TECHNICAL REPORT

MINERALS MANAGEMENT SERVICE

PIPELINE DAMAGE ASSESSMENT FROM HURRICANES KATRINA AND RITA IN THE GULF OF MEXICO

REPORT NO. 448 14183

REVISION NO. 1

DET NORSKE VERITAS

TECHNICAL REPORT

Date of first issue: 2007-01-22	Project No.: 448 14183
Approved by: G. Abdel Ghoneim	Organizational unit: Pipeline Services
Client: Minerals Management Service	Client ref.: Mik Else TARS Project Number 581

Summary:

Det Norske Veritas (DNV) performed an assessment of the damage to the Gulf of Mexico (GOM) offshore pipelines resulting from the passage of Hurricanes Katrina and Rita in August and September 2005, under contract with the Department of Interior's Mineral Management Service (MMS). The objective was to determine what happened to pipelines during Hurricanes Katrina and Rita, and how to minimize the damage to pipelines, and the disruption of the U. S. oil and gas supplies originating in the GOM, as a result of hurricanes.

Study deliverables include a web-based damage mapping system concept, and report on damage effects, potential root causes, industry practices, and data collection methods assessment.

Report No.: 448 14183	Subject Group: Pipeline Damage
Report title: Pipeline Damage Assessment from Hurricanes Katrina and Rita in the Gulf of Mexico	
Work carried out by: Molly Atkins, Complico/Bridge Solutions – Tim Edward, Denis Johnson, and Michael Dance	
Work verified by: G. Abdel Ghoneim	

Date of this revision:	Rev. No.:	Number of pages:
2007-03-15	1	104

Indexing terms

Key words	Service Area
Hurricane Rita Katrina Pipeline Damage Assessment	Integrity Management Market Sector Oil and Gas

- ☒ No distribution without permission from the client or responsible organizational unit
- ☐ free distribution within DNV after 3 years
- ☐ Strictly confidential
- ☐ Unrestricted distribution

Table of Contents *Page*

1 EXECUTIVE SUMMARY

DNV performed an assessment of the damage to the Gulf of Mexico (GOM) oil and gas pipelines in the Outer Continental Shelf (OCS) resulting from the passage of Hurricanes Katrina and Rita in August and September, 2005, respectively, upon request from the Department of Interior's Minerals Management Service (MMS). The objective was to determine what happened to pipelines during these two hurricanes, and how to minimize the damage to pipelines and the disruption of the U. S. oil and gas supply originating in the Gulf of Mexico, as a result of hurricanes.

DNV evaluated the available failure reports and industry practices and has concluded that the vast majority of GOM offshore pipelines performed well during the passage of Hurricanes Katrina and Rita. Public and personnel safety experience with respect to the offshore pipeline operations has been excellent. Evacuations of non-essential personnel, and other operational precautions taken prior to hurricane events, including training, planning, spill response exercises, and industry alliances provided results that have protected life as the first priority. The impact to the environment has been minimal in hurricane events, primarily due to the design features, and industry practices intended for protection of life that are also focused on minimizing releases to the environment through planning, preparedness and response. The most significant impacts appear to have been the disruption of the oil and gas supply, and financial losses from the oil and gas infrastructure damage. While these are not desirable outcomes, the overall goal of prioritizing protection of life and the environment is clear in the demonstrated performance of the industry, meeting two of the major goals of the MMS for personal and environmental safety.

This report addresses 542 damage reports that were known at the time of the award of this project to DNV. However, at the time of the final DNV report presentation, the number of pipeline damage reports received by the MMS had exceeded 600 and are expected to continue to increase over time as more damages are found and reported. The majority of the 542 reported pipeline damages studied by DNV occurred at or near platform interfaces, or as a result of impact by an outside force other than the hurricane, such as platform failures, riser damages or anchor dragging. The remaining pipeline damages were primarily due to loss of cover and movement of pipelines that are near shore and in shallow water. The ability to determine the actual root causes of pipeline failures is limited by the incomplete data that we have about the pipeline's in-situ condition and the actual sequence of events that occurred during the hurricane with respect to failure or loadings imposed by movement of interconnected facilities at platforms and tie-ins, as well as the lack of detailed data reported about the pipeline damages.

There was an increased amount of pipeline damages from drilling rigs that lost stationkeeping during the two storm events that were studied than has been experienced during other historical events that have been studied. Industry actions were prompt to address remedial actions prior to the 2006 hurricane season. The 2006 hurricane season produced no hurricane events in the GOM, so the testing of these recommended practices will not occur until another hurricane season produces storms reaching the intensity of the hurricane events experienced in the GOM during the 2004 and 2005 hurricane seasons.

The data collection and damage reporting is an area that could be improved through report automation, consistent methodology and format, and industry wide definitions of the failure categories for the purposes of data analysis.

Graphical Internet based mapping tools can enhance operator reporting and assist the MMS assessments of hurricane impacted areas, development of NTLs that are technically based, and enable the MMS to have the ability to easily perform visual data management of the data contained in the MMS GIS.

2 INTRODUCTION

2.1 Objective

On behalf of the Department of the Interior (DOI), Minerals Management Service (MMS), Det Norske Veritas (DNV) carried out a damage assessment of the pipelines in the Gulf of Mexico, resulting from the passage of Hurricanes Katrina and Rita in 2005. The objective of the assessment was to determine the performance of offshore pipelines during Hurricanes Katrina and Rita, and to develop recommendations to minimize damage to the pipelines and disruption of the U.S. oil and gas supply originating in the Gulf of Mexico resulting from hurricanes.

2.2 Scope

The project scope included an assessment of the pipeline infrastructure damage caused by Hurricanes Katrina and Rita, with an attempt to identify the root causes of the damage through analyses of the damage reports, interviews of pipeline operators and participation in industry hurricane-related workshops. The scope also included investigation of current design, operations, maintenance and hurricane preparedness and response practices by Gulf of Mexico pipeline operators. The results were collected and evaluated through technical and graphical analyses to determine what happened to the pipelines and any possible revisions to practices with the intent of better protecting pipelines during subsequent major hurricane events.

This report describes the GOM OCS pipeline system in Section 3 and gives background on the hurricane environment in Section 4 including the latest 2006 hurricane season. Hurricane trends are discussed in Section 5. The work related to pipeline damage assessment and response to Hurricanes Katrina and Rita is covered in Sections 6 to 9. Section 10 is dedicated to the damage mapping development while Section 11 lists the DNV conclusions and recommendations made as a result of this study.

3 GULF OF MEXICO OUTER CONTINENTAL SHELF PIPELINE SYSTEM DESCRIPTION

The MMS Gulf of Mexico Regional Office (GOMR) conducts all leasing and resource management functions on the GOM Outer Continental Shelf (OCS). The OCS consists of submerged Federal lands off the United States coasts. MMS leases these Federal offshore areas for exploration and production and closely monitors OCS operations to protect coastal environments and ensure proper royalty collection. As well as meeting major energy needs through management of the production of roughly 30% of the US oil supply at roughly 1.5 million barrels per day, and 22% of the US natural gas supply totaling over 10 billion cubic feet per day, MMS provides about $6 billion in annual revenue benefits to the Nation. The MMS' Gulf Regional office has responsibility for OCS oil and gas and some other mineral matters. Most of the activity overseen by the GOMR is concentrated in the Gulf of Mexico. The GOMR's three planning areas in the Gulf of Mexico include 42 million acres under lease (as of January 2007), as represented by the map in Figure 1.

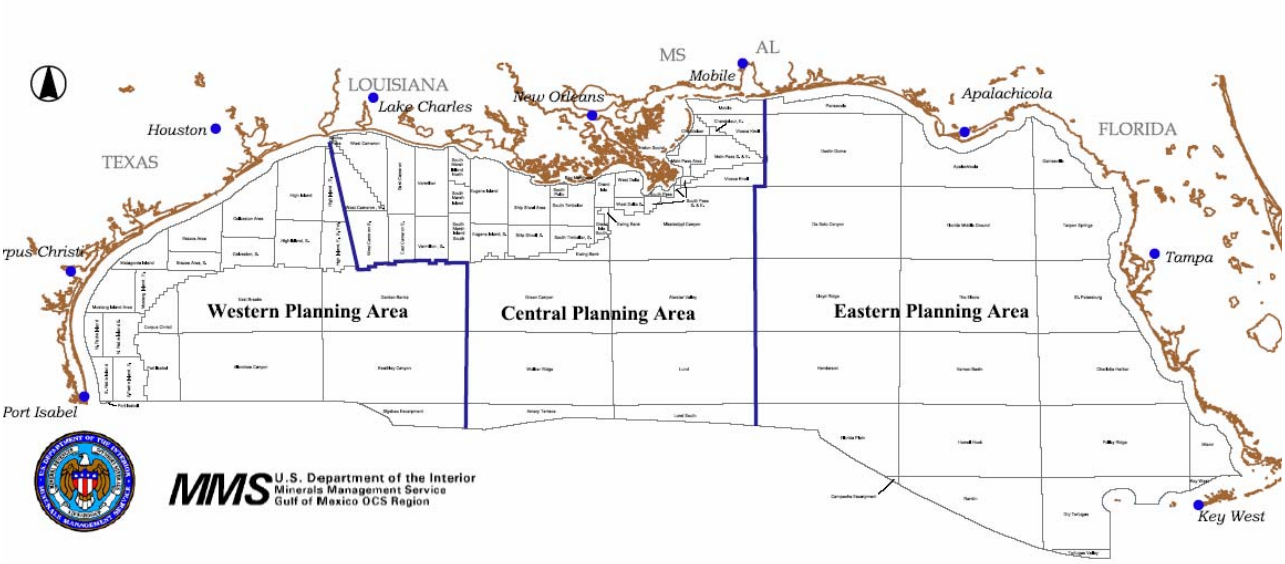


Figure 1 GOMR Area Map

The GOMR Regional Director describes the role and responsibilities of the GOMR OCS Region on the Regional Director's page found on the MMS GOMR website. "The office's role in all this activity is substantial. By law, MMS must approve every exploration well, every production proposal, the structural design of every platform as well as every pipeline, and must issue literally dozens of other approvals for the design and operation of facilities and measurement of product. It conducts extensive environmental review of proposed projects. MMS also conducts thousands of inspections every year to ensure operational safety and protection of the marine, coastal, and human environment. All of these activities are accomplished with a staff of 600 region employees. The offshore oil and gas industry in the Federal part of the Gulf of Mexico is a large and multifaceted group. In December 2006, 86 exploration wells were being drilled in Gulf waters and 39 of these were in water depths of 1,000 feet or greater. Ten exploration wells were in 5,000 feet of water or greater. As of January 1, 2007, there are 3917 producing platforms, of which about 1,962 are major platforms (954 of these are manned by personnel), roughly 33,600 miles of pipeline, and some 152 companies that are active in the Gulf."

The GOM OCS oversight of pipelines is managed by the Pipeline Section, a unit of Field Operations reporting to the Deputy Regional Supervisor for Field Operations. The Pipeline Section has approved on the average of 1,700 miles of new pipeline per year over the past five years. The volume of repairs, abandonments and modifications handled by this section is significantly impacted by hurricane activities. With the 2004 Hurricane season generating 168 damage reports, and the 2005 hurricane season resulting in 542 damage reports, the workload impact to the pipeline section increased dramatically. Coupled with the loss of the use of the MMS Elmwood office location after Hurricane Katrina, the temporary relocation of the GOM Regional and New Orleans District office to Houston under the Continuation of Operations Plan (COOP) was carried out and the expeditious review and approval of repairs, and ongoing oversight by the MMS was accomplished, even with many of the personnel having been personally impacted by the hurricane events. The commitment and dedication of the GOMR employees should not go without notice during this extremely stressful and difficult time with the loss of homes, relocation and personal losses that were suffered as a result of the hurricanes.

4 GOM HURRICANE HISTORICAL STUDIES AND EXPERIENCE

4.1 Hurricanes in Perspective

Hurricane Season:

The official Atlantic hurricane season takes place each year between June 1 and November 30, with peak hurricane activity generally occurring between mid-August and mid-October.

In an average year, ten tropical storms develop in the Gulf of Mexico, Caribbean Sea, or Atlantic Ocean; six of these storms become hurricanes. In a typical three-year span, five hurricanes hit the United States mainland; two are designated major (Category 3 – 5) hurricanes. The southeastern United States is the region most vulnerable to a hurricane strike. The States most likely to be hit by a major hurricane are Florida, Texas, and Louisiana.

--National Oceanic and Atmospheric Administration, Hurricanes: Unleashing Nature's Fury and U.S. Mainland Hurricane Strikes by State

The National Oceanic and Atmospheric Administration's (NOAA) 2005 seasonal Atlantic hurricane outlook was issued in May 2005. The outlook indicated a 70% likelihood that the season would be above normal for hurricane activity. In early August, the outlook was updated to indicate a 95% - 100% chance of an above-normal season, with the possibility of near-record activity. The outlook called for 18-21 named storms (previous record was 21), 9-11 hurricanes (previous record was 12), and 5-7 major hurricanes (record is 8).

The 2005 Atlantic Hurricane Season produced a record 27 named events, including a record setting four category-5 hurricanes. The 27 named events included 12 tropical storms and a record-setting 15 events reaching hurricane force winds, characterized as wind speeds above 74 mph, using the U.S. 1-minute average. With ten being the average number of systems normally occurring annually in the Atlantic Basin, the 2005 hurricane season was characterized as *extremely active*.

Two tropical storms, two hurricanes and four major hurricanes (Category 3 – 5) struck the Louisiana/southwestern Mississippi to northern Mississippi locale. This report is focused on Hurricane Katrina, which struck the central Gulf Coast in late August 2005, and Hurricane Rita which made landfall near the Texas – Louisiana border in September 2005. Katrina, one of the worst natural disasters to ever strike the United States, made the 2005 season the costliest in the nation's history. The events addressed in this study and the rest of the 2005 storms are represented in Figure 3.

The 2006 Atlantic Hurricane Outlook was made May 22, 2006. It forecast an 80% chance of an above-normal hurricane season, a 15% chance of a near-normal season, and only a 5% chance of a below-normal season. This outlook was produced by scientists at the National Oceanic and Atmospheric Administration's (NOAA) Climate Prediction Center (CPC), National Hurricane Center (NHC), and Hurricane Research Division (HRD).

The outlook called for a very active 2006 season, with 13-16 named storms, 8-10 hurricanes, and 4-6 major hurricanes. The likely range of the Accumulated Cyclone Energy (ACE) index was predicted to be 135%-205% of the median. This prediction indicated a continuation of above-normal activity that began in 1995. However, it was not expected to have a repeat of the 2005 record season at the time of the forecast.

An updated Atlantic hurricane outlook was issued August 8, 2006. The earlier forecast was revised downward slightly; however, NOAA continued to predict a high likelihood (75% chance) of an above-normal 2006 Atlantic hurricane season and a 20% chance of a near-normal season, according to a consensus of scientists at NOAA. Therefore, 2006 was forecast to be the tenth above-normal season in the previous twelve years.

The updated outlook called for a seasonal total of 12-15 named storms, with 7-9 becoming hurricanes, and 3-4 becoming major hurricanes (categories 3-5 on the Saffir-Simpson hurricane intensity scale). The likely range of NOAA's ACE index was predicted to be 110%-170% of the median. These totals included the three tropical storms (Alberto, Beryl, and Chris) that had already occurred. Therefore, for the remainder of the season, an additional 9-12 named storms, 7-9 hurricanes, and 3-4 major hurricanes were expected.

An important measure of the total seasonal activity is NOAA's ACE index, which accounts for the collective intensity and duration of Atlantic named storms and hurricanes during a given hurricane season. The ACE index is a wind energy index, defined as the sum of the squares of the maximum sustained surface wind speed (knots) measured every six hours for all named systems while they are at least tropical storm strength.

NOAA uses the ACE index, combined with the numbers of named storms, hurricanes, and major hurricanes, to categorize North Atlantic hurricane seasons as being above normal, near normal, or below normal. A value of 117% of the median (Median value is 87.5) corresponds to the lower boundary for an above-normal season. The following table shows the 1950-2005 seasonal means and ranges for named storms, hurricanes and major hurricanes during above normal, near normal, below normal and all Atlantic hurricane seasons. This table highlights the marked differences in activity between the three season types.

Season Type	Mean # of Tropical Storms	Range of Tropical Storms	Mean # of Hurricanes	Range of Hurricanes	Mean # of Major Hurricanes	Range of Major Hurricanes
Above-Normal	13.7	10 to 28	8.6	6 to 15	4.5	2 to 8
Near-Normal	9.4	6 to 14	5.6	4 to 8	1.9	1 to 3
Below-Normal	6.9	4 to 9	3.7	2 to 5	1.1	0 to 2
All Seasons	11	4 to 28	6.2	2 to 15	2.7	0 to 8

Table 1 – NOAA "Season Type" Categories of Hurricane Severity

The 2006 Atlantic hurricane season was an event in the annual cycle of tropical cyclone formation. The season was unusual in that no hurricanes made landfall in the United States. No tropical cyclones formed in the month of October, the first time this had happened since the 1994 season. Following the intense activity of the 2005 season, forecasts predicted the 2006 season would be very active, though not as active as 2005. However, in 2006, a rapidly-forming El Niño event, combined with the pervasive presence of the Saharan Air Layer over the tropical Atlantic, contributed to all tropical cyclone activity ceasing after October 2. Figure 4 shows the 2006 Atlantic Hurricane Season summary of storm events.

Figure 3 – 2005 Storm Events & Hurricane Track Chart

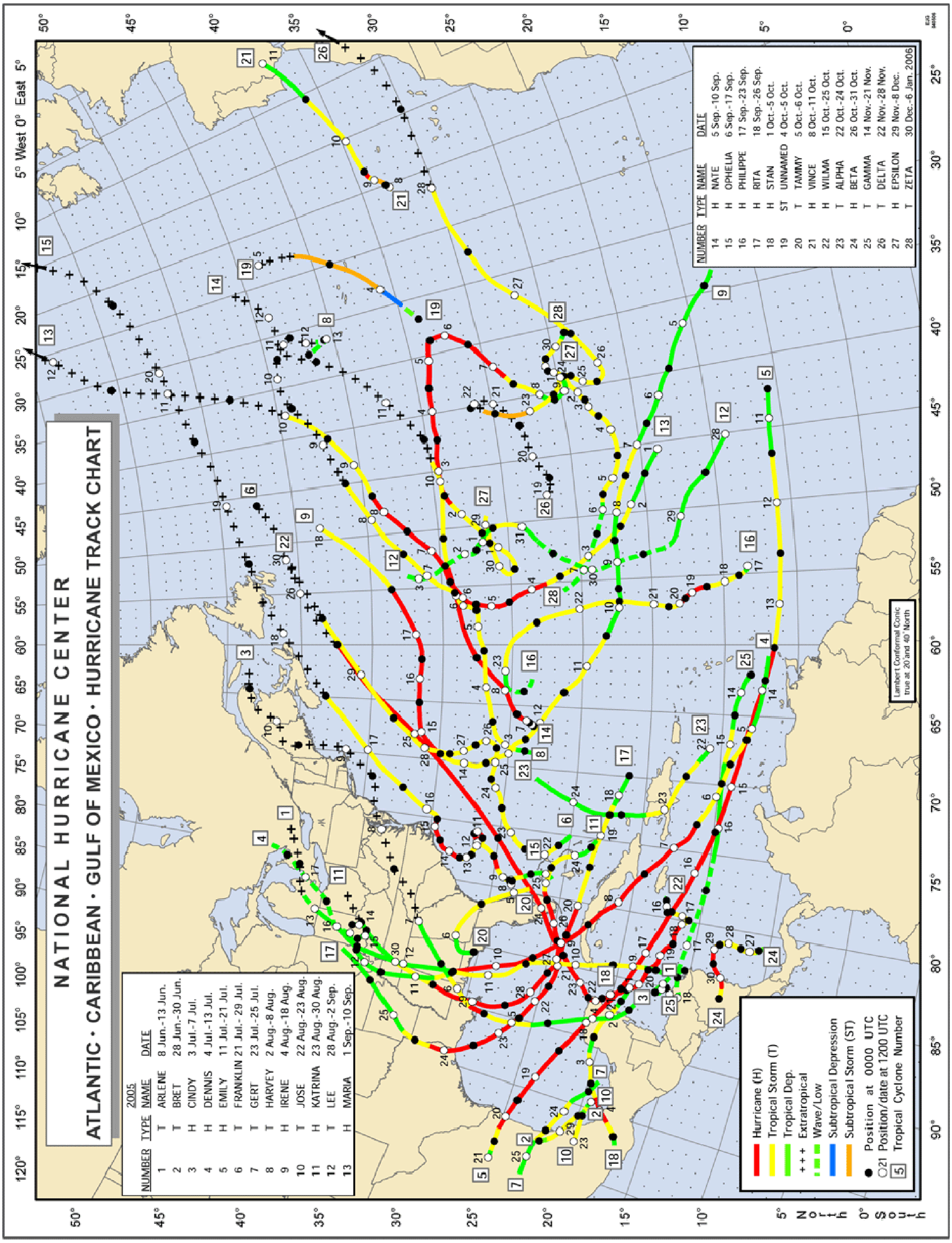
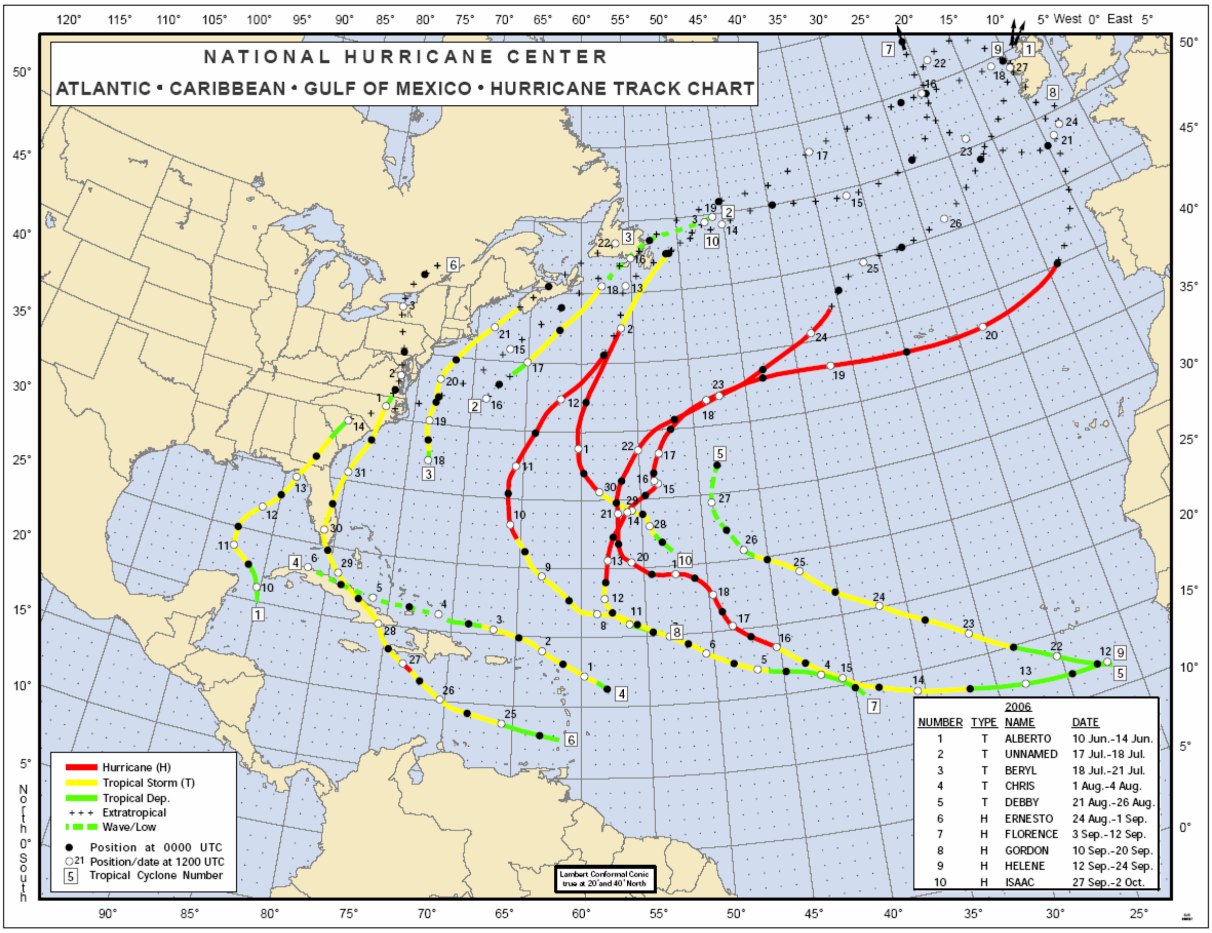


Figure 4 – 2006 Storm Events & Hurricane Track Chart



Hurricanes are rated on the Saffir-Simpson Hurricane Scale. The Saffir-Simpson Hurricane Scale is a 1-5 rating based on the hurricane's intensity. This is used to give an estimate of the potential property damage and flooding expected along the coast from a hurricane landfall. Wind speed is the determining factor in the scale, as storm surge values are highly dependent on the slope of the continental shelf and the shape of the coastline, in the landfall region. Note that all winds are using the U.S. 1-minute average.

Saffir-Simpson Hurricane Scale

Category	Storm Surge	Winds
1	4 -5 feet	74 – 95 mph
2	6-8 feet	96 – 110 mph
3	9-12 feet	111 – 130 mph
4	13-18 feet	131 – 155 mph
5	More than 18 feet above normal	Greater than 155 mph

* To be a Tropical Storm, winds must be between 39-73 mph.

The following is a summary of the historical hurricanes studied for comparison to the damage experienced during Hurricanes Katrina and Rita.

4.2 Hurricane Andrew

Figure 6 – Path of Hurricane Andrew

Hurricane Andrew damage to offshore pipelines was studied by Southwest Research Institute, and a Final Report was produced under MMS Contract No. 14-35-0001-30748 for the MMS Technical Assessment and Research Branch in March of 1995. Hurricane Andrew passed through the Gulf of Mexico in August 1992, following the path shown in Figure 6. About 36 major platforms and 145 satellite well jackets and caissons were damaged and more than 480 pipelines and flow lines were damaged by the passage of Hurricane Andrew. Hurricane Andrew was a category-4 level storm with sustained winds up to 140 miles per hour and significant wave heights estimated to be at 35-40 feet. Hurricane Andrew passed to the west of the Mississippi Delta, with its path overlaying some 700 structures, felling 22, and damaging to some degree about 65 others. Consequently, the westward path of Hurricane Andrew, shown in Figure 6 resulted in few pipelines being damaged by mudslides in this hurricane event.

Prior to Hurricane Andrew, minimal damage to pipelines had been experienced as a result of passing hurricanes. Pipeline failures from hurricanes for the period of 1971 through 1988 resulted in about 100 damage reports compared to Andrew's 485 damage reports. This dramatic increase in damages prompted the MMS to commission the study in an attempt to understand why when compared to the historical experience, the pipeline damages from Hurricane Andrew were so excessive. The results of the Hurricane Andrew study stated that most of the failures (87%) occurred in small diameter pipelines in the range of 2" to 6" diameter and that most of the failures were in depths less than 100 feet of water. The majority of the remaining damages were primarily attributed to riser and platform damage. No correlation was found to the age of the pipelines that sustained damage.

The study further concluded that the design standards appeared to be adequate, and the overall procedures followed by operators with regard to planning and recovery for hurricanes were also deemed to be adequate. Overall pollution from pipeline damages during all storms was low and was deemed not to be a major concern in the study report.

The summary recommendations from this study were:

- Efforts should be made to improve safety of platforms and jackets to withstand 100 year events to minimize pipeline damage
- Efforts should be made to improve anchoring and stationkeeping of mobile rigs
- Improvements for protection of small sized lines in shallow water depths
- Improvements for self burial installation stability for storm conditions

- Riser supporting clamps and adjacent pipeline sections should be carefully analyzed to verify integrity for the 100 year storm conditions
- Periodic inspection and maintenance of risers and supporting clamps are key in ensuring satisfactory performance to the intended design stress level.

4.3 Hurricane Lili

Hurricane Lili damage to offshore pipelines was evaluated and compared to prior hurricanes by Stress Engineering Services, Inc. in a study commissioned by MMS, and a Final Report was issued under contract 1435-01-03-RP-70926 in August 2005. Hurricane Lili was a category-4 level storm offshore, and was downgraded to a category-2 level at landfall, it passed through the GOM in late September 2002, making landfall on October 4, 2002. There were 120 pipeline damages reported to the MMS as a result of Hurricane Lili. Additionally, Hurricane Lili passed over approximately 800 platform structures resulting in the complete collapse of two platforms and serious damage to 17 others.

The primary focus of the Hurricane Lili pipeline damage assessment was on the comparison of the pipeline damage experience during Hurricane Lili with that of Hurricane Andrew. The study picked up where the Hurricane Andrew study left off, and evaluated the overall damage in much the same manner as the Hurricane Andrew report, focusing its attention on the area of pipeline riser damage, as recommended by the Hurricane Andrew study. As a result, the primary recommendations that resulted from the Hurricane Lili study were focused on recommended improvements in clamp design and maintenance for platform risers and their clamps.

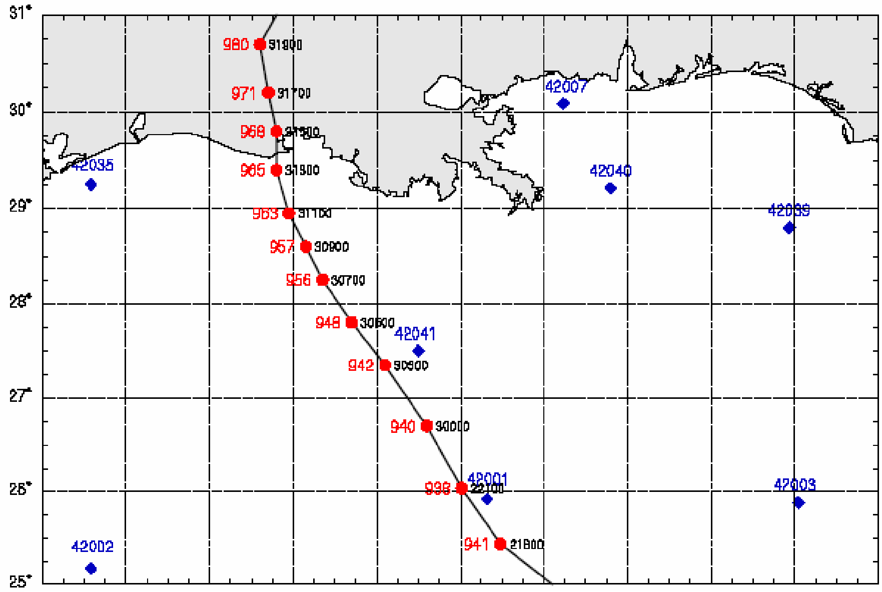


Figure 7 – Path of Hurricane Lili

The damage statistics from Hurricane Lili were contrasted to those of Hurricane Andrew, with similar statistical findings. As was true in Hurricane Andrew, the majority of the pipeline failures in Lili occurred in small pipeline diameter sizes (85%), and there was no apparent correlation by age. Again, the path of this hurricane, as shown in Figure 7, was to the west of the Mississippi delta, and as a result, the pipeline damage from mudflows was minimal.

The summary recommendations from the Hurricane Lili study were:

- Improvements in the questions asked of operators in the damage reporting process to better elicit root causes and improve data collection

- A simple check of riser clamp spacing by pipeline operators
- Evaluate improvements of riser inspection processes by operators in their maintenance programs
- Development of an in-situ riser integrity test for discovery and replacement of weak risers prior to storm events

4.4 Hurricane Ivan

Hurricane Ivan damage to offshore pipelines was evaluated and compared to prior hurricanes by DNV in a study commissioned by MMS, and a Final Report was issued under contract 1435-01-03-RP-70926, and was being conducted during the 2005 hurricane season. For the period of 1851 to 2004, Hurricane Ivan was ranked as 27 out of approximately 1325 storm systems as compared by Saffir-Simpson category at landfall and the measured minimum barometric pressure.

Hurricane Ivan produced record level wave heights and wind speeds that exceeded the 100 year design criteria for surface structures, and produced high levels of pipeline damage, many resulting from mudslides and excessive movement in the Mississippi Delta region.

The mapping of the pipeline damage with respect to the path of Hurricane Ivan is shown in Figure 8. Hurricane Ivan resulted in approximately 168 pipeline damage reports, 7 platforms were destroyed while 31 were seriously damaged, with an estimated 10,000 of the 33,000 miles of OCS pipelines, and 150 of the 4,000 platforms in the direct path of Hurricane Ivan.

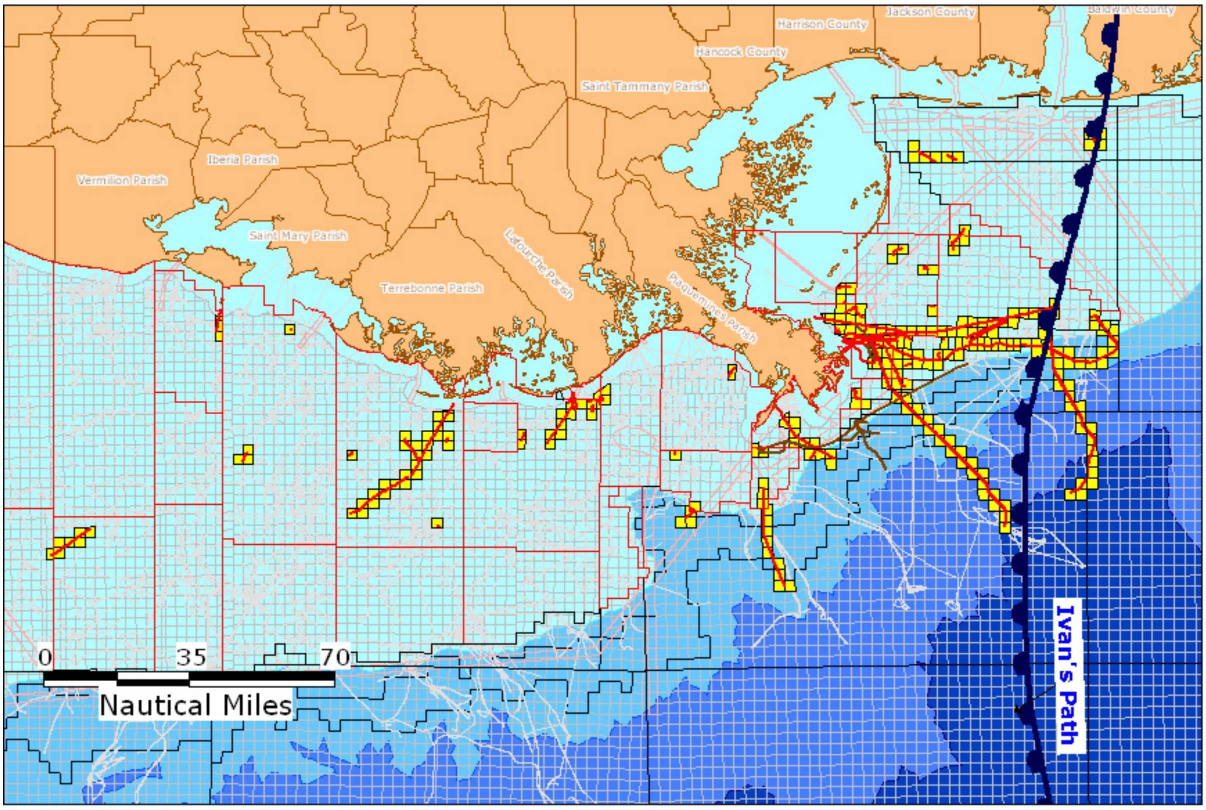


Figure 8 - Hurricane Ivan Path and Reported Pipeline Damage

The DNV study concluded that by and large, the pipelines performed well during Hurricane Ivan. Additionally, the practices used in design, construction, operations, and the planning and response to hurricanes were effective in protecting life and the environment. There were no significant findings with respect to design or construction practices that would suggest a need for revising the codes utilized in offshore GOM pipeline design.

The recommendations from the Ivan study focused on the ability to respond to hurricane and restore the energy supply safely and quickly to minimize the impact to the U. S. gas and oil supply.

The summary recommendations resulting from the Hurricane Ivan Study were:

- Evaluate the possible benefits of integrating DOI, MMS into National Response Plan
- Evaluate whether a formal process should be defined to identify and prioritize critical energy infrastructure
- Evaluate if any additional relaxation of MMS permit or regulatory requirements are warranted
- Consider treating pipelines in mudflow areas as higher risk facilities and require mitigation measures to manage risk to an acceptable level
- Consider creating risk zone maps of mudflow areas for use with a risk-based approach to the design and oversight of pipelines in mudflow areas
- Utilize improved designs and installation methods to maintain pipeline crossing minimum separation in shallow water less then 200 feet of depth, and mudflow areas
- Review of pipeline operators' operating procedures by MMS for inclusion of hurricane plans and review of records of hurricane drills having been conducted
- Automate and simplify the damage reporting process for pipeline operators to include a consistent format and definition for data collected in an on-line format
- Consider further study of the methods for modeling on-bottom stability
- Consider use of web-based tools to provide additional resources to the MMS for use in pipeline information management, including the assessment of damages from hurricane passage in the GOM

4.5 Hurricanes Katrina and Rita

Hurricanes Katrina and Rita caused significant damage to the oil and gas production structures in the GOM, with estimates by MMS stating that roughly 3050 of the 4000 platforms and about 22,000 of the 33,000 miles of offshore pipelines were in the path of these two hurricanes. Additionally, the onshore damage caused a significant impact in the ability of the oil and gas industry to respond due to the lack of resources, personnel, and infrastructure, as well as significant damage to onshore processing facilities and power supplies. There were significant competing resource needs with the impacts caused by the devastation of New Orleans and western Louisiana/eastern Texas shore communities that normally provide the services and supplies for the industry. These impacts included the temporary relocation of the MMS GOMR staff and functions to Houston, Texas.

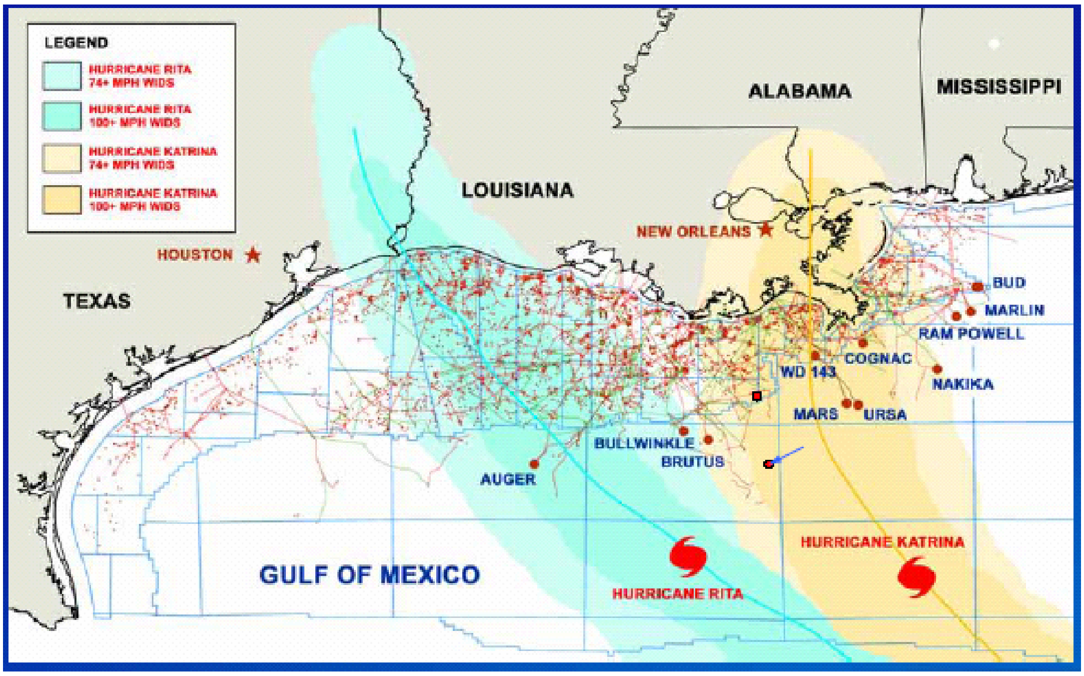


Figure 9 – Hurricanes Katrina and Rita and Maximum Wind Speeds

Hurricane Katrina was a category 5 hurricane when it entered the OCS, destroying 46 platforms and damaging 20 others, making landfall on August 29, 2005. Katrina's path is the easterly one in Figure 9. There were about 211 minor pollution incidents reported to the MMS. Minor pollution incidents are categorized as incidents involving less than 500 barrels of oil that do not reach the coast line. Hurricane Rita was a category 4 hurricane when it entered the OCS and destroyed 69 platforms and damaged 32 others, making landfall on September 24, 2005. Rita's path is the westerly one shown Figure 9.

4.5.1 Hurricane Katrina

Hurricane Katrina was the costliest and one of the deadliest hurricanes in the history of the United States. It was the eleventh named storm, fifth hurricane, third major hurricane, and second Category 5 hurricane of the 2005 Atlantic hurricane season, and was the sixth-strongest Atlantic hurricane ever recorded.

Katrina formed over the Bahamas on August 23, 2005, and crossed southern Florida as a moderate Category 1 hurricane before strengthening rapidly in the Gulf of Mexico and becoming one of the strongest hurricanes ever recorded in the Gulf. The storm weakened considerably before making its second landfall as a Category 3 storm on the morning of August 29 in southeast Louisiana.

Figure 10 - Flooded I-10/I-610/West End Blvd. Interchange and Surrounding Area of Northwest New Orleans and Metairie, Louisiana

It is possible that Katrina was the largest hurricane of its strength to approach the United States in recorded history; its sheer size caused devastation over 100 miles from the center of the storm. The storm surge caused major or catastrophic damage along the coastlines of Louisiana, Mississippi, and Alabama, including the cities of Mobile, Alabama, Biloxi and Gulfport, Mississippi, and Slidell, Louisiana. Levees separating Lake Pontchartrain from New Orleans, Louisiana were breached by the surge, ultimately flooding roughly 80% of the city and many areas of neighboring parishes. Severe wind damage was reported well inland. Katrina is estimated to be responsible for $75 billion (2005 US dollars) in damages, making it the costliest hurricane in U.S. history. The storm killed at least 1,604 people, making it the deadliest U.S. hurricane since the 1928 Okeechobee Hurricane

4.5.1.1 Hurricane Katrina Synoptic History

(Source: Excerpted from the Tropical Cyclone Report, Hurricane Katrina, 23-30 August 2005, Richard D. Knabb, Jamie R. Rhome, and Daniel P. Brown, National Hurricane Center, 20 December 2005)

Katrina made its first landfall in the United States as a Category 1 hurricane on the Saffir-Simpson Hurricane Scale, with maximum sustained winds of 70 knots, near the border of Miami-Dade County and Broward County at approximately 2230 UTC 25 August. While not discernible in conventional satellite imagery, a well-defined eye became evident on the Miami National Weather Service (NWS) WSR-88D Doppler radar just prior to landfall on the southeastern Florida coast. In fact, the eye feature actually became better defined while Katrina moved inland, and it remained intact during its entire track across the peninsula. The convective pattern of Katrina as it crossed southern Florida was rather asymmetric due to northerly wind shear, which placed the strongest winds and heaviest rains south and east of the center in Miami-Dade County. Katrina continued west-southwestward overnight and spent only about six hours over land, mostly over the water-laden Everglades. Surface observations and velocity estimates from the Miami and Key West Doppler radars indicated that Katrina weakened over mainland Monroe County to a tropical storm with maximum sustained winds of 60 knots. The center of Tropical Storm Katrina then emerged into the southeastern Gulf of Mexico at approximately 0500 UTC on 26 August just north of Cape Sable.

Once back over water, Katrina quickly regained hurricane status at 0600 UTC with maximum sustained winds of 65 knots. Even though the center of Katrina continued west-southwestward over the southeastern Gulf of Mexico and away from the southern Florida peninsula, a strong and well-defined rain band impacted large portions of the Florida Keys with tropical storm-force winds for much of the day on 26 August.

Sustained hurricane-force winds were briefly measured at Dry Tortugas on the far western end of the island chain that afternoon.

Situated beneath a very large upper-level anticyclone that dominated the entire Gulf of Mexico by 26 August, resulting in very weak wind shear and efficient upper-level outflow, Katrina embarked upon two periods of rapid intensification (defined as a 30 kt or greater intensity increase in a 24-h period) between 26 and 28 August. The first period involved an increase in the maximum sustained winds from 65 kt to 95 kt in the 24-h period ending 0600 UTC 27 August. An eye became clearly evident in infrared satellite imagery early on 27 August, and Katrina became a Category 3 hurricane with 100 kt winds at 1200 UTC that morning about 365 n mi southeast of the mouth of the Mississippi River. During the remainder of the day, the inner eyewall deteriorated while a new, outer eyewall formed, and the intensity leveled off at 100 kt. Accompanying the intensification and the subsequent deterioration of the inner eyewall was a significant expansion of the wind field on 27 August. Katrina nearly doubled in size on 27 August, and by the end of that day tropical storm-force winds extended up to about 140 n mi from the center. The strong middle- to upper-tropospheric ridge that had kept Katrina on a west-southwestward track over the Florida peninsula and southeastern Gulf of Mexico began to shift eastward toward Florida, while a mid-latitude trough amplified over the north-central United States. This evolving pattern resulted in a general westward motion on 27 August and a turn toward the northwest on 28 August when Katrina moved around the western periphery of the retreating ridge. As Katrina churned westward on 27 August, it produced tropical storm-force winds and heavy rainfall over portions of western Cuba. The new eyewall contracted into a sharply-defined ring by 0000 UTC 28 August, and a second, more rapid intensification then occurred. Katrina strengthened from a low-end Category 3 hurricane to a Category 5 in less than 12 h, reaching an intensity of 145 kt by 1200 UTC 28 August. Katrina attained its peak intensity of 150 kt at 1800 UTC 28 August about 170 n mi southeast of the mouth of the Mississippi River. The wind field continued to expand on 28 August, and by late that day tropical storm-force winds extended out to about 200 n mi from the center, and hurricane-force winds extended out to about 90 n mi from the center, making Katrina not only extremely intense but also exceptionally large.

