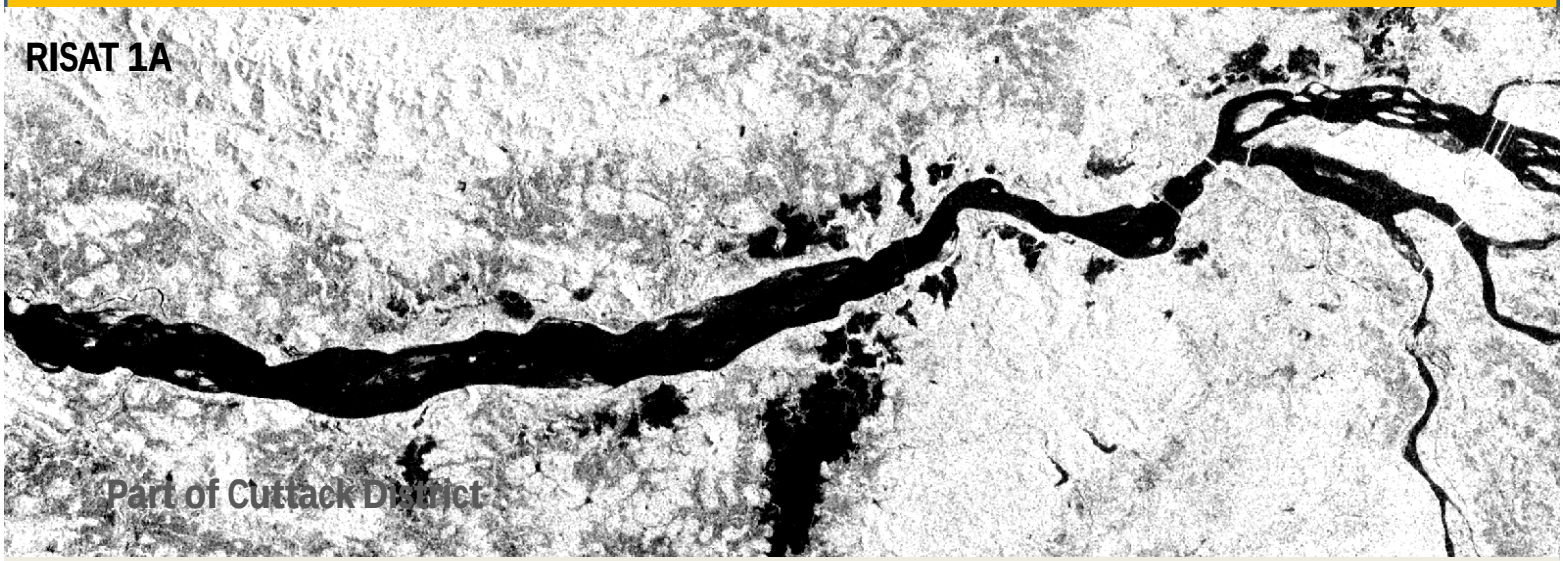
Satellite based Analysis -
Flood Mapping & Monitoring in Odisha State



Disaster Management Support Group
National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO)
Dept. of Space, Govt. of India , Balanagar, Hyderabad-37, Telangana State, India

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15.	Abstract:			

Heavy rainfall and heavy runoff during 13-16th, August 2022 in the Mahanadi river basin has hit the coastal region of Odisha inundating a large number of villages in 13 different districts which might have affected lakhs of people. NRSC has initiated to acquire the satellite data and map & monitor the flood inundation starting from 16th August to 24th August 2022 for providing near real time flood inundation maps to the State and Central Disaster Management Support organizations. Summary of study is provided in this report.

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1. Introduction

Heavy rainfall and heavy runoff during 13-16th, August 2022 in the Mahanadi river basin has hit the coastal region of Odisha inundating a large number of villages in 13 different districts which might has affected lakhs of people. Districts those have come under flood impact include Cuttack, Khordha, Puri, Kendrapara, Jagatsinghpur, Boudh, Sambalpur and Angul. NRSC has initiated to acquire the satellite data and map & monitor the flood inundation starting from 16th August to 24th August 2022 for providing near real time flood inundation maps to the State and Central Disaster Management Support organizations. Summary of study is provided in this report. NRSC has followed up with the rainfall pattern, predicted runoff scenarios on a daily basis and planned for acquisition of satellite data during the flood duration. The report describes the summary of the study carried out on flood mapping and monitoring using satellite data and the view of satellite images .

2. Rainfall Pattern Analysis

Rainfall pattern in various districts of Odisha is shown in this table. District wise cumulative rainfall departures(Source : IMD) indicate that, normal and excess in most of the districts of Mahanadi river basin as shown in Table.1., Figure 1.

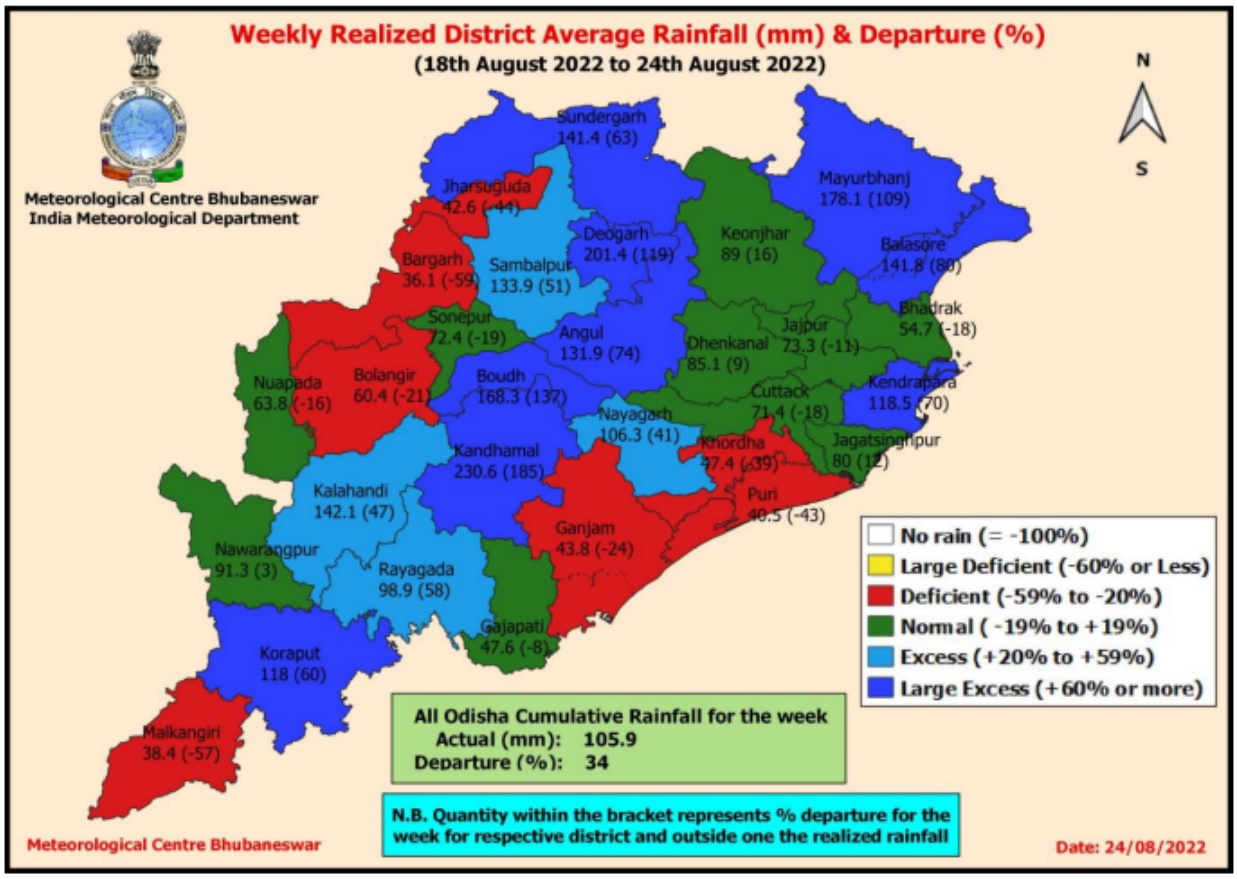


Figure.1 . Rainfall (mm) & Departure(%) During 18-26th August 2022
Source : IMD

Table 1: Cumulative Rainfall Departures in Districts of Mahanadi River Basin; Source: IMD

S NO.	Name of District	Week End 3-8-2022	Week End 10-8-2022	Week End 17-8-2022	Week End 24-8-2022
1	ANUGUL	-17	-14	-4	3
2	BALANGIR	-22	-10	4	2
3	BARAGARH	-10	-5	14	7
4	BAUDA	27	32	48	57
5	CUTTACK	-10	-1	8	5
6	DEOGARH	3	6	26	36
7	DHENKANAL	17	25	29	27
8	GANJAM	-15	12	15	12
9	JAGATSINGHAPUR	4	1	20	19
10	JAJAPUR	-5	-2	5	3
11	JHARSUGUDA	-23	-20	4	0
12	KALAHANDI	-21	-6	10	14
13	KANDHAMAL	24	36	55	68
14	KENDRAPARHA	-10	-7	2	8
15	KHORDHA	-9	-2	6	1
16	NABARANGAPUR	-11	5	17	16
17	NAYAGARH	-2	21	22	24
18	NUAPARHA	4	17	21	17
19	PURI	-17	-1	10	5
20	RAYAGARHA	2	15	29	32
21	SAMBALPUR	-32	-24	-1	4
22	SUBARNAPUR	-11	-6	10	7
23	SUNDARGARH	-42	-42	-12	-5
24	GADCHIROLI	47	55	56	44
25	GONDIYA	9	27	47	37
26	BASTAR	21	47	58	51
27	BILASPUR	13	14	36	29
28	DHAMTARI	21	35	41	31
29	DURG	-1	16	16	8
30	JANJGIR_CHAMPA	21	25	47	38
31	JASHPUR	-62	-58	-45	-39
32	KABIRDHAM	35	34	51	42
33	KANKER	15	18	29	19
34	KORBA	-26	-31	-7	-11
35	KOREA	-47	-46	-32	-27
36	MAHASAMUND	-1	10	30	21
37	RAIGARH	-7	-6	18	14
38	RAIPUR	-34	-8	-2	-9
39	RAJNANDGAON	22	37	50	38
40	SURGUJA	-62	-61	-53	-50
41	SIMDEGA	-51	-47	-31	-19
42	ANUPPUR	-6	-11	5	17

3. Spatial Surface Runoff analysis

Runoff Maps (current and one day forecast) of the country is computed using slope corrected curve number grids of different AMC conditions. All India CN grid is prepared using 250 k LULC, Soil Map from NBSS&LUP, and 30m CARTO DEM. Model computes 5 day Antecedent Moisture condition (AMC) condition based on GPM / IMD-GPM Merged/ GEFS (used in order, which is decided based on availability) rainfall source data. GPM/IMD-GPM Merged/GEFS rainfall data is used for current day runoff calculation and GEFS data is used for calculating one day forecast runoff in the country (previous day 8:30AM to current day 8:30 AM rainfall is considered as current day rainfall for example current date is 02-Jan-2018 then rainfall is used from 01-Jan-2018 08:30 AM to 02-Jan-2018 08:30 AM and runoff is calculated accordingly). The spatial surface runoff grids are computed for entire India as part of Disaster Watch report by Flood Modeling Division (FMD) is utilised for computation of overall runoff pattern across the country to assess flood situation. As these are calculated based on satellite based rainfall. National Database for Emergency Management (NDEM) Portal provides daily runoff at 3'x3'grid on daily basis and also one day forest is also provided. The source for the data captured in this report is www. ndem.nrsc.gov.in.

