To: All Representative Governing Bodies within the Seneca Lake Watershed

Dear Representative,

This letter is being sent by Seneca Lake Pure Waters Association to over 40 representative governing bodies within the Seneca Lake Watershed at the County, Town, City and Village level of government. The Mission of the Seneca Lake Pure Waters Association is to, “promote the understanding, preservation and improvement of the water quality, natural habitat and general environmental conditions of Seneca Lake and its watershed by sponsoring or undertaking scientific research, by collecting, preserving, publishing and disseminating information concerning Seneca lake and its watershed and by encouraging and supporting the enforcement of laws and regulations and patterns of development and technology aimed at preserving and enhancing the water quality of the lake”. In so doing, SLPWA provides a “voice for Seneca Lake and its watershed. As elected officials you represent the thousands of residents in our watershed and provide a voice for them.

Today, Seneca Lake and its watershed are faced with two major threats due to industrialization. Drilling for natural gas in the Marcellus Shale could potentially have an impact on every community within our watershed and the storage of Liquefied Petroleum Gas (LPG) in the salt caverns at the southern end of Seneca Lake can impact those surrounding communities. While we “support environmentally and fiscally responsible” drilling for natural gas and LPG storage we believe that today both of these projects cannot be done in a manner that Seneca Lake and its watershed will not face irreparable environmental and fiscal harm. SLPWA itself and as a member of the Finger Lakes Regional Watershed Alliance will continue to provide a “voice for Seneca Lake” regarding what we feel are the environmental and fiscal threats to the lake and its watershed.

As elected representatives of the residents of our watershed, you have the mission to speak for those residents and to protect their way of life and the character of our communities. In so doing, you develop master land use plans, enact zoning rules and ordinances and restrict and control development within your respective jurisdictions. Many of these “local rights” are granted to you by the home rule provisions of the New York State Constitution. A number of our communities have made use of these provisions to protect the character of their communities and their way of life, many have not.

SLPWA urges you to consider what character you and your residents want for your community and act appropriately to preserve that character. Do you want “Boom and Bust”
industrialization, transient “man camps”, increased truck traffic, drilling access roads, noise, air and light pollution, pipe laydown yards, pipe line gathering and distribution systems, gas transfer stations, pressure boosting compressors, drilling mud disposal areas, flaring stations, well flow back treatment facilities or holding tanks and trucking of these wastes in your community? Are you prepared to deal with access roads, heavy truck traffic on your rural roads, and the social and economic demands these projects can have on a community?

Please consider the impact these and similar industrial projects can have on your community and if that is what you want to become. In the next several months, gas drilling in the Marcellus Shale and LPG storage in the salt caverns at the southern end of Seneca Lake can become realities. As representatives of your communities you have the right and obligation to shape, guide and manage the development of your community. Do you want to preserve the natural beauty and way of life you currently have or do you want to abandon that way of life for a future unknown and one that is potentially damaging to Seneca Lake and its watershed?

Seneca Lake Pure Waters Association urges you to exercise your “home rule” rights to protect your communities, Seneca Lake and its watershed. The natural gas within our watershed and the capabilities of the salt caverns to store LPG will not go away in the future. Delaying these activities until we are certain of their environmental and fiscal impact of our communities, our lake and its watershed is your right and obligation. Please act now as you may only have this one opportunity to do so.

Sincerely,

The Officers and Board of Directors of the Seneca Lake Pure Waters Association

Phil Cianciotto
President of Seneca Lake Pure Waters Association

This letter has been sent to the following elected bodies:
Chemung County Legislature
Ontario County Board of Supervisors
Schuyler County Legislature
Seneca County Board of Supervisors
Yates County Legislature
Town Board of Barrington
Town Board of Benton
Village Board of Burdett
Town Board of Catharine
Town Board of Catlin
Town Board of Cayuta
Town Board of Dix
Village Board of Dresden
Village Board of Dundee
Town Board of Fayette
City Council of Geneva
Town Board of Geneva
Town Board of Gorham
Town Board of Hector
Town Board of Horseheads
Village Board of Horseheads
Town Board of Jerusalem
Town Board of Lodi
Village Board of Lodi
Town Board of Milo
Village Board of Millport
Town Board of Montour
Village Board of Montour Falls
Village Board of Odessa
Town Board of Orange
Town Board of Ovid
Village Board of Ovid
Village Board of Penn Yan
Town Board of Phelps
Town Board of Potter
Town Board of Reading
Town Board of Romulus
Town Board of Seneca
Town Board of Starkey
Town Board of Torrey
Town Board of Tyrone
Town Board of Varick
Town Board of Veteran
Town Board of Waterloo
Village Board of Watkins Glen
September 19, 2011

David Bimber  
Dep. Regional Permit Administrator  
NYS Dept. of Environmental Conservation  
6274 East Avon-Lima Road  
Avon, NY 14414-9516

Dear Mr. Bimber,

On behalf of the Danby Town Board, I want to express our concern about the potential significant adverse impacts of the proposed Inergy LNG storage and distribution facility, proposed to be located in the Town of Reading near Watkins Glen.

The magnitude of the facility and its proposed features and activities have great potential to adversely impact many aspects of the environment, including water quality, wildlife, road systems, noise and light pollution, and the tourism and wine production industries which are essential to the area economy.

The facility could conceivably have a cumulative adverse impact outside of its immediate area, including but not limited to the towns near Cayuga Lake. Increased traffic in the Greater Ithaca area, of which Danby is a part, would be likely.

Thank you for your consideration of our concerns.

Very truly yours,

Fredric Dietrich,  
Town Supervisor
Andrew M. Cuomo  
Governor

(State of New York)  
Department of Agriculture & Markets  
10B Airline Drive, Albany, NY 12235  
518-457-8676  
http://www.agmkt.state.ny.us

Darrel J. Aubertine  
Commissioner

August 11, 2011

Louis G. Damiani  
5810 Walsh Road  
Hector, NY 14841

Dear Mr. Damiani:

Thank you for your letter dated July 27, 2011 regarding our mutual interest in promoting agriculture and protecting the natural resources of New York State. Governor Cuomo and I are both very supportive of a vibrant agricultural industry that is full of opportunities that stem from vast soil and water resources. Complimentary to this, and just days prior to your letter, the Governor signed into law new legislation under the Farm Winery Bill, which reduces regulatory burdens on farm wineries. This is just one of many partnership opportunities that continue to promote the expansion of the wine and grape industry.

By design, legislation, amongst other actions by the Department, continues to support the sustainability of agricultural businesses in NYS. Agriculture is an important part of New York's economy along with many other industries. Together all businesses play a vital role in the protection of our natural resources. The Department works hand-in-hand with other federal, state, and local agencies to minimize neighbor relation concerns and environmental impacts on matters within its statutory charge. It is equally important that the State and local agencies work with other industries such as Inergy, L.P. to achieve the best level of environmental stewardship possible.

The referenced Inergy, L.P. project falls under the environmental review and permitting authority of the NYS Department of Environmental Conservation (DEC), at least two Federal agencies and most likely a local government special use permit. This process is used to facilitate public comment and assure that these businesses can be operated safely with minimal impact to the environment. To the degree possible, I urge you to fully utilize these mechanisms available to you as a member of the public to provide comment.

From a review of the available literature, I understand that much of the speculated long-term environmental risk to Seneca Lake is from increased Chloride releases from the storage of natural gas, and associated geology and displacement of accumulated underground pressure. Under the DEC environmental review process, Inergy, L.P. will need to address the impacts on water and mitigation measures that will be performed to ensure the integrity of structures above and below ground. The Department will continue to stress to the DEC that complete and thorough assessments are done to protect the integrity of our water resources.

Andrew M. Cuomo  
Governor

RAR  
Governo

Louis G. Damiani  
5810 Walsh Road  
Hector, NY 14841

Dear Mr. Damiani:

Thank you for your letter dated July 27, 2011 regarding our mutual interest in promoting agriculture and protecting the natural resources of New York State. Governor Cuomo and I are both very supportive of a vibrant agricultural industry that is full of opportunities that stem from vast soil and water resources. Complimentary to this, and just days prior to your letter, the Governor signed into law new legislation under the Farm Winery Bill, which reduces regulatory burdens on farm wineries. This is just one of many partnership opportunities that continue to promote the expansion of the wine and grape industry.

By design, legislation, amongst other actions by the Department, continues to support the sustainability of agricultural businesses in NYS. Agriculture is an important part of New York's economy along with many other industries. Together all businesses play a vital role in the protection of our natural resources. The Department works hand-in-hand with other federal, state, and local agencies to minimize neighbor relation concerns and environmental impacts on matters within its statutory charge. It is equally important that the State and local agencies work with other industries such as Inergy, L.P. to achieve the best level of environmental stewardship possible.

The referenced Inergy, L.P. project falls under the environmental review and permitting authority of the NYS Department of Environmental Conservation (DEC), at least two Federal agencies and most likely a local government special use permit. This process is used to facilitate public comment and assure that these businesses can be operated safely with minimal impact to the environment. To the degree possible, I urge you to fully utilize these mechanisms available to you as a member of the public to provide comment.

From a review of the available literature, I understand that much of the speculated long-term environmental risk to Seneca Lake is from increased Chloride releases from the storage of natural gas, and associated geology and displacement of accumulated underground pressure. Under the DEC environmental review process, Inergy, L.P. will need to address the impacts on water and mitigation measures that will be performed to ensure the integrity of structures above and below ground. The Department will continue to stress to the DEC that complete and thorough assessments are done to protect the integrity of our water resources.

Andrew M. Cuomo  
Governor

(State of New York)  
Department of Agriculture & Markets  
10B Airline Drive, Albany, NY 12235  
518-457-8676  
http://www.agmkt.state.ny.us

Darrel J. Aubertine  
Commissioner

August 11, 2011

Louis G. Damiani  
5810 Walsh Road  
Hector, NY 14841

Dear Mr. Damiani:

Thank you for your letter dated July 27, 2011 regarding our mutual interest in promoting agriculture and protecting the natural resources of New York State. Governor Cuomo and I are both very supportive of a vibrant agricultural industry that is full of opportunities that stem from vast soil and water resources. Complimentary to this, and just days prior to your letter, the Governor signed into law new legislation under the Farm Winery Bill, which reduces regulatory burdens on farm wineries. This is just one of many partnership opportunities that continue to promote the expansion of the wine and grape industry.

By design, legislation, amongst other actions by the Department, continues to support the sustainability of agricultural businesses in NYS. Agriculture is an important part of New York's economy along with many other industries. Together all businesses play a vital role in the protection of our natural resources. The Department works hand-in-hand with other federal, state, and local agencies to minimize neighbor relation concerns and environmental impacts on matters within its statutory charge. It is equally important that the State and local agencies work with other industries such as Inergy, L.P. to achieve the best level of environmental stewardship possible.

The referenced Inergy, L.P. project falls under the environmental review and permitting authority of the NYS Department of Environmental Conservation (DEC), at least two Federal agencies and most likely a local government special use permit. This process is used to facilitate public comment and assure that these businesses can be operated safely with minimal impact to the environment. To the degree possible, I urge you to fully utilize these mechanisms available to you as a member of the public to provide comment.

From a review of the available literature, I understand that much of the speculated long-term environmental risk to Seneca Lake is from increased Chloride releases from the storage of natural gas, and associated geology and displacement of accumulated underground pressure. Under the DEC environmental review process, Inergy, L.P. will need to address the impacts on water and mitigation measures that will be performed to ensure the integrity of structures above and below ground. The Department will continue to stress to the DEC that complete and thorough assessments are done to protect the integrity of our water resources.

Andrew M. Cuomo  
Governor

(State of New York)  
Department of Agriculture & Markets  
10B Airline Drive, Albany, NY 12235  
518-457-8676  
http://www.agmkt.state.ny.us

Darrel J. Aubertine  
Commissioner

August 11, 2011

Louis G. Damiani  
5810 Walsh Road  
Hector, NY 14841

Dear Mr. Damiani:

Thank you for your letter dated July 27, 2011 regarding our mutual interest in promoting agriculture and protecting the natural resources of New York State. Governor Cuomo and I are both very supportive of a vibrant agricultural industry that is full of opportunities that stem from vast soil and water resources. Complimentary to this, and just days prior to your letter, the Governor signed into law new legislation under the Farm Winery Bill, which reduces regulatory burdens on farm wineries. This is just one of many partnership opportunities that continue to promote the expansion of the wine and grape industry.

By design, legislation, amongst other actions by the Department, continues to support the sustainability of agricultural businesses in NYS. Agriculture is an important part of New York's economy along with many other industries. Together all businesses play a vital role in the protection of our natural resources. The Department works hand-in-hand with other federal, state, and local agencies to minimize neighbor relation concerns and environmental impacts on matters within its statutory charge. It is equally important that the State and local agencies work with other industries such as Inergy, L.P. to achieve the best level of environmental stewardship possible.

The referenced Inergy, L.P. project falls under the environmental review and permitting authority of the NYS Department of Environmental Conservation (DEC), at least two Federal agencies and most likely a local government special use permit. This process is used to facilitate public comment and assure that these businesses can be operated safely with minimal impact to the environment. To the degree possible, I urge you to fully utilize these mechanisms available to you as a member of the public to provide comment.

From a review of the available literature, I understand that much of the speculated long-term environmental risk to Seneca Lake is from increased Chloride releases from the storage of natural gas, and associated geology and displacement of accumulated underground pressure. Under the DEC environmental review process, Inergy, L.P. will need to address the impacts on water and mitigation measures that will be performed to ensure the integrity of structures above and below ground. The Department will continue to stress to the DEC that complete and thorough assessments are done to protect the integrity of our water resources.
I sincerely hope that the matters you discuss in your correspondence with me get resolved to an appreciable level. New York’s economy is diverse and under constant evolution, we must continue to work together to ensure a productive future.

Thank you for expressing your concerns.

Sincerely,

[Signature]

Darrel J. Aubertine
Commissioner

cc: Commissioner Joseph Martens
NYS Department of Environmental Conservation
William M. Newell
4610 Rt. 14
Rock Stream, NY 14878
September 29, 2011

David Bimber
Deputy Regional Permit Administrator
New York State Department of Environmental Conservation
6274 East Avon-Lima Road
Avon, NY 14414-9516

Re: DEC Facility No. 8-4432-00085
Finger Lakes, LLC Underground LPG Storage Facility
Reading (T), Schuyler County

Dear Mr. Bimber:

I have been a member of the Town of Reading Planning Board since it’s inception in 1990. I served as chairman from 1992 until 2007, and have been active to the present. Our Land Use Law went into effect on 1/1/95. Since that time, we have handled several projects involving both U.S. Salt and NYSEG.

We approved NYSEG’s Natural Gas Storage Project with DEC as lead agency and with heavy involvement from the PSC. We approved two U.S. Salt projects: one was for structural changes in their plant. The most recent around 2006/2007 was to build a biomass system for the production of electricity. The construction was completed, but I am not aware of it ever having been put into operation. Once operating it would require numerous truckloads of wood chips, I don’t know if this has been considered in the study of potential truck traffic from the LPG Storage Project. I have no knowledge of what agency may have issued permits prior to our Land Use Law’s adoption.

Much comment has been made about the trestle over the Watkins Glen Gorge. The supposition is that all rail traffic connected with this project will come and go from the south. If, however, any rail traffic is to the north, it will require crossing bridges over Big Stream and Rock Stream within 5 miles as well as over many unguarded rail crossings. The nearest being on the Nye, Spencer and Chase Roads. Due, no doubt, to the infrequency of rail traffic on this line, I have observed people driving over these crossings without stopping or looking. The danger of collision and derailment should be cause for concern.

I don’t intend to repeat points that have been made at the Public Hearing, nor do I feel knowledgeable enough to discuss many aspects of the project. But these are among many concerns of a general nature. I’ll be more specific further on.
Consider these:

1. The capacity of the salt caverns being much greater than that of the brine pond.
2. The danger of interconnections between caverns allowing propane to invade other wells.
3. The age of the well casings.
4. The danger from seismic activity.
5. The applicants insisting that the brine pond be located in the Seneca Lake Protection Area.

This is a good time to mention the town’s Land Use Law. In the charette which produced the first draft of the law and two years and seven more drafts with great public involvement, one of the main priorities was to protect Seneca Lake. Thus we created the Seneca Lake Protection Area, with a higher standard of review than the rest of the town. We had in the beginning considered banning all hydrocarbons, but didn’t include it in the final draft because of the existing gas storage with would have been grandfathered. We did ban gas stations, dry cleaners and other possible contaminants. So it should be no surprise that the public is upset.

The D.I.E.S. doesn’t adequately deal with worst case scenarios and relies too much on assurances that Inergy will do everything it can to prevent accidents etc. Much of it sounds like lawyers produced it — not engineers. And it contains statements that defy common sense. For instance:

1. In the event of a collapse of the brine pond, only 78,450,000 gallons would spill and it would descend down the slope only to the elevation of 811 ft. This is nonsense. Anyone who has lived long in the Finger Lakes, knowing the power of falling water, would find the idea ridiculous.