The new eyewall that formed late on 27 August and contracted early on 28 August began to erode on its southern side very late on 28 August, while another outer ring of convection consolidated. These structural changes likely contributed to the rapid weakening that was observed prior to final landfall. Katrina turned northward, toward the northern Gulf coast, around the ridge over Florida early on 29 August. The hurricane then made landfall, at the upper end of Category 3 intensity with estimated maximum sustained winds of 110 kt, near Buras, Louisiana at 1110 UTC 29 August. Katrina continued northward and made its final landfall near the mouth of the Pearl River at the Louisiana/Mississippi border, still as a Category 3 hurricane with an estimated intensity of 105 kt. The rapid weakening of Katrina, from its peak intensity of 150 kt to 110 kt during the last 18 h or so leading up to the first Gulf landfall, appears to have been primarily due to internal structural changes, specifically the deterioration of the inner eyewall without the complete formation of a new outer eyewall. However, Katrina remained very large as it weakened, and the extent of tropical storm-force and hurricane-force winds was nearly the same at final landfall on 29 August as it had been late on 28 August. The weakening could have been aided by entrainment of dry air that was seen eroding the deep convection over the western semicircle while Katrina approached the coast.

Gradually increasing wind shear, slightly lower ocean temperatures, and (following the first Gulf landfall) interaction with land each could also have played a role. Without extensive investigation, however, it is not possible to assess the relative roles played by these various factors. The weakening of major hurricanes as they approach the northern Gulf coast has occurred on several occasions in the past when one or more of these factors have been in place. Indeed, an unpublished study by the National Hurricane Center (NHC) reveals that, during the past 20 years, all 11 hurricanes having a central pressure less than 973 mb 12 h before landfall in the northern Gulf of Mexico weakened during these last 12 h.

Katrina weakened rapidly after moving inland over southern and central Mississippi, becoming a Category 1 hurricane by 1800 UTC 29 August. It weakened to a tropical storm about six hours later just northwest of Meridian, Mississippi. Katrina accelerated on 30 August, between the ridge over the southeastern United States and an eastward-moving trough over the Great Lakes. It turned northeastward over the Tennessee Valley and became a tropical depression at 1200 UTC 30 August. The depression continued northeastward and transformed into an extratropical low pressure system by 0000 UTC 31 August. The low was absorbed within a frontal zone later that day over the eastern Great Lakes.

4.5.2 Hurricane Rita

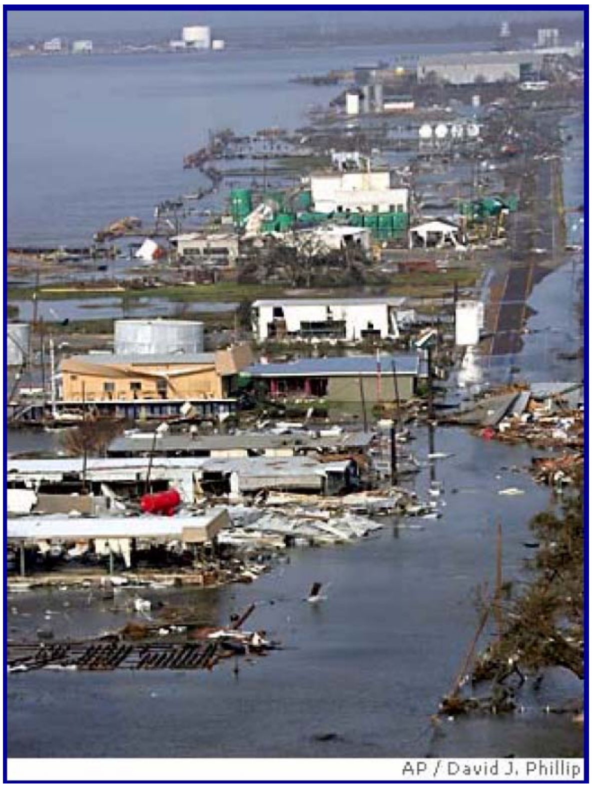


Figure 11 Cameron, Louisiana Flooding

Hurricane Rita was the fourth-most intense Atlantic hurricane ever recorded and the most intense tropical cyclone ever observed in the Gulf of Mexico. Rita caused $10 billion in damage on the U.S. Gulf Coast in September 2005. Rita was the seventeenth named storm, tenth hurricane, fifth major hurricane, and third Category 5 hurricane of the 2005 Atlantic hurricane season.

Rita made landfall on September 24 near the Texas-Louisiana border as a Category 3 hurricane on the Saffir-Simpson Hurricane Scale. It continued on through parts of southeast Texas. The storm surge caused extensive damage along the Louisiana and extreme southeastern Texas coasts and completely destroyed some coastal communities. The storm killed seven people directly; many others died in evacuations and from indirect effects.

Rita was an intense hurricane that reached Category 5 strength (on the Saffir-Simpson Hurricane Scale) over the central Gulf of Mexico, where it had the fourth-lowest central pressure on record in the Atlantic basin. Although it weakened prior to making landfall as a Category 3 hurricane near the Texas/Louisiana border, Rita produced significant storm surge that devastated coastal communities in southwestern Louisiana, and its winds, rain, and tornadoes caused fatalities and a wide swath of damage from eastern Texas to Alabama. Additionally, Rita caused floods due to storm surge in portions of the Florida Keys.

4.5.2.1 Hurricane Rita Synoptic History

(Source: Excerpted from the Tropical Cyclone Report, Hurricane Rita, 18-26 September 005, Richard D. Knabb, Daniel P. Brown, and Jamie R. Rhome, National Hurricane Center, 17 March 2006)

Rita proceeded westward into the southeastern Gulf of Mexico as a Category 3 hurricane early on 21 September. Throughout most of the remainder of that day, Rita quickly intensified over the very warm waters of the Loop Current and within an environment of very weak vertical wind shear, reaching an intensity of 145 kt by 1800 UTC. Rita had strengthened from a tropical storm to a Category 5 hurricane in less than 36 h. It remained at Category 5 strength for about the next 18 h, reaching its estimated peak intensity of 155 kt by 0300 UTC 22 September while located about 270 n mi south-southeast of the mouth of the Mississippi River. During that time it also turned toward the west-northwest around the western extent of the middle- to upper-tropospheric ridge centered over the southeastern United States.

The inner eyewall deteriorated later on 22 September and Rita abruptly weakened to Category 4 strength with 125 kt maximum winds by 1800 UTC that day. By early on 23 September a new, outer eyewall had consolidated and the hurricane had grown in size. However, Rita did not re-intensify following the structural changes. Due to increasing southwesterly wind shear and slightly cooler waters, steady weakening continued on 23 September. Rita rounded the western periphery of the deep-layer ridge and turned toward the northwest that day, with a slight increase in forward speed from about 8 to about 10 kt. It weakened to a Category 3 hurricane with 110 kt maximum winds by 1800 UTC 23 September about 140 n mi southeast of Sabine Pass at the Texas/Louisiana border. Rita maintained Category 3 status up to the time of landfall of the center, which occurred at 0740 UTC 24 September with an estimated intensity of 100 kt, in extreme southwestern Louisiana just west of Johnson's Bayou and just east of Sabine Pass.

Rita weakened after making landfall, remaining a hurricane until only about 1200 UTC 24 September when it was centered about 35 n mi north of Beaumont, Texas. As a steadily weakening tropical storm, Rita proceeded northward, with its center moving roughly along the Texas/Louisiana border during the remainder of that day. Rita weakened to a tropical depression by 0600 UTC 25 September while centered over southwestern Arkansas and then turned northeastward ahead of an approaching frontal system. The depression lost its organized convection and degenerated to a remnant low early on 26 September over southeastern Illinois.

5 HURRICANE ACTIVITY AND ECONOMIC FACTORS

The 2005 Atlantic hurricane season was the most active season since accurate recordkeeping began in 1944. The oil and gas industry has seriously studied the adequacy of the current design practices for the interrelated activities of the various oil and gas infrastructure groups in the GOM as a result of the significant impacts inflicted to the industry by these two events. The increased hurricane activity and severity has exceeded older design criteria for various sectors of the offshore infrastructure, and while the focus of this study is on pipeline damage – the fact exists that at least 50% to 70% of the pipeline damage reports for the last three significant hurricane events were related to pipeline and riser failures that occurred at the pipeline to platform interface zone. The most significant reduction in the number of damage reports for pipelines will be realized by reduction of damage in this area of the offshore infrastructure. However, finding the economic balance for design criteria and continued growth in the GOM offshore environment is highly dependent upon the understanding of the hurricane forces and the nature of the severe storm patterns that have been experienced since 1995.

The question that is being asked by many groups and varied interests is depicted in ImpactWeather's graphic from their presentation that was given as part of the 2006 Offshore Technology Conference (OTC). The question asked is "Are we experiencing a New Era of Hurricane Activity?"

During the 2005 and 2006 API Hurricane Readiness and Recovery Conferences, many presentations and API task forces pondered this very question, and many discussions have surrounded this aspect of the tropical storms experienced since the 2004 Hurricane season. Is the current hurricane activity level an upward trend, or is it a cyclical variation? The paths of five of these hurricanes passed through the Gulf of Mexico, with Ivan, Katrina and Rita significantly disrupting oil and natural gas production by cutting through more than 75 % of the GOMR OCS facilities.

Hurricanes Katrina and Rita hit in rapid succession and impacted the oil and gas production more significantly, and for a longer period of time than any other historical hurricane event, including the most recent prior event, Hurricane Ivan. The shut-in statistics and comparisons of the three most recent events are shown in Figures 12a and 12b. These shut-in statistics represent the amount of OCS facilities that are shut-in and not producing from the date of the hurricane's landfall to correlate the data for the three events. It should be noted that evacuations and some shut-ins occur prior to the hurricanes making landfall in preparation of the storms, but are not represented in these statistics which are for the total industry after the events have passed.

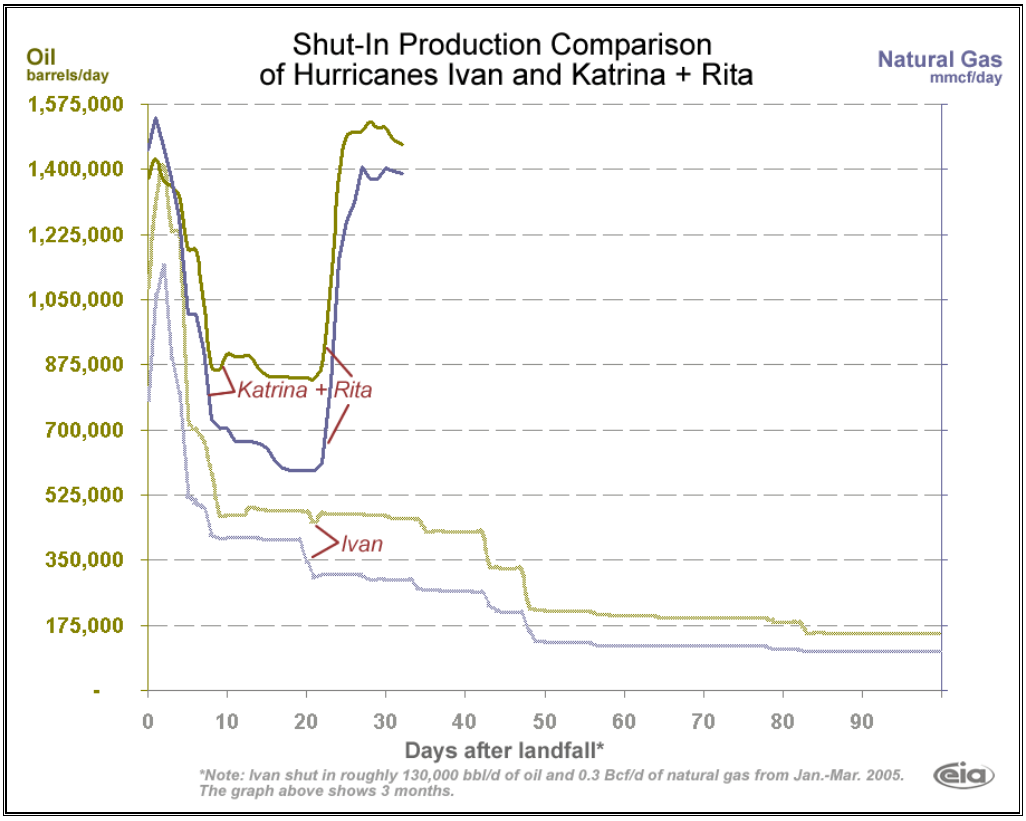


Figure 12a - OCS GOM Shut–In Comparison Chart for Hurricanes Ivan, Katrina, Rita

	Oil Production Shut-In			Gas Production Shut-In		
	Ivan	Katrina	Rita	Ivan	Katrina	Rita
Max Shut-In	82.9%	95.2%	100.0%	53.0%	88.0%	80.5%
1 Day After	72.5%	91.5%	100.0%	41.6%	83.5%	78.4%
2 Days After	64.7%	90.4%	100.0%	34.1%	78.7%	78.6%
3 Days After	51.5%	88.5%	100.0%	27.6%	72.5%	80.3%
4 Days After	41.1%	79.0%	98.6%	23.5%	57.8%	79.8%
5 Days After	39.2%	73.3%	97.8%	22.7%	55.0%	79.4%
6 Days After	34.0%	69.6%	94.7%	19.5%	52.3%	76.8%
7 Days After	27.7%	58.0%	92.8%	18.9%	41.6%	75.0%
14 Days After	28.5%	56.4%	77.5%	18.9%	37.2%	64.2%

Source: MMS/rigzone

Figure 12b - OCS GOM Shut–In Comparison Table for Hurricanes Ivan, Katrina, Rita

This leads into the second factor; the economic criticality of the oil and gas supplied by the production facilities of the GOM. With more than 30% of the US oil consumption and nearly one quarter of the country's natural gas supply coming from the production in the GOM, the hurricane impacts have a direct affect on the US economy with respect to oil and gas commodities, and pressure is intense to return facilities to production as soon as safely possible.

The MMS GOM OCS activities have received heightened visibility as production shut-in and supply curtailments have a sharper economic and energy supply impact with the growing share of the oil and gas supplies coming from the GOM. Figure 13 represents the 2005 oil and natural gas production percentage that the GOM contributed to the total U.S. production as of June 2005, immediately prior to the 2005 hurricane season.

Gulf of Mexico Oil & Natural Gas Facts
Energy Information Administration
Data as of June 2005 unless otherwise noted.

	Gulf of Mexico	Total U.S.	% from Gulf of Mexico
Oil (million barrels per day)			
Federal Offshore Crude Oil Production (5/05)	1.576	5.494	28.7%
Total Gulf Coast Region Refinery Capacity (as of 1/05)	8.068	17.006	47.4%
Total Gulf Coast Region Crude Oil Imports	6.490	10.753	60.4%
- of which; into ports in LA, MS and AL	2.524	10.753	23.5%
- of which; into LOOP	0.906	10.753	8.5%
Natural Gas (billion cubic feet per day)			
Federal Offshore Marketed Production (5/05)	10.1	50.58	20.0%

Figure 13 – Gulf of Mexico Oil & Natural Gas Facts for 2005 Production

The Department of Energy's short term energy outlook, presented by the Energy Information Administration (EIA), was developed from information that included the MMS provided shut-in statistics presented earlier in this report, to depict the economic and production forecasts for offshore oil and gas production after Hurricanes Katrina and Rita. Figures 14a and 14b represented the March 2006 forecast for the oil and gas price forecasts from the EIA. These figures show the amount of offshore oil and gas production that remained shut-in as a result of Hurricanes Katrina and Rita in February 2006, up to six months after the hurricanes made landfall and the price impacts resulting from the shut-in production and supply disruption.

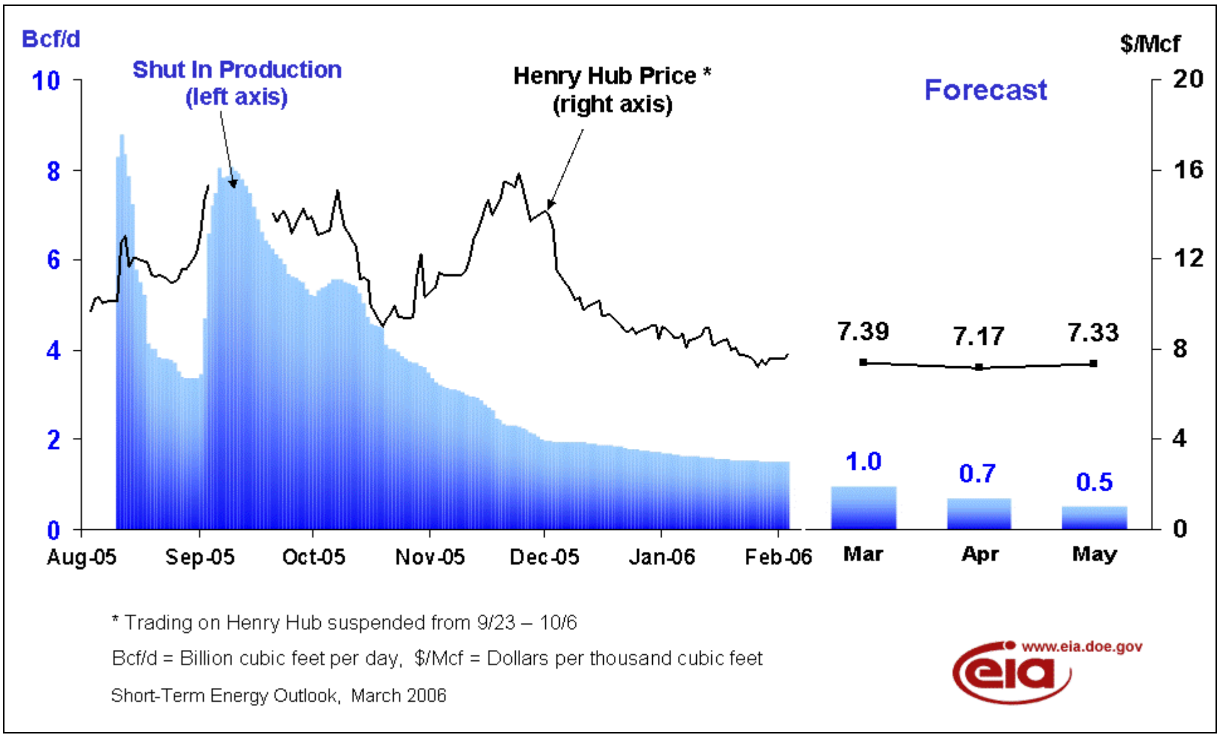


Figure 14a – Offshore Gulf Natural Gas Production

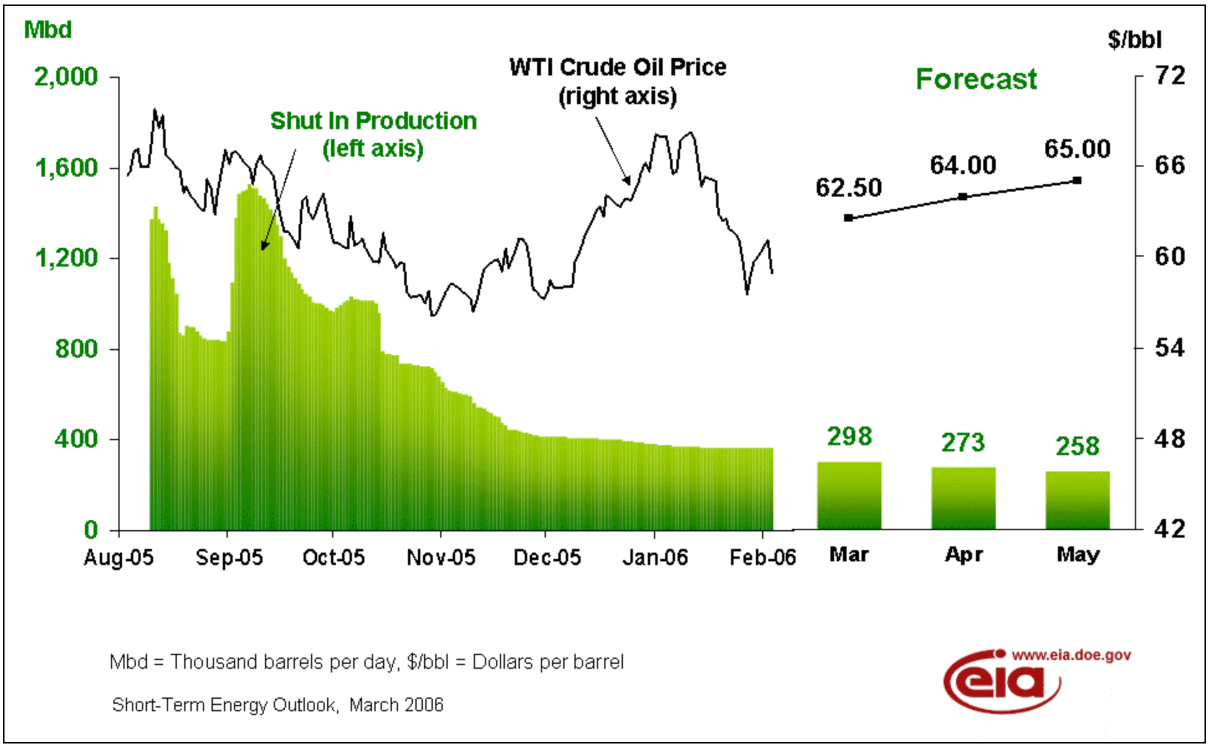


Figure 14b – Offshore Gulf Crude Oil Production

The final shut-in report for Hurricanes Katrina and Rita was issued on June 19, 2006. The 2006 Hurricane Season started June 1, 2006, and the reporting of shut-in and production statistics focus was shifting to the next hurricane season. Even then, almost ten months after Hurricane Katrina made landfall, and at the beginning of the next hurricane season, 8.3% of the manned platforms remained evacuated, and 12% of daily oil production and slightly more than 8% of the daily gas produced in the GOM OCS remained shut-in.

The cumulative shut-in oil production for the period August 26, 2005 through June 19, 2006, was 166,312,453 bbls, which is equivalent to 30% of the yearly production of oil in the GOM (approximately 547.5 million barrels).

The cumulative shut-in gas production for the period August 26, 2005 through June 19, 2006, was 803.604 BCF, which is equivalent to 22% of the yearly production of gas in the GOM (approximately 3.65 TCF).

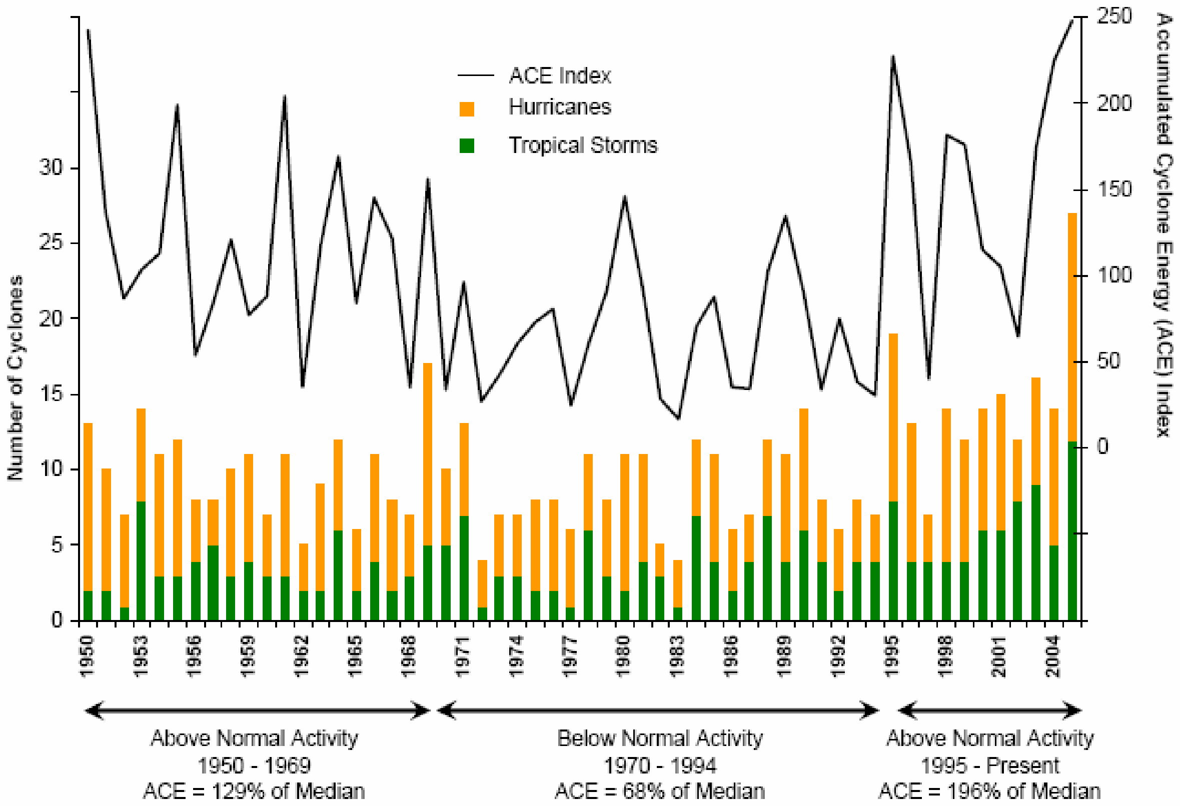
Figure 15 – Final 2005 Hurricane Season Shut-in Data Reported June19, 2006

This data reflects 41 companies' reports						
Districts	**Lake Jackson**	**Lake Charles**	**Lafayette**	**Houma**	**New Orleans**	**Total**
Platforms Evacuated	0	21	18	2	27	68
Rigs Evacuated	0	0	0	0	0	0
Oil, BOPD Shut-in	0	12,663	23,544	31,558	112,205	179,970
Gas, MMCF/D Shut-In	2.80	278.74	262.82	140.65	250.67	935.67

5.1 Hurricane Trends

There is widespread agreement that the 2004 and 2005 hurricane seasons were higher than average years for the number of named storms in the Atlantic Basin. However, general debate exists as to whether this timeframe marks an upward trend in hurricane activity, or if it is part of a normal cyclical variation.

As explained by NOAA, the seasonal intensity of tropical cyclones runs in what are termed multi-decadal cycles. The historic hurricane activity level tracked by the National Oceanic and Atmospheric Administration (NOAA) is shown in Figure 16. As you can see, during the 1950s and 1960s, hurricane activity was above the annual median ACE index, while the 1970s, 1980s, and early 1990s were below average. Since 1995, the Atlantic Basin has again been experiencing above-average activity. However, the 2006 hurricane season produced a very quiet year for tropical cyclones which provided the oil and gas industry in the GOM a bit of relief from the previous two seasons.



Note: Median Atlantic ACE index = 89.3 for 1950-2005.
Source: Hurricane tracking data from National Oceanic and Atmospheric Administration.
(http://hurricane.csc.noaa.gov/hurricanes/download.html)

Figure 16 – North Atlantic ACE Index and Number of Tropical Cyclones for 1950 – 2005

DNV has relied upon the numerous studies carried out that have concluded that the current activity level is a cyclical swing and is not an upward trend and has premised its basis for the observations and recommendations in this study. DNV contends, as was the contention in the

DNV Hurricane Ivan report, that current hurricane trends are part of cyclical variations in the hurricanes experienced in the GOM.

5.2 Criticality of the Oil and Gas Infrastructure

Hurricanes Katrina and Rita caused major disruption to the oil and gas facilities in the GOM. Gulf tropical storms and hurricanes typically cause small disruptions when measured on a seasonal basis. The average seasonal shut-in production, as a percentage of normal annual GOM OCS production, from 1960 to 2005 is 1.4% for crude oil and 1.3% for natural gas. However, these averages are skewed upwards by the 19% of oil production and 18% of natural gas production that was shut-in during the 2005 hurricane season. Without the 2005 hurricane season, the average shut-in statistics have only been 0.6% and 0.5% of the annual GOM OCS oil and natural gas production, respectively.

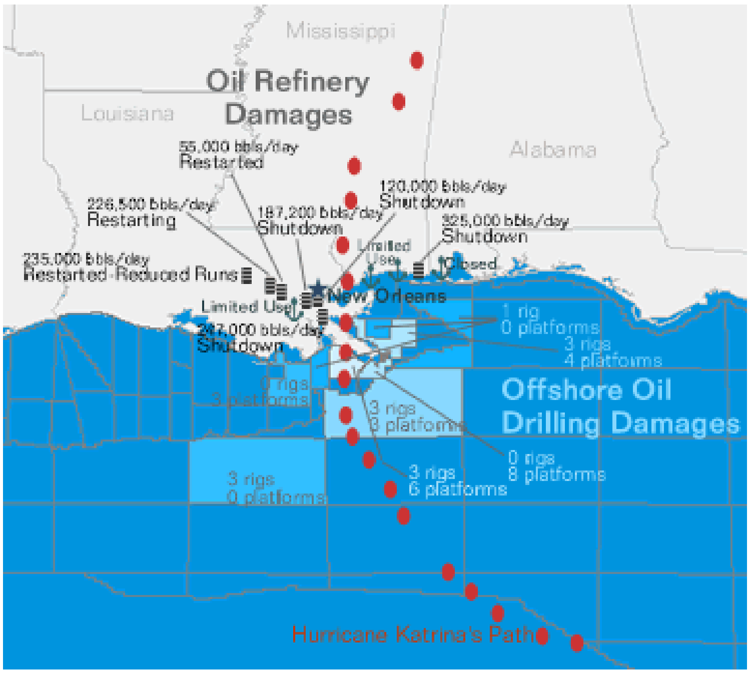
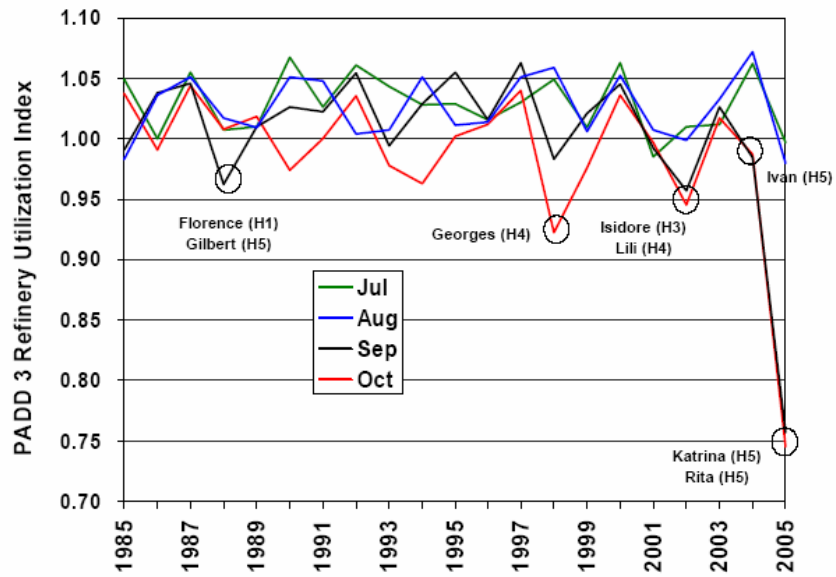


Figure 17a – Katrina Onshore Refinery Damage

The most profound effects to supply were to the refined products due to the very significant onshore impacts to the processing and refining facilities which are shown for the impacts by Hurricane Katrina in Figure 17a. At one point, about one third of the nation's refining capacity was closed due to the two events.

There is no long-term data source that tracks the impact of hurricanes and tropical storms on the refinery sector. However, Figure 17b provides a utilization index developed by EIA that depicts the affected capacity as a result of Hurricanes Katrina and Rita in contrast with Hurricane Ivan and highlights the uniqueness of the refinery damage experienced in 2005.



Note: The Refinery Utilization Index is calculated by taking the ratio of the refinery utilization in a given month divided by the average utilization for January through June in the same year.

Figure 17b – PADD 3 Refinery Utilization Index for 1985 – 2005

The refined product supplies were initially made up from the release of 30 million barrels of gasoline, middle distillate and other products from strategic reserves of member nations of the Organization for Economic Cooperation and Development (OECD) who are International Energy Agency (IEA) members.

With natural gas, about 85% of the nation's supply comes from domestic production; there is very little opportunity to import replacement supply. As of October 2005, 10% of the nation's consumption was still shut-in because of production problems in the GOM, or critical infrastructure damage, and another 3% of nationwide supply from Louisiana state lands was shut-in. Combining lost gas output from the state and federal lands, the total amount of 6.7 bcf per day, the equivalent of about 11% of an average day's total consumption for the whole country.

These two storms shut down oil and gas production from the GOM longer, and to a higher extent with respect to volumes than any previous event. Katrina made landfall on August 29, 2005, resulting in the shutdown of most crude oil and natural gas production in the GOM, as well as a great deal of refining capacity in Louisiana and Alabama. As of late October, 2005, 554,000 barrels per day were still closed. Offshore oil and gas production was resuming when Hurricane Rita made landfall on September 24, 2005, and an additional 4.8 million barrels per day of refining capacity in Texas and nearby Louisiana was closed. Combining the effects of both storms, 1.3 mbd of refining, about 8% of the nation's capability was shut down, reducing the supply of domestically refined fuels significantly.

The U.S. dependence upon the supply of oil and gas from the GOM, and the affects to the economy when supplies are curtailed has increased visibility of the MMS Daily Production Shut-In Statistics that are published after hurricane events. The pipeline damage reporting process, MMS instructions with inspection requirements to survey pipeline facilities and the permitting of repair, modification, replacement or abandonment of facilities are all oversight activities that MMS must perform in the process of returning to operations.

6 ENVIRONMENTAL IMPACTS

Offshore environmental impacts as a result of hurricane events in the GOMR have typically been minor due to the downhole safety valves at wells and operating practices conducted by the oil and gas industry with respect to platforms and pipelines in advance of approaching hurricanes, and the Oil Spill Response Plans that are developed by operators and submitted to the MMS.

The impacts from Hurricanes Katrina and Rita were typical of this historical experience. While cleanup was required. The volume of oil spilled and impacts to shore from the offshore infrastructure were categorized as minor. Onshore impacts from localized tank failures resulting from flooding were more significant, but are not in the scope of the damage assessment carried out by DNV.

The summary analysis of oil spills was presented by the Region Response Team for the MMS and was the source of the data in Table 2. The data is categorized by storm and source locations, and captures all spills one barrel or larger from federal OCS facilities that resulted from damages related to Hurricanes Katrina and Rita. As a result of both storms, 124 spills were reported with a total volume of roughly 17,700 barrels of total petroleum products, of which about 13,200 barrels were crude oil and condensate from platforms, rigs and pipelines, and 4,500 barrels were refined products from platforms and rigs.

Pipelines were accountable for 72 spills totaling about 7,300 barrels of crude oil and condensate spilled into the GOM. Response and recovery efforts kept the impacts to a minimum with no onshore impacts from these spill events.

Storm	Source	Petroleum	Crude Oil & Condensate	Refined Petroleum	Counts
Combined	Total	17,652.2	13,137.3	4,514.8	124
	Platforms & Rigs	10,365.4	5,850.6	4514.8	52
	Pipelines	7,286.8	7,286.8	-	72
Katrina	Total	5,552.1	4,961.9	590.1	70
	Platforms & Riga	2,842.5	2,252.4	590.1	27
	Pipelines	2,709.6	2709.6	-	43
Rita	Total	12,100.1	8,175.4	3,924.7	54
	Platforms & Rigs	7,22.9	3,598.2	3,924.7	25
	Pipelines	4,577.2	4,577.2	-	29

Table 2 – Spill Statistics from Hurricanes Katrina and Rita Damages to OCS Structures

Out of the 542 damage reports related to pipelines, 72 spills were reported that had a volume of one barrel or more of crude oil or condensate. This represents approximately a 13% per capita spill rate for the total damages reported as a result of Hurricanes Katrina and Rita.

Pictures of Chevron's Typhoon Tension Leg Platform (TLP) shown in Figure 18 before and after the passage of Hurricane Rita clearly conveys the severity of the damage that caused pollution events typical of the spills reported in the table above. Chevron's Typhoon was located in 2,000 feet of water in the Green Canyon area approximately 165 miles south-southwest of New Orleans. It was severed from its mooring and suffered severe damage during Hurricane Rita. Chevron mobilized appropriate resources to address any environmental concerns. No employees were at risk. Prior to the storm, the company safely evacuated employees and contractors from GOM facilities.

Figure 18 - Typhoon TLP - Pre and Post Hurricane Rita

6.1 MMS Oversight of Return to Service

The MMS post hurricane activities include oversight of the conditions of the permits held by leaseholders, while updating and managing the information about the facilities being repaired, for which MMS has jurisdiction. The oversight activities are intended to facilitate the safe return to service of oil and gas facilities, in the most expeditious manner possible, without compromising the safety of the public, environment or operating personnel. The experience with respect to safety and environmental protection in the GOM with respect to hurricanes has been excellent, with no loss of life or significant environmental impact.

One of the difficulties experienced in the assessment of the pipeline damages to the GOM oil and gas pipeline facilities by MMS is the reliance upon the industry to accurately and timely report the damages that have resulted from the hurricane passage. Equally as difficult for the pipeline operators is the ability to assess the damages and find all of the damages that have occurred, particularly for assets that are below the water surface, and report them to the MMS. Due to the nature of the 2005 hurricane season, operators had a very large area of pipelines to survey and inspect within the specified timeframes established by MMS. Several time extensions were granted as a result of the magnitude of the damages, both to the offshore structures, and the onshore services competing for the same services to restore the Gulf Coast Regions impacted by Hurricanes Katrina and Rita.

Updating of the initial findings from inspections was not reflected in all of the damage reports studied by DNV. Improvement of the quality and consistency of the initial damage reporting could significantly improve the overall data quality, in absence of receipt of updated reports of findings to initial damage assessments.

The primary use of the data that MMS receives is in the management of the permits, and it is not readily adaptable to research needs or quality. DNV would suggest that the simplest and most cost effective effort that could be undertaken to improve the usefulness of the data for use in assessment of the damage that has occurred on a collective basis is the use of consistent reporting tools, or forms, whether they are automated or written, to develop a consistent definition of the damages reported for future assessment of the damages, and trending over time. The cost of the manual assessment of the data is a significant portion of the investigation that must take place to perform even cursory analyses of the pipeline damages. Additionally, the multiple handling of data increases the possibility of inaccuracies, and reduces the efficient use of MMS skilled engineering personnel. Automated reporting could enhance this area of data management for pipeline damage reporting.

DNV developed visual tools and a pilot mapping application as part of the Ivan study scope that allowed improved assessment abilities through graphical representation of the storm hindcast data, water depth, damage reports, and hurricane path for use as overlays on the pipeline facilities maps.

The mapping application could assist in tracking rigs that have lost stationkeeping and provide notice to pipeline operators that should inspect potentially impacted structures through cooperation with the rig owner/operators by providing tracking coordinates if a rigs breaks mooring during a storm event. The mapping application includes a graphical interface that allows Internet based automated reporting that could be utilized in conjunction with the MMS eWell application, or as a stand alone interface to the MMS GIS database.

By mapping and overlaying the hurricane data, it is much easier to manage and analyze the data visually to make correlations, develop categorical hypotheses, and make initial assessments of the factors that influenced the pipeline damage. Much of the affects of the hurricanes are geospatially dependent, and these factors are not clearly represented in Excel type tables. Much of the historical analysis of pipeline damage caused by hurricanes has been largely statistical in nature, grouping the damage reports by pipeline attributes such as age, outer diameter, water depth, and failure causes. However, the conclusions have consistently resulted in the fact that there are no correlations to the factors that have been statistically compared in all of the studies that have been conducted to date.

For example, when mapping the damage data for the impacts of Hurricanes Katrina and Rita, it became clear that many of the damages reported did not mention Platforms destroyed or Outside Force as a cause, yet when mapped, the damages were clearly in areas of potential damage caused by anchor drags and other impacts from debris and structural failure of platforms.

The statistics available for analysis are only as accurate of the reported causes of the damages, and it appears that for Hurricanes Katrina and Rita, the damage attributed to platform damage and outside forces would be significantly under-reported if one relied solely upon the information provided in the pipeline damage reports. Table 3 provides a summary comparison of the reported damage categories for recent hurricane events that have had studies commissioned by MMS.

Table 3 Hurricane Pipeline Damage Summary

Hurricane	Year	Total Damage Reports	Platform Damage	Mudflow Damage	Riser Damage	Pipe & Displacement Damage	Outside Force Damage	Other and Unknown
Andrew	1992	485	253	10	103	44	18	57
Lili	2002	120	16	NR*	78	NR*	NR*	6
Ivan	2004	168	20	16	67	38	9	18
Katrina	2005	299	139	1	66	61	9	14
Rita	2005	243	94	0	89	31	8	21

* NR = Not Reported

While platforms were not in the scope of this study report, the damage statistics in Table 4 are provided for relative performance in the same hurricane events represented for the pipeline damages presented in Table 3. On the average, platforms have suffered a relatively constant 3% *destroyed* loss rate and a variable *damage* rate that averages to about 3.5%.

Table 4 Hurricane Platform Damage Summary

Hurricane	Year	Platforms Exposed to Hurricane Forces	Platforms Destroyed	Platforms Damaged	Percentage Exposed Platforms Destroyed	Percentage Exposed Platforms Damage
Andrew	1992	700	22	65	3.1%	9.3%
Lili	2002	800	2	17	¼%	2.1%
Ivan	2004	150	7	31	4.7%	20.1%
Katrina	2005	1000	47	20	4.7%	2%
Rita	2005	2050	66	32	3.3%	1.6%
Total		4700	144	165		---
Average		940	29	33	3.2%	3.5%

It is interesting to note that while the numbers of platforms destroyed and damaged are significantly higher than in past events, the percentage of structures exposed that were damaged is relatively constant. It should be noted that Hurricane Ivan passed to the east of the Mississippi River Delta region, and while it did not expose as many platforms to hurricane force winds, there was significant platform damage that resulted from mudslide activity in this area. Additionally, those storms that pass to the East of the Mississippi River Delta region also seem to present slightly different impacts to the oil and gas infrastructures. These differences will be discussed in the damage assessment narrative later in the report.

6.2 Data Quality and Damage Reporting Limitations

The pipeline damage data collected by MMS is submitted by pipeline operators or their authorized representatives in response to the instructions provided by MMS in Notice to Lessees and Operators and Pipeline ROW Holders (NTLs) that are issued after the passage of a hurricane. MMS receives damage report data in various formats, and there is not an industry standard reporting form or method that is prescribed other than the instructions that are found in the NTL. There are operators that are extremely careful and accurate in their reporting and provide excellent detail, and there are operators that do not submit reports at all. The range of data that is received, and the inconsistent manner of the reporting that occurs makes statistical analysis of the damage reports somewhat unreliable as a measure of the severity of the damages, and is really only a summary of the number and type of damage reports received.

The data is extracted from the damage reports that are submitted to MMS by Pipeline Section personnel who then manually enter it into the GIS database. The summary report provided to DNV was extracted by a database query of the MMS GIS and provided in an Excel spreadsheet by the MMS GOMR Pipeline Section.

The hurricane pipeline damage reports are categorized by the primary cause of "Natural Hazard," with secondary causes identified as "Storm/Hurricane" or "Mudflow" and the damage described in terms of type and location. The reports are often submitted much later than the actual damage has occurred. This is due to many factors, and is generally not an indication of poor performance. The delay in receiving the damage reports does present difficulties for timely use of the information contained within the reports by the GOMR Pipeline Section in characterizing the type of damage that has occurred, and to assist in recovery activities. The following Timeline in Figure 19 represents the 2005 hurricane season pipeline damage report receipt experience.

