New Mexico
GAS COMPANY

April 29, 2011

2011 APR 29 PM 4:15

Mr. Nick Guillen
New Mexico Public Regulation Commission
1120 Paseo de Peralta
Santa Fe, NM 87501

Re: NMPRC Case No. 11-00039-UT
In the Matter of an Investigation into New Mexico Gas Company's Curtailments of Gas Deliveries to New Mexico Consumers
Supplemental Testimony of Ken Oostman

Dear Mr. Guillen:

Enclosed for filing in the above referenced case are an original and five copies of New Mexico Gas Company's Supplemental Testimony of, Ken Oostman.

Copies of these testimonies have been sent to all parties listed on the Certificate of Service.

Please conform the sixth copy of each of the testimonies and return to our courier for our records.

If you have any questions regarding this filing, please contact me at 505-697-3832.

Sincerely,

Rebecca Carter
Regulatory Affairs

cc: Certificate of Service

NMGCO#2364031

BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF AN INVESTIGATION INTO NEW MEXICO GAS COMPANY'S CURTAILMENT OF GAS DELIVERIES TO NEW MEXICO CONSUMERS	)	Case No. 11-00039-UT
NEW MEXICO GAS COMPANY, INC.,	)	
Respondent.	)	

SUPPLEMENTAL DIRECT TESTIMONY

OF

KEN OOSTMAN

April 29, 2011

Q. PLEASE STATE YOUR NAME, TITLE, AND BUSINESS ADDRESS.

A. My name is Ken Oostman. I am the Vice President of Technical Services for New Mexico Gas Company ("NMGC" or the "Company"). My business address is 7120 Wyoming Blvd., N.E., Albuquerque. New Mexico.

Q. HAVE YOU PREVIOUSLY FILED TESTIMONY IN NMPRC CASE NO. 11-0039-UT?

A. Yes, my Direct Testimony was filed on March 17, 2011 with the New Mexico Public Regulation Commission ("NMPRC" or the "Commission")

.

Q. **WHY ARE YOU PROVIDING SUPPLEMENTAL TESTIMONY?**

A. As stated in my Direct Testimony at page 32, lines 18-32 and page 33, lines 1-2, the Company has been working with Los Alamos National Laboratories ("LANL") to evaluate the system pressures and flows at the time the decisions were made to curtail gas utility service in reaction to the early-February events. On, February 3, 2011, at the suggestion of Congressman Lujan, NMGC began working with the Energy and Infrastructure Analysis group at LANL to perform an analysis of mitigation options using a regional model of the New Mexico natural gas system. At the time of my Direct Testimony in this case, March 17, 2011, the Report from LANL had not been completed. Today, Friday April, 29, 2011, the Company received the final report as prepared by LANL. A copy of the LANL report dated April, 30, 2011, is attached to my Supplemental Testimony as NMGC Exhibit KO-Supp. 1.

Q. **DOES THIS CONCLUDE YOUR SUPPLEMENTAL TESTIMONY?**

A. Yes.

LA-CP-11-00476
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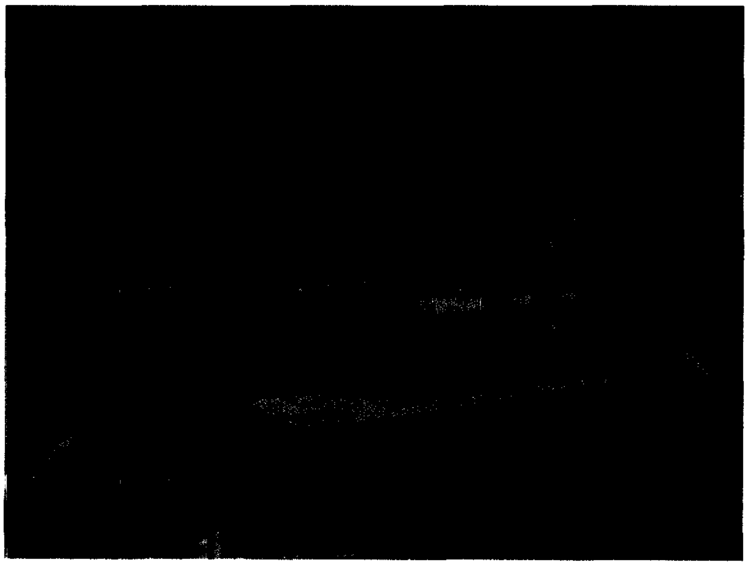
New Mexico Natural Gas Study

Energy and Infrastructure Analysis Group



Report to the New Mexico Gas Company
30 April 2011

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This study was funded under WFO Agreement Number NFE-11-0026.

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Executive Summary

During the week of January 31, 2011, severe cold weather affected large areas of the southwestern United States, resulting in abnormally high demand for heating and electric power. The increased demand for electric power coupled with direct effects of the cold weather on power system components led Texas power utilities to implement controlled power outages, i.e., rolling blackouts, to stabilize the grid and prevent widespread power failures. The increased demand for natural gas across the Southwest created conditions where utilities requested increased deliveries of gas to maintain system stability and customer deliveries. In New Mexico, the balance between the increased customer load and the supply of gas became an issue of significant concern for system operators. New Mexico, while itself a large producer of natural gas, relies on a series of interstate transmission lines that flow from western Texas, northwest toward Albuquerque. Natural gas systems use compressors at wellheads, processing plants and along pipelines to move gas from point of extraction to the point of delivery. Regional rolling blackouts in Texas created concerns about gas deliveries from western Texas to New Mexico due to the effects of lost electric power at compressors at wellheads and processing plants. On February 3, the effects of the Southwest cold weather snap on regional energy systems created a projected shortfall in supply relative to demand in the NM Gas Company service area. The shortfall in receipts of bulk gas deliveries to New Mexico Gas Company (NM Gas) prompted system operators to consider drastic options on system operation to prevent system collapse, i.e., uncontrolled loss of pressure, of their pipeline network. A system collapse would have generated significant safety concerns for affected communities.

In response to this event and under severe time and logistical constraints on how and when the load was to be shed, on February 3, 2011 at 0840 mountain standard time, NM Gas implemented a controlled outage by shutting in (i.e., closing) 1) the Otowi junction regulator station (north of Santa Fe), 2) the Bernalillo and Placitas border stations, and 3) requesting that PNM take the Cobisa electric power station offline to stabilize the northern New Mexico natural gas transmission pipeline system. This action stopped the flow of natural gas in Bernalillo, Placitas, and north of Otowi junction location, including the New Mexico communities of Espanola, Dixon, Taos, Questa, and Red River.

NM Gas requested that the Energy and Infrastructure Analysis group at Los Alamos National Laboratory (LANL) perform an analysis of mitigation options using a regional model of the New Mexico natural gas system. Using the WinTran and WinFlow models of the northern New Mexico natural gas transmission pipeline system provided by NM Gas, LANL analyzed alternative mitigation strategies that characterized the feasibility and impacts of other options on curtailment of service in the NM Gas Company service areas. For this work, LANL used a load contingency analysis approach, wherein different assumptions associated with probable events, i.e., removing a specific load (the contingency) from the model, are used to examine system response to that action. LANL also examined system response had no mitigation strategy been employed as well as response if all scheduled gas deliveries had been received. The study presented in this paper focuses on only the northern New Mexico transmission pipeline system.

The results of this study found that due to increased demand and a shortage of gas supplied to the NM Gas, customer load (demand for gas) on the northern New Mexico transmission pipeline system had to be shed to protect the system and the communities it serves. The total amount of demand shed was approximately 58,000,000 standard cubic feet per day (SCFD): 24,000,000

SCFD by shutting in Otowi Junction, 26,000,000 SCFD when Cobisa power station went offline, and 8,000,000 SCFD by shutting on Bernalillo and Placitas border stations. This amount of load shed allowed the transmission system to stabilize and line pack began to recover.

Of the modeled mitigation strategies, only one scenario, shutting in the Otowi junction regulator station and removing the Cobisa plant from service, allowed the transmission pipeline system to stabilize and line pack to begin to recover. The other modeled mitigation strategies shed load in other portions of the transmission system, but the amount of load shed was insufficient to stabilize the system (less than 58,000,000 SCFD). Analysis results indicate that had scheduled gas deliveries been received, the system would have remained stable.

The study indicates that, among mitigation actions considered, the combination of shutting in the Otowi junction regulator station and removing Cobisa from service was the best option to stabilize the NM Gas system, however further study of the conditions which led to the shortfall in gas deliveries to NM Gas, including an evaluation of the interdependencies between the electric power and natural gas systems, would lead to a greater understanding of system resilience and support emergency planning. For example, shedding natural gas load at the electrical power generation stations in Albuquerque may have been a possible means to reduce the extent of residential customer outages in Northern New Mexico. Although this alternative is possible, the effects on the electric power system may be more damaging than the NM Gas outage. Analyzing this type of contingency requires an electrical power/natural gas interdependency modeling effort. The LANL Energy and Infrastructure Analysis group is well poised to perform such studies.