2. The “Mass Balance Model” doesn’t fit the situation. While the contents of a full brine pond could be assimilated in the total mass of the lake — in time, the immediate effect on drinking water would be a serious problem.

3. The “AHRNSPACK Salt Plume Study of 1974” is inappropriate to the present, is obsolete and never anticipated the volume of what Inergy says is 84,000,000 plus gallons.

Consider this objectively: a pond containing 92 million gallons of a saturated brine solution, contained within a 3000 ft earthen dam at an elevation of 400 ft and on an overall slope of 6 to 1 above the largest fresh water lake in the state — a lake that people depend on for drinking water. Any right thinking person would say this is insane. Consider too that the Department of Environmental Conservation by its very name should conserve the environment, not lightly allow it to be the victim to dangerous contaminants. Consider too that our Land Use Law is so conscious of the importance of the lake that it has designated the land to the east of Route 14 as the Seneca Lake Protection Area, and in
this district things like Gas Stations, Dry Cleaners are prohibited. Yet this proposal of Inergy would introduce high quantities of propane.

While I hope this project never gets built, I am a realist enough to think that it might. Nothing, however, can mitigate the risks of a brine pond located east of Route 14. When the applicants first presented their plan I told them I would never vote approval with the pond in that location, and that unless it was located west of Route 14 it could never be acceptable. They said at first that they didn’t own enough land. Then they said it would cost too much, then that it would increase the head, then it would require rerouting part of the pipeline. At each meeting with Inergy I reiterated my objections and at each subsequent meeting they presented a revised design of the brine pond, finally coming up with the plan in the D.I.E.S. I still find it unacceptable.

Early on I pointed out to Inergy that the danger of collapse would send a saturated brine solution into the lake with at least temporary water pollution affecting drinking water from the lake and having a devastating effect on marine life in the area. I consulted with a geologist who said the danger of collapse by earthquake or landslide was real, and with a biologist who confirmed my fears for aquatic life. While there has been no recent earthquake centered at the site, there have been frequent minor earthquakes to the east and west. And I was informed that a fault ran under the lake from Himrod to Montour Falls.

I refer to Option Two in the D.I.E.S which is an alternate location for the brine pond to the west of Route 14. It has several improvements on all the other designs, amongst them being rectangular – which even the applicants say is desirable – and it is away from the lake with “less slope”. But there is nothing in Option Two to suggest that they are not wedded to an earthen dam. The dimensions on the map appear to be approx. a 600x1200 ft. rectangle. They appear not to have considered other rectangular configurations such as 720x1000 ft. at the same depth or reducing the surface area by making the pond deeper, such as 600x800 ft. or 500x900 ft. by making the pond 11/2 of the depth of Option Two. Or by making the surface area even smaller by doubling the depth of Option Two. There are many possibilities that appear not to have been considered. Which leads me to believe they made no serious effort in this direction.

A further point is that digging down into the existing slope with the top of the brine level below grade would make an earthen dam unnecessary except for an uphill berm to prevent run off from entering the pond. Furthermore the raised railbed to the west would also limit the amount of run off.

Inergy would probably offer the same objections, but if they must have a brine pond, this could be done. The likelihood of collapse would not be an issue. It might cost more – I don’t know – but money is nothing versus protecting Seneca Lake. I am not aware of test boring having been done, but my knowledge of the area’s land suggests perhaps even as much as 25 ft. of soil over the horizontal strata of fragmented shale. Going down into the
shale should not be a monumental task and a clay lining before the membranes are in place should insure an acceptable solution to the problem.

If the D.E.C. should approve this project – something I dearly hope never happens – it should be with conditions and those conditions, among others, should be:

1. **That the brine pond be relocated to the west of Route 14 along the lines I have suggested.**
2. **That all salt wells and caverns other than those specified should be permanently sealed so that no expansion of this project can take place.**

Perhaps I’m playing into the hands of the enemy by suggesting ideas on how the brine pond could be relocated. But my fear of the project being accepted compels me to try to find some solution that is more benign. I hope the D.E.C. will take this into serious consideration.

In closing I’d like to point out that early on Mr. McDonough was most informative and helpful and that I have since had many conversations with you, Mr. Bimber. I have always found you to be open and honest and a model of what I think a public servant should be. Whatever the outcome I wish to express my thanks.
4.10 Seneca Lake Protection Area

The Town of Reading finds that Seneca Lake is a recreational and economic resource of great value to the community and desires special protection of this valuable asset.

4.10-1 Applicability
This Section 4.10 shall apply to all land lying east of New York State Route 14 as well as within 50 feet of the banks of first order streams that drain into Seneca Lake:

4.10-2 Prohibited Uses
The following uses, when conducted at a scale larger than that of an ordinary household, shall be prohibited in the Seneca Lake Protection Area. Existing activities that engage in these activities may continue and expand, provided that they comply with all applicable federal, state, and county laws and regulations and do no increase their non-compliance with this section. Existing activities that are in full compliance with a valid State Pollution Discharge Elimination System (SPDES) Permit shall be exempt from Section 4.10.

a. Disposal of hazardous materials or solid waste including operation of a landfill.
b. Treatment of hazardous materials, except rehabilitation programs authorized by a government agency for treating hazardous materials that existed on the site prior to the adoption of this land use law.
c. Storage of hazardous materials, except in sealed or unopened containers for resale or as needed for ordinary household use.
d. Production of hazardous materials.
e. Dry-cleaning and dyeing establishments and laundries that use cleaning solvents.
f. Printing and photo processing establishments.
g. Furniture and finish stripping establishments.
h. Disposal of septic sludge.
i. Uses which discharge hazardous materials into groundwater or surface water.
j. Automotive service stations.
k. Junkyards.

4.10-3 Regulations

a. No structure shall be built on expanded within 25 feet of Seneca Lake (measured horizontally from the mean high water line) or within the 100-year flood plain as shown on Flood Insurance Rate Maps (FIRM) of the Federal Emergency Management Agency, except docks, boat houses, and storage buildings not exceeding 300 square feet.
b. No boat house or storage building shall be used for residential purposes.
c. No excavation or fill shall be permitted within 25 feet of Seneca Lake excepting shore wells (also knows as beach wells), seawalls and permitted docks.
d. Residential density shall not under any circumstances exceed one dwelling unit per two acres.
e. All uses which would otherwise require Site Plan Only approval shall instead be subject to Special Permit review.
f. Maximum lot coverage by roofed structures or other impervious surfaces shall be 20%.
g. Within 200 feet of Seneca Lake minimum lot width shall be 100 feet for dwellings which use the lake, or a municipal or off-site system for water supply and 150 feet for dwellings which use a private well and septic system both located on the lot.
Joe Martens, Commissioner
New York State Department of Environmental Conservation
625 Broadway
Albany, New York 12207

Dear Commissioner Martens:

As the New York State Senator representing the Finger Lakes region and its many beautiful lakes, rivers and streams, it was with great concern that I read the Department of Environmental Conservation’s Environmental Impact Statement for a proposed Liquefied Petroleum Gas (LPG) Storage Facility in Reading, NY. A number of my constituents have expressed concerns that this statement does not address many questions about the environmental, economic, and cultural impact this project will have on Seneca and Cayuga Lakes, as well as the tourist industry that provides hundreds of jobs and brings thousands of visitors to our region.

The proposal by the company Inergy to build this facility here raises a number of economic and safety issues, including the heavy amount of truck traffic it will bring through our local communities, the transport of potentially explosive substances near residential areas and the proximity of the facility itself to the scenic waterfront area in Watkins Glen, a major tourist destination. A more thorough review needs to be given to how the facility will affect local property values and the tax base. Already, many homeowners are selling their property or delaying remodeling plans in anticipation that the project will decrease the value of their homes.

In addition, the DEC’s Environmental Impact Statement does not address the potential for LPG and other chemicals stored in the salt mines to seep into Seneca Lake. The proposed facility also includes a brine pond that would be located directly above the local water table. Seneca Lake is the source of fresh drinking water for over 100,000 residents and hundreds of local businesses, farms, wineries, and vineyards. If it were to be in any way contaminated, the effects on the entire region would undoubtedly be severe and devastating.

-continued-
It is vitally important that our New York State government take every precaution necessary to protect our fresh water resources and the communities that rely on them.

Therefore, it is my strong recommendation that the DEC conduct an independent Qualitative and Quantitative Risk Analysis (QRA) to thoroughly and impartially evaluate the risk and impact that this facility would have on the region.

Your immediate attention to this very serious issue is needed and will be appreciated.

Sincerely,

Michael F. Nozzolio,
Senator, 54th District

MN/km
The Honorable Andrew M. Cuomo  
Governor of New York State  
NYS State Capitol Building  
Albany, NY 12224  

Dear Governor Cuomo,

In September 2009 Inergy, a Kansas City based company proposed a $40 million project to expand the storage and distribution of propane and butane on a 576 acre site near Routes 14 and 14A, north of Watkins Glen. The proposal is to use existing salt caverns with a capacity of 88.2 million gallons to store LPG. The caverns currently are filled with salt brine. The LPG would displace the salt brine which would be stored in a 14 acre lined surface pond above Seneca Lake. As LPG is withdrawn the stored brine from the pond would be used to displace the LPG in the cavern. Inergy also announced plans for a transfer station to transport propane and butane by truck from the site and butane by rail. Since Feb. 2010 the NYS DEC has been in charge of the State Environmental Quality Review (SEQR).

Seneca Lake Pure Waters Association has provided the attached comments regarding the proposed LPG storage facility by the Finger Lakes LPG Storage LLC in Watkins Glen, New York. Our comments were in response to a request by the NYSDEC for public comments in regards to the Draft Supplemental Environmental Impact Statement (DSEIS) submitted for this project (DEC 8-4432-00085/00001 issued August 1, 2011. Our Association represents over 400 member residents within the Seneca Lake watershed.

As stated in the attached documents we have the following primary concerns regarding Seneca Lake:

1. We are concerned that the salt caverns do not have the geologic stability to properly contain the Liquefied Petroleum Gas (LPG) under the pressures specified without failure and potential harm to Seneca Lake.

2. We are concerned about the environmental safety of Seneca Lake in regards to catastrophic failure of the proposed brine pond above Seneca Lake.

In addition, while outside of our association’s mission as the “Voice of Seneca Lake”, SLPWA believes that the DEC should give consideration to three other issues related to the proposal by Inergy.

1. An independent 3rd party evaluation of a Quantitative Risk Assessment has merit and should be pursued to evaluate the geologic stability of the US Salt solution salt caverns, and the feasibility of such a facility near Watkins Glen given the geographic location within a glacial valley.
2. A study to evaluate the social-economic impact of the project on the already established and growing tourism and wine industry of the region. Risking the vitality of this growth in an area that has faced economic uncertainty in the past maybe misguided.

3. The ability of first responders (police, fire and rescue teams and medical facilities) to cope with an emergency at the proposed facilities should not be overlooked and properly funded by Inergy, prior to approval for construction.

Seneca Lake Pure Waters Association strongly recommends that the SEIS Scoping Outline include additional geological assessment of these salt caverns to assure that the proposed facility can be used safely for the long term storage of LPG. We also urge the DEC to require Inergy to look for a more environmentally suitable location for the brine pond that would protect Seneca Lake from a catastrophic failure.

Sincerely,

Phil Cianciotto
President, Seneca Lake Pure Waters Association

cc.
NYS Lt. Governor Robert J. Duffy
NYS DEC Commissioner Joe Martens
NYS Attorney General Eric T. Schneiderman
NYS Assemblyman Brian M. Kolb
NYS Assemblyman Christopher S. Friend
NYS Assemblyman Philip A. Palmesano
NYS Senator Michael F. Nozzolio
NYS Senator Thomas O’Mara
US EPA Region 2 Administrator Judith A. Enck
Village Board of Watkins Glen, NY
Town Board of Reading, NY
Dear Mr. Bimber,

Seneca Lake Pure Waters Association (SLPWA) welcomes the opportunity to comment on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Finger Lakes LPG Storage LLC Watkins Glen LPG Storage Facility DEC 8-4432-00085/00001 issued August 1, 2011. Our association represents over 400 member residents within the Seneca Lake watershed.

In our response to the Department of Environmental Conservation this past January on the initial Scoping outline we were concerned with the geologic stability of the salt caverns to properly contain the Liquefied Petroleum Gas (LPG) under the pressures specified without failure and potential harm to Seneca Lake. As we noted then, there is significant evidence of an incursion of the glacial lake bed and the salt formation where the LPG is to be stored. This incursion is believed to be the source of the higher salt concentration found in Seneca Lake (125 ppm) which is 3-4 times higher than in our neighboring lakes. There is further evidence as noted in our January comments (see attached) that the higher concentrations of salt in Seneca Lake correlates with the start up of solution mining for salt at the beginning of the 20th Century. We believe that further geological testing of the salt caverns and surrounding area need to be conducted to verify the stability of these salt caverns. It was interesting to note during the public hearing held on Sept 27th in Watkins Glen, the comment was made that while solution mining salt caverns are used to store 8% of the stored LPG they are involved in 45% of the accidents. Unfortunately we could not verify the authenticity of that comment. Indeed, if the use of solution mined salt caverns for gas storage are inherently more problematic the DEC should insist on special consideration in the design and safety measures before permitting the use of these structures for LPG storage.

We remain concerned about the environmental safety of Seneca Lake in regards to a catastrophic failure of the proposed brine pond above Seneca Lake. While the loss of the pond would unlikely have a long term effect on the lake (the pond content would only marginally increase the salt content of the lake and likely be fully dissipated throughout the lake within a matter of days) the localized effects can be significant to the local environment of the lake and the area downhill of the brine pond for much longer periods of time.

In their DSEIS issued this August, Inergy states on page 61-64 that they have evaluated four alternative siting options for the brine pond. Two of the options involve creating two ponds to potentially reduce the impact of a failure by 50% and two options explore alternate locations for a single pond. The conclusion presented by Inergy was that the location and size of the brine pond
was the best they could offer after a careful examination of the entire US Salt property. It was not clear from their review if this search included the recently acquired property from Casella Waste Management and NYSEG or just the former property of US Salt. Given the potential for environmental impact of a brine pond failure on Seneca Lake we strongly urge the DEC to require Inergy to conduct a full site review of not only Inergy owned property for a more suitable location for the brine pond but also alternative acquirable sites which would reduce the environmental risks to Seneca Lake. If no other site is determined suitable for the brine pond we would think it responsible to include plans for secondary backup containment for their current proposal. It should be noted that if no other site is considered acceptable for the construction of a brine pond, then any further expansion of gas storage capability requiring a brine retention pond should be ruled out.

While outside of our association’s mission as the “Voice of Seneca Lake”, SLPWA believes that the DEC should give consideration to 3 other issues related to the proposal by Inergy.

1. An independent 3rd party evaluation of a Quantitative Risk Assessment has merit and should be pursued to evaluate the geologic stability of the US Salt solution salt caverns, and the feasibility of such a facility near Watkins Glen given the geographic location within a glacial valley.

2. A study to evaluate the social-economic impact of the project on the already established and growing tourism and wine industry of the region. Risking the vitality of this growth in an area that has faced economic uncertainty in the past maybe misguided.

3. The ability of first responders (police, fire and rescue teams and medical facilities) to cope with an emergency at the proposed facilities should not be overlooked and properly funded by Inergy, prior to approval for construction. Within the past year we recall two significant events in the Rochester/Monroe County area where propane facilities faced such emergencies – one event on a Monroe County operated fueling station and the other on a privately owned fuel depot. Both events required the capability of emergency services found in a larger metropolitan area like Rochester/Monroe County.

In summary, Seneca Lake Pure Waters Association strongly recommends that the SEIS Scoping Outline include additional geological assessment and testing based on an intrusion of salt into Seneca Lake potentially from these salt caverns to assure that the proposed facility can be used safely for the long term storage of LPG. We also urge the DEC to require Inergy to re-evaluate its entire property site as well as the adjoining area for a more environmentally suitable location for the brine pond that would protect Seneca Lake from a catastrophic failure. In addition, consideration by the DEC should be given regarding the need for an independent Quantitative Risk Assessment, a social-economic impact review this project would have on the existing wine and tourism industry of the region, and the ability of first responders to deal with an emergency if one should arise

Sincerely,  

Phil Cianciotto,  
President, Seneca Lake Pure Waters Association
Seneca Lake Pure Waters Association
P.O. Box 247
Geneva, NY 14456
SLPWA@senecalake.org
January 27, 2011

Dear Mr. Bimber


We have reviewed the draft scoping document and find that the scope is limiting in one area of major concern to us. We believe the proposed scoping document fails to adequately address the unique geology of the Seneca Lake basin and the potential intrusion of that basin into the Syracuse Formation of Shale/Rock Salt as suggested by Wing et al. in their 1995 publication\(^1\) and substantiated by Halfman et al., in their 2006 paper\(^5\).