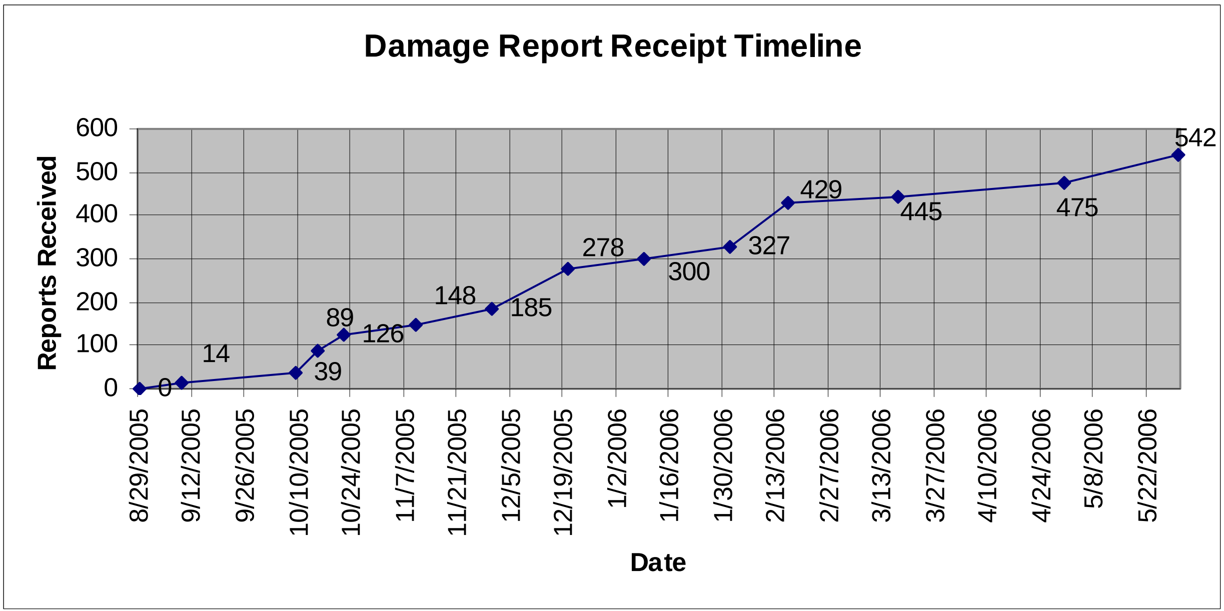


Figure 19 – Damage Report Receipt Timeline

Historical difficulty in the hurricane pipeline damage assessment review is that root causes of the failures are indeterminate due to limited or incomplete reporting or data availability. The Hurricane Katrina and Rita damage reports were even less specific and missing data or information, often with no description other than "Leak Test Failed". While this is not a criticism of the actions taken as part of the recovery after the serious impacts created by Hurricanes Katrina and Rita, it is a limitation in the usefulness of the data for MMS' use, and the research carried out after the hurricanes have passed. The uncertainties of the data were previously characterized by Southwest Research Institute as *random variables* and *random processes*. The volume of damages reported in 2005, and the significant impacts to both industry and the MMS have contributed to incomplete data which is now another limitation in the data quality. Thus, all characterization of damage should be viewed as categorical, only, and not as having been formally determined by scientific root cause methodologies for the purposes of the discussions in this study report.

7 STUDY APPROACH

The study approach undertaken by DNV followed these steps:

1) Data Analysis
    - Collect impact data from various research activities and sources
    - Participate in industry workshops related to hurricanes
    - Obtain pipeline damage reports from MMS
    - Coordinate with other MMS TAR research projects to collect data on platforms and metaocean data
    - Develop reference library of Hurricanes Katrina and Rita technical reports and study findings

2) Damage Analysis and Mapping
    - Identify commonalities or exceptions in past hurricane experiences with Katrina and Rita experiences
    - Categorize damages by primary failure descriptions
    - Map pipeline damage and relate to metaocean data
    - Identify commonalities or exceptions in damage experiences by pipeline

3) Create a Study Set of Pipeline Damage Reports
    - Identify a subset of pipeline damages that are not clearly tied to platform, riser or identified outside force damage and study the data set to understand the damage causes that initiated pipeline failures
    - "Hypothesize" the root causes of failures for pipeline damages that were not associated with mudflows, risers, or platform failure to identify pure pipeline failure modes through closer scrutiny to company and MMS data sources other than the MMS Excel spreadsheet
    - Map the Study Set of pipeline damages as characterized and look for any patterns or similarities in the nature of the pipeline damage
    - Identify commonalities or exceptions in damage experiences by pipeline

4) Summarize findings and develop study recommendations

7.1 Damage Analysis

DNV conducted analyses of the MMS pipeline damage spreadsheet summaries for the two events, including available operator damage reports, and interviewed pipeline operators for additional data needed to conduct the damage analyses. The damage analysis was the first step for determination of possible root causes of the pipeline failures that occurred in Hurricanes Katrina and Rita. Categorization of failures was carried out in various formats to identify commonalities or anomalies in the types of failure events that occurred.

7.1.1 Damage Statistics for All Reported Damages

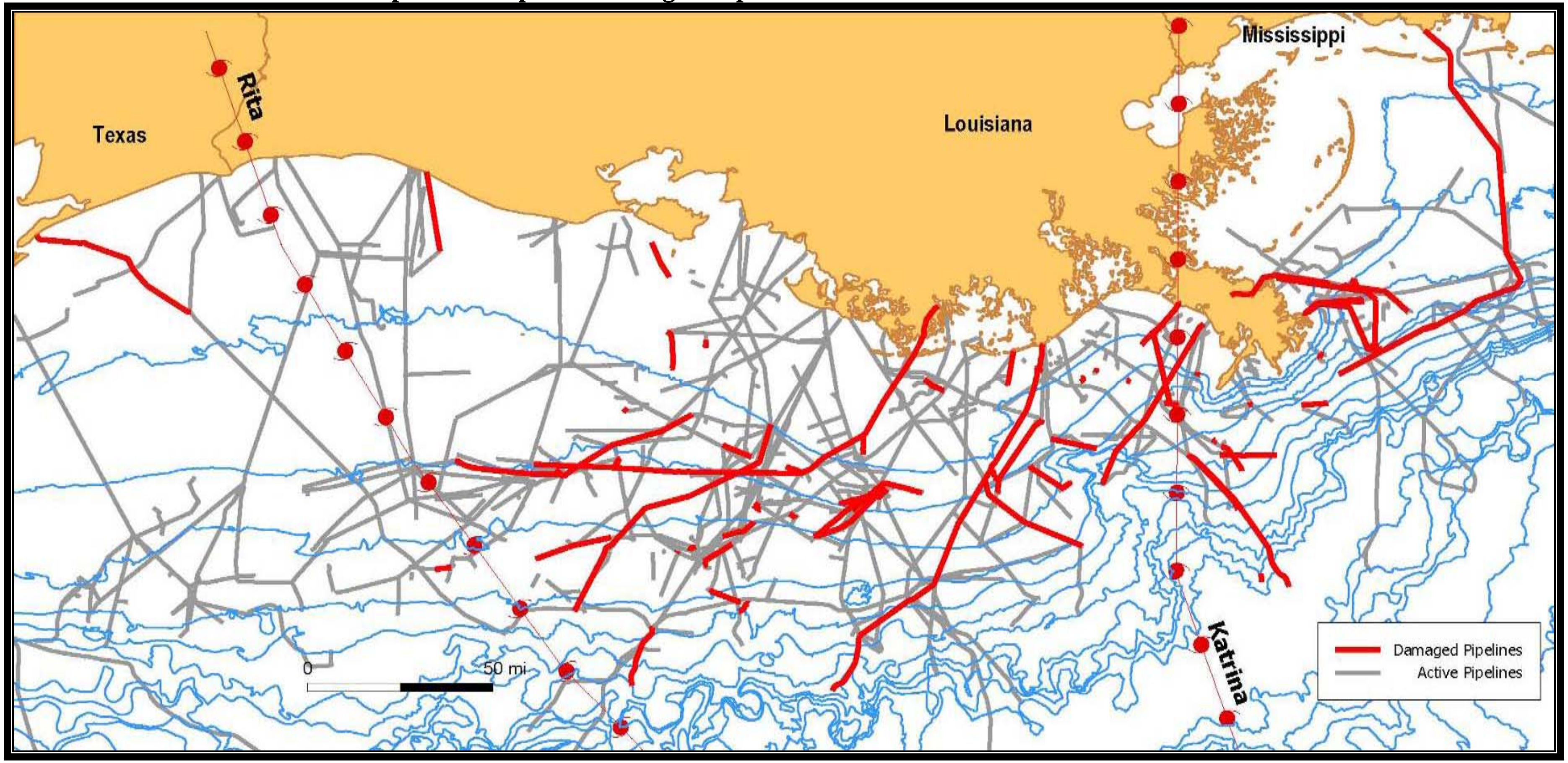
MMS GOMR identified 543 pipeline damage reports that were described with varying degrees of detail in the Excel spreadsheet provided by the GOMR Pipeline Section. Some damages were identified by the MMS as having been reported through media damage reports. Upon further analysis, duplicates and prior hurricane reports adjusted the total damages reported to 542 unique reports resulting from Hurricanes Katrina and Rita to be analyzed by DNV. The pipeline damages were categorized in the spreadsheet by MMS as Primary Cause: *Natural Hazard*, Secondary Cause: *Storm/Hurricane* and the description of the *Damage* which were broken down into categorical descriptions of the damages as represented by Figures 20 through 22.

The primary reason for the data fields in the MMS spreadsheet, as described above, is to have the ability to retrieve the data as a group and distinguish the hurricane damage reports from the other damage reports that are contained within the GIS database that are not hurricane related. Inconsistencies in reporting practices were identified during the course of this study. While some companies provided excellent reports with adequate detail of the type, location and cause of damage for each segment, other reports were vague, and contained multiple damages, locations or causes. Comparing company statements of the number of pipeline damages experienced with the number of reports filed by two different companies indicated a wide disparity between the various companies reporting practices. Some companies' statistics had almost a one to one correlation of number of reports to number of damages, while others had anywhere from a five to one to twenty to one ratio of damages experienced to reports filed by the operator due to multiple segments and damages covered by one report. This further distorts the statistical accuracy of the number of reports in correlating the number of pipelines damaged. Merely counting damage reports does not provide an accurate reflection of the number of segments or pipelines damaged. DNV refers to "reported damages" or "reported pipeline damages" in this report due to the inability to distinguish between actual pipelines, risers and segments in the overall counts.

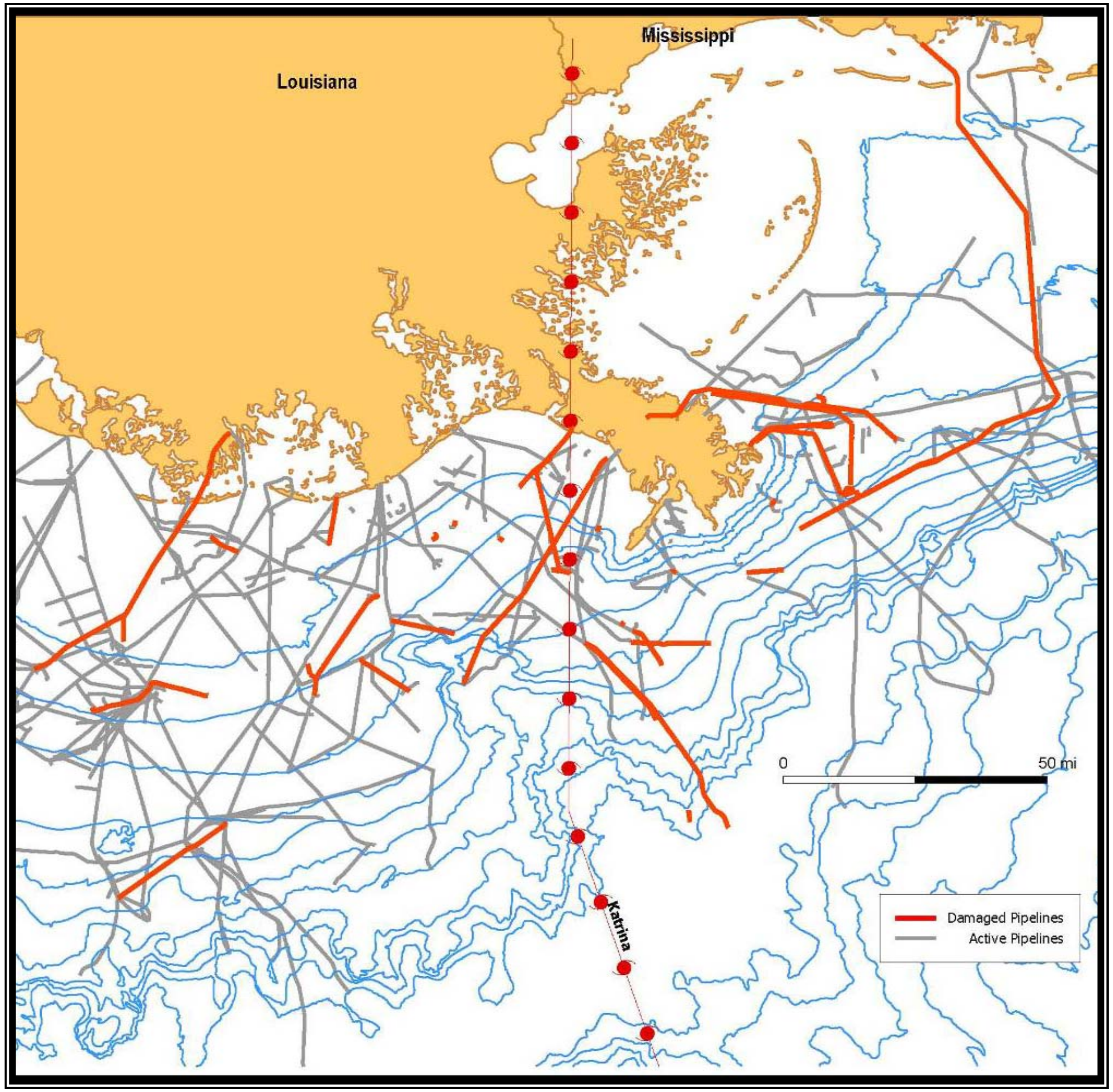
Additionally, 378, or roughly 70% of the pipeline damage reports are at risers, which are not included in the pipeline segments or mileage in the GOMR GIS database pipeline mileage. By MMS definition, the pipeline segment lengths are the lengths of pipe on the seafloor and do not include risers or platform piping.

Improvements focused on the riser/platform interface zone performance requires a cooperative approach between the pipeline and structures subdivisions in industry activities, as well as regulatory organizations so that the sharing of the knowledge and damage experiences can cross the Pipeline – Platform organizational boundaries, in an effort to reduce the overall damage experience at the riser locations.

Map 1 – All Pipeline Damages Reported for Hurricanes Katrina and Rita



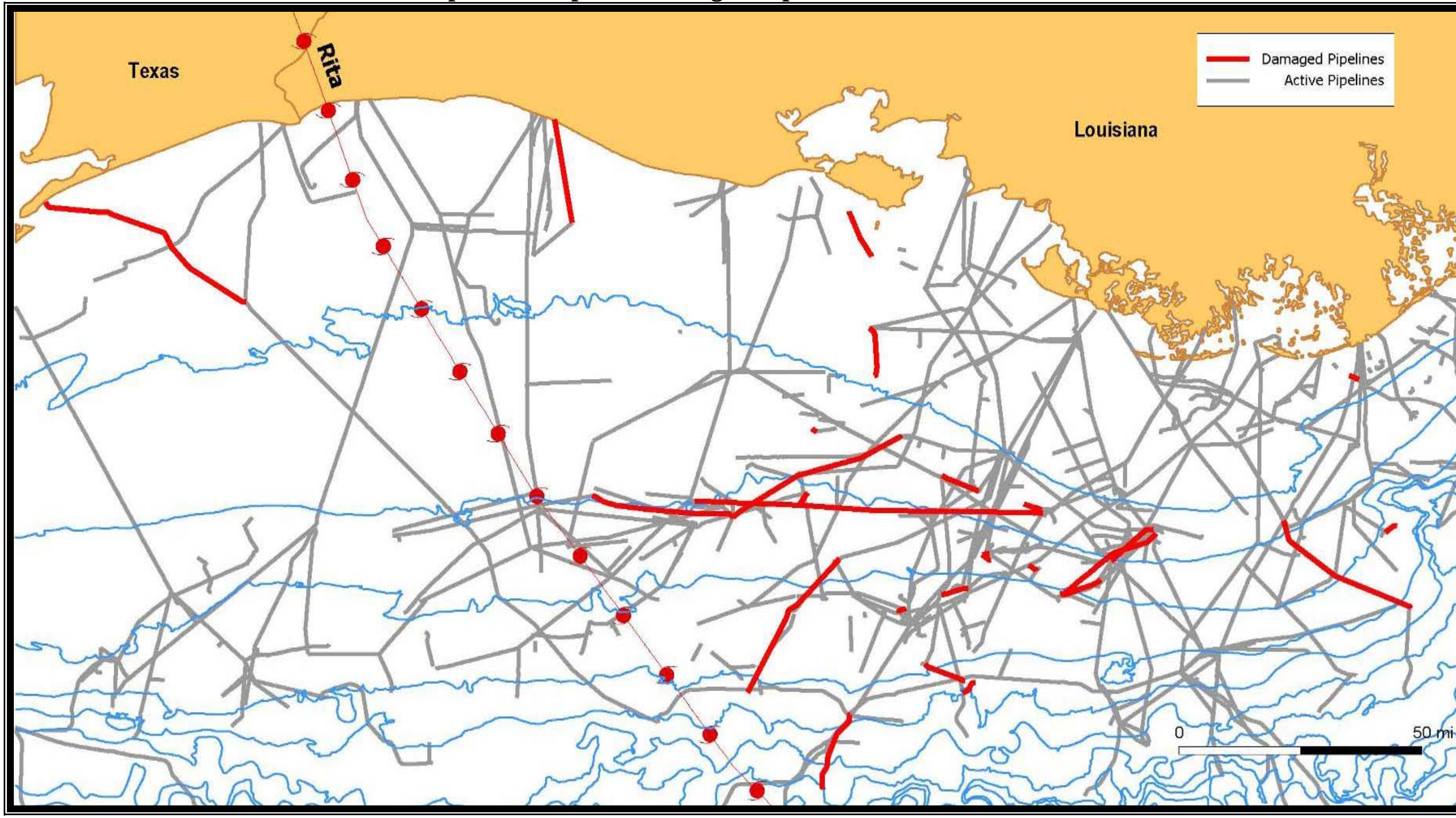
All pipeline damages reported for both Hurricanes Katrina and Rita are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in red and the undamaged active pipeline network is shown in gray. This map represents 542 damage reports; 299 reports for Hurricane Katrina and 243 for Hurricane Rita.



Map 2 – All Pipeline Damages Reported for Hurricane Katrina

All pipeline damages reported from Hurricane Katrina are mapped over the hurricane route and seafloor contours. Damaged pipelines are in red and the undamaged active pipeline network is shown in gray. This map represents the geographical extent of the 299 damage reports for Hurricane Katrina.

Map 3 – All Pipeline Damages Reported for Hurricane Rita



All pipeline damages reported for Hurricane Rita are mapped over the hurricane route and seafloor contours. Damaged pipelines are in red and the undamaged active pipeline network is shown in gray. This map represents the geographical extent of the 243 damage reports for Hurricane Rita.

7.1.2 Damage Distribution by Type of Damage

The damage reports are categorized in the MMS Excel spreadsheet by the type of damage to the line, in the column DAMAGE as listed in the key for the figures that follow. This first distribution chart covers the total damage experienced in both events and then each event is shown individually in the following charts in Figures 20 through 22, and data in Table 5.

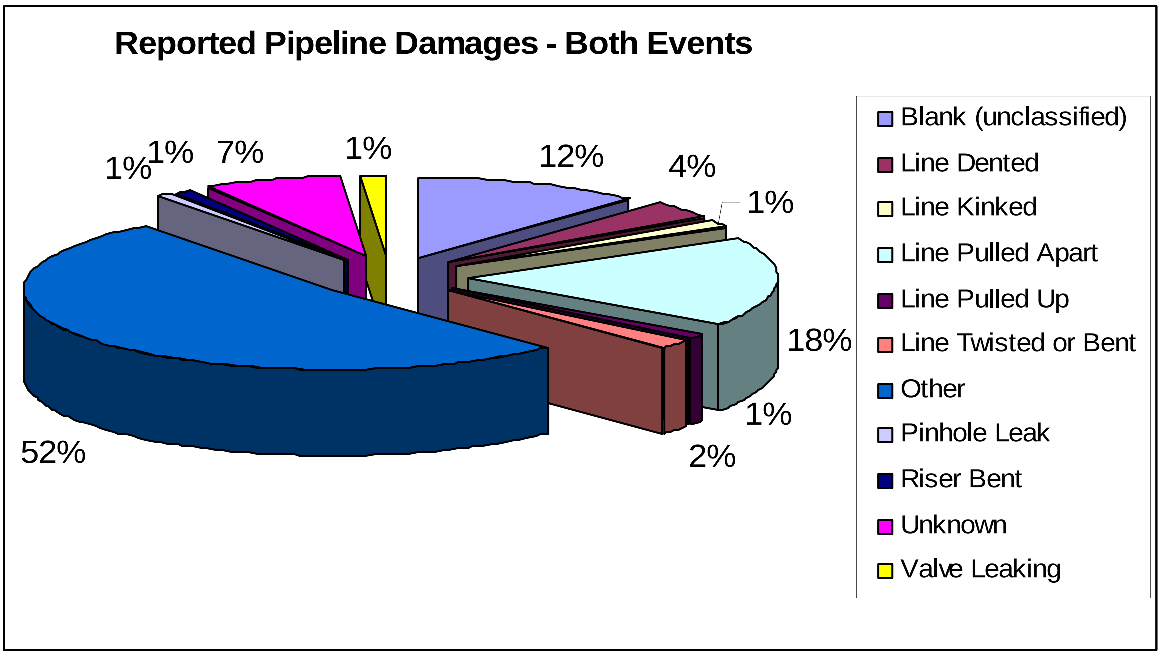


Figure 20 - Breakdown of all damage to the pipelines and risers reported due to both Hurricanes Katrina and Rita

Damage		By Hurricane Event	
Damage Category	Total	Katrina	Rita
Blank (unclassified)	64	46	18
Line Dented	21	7	14
Line Kinked	7	6	1
Line Pulled Apart	97	62	35
Line Pulled Up	6	2	4
Line Twisted or Bent	10	2	8
Other	281	148	133
Pinhole Leak	5	2	3
Riser Bent	5	2	3
Unknown	39	17	22
Valve Leaking	7	5	2
Grand Total	542	299	243

Table 5 – Total Damage Reports Categorized by Reported Damage Category

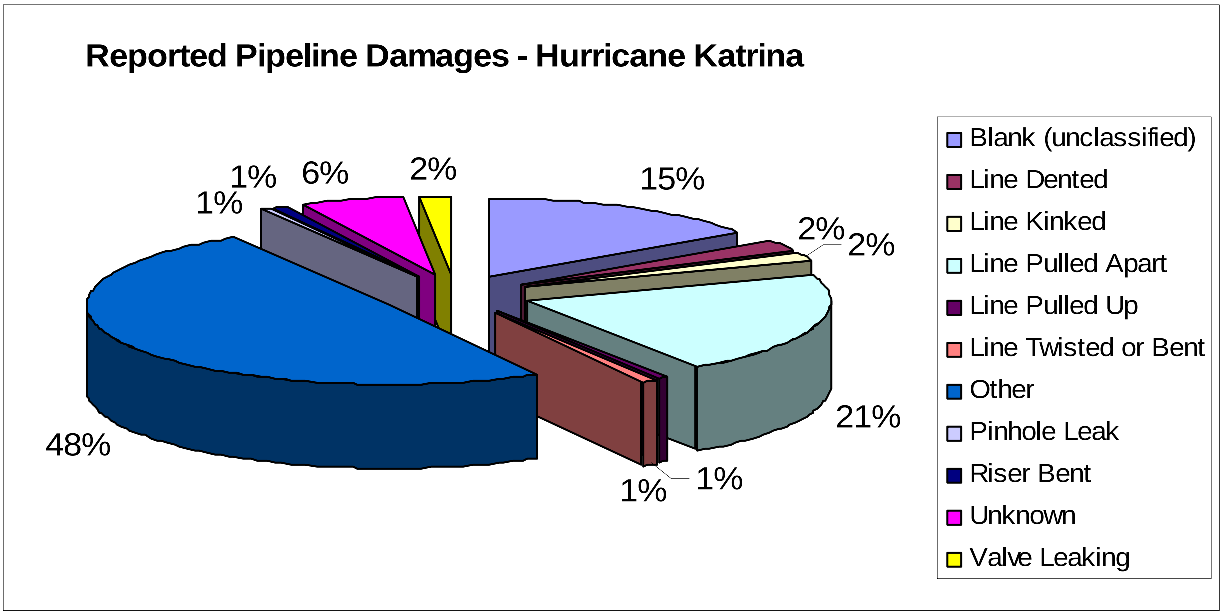


Figure 21 - Breakdown of all reported damage to pipelines and risers - Hurricane Katrina

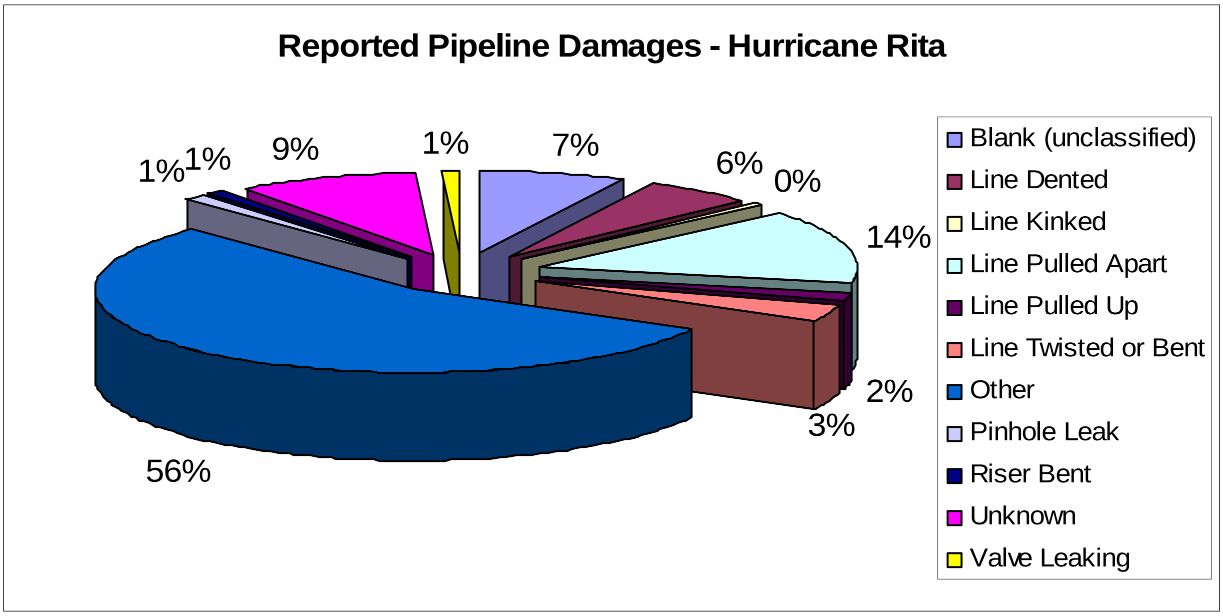


Figure 22 - Breakdown of all reported damage to pipelines and risers - Hurricane Rita

7.1.3 Damage Distribution by Location of Damages

The reported damages are further described in the MMS Excel spreadsheet by the location of the damage, falling into one of the following six groups:

Damage Location		By Hurricane Event	
Location	Total	Katrina	Rita
Both Risers	28	21	7
Departing Riser	212	106	106
Receiving Riser	138	68	70
Submerged Pipe	112	76	36
Subsea Tie-In	18	11	7
Unclassified	34	17	17
Grand Total	542	299	243

Table 6 – Total Damage Reports Categorized by Damage Location

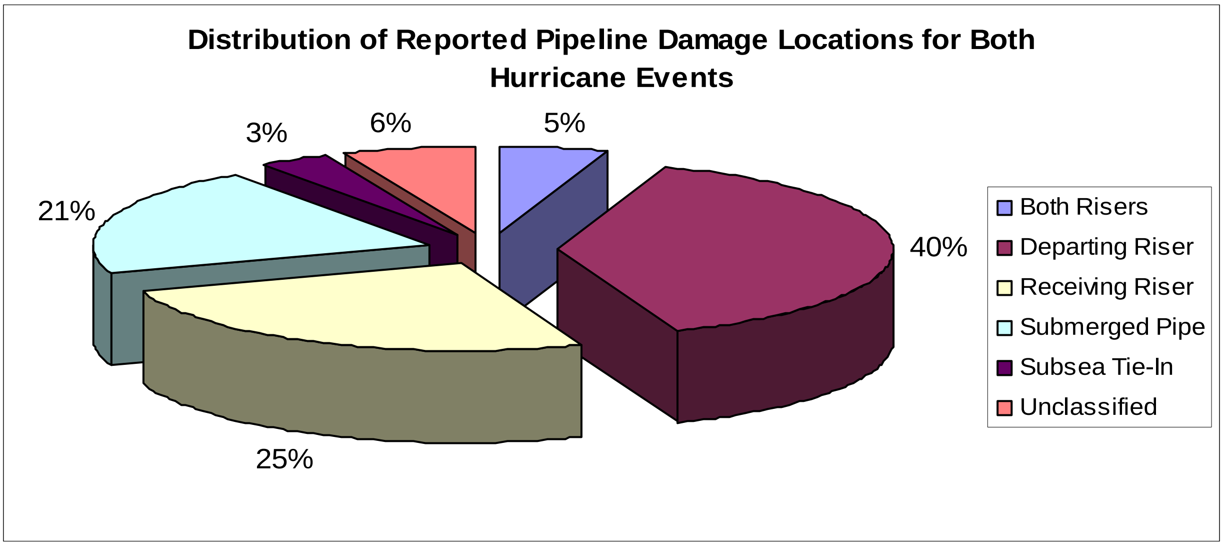


Figure 23a - Distribution of Damages Reported by Location of Damage

Figure 23a shows that Risers (Departing, Receiving and Both) made up roughly 70% of the reported damages when grouped by the Damage Location category. Almost two thirds of the damages to risers were at the departing riser. The next largest category by Damage Location category was Submerged Pipe with 25% of the damages, and roughly 3% were at Subsea Tie-ins. The remaining 6% of the damages were Unclassified and the location of the damage was not stated in the Excel spreadsheet.

The distribution of the reported Damage Location categories was similar for the two events as shown in Figure 23b, except for Submerged Pipe. The Hurricane Katrina damage reports had roughly two times the number of reported damages for the locations of Submerged Pipe in comparison to Hurricane Rita. This is consistent with the type of damages experienced in the two events where there were more crossings and pipelines that were damaged or displaced in the Katrina event than the Rita event. This is shown more clearly in the mapping of the pipeline damages, later in the report.

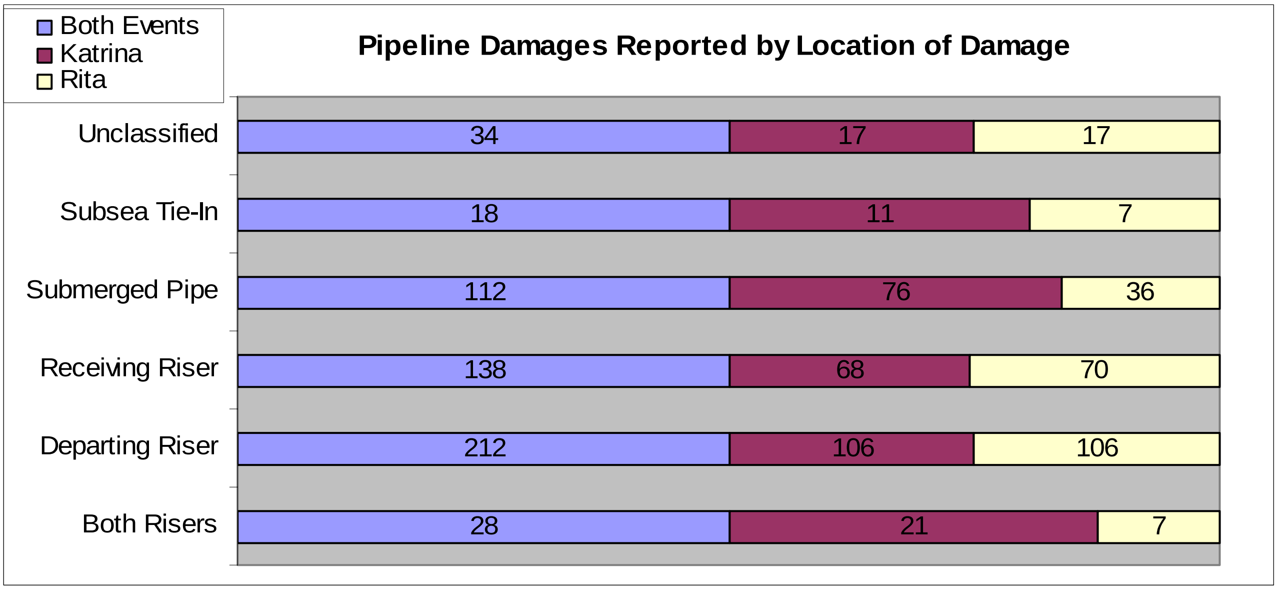


Figure 23b - Distribution of Damages Reported by Location for Total Damages Reported and as Categorized by each Hurricane Event

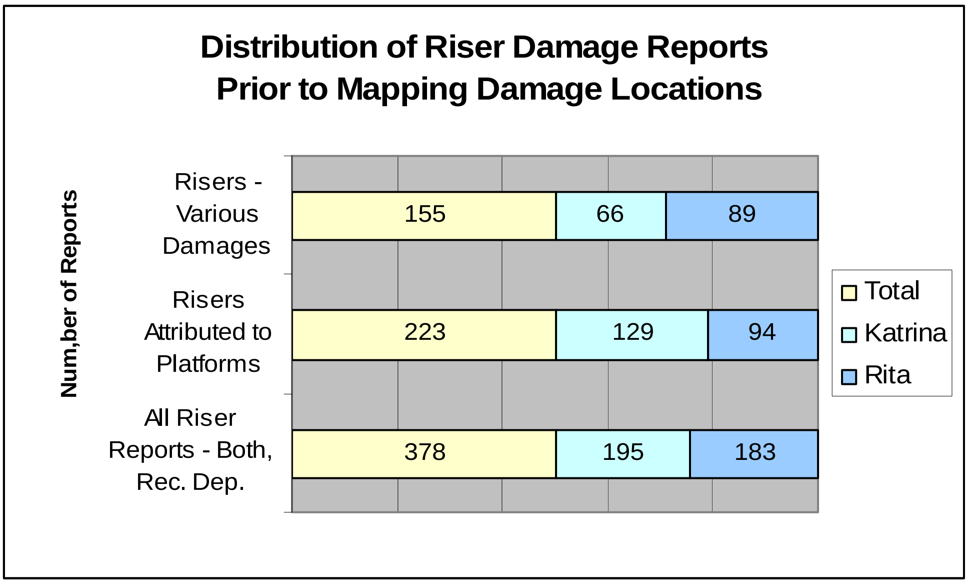


Figure 23c - Distribution of Damage Location Reported to Risers, and Assignment of Damage Category Prior to Mapping Analysis (Damage Reports Only)

7.1.4 Damage Distribution by Product Code

DNV looked at the distribution of damage reports by the type of product carried as designated by the Product Code in the summary Excel spreadsheet. The Product Code is a two to four letter designation that enables the reader to determine the type of line and product carried within it. The types of Product Codes and the corresponding definition for the damage reports from Hurricanes Katrina and Rita are listed in the following table.

Product Code	Product Code Definition	Number of Reports
AIR	Pneumatic	4
BLGH	Bulk gas with trace levels of hydrogen sulfide	2
BLKG	Bulk gas – full well stream production from gas well(s) prior to first processing	98
BLKO	Bulk oil – full well stream production from oil well(s) prior to first processing	100
CHEM	Corrosion inhibitor or other chemicals	2
COND	Condensate or distillate transported downstream of first processing	1
FLG	Flare gas	9
G/C	Gas and condensate service after first processing	21
G/O	Gas and oil service after first processing	18
GAS	Gas transported after first processing	110
GASH	Processed gas with trace levels of hydrogen sulfide	4
INJ	Gas injection	1
LIFT	Gas lift	72
NGER	Natural gas enhanced recovery	1
O/W	Oil and water transported after first processing	5
OIL	Oil transported after first processing	79
SPLY	Supply Gas	9
TEST	Test	1
UMB	Umbilical line, usually includes pneumatic or hydraulic control lines	4
UNKNOWN	Field left blank in Excel spreadsheet	1

Table 7 – List of Product Code Definitions and Damage Reports by Product Code

The same data is presented in the following chart. The majority of the damage reports were for the categories of bulk oil and gas, evenly distributed, and oil and gas transportation pipelines, slightly more damage to gas than oil, and gas lift lines. These five categories made up roughly 85% of the reported damages. The only anomaly identified relative to the product type is discussed later with regard to displaced pipelines, which were all Product Category GAS. The product category distribution is shown in Figure 24.

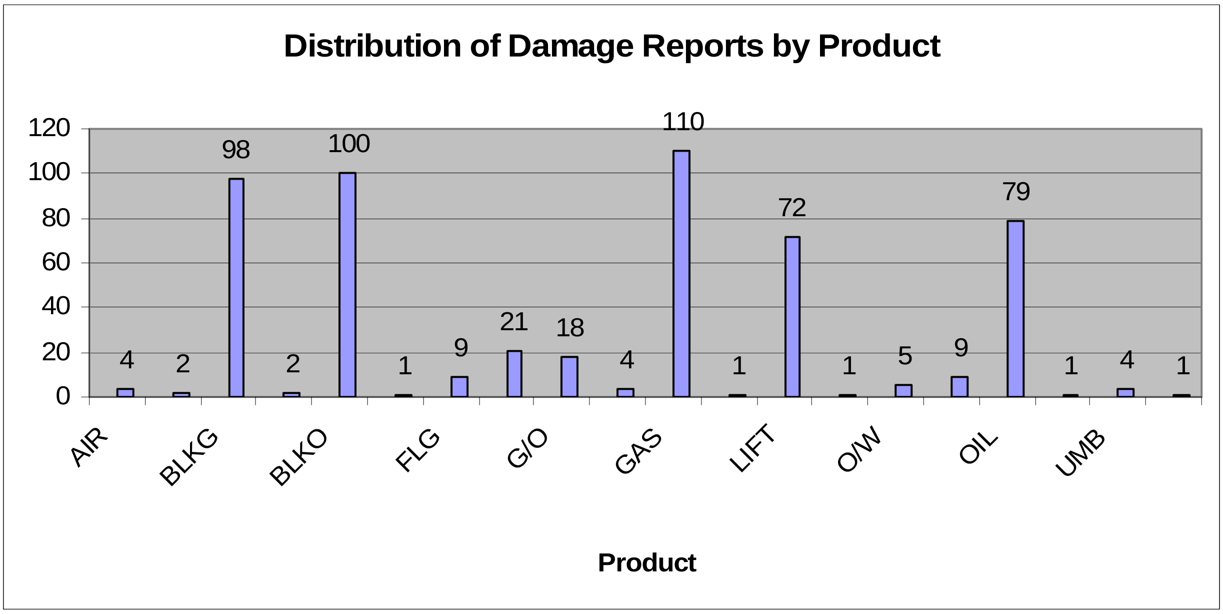


Figure 24 - Distribution of Damages Reported by Product Code

7.1.5 Damage Distribution by Pipeline Age

The damage reports were sorted by age. No correlation was found as a result of the age of the pipelines that had damages reported as a result of Hurricanes Katrina and Rita. The majority of the risers do not have an age associated with them which explains most of the 140 damage reports that had no information in the AGE data field in the Excel spreadsheet provided by the GOMR. For the 402 damage reports that did have age information, roughly 30% were 10 years old or less, when combined with the pipelines 20 years old or less, this percentage increased to roughly 53% of the damage reports. The pipelines that were more than 30 years old represented approximately one quarter of the 402 damages reported that had ages in the database.

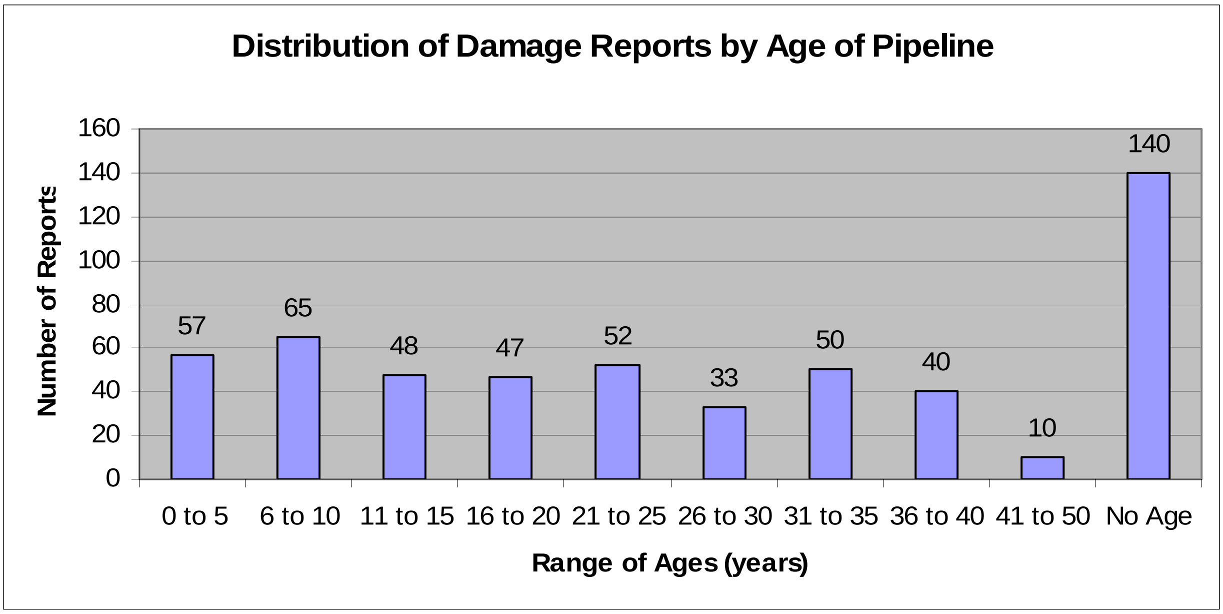


Figure 25 - Distribution of Damage Reports by Pipeline Age

The findings of this study are consistent with the findings of previous historical studies that have concluded that there is no apparent correlation of age to damage reports from hurricane events. However, without having a breakdown of percentage of the pipelines by age to provide a unitized percentage, it is difficult to represent this conclusion as anything other than the percentage of damages reported, and not as indicative of the entire pipeline population.

7.1.6 Damage Distribution by Pipeline Diameter

The pipelines and risers were further studied by their diameter. As has been found in historical hurricane studies, the majority of the pipeline and riser damage occurs in pipeline diameters that are less than 8 inches. However, as with pipeline age, this is again a percentage of the reported damages, and not for the entire pipeline population in the GOM OCS. With the majority of the damage reports attributed to risers, this would be consistent for riser sizes.

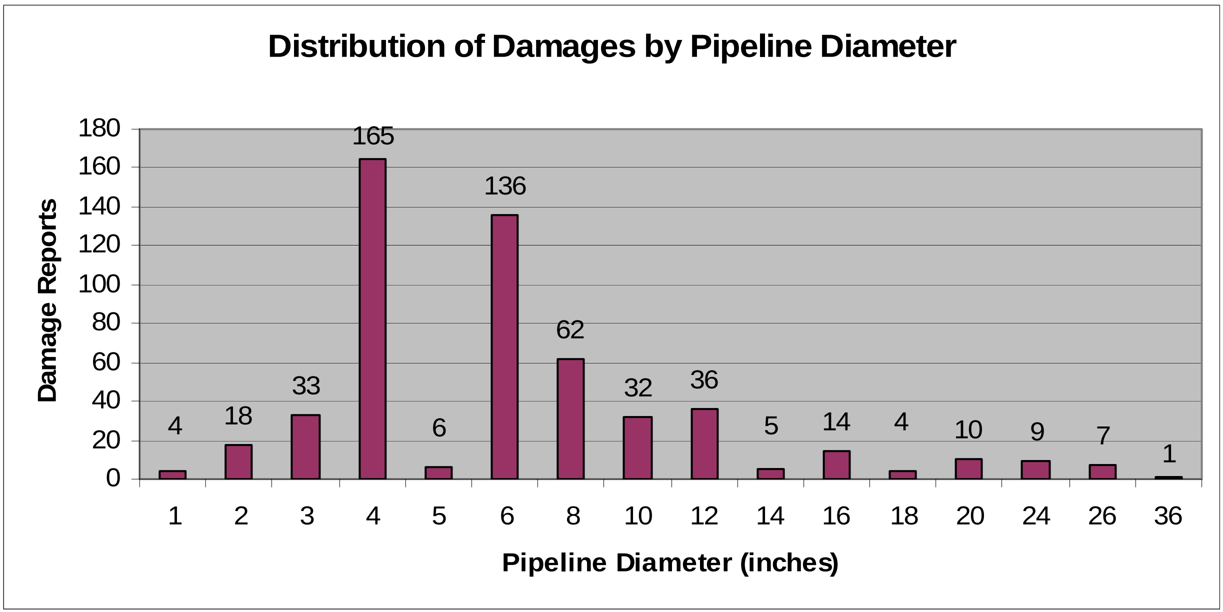


Figure 26 – Distribution of Damages by Pipeline Diameter

7.2 DNV Categorization of the Damage Reports

The categories of pipeline damages and locations represented above did not serve as an useful method for categorization of damage necessary to perform causal analyses. With this in mind, DNV evaluated the damage information spreadsheets provided by MMS and assigned the damages into one of the six categories that were selected by DNV to enable the selection for further study of pipeline related failures that were not attributable to platform and riser damage or clearly identifiable outside force. The categories selected by DNV are as follows:

- Platforms
- Risers
- Outside Force
- Subsea Tie-In
- Unknown-Other
- Submerged Pipe

DNV then created a subset of the reported damages from the three groups of Submerged Pipe, Subsea Tie-in, and Unknown–Other for further study of these segments. DNV examined the available information and data to attempt to assign hypothetical root causes and determine the location for the subset of the reported damages prior to mapping the damages.