1. Introduction

During the week of January 31, 2011, severe cold weather affected large areas of the country, resulting in abnormally high demand for heating and electric power. Increased demand led Texas power utilities to implement controlled power outages, i.e., rolling blackouts, to stabilize the grid and prevent widespread power failures. New Mexico, while itself a large producer of natural gas, relies on a series of interstate transmission lines that flow from western Texas northwest toward Albuquerque. In a situation where supplies are inadequate to meet demand and with a limited amount of natural gas stored in the system from line pack, curtailments, i.e., decreases in service, are inevitable. The gas shortage event was basically a result of increased demand and a decrease in supply of natural gas.

The shortfall in receipts of bulk gas deliveries to New Mexico Gas Company (NM Gas) resulted in dangerously low pressure in their pipeline network. Figure 1 shows the transmission pipeline system in New Mexico. Two pipelines in central New Mexico, the Transwestern pipeline (shown in green) and the El Paso pipeline (shown in blue), flow natural gas northwest toward Albuquerque and into the northern New Mexico transmission system, but also serve southern New Mexico, including the communities of Alamogordo and Silver City.

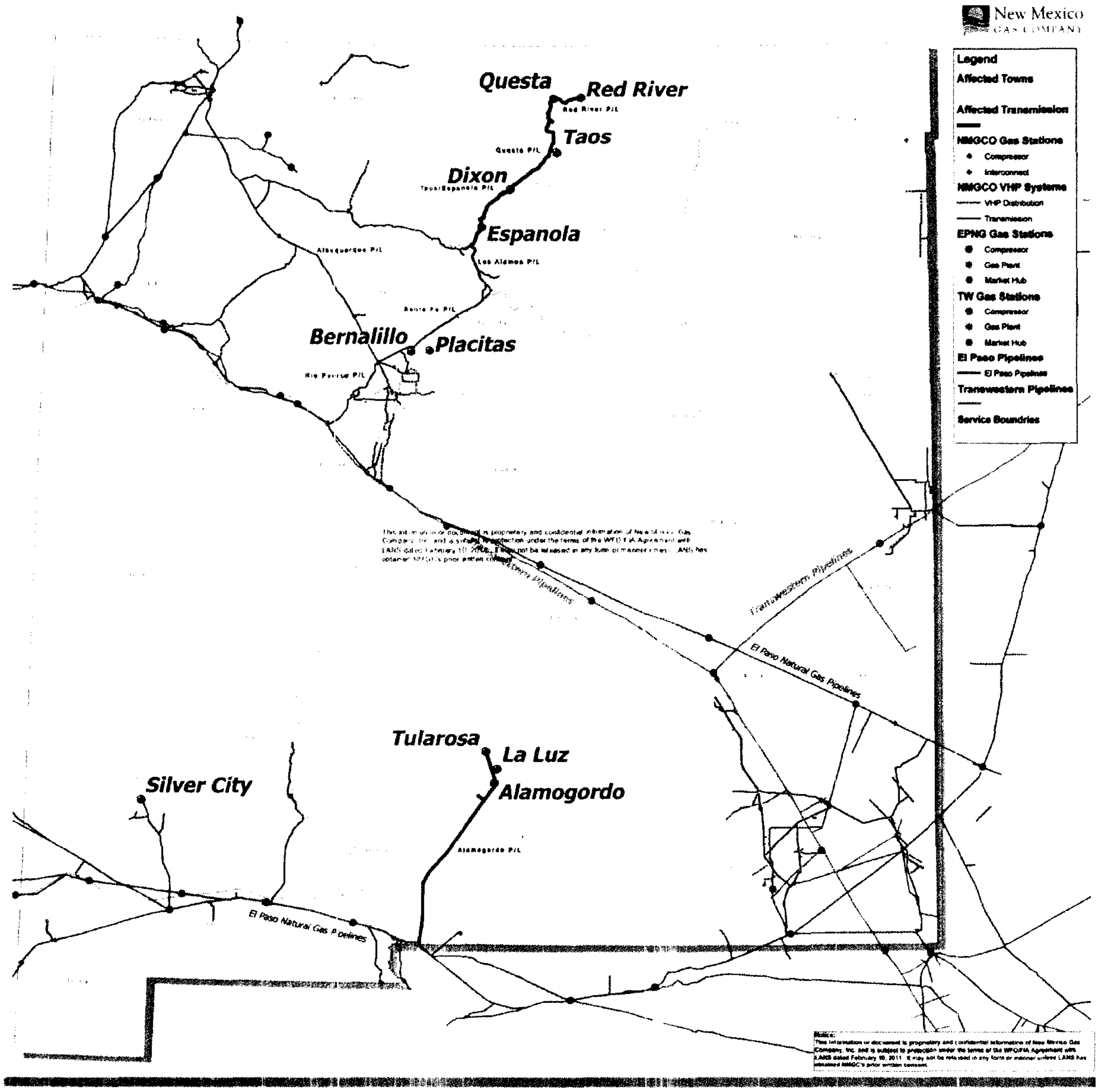

Figure 1. New Mexico Gas Company pipeline network. Note the Transwestern (green) and El Paso Natural Gas (blue) pipelines that traverse central New Mexico supplying natural gas to northern New Mexico. (Graphic provided by NM Gas)

NM Gas had scheduled deliveries of gas in excess of the anticipated demand but the actual amount delivered to the northern New Mexico transmission system was much less than ordered. The lack of physical deliveries of natural gas from the New Mexico Gas storage at Winkler County, TX, as well as inadequate deliveries from the transmission system providers shown in Figure 1, to NM Gas are likely results of a combination of events that reached convergence during the record cold temperatures in early February 2011. Figure 2 shows the scheduled gas and the amount actually delivered throughout the study period.

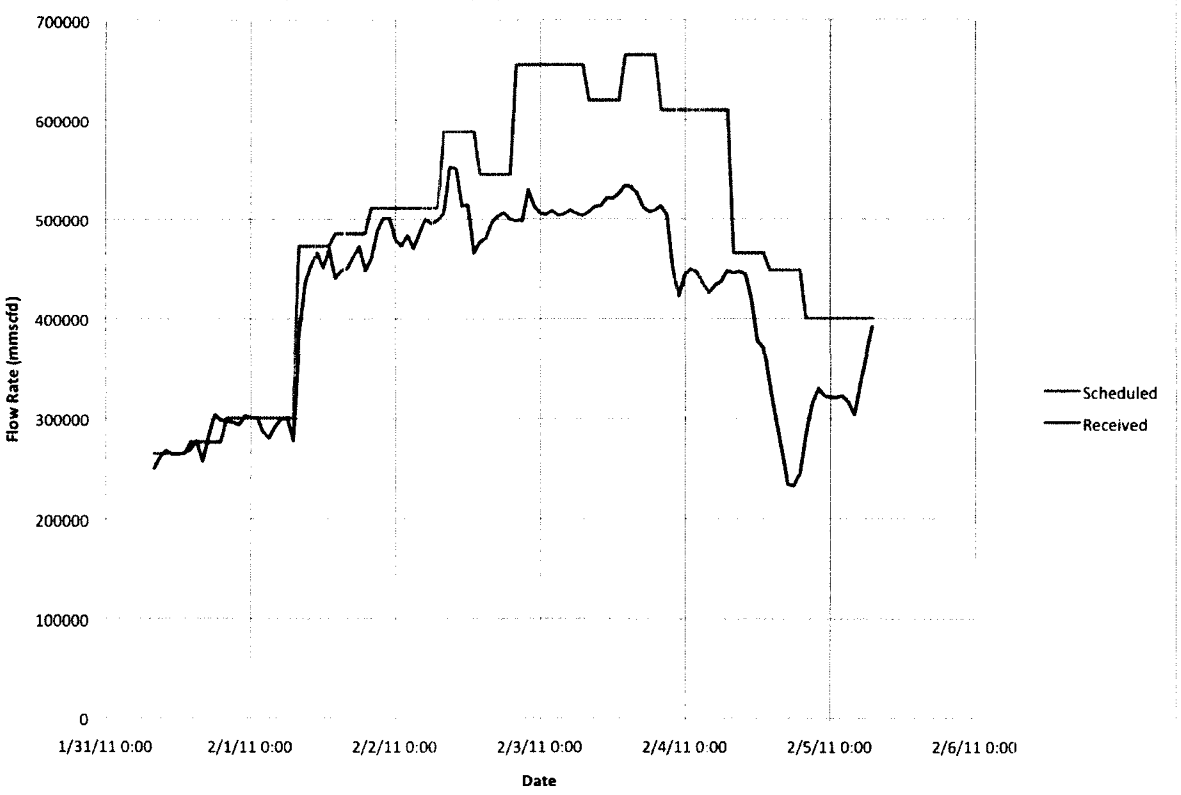

Figure 2. Total scheduled and received natural gas flows from all providers

In response to this event, at 0840 mountain standard time on February 3, 2011, NM Gas shut in (that is, closed off) the Otowi junction regulator station in an effort to stabilize the entire northern New Mexico natural gas transmission pipeline system. This stopped the flow of natural gas north of that location, including to the New Mexico communities of Espanola, Dixon, Taos, Questa, and Red River. More than 28,000 natural gas customers in the state were without natural gas during this shortage.[1] Figure 3 shows line pack as registered by NM Gas as well as their decision points during the event.