Wing et al. reported that chloride concentrations in Seneca Lake are 5 to 6 times higher than all other Finger Lakes and about twice the levels reported for Cayuga Lake which has chloride concentrations 2-3 times higher that the other Fingers Lakes. They argue that source of the salts is the underlying salt beds, and the flow of salty brines from the bedrock into the lake. Seneca and to a lesser degree Cayuga Lake are the only Finger Lakes impacted by the underlying salts due to the great depth of both basins. Our concern is that the dissolution of salt into the lake suggests potential pathways to the proposed salt cavern storage areas. It is our belief that to fully understand the geological suitability of the existing salt caverns for the safe storage of LPG, the DSEIS needs to go beyond “borrowing from publicly available information submitted in connection with the underground storage permit application and site specific information”. The unique geology of the Seneca Lake basin which intersects with the Syracuse Salt Formation requires a more detailed study to understand the potential for catastrophic failure of the proposed gas storage caverns such as occurred in Livingston County in 1994\(^2\) due to the incursion of groundwater. A similar occurrence due to lake water in the proposed LPG storage facility could result in a massive environmental release of the stored LPG and brine into the Seneca Lake the water supplies that depend on it and its atmosphere.


In addition to the pioneering work by Wing, et al., three other research groups\(^3\), \(^4\), \(^5\) concluded that further geological testing and scientific investigative work is needed to understand the geology of the Seneca Lake basin and the long-term impact of natural occurring salt intrusion on the lake and surrounding salt beds. These studies suggest that the long-term stability of the proposed LPG storage in these salt caverns may pose a very high risk to the air and water environment of Seneca Lake. Finally, recently compiled historical chloride data spanning back to the 1990s for Seneca Lake reveal low chloride concentrations (~30 ppm) in the early 1990s, increasing to the highest chloride concentrations in the 1960s and 1970s (~160 ppm), and slowing decreasing to modern day concentrations (~120 ppm)\(^6\),\(^7\). We wonder if the century scale rise and decline, changes that mimics mining activities in the watershed, suggest that solution mining hydrostatic pressures influenced the groundwater discharge of the brines into the lake.

Seneca Lake Pure Waters Association strongly recommends that the DSEIS Scoping Outline include a geological assessment and additional testing based on an intrusion of salt into Seneca Lake from these salt mines to assure that the proposed facility can be used safely for the long term storage of LPG.

Sincerely,

\[\underline{\text{Phil Cianciotto,}}\]
\[\text{President, Seneca Lake Pure Waters Association}\]

---


Dear Mr. Bimber,

This letter provides further comments from me on the proposed LPG storage facility in the Town of Reading (DEC Facility ID 8-4432-00085).

As I pointed out at the public forum in Watkins Glen on September 27th, I bring to your attention NYCRR Section 617.9(b)(6), which is cut & pasted below;

6) In addition to the analysis of significant adverse impacts required in subparagraph 617.9(b)(5)(iii) of this section, if information about reasonably foreseeable catastrophic impacts to the environment is unavailable because the cost to obtain it is exorbitant, or the means to obtain it are unknown, or there is uncertainty about its validity, and such information is essential to an agency's SEQR findings, the EIS must:

(i) identify the nature and relevance of unavailable or uncertain information;

(ii) provide a summary of existing credible scientific evidence, if available; and

(iii) assess the likelihood of occurrence, even if the probability of occurrence is low, and the consequences of the potential impact, using theoretical approaches or research methods generally accepted in the scientific community.

This analysis would likely occur in the review of such actions as an oil supertanker port, a liquid propane gas/liquid natural gas facility, or the siting of a hazardous waste treatment facility. It does not apply in the review of such actions as shopping malls, residential subdivisions or office facilities.

It would appear that the SEQR process specifically requests an assessment of probability and consequence of proposed LPG facilities with respect to off-site risks. My interpretation of what "theoretical approaches and research methods generally accepted in the scientific community" means is that the regulation is calling for a quantitative risk assessment including dense-gas dispersion modeling to assess probability and consequence of potential above-ground LPG releases. There are several qualified 3rd-party engineering firms that specialize in this type of study for LPG. One of these firms could be employed to complete the risk assessment and describe the potential off-site risks in a more definitive way than currently described by the draft environmental document.

The EIS has insufficient information in it about the fire protection systems that would be used by the facility. Given the highly flammable nature of LPG and the potential for off-site consequence, the facility should strongly consider investing in a fire protection system that can provide remote and/or automated application of water in the storage and LPG transportation loading areas. Other facilities in New York State, most notably the Enterprise terminal at Selkirk, NY have done so.
However a QRA or similar hazard analysis may take a look at these questions and come to other conclusions.

I believe that the project should follow the National Fire Protection Association (or NFPA) Code 59, the LP Utility Gas Plant Code—this in addition to NFPA 58 the Liquefied Petroleum Gas Code. For additional security, I recommend that the applicants consider including the American Petroleum Institute's standards for LPG facilities API 2510 and 2510A, as some other LPG facilities in New York State have voluntarily undertaken.

I had previously written the DEC with comments about the Inergy project in a letter from June 3, 2011. I would like to correct a mistake in that letter based on new information. I had said that the amount of LPG proposed for storage by Inergy was 74 times greater than that of the adjacent Enterprise Products pipeline and storage facility. My information about the quantity of propane stored by Enterprise was obtained from the Right-to-Know Network website, rtknet.org, which publishes certain EPA Risk Management Program (RMP) data. The RMP data published on that site was provided to them by the US EPA on February 25, 2011. According to EPA and rtknet.org, the total amount of propane stored at the Enterprise Watkins Glen facility is listed as 5,317,600 pounds which is equivalent to a little over 30,300 barrels. This amount is meant to include both underground storage and above-ground storage containers.

However other information sources, especially presentations from TEPPCO (predecessor to today's Enterprise Products) to the New York State Energy Research and Development Authority (NYSERDA) in 2007 and 2008 indicated that Enterprise has a 1.2 million barrel underground storage capacity. I called Enterprise Products in September and questioned the 5 million pound quantity that they apparently had filed with the US EPA. Enterprise confirmed to me that their RMP submission was in error and that they had mistaken gallons for barrels in their conversion of volume to mass units, thus the actual quantity was some 42 times greater than communicated to the EPA. Enterprise told me that they immediately filed an amended RMP report to the EPA to correct this error. Based on the correct information, the amount of LPG proposed for underground storage at the Inergy facility is 1.75 time the underground storage at the nearby Enterprise Products facility (e.g. 2.1 / 1.2 million barrels = 1.75).

I have made an account of the quantities of LPG stored at the major LPG distribution facilities in New York State, based on the assumption that publicly available storage quantities are accurate. Storage bullets are 30,000 gallons each unless noted as 90,000 gals. Results are shown in Table 1.

**Table 1 - Total LPG Inventory On-Site (includes underground, and above ground storage)**

<table>
<thead>
<tr>
<th>Location / Project</th>
<th>Quantity lbs</th>
<th>Quantity BBL</th>
<th>Primary LPG</th>
<th>Underground Storage?</th>
<th>Brine?</th>
<th>Aboveground Storage?</th>
<th>Truck Rack?</th>
<th>Railcar Max # of Cars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reading - Phase 1</td>
<td>389,510,309</td>
<td>2,103,994</td>
<td>C3 / C4</td>
<td>Yes</td>
<td>Yes</td>
<td>5 bullets</td>
<td>Yes</td>
<td>32</td>
</tr>
<tr>
<td>Savona</td>
<td>297,562,217</td>
<td>1,699,008</td>
<td>C3 / C4</td>
<td>Yes</td>
<td>Yes</td>
<td>6 bullets</td>
<td></td>
<td>15</td>
</tr>
<tr>
<td>Harford Mills</td>
<td>250,000,000</td>
<td>1,313,235</td>
<td>C3 / C4</td>
<td>Yes</td>
<td>Yes</td>
<td>7 bullets</td>
<td></td>
<td>12</td>
</tr>
<tr>
<td>Watkins Glen</td>
<td>210,418,200</td>
<td>1,201,429</td>
<td>propane</td>
<td>Yes</td>
<td>No</td>
<td>2 bullets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selkirk</td>
<td>3,500,000</td>
<td>19,964</td>
<td>C3 / C4</td>
<td>Yes</td>
<td>Yes</td>
<td>6 bullets (90's)</td>
<td>Yes</td>
<td>10</td>
</tr>
<tr>
<td>Phoenix</td>
<td>2,016,000</td>
<td>11,511</td>
<td>propane</td>
<td>No</td>
<td></td>
<td>n/a</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Albany</td>
<td>1,125,900</td>
<td>6,429</td>
<td>propane</td>
<td>No</td>
<td></td>
<td>3 bullets (90's)</td>
<td>Yes</td>
<td>many</td>
</tr>
<tr>
<td>West Oneonta</td>
<td>465,000</td>
<td>2,655</td>
<td>propane</td>
<td>No</td>
<td></td>
<td>2 bullets</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

Source: EPA Risk Management Plan Filings & Public Information, Inergy DSEIS

Based on these numbers, the proposed Inergy project at Reading would become the largest storage facility in New York State.
While I agree that underground storage of large quantities of LPG is safer than storing the material above-ground, it is the above-ground interim storage quantities at Reading and the frequency of transfers of this product that may need further scrutiny. Table 2 shows my accounting of LPG product proposed for above-ground storage at Inergy and a comparison with the nearby Enterprise facility. The proposed project would store significantly larger quantities, especially if I include up to 32 railcars that could be on-site at one time.

Table 2 - Surface LPG Storage Inventory Comparison

<table>
<thead>
<tr>
<th></th>
<th>Inergy Proposed Inventory (Propane-Only Basis)</th>
<th>Barrels</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Ground Storage Tanks</td>
<td>3,143</td>
<td>550,440</td>
<td></td>
</tr>
<tr>
<td>Above Ground Storage Rail Cars</td>
<td>23,131</td>
<td>4,051,238</td>
<td></td>
</tr>
<tr>
<td>Total Potential Above-Ground</td>
<td>26,842</td>
<td>4,701,194</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Enterprise Products Above-Ground Inventory @ Watkins Glen Facility</th>
<th>Barrels</th>
<th>Pounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Above Ground Storage Tanks</td>
<td>1,257</td>
<td>220,176</td>
<td></td>
</tr>
</tbody>
</table>

Ratio of Inergy Phase-1 to Enterprise  21 x

I hope this information and the comments I have made here are helpful to you and the DEC, as the decision process moves forward.

Sincerely,

Charles M. Sorensen
June 3, 2011
2602A Spencer Hill Rd
Corning, NY 14830

David L. Bimber
NYS DEC-Region 8
6274 East Avon Lima Rd
Avon, NY 14414
(585) 225-3401

Dear Mr. Bimber,

I am writing this letter to highlight certain issues related to the proposed Inergy LPG storage facility in Reading, NY. My background is that I hold a PhD in Chemical Engineering from the University of Delaware (1985), have a professional engineering license, and 26 years experience. I spent 14 years working for Mobil Oil (now ExxonMobil) in a variety of oil refinery-related capacities including R&D, engineering, process and equipment design, operations, and safety including accidental release and offsite consequence issues for hydrocarbons and toxics stored under pressure. I hold 24 US patents including several that involve processing of LPG at high pressure.

I have read through the Inergy DSEIS document and would like to make some comments on it. After that, I have some insights and significant concerns with the safety of the project in the event of accidental releases.

As others have pointed out, the assumption of perfect mixing in the catastrophic brine release calculation into Seneca Lake on page 91 is an unacceptable simplification. In the event of a large release the local concentration of salt in the area near the brine spill would be very high. Detailed modeling of the scenario should be performed.

I did not see anything in the DSEIS that addressed the potential for odors from the facility. Concerns that I have include the potential for odors from the brine pond, from process operations including process upsets, fugitive odors from pumps, flanges, sample taps, and valves. While propane (without odorant) is considered odorless, the presence of propylene and other LPG constituents within allowable specification limits result in odor.

There was nothing in the DSEIS that indicated that Inergy plans to use LPG odorant in the facility. I think this is an omission on their part since odorant is required for rail and on-road transport and it seems it should be part of their rail and truck depot plans. Does Inergy plan to store and use ethyl mercaptan at the facility, and if so at what storage volume?

The flare is another area where I have questions. When brine is moved from the underground cavern to the storage pond, it will go through a separator to remove any dissolved or entrained LPG, and the LPG off-gas will be flared. There was not enough information in the DSEIS to assess the impact of a process flare on the surrounding area. Flares can affect the visual aesthetics, generate noise, produce smoky particulates, and gaseous emissions. The potential for brine-sourced chlorides in the flare gas raises additional questions about the types of gaseous emissions from such a facility (e.g. trace chlorinated hydrocarbons formed in-situ). It is my personal experience working in refineries that the flare is responsible for the majority of safety, health, and environmental community complaints, especially when process upsets occur and a significant amount of flare activity occurs.
I would also like more information about the potential release of hydrocarbons from the storage pond itself. Over time, and after contact with a significant quantity of hydrocarbon, there is the potential that trace contaminants in LPG would build up in the brine system. From my perspective, the brine is a “recycle loop” in Inergy’s system and the build up of undesirable components in a recycle loop is a fundamental watch-out for any chemical process. Other sources of unexpected hydrocarbons in the brine could come from microbial action. If trace components are heavier than LPG and/or have organic functional groups that affect their solubility, the flare separator may not remove them.

There was no mention in the DSEIS about auxiliary LPG process units such as dehydrators. LPG in contact with brine would be expected to pick up some water and dehydrating units have been used at other storage facilities to dry the hydrocarbon. What other processing and handling operations and associated equipment are planned?

I did not see any remarks in the DSEIS about the impact of seasonal ambient conditions. The freezing point of brine is lower than that of water, but there is potential that under severe cold winter conditions such as those experienced in Reading, NY this January, brine can freeze. While it would be unlikely that the pond would freeze over, I am more concerned with the lesser quantities contained in pipes, valves, pumps, etc. This could affect Inergy’s ability to operate and could pose a safety issue. It is worth noting that there are only three other salt caverns in the northern latitudes in the United States – Inergy’s Savona, NY LPG facility and two in Michigan according to an Energy Information Administration 2004 map. I am not able to determine if the Michigan facilities are brine compensated. A Google map image of the LPG storage facility in Alto, MI suggests that it is not brine compensated.

My other comments concern the potential for accidental release of flammable liquids and gases from the facility. The Inergy DSEIS referred to EPA RMP and OSHA PSM analyses which will be forthcoming, presumably after a project would be approved. I think the potential issues involving an accidental release are significant and should be discussed before approval is considered.

The quantity of flammable propane and butane proposed by Inergy at the 2.1 million barrel initial phase is 74 times more than the amount stored at the nearby Enterprise-TEPPCO facility in Watkins Glen. If Inergy were permitted to expand to the full 5 million barrel storage capacity, as indicated on their website, it would be over 170 times larger than TEPPCO. This significant amount of hydrocarbon storage presents potentially catastrophic offsite consequences if an accident were to occur. While I believe that underground storage is considerably safer than above-ground, the facility will be handling very large quantities of LPG under high pressure (e.g. 1000 psig at the well head), and making transfers through pipelines, trucks, and rail cars. The frequency of transfer operations, equipment failure, engineering design weakness, corrosion, poor maintenance, and most importantly human error are some of the factors that conspire to create unexpected accidents.

It is my belief that Inergy has no experience planning and building a storage facility of this size and complexity. I have not found evidence to the contrary. My understanding is that they bought the existing Savona, NY facility in 2006. I am concerned that they may be underwhelming the potential risks.

With respect to accidental release of LPG, a major concern I have with this project is the location of the well, the distribution terminal, the pumps, and pipelines on the side of a down-sloping hill above Seneca Lake. In the event of an accidental release, the heavier-than-air nature of a LPG
cloud would likely send the release down onto the lake where predominant winds could sweep it into Watkins Glen or other residential and commercial areas, creating major offsite risk. In the 1990 LPG pipeline accident and release in North Blenheim, NY, the cloud moved downhill into the town and ignited, killing two, injuring seven, and causing millions of dollars of destruction. In Georgia in September 1962 an 8" LPG pipeline leak resulted in the movement of a LPG cloud 10 miles down a river valley. The history of major releases, fires, and explosions at salt cavern storage facilities is well-documented, with the most recent events occurring in 2004.

I have been searching databases and reviewing aerial maps of other LPG storage facilities in the United States and have yet to find any that are sited on the side of a hill with residential populations below. I think it is important to point out that state of the art dense cloud models such as the DEGADIS program used by industry and the EPA are designed for flat terrain only. The Inergy project is essentially entering unknown territory as far as understanding the off-site consequences of an accidental release.

It is my opinion that the proposed Inergy project represents a substantial risk to the community if an accidental release were to occur. Moreover, a risk analysis and assessment would require analytical tools that industry and scientific community do not possess today. For these reasons I urge the State of New York to carefully analyze this project and understand the hazards, risks, and consequences of this facility as part of the review process. At minimum a Quantitative Risk Analysis/Assessment by a competent 3rd party engineering firm should be considered.

If I can supply more information or if you have questions about what I have presented here, please contact me during weekdays at (607) 974-0186.