The distribution of the total data, and statistics related to the DNV categorization of the full set of damage reports follows.

		By Hurricane Event	
Damage Category	Total	Katrina	Rita
Platforms	233	141	92
Risers	155	63	92
Submerged Pipe	92	61	31
Unknown-Other	29	14	15
Subsea Tie-In	16	11	5
Outside (OS) Force	17	9	8
Grand Total	542	299	243

Table 8 – Damage Categories Assigned by DNV for Total Damages Reported

The highest incidence of failure, or 43% of all reported damages, was related to platform damage or failure. Roughly 28% of the total damages reported were riser damage not *reported* as attributable to a platform being damaged or destroyed, 17% of the damage reports were associated with submerged pipe, roughly 6% were described as unknown or other, 3% resulted from outside force, and the remaining 3% were related to subsea tie-in damage.

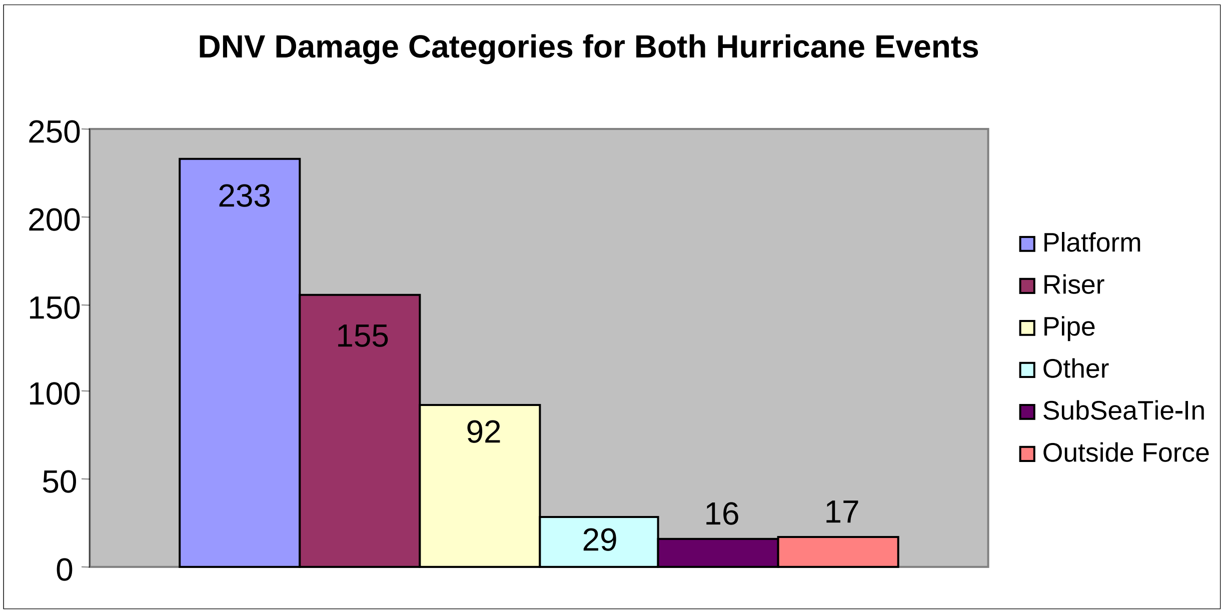


Figure 27 – DNV Categorized Pipeline Damage Reports

The category called Platform is a group of damage reports that clearly identified damaged or destroyed platforms as the cause of the damage or as a contributing factor. This set includes risers that are associated with platforms that were destroyed or damaged.

The category titled Risers includes damage reports for risers that were not reported as having been associated with a damaged or destroyed platform. This group of damage reports will be reviewed for statistical purposes and identification of any commonalities of the damage locations or contributing factors.

The category titled Submerged Pipe includes many different types of damages from pipeline movement to crossings, to ruptures, dents, kinks and other forms of mechanical damage that was not clearly identified as to the cause of the damage. This set forms the majority of the damage reports selected for additional study and assessment.

The category titled Outside Force contains damage reports that were all a result of anchor drags except one report that stated the damage was as a result of a mudslide. This group of damages had clear causes identified and were not studied further in the DNV subset of damage reports.

The category titled Subsea Tie-in includes damages attributed to the location of subsea tie-ins, but had little other information. Mapping of these damages is intended to help identify any common failure mode factors and increase the understanding about these reported damages.

7.2.1 Platform Damage and Failures

Figure 28 - Source: MMS GOMR Presentation

Platforms are being studied by others to assess the adequacy of current design practices. Any recommendations should be incorporated into pipeline-riser-structural interface design practices. The performance of the pipelines after failure, and the minimal release of hydrocarbons indicate that the offshore industry operations and planning efforts in advance of hurricanes are by and large meeting the expectations of the environmental protection goals of the MMS.

The MMS data shown to the left provides a summary of the damages as of October 4, 2005, immediately after Hurricane Rita. While the numbers were very high, the percentage of failed platforms was typical of significant storm events previously studied as discussed earlier in this report. The details of the Platform pipeline damages are mapped on Map 4.

However, the largest category of pipeline damage reports of the 542 reports studied were directly related to downed or destroyed platforms. Of the total reports received by GOMR, 233 of the reports could be directly associated with destroyed platforms. Another 155 reports were for risers that were damaged, but did not clearly indicate whether or not a platform was associated with the riser damage that was being reported. Combined, these two categories represent more than 71 % of the pipeline damages reported as a result of both hurricanes.

7.2.2 Riser Damage

The 378 pipeline damages reported as being at risers were analyzed. The riser damages resulting from identified platforms failing or identified outside force were taken out, leaving 155 riser damage reports, of which 90 were a result of Hurricane Rita and the remaining 65 were associated with Hurricane Katrina. The 155 riser damages not attributed to platforms were grouped by hurricane event, product, and location of riser damage as tabulated in the following tables.

Riser Damages		Riser Damages – By Event	
Damage Location	Total	Katrina	Rita
Above Waterline (Wave Action)	53	23	30
Below Waterline (Near Surface)	37	8	29
Unidentified (No Location)	37	11	26
Near Mudline (Bottom Conditions)	12	7	5
At Clamp (failed)	9	9	0
Leak/Failed Test	8	8	0
Total	155	65	90

Table 9a – Riser Damage Locations

Riser Damages		Riser Damages – By Event	
Product Code	Total	Katrina	Rita
BLKG	40	18	22
BLKO	25	12	13
COND	16	7	9
GAS	24	11	13
LIFT	28	9	19
OIL	18	7	11
SPLY	4	1	3
Total	155	65	90

Table 9b – Riser Damage by Product Code

Damage Location	Both Events	Katrina	Rita
Receiving Riser	50	20	30
Departing Riser	98	44	54
Both Risers	7	1	6
Total	**155**	**65**	**90**

Table 9c – Riser Damage by Type

The largest category of riser damage for reports not related to platform damage was due to pulled risers. It is unclear from the damage reports if the platforms associates with these pulled risers were damaged. Riser damage reports were only placed in the Platform category when it could be confirmed that the platform had toppled or was destroyed, or it was otherwise stated in the damage report. However, pulled risers infer outside force such as that from anchor drags or a falling platform, and would indicate that this is not practical to address with revisions to design codes for risers, and should be addressed through management of practices related to platforms and rigs.

Interviews conducted as part of this study have indicated that this is one area where maintenance may play an important role in the reduction of pipeline damage reports. However, without maintenance records and detailed damage information for the risers, it is not possible to develop meaningful conclusions or offer recommendations, other than to note the observation provided to DNV about riser maintenance. This is also consistent with findings and recommendations of the Hurricane Lili pipeline damage study.

The recommendations that are developed as part of the platform failure studies should be evaluated for possible incorporation in platform riser design for structures above the waterline, or damage prevention. The details of these damage reports are found on Map 5.

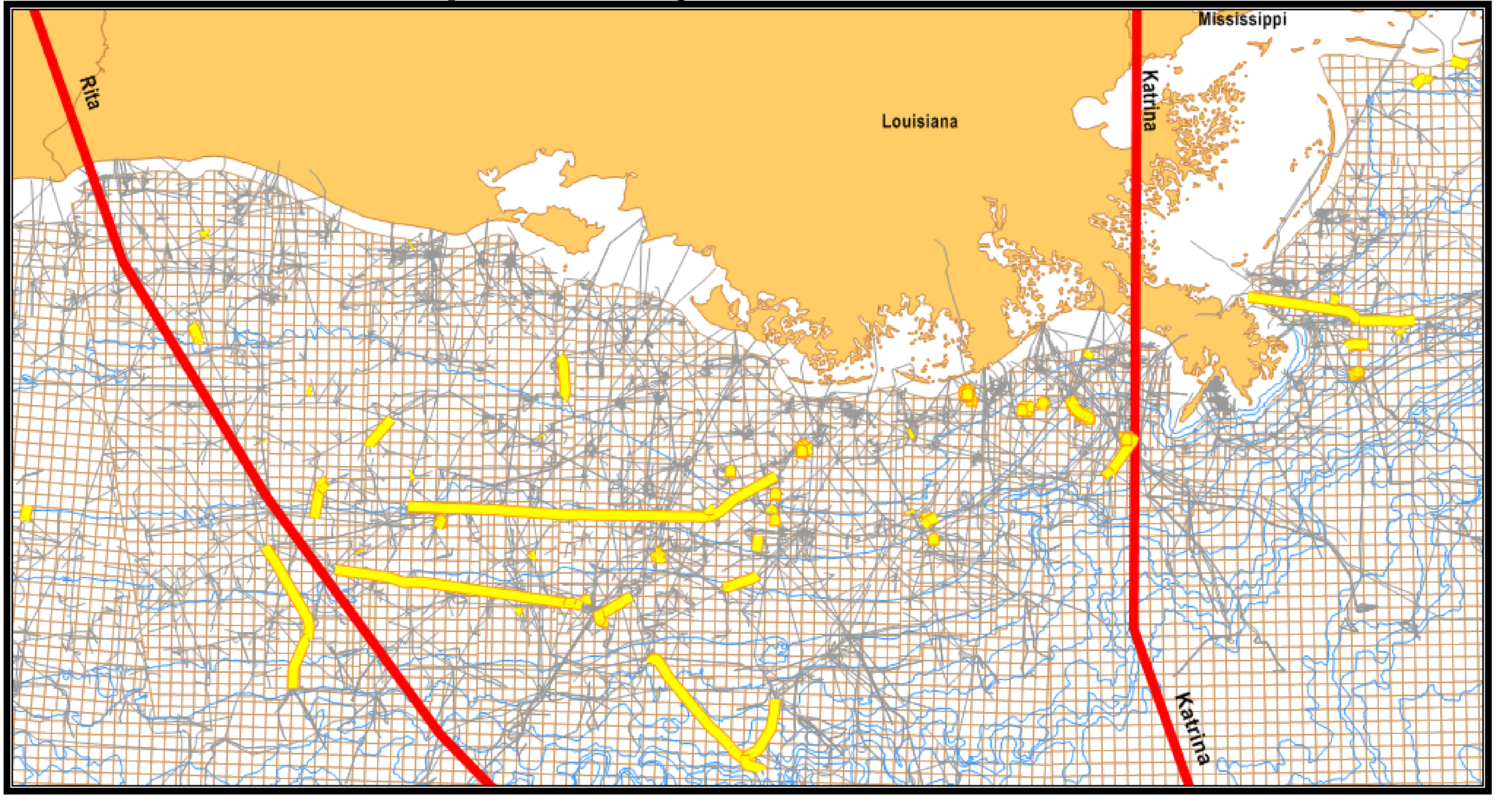
7.2.3 Outside Forces

Damage reports that were not attributable to platforms or riser failures, and had clearly identified causes of damage such as anchor drags and mudslides were included in this category.

The primary protection method to reduce outside force damages is through the management of the structures applying the forces, such as MODUs dragging anchors, platforms falling onto the pipelines, or other debris that impacts the pipelines. In some of the damages studied, barriers could have reduced damage to pipelines and consideration of these risk control strategies are typically a part of a threat assessment performed in design.

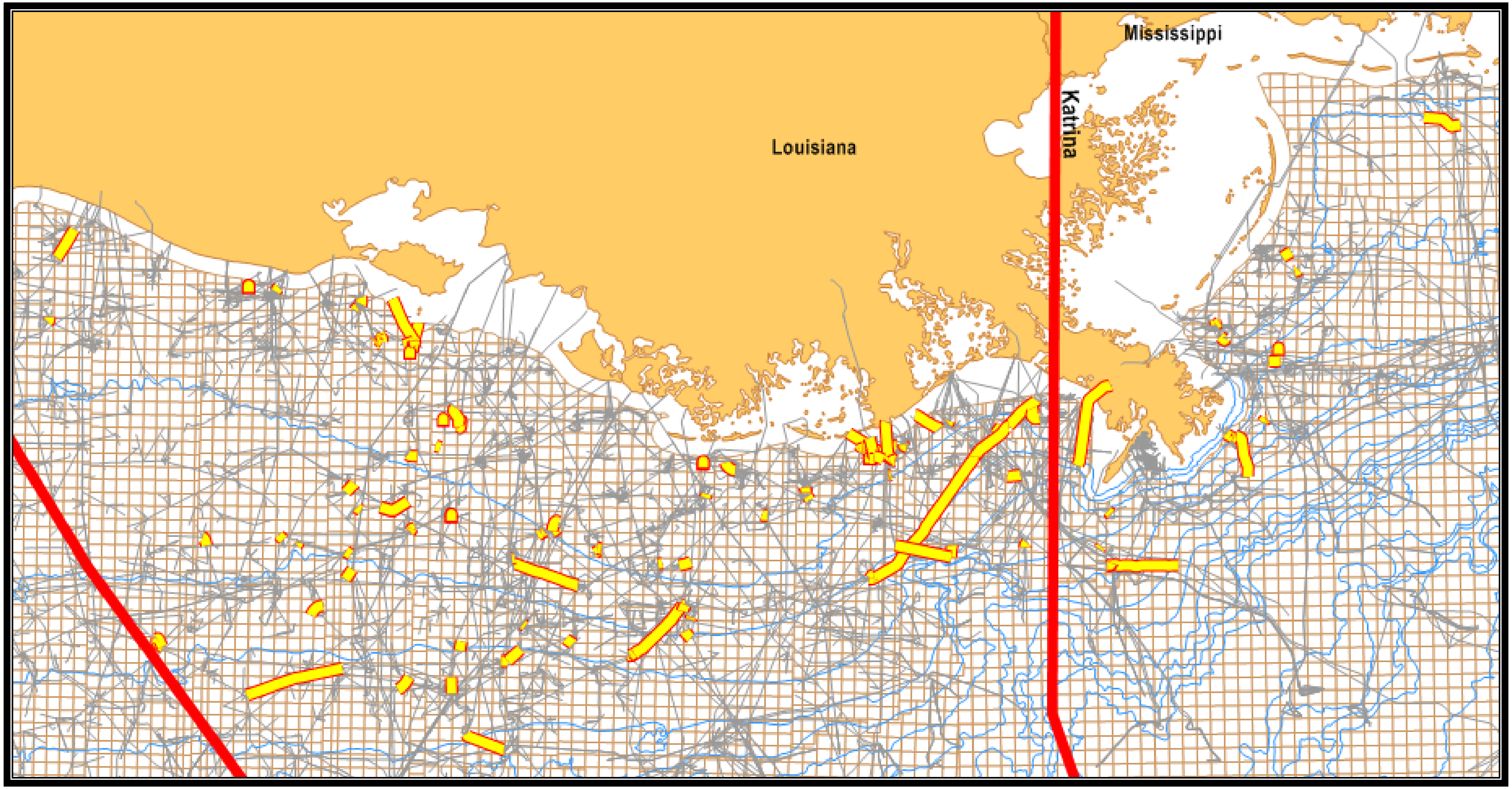
Coatings, mats, burial, crossing design and other barrier methods where practical should continue to be considered in the design, or installation of new crossings, particularly in shallow water, or areas of active production and congested structures. The details of these damage reports are found on Map 9.

Map 4 – Platform Damages for Hurricanes Katrina and Rita



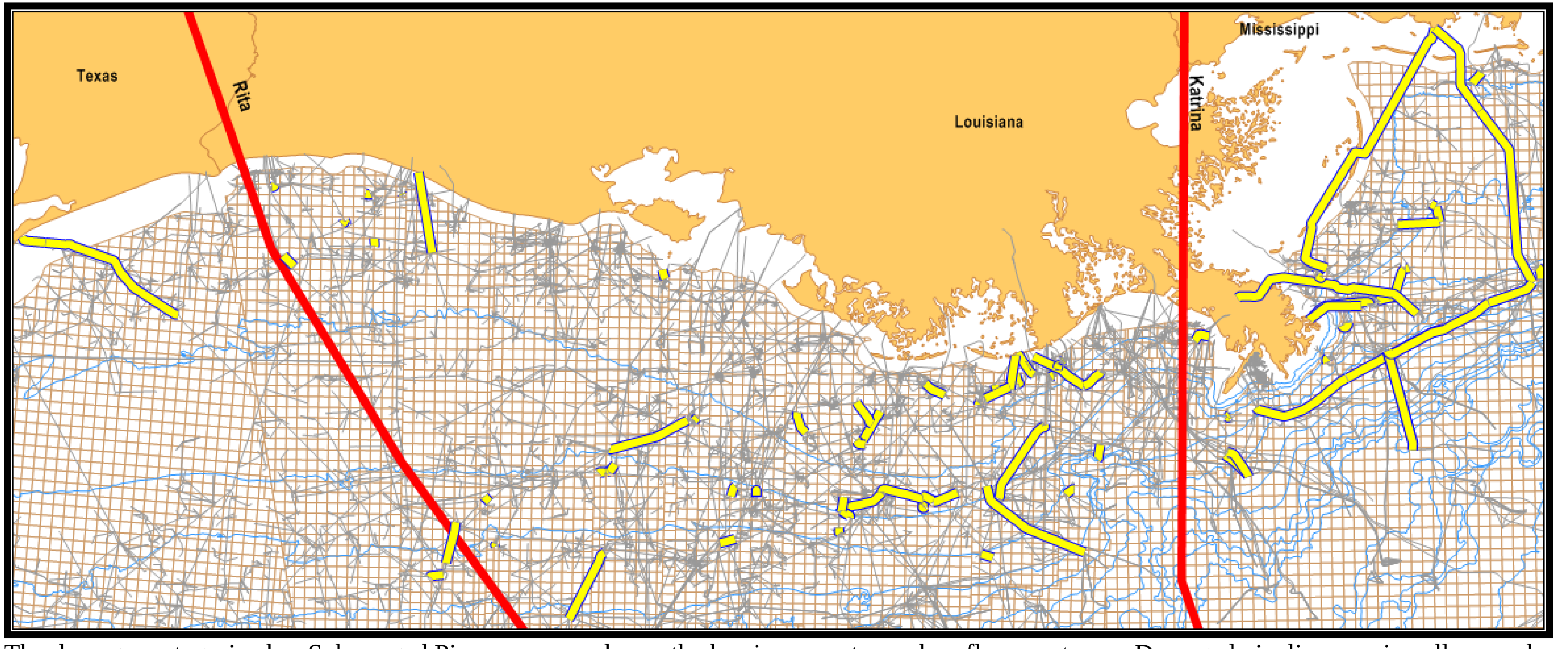
The pipeline damages categorized as Platform are mapped over the hurricane routes and seafloor contours. Damaged pipelines are yellow, and the undamaged pipeline network is shown in gray. This map represents 233 damage reports; 141 reports for Hurricane Katrina and 92 for Hurricane Rita.

Map 5 – Riser Damages for Hurricanes Katrina and Rita



The pipeline damages categorized as Riser are mapped over the hurricane routes and seafloor contours. Damaged pipelines are yellow, and the undamaged pipeline network is shown in gray. This map represents 155 damage reports; 65 reports for Hurricane Katrina and 90 for Hurricane Rita. Risers are not part of the MMS GIS database and are associated with the pipeline segment that the riser connects to the platform. Mapping of the riser damage categories yields the mapping of the entire segment that the riser is associated with, as shown in Map 5, above.

Map 6 – Submerged Pipe Damages for Hurricanes Katrina and Rita



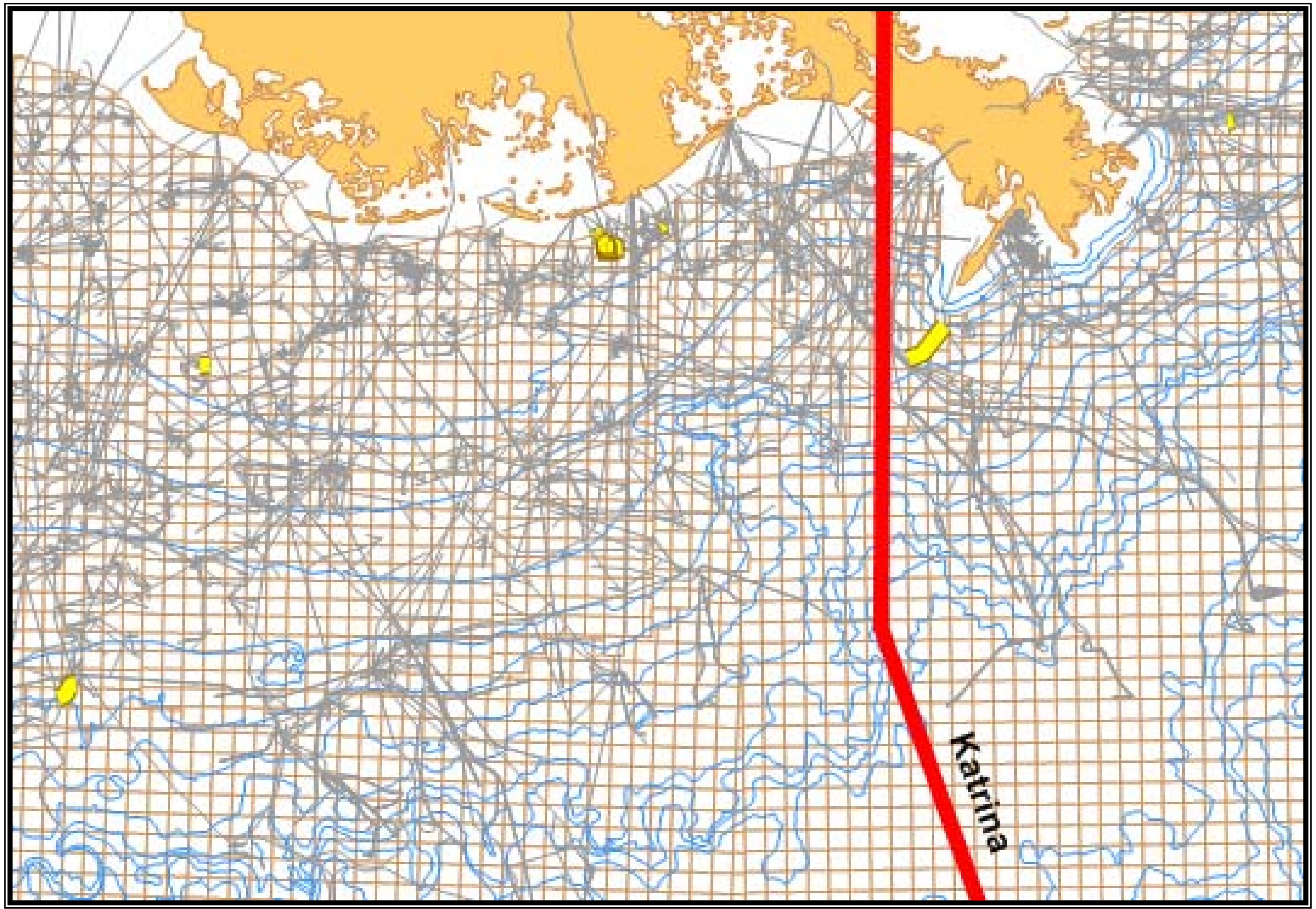
The damages categorized as Submerged Pipe are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in yellow, and the undamaged pipeline network is shown in gray. This map represents 92 damage reports; 61 reports for Hurricane Katrina and 31 for Hurricane Rita.

This group of damage reports will be analyzed in more detail as part of the DNV category called Pipeline Study group.

There were 52 reports that were for pipelines 8 inches or under and the remaining 40 pipelines were 10 inches and above in diameter.

There were 64 reported damages were for gas pipelines, 23 were for oil, the remaining five were supply and lift lines. Of these, 49 reports for pipeline segments were transportation downstream of the first processing.

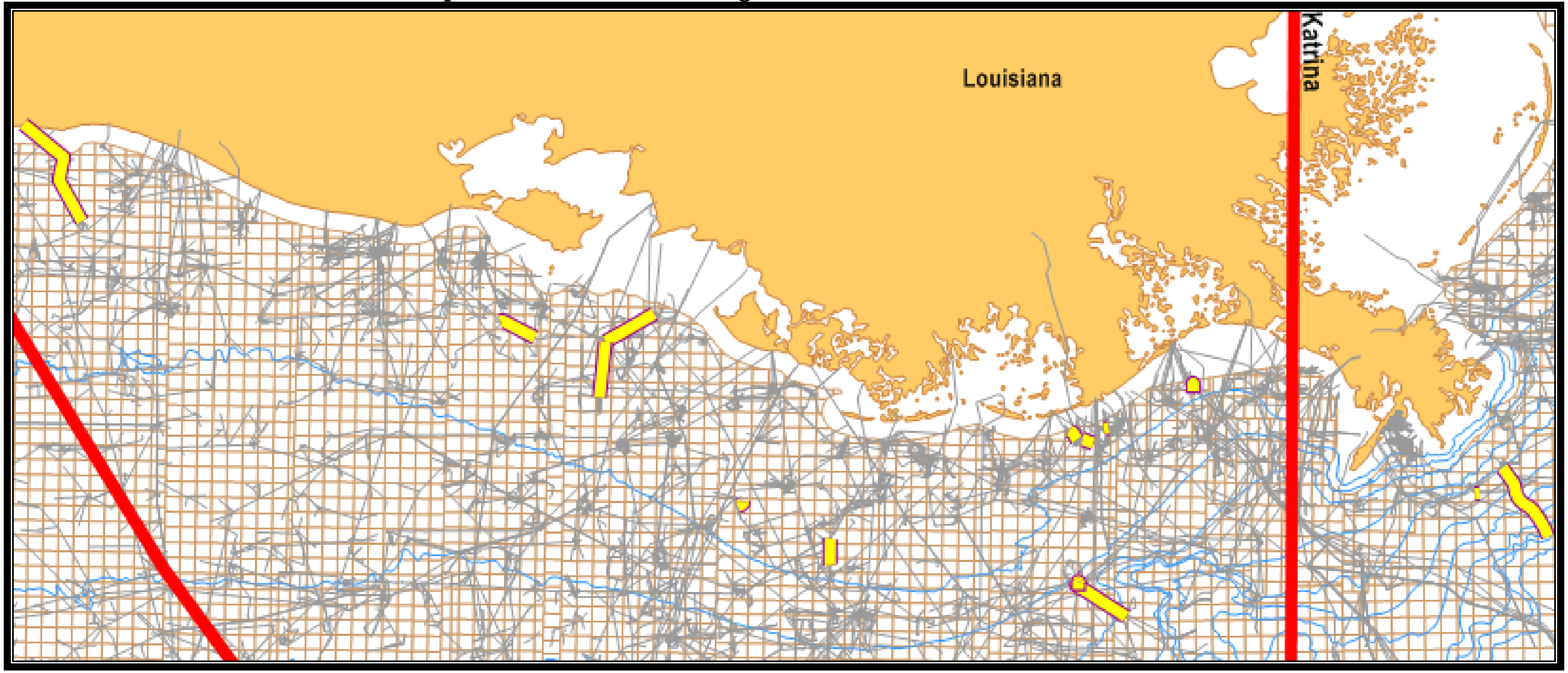
Map 7 – Unknown - Other Damages for Hurricanes Katrina and Rita



The damages categorized as Unknown-Other are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in yellow, and the undamaged pipeline network is shown in gray. This map represents 29 damage reports; 14 reports for Hurricane Katrina and 15 for Hurricane Rita.

The majority of these damage reports are in ST 21, and have overlapping segments as seen in the area that is at the top center of the map.

Map 8 – Subsea Tie-In Damages for Hurricanes Katrina and Rita

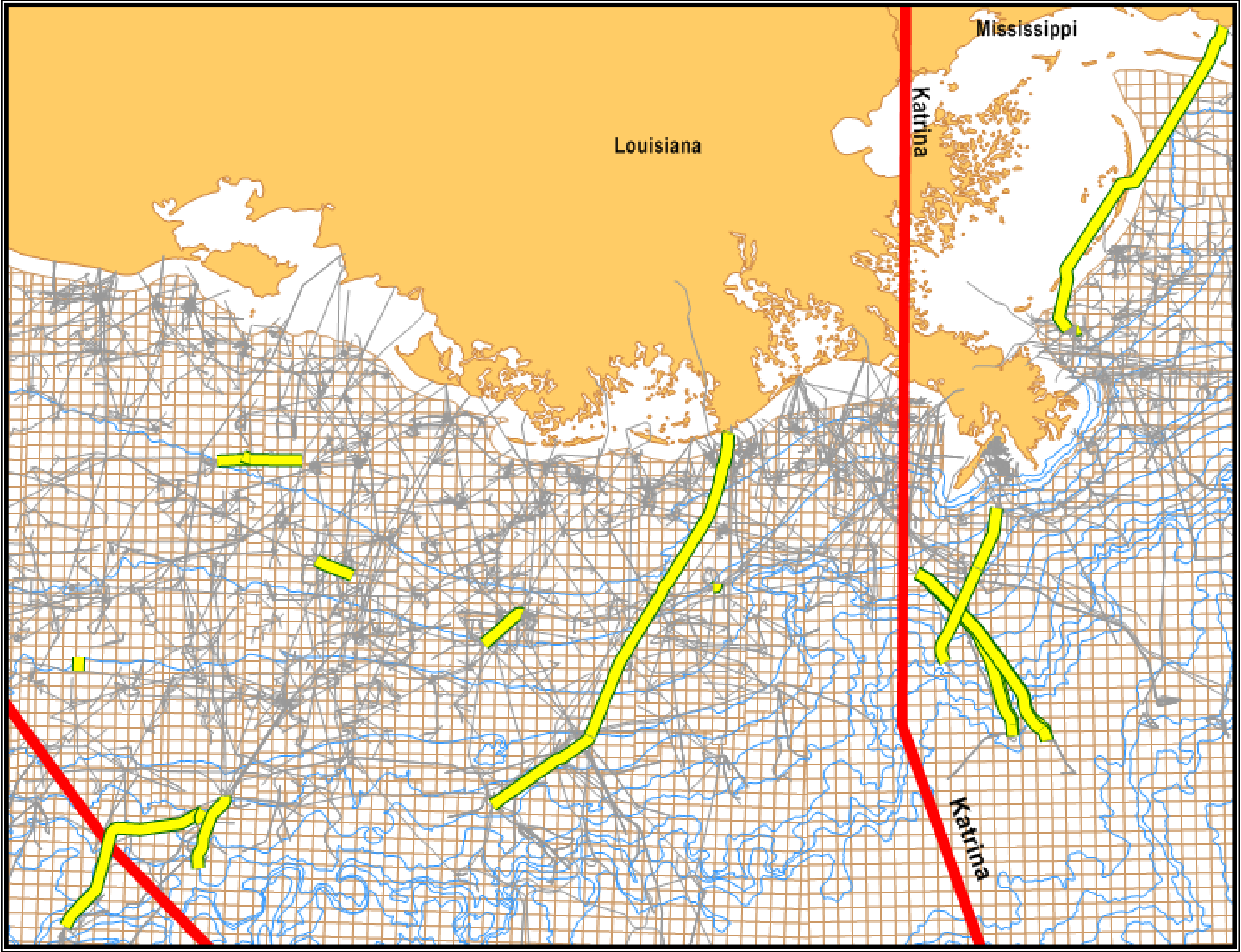


The damages categorized as Subsea Tie-In are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in yellow, and the undamaged pipeline network is shown in gray. This map represents 16 damage reports; 11 reports for Hurricane Katrina and 5 for Hurricane Rita.

The only commonality identified in the damage characteristics in this group is the location of the damage. Nine of the pipelines were 8 inches or under the remaining 7 pipelines were 10 inches and above in diameter. Six of the 16 reports were for lines that were pulled apart.

Ten of the reported damages were for gas pipelines and three were oil, the remaining five were test or supply lines, and nine of the 16 pipeline segments were transportation downstream of the first processing.

Map 9 – Outside Force Damages for Hurricanes Katrina and Rita



The pipeline damages categorized as Outside Force are mapped over the hurricane routes and seafloor contours. Damaged pipelines are in yellow, and the undamaged pipeline network is shown in gray.

This map represents 16 damage reports; 9 reports for Hurricane Katrina and 7 for Hurricane Rita. Out of the group of 16 reports, one report indicated damage from mudslides, four from impact by foreign object, and eleven due to anchor drags or rigs crossing.

Four of the pipelines were 8 inches or under and the remaining 12 pipelines were 10 inches and above in diameter.

Nine of the reported damages were for gas pipelines and seven were oil, and 10 of the 16 pipeline segments were transportation downstream of the first processing.

7.3 Damage Statistics for DNV Pipeline (PL) Study Damages

The subset of damage reports created by DNV resulted in a group of 137 damage reports from the total set of 542 reports. These reports represented damages where there was a limited understanding as to the cause of the reported damage. This subset of the total damages hereinafter is referred to as the Pipeline (PL) Study Damages. These are the damages that DNV identified as being beneficial to study further for the purposes of identification of commonalities, failure locations and categorization of hypothetical root causes for the study of potential actions or recommendations to GOMR OCS practices.

Through more detailed analysis of the damages reported, DNV further grouped the PL Study Damages in the following categories, and then created a mapping category for the specific damage categories for further geospatial assessment of the damage locations and types represented in Table 10 and Figure 29.

PL Study Damages		PL Study Damages – By Event	
Damage Category	Total	Katrina	Rita
Crossing	6	6	0
Displaced	8	4	4
Failed Leak Test	23	7	16
Leak	13	7	6
Dented-Kinked	4	3	1
PL Exposed/Span	45	31	14
Pulled Apart – Rupture	24	18	6
Unknown-Other	13	7	7*
TOTAL	136	83	54*

* One "other" category damage report indicated no damage, therefore the report was not placed in a damage category and the total damages were reduced by one report.

Table 10 – PL Study Damages

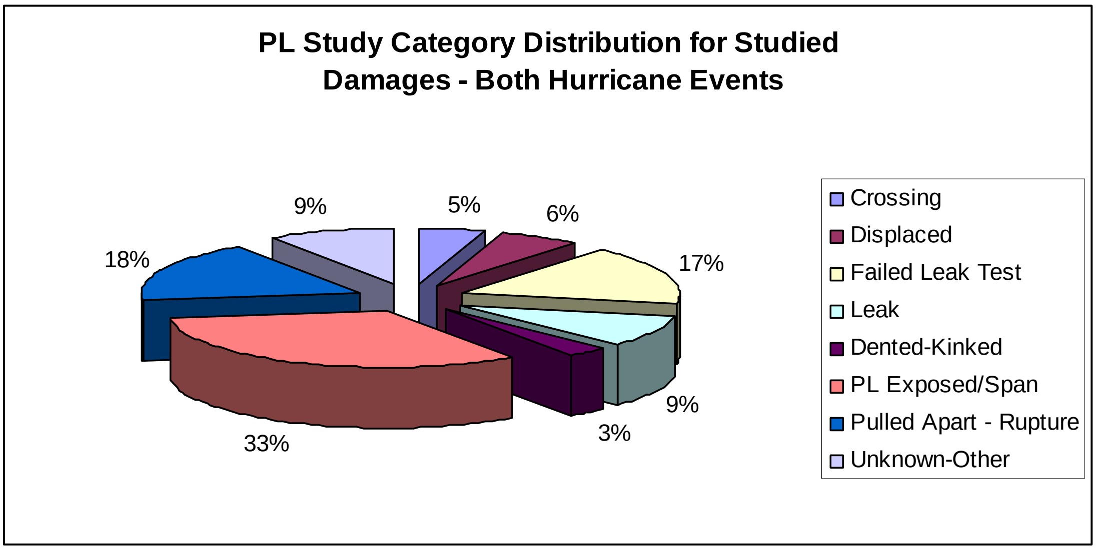


Figure 29 – PL Study Damage Categories for Both Hurricane Events

The distribution of the pipeline diameter size of the subset developed from the total reported damages followed roughly the same distribution as the total data set as shown in Figure 30, providing a good representation of the total reported pipeline segment sizes.

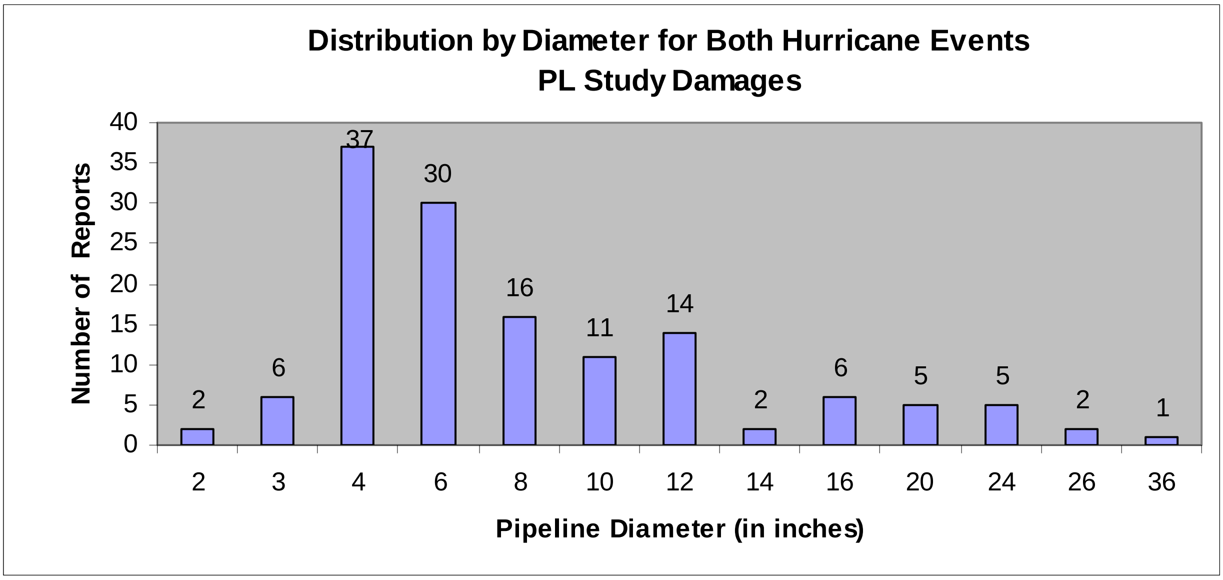


Figure 30 – PL Study Damage Diameter Size Distribution

7.3.1 Root Cause Analysis

Observations about the lack of reporting consistency and data quality have been made in this and previous hurricane pipeline damage studies and by pipeline operators and industry teams trying to perform root cause analyses. The manner in which the data is collected and analyzed is an area where possible improvements and increased efficiencies can be realized.

DNV's analysis of the damage reports and data analysis quickly concluded that the information was not detailed enough to perform scientific root cause analyses or other failure mode type criticality studies that could definitively identify design code inadequacies. While the variations in reporting definitions could be easily addressed, the inability to assess the in-situ condition of the offshore pipeline structures at the time of failure, or the actual sequence of the failures made the analyses at best, educated guesses as to what had occurred, or the sequence in which the events occurred.

The pipeline industry has historically taken actions and enacted solutions through consensus standards, and the regulatory authorities have addressed similar issues through regulatory requirements. DNV has evaluated where additional practical recommendations may be offered, but has concluded that by and large, the design practices and operating procedures are adequate. It appears that there may be benefits from preventing damage to pipelines from platforms, drilling rigs, and risers; however those areas of study are outside of the scope of DNV's pipeline study, or are being addressed by other research projects carried out on behalf of MMS. However, industry wide design code or regulatory revisions do not appear to be required with respect to pipeline design or installation.

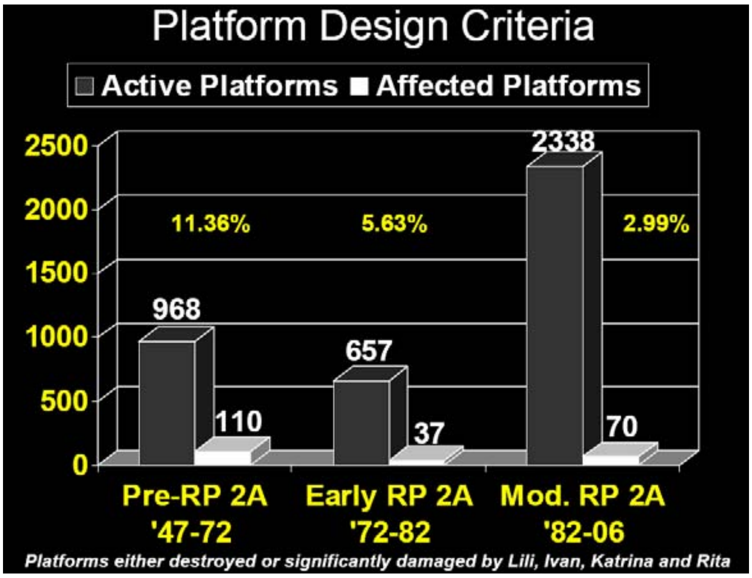
The findings of this study are consistent with the identified failure mode experience of previous Hurricane Andrew, Lili and Ivan studies, relative to the general types of failures experienced. The primary distinction between the other three studies and this study was the higher than previously experienced damage incidence that could possibly be attributed to the loss of stationkeeping of drilling rigs. As noted in Hurricane Andrew and Ivan study reports, the majority of the failures were in water depths less than 200 feet. This was consistent with the findings in this study.

Water Depth in Meters	Active Leases	Approved Applications to Drill	Active Platforms
0 to 200	3,606	41,651	3,853
201 to 400	227	1,250	21
401 to 800	429	839	10
801 to 1000	363	425	6
1000 and Above	3,482	1,186	15

Table 11 - Distribution of GOMR OCS Structures by Water Depth

Looking at the statistics in Table 11, it would be a reasonable expectation that the majority of the damages would occur where the majority of the platforms and pipelines are located, and these findings have been consistent in the studies carried out for Hurricanes Andrew, Lili, Ivan, and Katrina and Rita.

Figure 31 – 2006 API Hurricane Conference Presentation



As with Hurricanes Andrew, Lili, and Ivan no correlation was found for the age of pipe. The pipelines that were damaged ranged in age and date of installation, with no pattern indicated in the damage modes. The location of the leases tend to be grouped by age, and the hurricane's path may impact more platforms of a certain age due to the path, but the performance of pipelines appears to have no correlation once the riser and platform damages are removed from the study data. Other historical studies focused on platforms have identified issues with respect to the vintage of the platforms and their design standard, but this is not true for pipelines.

The findings and correlations identified in this study with other study findings are:

- Platform failures contribute to the majority of the damages, but may not be clearly reported as such on pipeline damage reports
- Water depths less than 200 feet have had the highest volume of damage reports, but this is also where the majority of the pipelines are located
- Mudflow damage tends to occur primarily when the storm track is to the East of the Mississippi River Delta
- There is no correlation with the age of pipe, however, some correlation of damages to age has been noted for platforms of varying code design vintage in other studies, which can directly influence the number of pipeline damage reports
- The majority of damages are consistently in the small diameter pipelines, particularly risers and pipelines having a diameter of 4 inches
- There is no correlation of the type of product carried by the pipeline and the damage reports except for pipelines that were displaced over a large distance

The following sections provide additional discussion of the review of the damage categories that are part of the DNV PL Study Damage subset.

7.3.2 Crossing Damage

Seven damage reports resulted from Hurricane Katrina that identified crossing damage. There were no reports of crossing damage from Hurricane Rita. The vicinity of these crossing damages is in areas where previous crossing damage occurred due to Hurricane Ivan. It appears that design for hurricane resistant crossings in lieu of mats may be appropriate in the region to the east of the Mississippi River Delta and where water depths are less than 200 feet. This could be handled on a case by case basis during the design review.

Three of the crossing damage reports indicated that the mats had been displaced and there was pipe to pipe contact, and the remaining four reports indicated a loss of mats and no damage to pipe other than the pipe was exposed. All of the pipelines were less than 7 years old, and their sizes ranged from four to twelve inches in diameter. All but one line had the product code BLKG, and the other line was BLKO.