[1] New Mexico Gas Company. 2011. "Frequently Asked Questions — Gas Outage." www.nmgco.com/pdf/FAQ_Gas_Outage.pdf. accessed March 22, 2011.

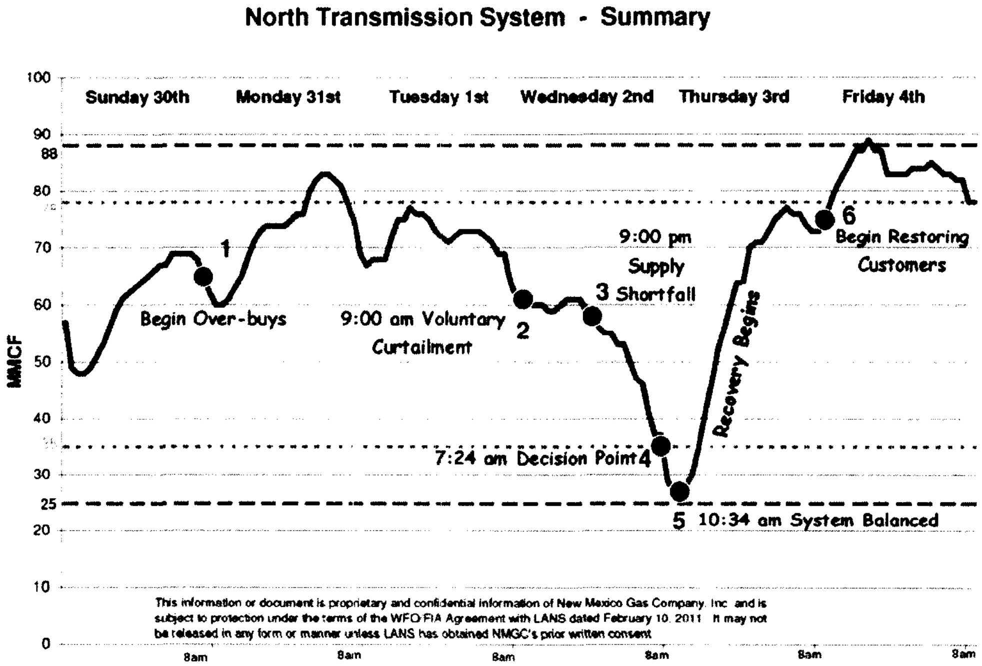

Figure 3. Measured gas control system line pack and decision points (Graphic provided by NM Gas)

These operational challenges raised concerns about the resilience of the natural gas system in northern New Mexico. NM Gas requested that Energy and Infrastructure Analysis group at Los Alamos National Laboratory (LANL) perform a system resilience study using a regional model of the NM Gas system. The study presented in this paper focuses on only the northern New Mexico transmission system. To test the model, LANL modeled system response had the scheduled gas been delivered as contracted as well as the actual mitigation strategy employed by NM Gas, i.e., shutting in Otowi junction. Working with NM Gas, LANL modeled four other possible mitigation strategies that involved removing individual system components from the model to assess system response. This report discusses the results of these analyses.

2. Study Method

2.1 Models

LANL used the WinTran and WinFlow software developed by Gregg Engineering[2] and northern New Mexico transmission system models provided by NM Gas. WinFlow is a steady state, one-dimensional, compressible natural gas pipeline simulation tool; WinTran is the transient (time-dependent), one-dimensional, compressible flow solver. WinFlow and WinTran model the flow of natural gas within pipeline systems, including the effects of compressors, pipeline pressure losses due to friction, elevation changes, changes in ambient temperature, and precipitation of liquids. WinTran (transient) analyses use the WinFlow (steady state) model as the pipeline system description. Schedules of gas delivery and consumption at specific locations are created in the model as a function of time. Schedules also include the times when compressors turn on or off, set points for flow regulators, minimum and maximum operating pressure alarms, and remote control valves.

Because natural gas is a compressible fluid, one can "store" gas in the pipeline system by increasing the pressure in certain segments, called "legs." If the demand (outflow) of gas remains constant in the system and the pressure increases in some of the pipes, gas is accumulated or stored. At times when the demand for gas exceeds the supply (inflow) into the pipeline transmission system, the line pack can provide a short-term buffer for this imbalance in supply and demand, until gas supply increases or the demand decreases.

The WinFlow and WinTran models solve the conservation equations for mass, momentum, and energy for one-dimensional compressible gas flow. At certain locations, called nodes, the pressure and flow rate of the gas flowing into the transmission pipeline system is specified as a function of time. At other locations, the demand, or outflow, is either a specific flow rate or pressure as a function of time. By convention, flows of natural gas into the pipeline system are positive, and flows out of the pipeline system are negative. This type of problem is considered an initial/boundary value class of problem. The initial conditions, the pressure and amount of gas flowing into the pipeline system, are known. The boundary values, the demand or outflow at a particular location, are also known. The boundary conditions are specified as a flow rate leaving that node, or as a set pressure; one or the other may be specified, but not both. Typically, the flow rate leaving a particular node is specified as a function of time. The computer model then solves the mass, momentum, and energy equations and calculates the pressures required at the nodes to satisfy the flow rate specified. If more gas is flowing into the system than is flowing out, the gas compresses in sections of the pipeline system, creating "line pack." If the gas flowing into the system is less than that specified to flow out, any line pack is used to satisfy the demand flow rates. If the demand exceeds the supply and all the line pack is used, the model can calculate negative pressures at some locations in an attempt to solve the equation set. In the situation where the demand exceeds the supply, the decrease in pressure is usually first seen at the geographically extreme points in the pipeline system. For the northern New Mexico pipeline system, the most extreme point is the Red River border station.

Negative gauge pressures are permissible in the model, up to absolute zero pressure or −14.7 pounds per square inch gauge (PSIG), and then the model will stop in an error condition. In a

[2] Gregg Engineering. "WinTran." www.greggeng.com/index.php?option=com_content&view=article&id=29&Itemid=29.

real system, pipeline pressures would not reach large negative gauge. However, the computational model has no such constraints so negative gauge pressures are allowed up to the point of absolute zero. By taking advantage of this modeling convenience, one may explore the behavior of the system in non-ideal, off-design, conditions. This advantage is used to evaluate all of the mitigation strategies in this study.

Figure 4 shows a screenshot of the WinFlow model of northern New Mexico. Gas flows into the pipeline system are shown at approximately three geographical locations. The Rio Puerco delivery points for the Transwestern and El Paso pipelines traveling from Texas through central New Mexico are the southern-most points. At the northwestern-most location, near Farmington, New Mexico, gas is delivered into the pipeline system from Transwestern, El Paso, and Williams Field Services pipelines. At the western-most point, gas flows into the system at two locations, El Paso and Transwestern, at Fort Wingate. The flows into the pipeline system are shown as positive flows. Figure 4 also shows demand nodes at other locations; their flows are shown as negative numbers.