Continuous analysis has been made on daily and cumulative runoff which could result into inflows into Mahanadi and its tributaries and the same can be observed through the following Figure 2(a), 2(b), 2(c), 2(d) and 2(e).

Figure. 4(a), 4(b), 4(c) indicates the runoff is initiated in the range of 50-100mm during 13th August 2022, 14th August 2022 and 15th August 2022 in scattered parts of Mahanadi river basin where Odisha is the major part of river basin. Further, the Cumulative runoff during 12-16th, August 2022 in majority parts of Mahanadi river basin which is order of 100-150mm (in many grids)(Figure2d) . This is resulting in heavy inflows into Mahanadi river. However, minimal runoff is observed during 17-26th August 2022 (Figure-2e) but it appears to be gradual during this period and hence, the flood inundation has started receding

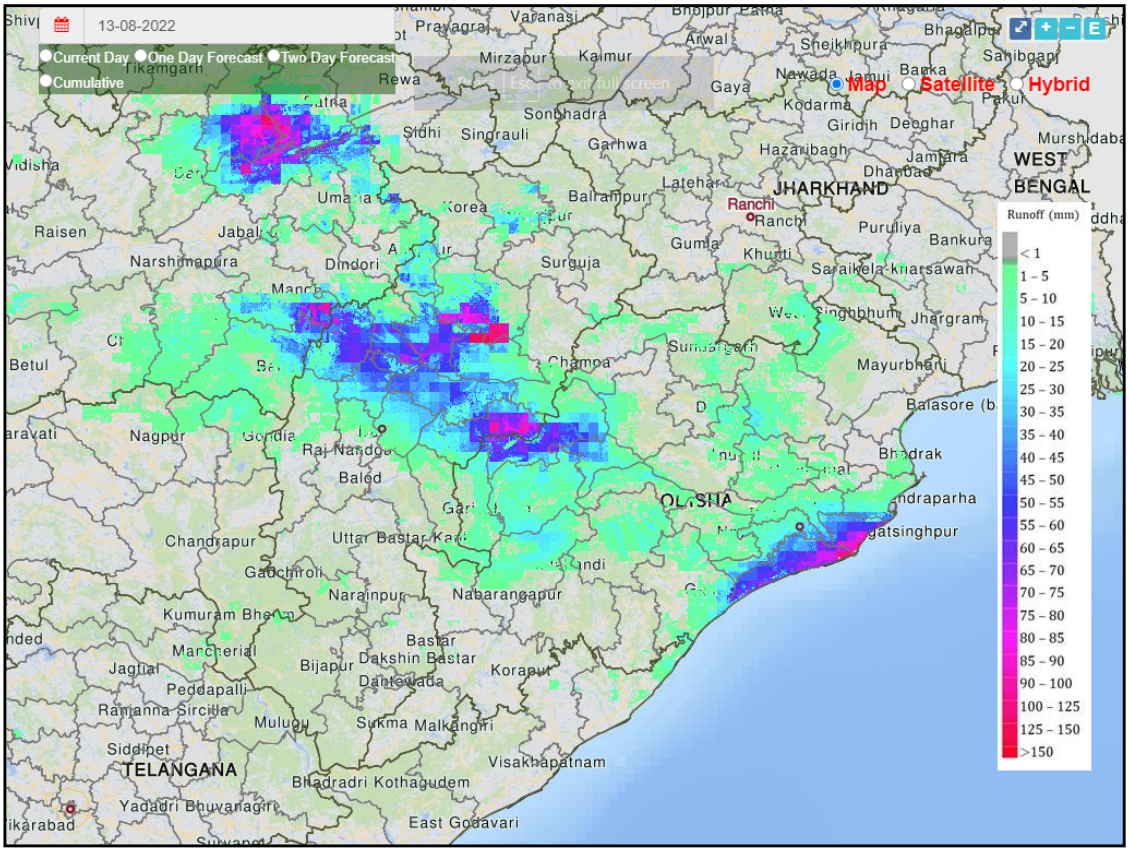


Figure.2(a). Runoff during 13th, August 2022 in parts of Odisha District (Source : www. ndem.nrsc.gov.in.)

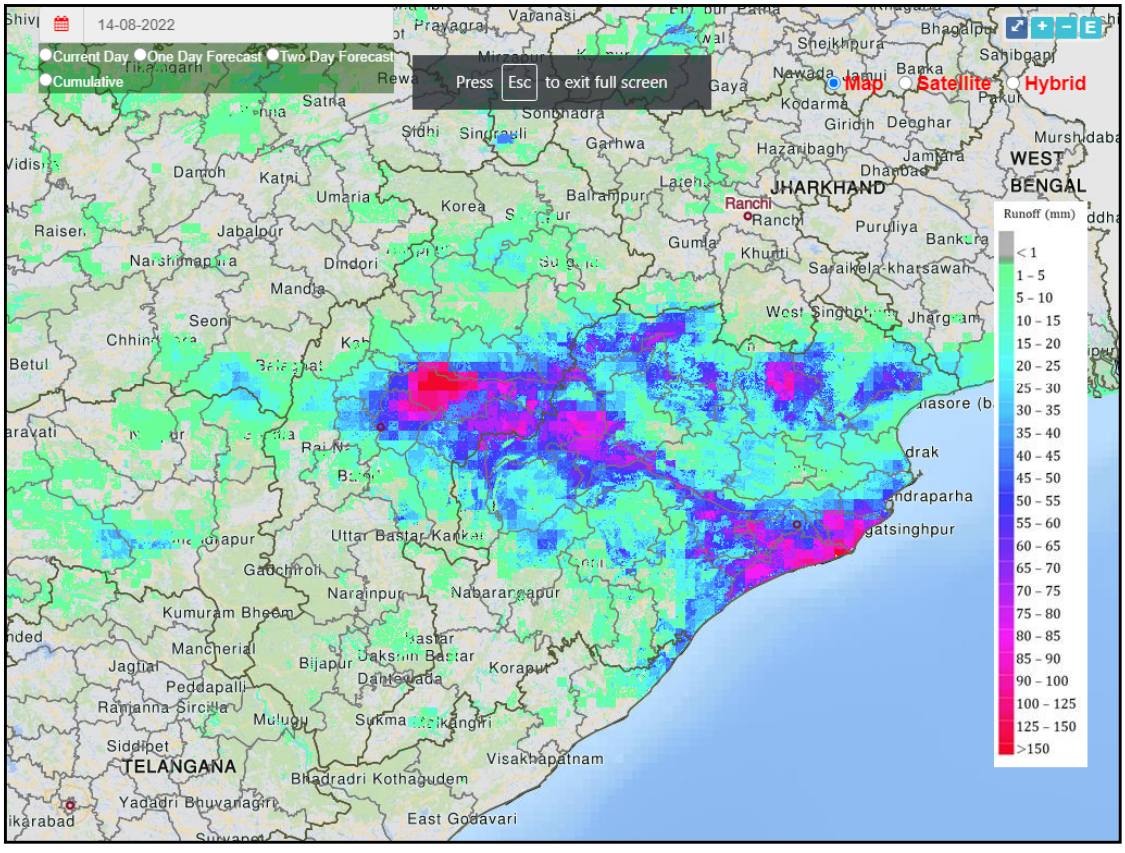


Figure.2(b). Runoff during 14th, August 2022 in parts of Odisha District (Source : www. ndem.nrsc.gov.in.)

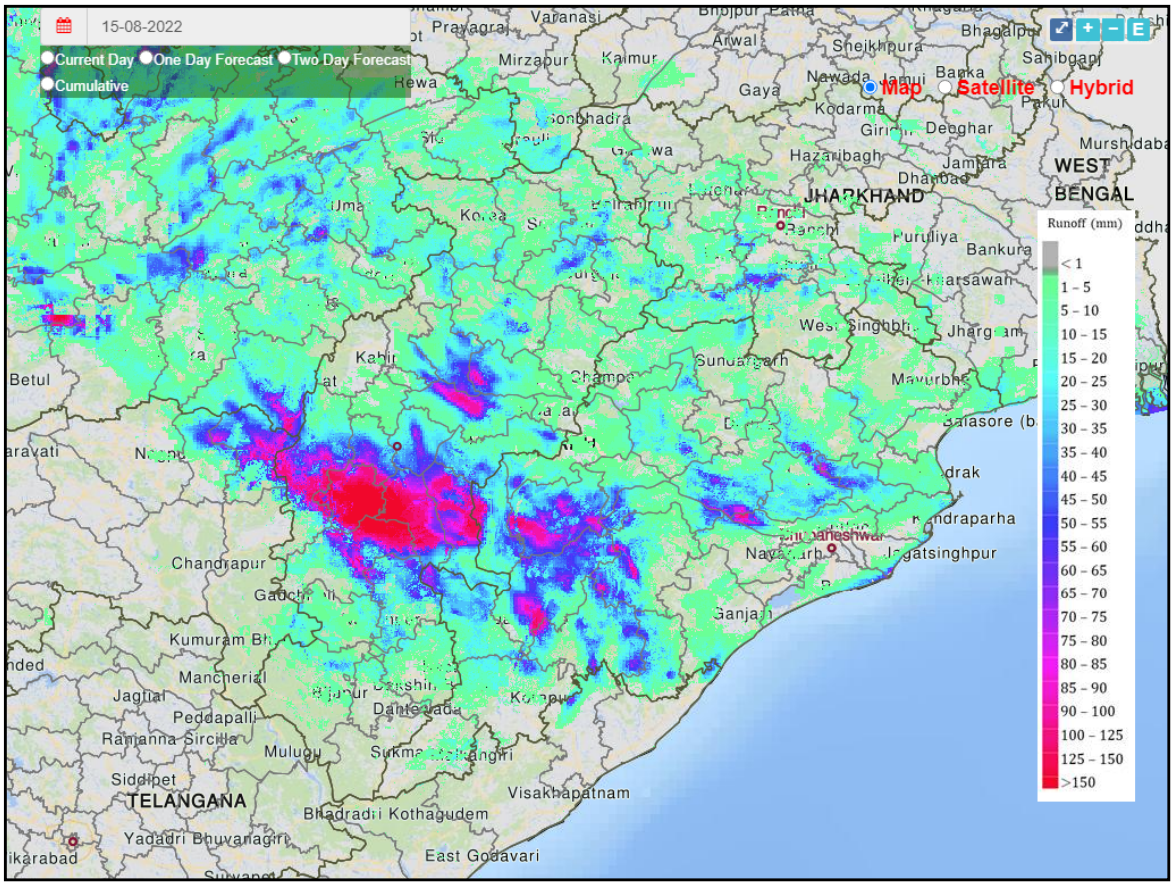


Figure.2(c). Runoff during 15th, August 2022 in parts of Odisha District
(Source : www. ndem.nrsc.gov.in.)