7.3.3 Displaced Pipelines

Eight pipelines were displaced over a very large portion of their length, and for a very long distance without rupturing. All of these pipelines were GAS product code and six were large diameter lines ranging from 10 to 26 inches in diameter. The other two lines were 6 inches in diameter. While there are not many reports in this category, the significance of these lines for restoration of many other facilities is of greater importance than the volume of the damage reports in this category. Replacement of many miles of pipe resulted from these damages and delayed restoration of production due to the lengthy nature of repairs or replacements.

7.3.4 Failed Leak Tests

This group of damage reports was a bit odd in that all but one of the 23 reports were submitted on the same day by one company for unknown damages and locations that resulted from failed leak tests. The one remaining report was for a leak at a crossing that was discovered during a leak test. While many damages are not discovered until a leak test is performed, typically a damage report is submitted for the actual damage with additional information in the data fields. It is unclear if additional information is available and it has not been updated in the spreadsheet, or if there have been no additional reports filed. The mapping of this category indicated that the majority of these reports were related to the failure of a platform, and as a result were recategorized in the mapping analysis summary section. All lines had LIFT and BLKO product codes and ranged in age from 4 to 35 years and were all four inches in diameter.

7.3.5 Leaks

Thirteen damage reports reported leaks at clamps, welds, flanges, fittings, and three reports that were for leaks in the pipe body. No commonalities were identified by age, size, product type or cause.

7.3.6 Dented/Kinked Pipelines

This category included four reports of lines that were kinked or dented. All appeared to be from outside forces with visible damage that would indicate impact or anchor drags,

Photo Courtesy of Shell – 2006 Hurricane Pipeline Presentation - Kinked Pipeline Example

7.3.7 Exposed and Spanned Pipelines

The largest damage category in the PL Study subset was that of Exposed Pipelines and Pipeline Spans. There were 45 of the 138 reports, or 33% reported due to loss of cover or support that exposed the pipeline. Mudflow related pipeline damages were not as significant in these events as the Hurricane Ivan experience the year prior. The only mudflow damage reported was as a result of Hurricane Katrina, whose path was directly over the South Timbalier Area. However, there were a significant amount of pipelines exposed in this area during 2005, instead of mudslide damage.

Exposed crossings were also a subset of this category of damage and seven reports were for exposed crossings. All were less than two years old with the majority of them having a product code of BLKG.

Twelve damage reports identified 25 spans that ranged from 50 to 200 feet in length, mostly in water depths under 200 feet. Four damage reports were for pipelines in greater than 200 foot depths. The size of the pipelines was widely distributed with 29 of the reports covering pipelines that were eight inches or less in diameter and 16 reports that ranged from 10 to 36 inches in diameter. The majority of the pipelines were gas, with 32 of the 45 reports having BLKG, G/C, GAS or LIFT product codes.

The exposed pipelines were primarily older lines that were 19 to 40 years old, with a roughly equal distribution of OIL and GAS product codes.

While the pipelines are technically not damaged, the maintenance of adequate cover can be critical for on-bottom stability and damage prevention, and unsupported spans can create potential structural issues, and future damage due to inadequate separation and pipe to pipe contact, as well as deviating from the permitted ROW and pipeline route. These pipelines were inspected and either handled as a permit modification, reburied, supported or relocated to correct the change in conditions, after performing a stability analysis for approval by the GOMR Pipeline Section.

There is no evidence that exists that would suggest a change in design practices is required to address this category of damage, as long as appropriate assumptions are used in the force and soil property selections during design. DNV has no recommendation to design practices, but suggests the review of soil and metaocean data criteria selected by operators in light of the changing bottom and soil conditions in mudflow areas in the GOM.

7.3.8 Pulled Apart – Ruptured Pipelines

The second largest category of pipeline damages in the PL Study Damage subset was that of pulled apart and ruptured pipelines. This category included 24 reports, 18 from Hurricane Katrina and 6 from Hurricane Rita.

Fourteen of the reports indicated the pipeline was pulled apart some distance from the platform with a break in the pipe body causing a rupture of the line. The distance from the platform ranged anywhere from 30 to 4,000 feet, and the product codes were primarily GAS and BLKG. These failures appeared to be as a result of pipeline displacement that resulted in a rupture due to lack of on-bottom stability or anchor drags. However, none of these reports indicated anchor drag marks or rigs having crossed.

Eight of the reports indicated that the pipelines pulled apart at the subsea tie-in. This group of reports looked to be indicative of anchor drags or platforms falling, and did not resemble displacement related failures causing the lines to be pulled, but there was no indication of drag marks reported in any of the reports.

The remaining two reports were unknown as to the cause or location of where the line parted.

7.3.9 Unknown – Other Damages

The remaining damage reports that have not been covered by descriptions covered in Sections 7.3.2 through 7.3.8 of this report are difficult to address from a root cause approach due to the lack of detailed failure information about the pipelines in the damage reports. When mapped, these 14 damage reports show no common area, location or other characteristic other than a lack of data. One damage report in this category stated that there was no damage to the pipeline. Of the remaining 13 reports, nine list the damage as unknown as well as the damage location as unknown. The remaining four reports indicate unknown damage in submerged pipe. The damage reports had no pattern of age, size, ownership or product code.

8 PLANNING & PREPAREDNESS

The MMS has three overriding principles in dealing with tropical storms or hurricanes:

- Evacuate workers so there is no loss of life or injury
- Protect the Nation's supply of oil and gas from long-term disruption of production
- Protect the environment from oil spills

The MMS works on each of these goals in close cooperation with partners in the USCG and with the regulated oil and gas industry.

The oil and gas industry has very similar principles in dealing with tropical storms and hurricanes:

- Evacuate the workers so there is no loss of life or injury
- Protect company assets
- Protect the environment from oil spills
- Return to operations as soon as safely possible

The planning and preparedness begins long before a tropical storm develops. Policies, procedures and practices are developed, tested, refined and put into action, typically at the beginning of the official hurricane season.

As a standard practice, oil and gas operators shut in production when they evacuate the platform. In some cases, natural gas production is monitored remotely from onshore through Supervisory Control and Data Acquisition or SCADA systems. This allows the production to be stopped remotely if necessary.

MMS has mandatory requirements for the use of downhole safety valves to shut off the flow of oil and gas in the event of a well failure, for the prevention of oil release in a catastrophic failure.

9 RESPONSE & RECOVERY

9.1 MMS GOMR Required Inspections, Post Hurricane

The GOMR Pipeline Section handles many activities for the oversight of the GOM pipelines in the OCS. The approvals that are typically required cover new pipeline applications, modifications, repair procedures, completion reports, cathodic protection reading reports, pipeline construction commencement and hydrotest commencement notifications, out of service and return to service notifications, decommissioning applications and relinquishment of right-of-way (ROW) applications, requests to use alternate procedures or departure of operations requests are all processed upon receipt from pipeline operators during the routine course of business. The hurricane events can dramatically increase the approvals that must be processed, and seriously impact the operators' ability to timely file such requests when acting in an emergency or recovery mode, as well as the workload of the Pipeline Section. The GOMR communicates the procedures and requirements to the gas and pipeline industry in the GOM by issuance of a Notice to Lessees and Operators and Pipeline ROW Holders (NTL).

NTLs are formal routine documents that provide clarification, description, or interpretation of a regulation or OCS standard; provide guidelines on the implementation of a special lease stipulation or regional requirement; provide a better understanding of the scope and meaning of a regulation by explaining MMS interpretation of a requirement; or transmit administrative information such as current telephone listings and a change in MMS personnel or office address.

The first hurricane related NTL issued in 2005 was at the beginning of the hurricane season to provide guidance on the Hurricane and Tropical Storm Evacuation and Production Curtailment Statistics via NTL 2005 – G6, dated May 26, 2005. The process utilizes a standard reporting method and form for this reporting activity, a copy of which was attached to the NTL.

Immediately following Hurricane Rita, NTL 2005 G-11 was issued by the GOMR, on September 8, 2005, to provide interim procedures for Pipeline Approvals and other GOMR activities to ensure continued safe operations in the GOMR. NTL 2005 G-14 was issued September 16, 2005, to provide further guidance on the inspections to be conducted as a result of Hurricane Katrina, and NTL 2005 G-20 was issued October 24, 2005, superseding the previous NTL, as a result of the second storm, and to complete inspections to survey Hurricane Rita's impact to the oil and gas operations in the GOM.

Due to the volume of damage reports received in the 2005 Hurricane season, and the priority of the operational needs for both the pipeline industry and MMS, some of the pipeline damage report data is incomplete and inconsistent, such that a cause of the damage is unknown. While the quality of the data has been an ongoing issue for the assessment of the pipeline damages, the sheer volume of the reports in 2005 overwhelmed the labor intensive process that is currently in place for pipeline operators and the GOMR Pipeline Section to manage the data related to the pipeline damage reports. Standardization and automation of this process can improve the quality of the data that is collected about the nature of the pipeline damages experienced as a result of hurricanes in the GOMR.

After the passage of a hurricane, the MMS issues an NTL to direct pipeline operators to undertake certain activities to inspect assess and restore their pipeline facilities, within a specified area relative to the hurricane's path, and a specified timeframe. All activities are subject to the review and approval of the GOMR Pipeline Section. The MMS works closely with operators in the reporting, review and permitting processes that are necessary to provide the oversight of the pipeline repairs and other activities intended to ensure the integrity of the facilities, within the permit conditions. The primary steps are:

1. Report failures to the Pipeline Office, MMS GOMR
2. Identify the permitting procedure type (Construct, repair, abandon, replace, etc.)
3. Submit permit request
4. Make pipeline repairs
5. Submit completion report

The balance that must be achieved in expediting the return to operations, without harm to people or the environment is the role that the oversight by MMS GOMR Pipeline Section provides. There have been many issues in returning to operations that have prompted both the industry and the GOMR to evaluate their current practices and incorporate lessons learned. The primary issues facing the MMS and industry with respect to pipelines returning to operations are:

- Identification and detection of damages
- Protection of life, property and environment
- Assessment of damage of pipelines
- Permitting activities and approvals
- Testing prior to return to operations
- Restoration of supply

9.2 MMS Communications by NTL

The MMS GOMR issued NTL 2005-G14 with an effective date of September 16, 2005, to describe the inspections that pipeline operators needed to conduct because of the known and potential damage to OCS facilities caused by Hurricane Katrina passing through the GOMR and making landfall August 29, 2005.

NTL 2005-G20 was issued following Hurricane Rita with an effective date of October 24, 2006, to describe the actions to be taken subsequent to the combined events of Hurricanes Katrina and Rita. The NTL directed that inspections of pipeline tie-ins and crossings in water depths up to 299 feet, and risers in all water depths, and any areas that it was suspected that MODUs had crossed pipelines were to be completed by prior to June 1, 2006.

NTL 2005-G20 Amendment 1 was issued to extend the deadline to conduct pipeline inspections to October 6, 2006, and complete repair work to November 1, 2006.

The area to be inspected as a result of the passage of the two hurricanes is depicted by the map in Figure 32.

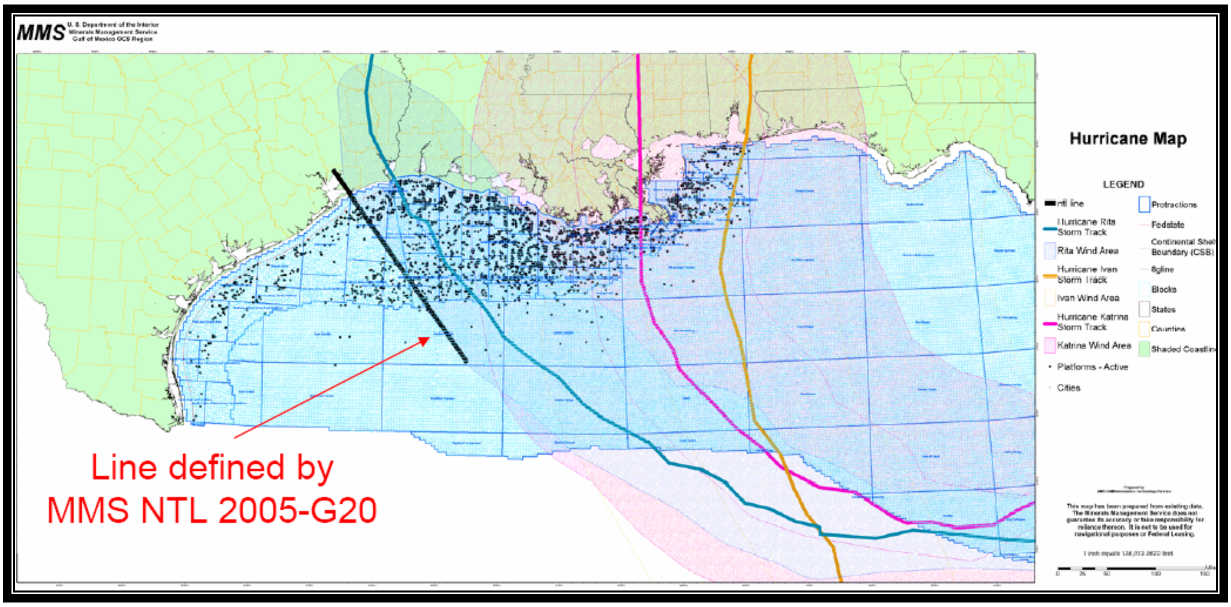


Figure 32 – Map of Area to be Inspected for Pipeline Damage Subsequent to Hurricanes Katrina and Rita – Everything to the East of the Line

9.3 Operators Response to Damage, and MMS NTLs

Operators do not rely upon the issuance of NTLs to initiate inspection or recovery activities in the GOM after the passage of a hurricane. As soon as it is safe to travel, aerial surveys are conducted, and damage assessments are initiated. Ongoing monitoring of SCADA systems can indicate areas of damage due to loss of communications or indications of loss of pipeline pressure. U. S. Coast Guard notification from spill response teams and other forms of information find their way to pipeline operators who are working to assess the situation that has resulted from the storms impacts, as well as the impacts from other structures and activities in the GOMR.

The most significant challenge to the response and recovery in 2005 that had not been experienced previously was the tremendous impact to the onshore facilities, resources, employees and infrastructure along the Gulf Coast from Texas to Mississippi as a result of Hurricanes Katrina and Rita. Electricity, water, transportation, fuel, supplies and communications were crippled in the first few days after the storms in many areas, and for longer periods of times in some areas. Orders to evacuate had scattered employees and families, and the ability to transport equipment and people was severely hindered. The New Orleans and southern Louisiana communities are some of the headquarter locations for federal agencies, operators, and service companies that operate, regulate and support the GOM OCS oil and gas industry, as well as the primary resource centers for materials and supplies. The near destruction of areas of New Orleans and the surrounding coastal areas was a significant impact to the ability to respond. Most companies deployed significant resources and supplies to communities and their employees to provide networks to locate employees and reunite them with their families, as well as support to the food water, clothing and shelter needs. Cooperative efforts were widespread among the pipeline companies, and restoration of operations slowly began to take place.

9.4 Lessons Learned

It is evident in the interviews, conferences and research activities that industry and MMS alike work diligently and proactively to incorporate lessons learned to continuously improve the planning, preparedness, and response into design, procedural and regulatory requirements.

Immediately following Hurricane Katrina, the lessons learned as a result of Hurricane Ivan by MMS were summarized in testimony to the Senate in a statement given by Rebecca Watson, Assistant Secretary for Land and Minerals Management, U. S. Department of the Interior before the Committee on Energy and Natural Resources on September 6, 2005.

> *"Following major hurricanes, we make a systematic effort to identify lessons learned and take steps to prepare for future hurricane seasons. Following Hurricane Ivan, we focused on five principal areas:*
>
> *First, MMS concluded that the basic design standards for deep water floating production systems seem adequate. We had no floating production facility failures.*
>
> *Second, MMS saw that some drilling units installed on the floating production platforms moved on their supports and caused damage. In consultation with MMS, industry has tightened the bolting mechanism and strengthened the clamps that secure these drilling packages on the floating platforms.*
>
> *Third, MMS issued a new reporting requirement for the 2005 hurricane season – NTL 2005 G-6. This requires industry to submit statistics to the MMS Gulf of Mexico Region (GOMR) regarding evacuation of personnel and curtailment of production because of hurricanes, tropical storms, or other natural disasters. Operators must include both those platforms and drilling rigs that are evacuated and those that they anticipate will be evacuated. Evacuation is defined as the removal of any personnel (both essential and non-essential) from a platform or drilling rig. In addition, operators submit a report regarding facilities remaining shut-in. This report includes basic platform information, prior production information, estimated time to resumption of operations and the reason for shut-in (facility damage or transportation system damage). Operators must notify the MMS GOMR when production is resumed.*
>
> *Fourth, MMS issued contracts for six new engineering and technical studies to look closely at the damage caused by Hurricane Ivan and what design or operational changes may need to be made.*
>
> *Fifth, MMS consulted heavily with industry experts and in July jointly sponsored with the American Petroleum Institute (API) a conference in Houston, Texas, on offshore hurricane readiness and recovery to more fully discuss these issues.*

Immediately following Hurricane Rita, Secretary Gale A. Norton, Department of the Interior shared the following lessons learned and observations from the hurricane recovery process following Hurricanes Katrina and Rita.

> *"There is good news regarding offshore operations. Katrina and Rita – both reaching Category 5 strength as they spun through the Gulf and the heart of the offshore energy production – caused no loss of life among offshore industry personnel or significant spills from any offshore wells on the Outer Continental Shelf (OCS). This bears repeating: We faced down two of the most devastating hurricanes ever to hit the Gulf of Mexico without one significant spill from any offshore well on the Outer Continental Shelf. Although there were some minor pollution events from lines or equipment, all subsurface safety valves installed beneath the seafloor successfully prevented uncontrolled releases of hydrocarbons into the Gulf of Mexico……*
>
> *Lessons Learned*
>
> *Damage reports post-Rita have highlighted a problem with Mobile Offshore Drilling Units (MODU). Nineteen MODU's broke loose from their moorings and were set adrift; some causing damage to pipelines as anchors dragged along the ocean floor. To address this issue, I have called for a Conference on Mobile Offshore Drilling Units to be held at the Department, here in Washington, D.C. on November 17, 2005. During this conference we will assess lessons learned and we will define a path forward.*
>
> *Hurricanes Katrina and Rita confirmed that our offshore oil and gas industry produces environmentally safe energy for America. Even in the face of two back-to-back major hurricanes, all subsurface safety valves held on the OCS and there was no significant spill from production. The small amounts of oil observed in the water surrounding platforms may have come from damaged pipelines or petroleum supplies for running platform machinery, but, as stated, it did not come from OCS production wells.*
>
> *In addition, the Katrina/Rita scenario has confirmed that our domestic offshore oil and gas resources are key components in the energy mix which provide some of the basic necessities Americans have come to expect – gasoline for our cars, heating fuel for our homes, natural gas to cook our meals, to power our factories, and to generate the electricity that is critical to our way of life and critical to powering our advanced economy. At present, more than 25% of America's total domestic oil and natural gas production comes from only 10% of the total OCS acreage.*

During the API conference, operators, regulators and industry experts shared their lessons learned with the attendees and offered insights into things that went well, and things that they will be addressing in the future to improve the practices that apply to preparedness and recovery from hurricane events.

The hurricane trends of 2004 and 2005 and the growing significance of the role of the GOM OCS to the nation's energy supply and resultant economics challenge the industry to continually evaluate all aspects of the oil and gas operations to identify any previously unrecognized opportunities to further protect and enhance the practices applied for hurricane resistant designs and hurricane preparation and recovery practices. The primary focus resulting from the 2006 conference was on improved stationkeeping of MODUs and Tie-Downs on Offshore Production Facilities, based upon the damage experiences from the 2005 hurricane events and damage experience.

Industry response to the hurricanes included a cooperative approach that included a commitment to work with government agencies to achieve enhanced infrastructure performance in the GOM in concert with sustained development of critical energy supplies for the nation. The primary industry initiatives were directed at development of standards for improved stationkeeping of mobile drilling rigs, jackup operations for hurricane season, guidelines for tie-downs on offshore production facilities, metaocean criteria and production platform performance. In addition to the industry response, the MMS has commissioned studies for evaluation of Assessment of Fixed Offshore Platform Performance in Hurricanes Katrina and Rita, Joint Industry Project to Study Risk-Based Restarts of Untreated Subsea Oil and Gas Flowlines in the GOMR, Hindcast Data on Winds, Waves and Currents in Northern Gulf of Mexico in Hurricanes Katrina and Rita (2005), and this study for the Pipeline Damage Assessment from Hurricane Katrina/Rita.

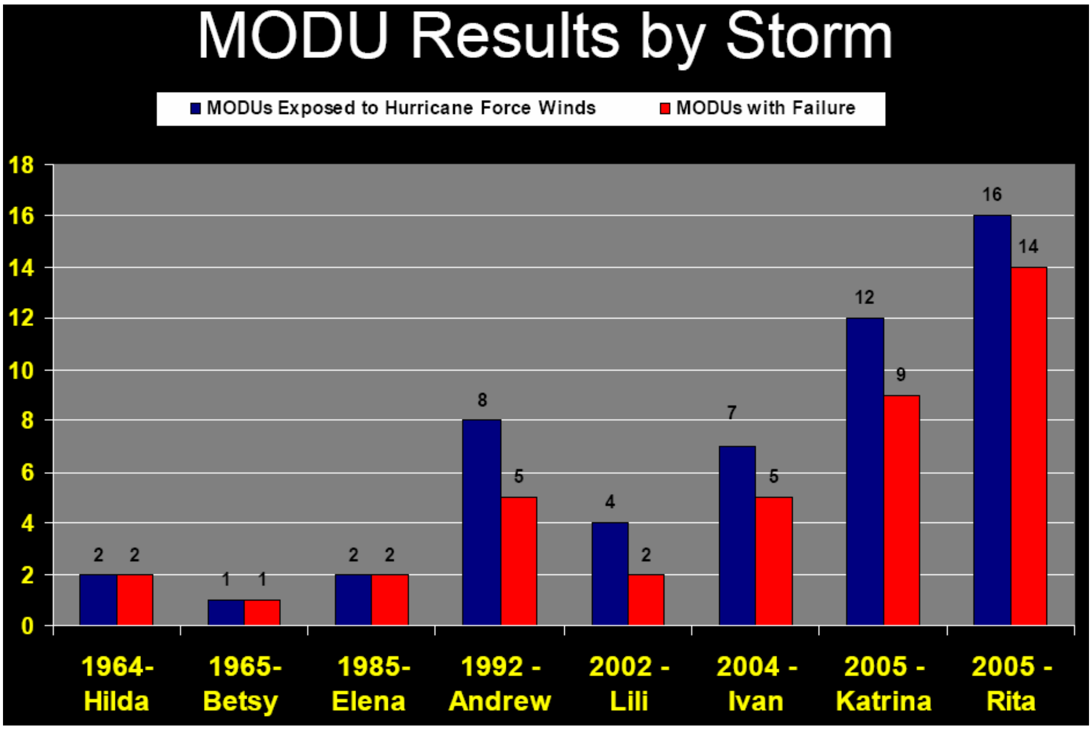


Figure 33 – MMS Presentation Slide 2006 Hurricane Readiness and Recovery Conference

The Director of the MMS, Ms. Johnnie Burton, recognized the industry efforts in an October 2005 letter to the OCS Operators and Drilling Contractors as follows:

> *"Three recent major hurricanes – Ivan 2004 and Katrina and Rita in 2005 – have further demonstrated the offshore industry's capabilities for safely evacuating facilities and securing wells. You are to be applauded for your leadership in protecting personnel and the environment from the threats posed by such intense storms."*
>
> *"I am now asking that you demonstrate similar leadership in resolving a major problem that was confirmed by these hurricanes – the failure of mobile drilling units to remain on location during hurricanes."*

"In recovering oil and gas resources in challenging environments throughout the world, your industry has demonstrated outstanding innovation and technological leadership. I am confident that you will fully apply these capabilities and successfully resolve the issues with mobile drilling rig station keeping."

9.5 Industry Response to Mobile Drilling Units (MODUS) Adrift

The response from industry to the experiences of hurricane season 2005, and the regulatory challenge to address the problem included the creation of standards that were intended to achieve the following three objectives:

- Enhance Stationkeeping Reliability During Next Hurricane Season
- Reduce the Consequences in the Event of Stationkeeping Loss
- Achieve the first two Objectives while Encouraging Continued Development of Energy Supplies on the US GOM OCS

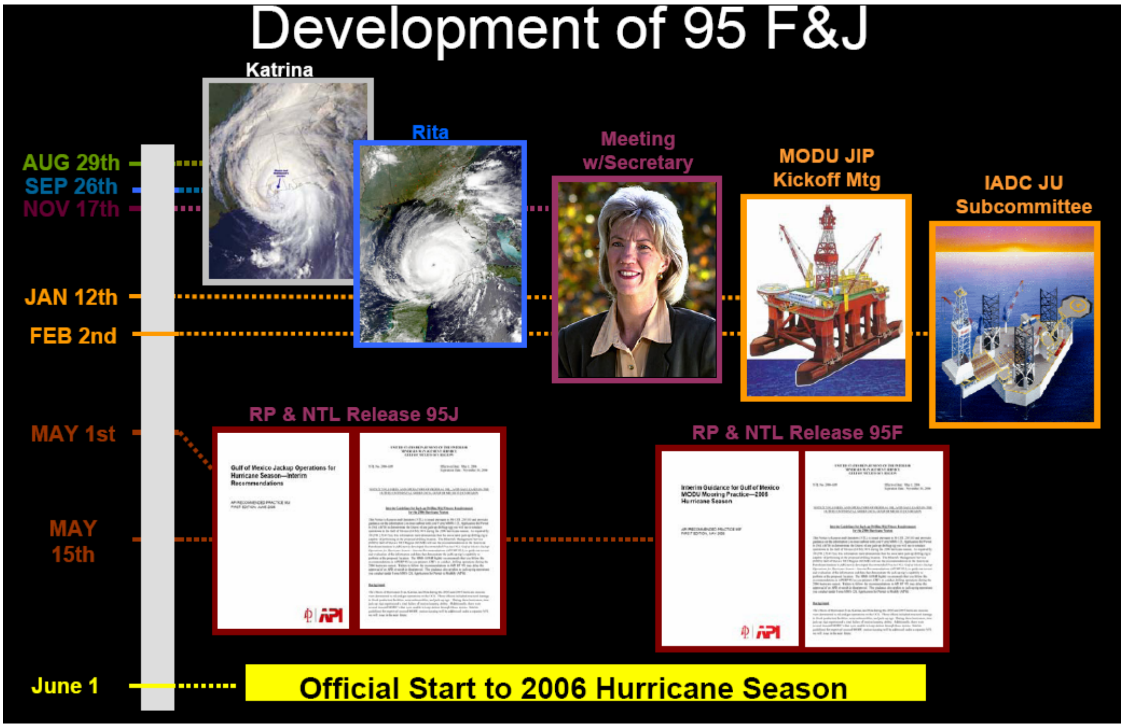


Figure 34 – MMS Presentation Slide 2006 Hurricane Readiness and Recovery Conference

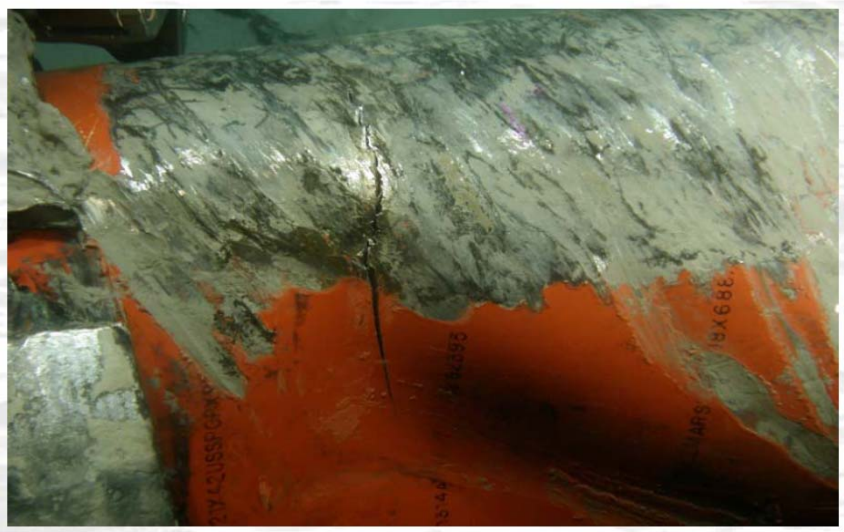
The industry reported successfully completing the stated objectives by delivering the following standards between November 2005 and June 2006:

- Bulletin 2TD, Guidelines for Tie-downs on Offshore Production Facilities for Hurricane Season
- Recommended Practice 95F, Interim Guidance for Gulf of Mexico MODU Mooring Practice – 2006 Hurricane Season

- Recommended Practice 95J, Gulf of Mexico Jackup Operations for Hurricane Season – Interim Recommendations

Continued work by industry in these areas is ongoing to further study and refine the interim practices that were issued prior to the 2006 hurricane season.

Figure 35 – MARS Pipeline Damage



While these standards do not directly address pipeline standards, they do address one of the pipeline damage categories that saw an increase in damages reported to pipelines when compared to prior events studied. The exact cause of pipelines dented, kinked, pulled apart, pulled up and otherwise impacted are unknown, but these categories of damage reports correlated with the general locations of the locations where rigs lost stationkeeping and may have traveled, and could easily be attributed to roughly 10 % of the total reported pipeline damages, and nearly one third of the 137 damages not attributed to platform and riser damage. If any of the platform and riser damage was caused by anchor drag impact, then the percentage of the damages would be an even higher portion of the damages that were incurred as a result of these hurricanes. Damage reports included information about anchor drags in 16 reports such as the type shown in Figure 35, however, there were far more pipelines in the paths of the rigs that were adrift when the damages were plotted over the paths that the rigs could have traveled after being set adrift by the hurricanes.

The diagram shown in Figure 36 was presented at the API Hurricane Readiness and Recovery Conference. The figure clearly depicts several of the paths of drilling rigs after Hurricane Rita passed, and the significant area where pipelines could have been exposed to anchor drags. DNV’s estimate of the impacted pipelines was based upon a manual assessment of damages reports that showed signs of mechanical damage that were in the general path of rigs that may have passed through and pulled, kinked, dented or otherwise damaged the pipeline and estimated the damages with a subjective assessment. If the data from the rigs positioning system were to be provided to MMS in the future, NTL requirements for inspection could be narrowed down significantly for pipeline operator inspections related to MODUs and anchor drags in post hurricane damage assessments.

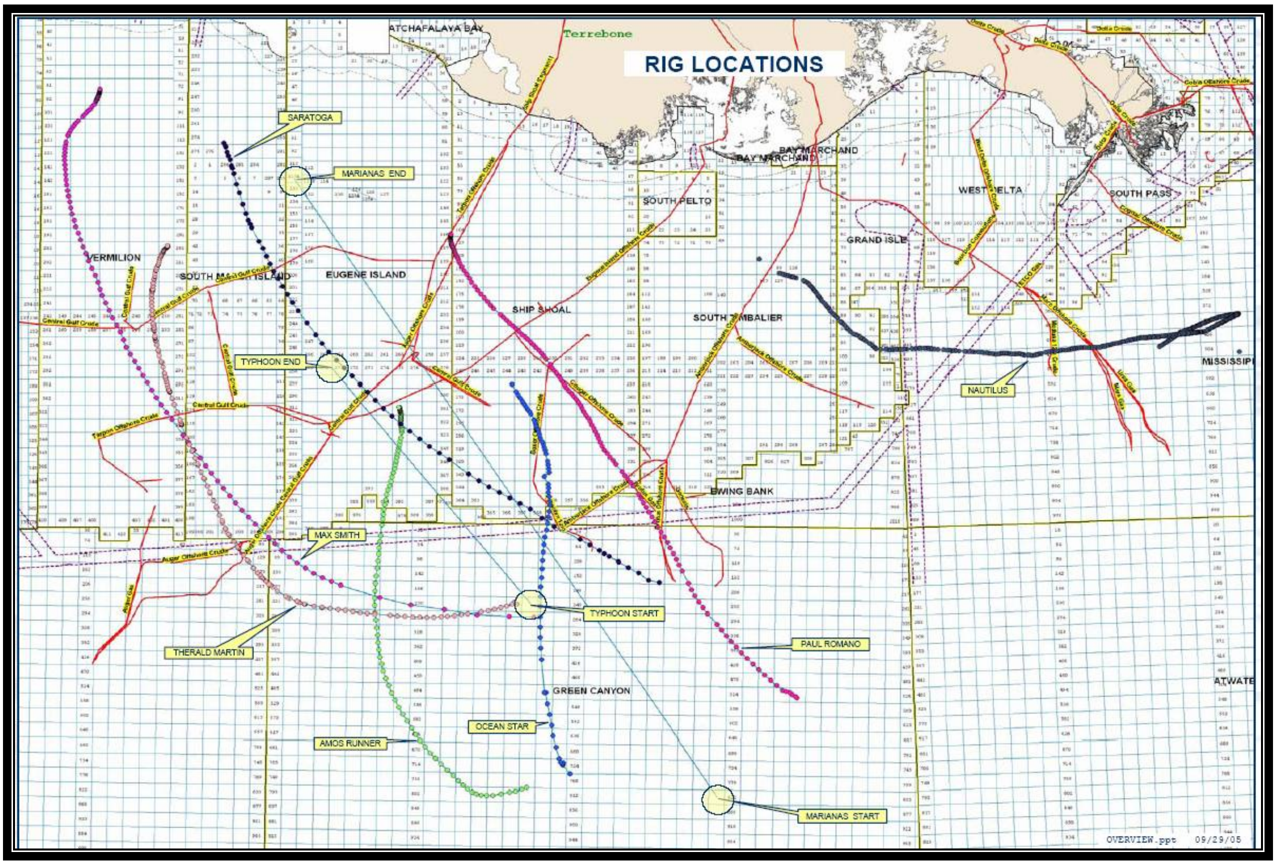


Figure 36 – Map of Rig Locations and Paths Adrift After Hurricane Rita

Two NTLs were issued by MMS prior to the 2006 hurricane season containing interim guidance for MODU Mooring and Jackup Operations, and Guidelines for Tie-Downs on Offshore Production Facilities for Hurricane Season were issued as Bulletin 2TD. There were no tropical storm events in 2006 that subjected these recommended practices to full hurricane forces.

10 DAMAGE MAPPING

DNV, in partnership with Bridge Solutions, Inc. has developed initial components of an Internet based damage reporting process that provides a mapping approach to the analysis and assessment of the pipeline damages. The concept was initiated in the study of Hurricane Ivan, and further developed in the process of analyzing the Hurricanes Katrina and Rita pipeline damage reports.

DNV's use of GIS to link all of the information that MMS presently has in its GIS that can be linked to a geographic location to the damage reporting for pipelines was how the study maps included in this report were developed. Upon mapping the damages, and linking the available information, queries, assessments, reports and status were utilized to evaluate the damages and reporting that might not have been otherwise possible to complete, as well as provide a visual interface for analysis and assessment of the damage by the DNV study team.

Figure 37 represents the screen view of the mapping tool that was used for analysis of the pipeline damage reports related to Hurricanes Katrina and Rita. All colors and symbols are those selected by the designers, and are for concept only. Lines and symbols are easily modified to meet local users' needs. As this is a concept model that was designed for use by DNV analysts, the reader should focus on the content and capabilities instead of the visual appearance. The yellow highlighted text has been added to describe the field in which it is placed.

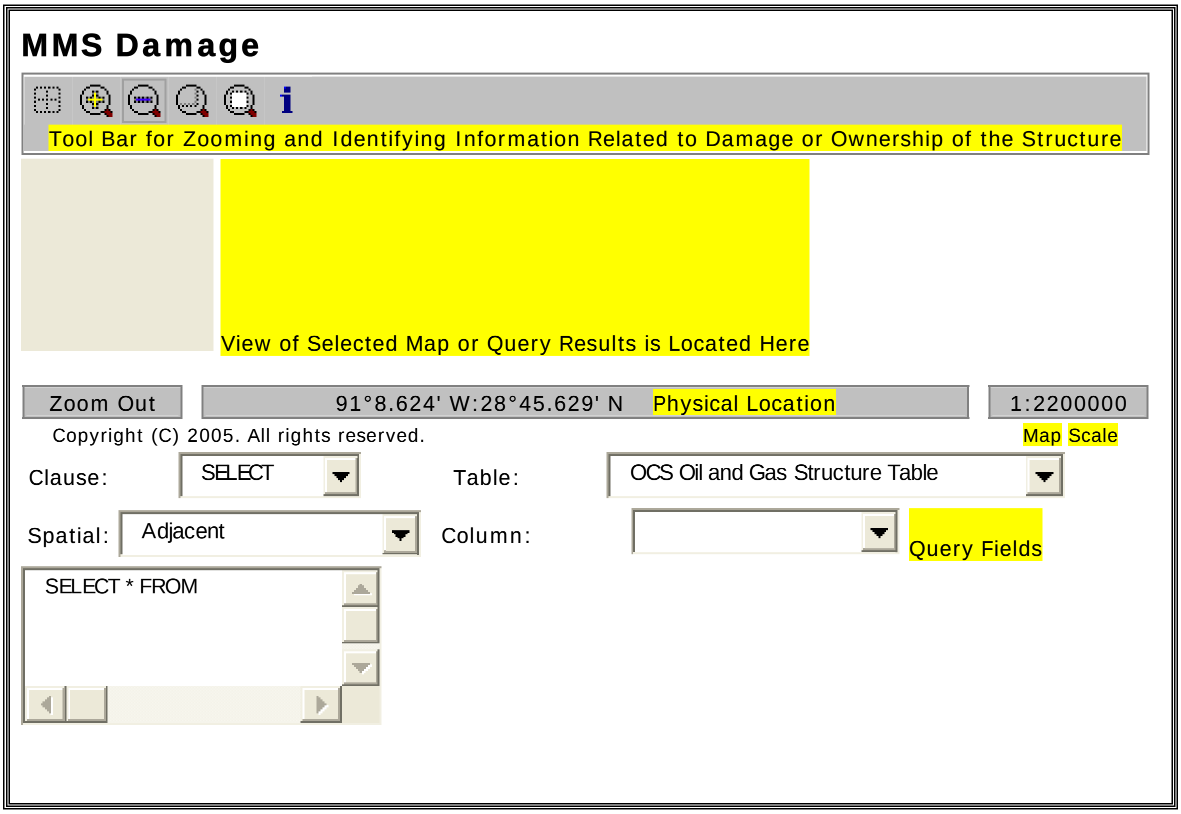


Figure 37 – Mapping Tool Query and Screen View

Maps generated from this GIS interface can be used to quickly evaluate parameters such as those found in the maps of the rigs that lost stationkeeping. Maps could be overlaid to pinpoint specific locations where surveys should be undertaken to evaluate potential damage from anchor drags, and allow direct communication with the specific pipeline operator instead of a blanket requirement published in an NTL.

The map in Figure 38 was created early in the development process and represents the top level view of the pipeline damage map which covers the extent of the area that had pipeline damage reports filed with MMS. As the user zooms in, the view reveals additional data that is shown in the key that has been overlaid on the screen view.

Continued development and refinement of the mapping layers and visual appearance is reflected in the maps that you see later in this section.

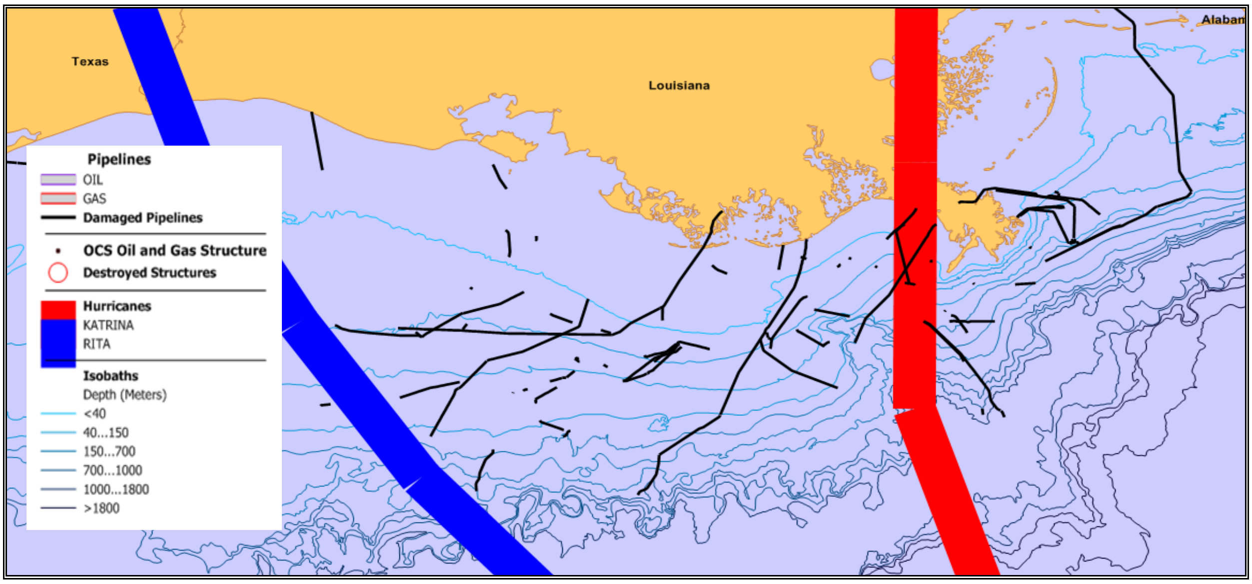
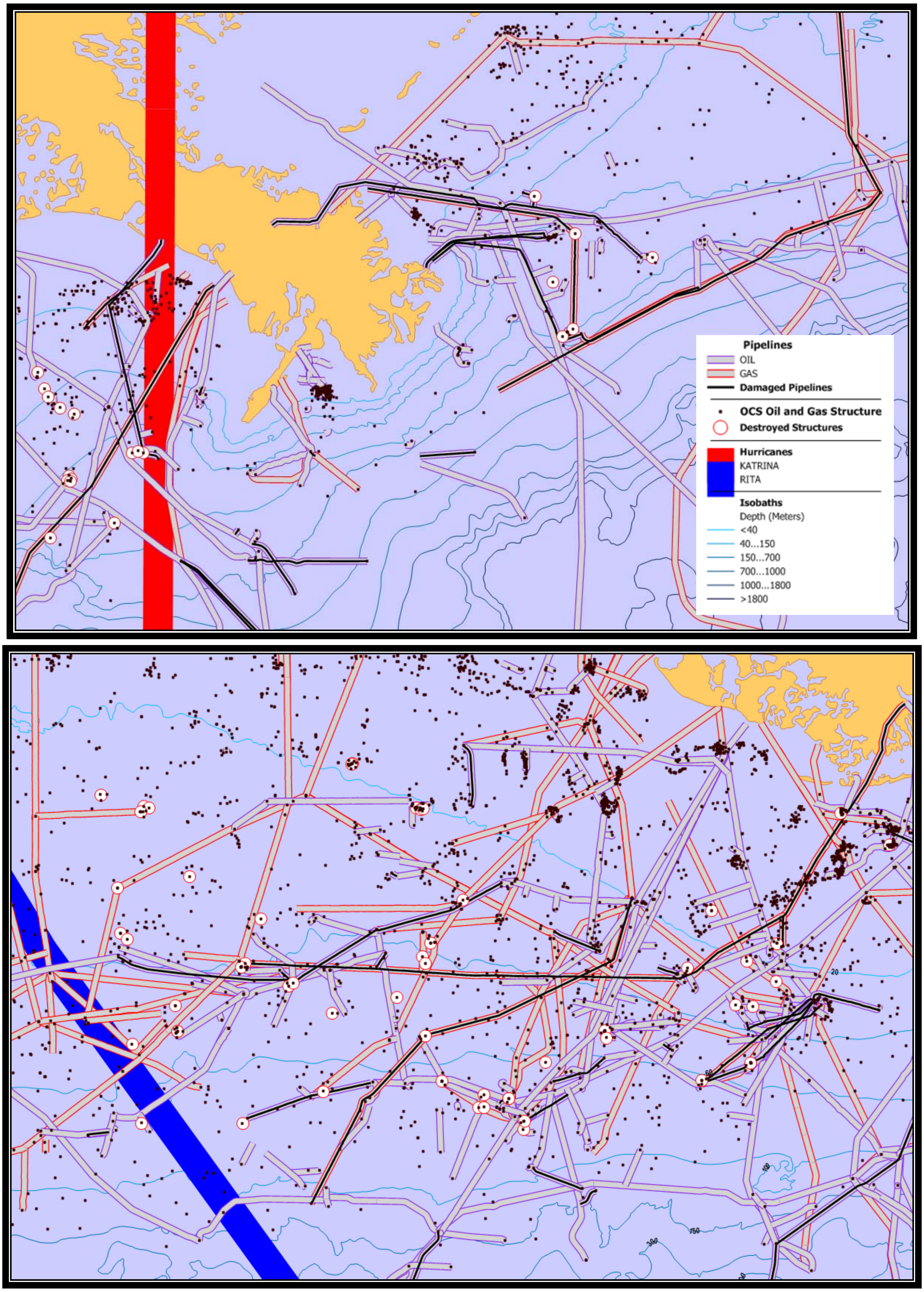


Figure 38 – Top Level View of Mapping Tool Visual Interface

Various colors can be used to represent parameters, and functionalities can be developed for queries and data representation. Presently, the model allows “mouse-over” information to identify the value of the colored visual layers, and zoom and database capabilities that can be demonstrated more comprehensively in a live presentation to the MMS. Examples of screen views used for analysis of the damages follow.

