तेल उद्योग सुरक्षा निदेशालय
Oil Industry Safety Directorate
ISO 9001:2015 certified

CASE STUDY

OISD/CS/2025-26/PL/16 Dt.: 06.11.2025

INTRODUCTION

Title: Pipeline failure incidents due to heavy rainfall/ flash floods during Monsoon season 2025.

Location: Inside/ nearby river/ waterbody crossings of hydrocarbon pipelines.

Loss/ Outcome: Loss of petroleum product/ gas due to snapping of pipelines. Additionally, pipeline replacement costs and throughput loss are also incurred by pipeline operator.

BRIEF OF INCIDENT (S)

Five incidents of pipeline failure happened in oil and gas pipelines as under:

- **Incident-1:** Natural gas pipeline snapped resulting in gas leakage. Pipeline failure was attributed to Right of Way (ROW) washout due to heavy rain resulting in flooding and change in river course.
- **Incident-2:** Natural gas pipeline snapped inside a major river resulting in gas leakage. The incident has been triggered by heavy rainfall and flash-flood-like conditions, resulting in significant rise of water level in the river. As a result, HDD punch-in portion of the pipeline in river crossing became fully exposed and came under direct contact with high-velocity river water flow. The strong hydraulic forces and continuous scouring action created significant mechanical stress on the pipeline, leading to its rupture.
- **Incident-3:** A multiproduct pipeline failed on the riverbank of a major river. Due to heavy downpour in the hilly region, erosion of soil on the bank led to exposing the pipeline at riverbank. As a result, HDD punch-in portion of the pipeline in river crossing became fully exposed and came under direct contact with high-velocity river water flow. The strong hydraulic forces and continuous scouring action created significant mechanical stress on the pipeline, leading to its rupture.
- **Incident-4:** A multiproduct pipeline failed inside the riverbed. The incident has been triggered by heavy rainfall, resulting in significant rise of water level in the river. This has resulted in riverbed erosion and subsequent pipeline rupture inside riverbed due to high stress.
- **Incident-5:** Natural gas pipeline snapped inside a major river resulting in gas leakage. The incident was triggered by heavy rainfall, cloud burst and flash floods resulting in riverbed erosion and subsequent pipeline rupture inside riverbed due to high stress.

OBSERVATIONS/ LAPSES

Basis site visit, internal reports, interaction with officials and checking of documents, committee observations are as under:

- **Incident-1:**
  - A. Due to heavy rainfall/cloudbursts in the hilly region, heavy gush of water was observed in the main river. At river meandering site (close to the pipeline failure location) river changed its course toward the minor stream (i.e. Nala) converting it to mainstream. This sudden increase in water flow in the Nala stream caused heavy erosion of the riverbank & riverbed, which in turn caused the heavy washout and exposed pipeline laid parallel to the nala.
  - B. The combined effect of pipeline exposure, and hydrodynamic stress caused the crack and rupture of the gas pipeline.
  - C. Washout incident was also reported at the nala/river crossing in past (upstream of the failure location), which was mitigated by carrying out a new HDD crossing. During HDD design & execution, parallel section of the pipeline was considered safe from washout point of view.
  - D. A Leak alarm in the Leak Detection System was logged, however the alarm was missed due to various other alarms.
- **Incident-2:**
  - A. Due to heavy rainfall/cloudbursts there was significant rise of the water level in the river. This caused heavy erosion of the riverbank & riverbed at the meandering site (just upstream of the pipeline crossing) which in turn caused the heavy washout in HDD punch-in portion & exposed the pipeline.
  - B. The combined effect of pipeline exposure, and hydrodynamic stress caused the crack and rupture of the gas pipeline, leading to gas leakage and failure of the pipeline.
  - C. Washout at same location was also observed in past. Accordingly, a gabion wall was constructed to protect the pipeline as per the design of a consultant.
  - D. Longer length HDD was planned at the same location as a permanent solution and action for the same was in progress (Geo Technical survey was completed). However, longer length HDD work to protect the pipeline could not be completed before this incident.
- **Incident-3**
  - A. Due to heavy rainfall/cloudbursts there was significant rise of the water level in the river. This caused heavy erosion of the riverbank & riverbed at the meandering site (just upstream of the pipeline crossing) which in turn caused the heavy washout in HDD punch-out portion & exposed the pipeline. The combined effect of pipeline exposure and hydrodynamic stress caused the crack and rupture of the pipeline.
  - B. Previously reduced soil cover was reported on this side of the riverbank, and it was noted that river's mainstream has shifted towards this side of the bank. Based on topographical survey, proposal for realigning the pipeline through fresh HDD was initiated and same was under administrative approval.
  - C. Few months back about 18-22m of pipeline was exposed on this side of the riverbank. Immediate actions like placement of bamboo and sandbags, installation of Geo tubes etc. were undertaken for prevention of pipelines from washout.
- **Incident-4:**
  - A. Multiproduct pipeline has crossed the seasonal river through open cut method. The region witnessed heavy rain and floods and meandering of the river location had caused its scouring. This has resulted in erosion of soil cover at riverbed.