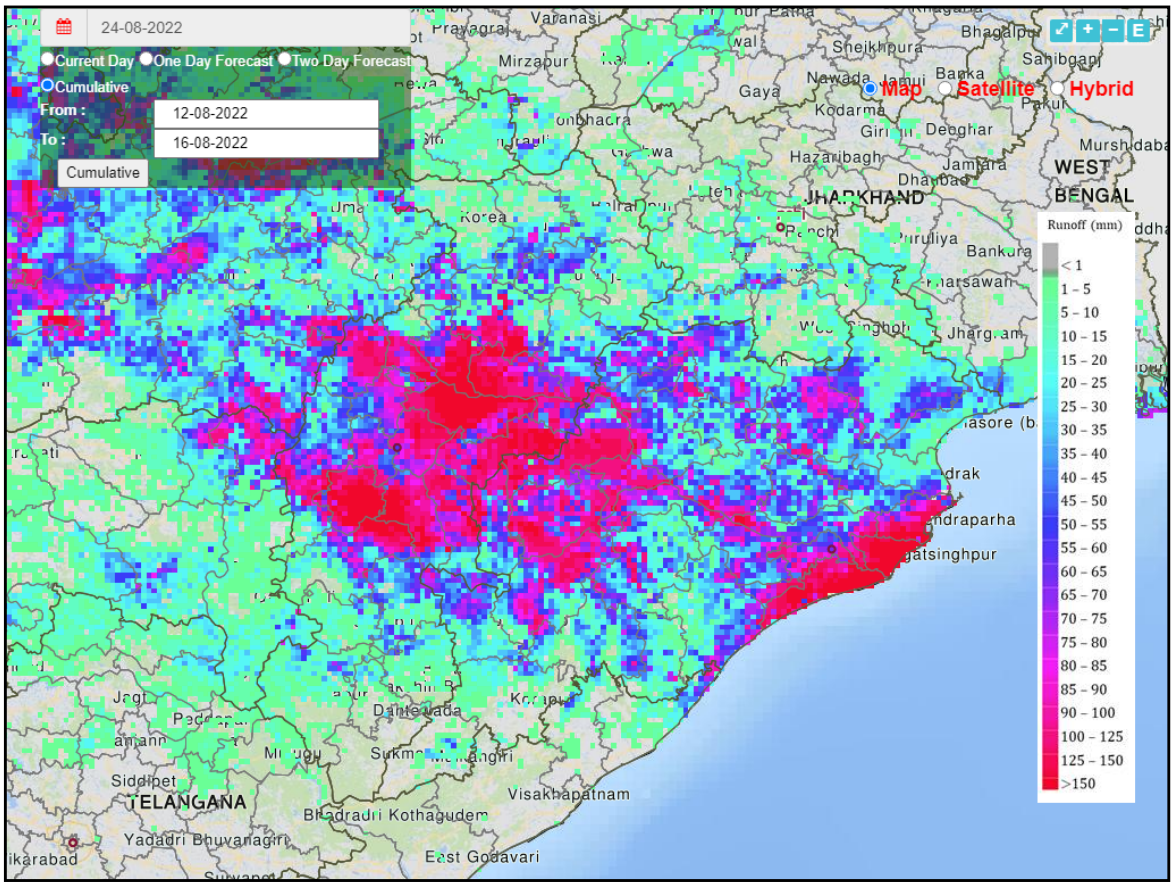


Figure.2(d). Cumulative runoff during 12-16th, August 2022 in parts of Odisha District
(Source : www. ndem.nrsc.gov.in.)

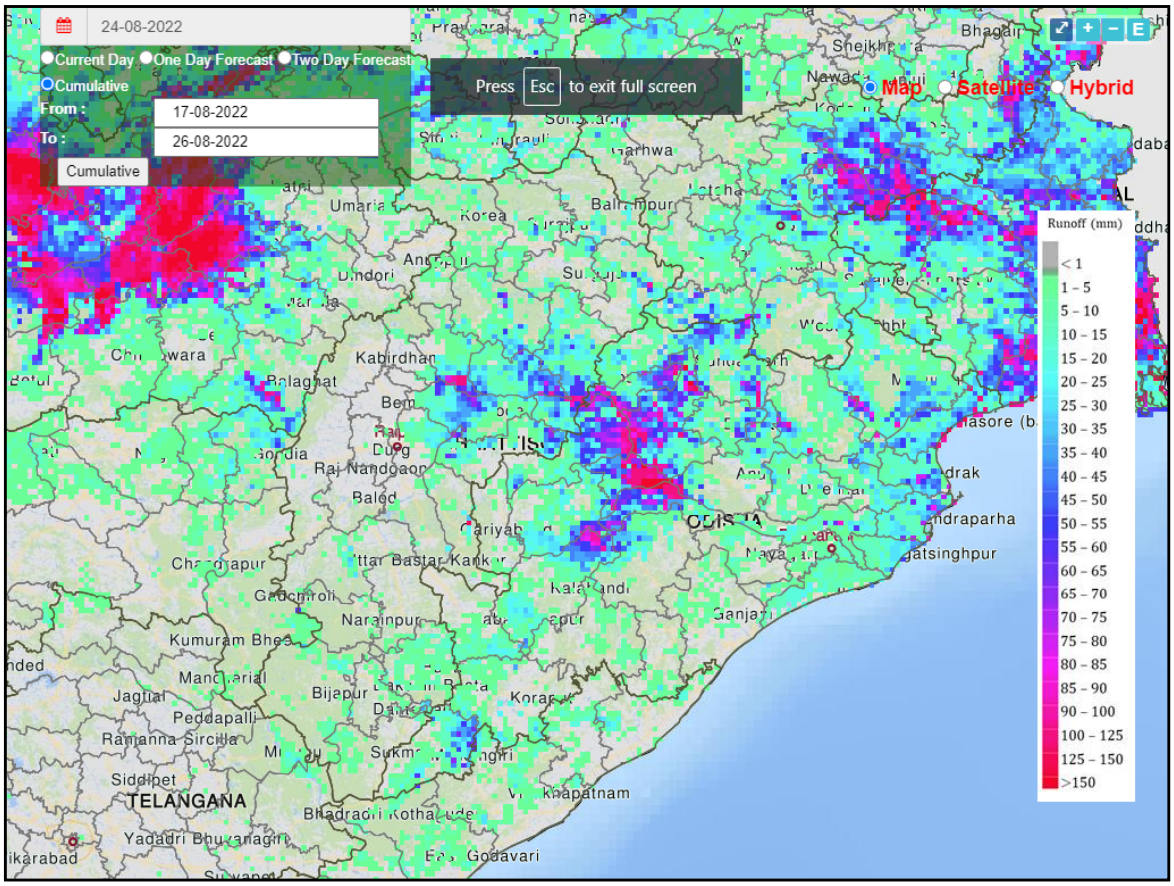


Figure.2(e). Cumulative runoff during 17-26th, August 2022 in parts of Odisha District (Source : www. ndem.nrsc.gov.in.)

4. Monitoring of Water Level Gauge stations along Mahanadi River

CWC measures water levels at various gauge stations and provide the information and to understand the warning and danger levels across the river. Table.2 provide the data over few stations along Mahanadi river basin

Table. 2. Water Level Measurements at Various Gauge Stations in Mahanadi River Basin

S.No	Station	Date	Water Level(m)	Danger Level(m)	HFL(m)
1	MANIYARI	13 August 2022	236.18		235.88
2	MANIYARI	14 August 2022	236		235.88
3	ANDHIYARKHORE	12 August 2022	260.2		260.15
4	BOUDH	15 August 2022	88.6		88.6
5	MALGAON	16 August 2022	327.86		326.71
6	ALIPINGAL	17 August 2022	12.00		11.76
7	NARAJ	17 August 2022	24.47	26.41	27.61
	NARAJ	18 August 2022	26.96	26.41	27.61
	NARAJ	19 August 2022	26.74	26.41	27.61
	NARAJ	20August 2022	226.57	26.41	27.61

5. Satellite data planning and acquisition

Satellite data acquisition plan has been made based on the indications of flood inundation understood through the rainfall and runoff information at grid levels and also water levels gauge stations. The available satellite data of optical and Microwave SAR sensors have been utilized to the best possible acquisitions from multiple satellites.

5.1. List of Satellite Data Utilized

List of satellite data utilized for the study is listed in Table.3. Resourcesat2 AWiFS, RISAT-1A and Sentinel 1A satellite datasets were utilized for large area analytics at district level for generation of flood inundation maps and reporting to the Disaster Management support organizations in near real time.

Table.3. List of satellite data used

S No	Date	Satellite / Sensor
1	16-08-2022	Resourcesat-2 AWiFS (1030 Hrs) Sentinel-1A SAR (0600 Hrs)
2	18-08-2022	Sentinel-1A SAR (1800 Hrs)
3	19-08-2022	RADARSAT-2 SAR (1800 Hrs)
4	21-08-2022	Sentinel-1A SAR (0600 Hrs)
5	22-08-2022	RISAT-1A SAR (1800 Hrs)
6	24-08-2022	RISAT-1A SAR (1800 Hrs)

6. Methodology Satellite based Flood Inundation Mapping & Monitoring

Role of space applications in supporting flood disaster management is important, if the information can be provided to disaster management support organizations in near real time. Satellite remote sensing data provides information on spatial flood extent on a continuous basis.

Satellite data can be used at regular intervals for updation of the flood condition on the ground in terms of flood progression, recedence and persistence.

The advantage of using radar data over the optical data is its ability to penetrate cloud cover and also data acquisition during day and night. Water surfaces are generally smooth at radar wavelengths and can be regarded as specular reflectors which yield small backscatter. The surrounding terrain is assumed to be rough at radar wavelengths which exhibits diffuse scattering with moderate backscatter. Hence, water is regarded as low intensity areas whereas the surrounding terrain corresponds to brighter intensities.

Thresholding is the traditional method of detecting flooding in open areas. Intensities below the threshold are regarded as flood or open water, whereas pixels with intensities above the threshold are regarded as dry land. The threshold will depend on the contrast between the land and water classes, and generally needs to be set for each SAR scene. The backscatter depends on the frequency, incidence angle, polarization and is sensitive to the ripples on the water surface induced by wind waves.

Before the onset of flood season, pre-flood satellite data over flood prone states are acquired and analysed. River banklines, permanent water bodies and active river channel are extracted using digitization tools. These datasets and layers will be used as master data sets for further analysis. Detailed steps are as follows. The raw satellite data during floods will be geometrically co-registered with the respective state masters for positional accuracy. These rectified data sets are considered as master data sets for that particular year. Classification is performed to extract water bodies from the image.