For example, Figures 39a and 39b depict zoom views of selected regions that are near the path of each hurricane that were selected by the researcher to focus on a particular area of damage. OIL and GAS product codes are shown in this view, as well as damaged pipelines and destroyed platforms. The user has the ability to click on the structure and identify the data that is associated with the selected facility. This works for hindcast data at specific points, pipeline ownership and damage reports, as well as the local bathymetry. As long as the data can be geospatially referenced and linked through the use of an Excel or Access type table, it can be easily tied to the visual image that enables the engineer or analyst to see the information in a geospatial manner.

The use of tools with a screen viewer would easily adapt to the input screens for use in damage reporting and information updating for status of repairs and conditions of permits. The pipeline operator could use the screen, click on their facility, and the data would be pre-loaded with the information that is stored within the MMS GIS database. The damage report information could be entered by the pipeline operator, and the fields for damage causes could be included in a drop down menu to control the selection of the possible data fields, and provide descriptions of data enabling a common definition for industry and agency use. Improvement of data consistency, quality and reduction of paperwork and data handling could be achieved through this process.

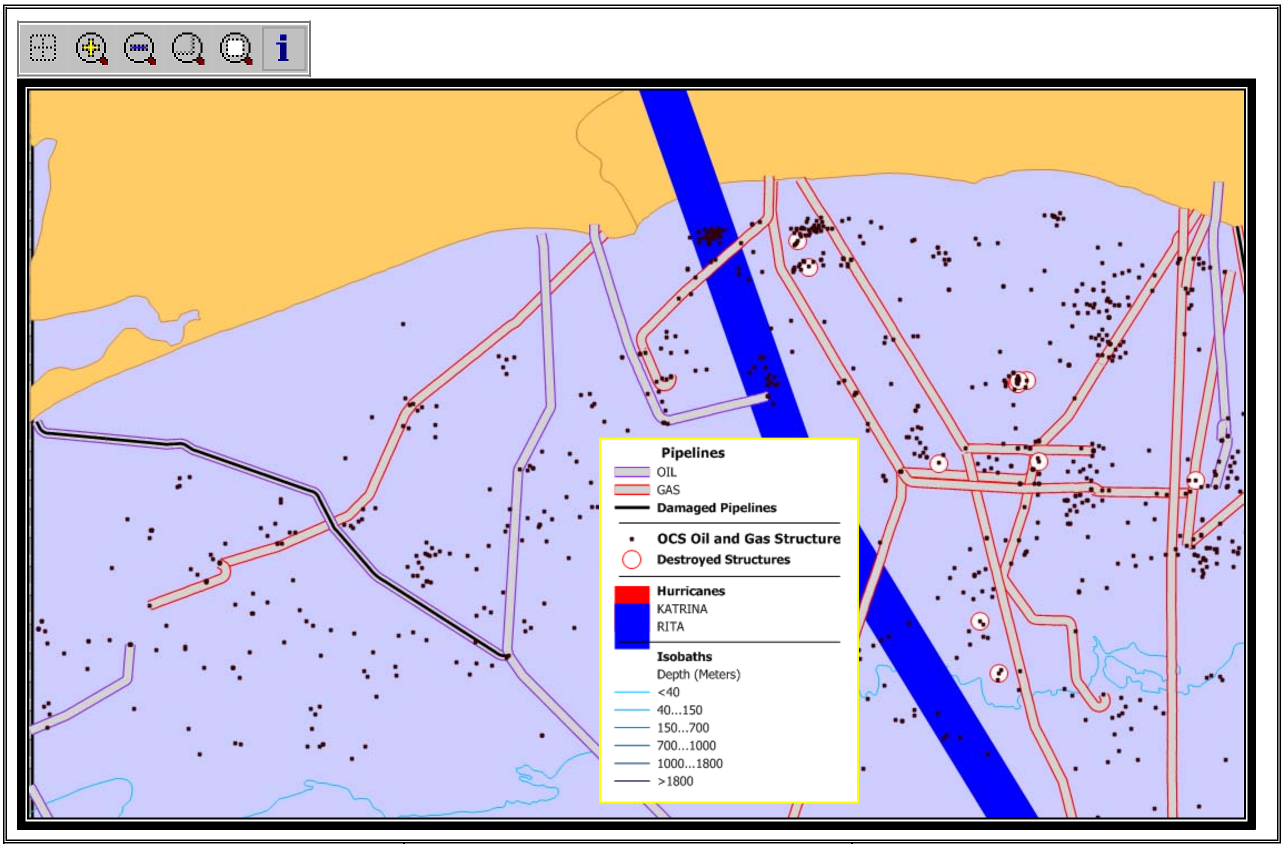


Figures 39a and 39b - Hurricane Maps - Screen Shots of ZoomView

The power of the visual representation of the data is quickly evident with the analysis of the information that has previously been dealt with in a paper or spreadsheet format.

For example, the Pipeline Damage in Figure 40 (center left side black line) appeared to be outside of the damage area when compared to the rest of the pipelines reported as damaged in Hurricane Rita, and did not fit into the general vicinity of the location of damages that had been reported.

Further review was accomplished by clicking on the information icon on the mapping tool screen, which provided the detail from the Excel spreadsheet, identifying that the damage was described as pipeline crossings exposed at three locations, however the pipeline suffered no mechanical damage. The ability to identify the damage is limited to the ability to accurately map the data. The entire segment is highlighted because the damage reports are tied to segments, not the physical location of the damage. Therefore, the mapping and damage assessments could be improved if the longitude and latitude of the damage locations were used instead of the segment number. This is particularly true for riser damages that would be better represented as a point instead of being associated with the pipeline segment that it is connected to.



PROD_CODE	OIL	ORIG_AR_CODE	HI	PPL_DMG_RPT_DT	05/11/2006
SEGMENT_NUM	13972	ORIG_BLK_NUM		PPL_DAMAGE_DESC	
PPL_SIZE_CODE	24	ORIG_ID_NAME		REMARKS	Pipeline crossings exposed - 3 locations
CO_NAME	[redacted]	DEST_AR_CODE			
Cat		DEST_BLK_NUM			
SEGMENT	0	DEST_ID_NAME			
SIZE		Age	2		

Figure 40 – Screen View - Pipeline Damage & Information Data Fields

The intended use of the pipeline damage data and the subsequent activities to be carried out by the end users set the objectives of the development of the mapping database. If the GIS is intended solely as a historical archive to maintain the records of the pipelines that are under MMS GOMR jurisdiction, then there would be little cause to provide a visual interface and revise the data that is collected other than to improve the ease of reporting and collecting the information. However, if it is intended for future use in analyzing the data and provide a tool for use by MMS GOM oversight, DNV would recommend the continued development of the mapping that has been used by DNV in the assessment of the pipeline damages from Hurricanes Katrina and Rita.

The enhancement of the mapping and visual interface capabilities of the GIS, coupled with additional data fields that are collected through damage reporting from pipeline operators as described herein, would provide a valuable tool for the management of the pipeline infrastructure in the GOMR. The following examples of the mapping and damage assessment and analysis by DNV should illustrate some of the benefits of the visual representation of the data to improve the understanding of what happened to pipelines as a result of the passage of the hurricanes. This highlights only some of the potential uses of this tool. Routine permitting and oversight activities not related to hurricanes could also benefit from the visual interface to the MMS GIS database, as well.

Damage assessment has traditionally been carried out by categorization of the type of damage that is described in the GIS data field called DAMAGE and DAMAGE LOCATION. The categories that were reported from the MMS data fields in the Excel spreadsheet supplied to DNV included:

DAMAGE	DAMAGE LOCATION
Line Dented	Both Risers
Line Kinked	Departing Riser
Line Pulled Apart	Receiving Riser
Line Pulled Up	Subsea Tie-In
Line Twisted or Bent	Submerged Pipe
Other	Other
Pinhole Leak	
Riser Bent	
Unknown	
Valve Leaking	

These categories are descriptors that are used to process repairs and are not indicative of the roots causes or the influencing factors or adjacent facilities that may have impacted the pipeline. This information is not necessarily needed for permit processes, but is necessary for damage assessment and categorization as to the types of damage causes that would enable the GOMR to evaluate the general pipeline performance as a group instead of looking at pipeline segments on an individual basis.

DNV categorized and mapped the total set of damage reports into the following six categories, based on the natures of the specific damage reports from Hurricanes Katrina and Rita. The DNV categories for the total pipeline damage report data set were Platform, Riser, Outside Force, Submerged Pipe, Subsea Tie-In, and Unknown-Other. In the DNV Hurricane Ivan study, the additional field of Mudslide was used, instead of making it a subset of outside force as was done in this study.

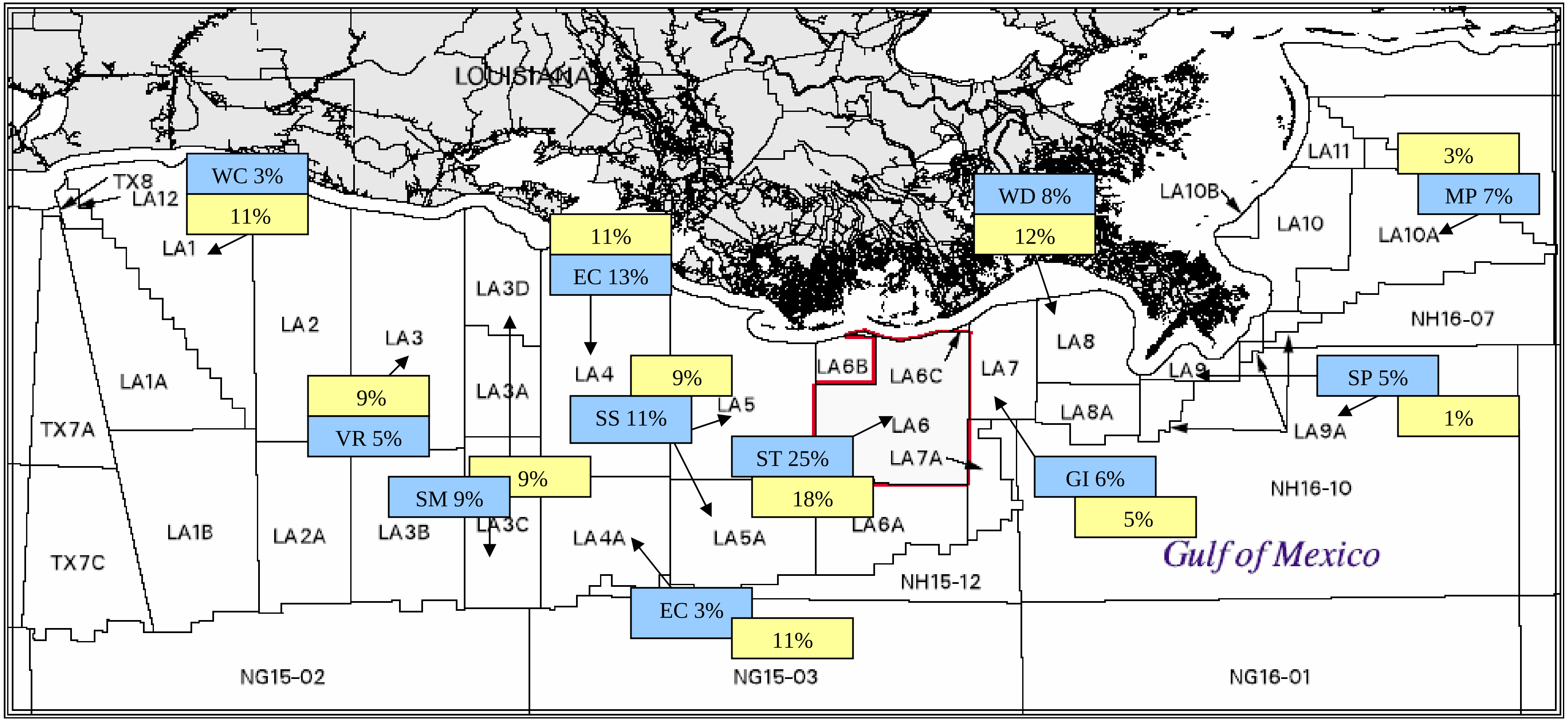
When the damages were categorized in this manner, the reports could then be sorted by the following categories through the creation of an additional data field category in the data tables. The second category that was created to further sort the damage reports for mapping purposes was to enable the mapping and assessment for the PL Study set of damages that included the following categories in the mapping data tables:

PL Study Set of Damage Categories
Crossing
Displaced
Failed Leak Test
Leak
Dented-Kinked
PL Exposed/Span
Pulled Apart – Rupture
Unknown-Other

The grouping of these damages by the above categories allowed the mapping tool user to turn on and off layers by category types, and look at the damages in specific lease blocks to identify commonalities or other contributing forces that may have influenced the pipeline damage. This resulted in findings related to damages not reported or categorized as one type and appearing to be related to other causes due to adjacent platform failures, impacts from debris or drilling rigs, or other pipeline damages.

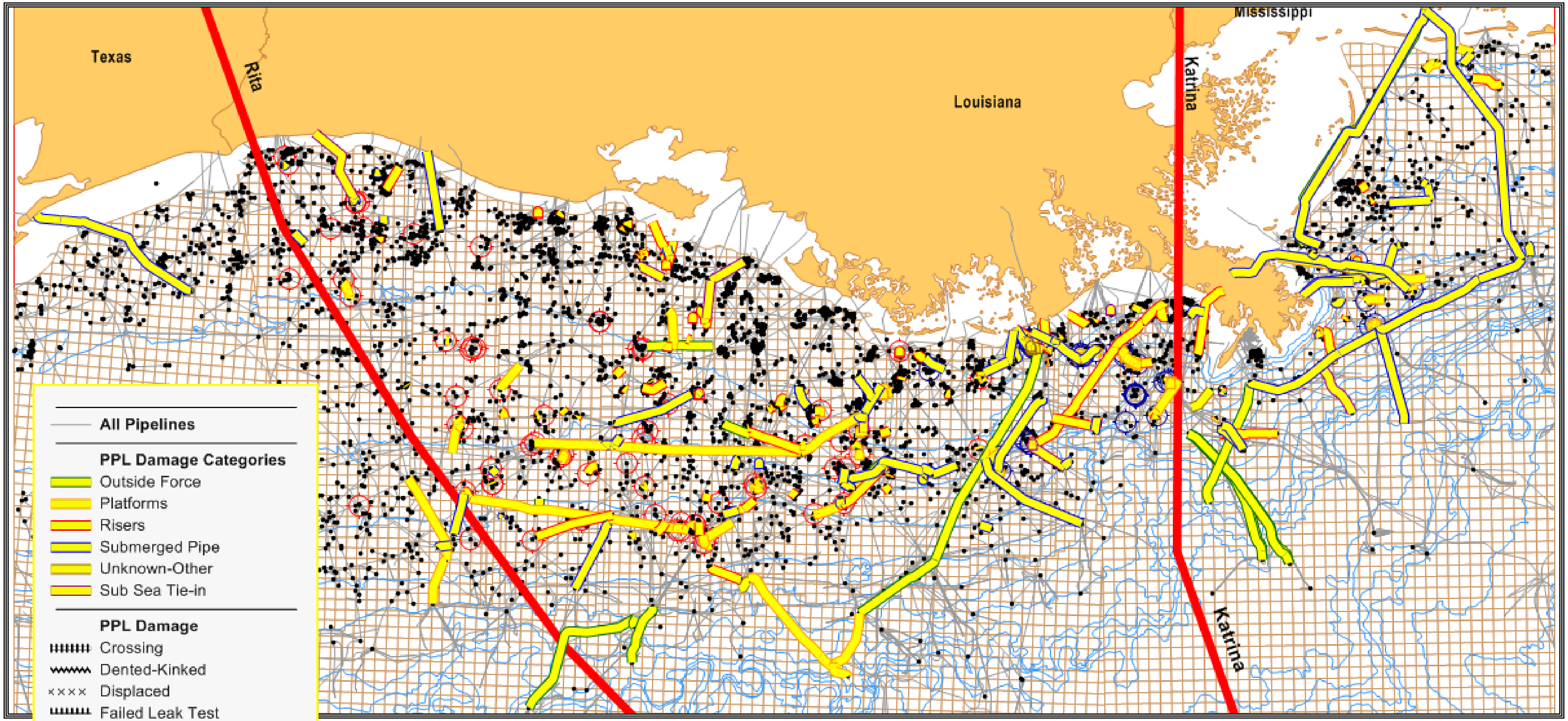
The following screen views of the mapping tool are an illustration of the visual aspect of the mapping interface that was developed by Bridge Solutions, Inc., in cooperation with DNV to create a visual representation of the data to allow DNV to analyze the various damage reports, categories, geospatial relationships, and created an overlay of the information that is needed to assess the conditions to which the pipelines may have been exposed.

DNV has selected not to include the hindcast data as an underlay to the GIS maps to reduce the visual clutter that can be created with all of the data, particularly since there have been no correlations found for the wind, wave or currents with respect to the pipeline damage reports. However, the shape files created by OceanWeather, Inc. as part of the Hindcast Study for the MMS are easily added as a layer that could be useful for other structures and their analysis within the MMS GOMR organization.

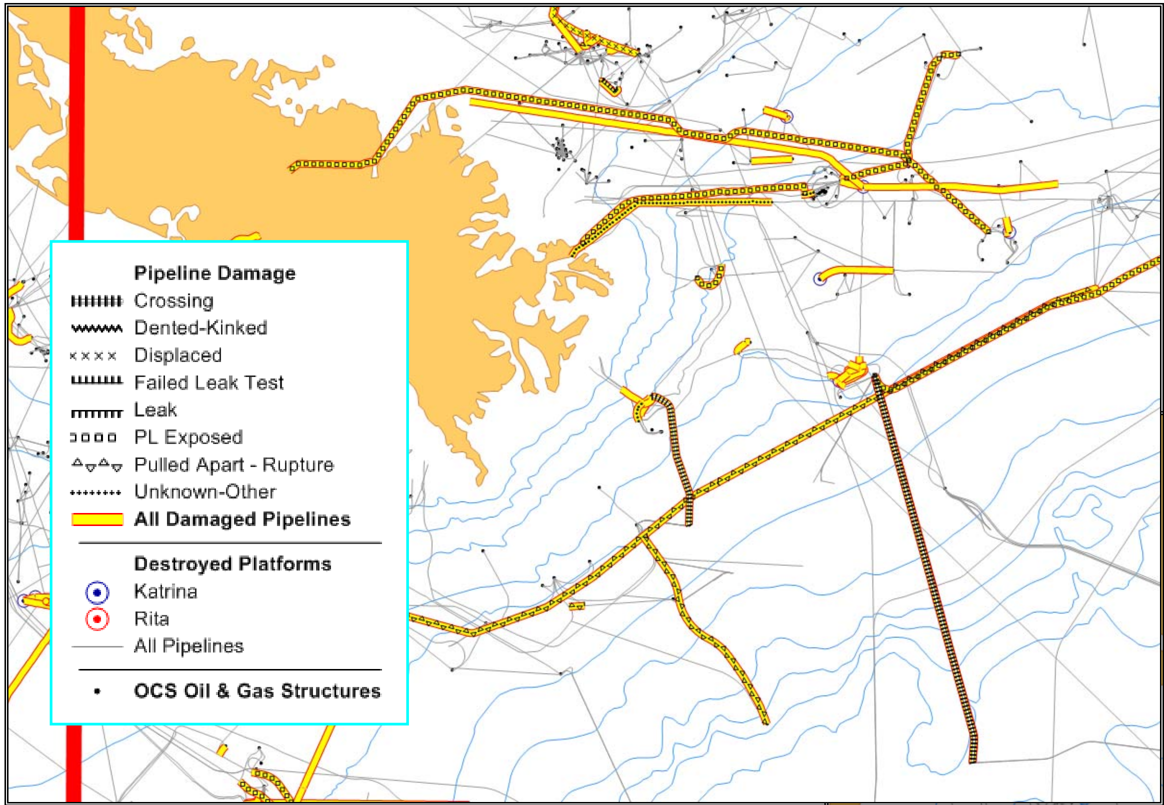


Pipeline Damages – Percent of Total Damage Reports **Platforms Destroyed – Percent of Total Destroyed Platforms**

Traditional statistical analyses have focused on the numbers of damage and their distribution with respect to location, size, age, and other attributes that can be represented in a database or spreadsheet format. The ability to combine statistics with geospatial data is the next step in the progression toward improved ability to analyze data for pipeline damages experienced offshore. The figure above represents the distribution of damage by Area name designation codes. If an assessment of damages relied solely upon the statistical evidence presented in the figure above, it would appear that there was a meaningful difference in the damage experienced in South Timbalier ST 21 with respect to the rest of the GOM facilities. The following mapping analysis example uses the mapping tool to evaluate the damages reported in this area.

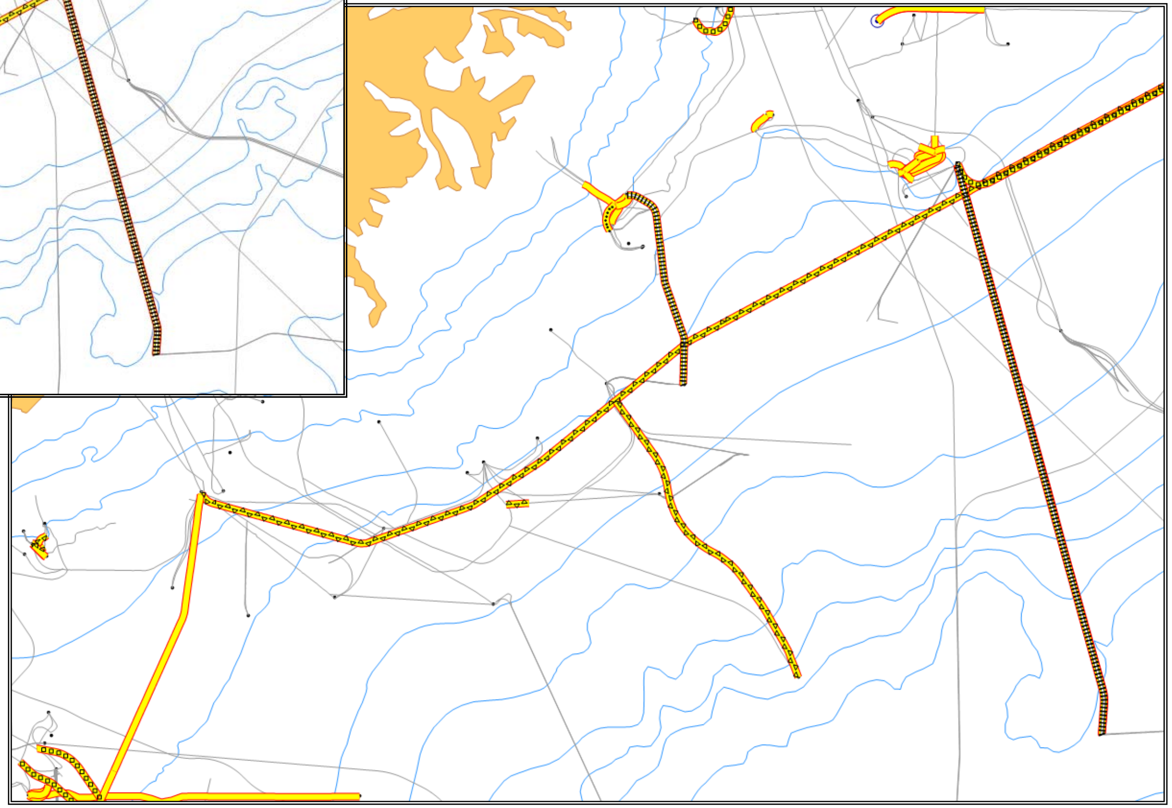


With all of the layers on, the map is quite busy. However, selecting the information to be reviewed is up to the user. This view of the top level of the map shows all of the layers including isobaths, structures, hurricane routes, lease blocks, damage categories, platforms, and destroyed platforms. Use of the icons at the top of the viewing window (shown below) allow the user to zoom in, select a structure or map layer detail and obtain information about it. The following buttons are at the top of the Screen View: Centers the Map Zoom In Zoom Out Zoom Box Zoom to Fit Information about the item selected by clicking on item.

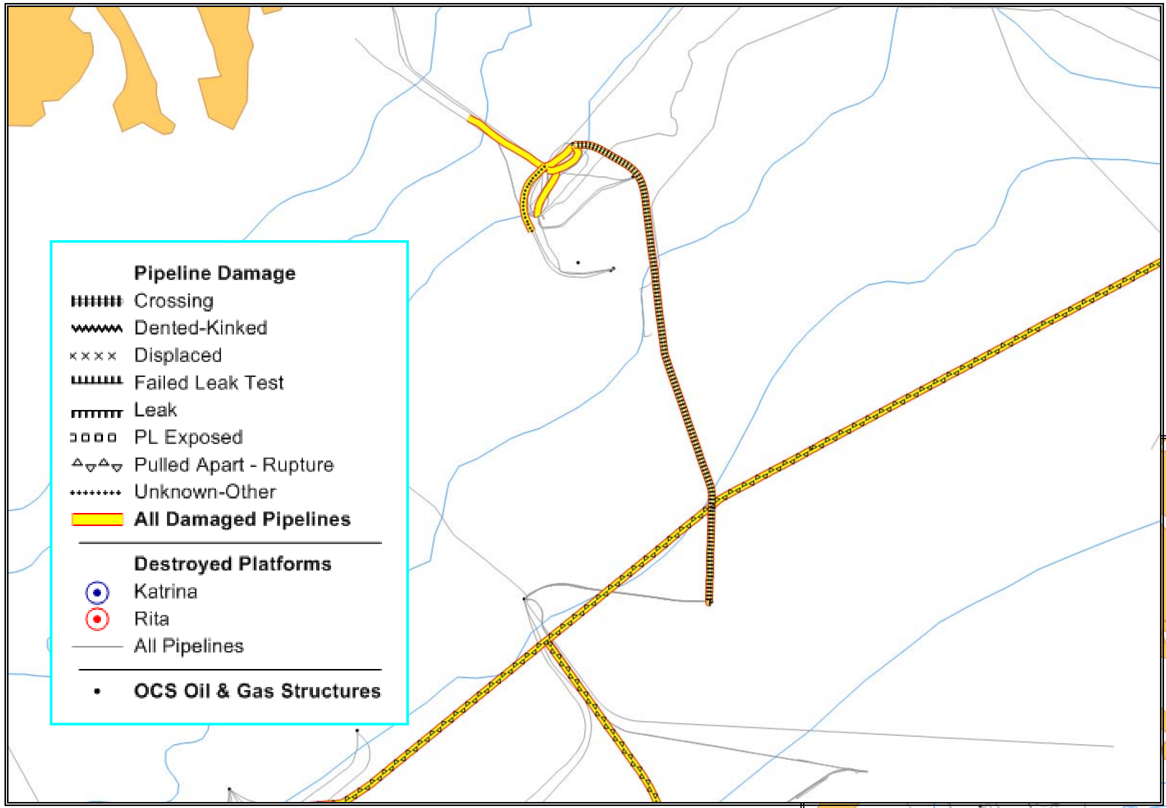


The figure to the left is a zoom view of the map that was selected by clicking on the Zoom Box icon and then drawing a box with the cursor around the area of interest to look at the damages in this area from the top level map. The lease blocks are turned off, and the pipeline damages are on, as well as the hurricane path, all pipelines, platforms, and destroyed platforms,

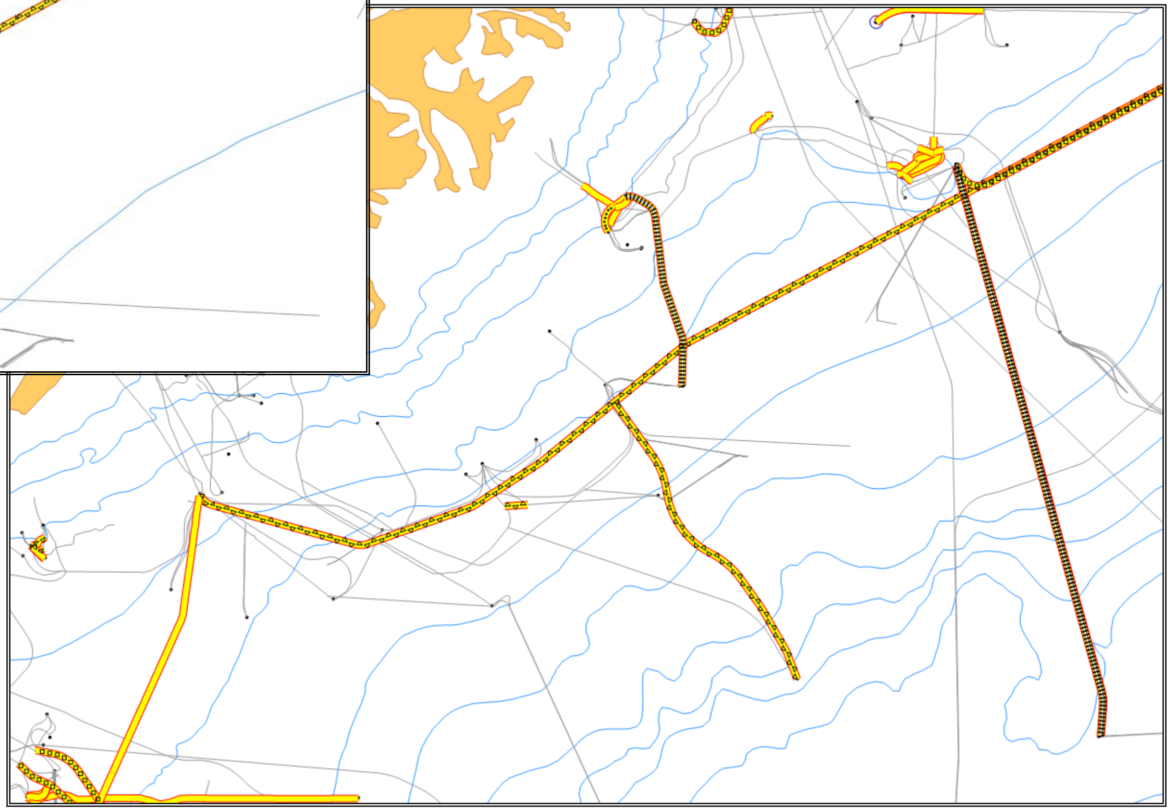
Too look more closely, the Zoom Box icon is still selected, and a new box is drawn with the cursor to select the view of the area to be further examined.



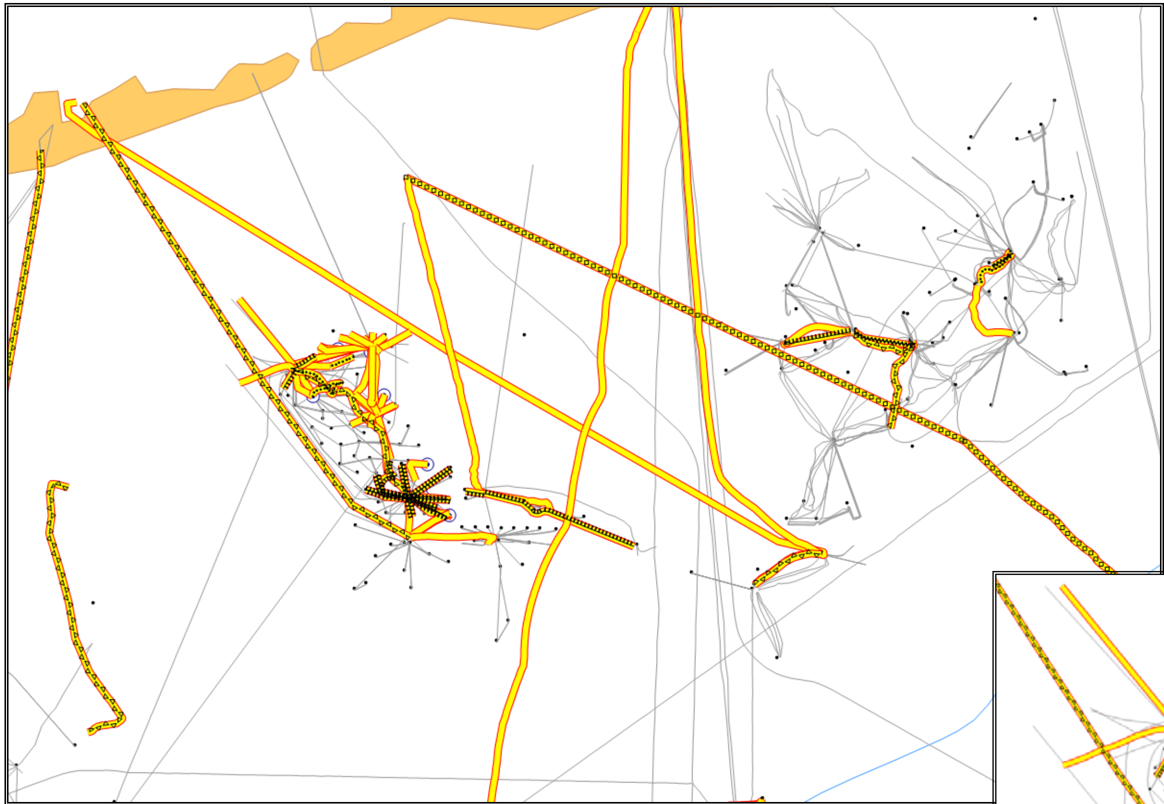
The figure to the right is a zoom box view of the map above to allow a closer look at the damages in this area, and allow the user to click on the pipelines of interest and look at the data about the pipeline and its damage report by clicking on the information key and then clicking on the structure.



The figure to the left is a zoom view of the map shown below. The damage descriptions in the area show pipelines that have been pulled apart and ruptured, have crossing damage, are associated with riser and platform damage and unknown failure causes. The ability to see the interrelated nature of damages in these apparently unrelated damages increases our understanding of the influences to the damages that have occurred in this area. What we are not able to identify is the initiating event that may triggered the various damages.

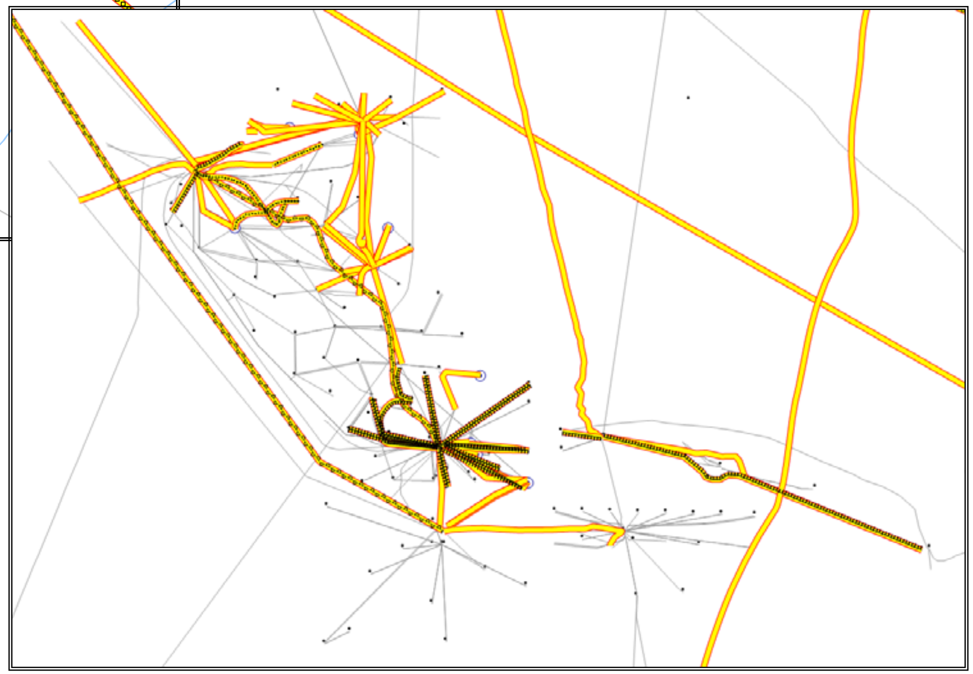


What we can see is that there may be other structures in this area that may require inspection or have possible damage from these pipelines and nearby structures, or that a damage report has not been received for these structures, or they are abandoned and do not have an active role in the GOM infrastructure, or other inferences that can be made that would signal the need for follow-up action. The damage report data, pictures or any relevant information could be made available to the user such that by clicking on the map, this information is opened for the map user to view.



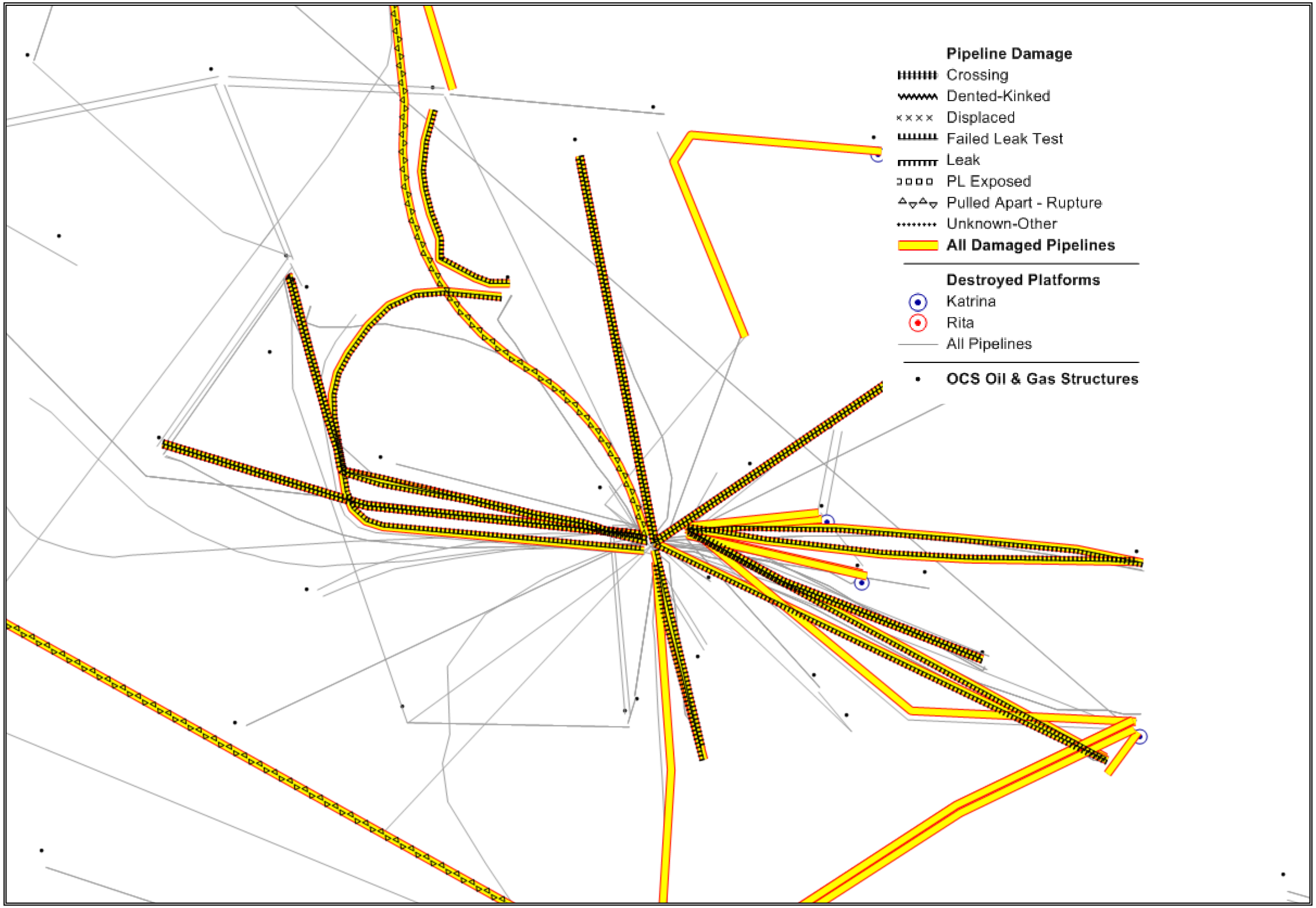
When 25% of the damage reports were identified in ST 21, DNV focused on the further analysis of this location with the mapping tool to see if there were any reasons to this Area's higher percentage of the total damages reported.

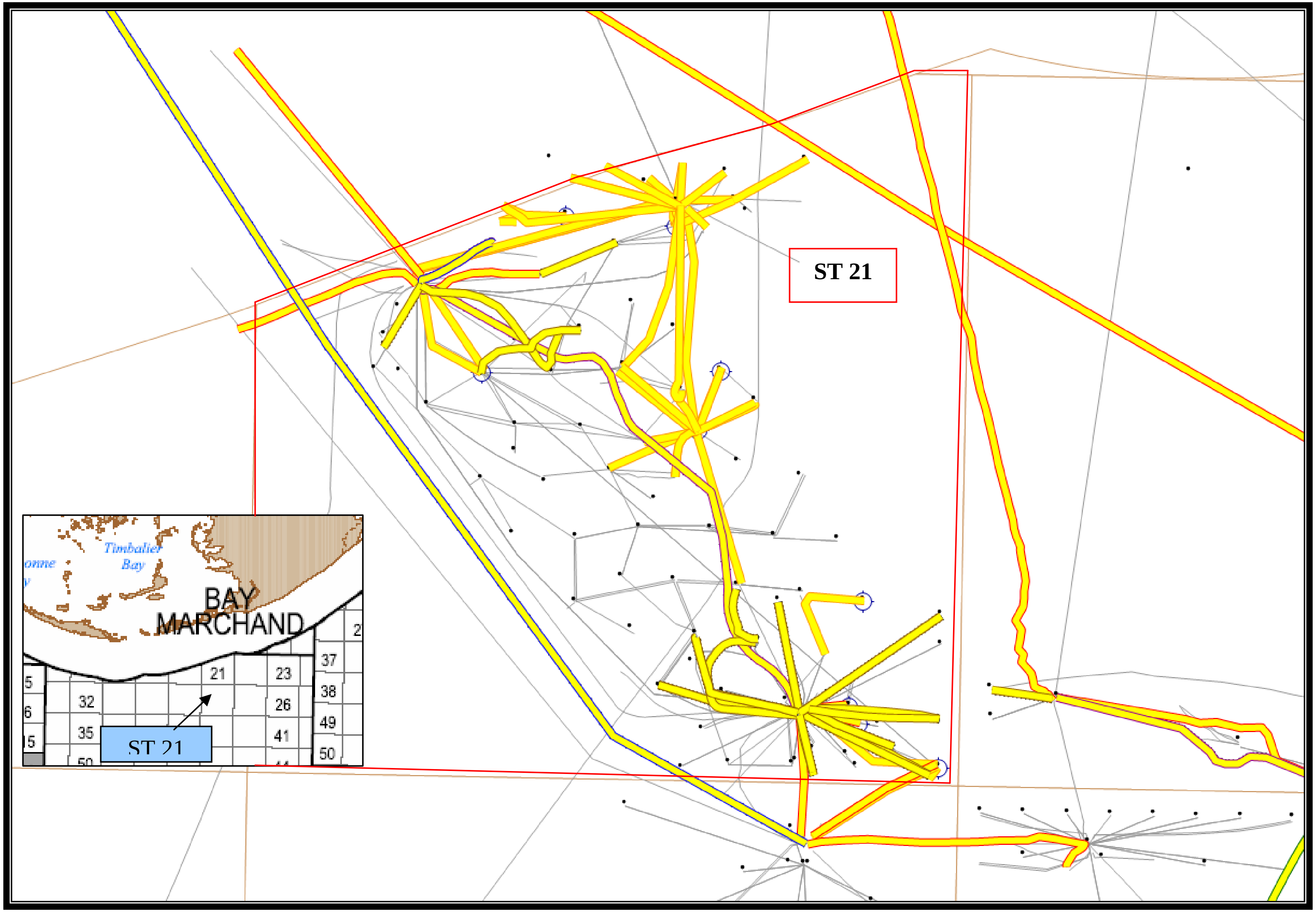
The area of South Timbalier experienced several platforms that were totally destroyed. As a result, numerous riser damage reports were filed by several companies to reflect these impacts to the risers from the platform damage. The map to the left is a zoom box view that focused on the damages in this area to further review what was reported by pipeline operators in and around ST 21, in particular.