Sincerely Yours,

Dr. Charles Sorensen
Dear Mr. Bimber:

The U.S. Environmental Protection Agency (EPA) has reviewed the August 2011 draft Supplemental Environmental Impact Statement (DSEIS) that was prepared by the New York State Department of Environmental Conservation (NYSDEC) on the proposed Finger Lakes LPG Storage, LLC (Finger Lakes) Liquid Petroleum Gas (LPG) Storage Facility in the Town of Reading, Schuyler County, New York. The purpose of the DSEIS is to satisfy the requirements of the State Environmental Quality Review Act (SEQRA) for NYSDEC to review and process a permit application for Finger Lakes LPG Storage, LLC to construct a multi-cycle LPG storage system with a major pipeline connection and rail and truck load/unload racks. This DSEIS is a supplement to the NYSDEC’s 1992 Generic Environmental Impact Statement on the Oil, Gas and Solution Mining Regulatory Program.

EPA has several comments on the DSEIS:

1) Brine Pond Leak Emergency Procedures: The DSEIS provided several scenarios whereby it may become necessary to remove some or all of the brine from the planned Finger Lakes brine pond. These scenarios include development of a possible leak of 0.55 gpm or less, development of a possible leak greater than 0.55 gpm and accumulation of precipitation in excess of evaporation resulting in fluid level rise. In each case, the brine level in the brine pond would be lowered by removing brine from the bottom of the pond and delivering it to US Salt’s brine pond where it would be used by US Salt in its operations and permanently lost to the LPG storage operation, and/or injection of brine into the LPG storage caverns. In more serious events, it is noted that US Salt could suspend solution mining activities at its facility in order to accommodate larger volumes of Finger Lake’s brine. EPA has several questions about these procedures, primarily concerning the speed with which Finger Lakes could partially or totally drain the brine pond to minimize a release.

a) There is no discussion of the timeframes for delivery of brine to US Salt and how quickly brine can be transferred through the piping to US Salt’s brine pond. In addition, discuss US Salt’s capacity to accept brine, e.g., the excess storage volume, if any, typically available in US Salt’s brine pond at any particular point in time that could be utilized by
Finger Lakes; how quickly US Salt processes its brine from its brine pond, i.e., how quickly can US Salt free up storage capacity in its pond to accommodate Finger Lakes brine should that become necessary. This should include how quickly US Salt can suspend solution mining activities if necessary.

b) The DSEIS also indicates that brine could be injected into the storage caverns in an emergency. However, this option is limited to the LPG aboveground storage capacity available at the time because LPG would have to be removed from the caverns and stored to enable the injection of brine.

c) The DSEIS indicates that, for smaller leaks, liner inspection and repair would be done when the brine pond level is at its lowest in the spring. Depending on the timing of leak development, this may mean that a leak could go unrepaired for upwards of a year, potentially allowing the leak to worsen.

2) **Operational Growth of the Storage Caverns:** the DSEIS states (Page 78) that the expected operational growth of the caverns is expected to be 1-2% per year due to the injection of "slightly" undersaturated brine. It is unclear if all relevant factors have been considered in developing this estimate:

a) The DSEIS notes that the brine that is injected into the caverns will be obtained from the bottom of the brine storage pond where saturation is expected to be highest. The DSEIS also notes that, in New York, precipitation is greater than evaporation which would result in a drop in saturation levels in the brine pond. Please discuss the expected saturation levels of the brine in the bottom of the pond and whether there will be a minimum salinity, i.e., if saturation levels drop below a certain value, will brine injection cease and more highly saturated brine obtained?

b) In the event that a liner leak develops or excessive precipitation raises fluid levels in the brine pond above operational limits, brine will be pumped from the bottom of the brine pond to US Salt's facility. This operation would remove the brine of highest salt saturation from the LPG storage facility, potentially only leaving brine of lower saturation for injection. Was this scenario considered in evaluating the likely cavern growth rates cited in the DSEIS? Can Finger Lakes obtain saturated brine from US Salt or elsewhere should brine pond saturation levels drop too far, e.g., after brine is removed to repair or replace the primary liner or after significant precipitation events?

c) The DSEIS indicates that Finite Element Analyses were performed to evaluate the stability of the proposed storage caverns and nearby solution mining and gas storage caverns over the next 50 years. While operational growth of the LPG storage caverns is expected to be 1-2% per year, the assumed operational growth rate, if any, of the adjacent caverns was not noted. The FEA discussion should include the assumptions made in evaluating the cavern stability (though perhaps this is included in the confidential information).

3) **Regulatory Oversight:** Section 4.6.3 references the agencies that have regulatory roles for various aspects of the LPG storage operations. The list does not include the permitting of the brine injection by the EPA UIC program.
4) **Wetlands Impacts:** While it is expected that any impacts to wetlands on the brine pond parcel will be minimal, the DSEIS should include a quantification of all wetlands impacts and proposed mitigation.

5) **Revegetation:** While Section 4.5 of the DSEIS discusses the use of native plants and grasses to revegetate the property, Appendix K, page 8 states that Russian olive (*Elaeagnus angustifolia*) will be used. Russian olive is considered invasive and/or noxious in several states. Please ensure that all vegetation is native and non-invasive.

Thank you for the opportunity to comment on the DSEIS. If you have any questions, please contact Lingard Knutson of my staff at (212) 637-3747.

Sincerely,

Grace Musumeci, Chief
Environmental Review Section.
October 5, 2011

David L. Bimber
Deputy Regional Permit Administrator
NYSDEC
6274 East Avon-Lima Road
Avon, NY
14414-9516

Subject DEC Facility ID 8-4432-00085

Dear Mr. Bimber,

Representatives from Norfolk Southern attended the NY DEC hearing regarding the above cited matter but due to time constraints were unable to speak at the meeting.

We address the following issues:

NS Safety record

For the last 22 years Norfolk Southern has been the safest Class I railroad in the United State and has received the coveted Harriman Safety Award for doing so. We have handled propane and butane deliveries safely, to facilities in nearby facilities at Bath and Owego, NY, close to the Finger Lakes for many years.

Service to the facility

Rail service will be provided to the Inergy facility up to 24 loaded cars per day 5 days per week. We currently, as mentioned, serve other propane and butane storage facilities in the area.

The Railroad bridge

Find enclosed a letter from our attorney Karin Stam to Kevin Bernstein regarding the safety of operating across this trestle.
Noise

It is anticipated that the switching operation of the propane and butane cars will produce no noise beyond that normally found in rail operations.

In conclusion, Norfolk Southern supports the application of the Inergy project and urges its approval. If you have any questions please let us know.

Michael Fesen
Manager
Government Relations Department
Norfolk Southern Railway
322 Third Street,
Elizabeth, NJ 07206
Phone 1 (717) 319-6870
Fax 1 (404) 653-3733
e-mail michael.fesen@nscorp.com
Re: Inergy Project

Dear Kevin:

You have asked that Norfolk Southern Railway Company provide certain information about our freight rail bridge that crosses the Watkins Glen Gorge, specifically with regard to future rail transportation of liquefied petroleum gas ("LPG") that may be associated with the proposed Inergy facility.

As you are aware, freight bridge safety is regulated by the exclusive jurisdiction of the Federal Railroad Administration ("FRA"). FRA’s regulations impose certain safety and inspection requirements on all rail bridges, including the Watkins Glen Gorge Bridge ("Bridge"). Pursuant to those requirements, the Bridge is regularly inspected. Those inspections confirm that the Bridge does not have any structural concerns, nor does it have any freight traffic restrictions.

Moreover, the Bridge’s load carrying capacity is sufficient to handle current and expected future rail traffic. You have asked me what the weight of a loaded LPG rail car is. The allowable weight of a loaded LPG rail car is 286,000 pounds gross weight. This is within the load carrying capacity of the Bridge.

As you are also aware, the transportation of hazardous materials by rail, such as LPG, is closely regulated by the federal Department of Transportation ("DOT"). Loading and packaging requirements, which apply to shippers, are specified by DOT. Additional DOT regulations apply to the movement of hazardous materials by rail. NS is subject to those requirements.

You have asked about the safety history of the Bridge. NS has operated over the Bridge since June 1, 1999. We have had no environmental releases or incidents associated with the Bridge during our period of operation and are aware of none occurring before then. As you may
be aware, NS is the industry leader in safety for all Class 1 railroads and has been the recipient of the E.H. Harriman Memorial Gold Medal award for the last 21 years.

Last, please be advised that NS is a common carrier that is required by federal law to provide transportation service upon reasonable request for any of the more than 1,200 commodities listed in the Standard Transportation Commodity Codes (STCC).

Very truly yours,

[Signature]

Karin Stany
DEC Commissioner Martens  
New York State Department of Environmental Conservation  
625 Broadway  
Albany, NY 12233-1010

Dear Commissioner Martens,

We at PSE (Physicians Scientists & Engineers for Healthy Energy) find that Inergy’s dSEIS for the proposed LPG storage facility at Seneca Lake inadequately addresses potential impacts on both the environment and the community.

As an organization, we are most concerned with the alarming history of catastrophic failure of hydrocarbon storage in salt caverns. The British Geological Survey has undertaken the most comprehensive examination of this storage method in a report entitled “An appraisal of underground gas storage technologies and incidents for the development of risk assessment methodology” (2008). The report demonstrates an alarmingly high frequency of reported incidents and problems. This history of failure should be addressed in the dSEIS, and it should adequately cover all potential areas of concern. According to the BGS report, failure mechanisms related to geology in salt caverns have to do with three principle factors that contribute to the breaching and collapse of salt caverns: salt creep, uncontrolled leaching, and unexpected anomalous zones in what had been thought to be homogeneous salt [1]. Equipment failures, such as valve failure, casing failure, or packer failure, must also be addressed as part of this, as these have been the principle causes of the catastrophic events involving salt cavern storage facilities since 1972 [2].

Claims in the current dSEIS that “underground gas storage is viewed as having an excellent environmental, health and safety record” (Evans, 2008 citing “Lippmann & Benson 2003; Imbus & Christopher 2005”) and that “salt caverns provide one of the safest answers to the problem of storing large amounts of hydrocarbons” (Evans, 2008 citing “Bérest et al. 2001” and “Bérest & Brouard 2003”) are not substantiated by data [3]. Paradoxically, the BGS report refers to the first of these claims in its summary, but as the report indicates with actual calculations, “the majority of problems have occurred at salt cavern storage facilities” [4]. According to the body of the BGS report, 41% (27/66) of all underground salt cavern storage facilities operational worldwide in 2005 experienced serious incidents. 7.6% resulting in casualties/fatalities [5]. This is significantly more hazardous than other underground storage methods and this does not speak to an excellent safety record.

The dSEIS ignores this worrisome track record, and fails to mention the BGS report. As an organization trying to bring transparency to science in the energy industry, PSE recommends these known risks need to be individualized, itemized and accounted for in the proposed LPG storage facility in an independent review. Although industry and policy makers may consider these risks low, citizens look at this data and do not share this view. Compared with other engineering projects such as bridges, aircraft, tunnels this incident rate and casualty/fatality rate is extraordinarily high.

Further concerns include, but are not limited to, the following:

- There is a likelihood the industrialization associated with the proposed storage facility will have a negative impact on the local economy, which relies heavily on wineries and tourism. Social and economic considerations are not adequately addressed in the current dSEIS. While few economic benefits are put forth, which include ~50 construction jobs and 8-10 permanent jobs at the facility, the impact this industry will have on the existing economy is ignored. The cumulative impacts of this industrialization of this region may seriously impact the local tourist based economy, effectively damaging the “brand” of the region. The wineries and businesses around Seneca Lake are locally owned, representing a long-term economic development trajectory for the local
communities. This trajectory should not be damaged by the proposed storage facility and its modest economic gains.

As economist David Kay writes in a working paper on the economic impact analysis of natural gas development in the Marcellus Shale, “the experience of many economies based on extractive industries is a warning that their short-term gains frequently fail to translate into lasting, community-wide economic development” [6]. We recommend a socio-economic impact review to study such concerns. This study should enlist the help of economists and address the following items: the value of tourism for the local economy, possible ways in which the tourism economy might be affected, now and in the future with the proposed storage facility, and if there is a potential harm to this economy, what policies and strategies might be enacted to mitigate these effects [7].

- There are fault lines on the Western side of Seneca Lake within a half mile of the proposed storage facility that could potentially lead to large scale accidents [8]. While the seismologic survey record and earthquake history indicates only minor activity in the area, we do not believe the geological assessment that gauges the risks these fault lines pose for the storage facility has been adequate. The USGS NEIC earthquake data, which only goes back to 1852, should not suffice as the sole means of investigation, especially given the critical nature of this proposed facility. As a California Geological Survey indicates, “certain faults have recurrent activity measured in tens or hundreds of years whereas other faults may be inactive for thousands of years before being reactivated” [9].

Other means of investigation besides seismicity and earthquake history should potentially be considered in relevant investigations and reports. These include surface observations, subsurface investigations, geophysical investigations, and age-dating techniques, among others [10]. In California, construction is prohibited on or near faults that have moved within the last 11,000 years (Holocene Epoch) [11]. Gauging fault activity often entails radiocarbon dating of organic material near the fault line, which can help project future activity. There is no mention of this in the dSEIS. It would be prudent to consult relevant seismologic experts to determine the adequacy of both conducted and suggested research when evaluating potential fault line hazards. The storage facility is a critical structure given the hazard posed by a large volume of liquefied gas under pressure and proximity to Seneca Lake. As such, it should be subject to more stringent investigation procedures with regard to fault lines and seismic activity.

- The proposed storage facility promotes the development of the natural gas industry in this rural area. While the storage facility construction is itself a single event, it should be seen as part of a larger project. For one, this infrastructure will likely be used for non-local industrial activities (e.g. Pennsylvania). This will likely involve the establishment of a network of new pipelines, transportation infrastructure, and associated industrial development. The proposed LPG storage facility at Seneca Lake will set the precedence for other salt mines in the area to be used for storing both liquefied petroleum and liquefied natural gas. For this reason, the project should be viewed in a wider, anticipatory lens. The cumulative effects this industry need to be explicitly expressed as related to issues of public health, the environment, and the economy.

Given the importance of this natural resource, we think it prudent for the pertinent data to be collected before the storage facility is developed. This becomes particularly relevant when one consider the infeasibility of remediation should anything go wrong.

"It should be noted that one of the important features of the oil/gas storage caverns in comparison with the caverns for other purposes is that there is almost no possibility for any remedial works inside the storage space after the facility is put into operation. Therefore, the long-term structural stability of the caverns has to be ensured for the whole life of the facility. Adequate rock support design by empirical means and numerical simulations based on reliable geomechanical characteristics of the rock mass and allowable operating conditions is essential for the lifetime safety of the facility" [12].
The current dSEIS summarizes some results, yet provides no data outsiders can review in their appendices. It also delays other essential studies until once the process is underway. The actual data, and not just abbreviated summaries of results, needs to be publicly available for review, preferably by an independent review panel with the requisite expertise.

In closing, the environment, community, and economy of the region should not be compromised in the name of short term gains. Until qualitative and quantitative risk analyses are conducted to address the concerns we have outlined above and the public have had a chance to evaluate them, we recommend delaying issuing permits for Energy to proceed with this project.

Sincerely,

Dr. Adam Law, MD
Board of Directors, PSE
References:


[3] Evans, D.J., Accidents at UFS sites and risk relative to other areas of the energy supply chain, with particular reference to salt cavern storage, Solution Mining Research Institute SMRI Fall 2008 Technical Conference, 13-14 October 2008


[5] Ibid. Figures 44.


[10] Ibid.


October 7, 2011

Senator Thomas F. O’Mara
District Office
333 East Water Street (3rd Floor, Suite 301)
Elmira, NY 14901

Dear Senator O’Mara,

We at PSE (Physicians Scientists & Engineers for Healthy Energy) find that Inergy’s dSEIS for the proposed LPG storage facility at Seneca Lake inadequately addresses potential impacts on both the environment and the community.

As an organization, we are most concerned with the alarming history of catastrophic failure of hydrocarbon storage in salt caverns. The British Geological Survey has undertaken the most comprehensive examination of this storage method in a report entitled “An appraisal of underground gas storage technologies and incidents for the development of risk assessment methodology” (2008). The report demonstrates an alarmingly high frequency of reported incidents and problems. This history of failure should be addressed in the dSEIS, and it should adequately cover all potential areas of concern. According to the BGS report, failure mechanisms related to geology in salt caverns have to do with three principle factors that contribute to the breaching and collapse of salt caverns: salt creep, uncontrolled leaching, and unexpected anomalous zones in what had been thought to be homogeneous salt [1]. Equipment failures, such as valve failure, casing failure, or packer failure, must also be addressed as part of this, as these have been the principle causes of the catastrophic events involving salt cavern storage facilities since 1972 [2].

Claims in the current dSEIS that “underground gas storage is viewed as having an excellent environmental, health and safety record” (Evans, 2008 citing “Lippmann & Benson 2003; Imbus & Christopher 2005”) and that “salt caverns provide one of the safest answers to the problem of storing large amounts of hydrocarbons” (Evans, 2008 citing “Bérest et al. 2001” and “Bérest & Brouard 2003”) are not substantiated by data [3]. Paradoxically, the BGS report refers to the first of these claims in its summary, but as the report indicates with actual calculations, “the majority of problems have occurred at salt cavern storage facilities” [4]. According to the body of the BGS report, 41% (27/66) of all underground salt cavern storage facilities operational worldwide in 2005 experienced serious incidents. 7.6% resulting in casualties/fatalities [5]. This is significantly more hazardous than other underground storage methods and this does not speak to an excellent safety record.