In case of optical data, unsupervised classification will be performed giving maximum number of classes and main active river channel, its tributaries and permanent water bodies are classified and converted into vector format. Enhancement techniques are used for increase contrast between the features in the image. On-screen digitization techniques are used for delineation of river banklines from the image in GIS environment and after post editing, the final layer is stored in vector format. In case of microwave data, back scattering image (Sigma nought) is generated and water bodies are extracted using variable threshold technique model. State mask, hill mask, hill shadow mask are applied on the extracted water layer. Further, stray water pixels are separated by grouping and removing them. Flow chart of methodology for pre-flood data preparation is shown in Figure 3 . Flow chart of methodology for flood delineation from satellite data is shown in Figure. 4

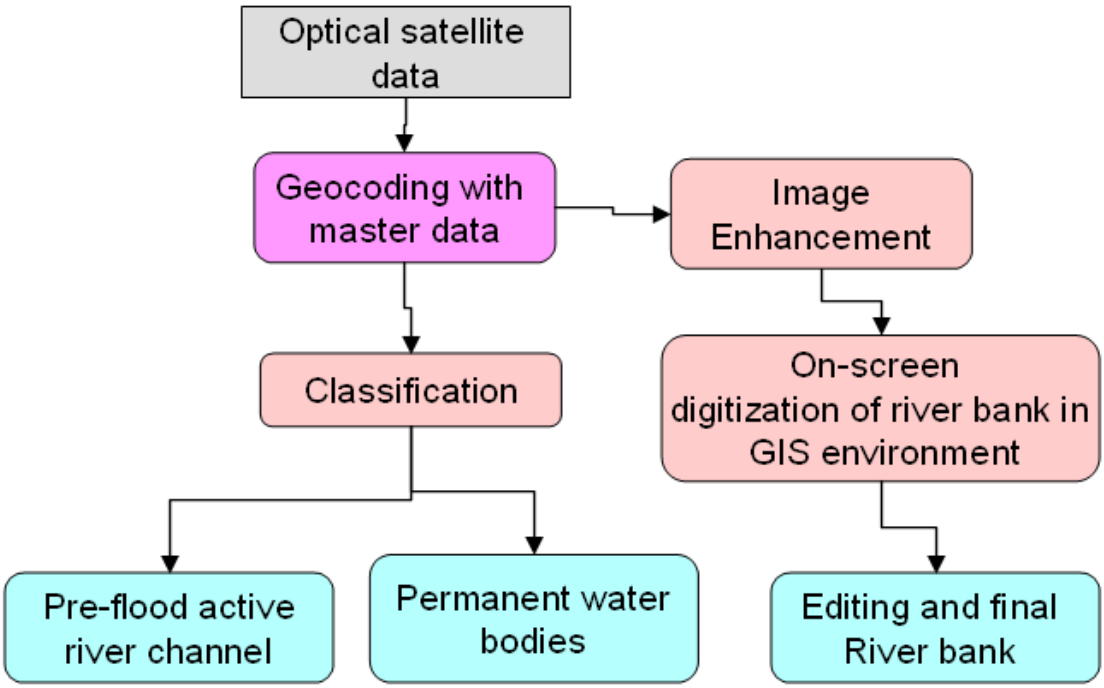


Figure.3. Methodology for Pre-flood data preparation

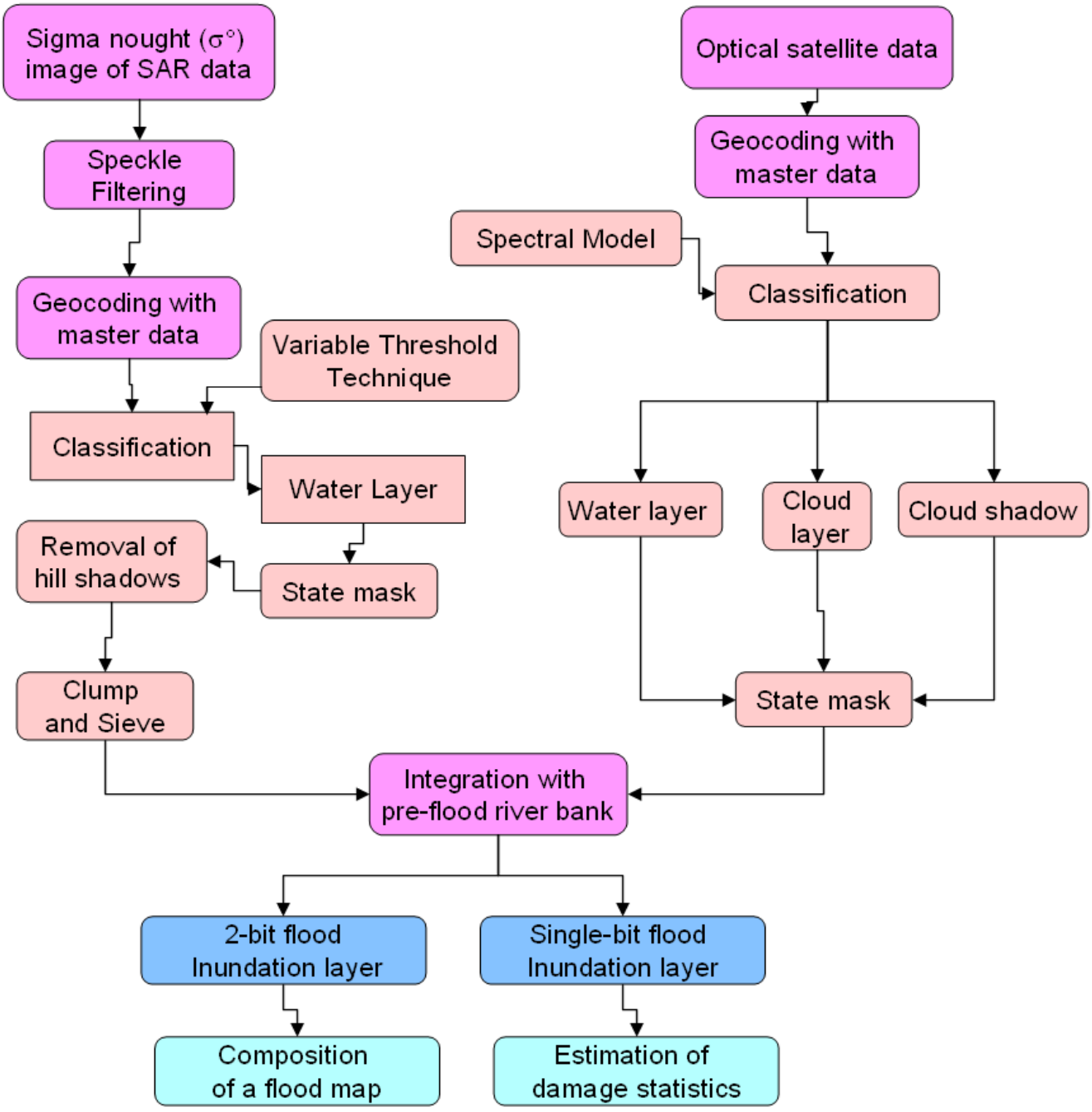


Figure.4. Methodology for flood mapping and monitoring

7. Flood Inundation Mapping and Monitoring

7.1. Analysis of Flood Inundation areas

Flood maps were prepared during 16th-24th August 2022 and 6 maps were sent to disaster management support organizations for supporting flood disaster management. It is observed that the 13 districts are affected due to flood as mentioned in the Table.3. Spatial map showing the cumulative flood inundation during 16th-24th August 2022 is shown in Figure. 5

Table.5. Cumulative Flood Inundation area statistics at district level in Odisha State during August 2022

S no	DISTRICT	Area (Ha) under flood inundation
1	PURI	75758
2	KENDRAPARHA	40047
3	BHADRAK	33266
4	JAGATSINGHAPUR	31463
5	CUTTACK	30225
6	JAJAPUR	24762
7	KHORDHA	21719
8	BALESHWAR	15173
9	GANJAM	6860
10	NAYAGARH	5507
11	ANUGUL	3992
12	BAUDA	1395
13	MAYURBHANJ	789
	TOTAL (Ha)	**290955**