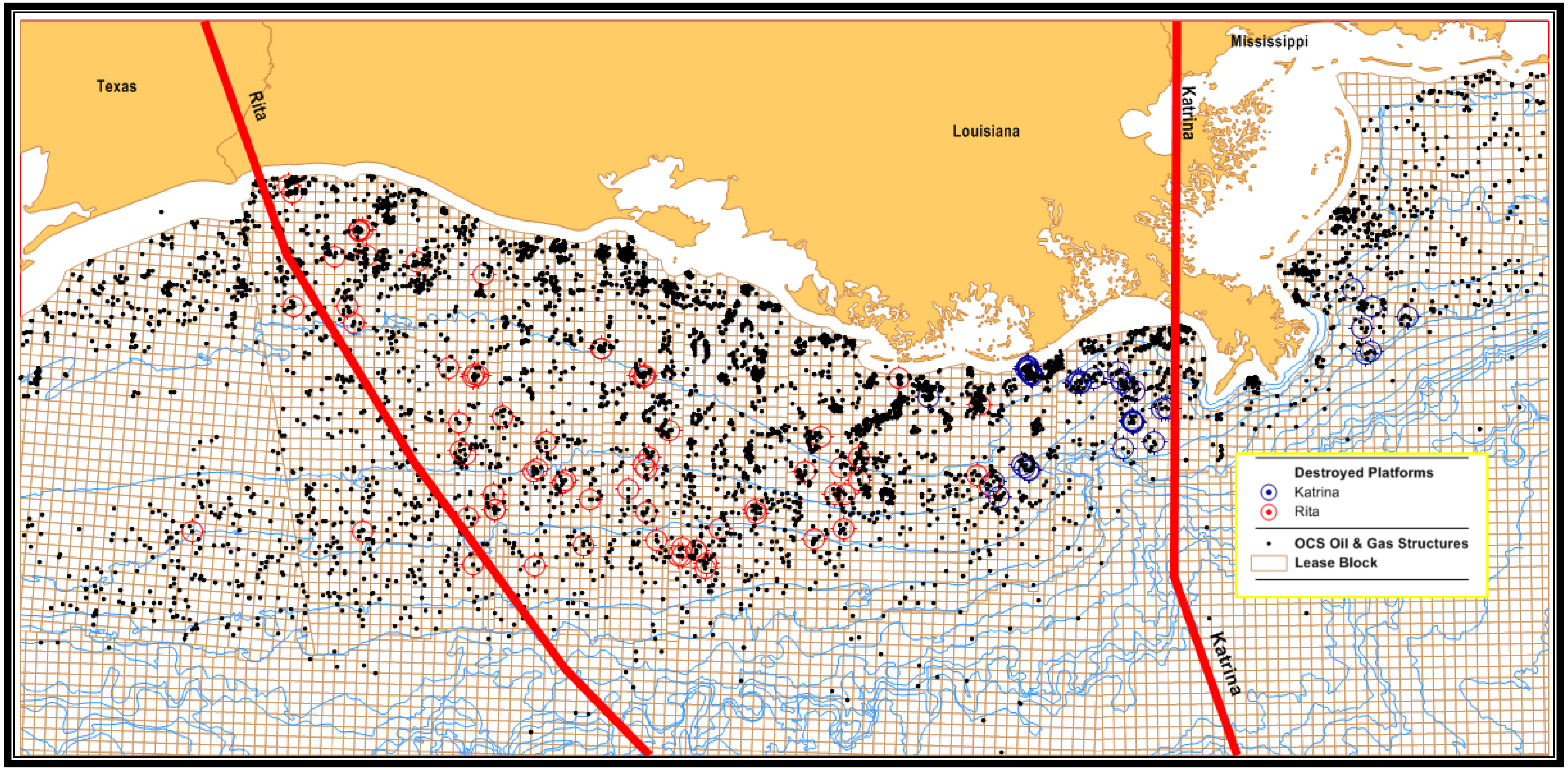


There were 81 damage reports for risers in this Area. Out of this total, ST 21 had 53 damage reports due to platforms destroyed and the associated damage reports filed for these segments. The views to the left and above were zoom views to look at the detail of the damages in this vicinity.

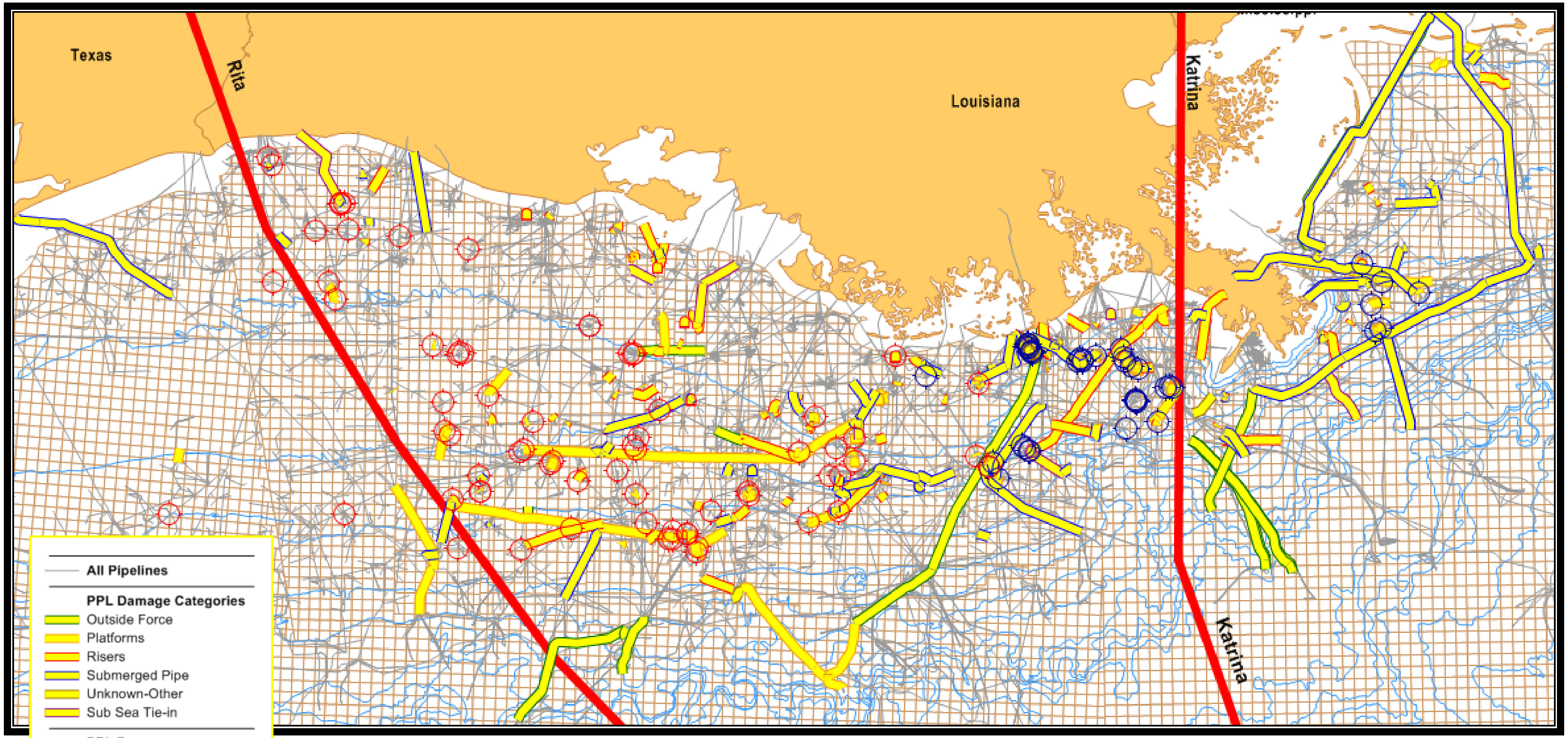
The next 2 pages show a larger view of the damaged segments in the vicinity of the south boundary of ST 21. The categorization of these segments based on the Excel spreadsheet damage description could not identify the fact that these are all associated with a destroyed platform. These segments will be recategorized to Platform in the final category analysis in the report Conclusions Section.

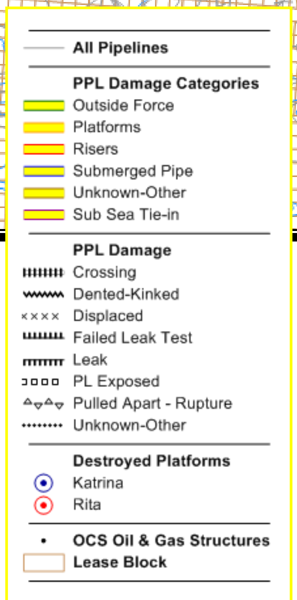

Pipeline Damage
Crossing
Dented-Kinked
Displaced
Failed Leak Test
Leak
PL Exposed
Pulled Apart - Rupture
Unknown-Other
All Damaged Pipelines
Destroyed Platforms
Katrina
Rita
All Pipelines
OCS Oil & Gas Structures


ST 21
Timbalier
Bay
BAY
MARCHAND
21
23
26
32
35
37
38
41
49
50
ST 21



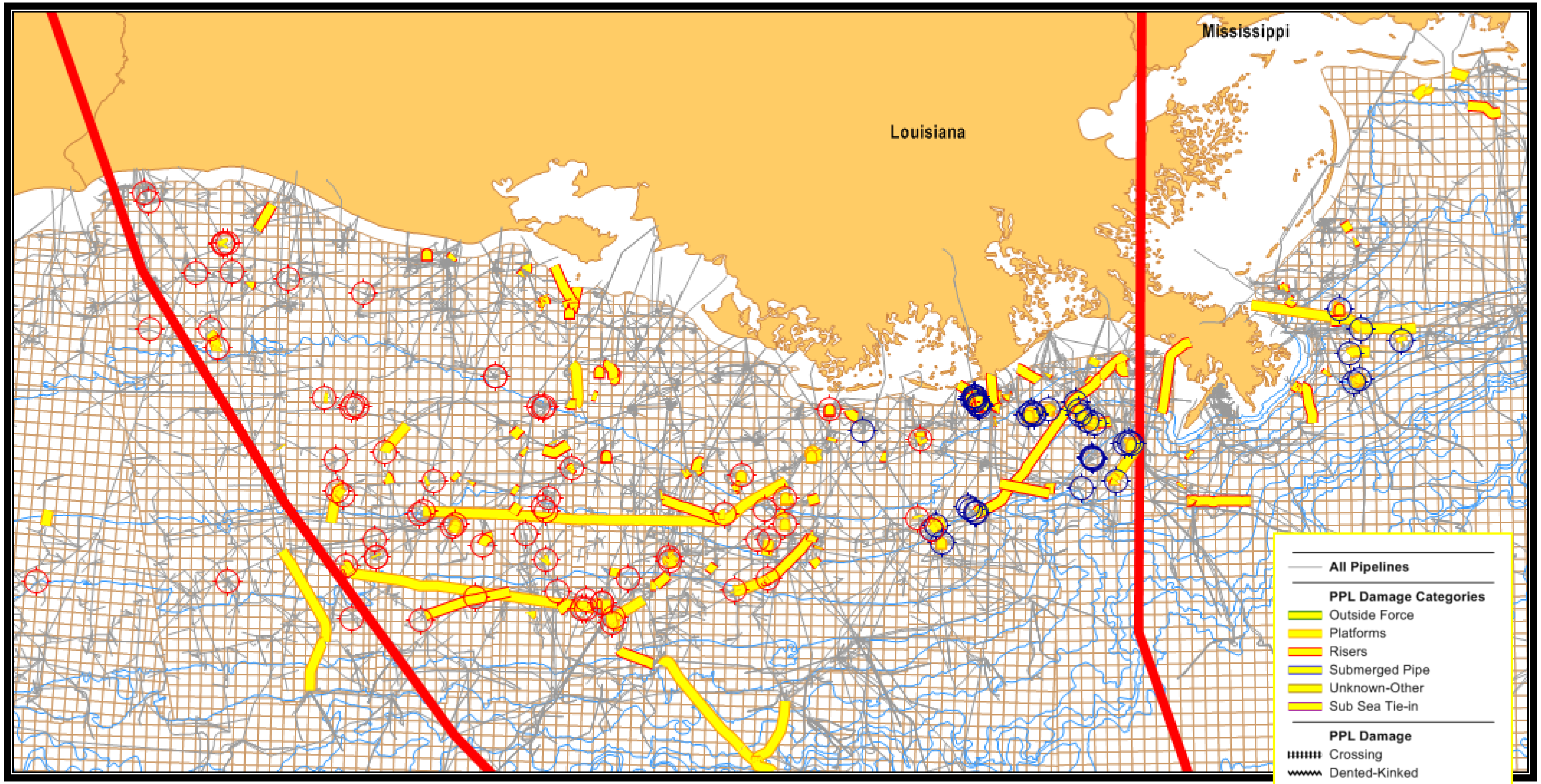
The total set of 116 Destroyed Platforms was plotted as a layer of the map, as represented in the screen shot shown above. The number of damage reports attributed to platforms damaged and destroyed numbered 233 reports. From a statistical perspective, this would suggest an average of 2 pipeline damage reports per destroyed platform, yet the platforms in ST 21 had more than 50 reports for the 10 destroyed platforms, averaging roughly 5 damage reports per platform destroyed. It would appear that there is a significant difference in the reporting of the riser and pipeline damages related to platform damages, and as noted earlier in this study, there appears to be no direct correlation to the number of damage reports and the actual number of damages that have occurred due to the inconsistency in reporting methods and formats. With the lack of reporting consistency by the industry, it is not accurate to use statistical methods for the assessment of damages related to pipelines in the GOM. However, with that said, and assuming that the inaccuracies in data reporting have been relatively constant; the statistical averages for these two hurricane events have been within the historical experience in the GOM as a result of Hurricanes.



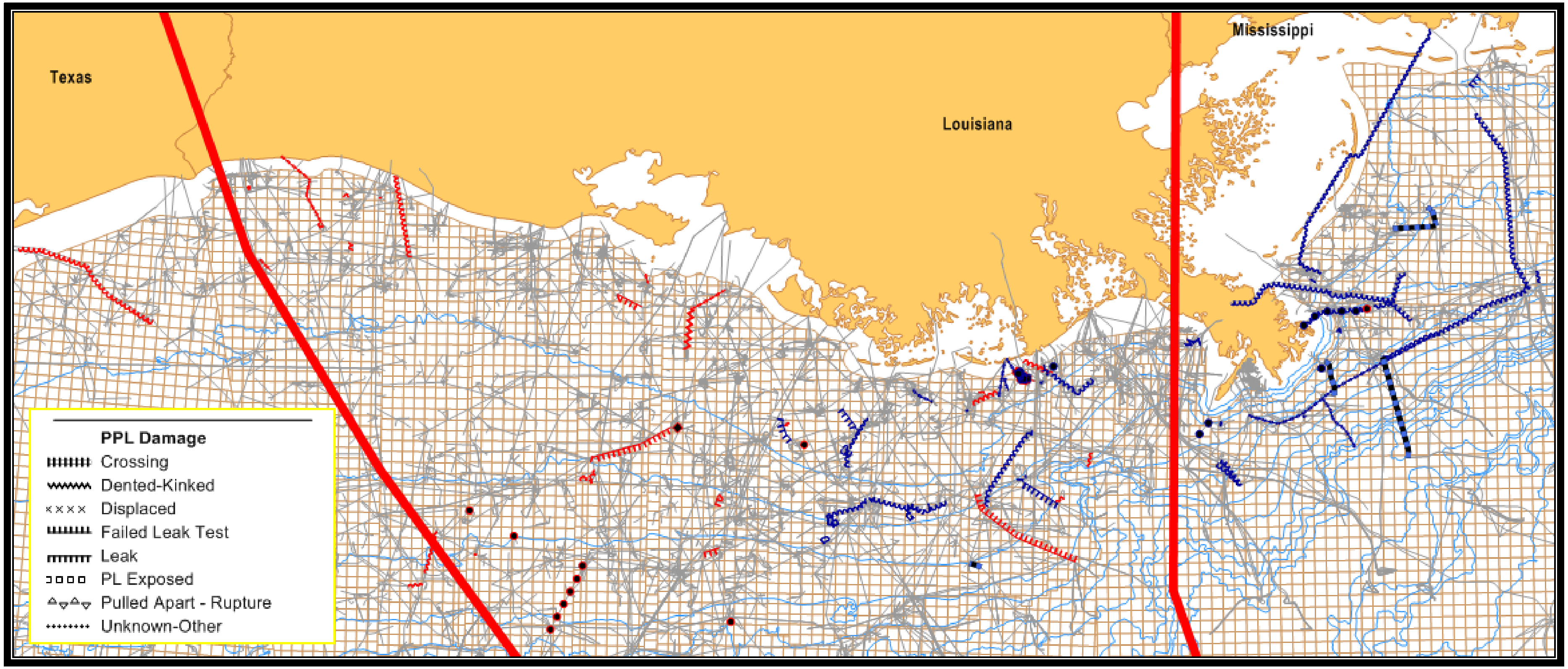


This map shows all 542 pipeline segment damage reports overlaid with the 116 Destroyed Platform Layer. From this map, the user can zoom in using the Zoom Box key to look at areas of interest, or select layers to turn on or off for further analysis. The map on the next page is a subset of this total damage set created by selecting the type of damage categories to be reviewed from the list of choices on the mapping tool screen view. Selection or de-selecting the layers turns the map symbols on or off for the user's visual analysis of the various damage category sets.

The following series of maps will show the various categories that were used in this report, all of which are subsets to the damages shown in the map shown on this page.

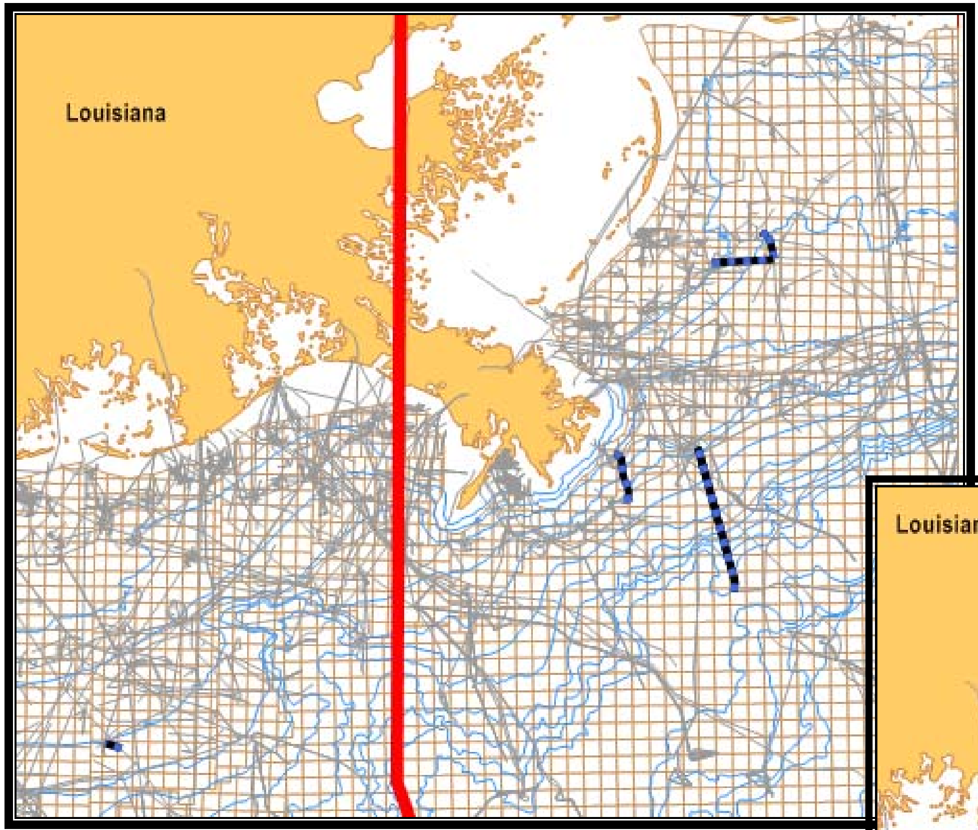


This map shows the damages that are categorized as Platform and Riser overlaid with the 116 Destroyed Platform Layer. Several layers, such as OCS Oil and Gas Structures have been turned off to remove some of the data from view. From this map, the user can zoom in using the Zoom Box key to look at areas of interest. As shown in the Key to the right, the platforms destroyed in Hurricane Katrina are shown as blue circles, and those destroyed by Hurricane Rita are shown as red circles. These circles represent the list of Destroyed Platforms studied by another MMS study team, and do not include platforms that were damaged. The yellow lines represent the pipeline segments that were categorized by DNV into the group Platform or Riser.



This view shows the DNV subset of 137 damage reports referred to herein as the DNV PL Study Damages which have been given a symbol for each damage category. The symbols represent a layer in the map for use in visual analysis of the various categories by turning map layers on or off, grouping and allowing zoom–in capabilities and the ability to look at other structures in the area.

This view has the lease blocks, hurricane paths, all pipelines, ocean floor contours and state map layers turned on along with the DNV PL Study Categories as represented by the various symbols in the map key. The screen version allows a much larger view than is captured here for the report format, and can be viewed in smaller sections, and can be zoomed-in and centered as selected by the user. This view is intended to show the entire damage area studied for this category for both hurricane events. The following maps are a view of each of these categories selected as a single layer, and then a second view adding the Destroyed Platform Layer.

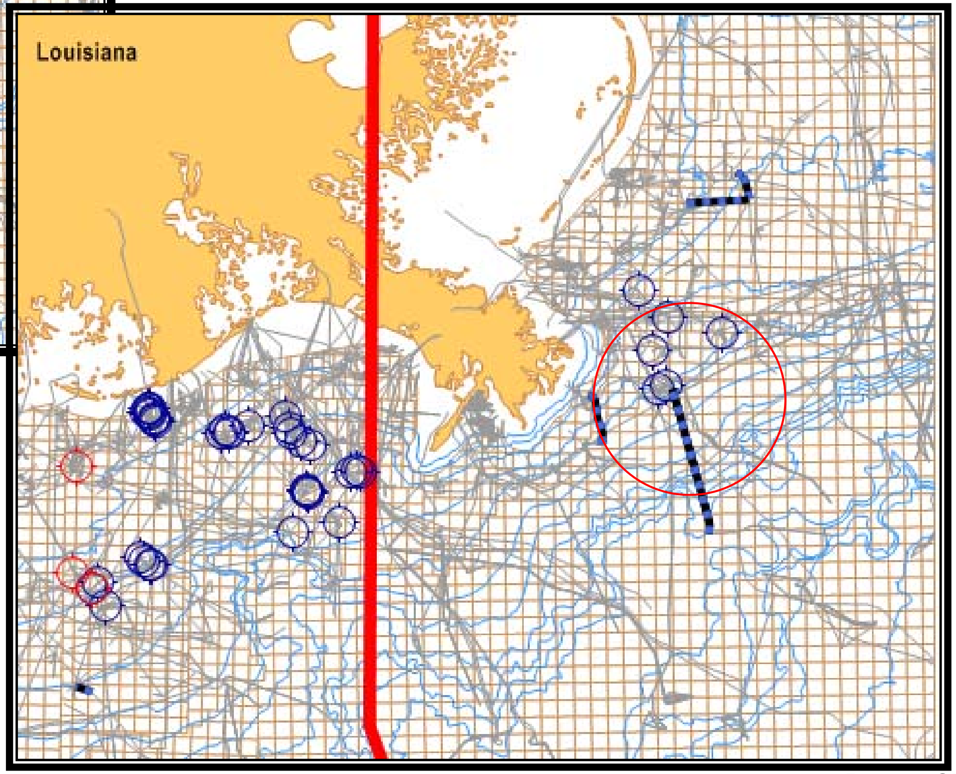


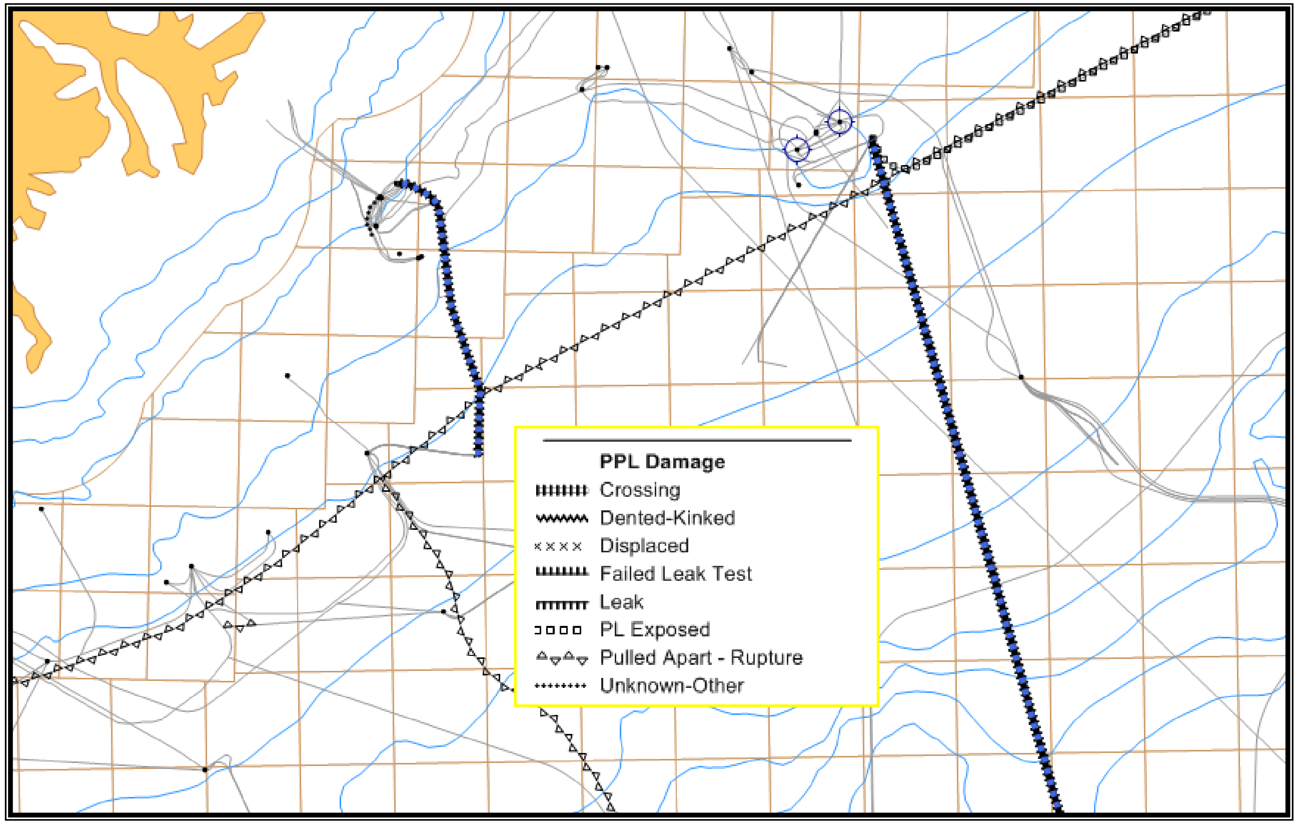
The view to the left shows the pipeline segments that were categorized as Crossing in the DNV PL Study Damage set of damage reports. This group represented 7 damage reports for segments that had no pipe or riser damage where the crossings had moved, lost separation, mats were lost, and two reports of pipe to pipe contact.

This group of reports were all BLKG except one report that was BLKO product codes, ranging in size from 4" to 12" in diameter, all under 7 years of age, except for two with no age reported.

The view to the right has added the Destroyed Platform Layer to see if any there might be contributing factors from platforms.

One segment appeared to be near a destroyed platform, so the area marked with the red circle was zoomed-in and then reviewed further to look at other damages in the areas, as well as Destroyed Platforms. These views follow on the next page. Upon further investigation, all of these were categorized as Outside Force for the final categorization of the damages.



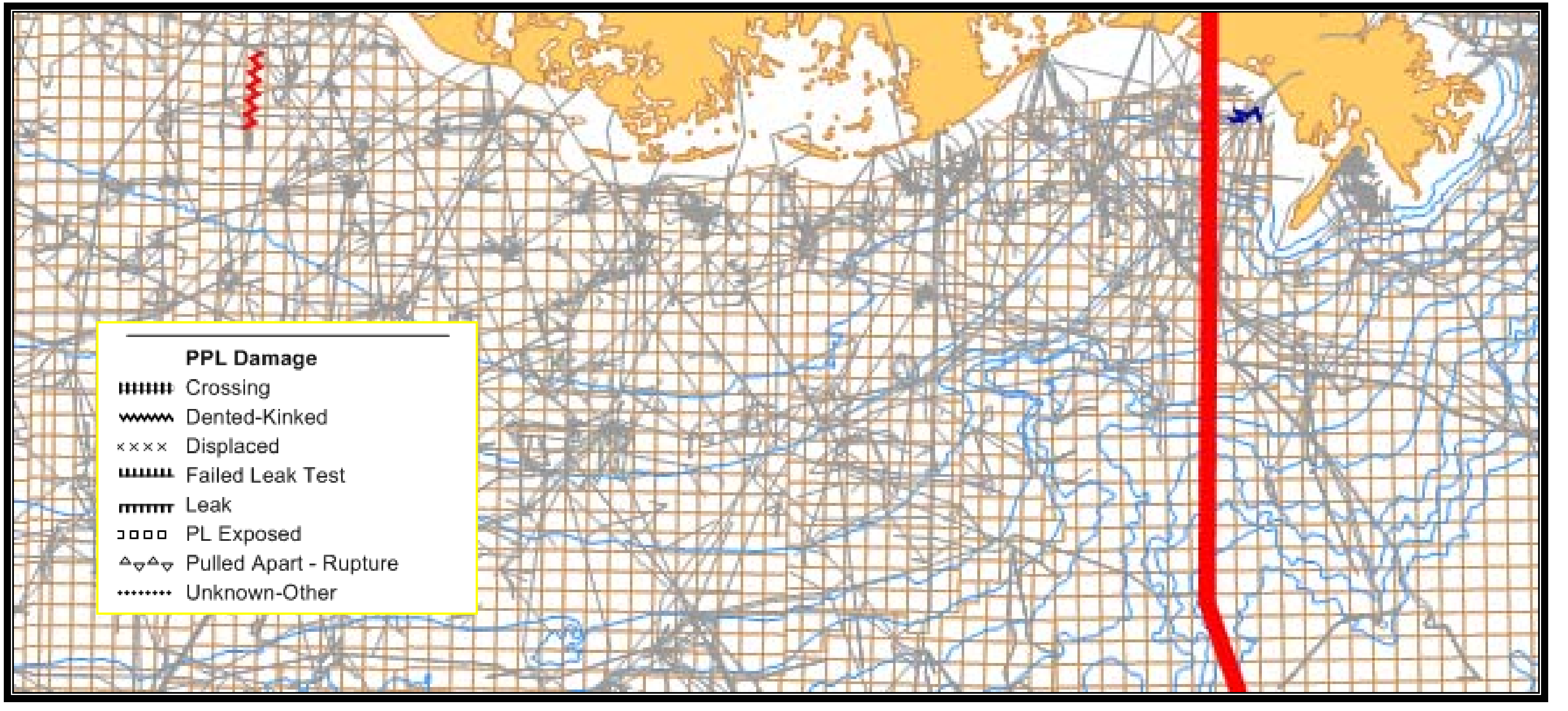


The zoom-in view of this area indicated that there were platforms adjacent to these facilities that were destroyed. It is unclear what impact they may have had upon adjacent pipelines, and there is no clear correlation as to platform damage. There are however, other pipelines that suffered movement and were displaced that were associated with these crossings, as shown by the inset to the left.

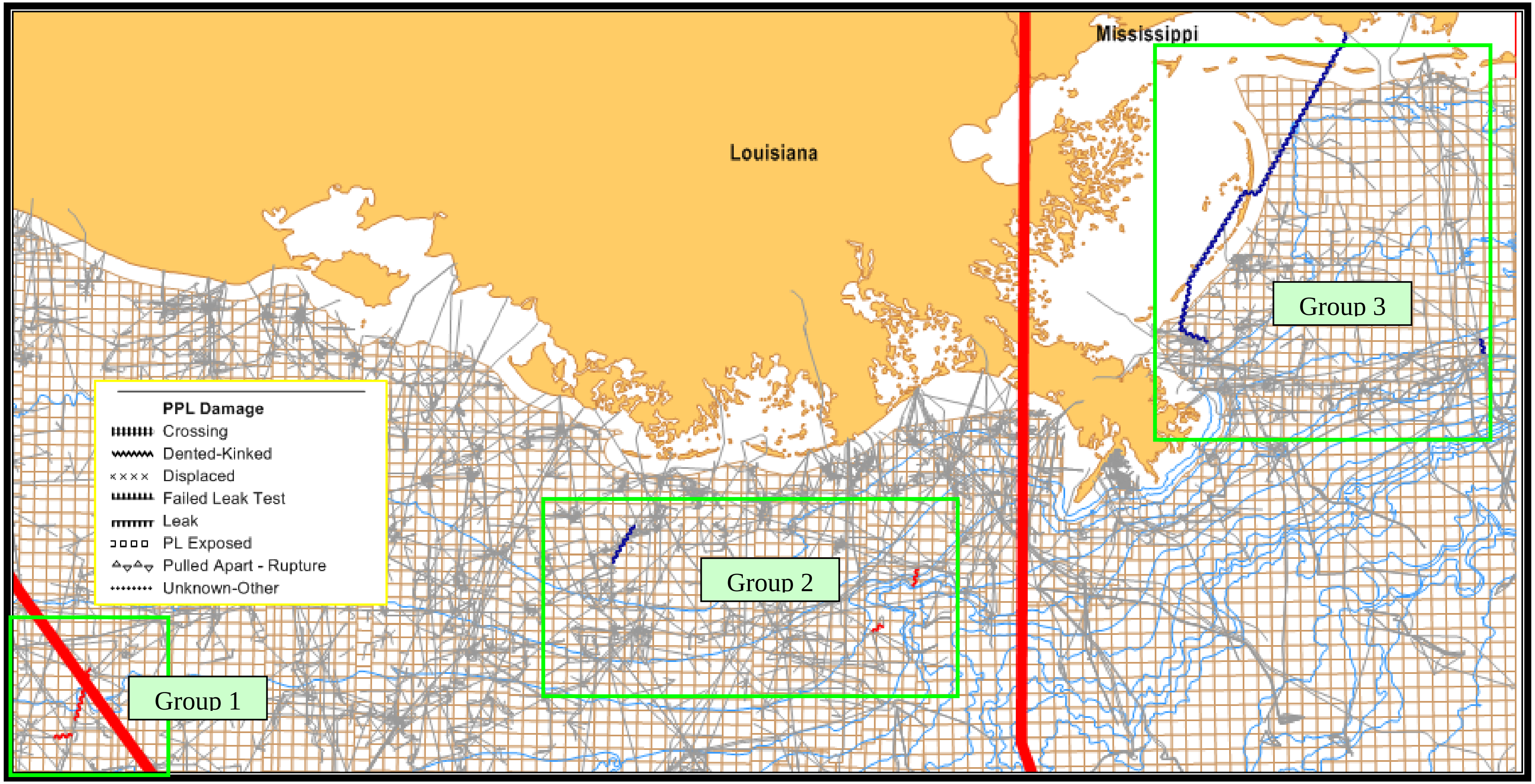
By turning on the other PL Study Damage layers, these two pipeline segments (highlighted in blue) clearly show influence from the pipeline segments that were reported as pulled apart and ruptured which were at the location of the crossing damage.

The damages reported in the Excel spreadsheet do not identify the location of the damage. Here in the map above, we can see that the damage occurred at the crossing, and not the entire segment that was mapped. Locations of the damages could be reported with the latitude and longitude for future improvements of the damage mapping. However, the reporting format as it exists ties the damage to the entire segment of the pipeline, and not the specific location. The map above shows damage to a long segment that crosses more than 8 lease blocks. If the location and extent of the pipeline damage was identified by coordinates, it could be shown in the actual location where it occurred.

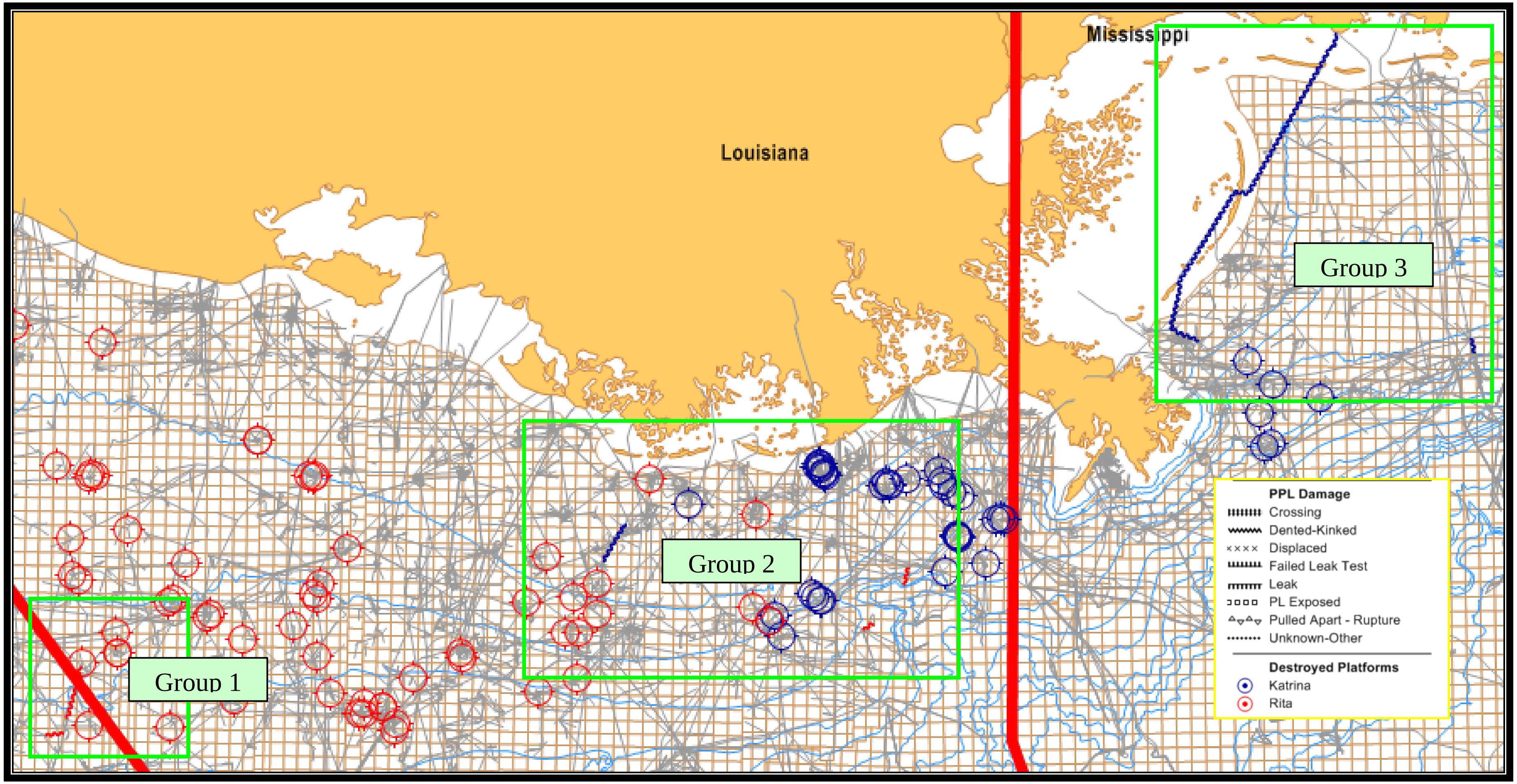
The pipelines that were pulled apart and ruptured will be studied to attempt to identify the possible causes and contributing factors for their damage as part of the category of PL Study Damages categorized as Pulled Apart – Rupture. The damage reports are all interrelated in the physical world in the OCS; however, the segments are reported in a manner that does not indicate the associated facilities that had damages. This is clearly visible through mapping of the damages.



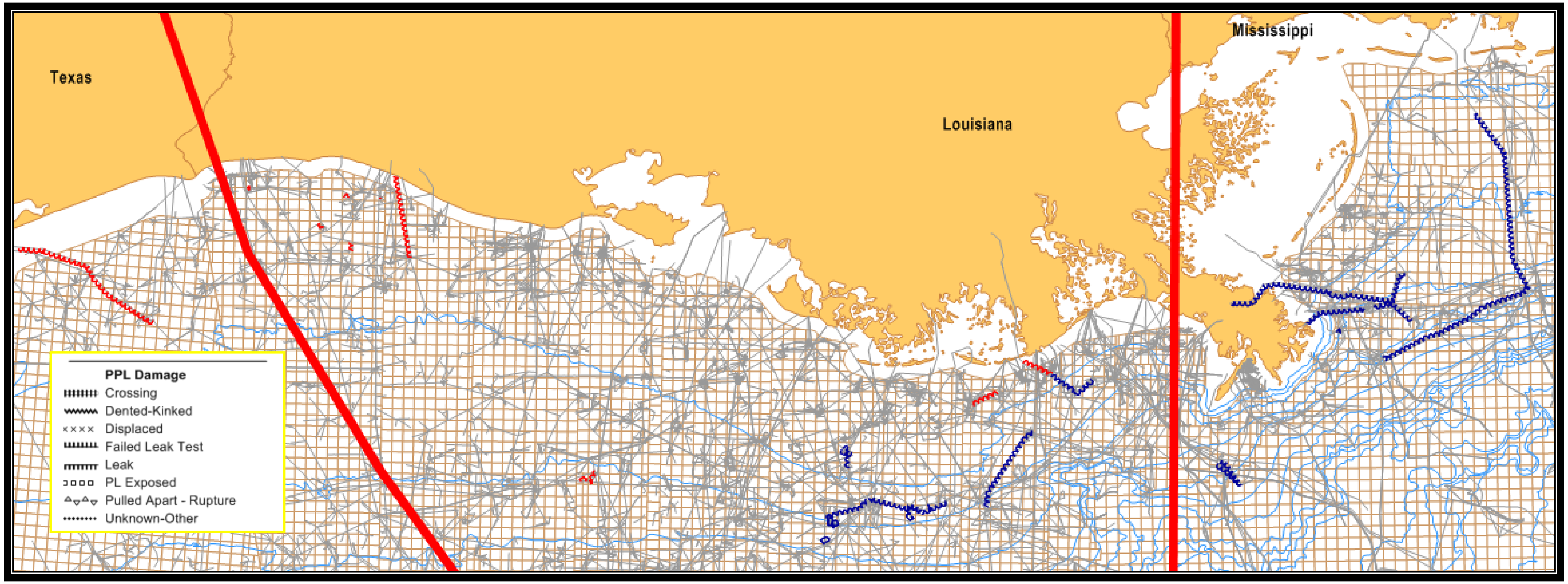
The group of damages from the DNV PL Study Damage set called Dented-Kinked had four damaged segments in the category. Two were clearly associated with damaged platforms, leaving the two damages shown above in blue for Hurricane Katrina damage, and red for Hurricane Rita damage. This view adds little information as to the cause of the damage, and further review of adjacent structures and detailed damage descriptions were necessary to categorize the possible cause or contributing factors. These two segments were not attributed to platform or riser failure, but had indication of outside force, and one was adjacent to a crossing that had a damage report associated with another segment. The cause of these remains indeterminate, but appears best categorized as Outside Force.



This view represents a group of 8 pipeline segments in the PL Study Damages that were categorized as Displaced. The Hurricane Katrina damage reports are shown in blue, and the Hurricane Rita damage reports are shown in red. Only seven of the damages were mapped as a result of one of the damage reports indicating the likelihood of the damage having taken place prior to the hurricane events as indicated by the marine growth on the pipeline. The remaining seven pipelines in this group range in size from 6" to 26" in diameter, and six were GAS and one was OIL product code categories. The range of ages was from 10 to 36 years old. The various damage reports were broken into groups and analyzed by the geographic location and other characteristics, along with adjacent damages that may have influenced their displacement.

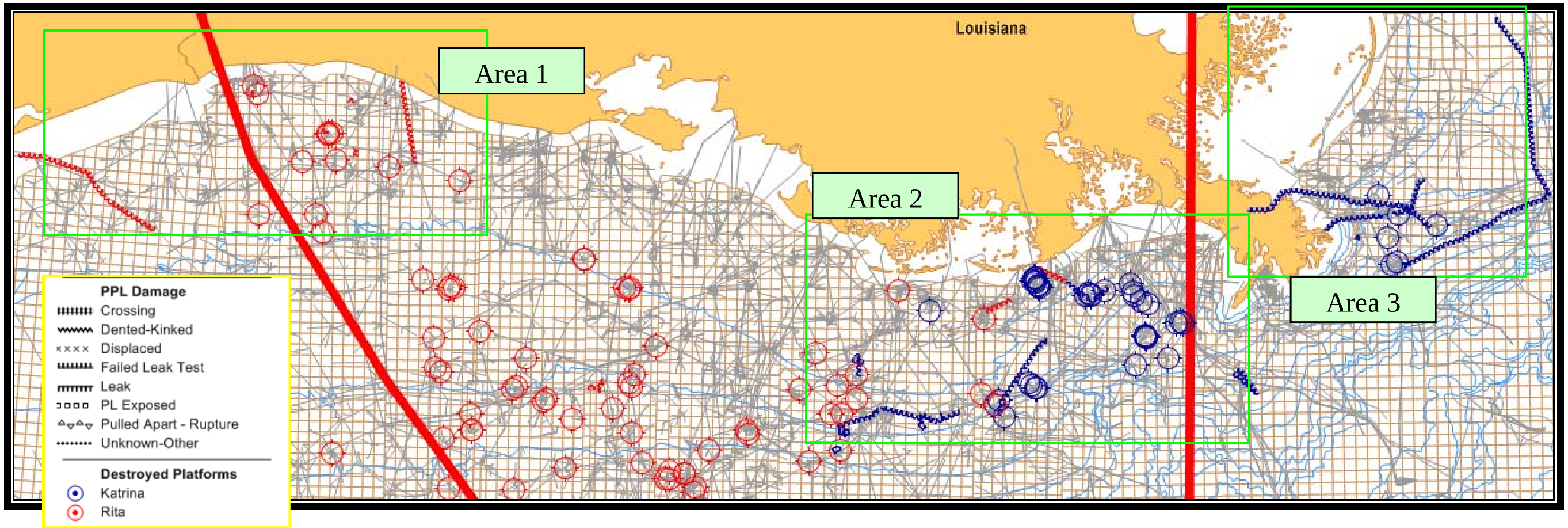


The three groups can be categorized as follows for cause categories. Group 1 is associated with Platform and riser damages for one damage, and Outside Force for the other. Group 2 are all associated with Outside Force, primarily impact from other objects, and Group 3 is Outside Force primarily associated with on bottom stability related concerns. These damages will be recategorized in the Conclusions Section of this report.