The dSEIS ignores this worrisome track record, and fails to mention the BGS report. As an organization trying to bring transparency to science in the energy industry, PSE recommends these known risks need to be individualized, itemized and accounted for in the proposed LPG storage facility in an independent review. Although industry and policy makers may consider these risks low, citizens look at this data and do not share this view. Compared with other engineering projects such as bridges, aircraft, tunnels this incident rate and casualty/fatality rate is extraordinarily high.

Further concerns include, but are not limited to, the following:

- There is a likelihood the industrialization associated with the proposed storage facility will have a negative impact on the local economy, which relies heavily on wineries and tourism. Social and economic considerations are not adequately addressed in the current dSEIS. While few economic benefits are put forth, which include ~50 construction jobs and 8-10 permanent jobs at the facility, the impact this industry will have on the existing economy is ignored. The cumulative impacts of this industrialization of this region may seriously impact the local tourist based economy, effectively damaging the “brand” of the region. The wineries and businesses around Seneca Lake are locally owned, representing a long-term economic development trajectory for the local
communities. This trajectory should not be damaged by the proposed storage facility and its modest economic gains.

As economist David Kay writes in a working paper on the economic impact analysis of natural gas development in the Marcellus Shale, “the experience of many economies based on extractive industries is a warning that their short-term gains frequently fail to translate into lasting, community-wide economic development” [6]. We recommend a socio-economic impact review to study such concerns. This study should enlist the help of economists and address the following items: the value of tourism for the local economy, possible ways in which the tourism economy might be affected, now and in the future with the proposed storage facility, and if there is a potential harm to this economy, what policies and strategies might be enacted to mitigate these effects [7].

- There are fault lines on the Western side of Seneca Lake within a half mile of the proposed storage facility that could potentially lead to large scale accidents [8]. While the seismologic survey record and earthquake history indicates only minor activity in the area, we do not believe the geological assessment that gauges the risks these fault lines pose for the storage facility has been adequate. The USGS NEIC earthquake data, which only goes back to 1852, should not suffice as the sole means of investigation, especially given the critical nature of this proposed facility. As a California Geological Survey indicates, “certain faults have recurrent activity measured in tens or hundreds of years whereas other faults may be inactive for thousands of years before being reactivated” [9].

Other means of investigation besides seismicity and earthquake history should potentially be considered in relevant investigations and reports. These include surface observations, subsurface investigations, geophysical investigations, and age-dating techniques, among others [10]. In California, construction is prohibited on or near faults that have moved within the last 11,000 years (Holocene Epoch) [11]. Gauging fault activity often entails radiocarbon dating of organic material near the fault line, which can help project future activity. There is no mention of this in the dSEIS. It would be prudent to consult relevant seismologic experts to determine the adequacy of both conducted and suggested research when evaluating potential fault line hazards. The storage facility is a critical structure given the hazard posed by a large volume of liquefied gas under pressure and proximity to Seneca Lake. As such, it should be subject to more stringent investigation procedures with regard to fault lines and seismic activity.

- The proposed storage facility promotes the development of the natural gas industry in this rural area. While the storage facility construction is itself a single event, it should be seen as part of a larger project. For one, this infrastructure will likely be used for non-local industrial activities (e.g. Pennsylvania). This will likely involve the establishment of a network of new pipelines, transportation infrastructure, and associated industrial development. The proposed LPG storage facility at Seneca Lake will set the precedence for other salt mines in the area to be used for storing both liquefied petroleum and liquefied natural gas. For this reason, the project should be viewed in a wider, anticipatory lens. The cumulative effects this industry need to be explicitly expressed as related to issues of public health, the environment, and the economy.

Given the importance of this natural resource, we think it prudent for the pertinent data to be collected before the storage facility is developed. This becomes particularly relevant when one consider the infeasibility of remediation should anything go wrong.

"It should be noted that one of the important features of the oil/gas storage caverns in comparison with the caverns for other purposes is that there is almost no possibility for any remedial works inside the storage space after the facility is put into operation. Therefore, the long-term structural stability of the caverns has to be ensured for the whole life of the facility. Adequate rock support design by empirical means and numerical simulations based on reliable geomechanical characteristics of the rock mass and allowable operating conditions is essential for the lifetime safety of the facility" [12].
The current dSEIS summarizes some results, yet provides no data outsiders can review in their appendices. It also delays other essential studies until once the process is underway. The actual data, and not just abbreviated summaries of results, needs to be publicly available for review, preferably by an independent review panel with the requisite expertise.

In closing, the environment, community, and economy of the region should not be compromised in the name of short term gains. Until qualitative and quantitative risk analyses are conducted to address the concerns we have outlined above and the public have had a chance to evaluate them, we recommend delaying issuing permits for Energy to proceed with this project.

References:


[3] Evans, D.J., Accidents at UFS sites and risk relative to other areas of the energy supply chain, with particular reference to salt cavern storage, Solution Mining Research Institute SMRI Fall 2008 Technical Conference, 13-14 October 2008


[5] Ibid. Figures 44.


[10] Ibid.


Mr. David Bimber
Deputy Regional Permit Administrator
New York State Department of Environmental Conservation
6274 East Avon-Lima Road
Avon, NY 14414-9516

Dear Mr. Bimber;

My name is Mitchell Dascher and I am the President of US Salt, which is the host site for the proposed Inergy LPG storage Project.

As background, I am the former plant manager of Repauno Products, LLC formerly located in Gibbstown New Jersey. As a producer of Sodium Nitrite and Nitrosylsulfuric Acid, we complied with the New Jersey Department of Environmental Protection's Toxic Catastrophe Prevention Act (TCPA), the precursor to the EPA's Risk Management Program. The program remains a standard for chemical process safety. I was directly responsible for the facilities detailed compliance with the program and as such am well versed about chemical releases, consequence modeling, emergency response, risk assessment and reduction and other pertinent subjects. I would urge you to contact John Notta, Chemical Safety Engineer with TCPA at 609-984-3691 or john.notta@dep.state.nj.us to discuss New Jerseys program and/or the compliance record and knowledge of this writer.

From an economic perspective, the opposition claims are largely unsupported and vague. I note the existence of three such facilities in the Finger Lakes region today (Bath, Watkins Glen, and Hartford Mills) without dire economic or environmental consequences-two of these facilities have brine ponds today and are in salt formations. Further, natural gas storage exists as well at the site in salt, again without negative environmental and economic consequences. The track record of performance over the years at these facilities (including the period of 1964-1984 where up to 4MM barrels were stored at the US Salt plant) provides evidence that this has been and can be safely done.

The history of propane storage in the Finger Lakes and especially at Watkins Glen is well documented. That upstate New York has been propane supply short is not in dispute (see www.scdemocrat.com/news/003March/06/propane.html). The shortfall is brought in by long haul trucks today. Wouldn’t pipeline transport provide a dramatic reduction in emissions for the State and the region?

With regard to chemical safety I find it naive of the opposition to downgrade the capabilities of the local fire departments. The very next day after the DEC’s Public Hearing on the LPG project I was invited to a Teppco/Enterprise table top emergency response drill and training session with several local fire departments, State Police, county officials and other responders. This drill had long been scheduled in advance and was certainly not the first training exercise on propane storage by the responders. Over 3.5 hours nearly 60 people were involved at a detail level working through various scenarios. I was impressed with their knowledge and professionalism. Fire Chief Dominick
Smith and I had a chance to meet after the session. I urge you to contact him directly to gain his views. He can be reached at 607-857-3471.

With regards to "risk assessments" demanded by the opposition I submit that they are misguided and uniformed. As the aforementioned NJDEP Chemical Safety Engineer John Notta told me "I would ask them what they meant by quantitative risk assessment (QRA), since many people I talk to have different ideas." Indeed the opposition cannot provide meaningful guidance on this subject since they believe it is an economic balancing exercise rather than its proper form to evaluate and reduce chemical release risks. Further the belief that "local governments and citizens should choose the people who make this risk analysis" is without basis or precedent.

Their inexperience is further demonstrated when they make claims about the whole storage cavern emptying out. Even the EPA does not recognize that underground storage in salt can fail catastrophically (www.epa.gov/oswere1/docs/chem/Chap-04-final.pdf).

When analyzing release scenarios, the worst case is the failure of an above ground bullet tank which has an impact of .4 miles—a long way from engulfing the town. Published failure rate literature assigns values of 1 x 10^-5 to x 10^-7 as frequencies which is state of the art. Further protection is provided by automatic shutdowns, relief valves, sensors, level instrumentation, administrative controls and many others. Other release scenarios which involve more frequent probabilities are of dramatically smaller consequences such as piping failures or leaks (1 x 10^-3 to 1 x 10^-5). Pump seal failures and hose failures again follow with even higher frequencies and even less material at risk. Essentially other than the salt cavern, this location is not unlike any of the numerous propane storage sites throughout the state and the country—which certainly don't receive this much attention.

Certainly the technology and process design for these facilities are well understood and follow well known industry codes. The text Layer of Protection Analysis compiled by the Center for Chemical Process Safety on Page 15 indicates that simple processes can be evaluated with Qualitative Analysis such as Hazop—which has already been done. The EPA in its RMP Program requires no Quantitative Risk Assessment but rather prescribes a list of acceptable tools for analysis. I would submit that if this facility is of greater concern than all the others, require that it submit itself to an annual PSM audit every year on each of the 14 required elements in detail. This remains standard practice in New Jersey. Clearly no good operator should be afraid of this oversight.

Sincerely;

Mitchell P. Dascher
President
Salt Point Road
PO Box 110
Watkins Glen, NY 14891
mdascher@ussaltllc.com
607-535-2850

1 Layer of Protection Analysis pg 71
2 Ibid
October 21, 2011

Joe Martens, Commissioner
New York State Department of Environmental Conservation
625 Broadway
Albany, New York 12207

Re: Fingerlakes LPG Storage, LLC
LPG Storage Facility, Town of Reading, New York

Dear Commissioner Martens:

The Village of Watkins Glen is located at the southernmost point of Seneca Lake in an area known for its scenic beauty, tourism, agriculture, wineries, and extensive recreational opportunities. The Village, as well as other municipalities, receive raw drinking water from the lake and the area depends on its local resources as a key element to help drive the economy. In addition, our small community of approximately 2,200 is situated roughly 3 miles south of the proposed Inergy LPG Storage Facility, which poses certain risk to the region due to its proximity and immense size. As such, we feel that it is the duty and responsibility of our Board, a conscientious municipal neighbor, to prepare this statement for your review to ensure that proper attention is given to the environment, economy, and above all, public health and safety.

We recognize that there is a vast shortfall in supply of propane and butane in the region. This has the net effect of increased costs for area users, primarily during the winter months. It is also understood that the vast majority of rural customers consume propane as their primary source of fuel since they are beyond the reaches of natural gas supply. In short, the locality depends on an economically feasible source of clean burning fuel.

While liquid propane and butane have historically been stored and distributed in the area, the expansive nature of the Inergy proposal has presented significant impacts that have sparked a number of concerns from Village constituents. After reviewing the Department of Environmental Conservation (DEC) Draft Supplemental Environmental Impact Statement prepared by Fingerlakes LPG Storage, LLC, it is clear that the company has incorporated many appropriate measures and precautions with conservative design, analytical testing, procedure, and plans for future monitoring to ensure the integrity of their operation.

The Village of Watkins Glen is an equal opportunity provider and employer. To file a complaint of discrimination, write USDA, Director, Office of Civil Rights 1400 Independence Avenue, S.W., Washington DC 20250-9410, or call (800) 795-3272 (voice) or (202) 720-6382 (TDD).
However, we feel that the emphasis on public health and safety impacts on local and neighboring communities is exceedingly inadequate.

At this time, we recommend that the DEC require Inergy to perform an independent (3rd Party) Qualitative and Quantitative Risk Analysis (QRA) to help the community better understand the health and safety risks that this project will have on the region. Please understand that we are aware that any industry has inherent risk associated with its operations and surrounding communities have accepted certain thresholds of those risks from facilities that have long since been established in the area. As such, we fully anticipate that an analysis of the Inergy project will address many previously known issues. What is not known are the impacts of existing or additional areas of concern should an industrial accident or catastrophic incident occur. The levels of those risks could significantly alter the approach taken by the corporation on standard operating procedures and design which could provide a greater level of comfort for the community.

We appreciate your time and attention in this matter and look forward to your response.

Sincerely,

R. Mark Swinnerton
Mayor, Village of Watkins Glen

Cc: Scott Gibson, Deputy Mayor
    Kevin Smith, Trustee
    Wayne Weber, Trustee
    Greg Coon, Trustee
    Donna Beardsley, Clerk
October 25, 2011

David L. Bimber
Deputy Regional Permit Administrator
New York State Department of Environmental Conservation
6274 East Avon-Lima Road
Avon, New York 14414-9516

Re: Proposed Finger Lakes Liquefied Petroleum Gas Underground Storage Facility in Reading, NY (DEC Facility ID 8-4432-00085)

Dear Mr. Bimber,

On behalf of the Schuyler County Farm Bureau members we kindly request that the DEC require a Quantitative Risk Assessment be performed by an independent agency for the proposed LPG storage project in order to minimize the negative impacts on Schuyler County's main industries of agriculture and tourism.

Sincerely,

Stephanie Bergen, President
Sue Gigliotti, Vice President
Kristina Hazlitt, Secretary

Schuyler County Farm Bureau
4060 Bergen Rd.
Odessa, NY 14869

cc: Village of Watkins Glen
    Village of Montour Falls
    Town of Reading
    Town of Hector
    Schuyler County Legislature
David Bimber
Deputy Regional Permit Administrator
NYS DEC
Region 8
6274 Avon Lima Rd
Avon, New York 14414-9516

Re: Proposed Finger Lakes Liquefied Petroleum Underground Storage Facility in Reading, NY
DEC Facility ID 8-4432-00085

Dear Deputy Bimber,

The Town of Reading Planning approval a motion on October 20, 2011, to ask DEC to require that Finger Lakes LPG Storage, LLC Project have a Quantitative Risk Assessment done by an independent third party.

Planning Board members present:
Frank Gigliotti, Chairman
William Newell
Kay Anderson
Wanda Centurelli
John Festmire
Judith Richards

Thank you,

Judith Richards, Sec.
October 26, 2011

Mr. David L. Bimber, Deputy Regional Permit Administrator
Region #8, New York State Department of Environmental Conservation
Division of Environmental Permits
6274 East Avon-Lima Road
Avon, NY 14414

Dear Mr. Bimber;

The Schuyler County Environmental Management Council (hereafter referred to simply as the Council) welcomes the opportunity to comment on the Draft Supplemental Environmental Impact Statement (DSEIS) for the Finger Lakes LPG Storage LLC Watkins Glen LPG Storage Facility DEC 8-4432-00085/00001 issued August 17, 2011. The Council is grateful for the DEC’s diligence as it carefully examined several iterations of this document before accepting this final form as suitable for Public Comment and scrutiny. The Council would also like to thank the applicant for the simple, yet immense, consideration of straight-forward and clear pagination.

It is the opinion of the Council that many of the issues it raised when commenting on the Draft Scoping Outline have been adequately or more than adequately addressed. These concerns were as follow:

1. The Proposed Brine Storage Pond. The Council questioned the adequacy of design to withstand the weight and pressure of 2.19 million barrels of brine. However, now that the Council has examined the double layer liner system with leak detection technology designed to current landfill specifications, as well as the impoundment construction following DEC “Guidelines for the Design of Dams,” it feels these issues have been addressed. The applicant also has anticipated several methods of draining/diverting the brine should a leak or overflow occur. The Council also found it helpful to realize that the brine pond was designed with excess capacity and that it would very rarely be near to capacity except in the fall, prior to the winter heating season.

2. The Underground Storage Caverns. After a thorough reading of the DSEIS, the Council is convinced that the applicant has been exhaustive in its historic research of both academic scientific and industry based resources. The Council is also convinced the applicant will continue to monitor this element of cavern behavior both for safety and fiduciary concerns. However, it is still the Council’s opinion that relying on publicly available information and historical records is less than ideal when considering seismic potential and faulting. A thorough and complete – and independent – geological and seismic assessment of the bedrock stratigraphy and faulting patterns of the Seneca Lake area would be the most ideal methodology to complete a thorough analysis. In a paper titled “Appalachian Foreland Thrusting in Salina Salt, Watkins Glen, New York,” by C.H. Jacoby and L.F. Dellwig, found in proceedings from the Fourth International Salt Symposium held in 1973 in Houston, Texas (see attached), mention is made on page 232 of interplay of fault movement and brine pressure, including possible emergence of brine at the surface further north along the lake shore. The wells mentioned are 29, 33, 34 and 43, all of which lie in close proximity to the proposed storage galleries. This reference, combined with the possibility of a feasibility model for compressed air energy storage (CAES) being constructed by NYSEG on a contiguous site (see pages 69-70 of the DSEIS), leads the Council to conclude that a current independently conducted geological assessment of the area would be a prudent measure to take.