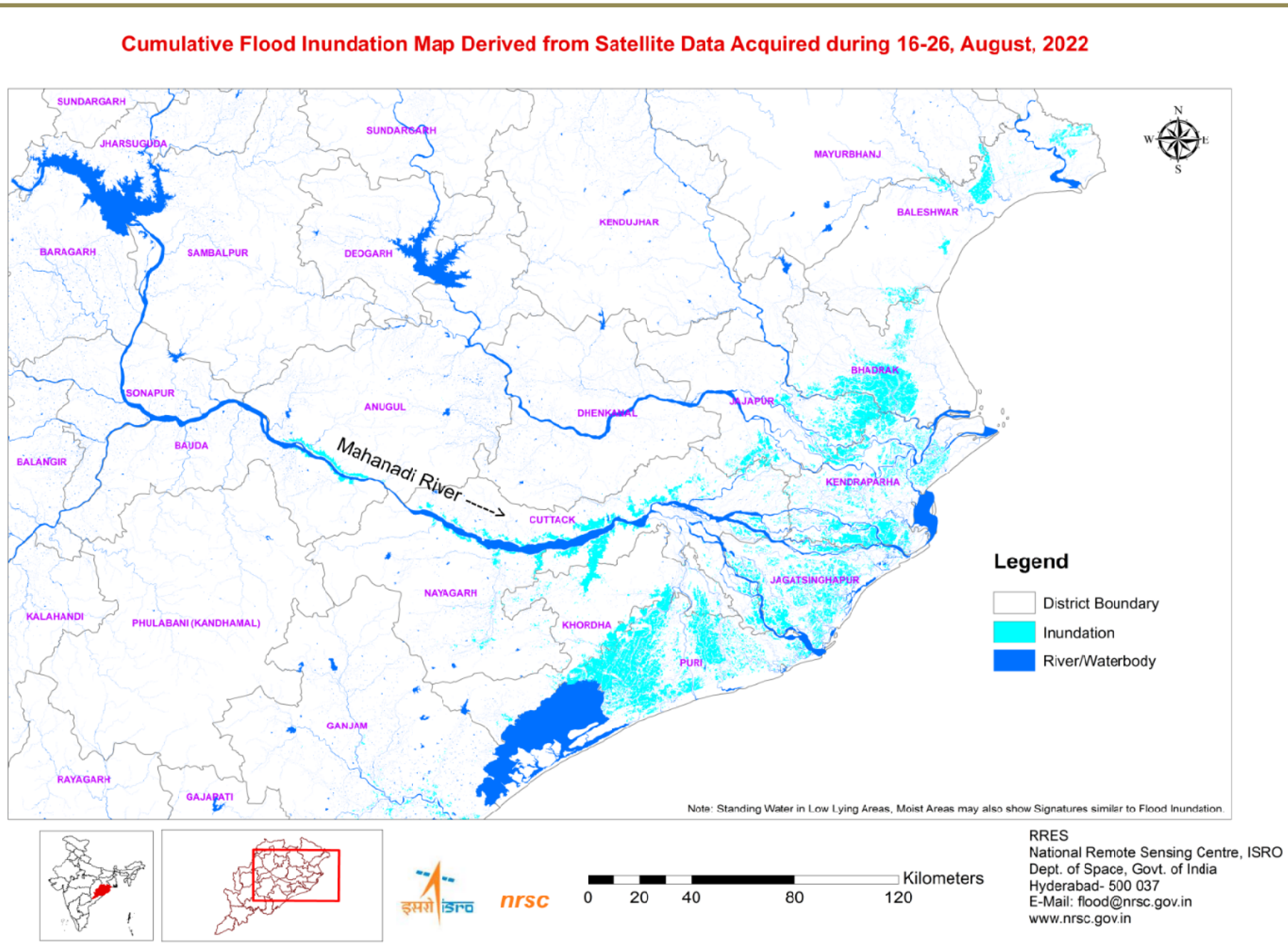


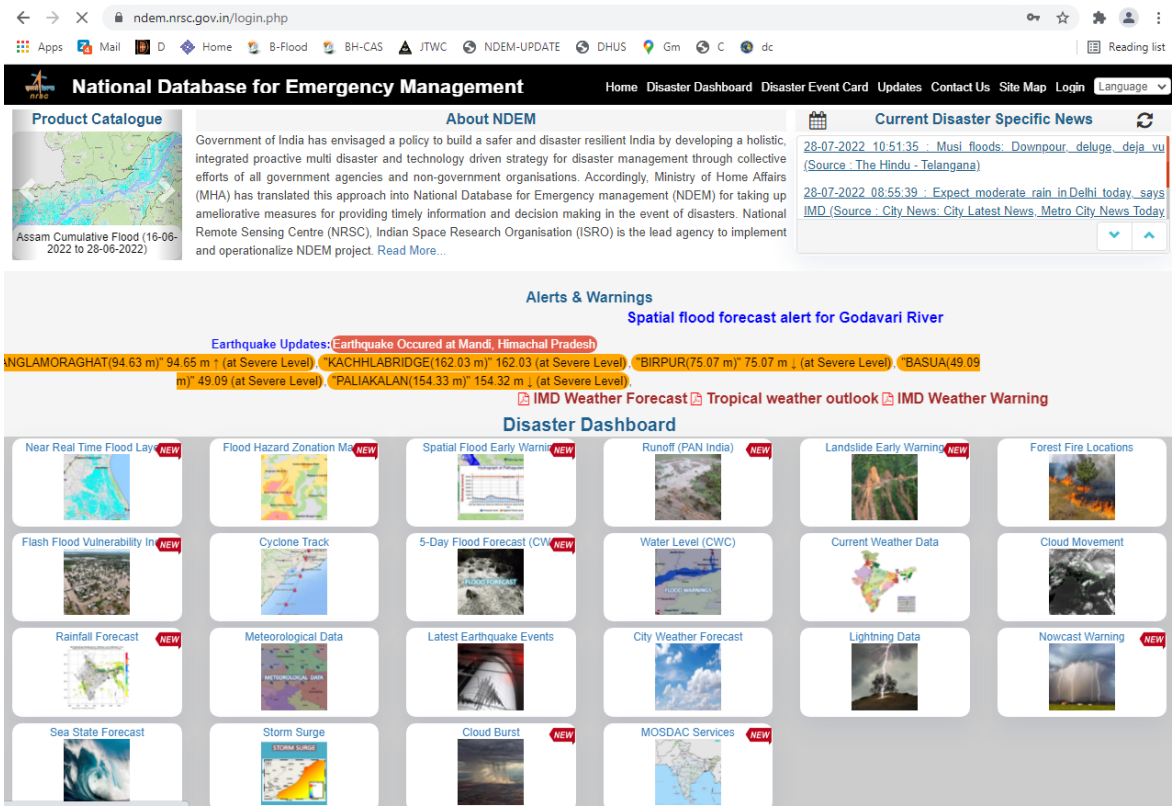
Figure.5. Cumulative Flood Inundation Map Derived from Satellite Data Acquired during 16-26 August, 2022

8. Dissemination to State / Central Disaster Management Organisations

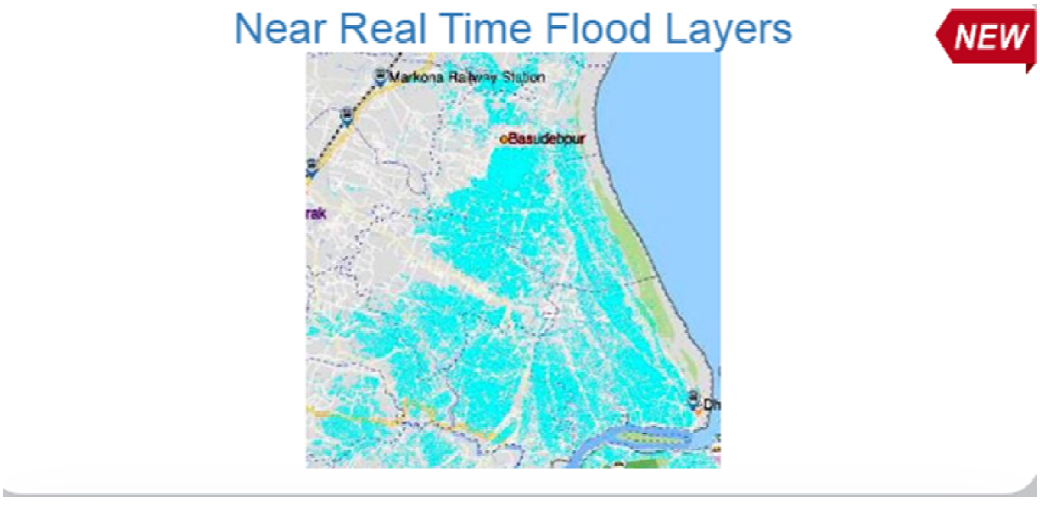
8. 1. Dissemination of Information through NDEM Web Portals

NRSC disseminated the maps and GIS and value added images by uploading GIS layers in National Database for Emergency Management (NDEM) portal for further visualisation of the current and historic flood information along with legacy layers and analytics

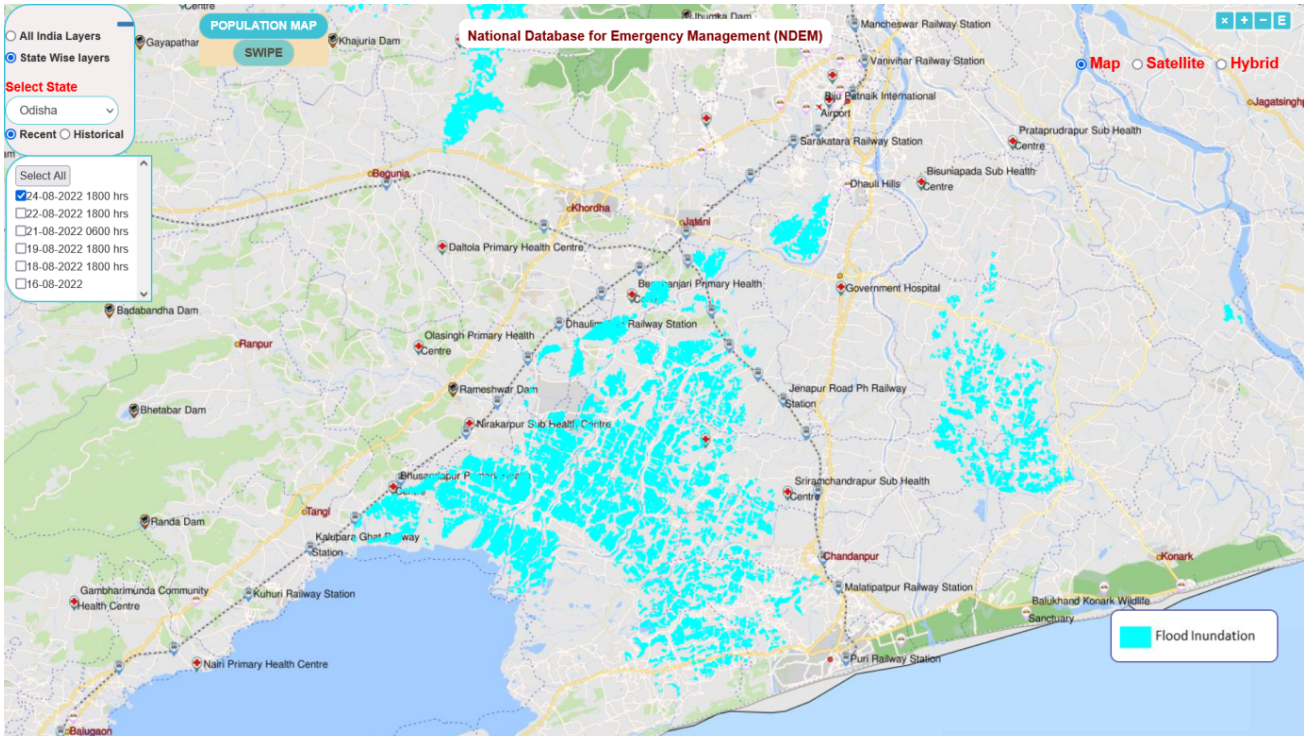
https://ndem.nrsc.gov.in



Click on **Near Real Time Flood Layers**

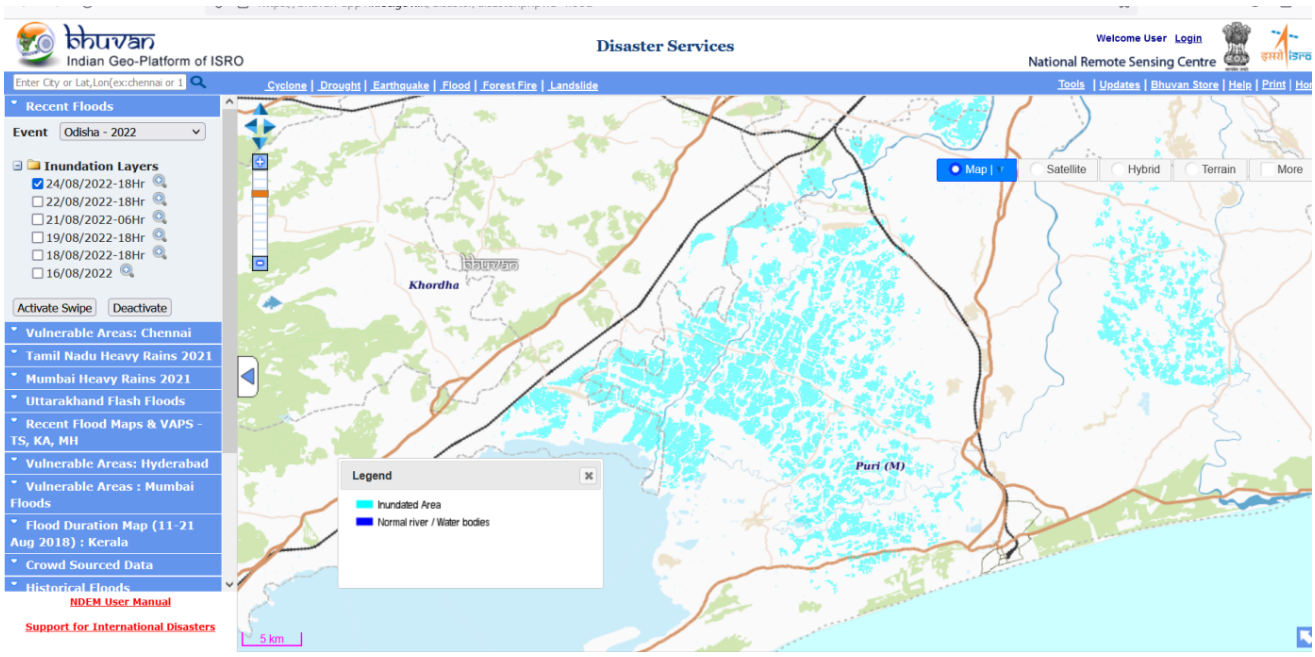


Select the State & Date of flood inundation map to zoom to the area of interest in NDEM Portal



8. 2. Dissemination of Information through Bhuvan Web Portals

Bhuvan Geoportal can be used for visualisation of the flood layers
https://bhuvan-app1.nrsc.gov.in/disaster/disaster.php?id=flood



Annexure-1

Satellite Images Showing Flood Inundation at District Level in Flood Affected Districts of Odisha State