Pipeline Exposed -Span is the largest group of damages in the DNV PL Study Damage categories. The 45 damage reports represented segments with pipe sizes ranging from 2” to 36” in diameter, and were all types of product codes. The pipeline segment reported damages are described in more detail in Section 7.3.7 of this report. The mapping analysis was used to further evaluate the possible causes of these damages, and look for any commonalities that may exist for this set of damage reports.

The majority of the reports occurred in waters less than 200 feet, and the rest of the reports were in water depths up to 300 feet. There may be a correlation to the damages and the water depths due to the fact that the MMS NTL directed that inspections of pipeline tie-ins and crossings be conducted in water depths up to 299 feet. Unless there were failures that would have otherwise generated a damage report, it would be expected that the exposed and spanned pipelines would only be found in the locations where the inspections took place. However, these are the depths where historical pipeline damages not readily apparent from the surface have taken place as a result of hurricanes. The MMS reasonably limited the pipeline inspections to the water depths of most likely impacts from the hurricanes.

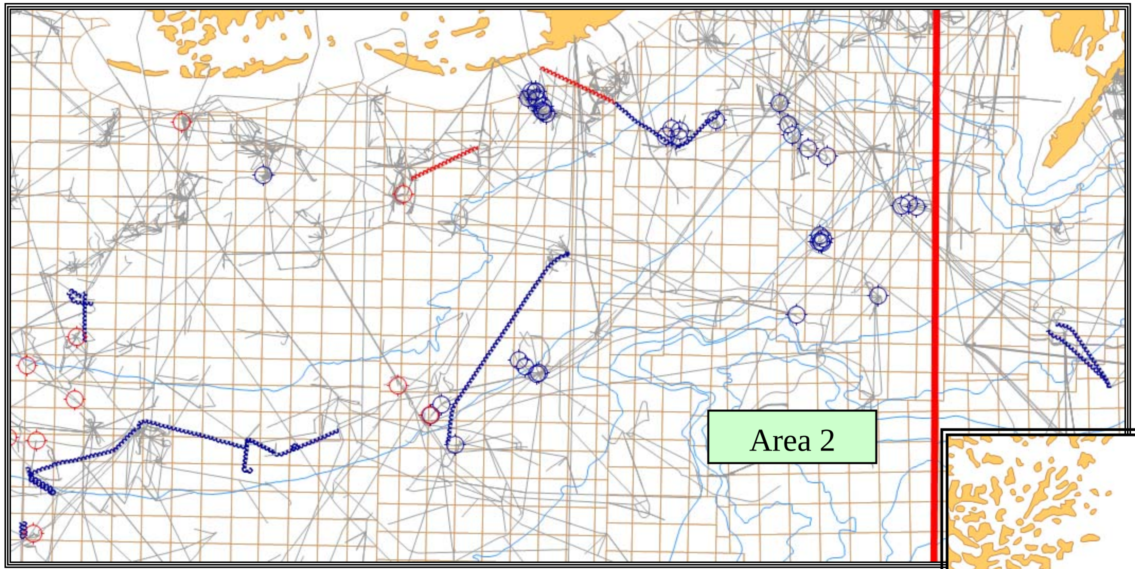


This category is the most difficult to assess as to the cause of the damage, as well as the ability to attribute the exposed pipelines and spans to hurricane events. The survey was triggered by the hurricane events, but when the pipeline was actually exposed or a span was created is indeterminate. DNV will categorize all of these causes into Outside Force, related to hurricane forces for lack of a more suitable category, at this time.

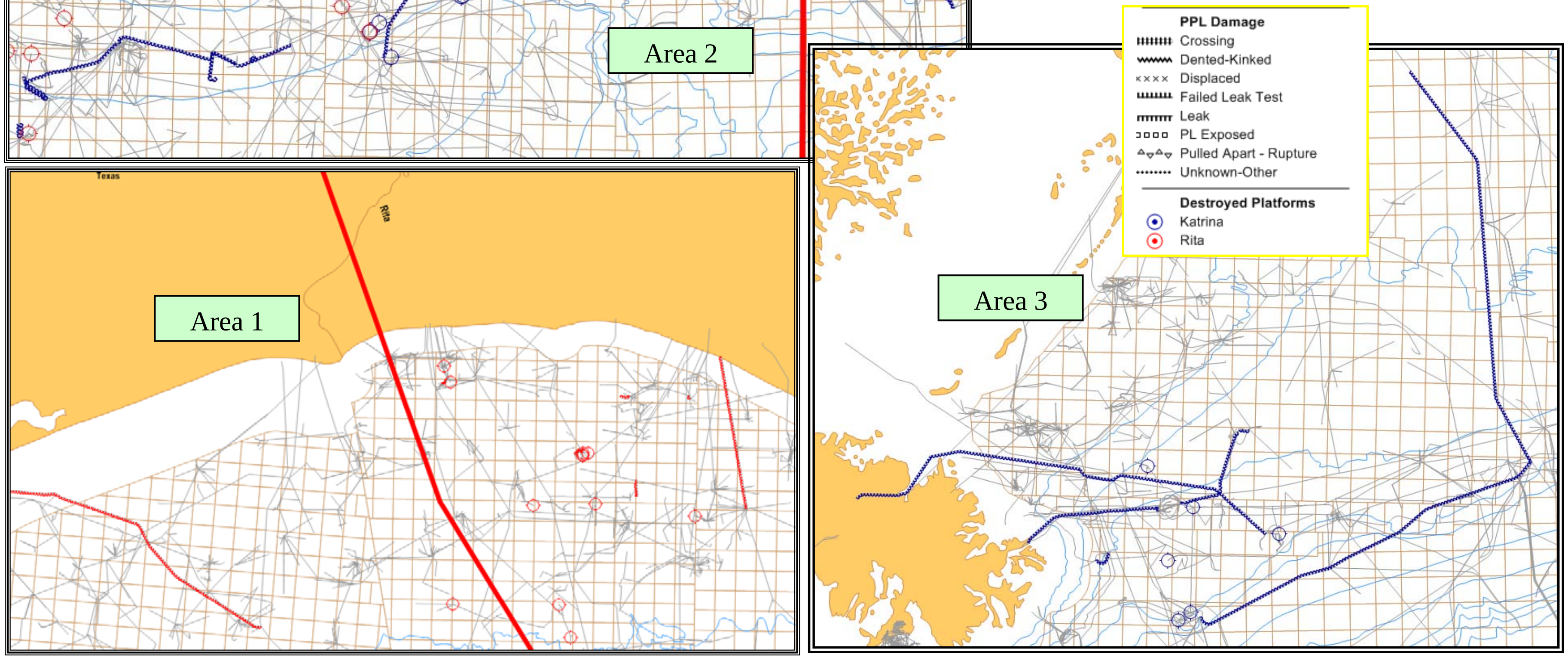
The following three maps break down the views into smaller areas to improve the ability to look at the Destroyed Platform overlay.

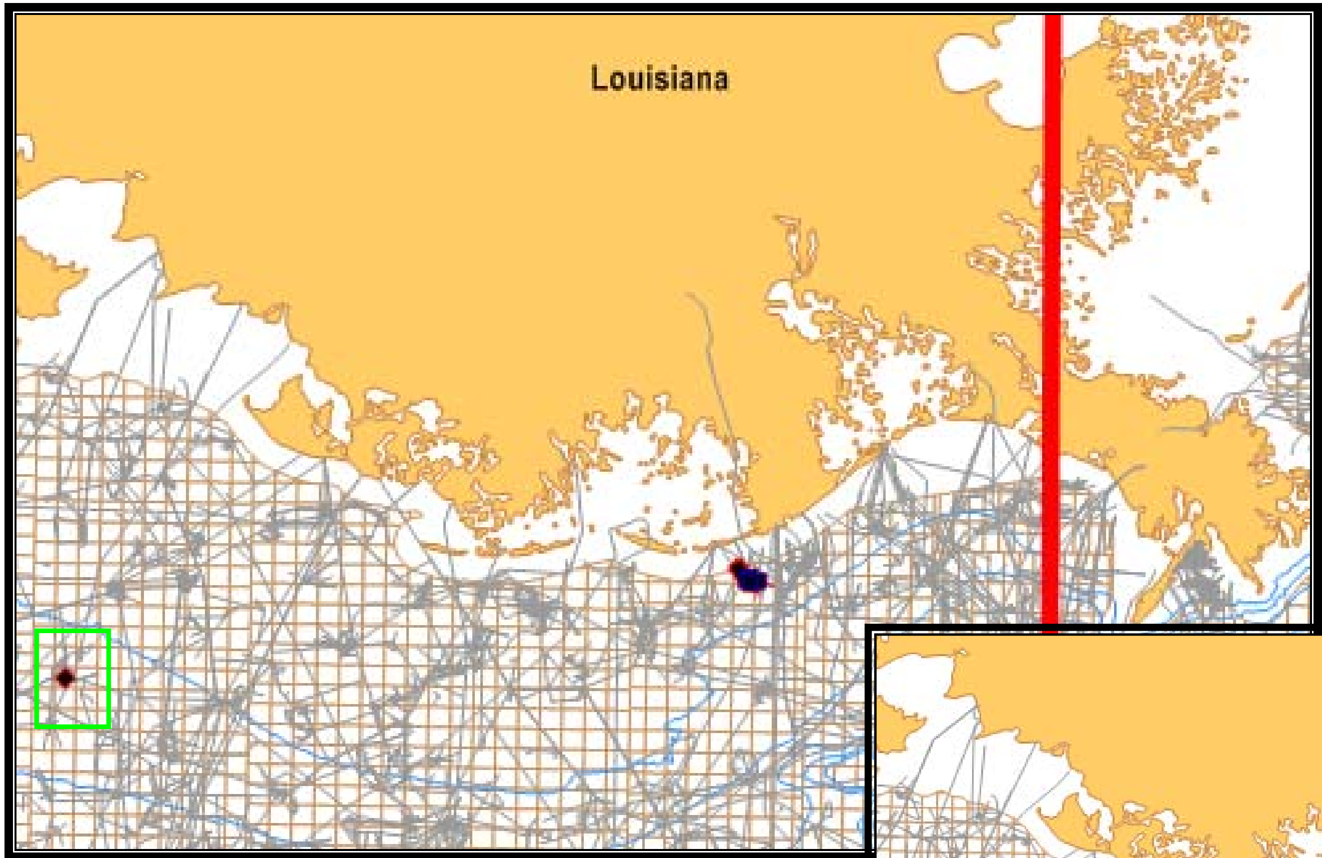
Destroyed Platforms would not usually contribute to this category of damage, however, the maps of the Exposed PL-Span were overlaid with the Destroyed Platforms to see if there were any identifiable contributing factors to this category of damages from the Destroyed Platforms.

.



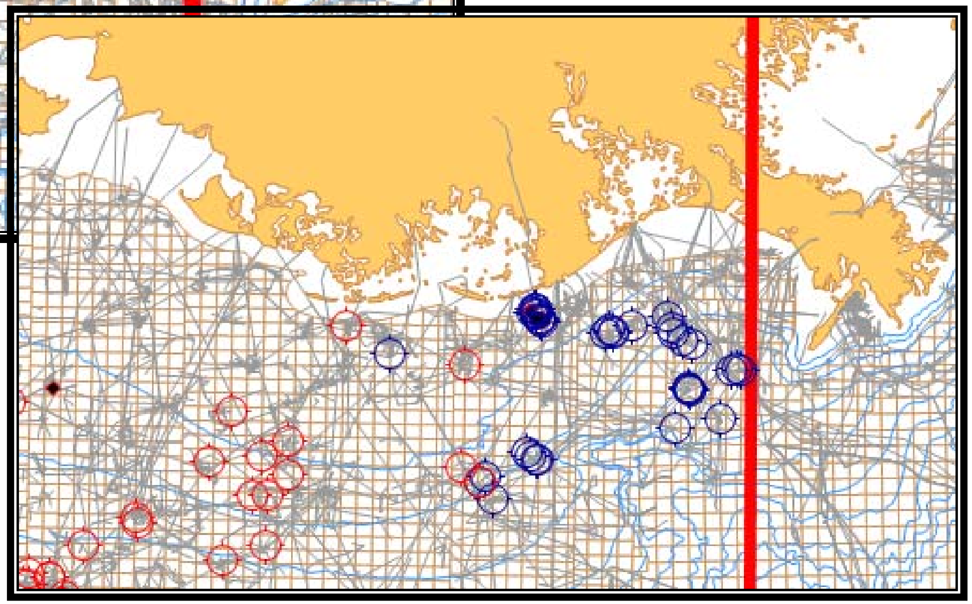
While many of the pipeline segments were adjacent to platforms that were destroyed, DNV could find no evidence that pipelines were exposed or spans were created as a direct result of the platform failures adjacent to these segments in all three areas.

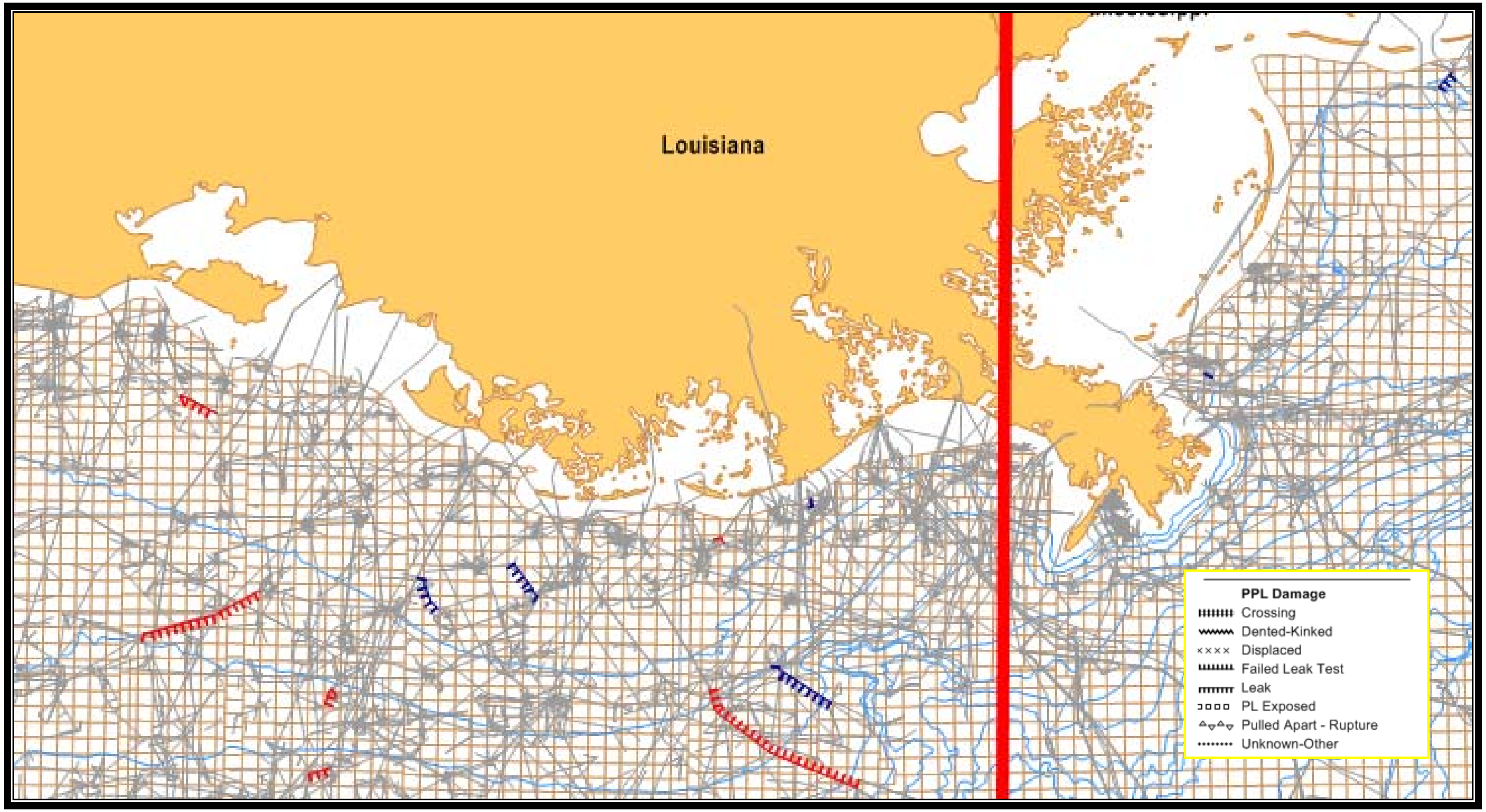




The category of Failed Leak Test damage reports shown in the map to the left were a subset of the DNV PL Study damages that were quickly shown to be attributed to Platforms Destroyed in the map shown below, as well as the analysis of the damage reports and other pipeline details. These damage reports were part of the mapping analysis example earlier in this report section.

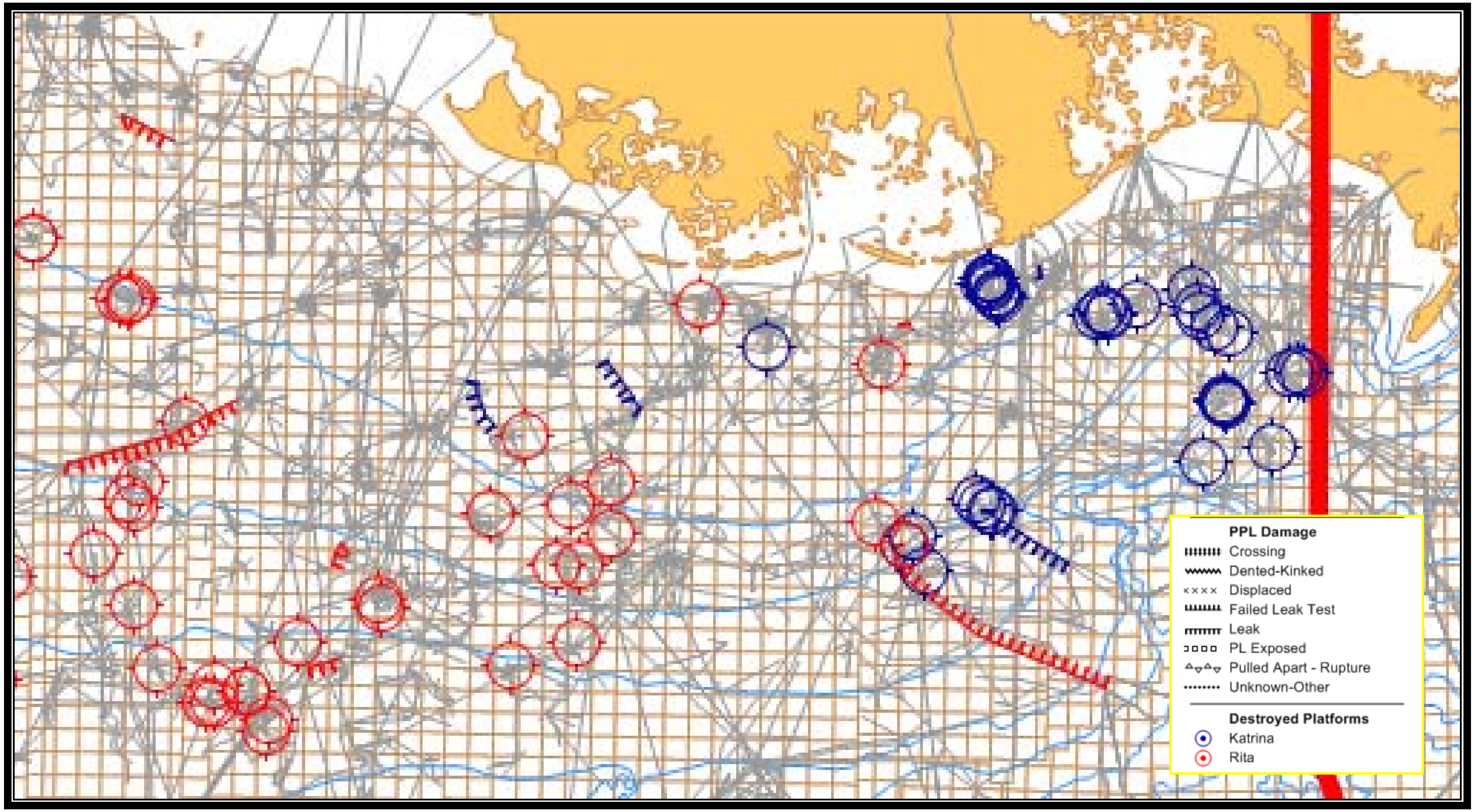
There was one outlier in the group of these 24 damage reports that was reported due to Hurricane Rita, shown in the green inset box on the map above. This damage was not attributable to a destroyed platform. There was enough detail in the damage report to attribute it to a leak from an outside force that contributed to crossing damage at this location. DNV will categorize this damage report as Outside Force in the Conclusion Section of this report, and the remaining 23 reports in the Platform or Riser category, as appropriate.



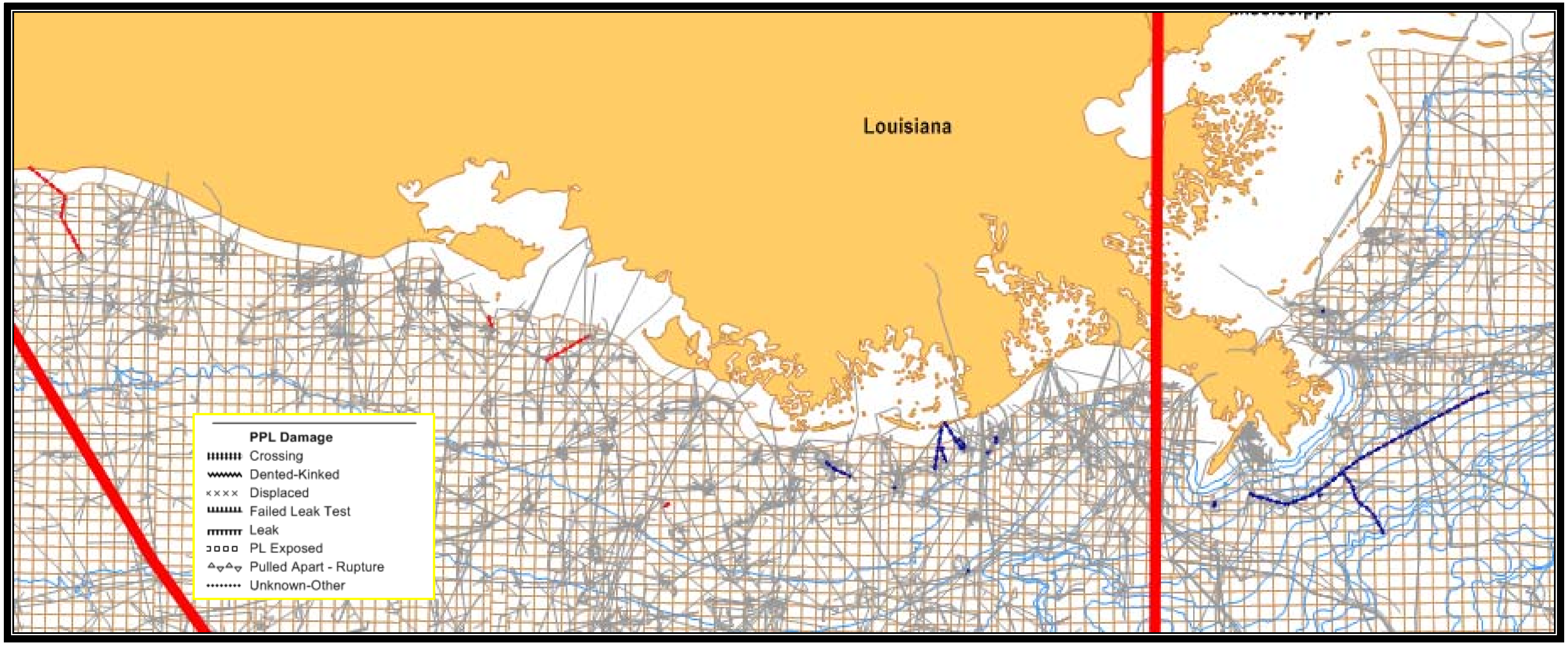


This map depicts the 13 damage reports that were categorized in the DNV PL Study Damage category of Leak. These pipelines all had reported leaks that were in various locations that all exhibited signs of mechanical damage that resulted from an outside force or impact that caused various forms of damages resulting in a leak at locations such as repair clamps, subsea tie-ins, welds or in the pipe body. None of these locations were risers.

When mapped, it was interesting to note that all fell within areas that were in the path of rigs that may have crossed over them as a result of mooring failures in the two events. Other than the potential exposure to outside force, there were no clear commonalities as the pipelines ranged in size from 4” to 24” in diameter, and were of all types of product codes, and ranged in age from 5 to 39 years.

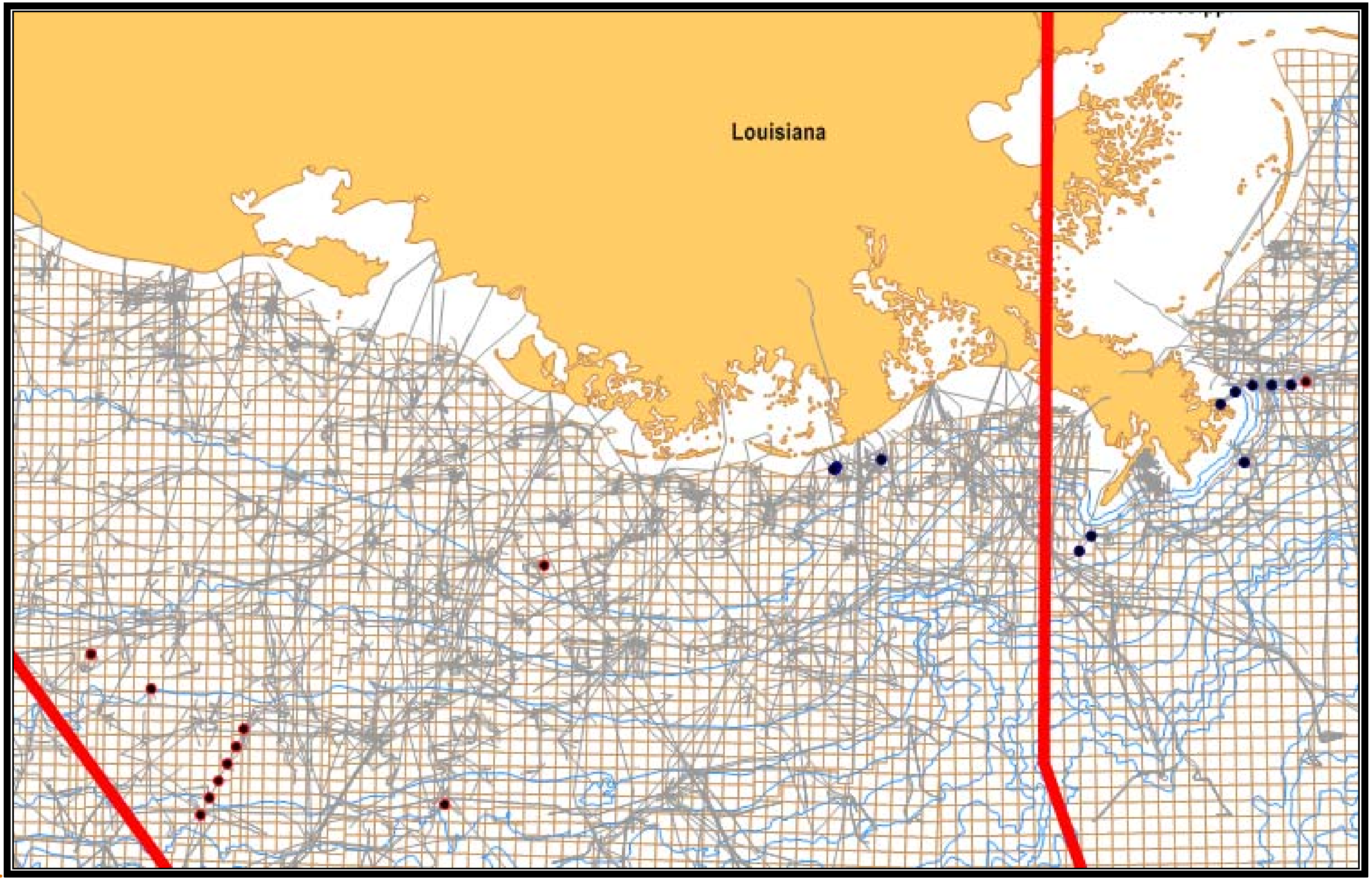


Mapping of the Platforms Destroyed over the damages reports categorized as Leak showed that platforms may have contributed to three of these segments, but it was unclear if the Platform was the cause of the impact. The damage reports made no indication of platform damage, and none of the damage reports were for risers. However, it was clear that some force or impact caused the damage, and as a result, DNV will characterize all of these damages as Outside Force for the purpose of categorization in the Conclusion Section of this study.

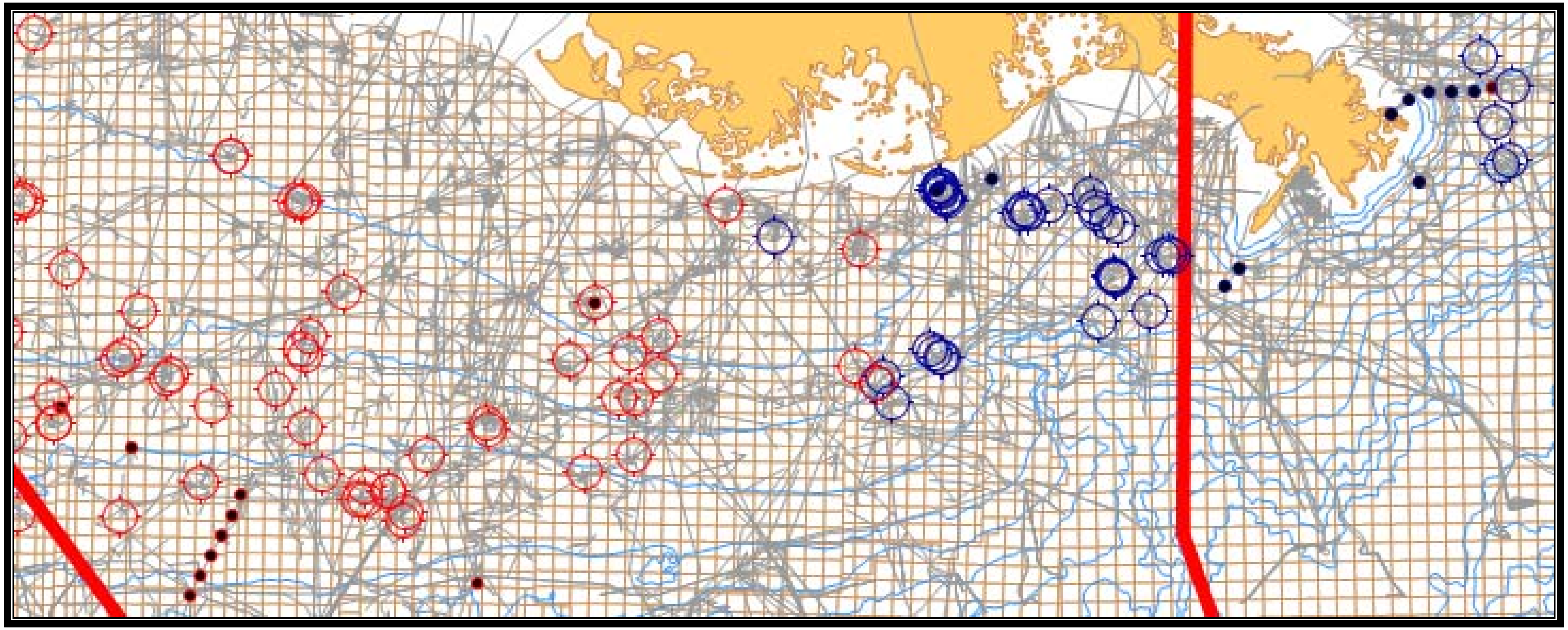


This map depicts the 24 damage reports that were categorized in the DNV PL Study Damage category of Pulled Apart-Rupture. These pipelines all had reported damages that were in various locations that all exhibited signs of mechanical damage that resulted from an outside force or impact that caused various forms of damages resulting in a line break. None of these locations were at risers.

When mapped, it was interesting to note that all fell within areas that were very near the OCS state water boundary. Other than the potential exposure to outside force, there were no clear commonalities as the pipelines ranged in size from 4” to 20” in diameter, had ages from 3 to 50 years, and were roughly equal in distribution of oil and gas and also equal in numbers of production and transportation pipelines. The damage locations were reported as 8 at subsea tie-ins, 3 unknown, and the remaining 13 in submerged pipe. Many of these segments were displaced, but it was not possible to identify if the displacement was the cause of the rupture, or the rupture allowed the displacement to occur. Of the total reports, 7 of these segments were attributable to damaged platforms that were not destroyed, and the remaining 17 damages will be characterized as Outside Force for the purposes of the summary categorization in the Conclusions Section of this report. It is unclear as to the cause of the pipeline damage, but it does appear the displacement due to lack of on bottom stability was a contributing cause, in absence of other outside forces.



This category includes 13 pipeline segments in the DNV PL Study Damages grouped as Unknown-Other. One damage report was for a pipeline that was under construction at the time of the hurricane, and roughly 7,300 feet of the pipeline could not be found, and was abandoned in place. The remaining 12 damage reports were identified as 3 having damage at submerged pipe location and the other 9 as unknown.



When the Unknown damages were overlaid with the Destroyed Platform layer, three of the damages clearly correlated with Destroyed Platform locations, and the rest were not identifiable as to the cause from the lack of damage information. This damage category will classify three of the damaged segments with the Platform group, and the remaining ten damaged segments as Unknown-Other.

11 CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations drawn from the work carried out in this study are listed in the following two subsections.

11.1 Conclusions

The conclusions reached during the performance of the study of the pipeline damage reports generated as a result of Hurricanes Katrina and Rita is that by and large, the pipelines are performing very well during Hurricane events, and that design code changes are not necessary.

The majority of pipeline damage experienced after Hurricanes Katrina and Rita occurred at risers and platforms, and as a result of outside forces. These threats are best managed through damage prevention and improved performance of the associated structures, and not design code changes to the pipelines.

Data does not exist to perform true scientific root cause analyses for pipeline damages except on a case by case basis where an investigation involving destructive testing has taken place. DNV does not see value equal to the cost of acquiring the data necessary to determine in-situ conditions of pipelines and instead sees the focus on the quality and ease of reporting and data management and development of visual mapping tools providing the most cost effective improvements to the data quality issues.

A small group of significantly large pipeline displacements occurred to older gas pipelines (15 to 40 years old) in shallow water. While pipelines are generally performing well, this was one area DNV identified that appeared to require attention due to the isolated experience in one sector of the industry that was not indicative of the performance for the rest of the industry.

Upon detailed analysis of available data and the mapping and damage assessments, DNV was able to better determine the categories of failures from what was originally reported. The original assessment of the damage causes prior to mapping and further assessment categorized the damaged segments as shown in Figure 41.

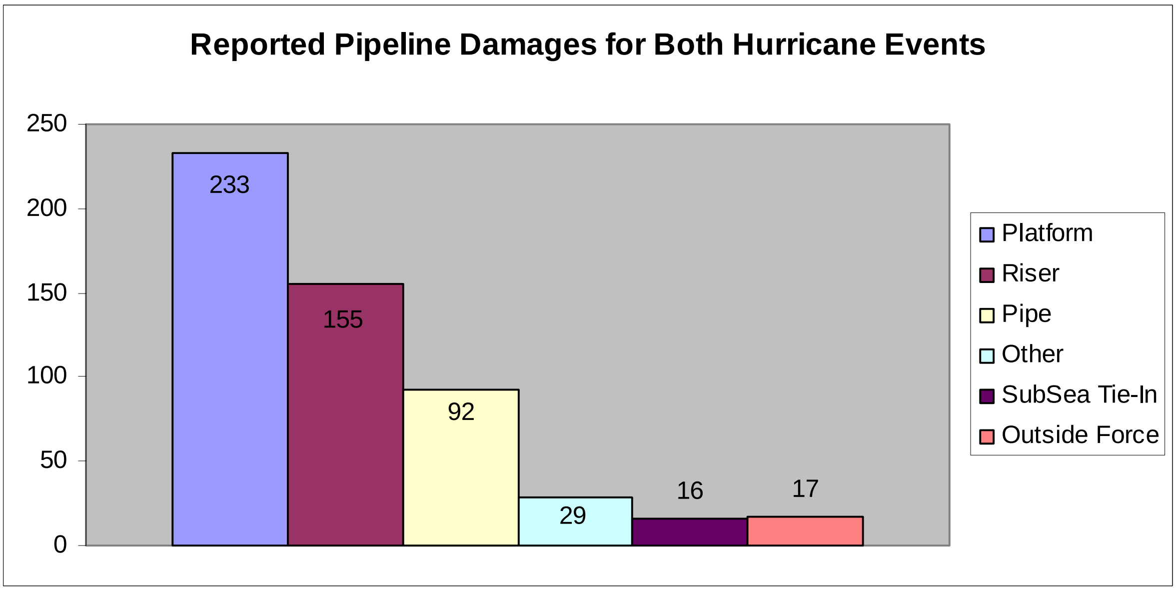


Figure 41- Categorization of Damages Prior to Assessment and Mapping

After the detailed analysis of the damaged segments, the available data, and the mapping assessment of the damages, the pipeline segments were categorized by cause as shown in Figure 42, resulting in fewer unknown causes, and a better understanding of the types of failures that occurred.

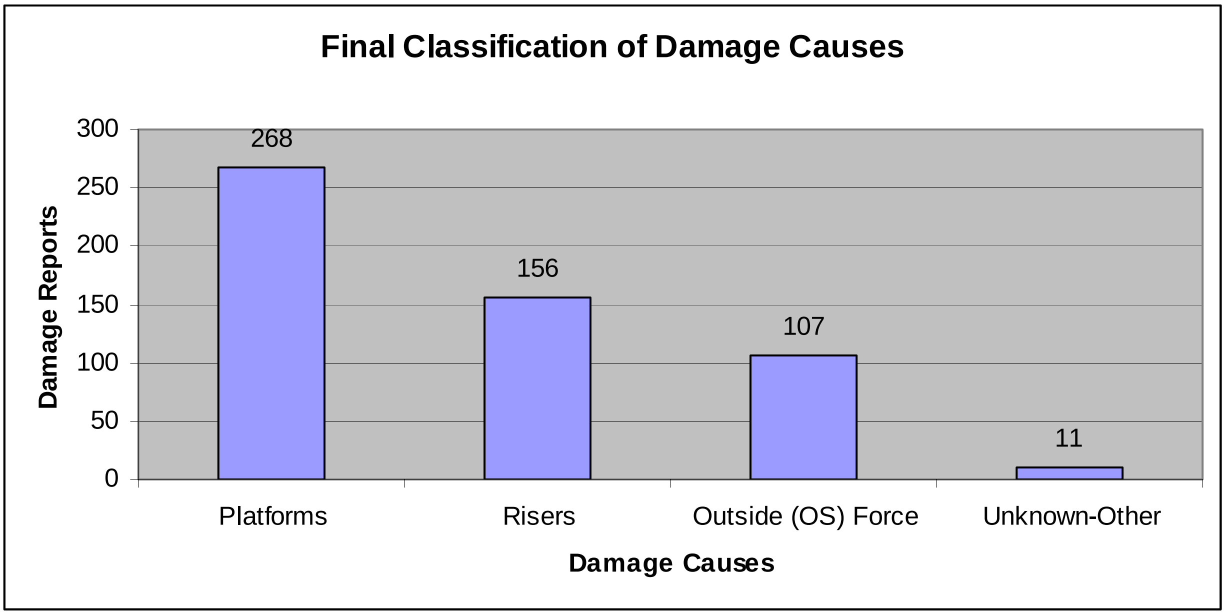


Figure 42 - Final Categorization of Damage Causes after Assessment and Mapping

The types of Outside Force were broken down into mechanical damage from impact or forces from other oil and gas facilities, and environmental damage from mudslide, hurricane or loss of cover or support.

The ratio of environmental to mechanical damage resulting from detailed assessment of the damage reports in the category of Outside Force is shown in Figure 43.

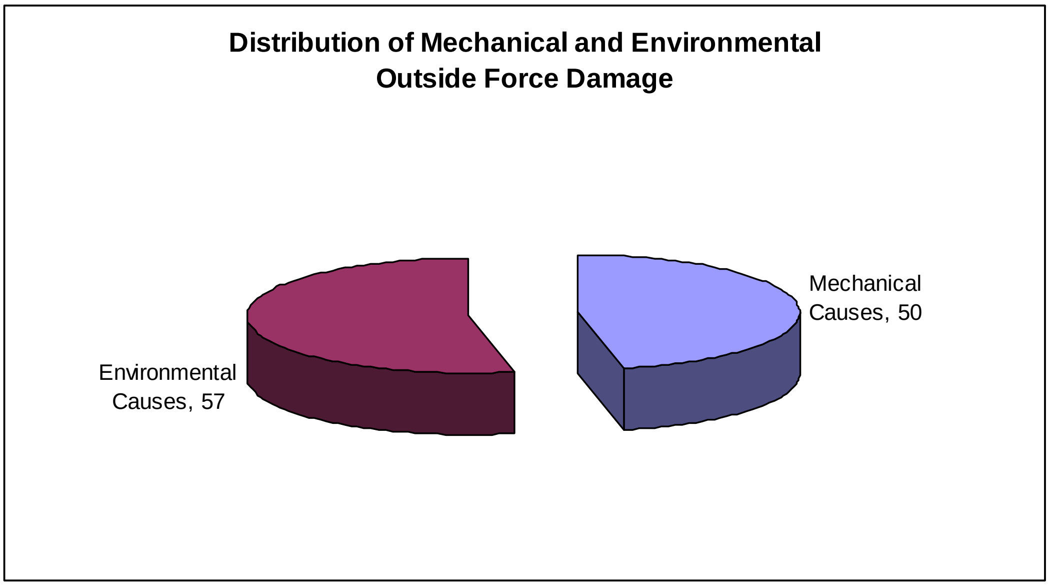


Figure 43 – Distribution of Outside Forces by Cause

In summary, the majority of the damages, or all but 57 of the 542 damage reports, were attributed to damages at platforms, risers or from mechanical forces causing an outside force related failure. The 57 damage reports are for segments that had hurricane impacts that resulted in loss of cover, spans, or movement as a result of hurricane forces. The majority of these 57 pipelines, or 45 pipeline segments of the 57, had a portion of the line exposed, or spanned as a result of changing bottom conditions, and did not suffer failures other than the loss of cover or spans that were created. The remaining 12 damage reports of this category could be considered as pipelines that could possibly have performed better than they did in comparison to design expectations mostly related to possible on bottom stability concerns. The group of 12 pipeline segments out of the 542 total set would equate to about a 2% rate of performance that was lower than design expectation for the total set of damage reports studied. If the entire pipeline mileage in the GOM was considered, this rate would be significantly below 1%.

Therefore, it is DNV's conclusion that the vast majority of the pipelines performed very well as a result of the hurricane forces, and pipeline damages would have been significantly reduced had there not been such significant impacts to platforms, risers, or the impact related outside force damages that occurred.

The minimization of environmental impacts and protection of life is an indicator of the commitment to safe operations in the GOMR and the industry. The hurricane preparedness and industry practices for response and recovery are producing the desired results. Continuing the activities that are in place in the GOMR should yield similar results in the future.

11.2 Recommendations

DNV offers the following recommendations to MMS:

1. Support the finalization of the efforts that have been initiated for the development of interim guidance on stationkeeping and platform design revisions to reduce damages to pipelines. Consider cross functional teams to facilitate sharing of pipeline and structure damage experiences in the industry and within the regulatory organizations.

2. Consider specific contact with non API members that do not participate in the Hurricane Readiness and Recovery conferences and study groups to expand the audience that receives the lessons learned from the valuable exchange of information and experience and continue the support of these industry activities.

3. Seek the sharing of position data from rigs that lose stationkeeping during hurricane events to notify pipeline operators where inspections are needed for potential impact to pipelines and risers.

4. Consider initiating a cooperative study with industry to identify pipelines that fit the profile similar to those that were displaced as a result of the passage of Hurricanes Katrina and Rita to identify potential corrective actions or preventive measures related to on bottom stability and exposed pipelines in the shallow water region in the vicinity of the Mississippi River Delta.

5. Consider development of a visual user interface for the damage database that allows the Pipeline Section engineers to visually analyze and query data for damage assessments and development of NTLs in response to hurricanes.

6. Emphasize the importance of maintenance practices at risers and platform pipeline interfaces through communications to operators via an NTL, or other method of industry outreach.

7. Consider identification of critical segments of the pipeline infrastructure for prioritization of restoration of service when competing interests are vying for resources.

8. Continue the industry and regulatory oversight practices related to planning, response and recovery to achieve the same good results.