3. Surface Water. The Council is satisfied with the very thorough Stormwater Pollution Prevention Plan prepared for Finger Lakes LPG Storage LLC. If implemented properly, it should be adequate to handle runoff from the site.
4. **Increased Truck Traffic.** The Council is grateful for the traffic studies conducted by the applicant, but it feels the issue would achieve far greater clarity if the applicant could quantify the percentage of product that will be moving in and out of the facility by rail, by pipeline and by truck each month and how that translates into truckloads, tanker car loads, etc. For instance, the Council assumes the product comes in to the facility mainly by rail or pipeline during off peak heating months, but then, if, indeed, this LPG is going to heat local homes and businesses, then most of it is leaving the facility in trucks during the peak heating months. So how does that translate into number of trucks? This would be a more helpful way to break it down for public understanding.

Because the Council did not raise the idea in its comments concerning the Draft Scoping Outline, it doesn’t feel this should be taken as a criticism of the DSEIS. However, in the absence of an Air Quality Study, the Council urges the DEC to recommend that the applicant design and implement a regimen for air quality monitoring (to include ground-level ozone readings) at the facility. The Council recognizes that, though truck exhaust (which is normally associated with ground-level ozone formation) may be concentrated in the winter months and sun and smog and ozone are usually tied to summer, the gap is disappearing (see attached). Such monitoring would be of benefit for Finger Lakes LPG Storage LLC employees as well.

5. **Railcar Transport.** While members of the Council remain concerned about certain concrete underpasses over which the rail line passes, after learning of the frequency of track and ancillary structure inspections, and recognizing the large volume of product that will arrive by pipeline, the Council is willing to accept the applicant’s assessment of the suitability of this infrastructure.

6. **Ecological Resources.** The Council greatly appreciates Finger Lakes LPG Storage LLC’s intention to landscape as a means to improve aesthetics and mitigate both light and noise pollution, and is delighted that the firm agreed to refrain from planting Russian Olive (*Elaeagnus angustifolia*) and chose instead Allegheny Serviceberry (*Amelanchier laevis*). The native wildlife will be even more appreciative.

In the interim, several additional issues have been brought to the Council’s attention for consideration. These can be summed up as follow:

7. **Is A QRA Needed?** Though the Council recognizes that it is not established practice by the DEC to require a QRA (Quantitative Risk Assessment) of a facility such as the one proposed by Finger Lakes LPG Storage LLC prior to permitting, and that QRAs are never considered in a vacuum separate from other risk and hazard analysis, given the potential for additional projects being developed in close proximity to the north of the proposed facility (again, see pages 69 and 70 in the DSEIS), and the continuation of natural gas storage in an adjacent facility to the south, requesting such a study does not seem unwarranted or specious. It is also not unprecedented (see attached documents concerning QRAs for LPG, propane, and butane storage, as well as CNG and LNG refueling stations).

The Council is especially concerned because if the proposal for NYSEG’s CAES feasibility study does materialize, then there will be three separate underground storage facilities, all within less than a square mile, operating in the same geologic formation under different pressure and storage constraints in salt galleries (or near salt galleries) that have lain idle for, in many cases, decades. Therefore it is the Council’s recommendation that Finger Lakes LPG Storage be strongly encouraged to pursue a third party QRA in the best interests of all concerned.

8. **Coordination with Local EMS:** The Council was pleased with the care and diligence the applicant devoted to design of both proactive and reactive safety measure/programs for the facility employees. Concern for safety is also evident in the redundant back-up systems in place on the facility infrastructure. Where the Council finds reason for concern centers on off-site incidents and integration with local Emergency Management Services/First Responders. While the Council recognizes that rail and truck accidents would not be the responsibility of the applicant, those possible accidents would not be occurring...
were the storage facility not built: therefore it behooves the DSEIS to consider whether the local EMS network would be capable of responding to those hypothetical emergencies. Similarly, the Council would like to see a more detailed accounting of the capabilities of the local first responders to be able to appropriately contain an incident that was beyond the scope of the specialized training of the storage facilities employees. Ideally, the Council would like to see in place a plan for coordinated training including both local EMS personnel and the Finger Lakes LPG Storage emergency team.

9. **Impacts on Climate Change:** The Council wonders why the DEC failed to require the applicant to assess any Climate Change impacts that might ensue from the facility and its operation. In particular the Council would think the flaring of LPG contaminating the brine might be an impact to consider. Also any additional CO$_2$ emissions from pumps, compressors, etc., could have been assessed and mitigations explored.

10. **Necessity for Special Permits?:** It is also the Council’s understanding that certain surface portions of the Finger Lakes LPG Storage LLC facility will still be subject to obtaining a Special Use Permit, namely the brine pond which is set to be developed wholly within what has been designated the Seneca Lake Protection Area according to the Town of Reading Local Law No. 1 of the year 1995. This document is also attached for your reference.

As always, many thanks for your time and consideration of these comments.

On behalf of the Council,
Respectfully,

Kate Bartholomew, Chair
Schuyler County Environmental Management Council
607-228-7371; kbarthol@wgcsl.org

cc: Dennis A. Fagan, Chair, Schuyler County Legislature
Schuyler County Legislature
Marvin Switzer, Supervisor, Town of Reading
Mark Swinnerton, Mayor, Village of Watkins Glen
Timothy O’Hearn, Schuyler County Administrator
Bill Moler, Inergy, LLC
Kevin Bernstein, Esq.
Gas Free Seneca, c/o Joseph Campbell
Kelsey Jones, SCOPED
Appalachian Foreland Thrusting in Salina Salt, Watkins Glen, New York

ABSTRACT

The Watkins Glen area lies along the western edge, and at the northern termination of mapped Allegheny Plateau folding. Surface mapping of the Devonian strata identified a series of northeast-southwest trending open folds. Studies to the northeast of the brine field in the mine of the Cayuga Rock Salt Company at Myers, New York resulted in the identification of a decollement beneath the mine-salt section. The faulting and folding being easily correlated with the major surface structure. In the Watkins Glen brine field, a major north-south strike-slip fault extends down at least to a bedding (step) thrust along which the block to the west of the tear fault has moved north a minimum of 1200' in the southern portion of the brine field. As the thrust breaks up into the upper portion of the section to the north, the fault divides into several faults each of which compensates for a portion of the total displacement along the single thrust to the south. Additional faulting on a small scale as well as minor folding are recorded in nearly all wells, but correlation of these is not possible.

INTRODUCTION

The Watkins Glen area lies along the northwestern edge, and near the northeastern termination of mapped Allegheny Plateau folding (Figure 1). Surface mapping of the Devonian strata in 1909 (Williams, Tarr, and Kindle) defined a series of east-northeast trending open folds, prominent among which is the Firtree Point anticline. Until 1955 most geologists considered such broad open folds of the Appalachian Plateau (Allegheny Plateau of the Watkins Glen area) as deep structures which persisted into the underlying Paleozoic sequence of rocks. Although this view prevailed for the plateau in general, the Cumberland Block marginal to the thrust faulted Valley and Ridge Province in the Southern Appalachians was documented as early as 1934 (Rich, 1934) overlying a bedding thrust (Pine Mountain). Subsequent study (Wilson and Stearns, 1958) resulted in the identification of a similar thrust to the south and west of the Sequatchie anticline.

Although bedding thrusts were accepted for the Cumberland Plateau of the Southern Appalachians, no such
structures were identified or even considered a probability in the Allegheny Plateau adjacent to the Central Appalachians. This in part might be attributed to the domination of the deformation of the adjacent Valley and Ridge Province by folding rather than by faulting. However, with the drilling of the Sandhill Well, in Wood County, West Virginia in 1955, there began the development of the concept of northwestward sliding of the near horizontal strata which overlie the viscoplastic Silurian salt on the Plateau (Figure 2), (Rogers, 1959). This concept has since been documented in several additional areas as a result of renewed subsurface exploration on the Plateau.

Although by 1955, the regional picture of the decollement tectonics in the Allegheny Plateau was well established, little was known about the details of movement in and above the lubricating Salina salt. In 1955 Jacoby obtained the first salt core recovered in the Watkins Glen area and a year later secured a similar Watkins Glen area core from Well 25 (Figure 3) which cut only the F3 and F2 salts. Partially due to the intense deformation and flowage which had been observed in the F1 salt in the Cayuga mine at Meyers, New York, the faulting in the Watkins Glen-Ludlowville area went uninterpreted.

With the drilling of Well 29 at Watkins Glen in 1958, core logs and gamma ray curves gave the first discernible evidence that thrust faulting had occurred. Coring and logging of additional wells led to the establishment of the first cross section of the Salina in this area in 1961 (Jacoby, 1963, 1969).

Prucha (1968) in 1964 conducted a study in the mine of the Cayuga Rock Salt Company at Meyers, New York which resulted in the identification of the decollement beneath the mine salt section, the faulting and folding being easily correlated with the major surface structure. In his analysis of deformation he predicts that southward the surface of detachment would pass into a thrust fault. In 1967, Dellwig undertook a comprehensive study of the structural aspects of the Watkins Glen brine field, utilizing additional cores and gamma logs made available by the drilling of Wells 39, 40, 41 and 42 in 1964. In 1968 this study was further expanded by utilizing logs from the newly drilled Wells 43 and 44 and again in 1972 with data from Wells 47, 48, 49, 50, 51 and 52.
BRINE FIELD

The first salt well was drilled in Watkins Glen at Salt Point in February 1893. This and the subsequent wells were located in and around International Salt Company's evaporator plant in the development of what is now termed the "South Field." These wells used the system known as "Annular Injection" in which water is pumped down the annulus formed by the casing and the tubing of the well and the brine is recovered through the tubing. Due to the folklore belief of the cable tool drillers as to the location of bottom of the salt formation, plus the presence of a 4 to 6 ft. layer of unhydrite within the F3 salt sequence which blankets the Watkins Glen area, wells were terminated after penetrating 90 ft. of the F3 salt.

Wells drilled during these early years were drilled as single wells equipped with a string of swaged two diameter wrought iron casing, some type of pumping device and tubing. The wrought iron casing was not cemented in place and occasionally was galvanized or wrapped to prevent its corrosion by the Oriskany or Cherry Valley "black water." The original air lifts which were installed in the wells were made necessary by the lack of the seal behind the casing which would have isolated the brining fluids from the overlying formational fluids. This air lift system gave way to modernization by the installation of submersible pumps and tubing. Gradually, during brining operations, all of these old style wells which had formed a morning glory-shaped cavity, coalesced with adjacent wells at the contact between the top of the F3 salt and the overlying shale. Due to the broad roof spans which were developed, there was apprehension of damage to the surface by rock movement. Brining operations in the vicinity of the plant were discontinued with the closing down of Wells 4 and 7A in 1960.

With the drilling of Well 25 in 1955, not only was the first accurate subsurface geological data obtained in the Watkins Glen area, but a rotary oil field rig was utilized for the first time for the drilling of a salt well in the state of New York. Additionally, this was the first salt well in the state of New York to be hydraulically fractured. This new style of salt well was fractured at the bottom of the salt sequences which was by then (1955) known to have a total aggregate thickness of over 500 feet. Generally, these wells were drilled with a 12-1/4 in. bit equipped with a string of 8-5/8 in. steel casing and cemented back to surface. This cementing not only allowed a pair of fracture connected wells to operate on pressurized U tube system, but it also protected the casing against the corrosional black waters of the formations penetrated by the well.

Fracturing of the salt formations was accomplished either by perforating the casing at a pre-selected point in the salt just above the Vernon shale or "landing" the casing just above this point, drilling out and applying the pressure to the formation exposed to the well bore.

All subsequent wells were cored and electrically logged in order to clarify an understanding of the local geology, interpret the results of hydraulic fracturing and extrapolate these findings for the location of other salt wells. As development proceeded with respect to fracturing and brining operations, it became obvious that more care was required in the interpretation of the geological data.

STRATIGRAPHY

The salt sequence of the Syracuse Formation penetrated by the brine wells at Watkins Glen consists of an interbedded sequence of salt, dolomite and shale, ranging in thickness from north to south from 725 ft. (a true thickness with no duplication through thrusting) to 800 ft. The base of the sequence is found to depths of 2900 ft. (at an elevation of -2100 ft.) as compared with a depth of -1880 ft. at the Cayuga Rock Salt Company mine. Based on subsurface log data, the base of the sequence strikes N. 78° E. and dips 185-190 ft./mi. to the south.

In the definition of stratigraphic units in the wells in the Watkins Glen brine field, both the classification used in early logging and that of Landes (1945) are indicated. The uppermost identifiable salt of the sequence was originally defined as the No. 1 Salt (F3 Salt) and the rock unit immediately below the No. 1 Rock. On this basis six salt and 5 intervening rock units were originally defined, units were easily recognized by the gamma ray log signature (Figures 4,5). Several stratigraphic logs show some digres-

Figure 4. North-south section correlating on gamma ray logs, No. 1 Salt to No. 4 Rock. Thick vertical lines indicate repeated section.
Figure 5. North-south section correlating on gamma ray logs, No. 1 Salt to No. 4 Rock. Thick vertical lines delimit repeated section.

Figure 6. Sample correlations in faulted sections. Left—Gamma-ray log for Well 40 is normal, correlation at top of rock unit with Well 36 is shown in center log, correlation at base is effected through movement into position on right. Center—Log for Well 40 is normal. Correlation with top of log 35 is shown in center log. Correlation with base of rock unit is effected through movement into position on right. Right—Duplication of section is demonstrated through movement of log as shown by arrow. Numbers are logging depth, not elevations.

Repetition within a salt unit is more difficult to recognize because of the lack of a characteristic signature.

STRUCTURE

In gross aspect the local structural picture is relatively simple, provided of course, that one ignores the multiplicity of small faults which play a critical role in the development of the brine field. A major north-south strike-slip fault is located east of Wells 41, 37 and 29; a tear which extends down at least to a bedding (step) thrust along which the block to the west of the tear fault has moved north a minimum of 1,200 ft. in the southern portion of the brine field. This estimate is based on the repetition of the No. 3 Rock in Wells 36 and 30 (Figure 4), the distance between these wells being approximately 1,200 ft. The north-south section through Wells 37 and 31 (Figure 5) shows good correlation of No. 3 Rock, duplication between 30 and 31, but to the south in Well 37 the repeated section is in No. 4 Rock, indicating some tearing between Wells 36 and 37. This condition is not uncommon throughout the brine field. The major tear has been defined by a consistent lack of correlation between wells across this line (Figure 7). As the thrust breaks up into the upper portion of the section to the north, the fault divides

generally easily identifiable, for the gamma ray-neutron log “signature” of each individual unit is unique (Figure 6). Repetition from the normal classification and these were revised to fit the normal sequence. At the northern end of the field, correlation of No. 4 Salt, No. 6 Salt and No. 4 Rock can be accomplished with little difficulty, whereas in the south end of the field, repetition of the lower units is common but correlation can be accomplished with relative ease in rock and salt units 1, 2 and 3. Repetition of rock units is
into several faults each of which compensates for a portion of the total displacement along the single thrust to the south. These movements, along with flowage in the incompetent salt units, collectively accommodate the movement along the single fault to the south. Additional faulting on a small scale as well as minor folding are recorded in nearly all wells, but correlation of these is not possible. East of the tear fault, thrusting is on a small scale and displacement is negligible. The absence of significant repetition through thrusting east of the tear fault has been used to establish the position of the fault.

The major thrust in the western half of the brine field is identifiable through repetition of beds in the lower portion of the section at the south end of the field. Thrusting apparently has occurred in shale beds or along salt-shale contacts. At irregular intervals the thrust breaks into and across the overlying rock and salt to the next higher lubricating shale layer along which movement can continue. As the fault breaks across the No. 3 Rock into the overlying salt, the angle of dip of the fault plane increases and the fault horsetails. Some thickening and locally high dips in the beds indicate that flowage has also compensated for some of the displacement which appears to have been along the single fault surface to the south. The structure contour map on the top of the salt gives no indication of the faults breaking up into the overlying sediments. It would seem reasonable to assume that to the south the fault drops down into the underlying Vernon Shale.

Structure contour and isopach maps reveal that both the upper and lower surfaces of the salt are relatively uniform; the lower surface shows a regional southerly dip and the upper surface shows a pronounced dip to the west as a result of a general southeasterly thickening of the salt unit. However, thickening to the southeast is contrary to expectations, because thickening through faulting has occurred west of a north-south tear fault east of Wells 41, 37, and 29 and west of Well 28. Repetition of units east of this line has been minor.

In addition to the faulting described, it is noted in lithologic logs that slickenslides at the top of the No. 3 Rock are apparently common to all wells. In general the section downward from the top of the No. 3 Rock is dominated by clastics, whereas the section above the No. 3 Rock is predominantly salt. The movement of the upper more plastic section over the underlying more rigid section would be anticipated and apparently has occurred, but the extent of movement cannot be determined. In the northern portion of the field, to accommodate slippage along this contact, the major strike-slip fault may extend down below the thrust fault to the top of the No. 3 Rock.