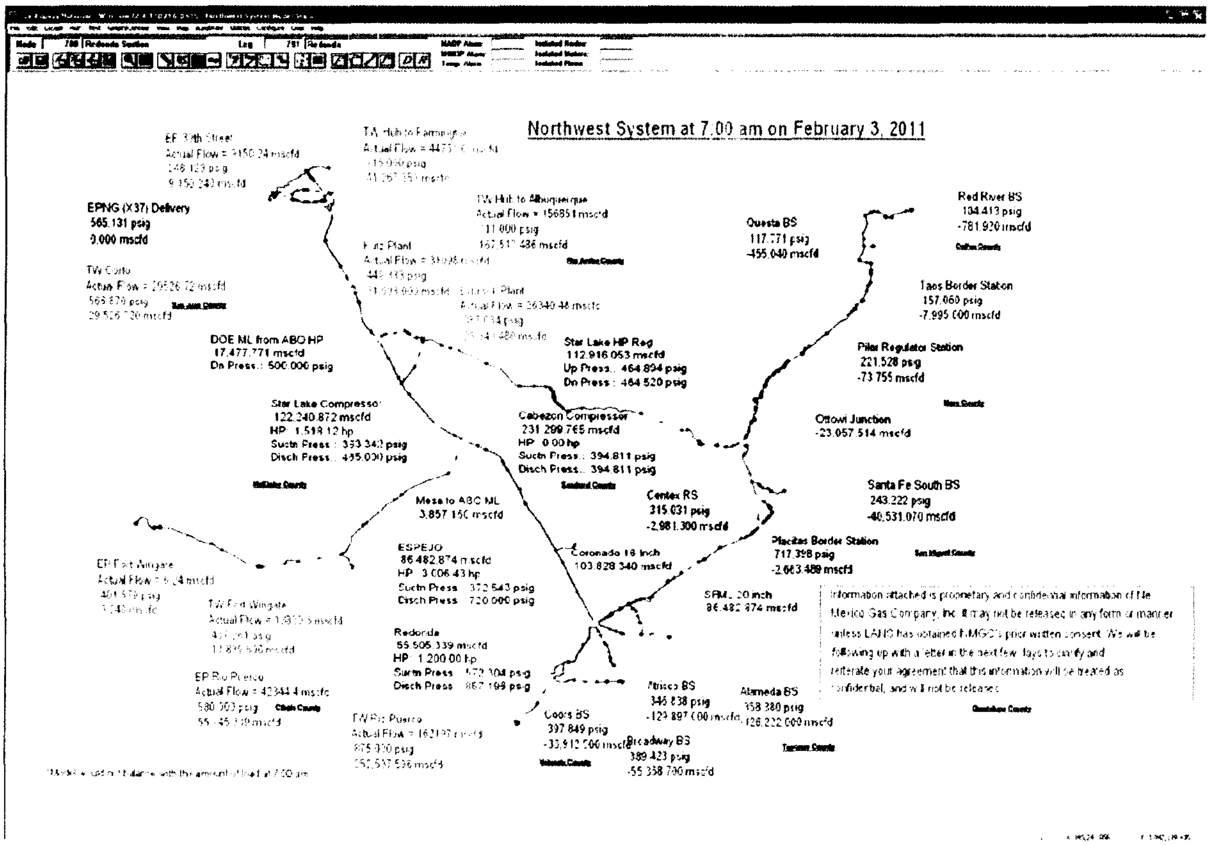

Figure 4. Screenshot of WinFlow/WinTran model of the New Mexico Gas Company's northern New Mexico transmission pipeline system as of February 3 at 0700

In general, the direction of gas flow starts at the delivery points, and flows into the triangularly shaped loop. In the northeastern portion of the model, the section that extends north from Otowi junction is of particular interest because it is the section where gas deliveries were interrupted starting February 3. That leg of the system must receive gas from either the Los Alamos or Santa Fe sides of the junction or both sides. The Otowi junction and the leg north of the junction are furthest from the delivery points of gas into the pipeline system. Gas must travel from south of Albuquerque (Rio Puerco) or from the Farmington area, either through the DOE main line or from Farmington through Albuquerque, to the Otowi junction.

2.2 Model Evaluation

Using WinFlow and WinTran, LANL modeled system response under two scenarios; all scheduled gas deliveries were received and shutting in Otowi junction.

2.2.1 All Scheduled Gas Deliveries Received

As noted previously, NM Gas had scheduled deliveries of gas in excess of the anticipated demand for the period but those deliveries were not received. LANL modeled expected system performance had the scheduled gas had been delivered. The results of this analysis serve as a baseline for system performance.

2.2.2 Otowi Junction Shut In (NM Gas Mitigation Strategy)

NM Gas shut in Otowi junction in an effort to restore system pressure. Prior to that, on February 3, 2011, at approx 0530, NM Gas began to experience low pressure conditions in certain Albuquerque segments being served through the Santa Fe junction. The system conditions were evaluated. The Espejo compressors located at Santa Fe junction and the Redonda compressors located at the beginning of the Rio Puerco mainline (inflow of gas from the El Paso and Transwestern delivery points) flow into the northern New Mexico natural gas transmission system. Because the Santa Fe mainline at this time had more than ample line pack and pressures, the decision was made to route volumes previously going towards Santa Fe into Santa Fe junction for approximately 30 to 45 minutes to balance the loads and stabilize the pressures within the junction. The Santa Fe junction pressures did not increase and it was evident that the system demands were continually increasing and the scheduled volumes were not being delivered. After this determination, volumes were again routed into the Santa Fe mainline. Had the Santa Fe junction received all the scheduled volumes, pipeline system pressures would have quickly increased. If NM Gas had not assisted the Santa Fe junction pressures, the Tennyson border station in Albuquerque would have run out of gas at approximately 0645. Had this outage occurred, it would have caused uncontrolled outages throughout the Albuquerque area. This action is included as part of the Otowi shut in analysis.

In the model, the Otowi junction regulator station valve was shut in on February 3 at 0840 and the demand (outflow from the pipeline system) set to zero for the following locations:

Border stations:	Alcalde	Hernandez
	Arroyo Seco	Los Colonias
	Chamita	Red River
	Country Club	Taos
	D. H. Lawrence Ranch	Molly Mine Corp.
	Espanola # 1	Goat Hill Sales
	Espanola No. 2	Questa
	Espanola No. 3	Dixon
Regulator stations:	Arroyo Hondo	Rinconada
	Camino De Cielo	Santa Clara
	Hernandez #2	Velarde #1
	Jackson Saw Mill	Velarde #2
	La Villata #2	Velarde #3
	Old Velarde Rd. #1	Valencia
	Pilar	

At 0800, the total demand from all of these meters and stations was a flow rate of approximately 24,000,000 standard cubic feet per day (SCFD), or 24,000 thousand standard cubic feet per day (MSCFD).[3] Using these results, a comparison between data measured by the NM Gas system control and data acquisition (SCADA) systems and the WinTran model results can be made.

2.3 Mitigation Strategies

Each of these mitigation strategies represents a contingency in the analysis. In a contingency analysis, different assumptions associated with probable events, i.e., removing a specific facility (the contingency) from use in the model, are used to examine system response to that action. The pipeline system response is calculated for each mitigation strategy, providing a quantitative basis to understand the analysis results.

2.3.1 No Mitigations Employed

LANL analyzed system response had NM Gas not employed any mitigation strategy.

2.3.2 Bernalillo and Placitas Border Stations Contingencies

LANL modeled three contingencies involving combinations of Bernalillo and Placitas border stations. In the first contingency studied, Bernalillo was isolated and Otowi junction valve remains open. To approximate this contingency, demand in WinTran was set to zero (no flow) at the Bernalillo border stations on the morning of February 3. At that point, the measured demand at these locations was approximately 4,581 MSCFD.

For the second contingency, Placitas border station was isolated and Otowi junction valve remains open. To model this contingency, demand was set to zero (no flow) at the Placitas

[3] MMSCFD is by convention equivalent to 1,000,000 SCFD.

border station on the morning of February 3. At this point, the measured demand at this location was approximately 3,805 MSCFD.

The third contingency shuts in Bernalillo and Placitas border stations while the Otowi junction valve remains open. Demand in WinTran was set to zero (no flow) at the Bernalillo and Placitas border stations on the morning of February 3. At this point, the measured demand at these locations was approximately 8,386 MSCFD.

2.3.3 Otowi Junction and Cobisa Electric Power Plant Contingency

During the event, the Cobisa electric power plant, located at the Broadway border station, went offline at 0920 on February 3, thus, it did not demand natural gas from the pipeline system. LANL added a parameter to the Otowi junction contingency analysis to determine system response had Cobisa stayed online. This contingency was modeled by increasing the demand at the Broadway border station by 26,000 MSCFD from 0920 forward to represent Cobisa's demand.

2.4 Data

NM Gas provided LANL with their WinTran and WinFlow models of the northern New Mexico natural gas transmission pipeline system. The pipeline model is geospatially registered; all of the node, meter, pipeline segments, compressors, valves, etc. are created in the model using the actual longitude, latitude, and elevation of the element. Additional data provided include the measured and projected flows, pressures, and line pack of gas in the system as a function of time.

3. Study Results

LANL examined two primary metrics for all modeled mitigation strategies: the gas control system line pack, and pressure and flow computed as a function of time at the Red River border station. The gas control system line pack region is a measure of the amount of stored natural gas in the northern New Mexico pipeline system. The Red River border station is the furthest point in northern New Mexico on the transmission pipeline system, and is, therefore, one of the first locations to exhibit anomalous readings if there are problems in the pipeline system. Two other metrics of interest are the pressure and flow as a function of time at the Alameda border station and model node name "RCF" (near Otowi junction), which are indicators of the system state in Albuquerque and north of Otowi junction, respectively.