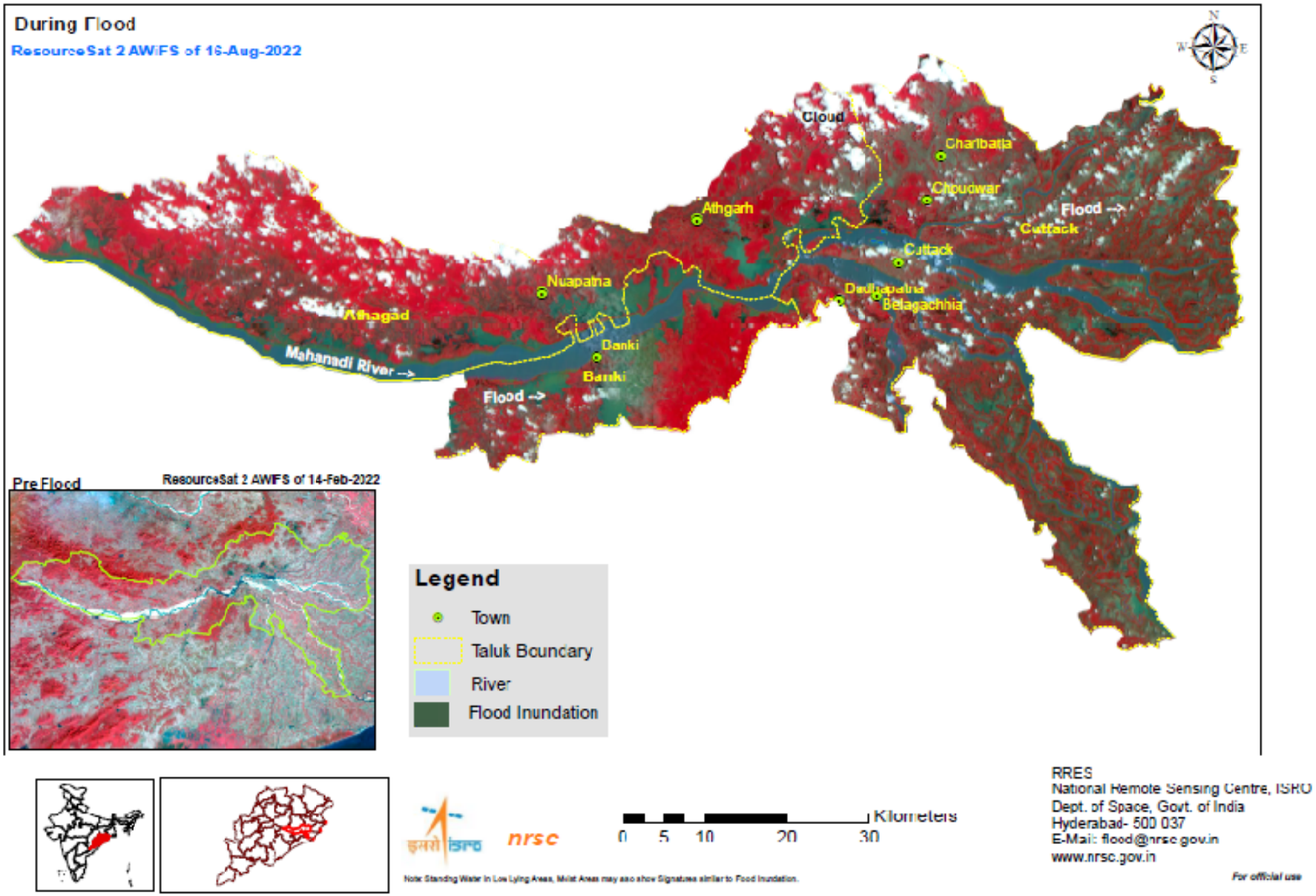


Figure.6(a) ResourceSat-2 AWiFS Image Showing Flood Inundation in Cuttack District, Odisha State

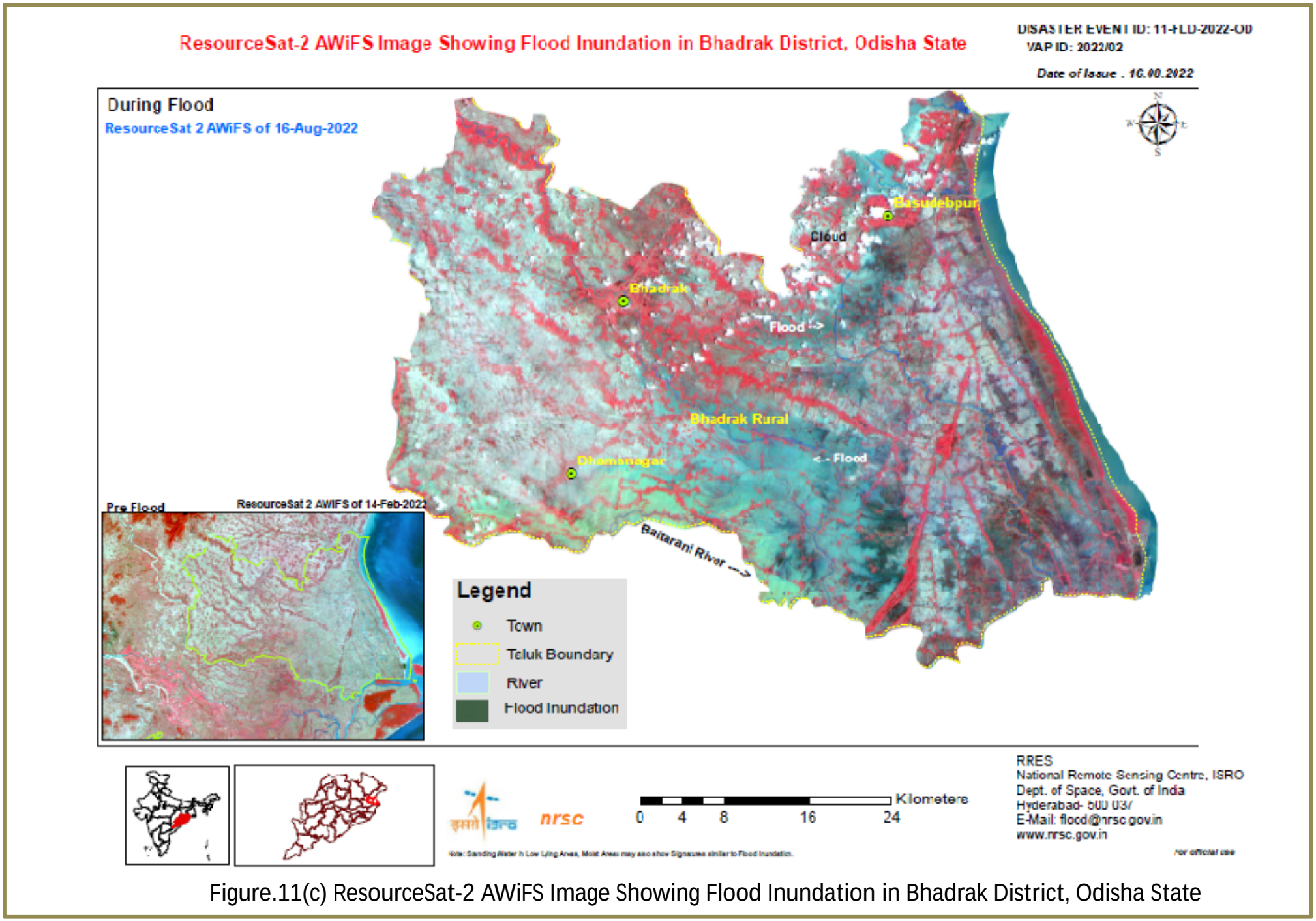


Figure.11(c) ResourceSat-2 AWiFS Image Showing Flood Inundation in Bhadrak District, Odisha State

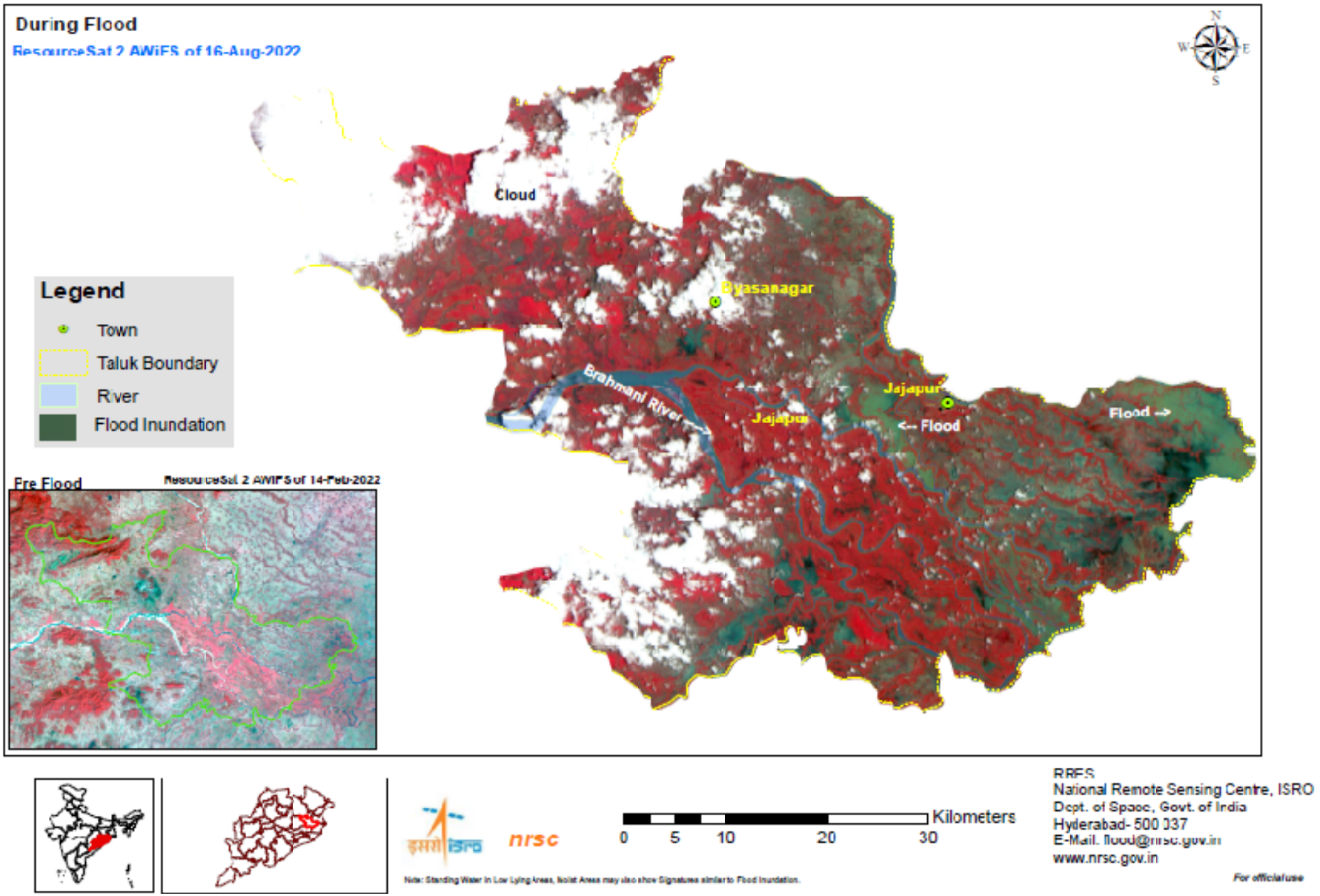


Figure.11(d) ResourceSat-2 AWiFS Image Showing Flood Inundation in Jajpur District, Odisha State