B. The combined effect of pipeline exposure, and hydrodynamic stress caused the crack and rupture of the pipeline.

- **Incident-5:**

A. Natural gas pipeline has crossed the seasonal river through open cut method. Due to heavy rainfall/cloudbursts in the hilly region, heavy gush of water was observed in the river. This sudden gush of water caused scouring in river which led to pipeline exposure and subsequent failure due to stresses from heavy river currents.

B. The pipeline was laid via open cut method across the river crossing. It was informed during the investigation that the pipeline was laid via open cut method after unsuccessful attempts of HDD due to presence of gravel, boulders etc. inside riverbed.

Root Causes

Based on investigation, team has identified the following root causes of incident:

a) It can be concluded that all the above incidents were triggered by high river flow/ flash floods due to heavy rainfall/ cloud bursts, which in turn caused the river path meandering/ course change and riverbank erosion/ riverbed scouring.

b) Heavy erosion at riverbanks/ riverbed resulted in exposure of pipeline, which in turn created the hydrodynamic stress on pipe causing crack/ rupture of the gas pipelines.

c) In some of the incidents, although reiver bank erosion was noticed and fresh HDD of longer length/realignment were planned, delay in execution had resulted in failure of pipeline during operation.

d) In one of the incidents, river crossing was carried out by open-cut method since HDD was not possible due to presence of gravel/boulders on riverbed. Additional precautions like increase in trench depth, higher thickness/grade of pipe might have been taken during design stage to avoid such incident.

Recommendations

1. Leak detection system to be suitably configured & regularly tested for early warning in case of such incidents. Also, close monitoring of the alarms to be carried out and suitable action to be initiated in-case of any Alarm.
2. Alarms may be configured with different priorities (audio-visual alarms) to avoid missing critical alarms.
3. Immediate actions to be initiated for river crossings, where riverbank erosion has started. Delay in execution of longer length/realignment in HDD job could have avoided by taking prompt action.
4. Based on deliberations with all concerned industry representatives, '*Guidelines for preventing Pipeline Failure due to heavy rainfall/ floods*' circulated by OISD on 15.10.2025 (Attached as Annexure) are to be implemented. Maintenance related points to be implemented at all existing locations whereas design related points to be taken care while laying any new pipelines/planning for section replacement.
5. Considering four out of above mentioned five incident locations were close to river meandering locations, recommendation of the above referred guidelines regarding the same at clause no. 2.d may be considered for implementation in the existing pipeline.

तेल उद्योग सुरक्षा निदेशालय / Oil Industry Safety Directorate

पेट्रोलियम और प्राकृतिक गैस मंत्रालय / Ministry of Petroleum & Natural Gas

8वीं मंजिल, ओआईडीबी भवन, प्लॉट-2 सेक्टर-73, नोएडा (यूपी) / 8th Floor, OIDB Bhavan, Plot-2 Sector 73, Noida (UP)

दूरभाष / Tel : 91-120-2593800; वेबसाइट / Website : www.oisd.gov.in

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Guidelines for preventing Pipeline Failure due to heavy rainfall/ floods

Background:

In view failure incidents of the six pipelines due to sudden gush of water owing to heavy downpour, flash floods and change of river course, industry level meeting was organized by OISD on 25.09.2025 and 13.10.2025. The agenda of the meeting was reviewing these incidents and finalizing mitigation measures to avoid such pipeline failures in future.

During the meeting all aspects related to design requirements for new river crossing and requirements for existing river crossing were discussed in detail. Based on the discussion, the guidelines were finalized and agreed by all industry representatives, for taking necessary actions to prevent such incidents in future.