3.1 Evaluation Results

To use the NM Gas model to evaluate alternative mitigation strategies, the predictive quality of the model must be assessed. To do so, LANL evaluated the performance of the model against the system conditions as it was operated during the event. The trends are predicted very well in the WinTran model. However the model is over-predicting the line pack by approximately 20 MMSCF. This over-prediction is very consistent throughout the six-day simulation. The reason for this over-prediction needs further investigation, but due to time constraints only a few comments will be made. One possible explanation is that WinFlow calculated in units of standard cubic feet, while NM Gas provided line pack measurements in units of actual cubic feet. The difference is related to the effect of pressure at altitude. Specifically, the conversion from standard to actual cubic feet is represented by the equation

$$ACF = SCF\left[\frac{P_{std}}{(P_{act} - P_{sat}\phi)}\right]\left(\frac{T_{act}}{T_{std}}\right)$$

where:

P_{std} = Standard absolute pressure (pounds per square inch absolute (PSIA))

P_{act} = Absolute pressure at the actual elevation (PSIA)

P_{sat} = Saturation pressure at the actual temperature (PSIA)

ϕ = Relative humidity

T_{act} = Actual ambient temperature (degrees Rankine (°R))

T_{std} = Standard temperature (°R)

The pressures (and temperatures) vary with altitude, which differs significantly throughout the pipeline system. More problematic is the calculation of the saturation pressure of the natural gas, which can be done using a Peng-Robinson[4] equation of state formulation. However, both the saturation pressure and ambient temperature would have to be computed in a segmented fashion for the pipeline system due to the differing elevations and temperatures. This calculation is

[4] Peng, D.Y., and D.B. Robinson, "A New Two-Constant Equation of State," *Indust. and Engr. Chemistry: Fundamentals* **15**, 59 (1976).

feasible, albeit time consuming; due to time constraints on this study, these effects were not been considered.

It should be noted that, in any case, accounting for the effect of actual verses standard volumes, the net effect would be to increase the value of the model results. The model results are in standard cubic feet; as the pressure decreases, a given amount (mass) of gas will expand to a larger volume, thus the modeled values would increase. The dominant term in the above equation is the pressure ratio in the first term. The saturation pressure is expected to be approximately two orders of magnitude lower than the standard and actual pressures, thus, when multiplied by the relative humidity, it may be ignored as a first approximation. Given that the temperatures are in absolute units (degrees Rankine), the ratio will be nearly one. Thus, we multiply the standard cubic feet as by the ratio of P_{std}/P_{act} as a first approximation. The value of P_{std} is 14.7 PSIA, and a nominal value of P_{act} for northern New Mexico is 11.0 PSIA, thus, the ratio is 14.7/11.0, which is approximately 1.3. Perhaps an alternate and simpler explanation of the discrepancy is that the modeled gas control line pack pipeline segments includes portions of the system that are not included in the measured line pack. The question about the extent of the gas control line pack was asked of the NM Gas and the current information is that the modeled gas control system is accurate. Additionally, the model captures the pressure trends that occurred in the system well. These trends were a driving factor behind operating decisions and are a key decision metric in this study.

As was borne out by actual events, the Otowi junction and Cobisa offline scenario resulted in a favorable effect on the pipeline system. In this case, the pipeline system recovered pressure and the line pack increased to normal ranges after the period of approximately 12 hours. Shutting in Otowi junction results in shut in of all demand locations downstream (north), i.e., they do not receive gas. The demand locations do not immediately lose gas; there is some gas in the pipeline and the demand locations will continue to operate until that gas is depleted. When the valve is closed, no additional gas flows into that segment of pipeline. In this case, the pipeline system recovered pressure and the line pack increased to normal ranges after approximately 12 hours. Figure 5 shows the adjusted line pack for the model period.

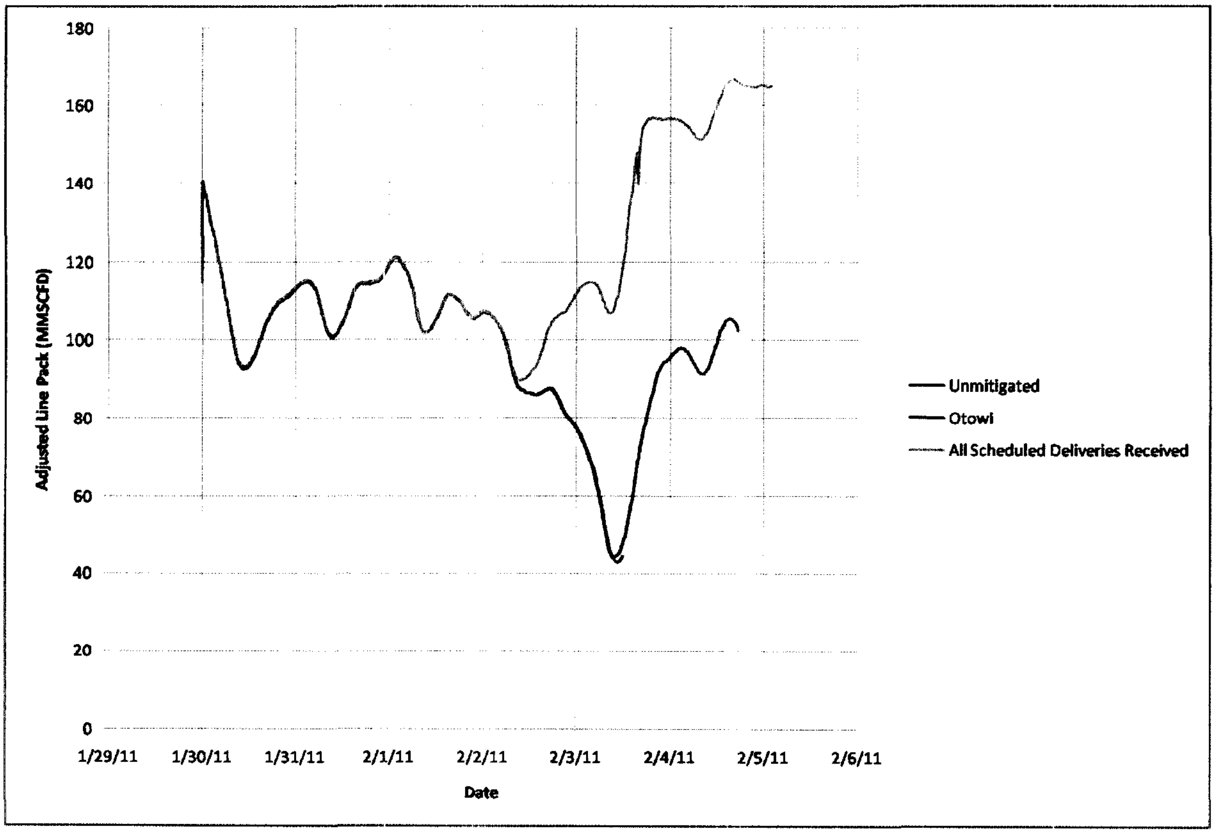

Figure 5. Adjusted line pack, Otowi junction mitigation strategy

At about 0100 on February 3, the total demand was approximately 24,000 MSCFD and increasing. By shutting in the Otowi junction valve and with Cobisa offline, the demand (load) north of Otowi junction was shed from the system, and the system recovered. If the valve not been shut, the locations north of Otowi junction would have run out of gas due to the lack of supply into the system and the pipeline system would have been driven to a low line pack and pressure condition, thus, there would likely have been instabilities and outages in other locations.

3.2 Alternative Mitigation Analysis

As was shown in the model evaluation, the Otowi junction and Cobisa offline scenario resulted in a favorable effect on the pipeline system. Except for receiving the scheduled gas deliveries, none of the other modeled scenarios resulted in system pressure recovery. In all other cases, the model stopped due to negative line gauge pressures. The Red River border station was the first location to reach the minimum operating pressure (MINOP) of 70 PSIG, at approximately 0930 on February 3. After 0930, MINOP alarm pressures were reached at locations south of Red River border station; this no-flow condition started backing up toward Otowi junction. The model stopped at approximately 1200 on February 3 due to negative gauge pressures approaching absolute zero throughout the northern portion of the Otowi junction leg. Note that no differences occur until February 3 at approximately 0700, when specific curtailment actions were modeled. Figure 6 shows the adjusted line pack for all modeled strategies. Figure 7 shows the adjusted line pack for the 48-hour period between February 3 and February 4. Note that the model stopped running for all but the contingencies for Otowi junction with Cobisa offline, and for all scheduled deliveries met at approximately noon on February 3.

