoreline position also indicates the erosion trend from 2000-2005, accreting trend from 2005-2010, stable trend from 2010-2015 and again eroding trend from 2015-2018. It can be noted that the study carried out by Thomas (1988) have discussed about the cyclic trend of erosion and accretion cycle at Valliyathura. These analysis shows that the beach undergoes alternative phases of erosion and accretion which is completely dependent on incoming waves respect to seasons and weather events. Periodic long period swell with high energy waves and tidal flooding creates beach erosion at these sites. Sanil Kumar et al, 2018 have discussed the increase in the significant wave height on western shelf seas (~1.2m) than the eastern shelf seas (~1.0m) due to stronger influence of summer monsoon in the Arabian sea compared to Bay of Bengal. In the last decade which plays an important role in the beach sediment transport. The year 2018 has been devastative in terms of beach loss which was led to major sediment deficit to the beach. The periodic fluctuations in the beach erosion are accompanied with fast recovery at some stretches (immediate south of Vizhinjam Port area i.e. between CSP 25 to CSP 37) and take longer at others beaches (CSP 63 to CSP 77).

The shorelines derived from the satellite image and beach profile has been compared with the shoreline collected from field. The beach profile data has also been used for the comparison and validation with the results from the satellite image data. The results from 2017-2018 with 500m transect interval has been compared with beach profile analysis. Further the analysis using satellite images has been extended with the higher resolution satellite images of different months (seasonal changes) within a year. The zones of high erosion and accretion have been compared with the reports of various organizations specific to this study area. The

shoreline change analysis carried out using high resolution satellite images show that spots of high erosion north of Vizhinjam remains more or less same before and after 2010. However, in the sector south of Vizhinjam, a high erosion zone is seen to be developed at Edappadu beach during 2010-2018. Similarly, from the shoreline change study carried out using beach profile analysis from 2015- 2018 shows the major spots of erosion at Valliyathura, Poonthura and Edapadu except the fact that the entire coastal stretch faced erosion during the natural calamities such as Ockhi cyclone and high wave activities.

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