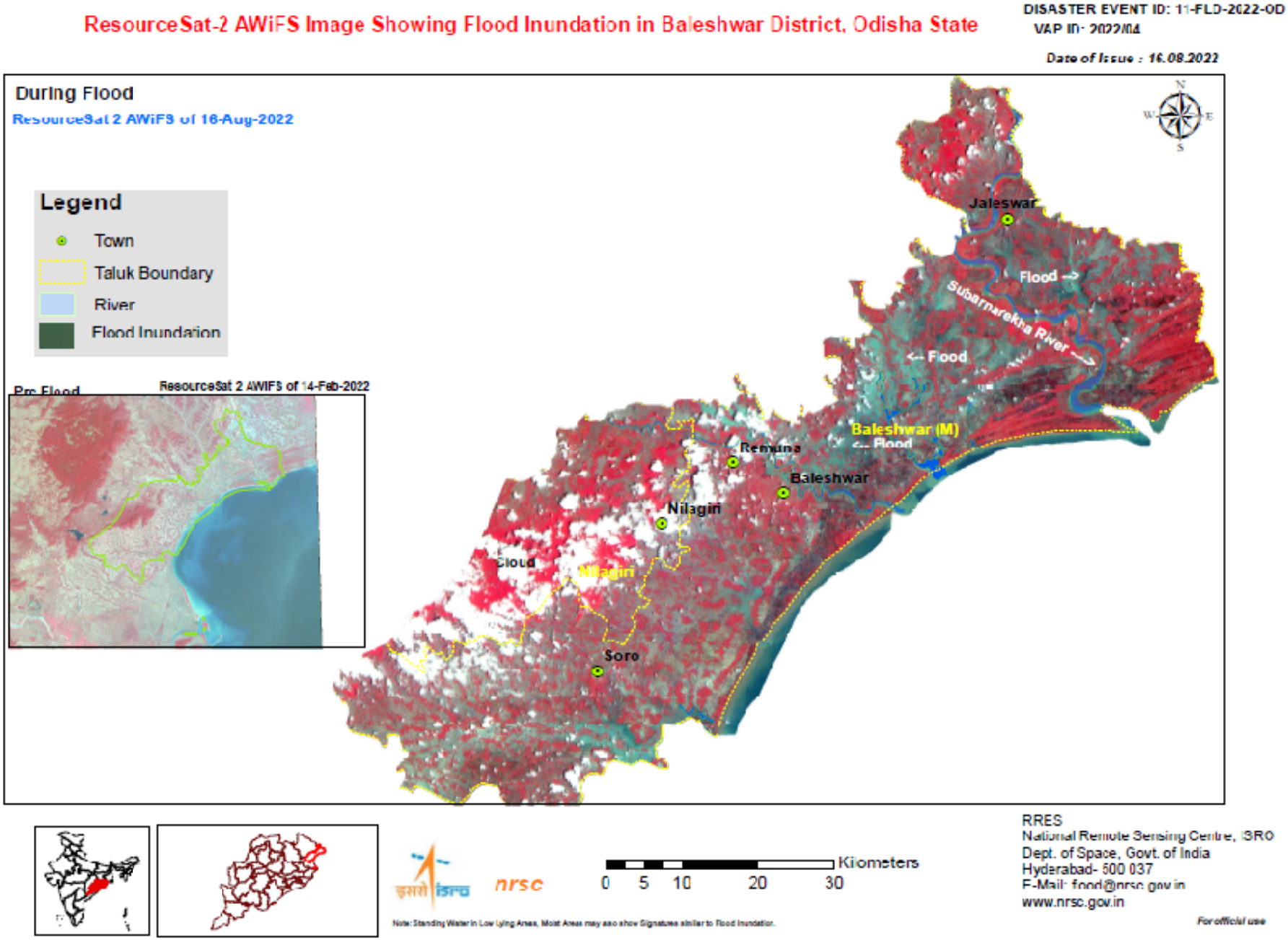


Figure.11(e) ResourceSat-2 AWiFS Image Showing Flood Inundation in Baleshwar District, Odisha State

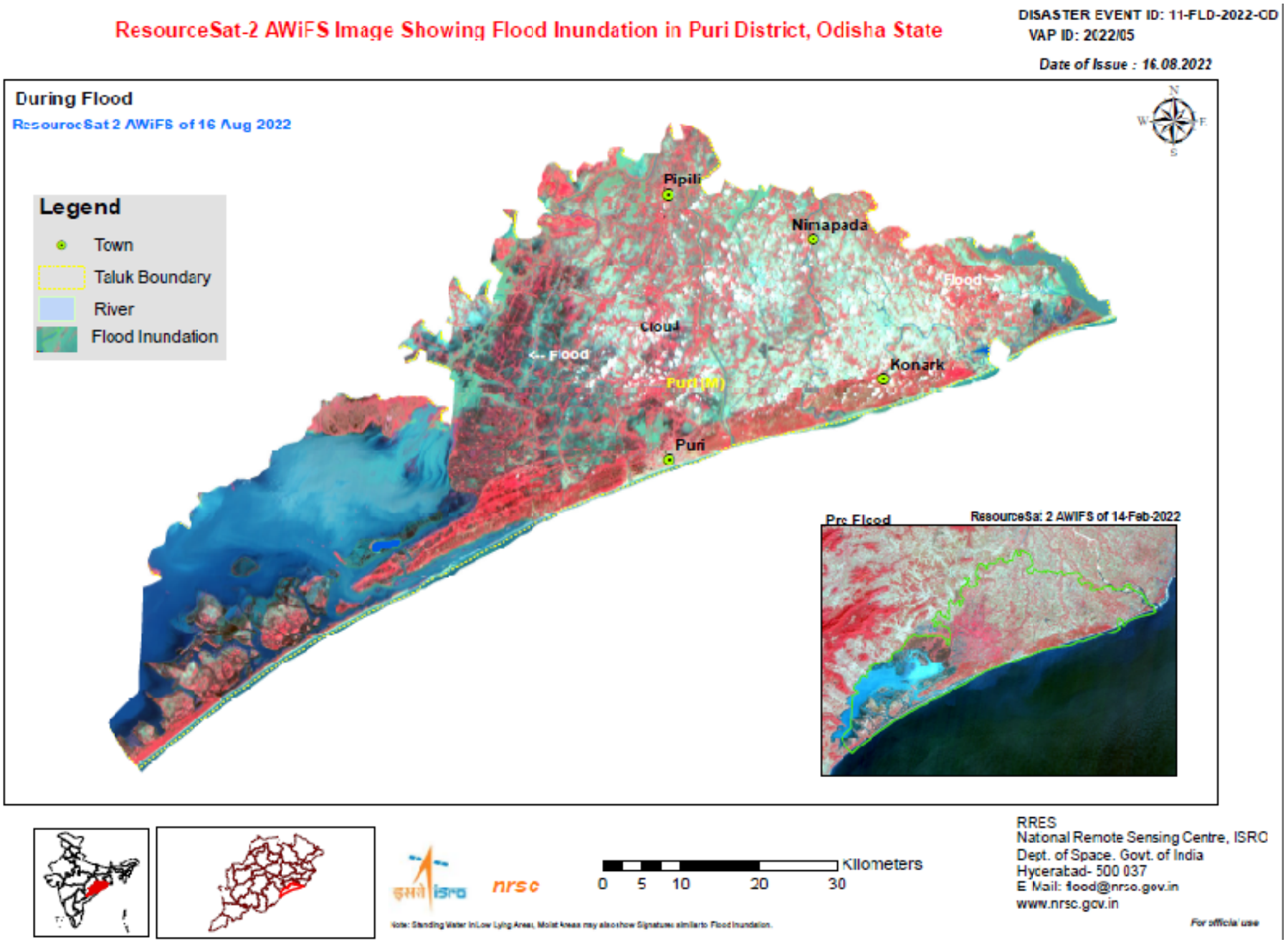


Figure.11(f) ResourceSat-2 AWiFS Image Showing Flood Inundation in Puri District, Odisha State

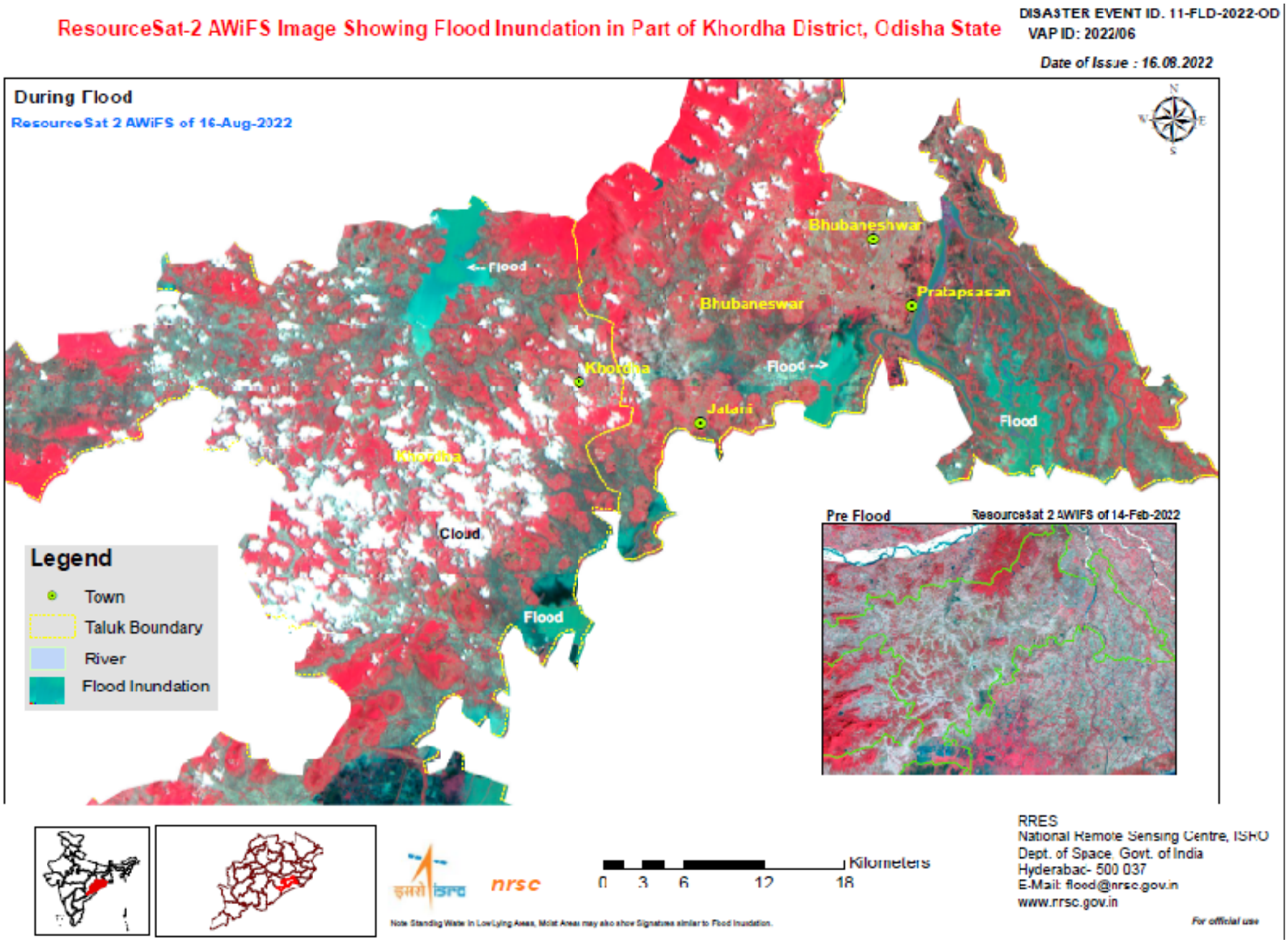


Figure.11(f) ResourceSat-2 AWiFS Image Showing Flood Inundation in Part of Khordha District, Odisha State