Guidelines:

Guidelines for taking necessary actions in new as well as existing pipelines to prevent failure due to heavy rainfall/ floods is as follows:

1) **Design requirements for new River crossings**: Design requirements are classified in two categories, i.e. for perennial and non-perennial rivers as detailed below:

    a. Crossings should be in a comparatively straight segment of the river at an angle of crossing as close to 90° as possible. Crossing close to meandering course of the rivers should be avoided. In case crossing near meandering course of the river is unavoidable, suitable precautionary measures like bank protection, longer length HDD etc. should be taken.

    b. Crossing of rivers in close proximity of downstream of Dam/Barrage should be avoided. In case where same is not possible, suitable precautionary measures should be taken.

    c. Parallel Laying of pipeline in proximity of any river should be avoided.

    d. **Perennial Rivers**: Following are to be considered while designing the pipeline crossing across perennial river:

        i. Pipeline crossing across perennial rivers shall be carried out through Trenchless techniques like HDD, Micro-tunneling etc. Incase single stretch trenchless method cannot be used due to technological limitations/ challenges, suitable alternate method may be used with engineering assessment and approval of competent authority not below the rank of Executive Director/Equivalent officer of entity.

        ii. Minimum depth of HDD/ Micro-tunneling from bank to bank, shall be maximum scour depth from lowest river bed plus 2.5m.

iii. Historical hydrological data (like High flood level, maximum flow, scour depth, river width, meandering etc.) of maximum available period shall be considered for designing of the HDD/Micro-tunneling. Based on these data, study for bank erosion, scouring rate & river meandering should also be done for next 25 years.

iv. Punch-in & punch-out point of HDD from riverbank (identified during design) should be 100 m or as per design requirement whichever is higher.

v. After completion of HDD/Micro-tunneling, riverbanks and hook-up points are shall be geo tagged and suitable physical marker (preferably with RFiD marker) shall be installed for identification & tracking of riverbank erosion in future, if any.

e. **Non-Perennial Rivers**: Following to be considered while designing the pipeline crossing across any non-perennial rivers:

i. Trenchless techniques shall be used for river/streams having a scour depth (from lowest riverbed) of more than 2.5 m and bank-to-bank width of minimum 100m. In this case, design requirement for trenchless method shall be same as mentioned above for perennial river crossings. Incase HDD method cannot be adopted due to technical challenges, laying with open cut method with additional cover of minimum 1 m (i.e. scour depth plus 3.5 m) may be carried out.

ii. Other smaller crossings (not meeting the criteria defined in above case) can be carried out through Open cut method.

iii. Anti Buoyancy measures such as concrete weight coating, anchors etc. shall be provided for complete section of the crossing (bank to bank) as minimum for open cut method.

2) **Requirements for existing River Crossings**: Following actions to be taken for existing River crossings/parallel pipeline sections:

a. For tracking the course change/riverbank erosion in future, Geotagging/ Physical pipeline markers (preferably along with RFiD markers) shall be installed for all the existing crossings at following locations:

i. At riverbanks for all river crossings (i.e. both perennial & non-perennial)

ii. At hook-up/tie-in point for HDD/Micro-tunneling/Open Cut crossings

b. Geotagging/ Physical pipeline markers (preferably along with RFiD markers) shall also be installed, for all the existing pipelines laid in parallel to rivers in close proximity (i.e. pipeline laid within 100m of riverbank). Markers shall be installed at every 50-100 m distance at pipeline to track the change in river course.

c. **Satellite/Drone imagery** may be used to monitor river course changes and bank erosion.

d. Amongst all existing river crossings in a pipeline, which are prone to erosion or near the river meandering locations, shall be identified. Suitable action like bank protection, bed protection, re-routing, longer HDD etc. shall be taken based on the review.

e. <u>Action to be taken for Perennial/Non-Perennial rivers</u>

i. Pipeline depth cover shall be measured at every 5m twice a year (i.e. pre-monsoon and post monsoon) in dry portion of the river and 100 m from either side up to river bank. The data shall be compared with previous data. In case, the depth is not meeting the OISD standard requirement, close monitoring with suitable action shall be taken.

ii. Bank erosion with respect to earlier bank marking (physical markers installed) shall be recorded along with depth cover. In case of bank erosion is observed, close monitoring with suitable action shall be taken.

f. In all existing pipelines, any new dam/barrage constructed/being constructed on perennial river within 100 km upstream of respective crossing shall be identified. In such cases, hydrological study (like bank erosion, meandering etc.) shall be conducted for its effect on the existing pipeline crossings and suitable mitigation measure shall be taken.

g. Check dams, if any, constructed in the close proximity (within 200m) of the existing pipeline crossing shall be identified and close monitoring shall be carried out for any erosion of the riverbed/riverbank near the pipeline crossing. Suitable action shall be taken, in case erosion is observed.

h. Gabion walls, sandbags are generally installed at washout locations to prevent any further washouts. However, regular monitoring is required along with taking up any other suitable action for permanent solution, if needed.

i. During the monsoon season, enhanced monitoring of the river crossing shall be carried with respect to bank erosion.

j. Regular meetings may be conducted with Irrigation Department/ Water resources to coordinate regarding the water release from Dam/barrage etc. Also, meetings to be conducted with district administration/ NDRF/ SDRF teams etc. to make them aware of pipeline river crossings & its emergency scenarios.

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