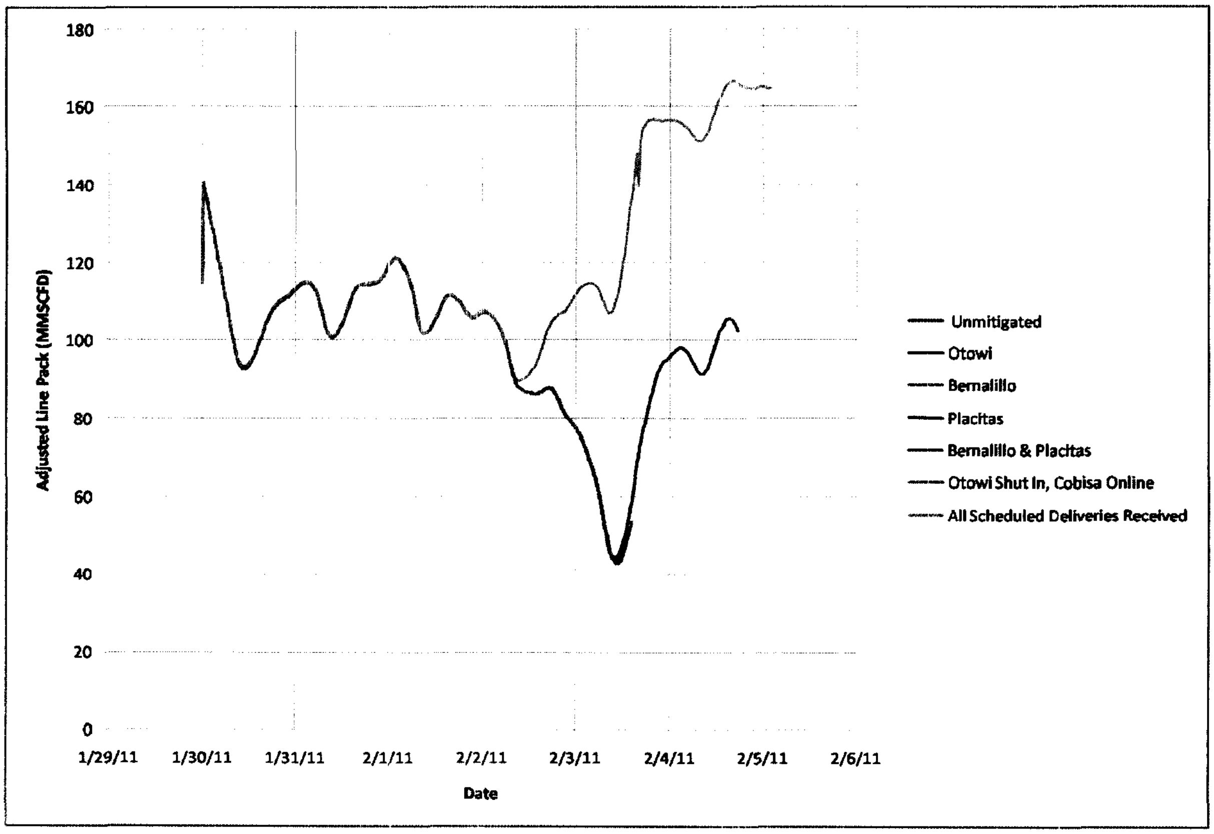

Figure 6. Adjusted line pack for all modeled mitigation strategies

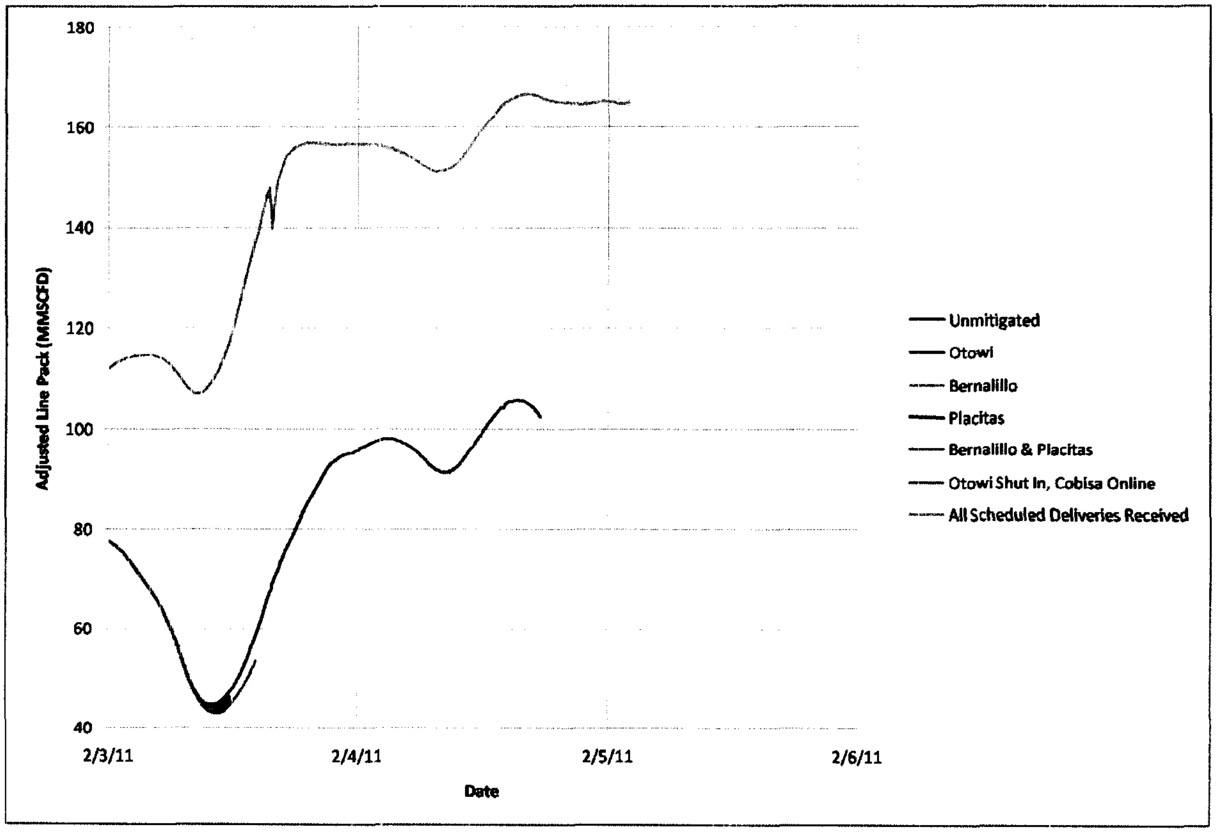

Figure 7. Adjusted line pack for the 48-hour period between February 3 and February 4

3.2.1 All Scheduled Gas Deliveries Received

The northern New Mexico transmission system could have met all projected demands if NM Gas had received all scheduled gas deliveries (Figure 8). Recall from Figure 2, that the large disparity in scheduled and received flows began around mid-day on February 2, 2011 and continued through mid-day on February 5, 2011. In the all scheduled deliveries received scenario, the flow of gas into the NM Gas system represented in the model were derived from expected deliveries of gas at Rio Puerco border station. This results in the transmission system being able to meet all demands and no mitigation strategies would have been required.