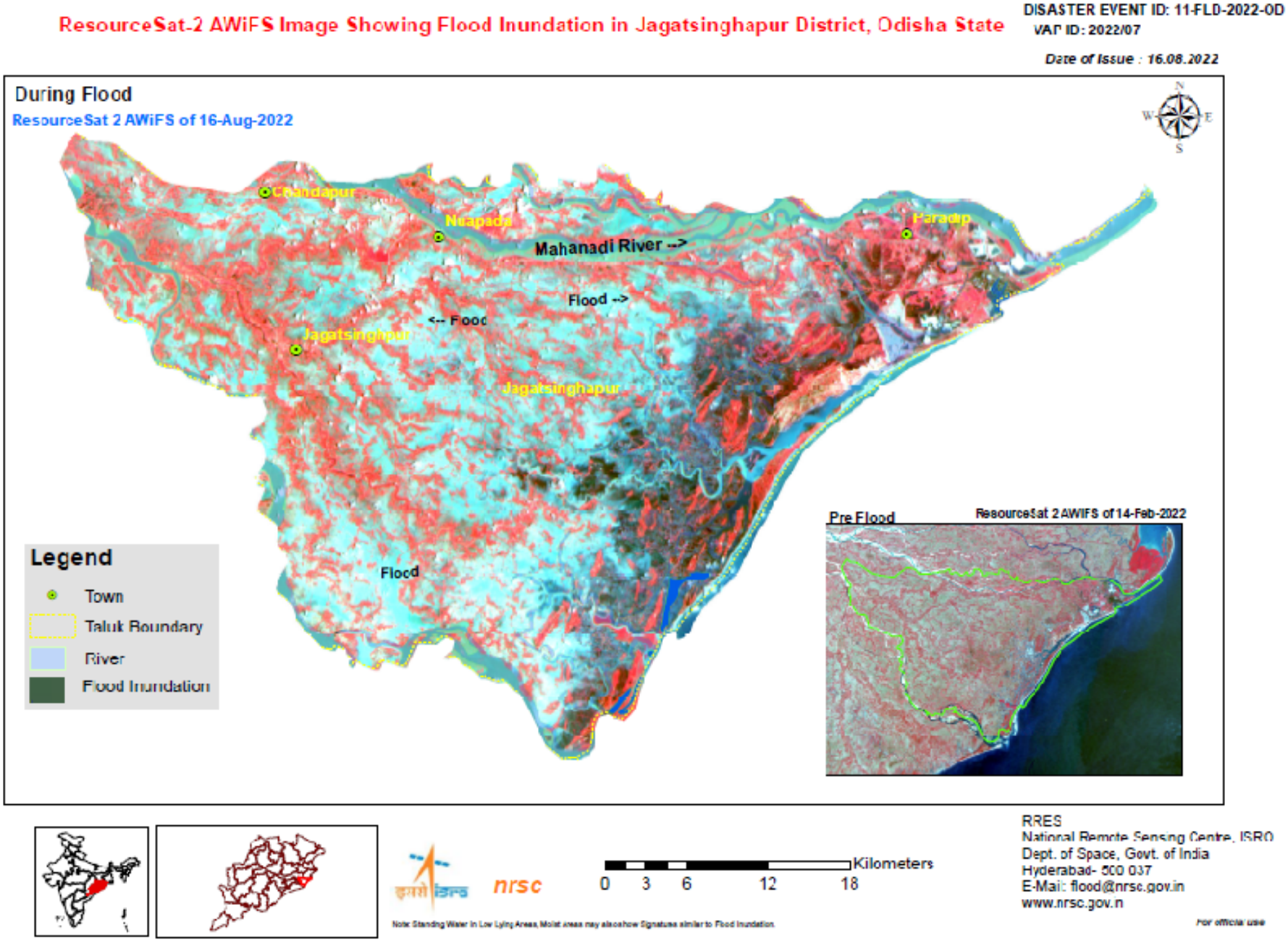


Figure.11(f) ResourceSat-2 AWiFS Image Showing Flood Inundation in Jagatsinghapur District, Odisha State

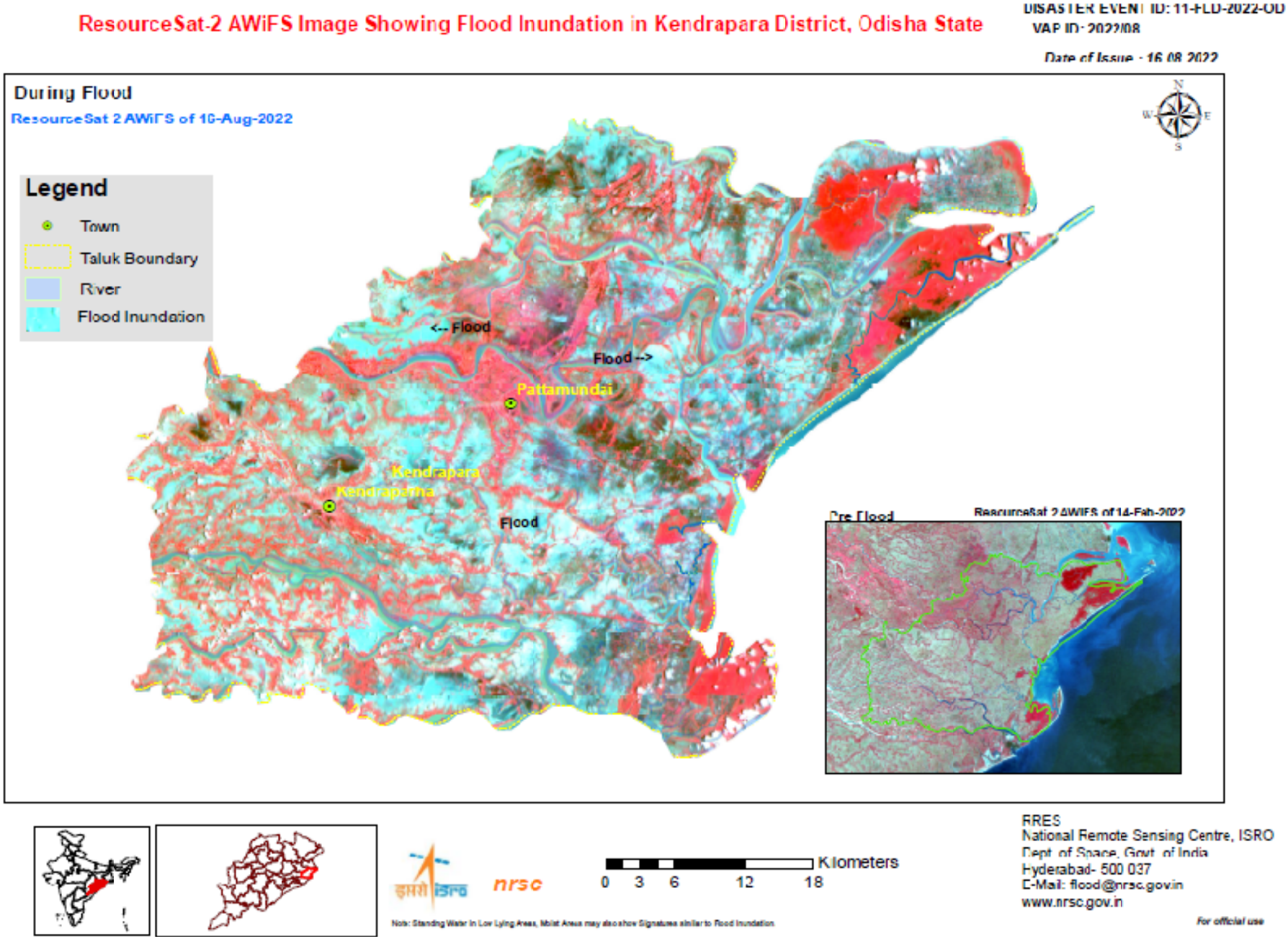


Figure.11(f) ResourceSat-2 AWiFS Image Showing Flood Inundation in Kendrapara District, Odisha State

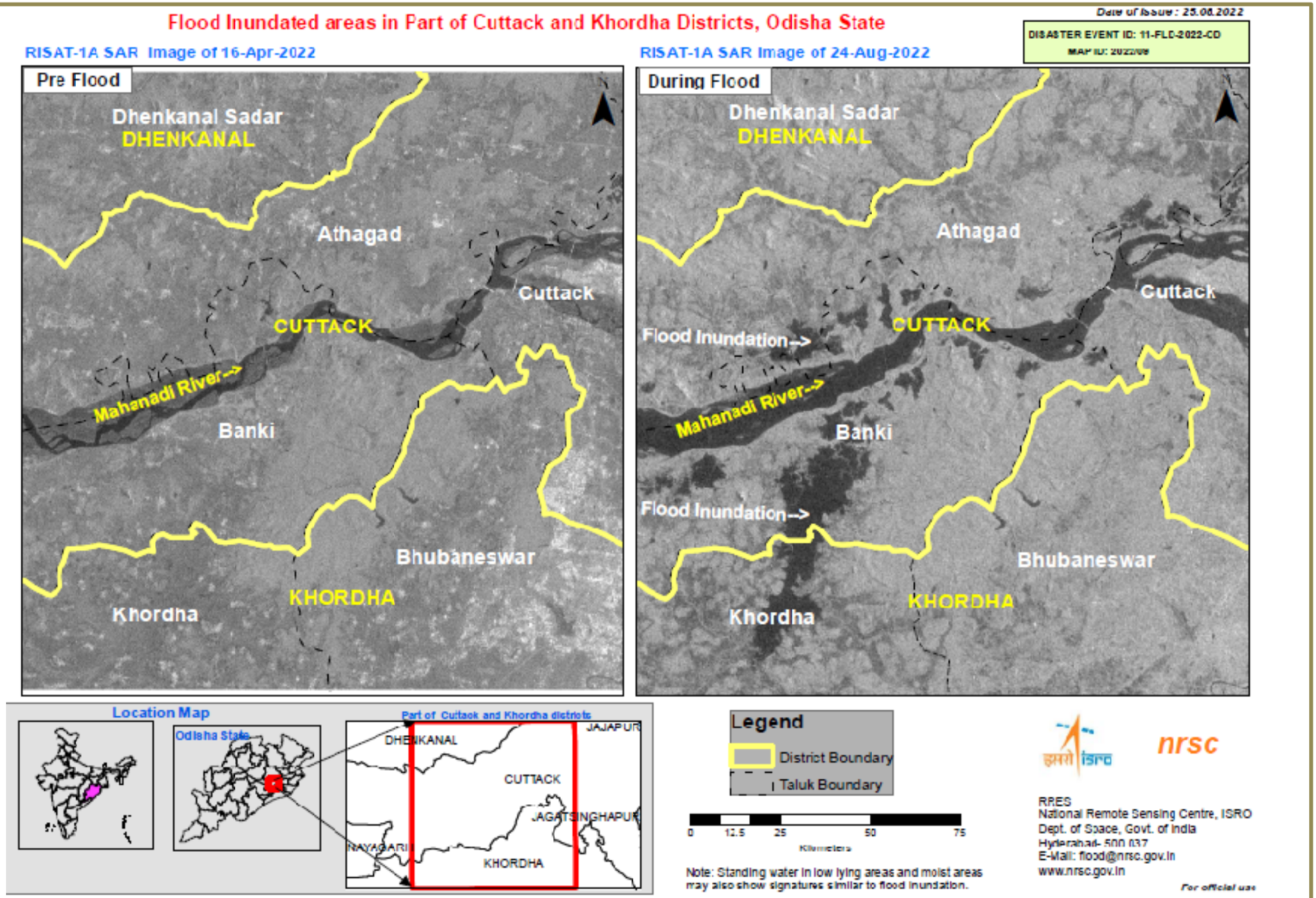


Figure.11(f) Flood Inundated areas in Part of Cuttack and Khordha Districts, Odisha State

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