In detail the picture is much more complex. Numerous small faults resulting in repetition of section and identifiable in only a single or several wells are found throughout the field. Variations in thickness of salt units though flowage and/or faulting (inseparable because of the lack of a characteristic log signature) is also not uncommon and this, combined with the faulting presents a complex pattern of minor displacements superimposed on a general
south dipping decollement broken by a major north-south tear, the terminal expression of the total movement finding surface manifestation in the Firtree Point anticline.

**STRUCTURAL CONTROL OF BRINEFIELD DEVELOPMENT**

It should thus be expected that difficulties in production arising from the geologic environment should be encountered and explainable at least to some degree in the light of the structural setting. For example,

*Well 29.* During fracturing, a flow of brine at the surface 0.5 mi. to the north must certainly be interpreted as the result of movement of brine from the well along the tear fault.

*Well 33, 34, 43.* In fracturing of Well 33 to 34, alternate buildup and recession of pumping pressures indicated that the solution channel was being closed by rock movement from time to time. In the light of subsequent geologic information, the occurrence of intermittent collapse should not have been unexpected, inasmuch as in this area of the brine field the major thrust has broken up, into and through the No. 3 Salt. Faulting above the cavity created by solution between Wells 33 and 34 may have resulted in a weakness which led to the observed periodic collapse and pressure buildup. It is over this area that the major thrust bifurcates at several different points, creating a series of planes of weakness in the section overlying the solution zone.

*Wells 41, 42, and 37.* The inability to fracture from Well 41 to 42 and the subsequent connection between 41 and 37 may be related to the position of the tear fault. One might postulate that movement of solution from Well 37 may have been blocked to some degree by the tear fault (if it extends below the thrust) but, even if this were not the case, movement of fluid along the tear fault or up dip along the thrust would be with a much greater degree of ease than across the tear fault into Well 42. However, an effort to fracture from Well 40 to Well 39 resulted in connection with Well 42; no connection was made with 41, demonstrating the complexity of the structural setting in this area.

**SENeca LAKE SALt ANTICLINE**

The total salt-rock sequence shows a constant increase in thickness in a west to east direction (Figure 8). As mentioned previously, the base of the salt shows a consistent dip to the south, whereas the top of the sequence expresses the increase through a dip to the west.

Seneca Lake stands a 445 ft. above sea level and bottoms at 174 ft. below sea level. Northward projection of data obtained through drilling south of the lake in glacial valley-fill suggests that the lake is bottomed with approximately 600 ft. of gravel, thus, the estimated elevation of the bedrock surface at the bottom of the lake is approximately 775 ft. The top of the salt section in Wells 24, 25, and 27 next to the lake is at an elevation between 1305 ft. and 1315 ft. Westward from the lake in the brine field area the ground elevation rises to approximately 300 ft. above lake level. Thus the salt in the brine field is loaded with approximately 2,000 ft. of rock compared with the salt beneath the lake which is loaded with the equivalent (assuming a porosity of 30 per cent for gravel and an average rock density of 2.7) of 1300 ft. of rock. In the present atmosphere of geofoam one cannot help but postulate that the higher elevation of the upper salt surface to the east toward the lake is in large part due to flowage of the salt toward the area of least overburden beneath Seneca Lake and there is the possibility of the existence of a salt structure province in west central New York.

**REFERENCES**


Prucha, J. J., 1968. Salt Deformation and Decollement in the 
Firtree Point Anticline of Central New York. *Tectonophysics*, 
6, no. 4:273–299.

as Illustrated by Cumberland Thrust Block, Virginia, Ken-
18:1584–1596.

Rodgers, J., 1959. Evolution of Thought on Structure of Middle 
33:1643–1654.

Vanuxem, L., 1842, Geology of New York, 3. Survey of the 
Third Geological District. N.Y. State Assembly, Albany, 

Williams, H. S., R. S. Tarr, and E. M. Kindle, 1909, Description 
of the Watkins Glen-Catatonk District, U.S. Geological Sur-
vey Atlas, Folio 169.

Wilson, C. W., Jr., and R. G. Stearns, 1958, Structure of the 
69:1283–1296.
Long Term Creep Closure of Solution Cavity System

Robert Chao
Serata Geomechanics
Berkeley, California

ABSTRACT
When multiple cavities are created in a salt formation, they experience much greater creep closure in both magnitude and duration than predicted by the conventional finite-element computational method. This phenomenon occurs regardless of cavity usage. In order to analyze this long-term large creep deformation, a special numerical technique employing a computer simulation method was developed in our laboratory. This technique introduces the concept of a "deterioration function" of material properties in which the property coefficients change with time rather than remaining fixed constants. The deterioration functions are determined from comparison of conventional finite element solutions with in situ stress-strain observations under controlled boundary conditions made by Dr. Serata using his instruments in various salt and potash mines over the past 10 years. The results of such studies indicate that when there are two or more cavities in the system, they produce a strong creep interference with each other even at large separation distances. The closure continues over many decades even after stress equilibrium of the system has been established. This creep interference is further intensified by an increase in the number of cavities in the system.

INTRODUCTION
Up until the present time, there has been no effective method of predicting solution cavity behavior. There exists a large discrepancy between conventional theoretical solutions including that by the finite element method and actual field observations. The difference is significant particularly when:

1. multiple cavities are created in a salt formation;
2. duration of creep is long lasting;
3. magnitude of creep is large;
4. material properties change with time;
5. cavity pressure fluctuates over a wide range.

These are fundamental rock mechanics problems which must be solved if cavity closure is to be minimized. The problems are serious regardless of cavity usage, whether it is for liquid or gas storage or even for solid waste disposal. These problems create the need for developing a technique useful for predicting the long-term behavior of multiple solution cavity systems.

This paper presents such a technique which was developed in our laboratory under a coordinated study of laboratory testing and underground observation. The technique is called the "deterioration technique." It is a computer method which first identifies the real difference between theoretical solutions using material coefficients determined in the laboratory and long-term field measurements. Then this difference is expressed as an empirical function of deterioration in which the material properties change or deteriorate with time. By introducing this deterioration function back to our theoretical method, the computer solution is matched with real cavity behavior. Thus the technique consists of two parts, theoretical and empirical. It is a hybrid model created by combining the plasticity theory, finite element method, long-term laboratory and field measurements. This technique was found to be in good agreement with field and laboratory observations made over the last several years. By utilizing such a technique, we can quite accurately predict the behavior of salt cavities over a long period of time, up to several decades. We are also able to evaluate the effects of basic design parameters upon cavity closure and stress distribution on existing cavities.

With careful consideration of specific field conditions, the technique can be utilized to produce optimum design...
and operational criteria. Basic parameters such as depth, material properties, cavity pressure, cavity shape, cavity separation distances, number of cavities and temperature can all be evaluated in regard to their effects on long-term creep deformation of the cavities. The evaluation of the parameter effects can be made individually as well as collectively. A specific set of these basic parameters is incorporated into the computer simulation each time. Important aspects of their effects on cavity closure are presented in the following sections.

CAVITY CLOSURE

The amount of cavity closure is a highly nonlinear time-dependent function of several factors. The most significant ones which will be examined here are: deterioration of material properties, differential pressure, separation distance between adjacent cavities, and the number of cavities in a system. Each of these factors can have a significant effect on the amount of cavity closure at any given age of a cavity or cavities.

DETERIORATION FUNCTION

The effect of deterioration function, \( \varepsilon \), on cavity volume reduction is shown in Figure 1. This function describes the basic material behavior which is due to the granular composition of rock salt. Under a given set of conditions, a cavity may have a varying amount of volume reduction depending on the material deterioration of the ground medium in which it is created. It is therefore important to check the deterioration function of the ground and take this factor into design consideration. In this particular example, if \( \varepsilon \) is of the order of 1.4% to 1.7%, the volume reduction is less than 10% at \( t = 100 \, t_0 \). If \( \varepsilon \) is greater than 2.5%, considerably more volume reduction results in a short time.

The stress distribution pattern around a cavity is highly dependent on the rate of deterioration, as illustrated in Figure 2. The extent of the plastic zone, which affects creep in a nonlinear way, is itself a nonlinear function of the deterioration rate. The peak of the curves, which indicates the extent of the plastic zone away from the cavity.

---

Figure 1. Relationship between Volume Reduction and Normalized Time \((t/\tau_0)\) at Various Deterioration Functions \((\varepsilon)\) of Material Properties.
Long Term Creep Closure

TANGENTIAL STRESS
\((10^3 \text{ psi})\)

\[ \text{TG} \]

\[ \text{fig2.png} \]

Figure 2. Stress Distribution Pattern in Ground Medium Around Cavity with Different Rates of Deterioration Function at
\[ t = 100 \times t_0 \quad r = \text{radius of cavity; } \Delta P = 3000 \text{ psi.} \]

wall, stretches out further at higher \( \epsilon \). As an example, for a material with \( \epsilon \) of 1.4%, the plastic zone extends approximately twice the radius. For a different material with \( \epsilon \) of 2.0%, the plastic zone extends four times the radius. When \( \epsilon \) increases beyond 2.0%, the amount of the plastic zone increases rapidly. The creep continues even after the stress envelope stabilizes with time (Fig. 3).

DIFFERENTIAL PRESSURE

The differential pressure, that is, the difference between overburden pressure and cavity pressure, is an important parameter in determining the long-term creep behavior of underground solution cavities. This differential pressure is usually constant for liquid storage, being equal to approximately half the overburden pressure. Additional complications arise for gas storage because differential pressure can vary between zero and overburden pressure. Solid waste disposal presents the worst case, since the differential pressure is always at its maximum. Gas storage makes long-term creep evaluation more difficult because of fluctuating gas pressure levels.

There exists a critical differential pressure level for each individual salt cavity operation. This critical pressure level is specific to cavity depth, material properties and scheme of storage operation. Even when pressure levels subsequently fall below the critical pressure, creep continues for a long time before stabilizing again.

In design of gas and liquid storage cavities, it is desirable to predetermine the allowable range of cavity pres-
The stress distribution pattern surrounding the cavity with cavity age is shown in Figure 3. The stress is plotted against cavity age, with the radius of the cavity indicated. The stress is given in units of psi, and the cavity age is in days. The graph shows that the stress decreases with increasing cavity age.

The stress is determined by the cavity depth and the maximum allowable differential pressure for the geology of given cavities. The upper limit of the allowable range is set by the overburden pressure while the lower limit is set by the amount of the overburden pressure minus the maximum allowable differential pressure.

It is this maximum allowable differential pressure that is determined by the deterioration technique. As shown in Figure 1, the acceptability of a certain differential pressure to a given cavity design is evaluated from the calculated relationship of cavity closure versus cavity age.

**NUMBER OF CAVITIES**

Another important factor in determining the long-term creep behavior of solution cavities, which has not been fully realized before, is the number of cavities in a system.

When more than a single cavity is created in a salt formation, each of the cavities suffers much greater creep deformation as shown in Figure 4. This factor is particularly important if the loading pressure is high. For instance, at a loading pressure of 5,000 psi, the normalized creep deformation for a single laboratory model cavity was $0.35 \times 10^{-3}$ in. When three additional cavities were created around the cavity, normalized creep became $4.4 \times 10^{-3}$ in.

A series of computer experiments comparing three systems; single cavity system, two-cavity system and three-cavity system was conducted. The cavity geometries are shown in Figure 5. The ground conditions and the material properties were set the same for all three systems. The results were summarized in Figure 6. For the single cavity system, creep deformation at normalized time $t = 100 t_0$ was 13.4% which corresponded to a 26% decrease in...
Figure 4. Effect of Number of Cavities and Loading Pressure on Creep Deformation.

Figure 5. Geometry of the Three Systems in Computer Simulation Experiment.

Figure 6. Comparison of Cavity Closures in Three Systems. \( \Delta V \) = volume lost at normalized time \( t = 100 \) psi. (A) Single Cavity System \( \Delta V = 26\% \); (B) Two-cavity System \( \Delta V = 45\% \); (C) Three-cavity System; (a) outside cavity \( \Delta V = 44\% \); (b) cantar cavity \( \Delta V = 60\% \).

volume. In the two-cavity system, each cavity shrank by 26% at the boundary, resulting in a total volume reduction of 45%. This indicated strong interaction between the stress fields of the two cavities. The interaction effect was further increased by introducing a third cavity into the system, resulting in an overall volume reduction of over 49%.

The results of this experiment show that there was a definite relation between cavity closure and the number of cavities interacting with each other. In some cases this effect can be relatively minor whereas in others it is of importance. The interesting thing about cavity interfe-
ence was the fact that cavity interaction increases with time. This is illustrated in Figure 7. By comparing the results of the three systems, it was found that initially there was little or no interaction. Each of the cavities in the three systems exhibited similar amounts of closure at the end of $t_0$. The difference began to show at $10 t_0$. The single cavity shrank quite uniformly. Each cavity in the two-cavity system was slightly skewed, and had a radial closure twice that of the single cavity. The shapes of the cavities in the third system were badly distorted. The center cavity was shown in the figure for comparison to the other systems. The interference became more intense with time. After about $100 t_0$, significant differences began to show up between the different systems. Such creep behaviors were verified with the available field data.

**SEPARATION DISTANCE**

Here another series of experiments was conducted, principally to determine the effect of separation distance between cavities in a two-cavity system. The important parameter is the separation ratio, S/D, which is defined as the ratio of the distance between the two cavity centers to the diameter of the cavity. S/D ratio was varied between 2 and 7 and the results of the experiment were summarized in Figures 8, 9, 10 and 11. It was found that the percentage of volume reduction increased with the reduction of separation ratio (Fig. 8). Figures 9, 10, 11 show the stress distribution pattern in the ground surrounding the cavities. The stress gradient increased with separation ratio decrease.

**LARGE SCALE ANALYSIS**

In analyzing long-term creep closure problems concerning solution cavities, it is also important to look into general problems such as permeability, heat conduction, overall cavity system stability and surface subsidence as illustrated in Figure 12. In this regard, it is particularly important to examine varied problems resulting from different ground conditions and cavity application. For a computer evaluation of the problems, they may be divided into two separate studies; one on inter-cavity behaviors in relation to the salt dome boundary and the other on the interaction between the salt dome boundary and the surrounding ground formations.

**CONCLUSION**

Basic parameters interact with each other and affect cavity closure in a highly nonlinear manner. The most important factors are identified as material coefficients and their deterioration functions, differential pressure and geometry. Their effects can only be analyzed effectively and realistically by adopting the hybrid model approach, partly theoretical and partly empirical. In development of this computer technique, a large quantity of controlled field data was utilized. The technique has been modified and substantiated to be in good agreement with past field data.

**ACKNOWLEDGMENT**

This paper presents a portion of the computer research work on field data simulation currently conducted at the Serata Geomechanics laboratory. The author expresses his appreciation to Dr. S. Serata for his permission, encouragement and assistance in making this publication possible.

**REFERENCES**

Adachi, T., Serata, S., and Sakurai, S. "Determination of Underground Stress Field Based on Inelastic Properties of
Figure 8. Volume Reduction Versus Normalized Time for Single Cavity and Two-Cavity Systems with Various Separation Ratios.

Figure 9. Stress Distribution Pattern in Ground Medium Around Two-Cavity System at 100 t_b with S/D = 7.
Figure 10. Stress Distribution Pattern in Ground Medium Around Two-Cavity System at 100 t₀ with S/D = 4.5.

Figure 11. Stress Distribution Pattern in Ground Medium Around Two-Cavity System at 100 t₀ with S/D = 2.
Figure 12. Large Scale Analysis of Problems that May Affect Long-term Creep Closure and Cavity Usage. (1) Cavity Stability (2) Surface Subsidence (3) Surrounding Ground Support to Salt Formation.


**METRIC CONVERSION**

1 ft. = 0.305 m
1 psi = 0.0703 Kg/cm$^2$
ABSTRACT

A survey of hydraulic fracturing case histories was conducted by collecting available data from member companies of the Solution Mining Research Institute. The experience of almost two decades of hydraulic fracturing for well communication in salt deposits shows that little is understood of the mechanics of fracture initiation and propagation, fracture inclination and direction. Field results have been mixed: total successes, partial successes, complete failures. It appears that the success of a 'frac' job depends among others on two main factors: the geology of the salt formation, and the design of well location, well completion, and fracturing sequence. The survey has indicated that a thorough geological investigation could be the key to success in formations disturbed by folding, faulting or other discontinuities. The mode of deposition and crystallization and existing regional forces affect the fracture even in flat undisturbed beds. Preferred directions of fracture propagation are observed in almost all cases studied. Low pressure connections are obtained very quickly in target wells located in the preferred fracture direction. With regards to well completion, available data indicate that open holes in the salt zone stand a better chance of communicating than cased and perforated wells, although the latter have been known to produce satisfactory results in some fields. It is recommended that a carefully designed experimental hydraulic fracturing be carried out in every newly developed salt field, and its results thoroughly examined before planning the final layout of wells and the sequence of fracturing. A group of four wells should be drilled, one in the center, with the others evenly spread around it at reasonable distances. The central well will be hydraulic fractured, with all four wells carefully monitored. The time elapsed to the formation of high and low pressure communications with each of three wells will determine fracture orientation and salt field well design.