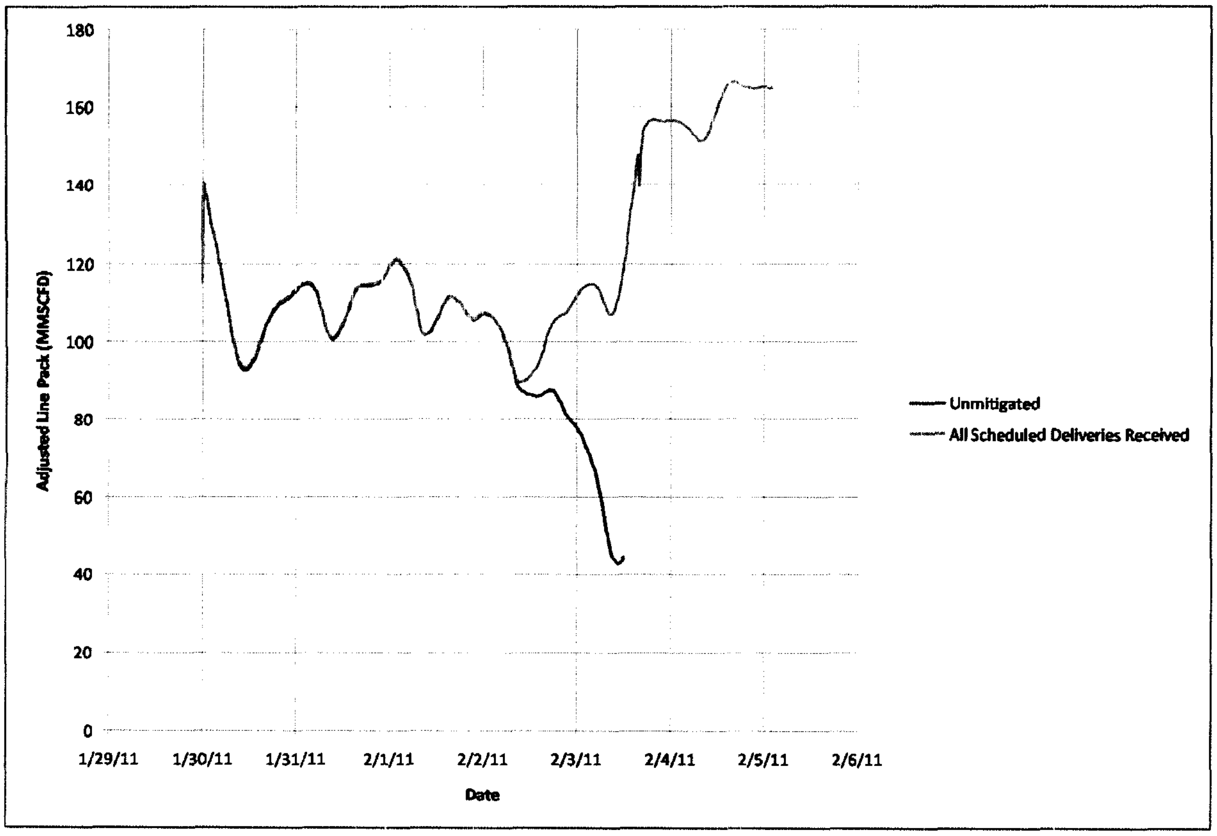

Figure 8. Adjusted line pack if all scheduled deliveries had been received

3.3 Mitigation Strategies

3.3.1 No Mitigation

Had no mitigation strategy been initiated, the Red River border station would have been the first location to reach the minimum operating pressure (MINOP) of 70 PSIG, at approximately 0930 on February 3. After 0930, MINOP alarm pressures were reached at locations south of Red River border station, and this no-flow condition started backing up toward Otowi junction. The model stopped at approximately 1200 on February 3 due to negative gauge pressures approaching absolute zero throughout the northern portion of the Otowi junction leg.

At about 0100 on February 3, the total demand was approximately 24,000 MSCFD and increasing. Locations north of Otowi junction would have run out of gas due to the lack of supply into the system and the pipeline system would have been driven to a low line pack and pressure condition, thus, there would likely have been instabilities and outages in other locations. Figure 9 shows the adjusted line pack if New Mexico Gas had not implemented mitigation strategies.

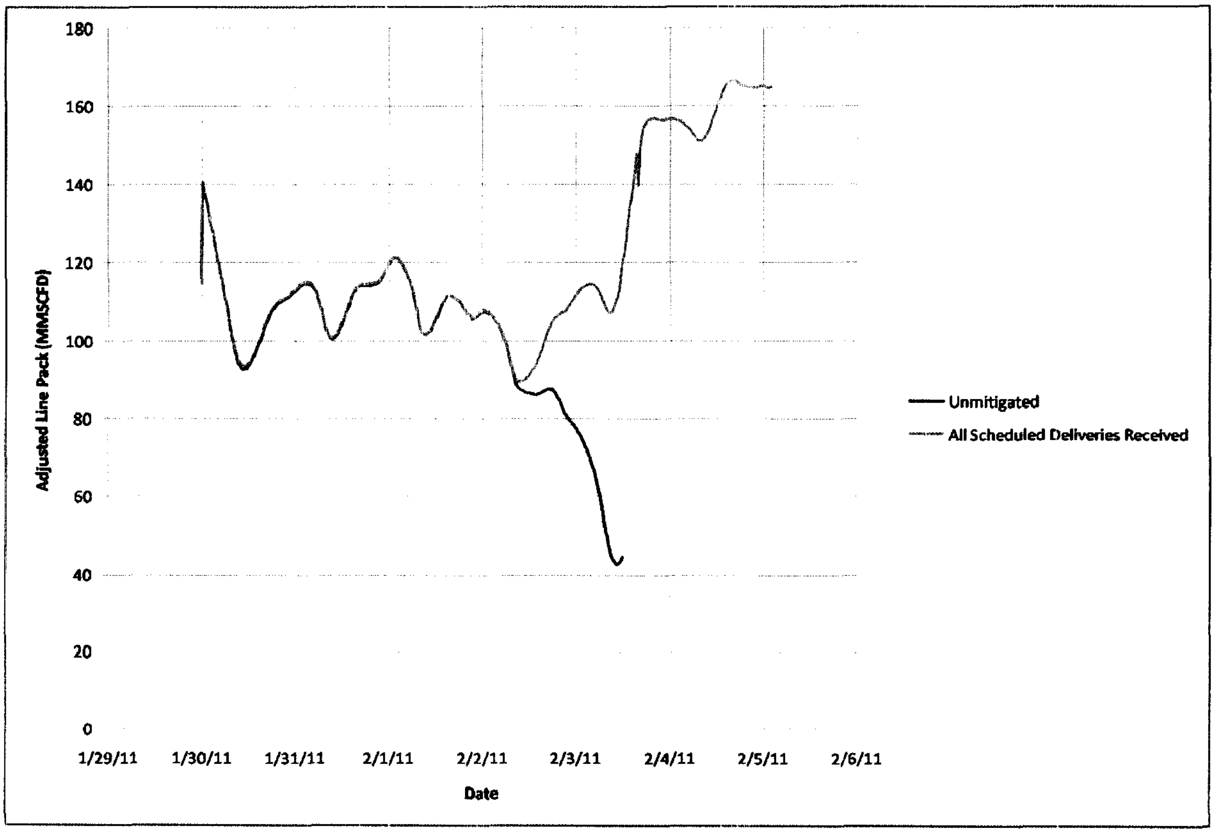

Figure 9. Adjusted line pack, no mitigation strategies

3.3.2 Bernalillo and Placitas Mitigation Strategies

LANL modeled three mitigation strategies using curtailment of Bernalillo and Placitas as contingencies. As shown in Figure 10, when the Bernalillo border station was set to zero in the model, line pack did not recover, thus, this mitigation was ineffective.

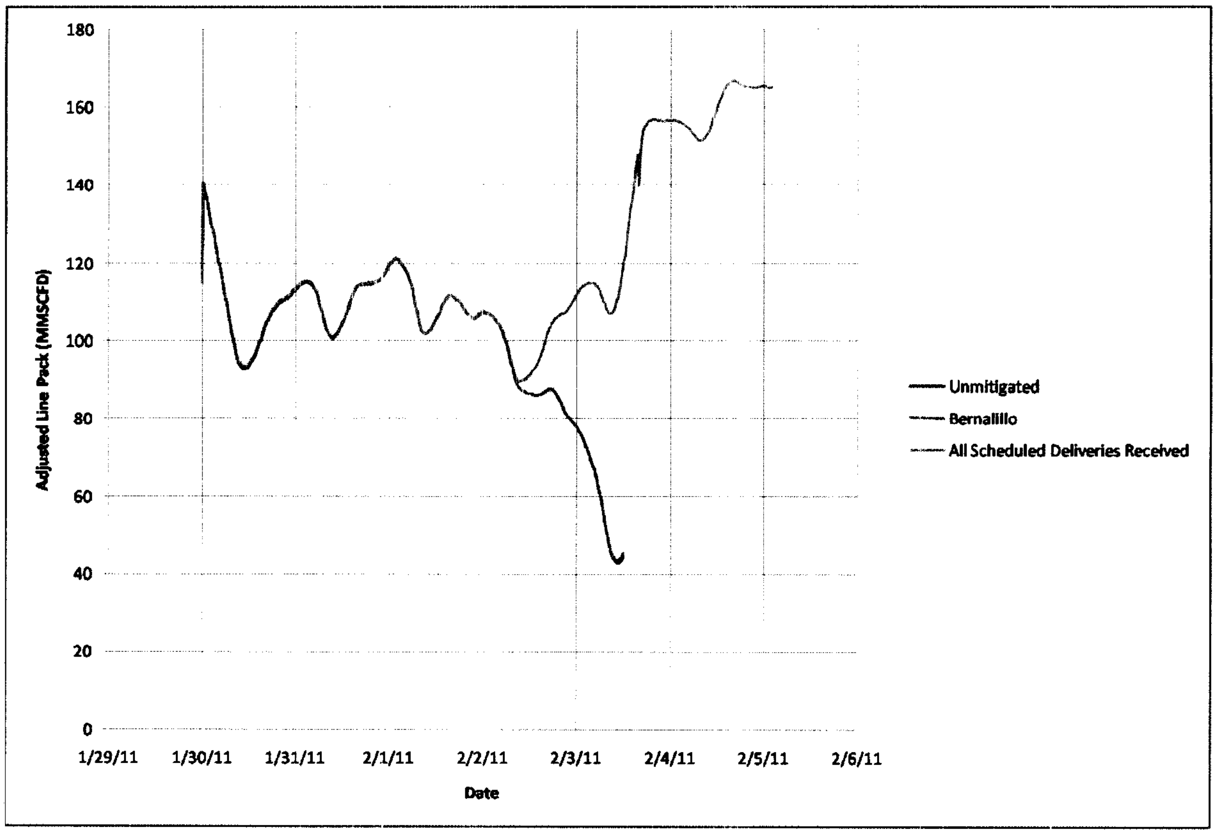

Figure 10. Adjusted line pack, Bernalillo mitigation strategy

Removing the Placitas load also failed to restore sufficient line pack, as shown in Figure 11.

Figure 11. Adjusted line pack, Placitas mitigation strategy

Figure 12 shows the adjusted line with the Bernalillo and Placitas contingencies both set to zero in the model. The demand at both Bernalillo and Placitas at 0700 on February 3 was approximately 8,500 MSCFD. This value is approximately a factor of 3 lower that the flow through Otowi junction. The system was unable to recover when shutting in both Bernalillo and Placitas, thus, this mitigation strategy was ineffective.

Figure 12. Adjusted line pack, Bernalillo and Placitas mitigation strategies

3.3.3 Otowi junction Shut In, Cobisa Electric Power Plant Online Mitigation Strategy

As noted, the Cobisa electric power plant went offline on February 3 at 0920. Had the Cobisa power plant remained online, it would have continued to draw gas from the Broadway border station. Figure 13 shows what would have happened at the Broadway border station had the Cobisa power station not gone offline at 0920 on February 3. Even with the Otowi junction valve shut in, the increased demand at the Broadway border station was enough to render the system unrecoverable, though the system was able to continue until approximately 1400. This shows that further curtailments in addition to the Otowi junction shut in would have been necessary.

Figure 13. Adjusted line pack with Cobisa electric power station online

4. Conclusions and Recommendations

Study results indicate that had all scheduled deliveries of gas into the northern New Mexico transmission system been met, no mitigation actions would have been necessary. Of the modeled mitigation strategies, shutting in the valve at the Otowi junction with Cobisa offine was the only action that allowed the system to recover from the shortage of gas.

The flow rate through the Otowi junction valve just prior to the shut in was approximately 24,000 MSCFD. With that amount of flow, plus Cobisa offline (additional 26,000 MSCFD), shed from the pipeline system, the system was able to recover, but just barely. By calculating the gas control system line pack and monitoring it as a function of time, LANL was able to evaluate the feasibility of other mitigation options. The other mitigation strategies evaluated showed a depletion of the available line pack. If either or both Bernalillo and Placitas were shut in, the system was unable to recover. The same result occurred when Otowi junction was shut in and the Cobisa electric power station was left online. If the Cobisa facility had stayed online, it would have represented an additional 26,000 MSCFD demand at the Broadway border station. The system did not recover under this mitigation strategy and further curtailments would have been necessary.

Ultimately, the NM Gas operators shed approximately 58,000 MSCFD, which was just enough to stabilize the northern New Mexico system. Unquestionably, load had to be shed, but how much, when, and where the load would be shed remained in question. There were also significant time and logistical constraints regarding the load shedding decisions. This study confirms that the proper amount of load was shed, as the system was able to recover with little margin for error.

There were several factors that contributed to the New Mexico natural gas shortage event. Increased regional demand for natural gas was undoubtedly a primary factor; however other variables potentially played an important role. Several coal-fired power-generating stations in the Texas Panhandle were unavailable due to maintenance. Coincident with the cold snap, other large generating stations were forced offline due to crippling freeze-ups of cooling towers and plant auxiliaries. The loss of an excessive number of major generating stations put the Texas power grid into a rolling blackout situation due to severe decreases in generating capability.

The rolling blackout conditions directly resulted in curtailment of electric power resources for the large, electric-drive compressors required to maintain natural gas production. Lack of continuity in compression due to power loss at compressors at natural gas wellheads, processing plants and along transmission lines produced system operational challenges that were exacerbated by the excess customer demand for natural gas. Natural gas production was further limited by freeze-ups of wellheads and gathering networks.

Much of the difficulty resulting from the cold snap may be attributed to economic considerations of energy industry companies. First, properly winterizing power-generating stations requires increased capital expenditures and higher ongoing maintenance costs. Second, clean air legislation regulates and limits reciprocating, natural-gas-fueled, engine-driven compressors on natural gas pipelines that would provide some measure of redundancy if electric power is unavailable. Under Environmental Protection Agency regulations, the limits on industrial combustion-air emissions and the scheme for trading carbon-emissions permits under federal clean air regulations provide economic incentives for natural gas pipeline companies to disable and/or remove reciprocating engine-driven pipeline compressors in favor of electric-drive units powered from the local power utility company. Reducing measured and certified combustion-emissions provides marketable credits that can be sold to other industrial companies to compensate for and license its own excesses in combustion-air emissions. Air permits and carbon credits have economic value and are readily traded in the marketplace.

This incentive entices natural gas production companies to make economic choices to convert to electric-drive compressors and to disable or remove gas-fueled engines from production, which resulted in elimination of a margin of emergency backup capability for natural gas production. The marketing of carbon credits under the air emissions cap-and-trade legislation has reduced production security and resilience in the gas and electric energy industry.

LANL did not evaluate additional possible mitigation strategies in this study as it was beyond the requested scope of work. However, such evaluations would improve the understanding of the natural gas transmission system and its dependence on other infrastructure sectors. For example, the extent of interdependence between natural gas and electric power systems in Texas and New Mexico is currently not fully quantified. More detailed understanding of the complex interplay between these systems will be useful for long range system planning. LANL has the expertise to investigate the complex interdependencies between these two systems.

LANL could also use its electrical power and natural gas modeling capabilities to evaluate shutting in natural-gas-fueled electric power stations in the region for events similar to the February 2011 cold snap. For example, two options are the Reeves and Cobisa generating facilities in the Albuquerque metro area. Specifically, the Reeves power station is rated at 154 MW of electrical output. At this rated load, and making some simplifying assumptions, the total natural gas flow required to maintain generation is approximately 40,000 MSCFD. If the Reeves plant had been shut in, this amount of load shed from the natural gas system would have been sufficient to stabilize the natural gas system and curtailments at Otowi junction may not have been necessary. However, shutting in the Reeves plant could have caused power blackouts in Albuquerque. The extent and magnitude of these interdependencies under adverse conditions such as extreme cold snaps is not fully characterized and may be a concern in the future as each system expands. This particular study could be very beneficial to NM Gas and the state of New Mexico as they examine future mitigation, infrastructure resilience, and emergency plans.

Acronyms

°R	degrees Rankine
LANL	Los Alamos National Laboratory
MAOP	maximum operating pressure
MINOP	minimum operating pressure
MMSCFD	million standard cubic feet per day
MSCFD	thousand standard cubic feet per day
NM Gas	New Mexico Gas Company
PSIA	pounds per square inch absolute
PSIG	pounds per square inch gauge
SCADA	supervisory control and data acquisition
SCFD	standard cubic feet per day

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BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF AN INVESTIGATION INTO NEW MEXICO GAS COMPANY'S CURTAILMENTS OF GAS DELIVERIES TO NEW MEXICO CONSUMERS	)	**Case No. 11-00039-UT**
NEW MEXICO GAS COMPANY,	)	
Respondent.	)	

2011 APR 29 PM 4:16

REGULATION COMMISSION

AFFIDAVIT OF KEN OOSTMAN

STATE OF NEW MEXICO)
) ss.
COUNTY OF BERNALILLO)

KEN OOSTMAN, Vice President of Technical Services, New Mexico Gas Company, upon being first duly sworn according to law, under oath, deposes and states: I have read the foregoing Supplemental Testimony and Exhibit and they are true and accurate based on my own personal knowledge and belief.

SIGNED this 29th day of April, 2011.

KEN OOSTMAN

SUBSCRIBED AND SWORN to before me this 29th day of April, 2011.

Notary Public

My commission expires:

April 24, 2013

NMGCO#2364011

BEFORE THE NEW MEXICO PUBLIC REGULATION COMMISSION

IN THE MATTER OF AN INVESTIGATION INTO NEW MEXICO GAS COMPANY'S CURTAILMENT OF GAS DELIVERIES TO NEW MEXICO CONSUMERS **NEW MEXICO GAS COMPANY,** **Respondent.**	))))))))	**Case No. 11-00039-UT**

CERTIFICATE OF SERVICE

I HEREBY CERTIFY that true and correct copies of the **Supplemental Testimony and Exhibit of Ken Oostman** were e-mailed, mailed or hand delivered to the following parties on April 29, 2011.

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