INTRODUCTION

One of the most efficient ways of producing salt is by circulating water between wells, and one of the fastest, least expensive techniques of connecting wells has been hydraulic fracturing (hydrofracturing or fracturing). The latter was introduced in 1948 as a method of stimulating oil well output. It was not originally intended to connect groups of wells, but rather to induce and extend a fracture from a well into the oil bearing formation for the purpose of artificially increasing its permeability. The salt industry adopted the method for the purpose of well communication which, when established, enables water pumped in through the 'injection' well to be extracted as brine from the 'target' well(s).

The hydrofracturing operation begins with the completion of the injection and target wells. That is when the decision is made whether the job will be run in open-hole or through casing. For safety reasons cased holes have been increasingly used for fracturing, although their usefulness as to the success of method may be questioned. Perforation or notching of the well at the depth where fracture initiation is sought are mandatory in cased holes, but only optional in open holes. Theoretically, mechanical notching should be preferred to explosive perforating because it controls the initial shape and inclination of the fracture. Perforations may cause uncontrolled fractures running in many directions. Open holes can also be hydrofractured without the help of a preliminary indentation.

Fracture connection between wells is attempted by pressurizing a packed-off interval in the injection well until the formation starts taking fluids. The well pressure drops and large amounts of water or brine are pumped in to extend the fracture towards the target well(s). The success of this operation in obtaining well communication has...
been consistent in some fields, erratic in most, and lacking in others. The initial well communication, when obtained, is a high pressure connection, i.e., the pressure required to keep the fracture propped open is high. In case of horizontal fractures this pressure is slightly larger than the overburden stress. Regardless of the fluid used up to this stage, once the connection is made, water is pumped in and the process of brine production is commenced. When enough salt is removed from the planes parted by the fracture a self-supporting gallery is usually created which does not necessitate a highly pressurized fluid to keep open. When this stage is reached, the final 'low-pressure connection' is achieved and the hydraulic fracturing process is completed. Unfortunately, high pressure connections do not ensure low pressure communications. Often this last stage lasts from a few hours to a number of days. Sometimes, however, it may take considerably longer or never be completed. Brine production by high pressure pumping is uneconomical and unless the low pressure connection is achieved the entire hydrofracturing job is often considered a failure.

The questions most often asked by those who have not had complete success in connecting wells are: How do fractures propagate in salt? How can fractures be controlled? What well completion ensures better success? What keeps a high pressure connection from yielding a low pressure one? These and many other questions cannot be answered in a definite way because of the lack of information with regard to the mechanical behavior of rock salt under hydraulic fracturing conditions. An investigation of this behavior has been planned by the author for quite sometime. However, prior to undertaking it, it was felt that a study of existing data on past jobs could identify more clearly the nature of the field problems, and yield conclusions that would be beneficial both to industry and to the planning of further research. Under the sponsorship of the Solution Mining Research Institute a case-history study was thus undertaken and some ten brine field hydrofracturing data were made available for analysis. The results of the study are detailed below. Because of management policies in some companies, no mention is made in this paper of salt field names or locations. However, all of the reported cases are authentic.

CASE HISTORY STUDY

The study of past experiences in hydrofracturing salt has been limited to flat or nearly flat bedded salt formations of the type encountered in Ohio, Michigan, Ontario, etc. The jobs analyzed span over a period of almost 20 years. The completeness of the records left varies considerably from job to job. The lack of documentation precluded a uniform type of study. Each analyzed case, however, contributed some to the general picture obtained of the hydrofracturing mechanism in salt.

The first important conclusion of the study is that field results have been mixed. Total successes, total failures and partial successes (or partial failures) have all been experienced within the limited number of cases studied. Each of these field results will now be described. Figure 1 is a legend defining the convention used in the diagramatic sketches that accompany most of the case histories.

Case 1—the success story

The mined salt layer is 40-50 m thick at a depth of approximately 700 m. Salt extraction is routinely performed by brining through two-well groups. Each group is connected by hydraulic fracturing. Figure 2 diagramatically depicts a typical fracturing operation and results. Both the injection and the target wells are drilled to about 15 m above the bottom of the salt. The wells are 120 m apart with the target well always updip of the fracturing well. The segment of the wells within the salt layer is left uncased and an open-hole packer is placed in the fracturing well, some 15 m from its end. The packer is connected to pumps on the surface through 14 cm tubing.

The hydraulic fracturing of this system has been consistently successful (more than 90% in some 20 attempts). Caliper logging has identified the well portion immedi-
Well Communication in Salt Formations

![Diagram](image)

Figure 2. Case 1—Typical well layout, completion and fracturing results.

ately below the open-hole packer as being the zone of fracture initiation. Similar logging of the target well has found the fracture to hit it at about the same elevation as where it originated. Only 150–500 m³ of brine are consumed to establish communication, an operation that typically lasts 1–2 hours. Switching to water occurs when a reasonable flow is established (2–4 m³/min). Normal brining operations are started as soon as the low-pressure connection is obtained (within 12–16 hrs).

Very little if any fluid loss is experienced and this is attributed mainly to the rather high elevation of the well bottom (15 m above the interface with a limestone zone). Salt has a tendency of healing, while other formations are often traversed by discontinuities like joints, faults, partings. By removing the potential fracture plane from such natural channels the danger of fluid losses is minimized and quicker communication is ensured. However, it is well known that the process of brining removes salt mainly from the hanging wall of the hydrofracture. To salvage the salt left in the 15 m layer between well-bottom and limestone, the fracturing well is deepened at a later stage.

The success of hydraulic fracturing in this field has not come overnight. It was predicated by some not-too-successful jobs, but the operators apparently managed to learn from their mistakes and perfected the method to an almost routine undertaking. This is also, perhaps, partly due to a rather homogeneous, predictable salt layer which takes the guessing out of the game.

In addition to the well-bottom elevation, the type of well completion should be noted. An open-hole fracturing job (without perforating or notching) allows the fracture to initiate where a weakness exists and to extend and reach the target well in the most natural way. Whether or not the updip position of the target well contributed to the successful results could not be established. The dip is very gentle, practically negligible, and cannot be considered a major factor.

Cases 2, 3, 4—complete failures

Cases of complete failure are considered those in which no apparent communication between wells has been established. Curiously, the reported cases represent three unrelated attempts in three different fields to connect wells in the "D" salt zone of the Salina (after classification by Landis).

Case 2 is a field, or a portion of, locked in between a highway and a railroad track, forming a long and narrow stretch. It is apparent that the layout of the wells was mainly dictated by the surface geometry and not by fracturing considerations. The efforts of numerous attempts (Fig. 3) to connect groups of wells in the "D" salt zone, using different permutations, were unsuccessful. The four frac jobs performed in well No. 1 are shown schematically in Fig. 4. Well No. 2 was never hit by any of the fractures induced in No. 1. Each of the four attempts represents a different well completion. None appeared to yield desired results.

Cases 3 and 4 represent groups of two wells in two separate fields in which considerable amounts of money and time (many months in each case) were spent on every
feasible hydraulic fracturing configuration with no apparent success.

Several explanations can be given to describe the consistent failures in the 'D' salt. They are all speculative since available data on the properties of this salt zone are scarce at best. One explanation is based on the fact that the salt layers in the sites under consideration are relatively thin (of the order of 1-20 m) and are separated by anhydrite, dolomite or mudstone. It is almost inconceivable that in such thin layers of salt a hydraulic fracture could be isolated from the neighboring rock layers. These rocks are substantially more brittle than halite, and show no tendency of healing existing fractures. The possibility exists that these intermittent layers are indeed precracked, and that once the hydrofrac reaches them their high permeability will direct most of the flow out of the salt. Since the target wells in most of the described cases were completed so that only a very restricted segment was left for fracture connection it is unrealistic that the flow of brine or water through the fracture of the neighboring layers went unnoticed.

Another theory related to the persistent failures is that the salt layers themselves, independently, or as a result of the intermittent strata of the more brittle rocks, are traversed by faults or other discontinuities which deflect the direction of fluid flow and disrupt the otherwise probable communication. Faults and fractures in halite are expected to heal with time and are generally considered non-existent, but many observations in underground mines confirm that discontinuities in salt are sometimes clearly detected.

A third explanation is based on the author's laboratory experimental results of hydraulic fracturing in salt. Unlike any other previously tested rock, hydraulic fracturing of salt specimens obtained from the Detroit mine yielded not one but a band of fractures. These looked more like a band of flow channels along grain boundaries, with the general orientation being vertical. Because of the limited number of tests, using only one type of coarsely crystalline salt, it is impossible to extrapolate as to the generality of the results. However, if the 'D' salt happened to behave in a similar manner, it is then conceivable that the oriented flow through the crystal boundaries could have missed the target well.

Cases 5-10—partial failures

Probably the most interesting cases are those of partial failures or partial success. They show how such parameters as geology, well layout, completion, and design can affect the results of a frac job.

One of the most fully documented cases is No. 5. A group of eighteen wells were planned to be connected by hydraulic fracturing into six galleries as shown in Fig. 5. No apparent consideration was given to fracture direction preference in the area. Surface considerations called for the six galleries to be north-south oriented, and to accomplish that the distance between wells in the N-S direction was kept at 150 m, while the span between E-W wells was set at 250 m. All wells were to be completed with casing and perforations at the depths desired for fracture connection.

The first designated group to be connected was B1-3, (Fig. 5) with the central well (B2) acting as the fracturing hole and the other two as the target holes. The only other hole drilled at the time was C3. Three and one half hours of pumping into well B2 (325 m²) produced a connection, but with the 'wrong' well, i.e., C3 (Fig. 6). Caliper and
radioactivity logs showed that the fracture hit well C3 at the same level that it initiated at B2.

After casing, cementing and shutting-in well C3, fracturing was resumed on B2 (at 1.2 m$^3$/min). Some 20 hours later partial flow was detected in well B3 (.3 m$^3$/min) and in B1 (.004 m$^3$/min). Soon, however, well A3, which was being drilled at the time, ran into a high pressure flow of brine, and fracturing was stopped again (Fig. 7). Later on, when all 9 wells shown in Fig. 6 had been drilled and completed all but B2 and B3 were shut-in to allow a new attempt to connect the two wells. C2 had erroneously been left open, however, and the full flow of brine was coming its way. Only after plugging C2 an eventual full flow connection B2–B3 was established. This was four months after the first frac attempt!

The above sequence of events shows beyond any doubt that the salt formation in case 5 had a preferred fracture and fluid flow direction which affected not only well communication but also the transition to low pressure connection. It so happened that the preferred direction was east-west, while the design called for north-south well connections. The result was a large consumption of fluids and eventual drastic redesign of galleries.

The same trend of preferred fracture direction can be observed in the second 9 well group. The sample shown in Fig. 8 is of an attempted connection A6–A5. Pumping into A6 yielded a connection with B6 after 10 hours and 600 m$^3$ of flow. Shutting-in well B6 still did not result in the desired connection. Rather B5 was communicated with.

It is strongly felt that in such a large hydrofracturing operation involving eighteen wells, more emphasis should have been placed on studying the mechanical reaction to fracturing of the formation involved before planning well location and gallery layout. One recommended method of initial fracturing to determine trends and preferred directions in a salt layer is described elsewhere in this paper.

Case 6 involves the first three wells (A1–3) to be connected by hydraulic fracturing in a new salt field, as shown in Figs. 9 and 10. The wells were 300 m apart, and about 750 m deep. They were aligned in an east-west direction. After completing wells A2 and A3 an attempt was made to connect them by fracturing A2. Twenty-four hours of pumping resulted not in a connection with A3 but in a brine flow out of a gas well some 2500 m to the west (Fig. 9). Prior to discontinuing fracturing operations some
10,000 m$^3$ of water were pumped into A2, 1000 m$^3$ were recovered from the gas well, and no flow was detected at A3. A strong case of preferred fracture direction to the west! The tremendous distance to the gas well could indicate that the advancement of the pumped water through the underground strata was not wholly due to fracturing but possibly a result of running into existing discontinuities. The fact remains, however, that the hydraulic fracture did not spread uniformly in all directions as theoretically assumed.

An attempt to fracture A3 into A2 was subsequently successful, supporting the hypothesis that hydraulic development had strong tendencies to the west in this field (Fig. 10). Fracing A1 and A2 also yielded an easy connection, but this result is most probably due to an existing fracture created when A2 had been fraced.

Case 7 (Fig. 11) is another example of cavity and well layout design based on surface consideration rather than on underground fracture trends. Six wells were to be drilled that would form two north-south galleries at about 750 m below surface, one connecting the A wells, another connecting the B wells. To 'ensure' that the fracture would not connect the wrong wells, a distance of 250 m was kept between the two groups, while only 150 m separated wells within a group. All wells were cased and perforated at the levels where fracturing was to be initiated or expected to connect.

The first attempt was to connect A2 to A1. Pumping in excess of 8000 m$^3$ of water yielded only a high-pressure connection with very little flow. During deepening operations in well B3, however, a full flow of brine was encountered. Moreover, shutting-in B3 raised the pressure in the well to a level equal to that in A1-A2. It was beyond doubt that the large volumes of water pumped into A1-A2 were actually flowing in a southwestern direction.

The attempt to connect B3 to B2 is an excellent example of the superiority of open-hole fracturing. Large quantities of fluid pumped into B3 appeared to yield no connection with B2. However, by cleaning out a few feet of cement that had previously been used to fill the bottom of B2 during casing a rapid inflow of brine was encountered and the connection to B3 was established. Were B2 open-hole in the salt zone the connection would have been made a number of days earlier.

The attempted connection B2 to B1 was a complete failure. Apparently, most of the water pumped into B2 went into the probable fracture shown in Fig. 11.

It should be noted again that the preferred direction of a fracture appears to control not only the actual connection between wells, but also the transition from high to low-pressure communication. The A2-A1 connection was finally achieved, although the wells were not ideally situated, because enough water was pumped in A2 to extend the fracture not only in the preferred direction, but also laterally towards A1. But the connection persisted at its high pressure level and partial flow in spite of additional large quantities of fluid. It was apparently more natural for the fluid to flow in the preferred fracture direction, at one point bringing the output at A1 to an almost complete halt.

Case 8 is an additional example of preferred fracture direction. This is a field where due to legal restrictions the wells must be drilled close to existing roads (Fig. 12). Hydraulic fracturing connections are also expected to follow road directions irrespective of their natural trends. To prevent any problems the wells to be connected are drilled within 30-80 m from each other. Because of the close distance most of the planned connections are eventually made, often at the expense of large quantities of flow and extended time. The part of the field shown in Fig. 12 appears to have a preferred fracture direction to the northeast, which unfortunately is not followed by the roads, resulting in long undesired connections.

Case 9 provides information on the importance of hydraulic fracturing depth and well completion. The first group of wells was drilled down to the bottom of the salt
honing that the interface with the underlying limestone would promote a horizontal fracture extension, and thus the entire salt zone would be brined (Fig. 13). What was overlooked was the condition of the limestone which is fractured and ruptured in that field. The result was a huge consumption of water and tremendous time loss (several months) before low-pressure connection was established.

In the second group of wells precautions were taken. The wells were drilled to some 2.5 m above the bottom of the salt and the fracturing which had previously been done through perforations was now initiated by the more precise way of noting. The results were almost perfect. Connection was immediately established and fluid losses were nil (Fig. 14). The small amount of salt under the fracture level which may not be completely recovered is just a small price to pay for a much improved frac job.

Case 10 is a similar example of connection failure in which fracturing was done through perforations at the very bottom of a 75 m thick salt layer. In addition to the possibility that the underlying strata was prefractioned and swallowed most of the pumped-in water, the perforations (like in case 9) could have caused formation damage and contributed to the failure of the job. A second fracture attempt some 20 m higher, and adjacent to a stringer, finally resulted in a good low-pressure connection.

**DISCUSSION AND RECOMMENDATIONS**

In the above review of ten case histories no attempt was made to provide detailed descriptions of each frac job. Rather, the more important aspects were singled out in an attempt to expose some of the fundamental reasons behind fracturing partial or complete failures.

The major conclusion of the study is, perhaps, that hydraulic fracturing in salt is not as erratic as it appears at first sight. What contributes to its unpredictable behavior is the fact that not enough emphasis is being placed on understanding the geology of each location. For example, a thorough investigation of the permeability (due to both pores and fractures) of neighboring rock strata could assist in planning hydraulic fracturing depths away from dangerous zones which would absorb most of the pumped-in fluids. A study of the mechanical reaction to fracturing of the major salt formations could provide answers to such questions as why frac attempts in the "D" salt have been consistently unsuccessful, or why some fractures prefer particular directions of propagation.
Improved recording of fracturing events is a prerequisite to better understanding of frac mechanism. Although considerable improvements have been made over the years there are still cases where pressure or flow records are inadequate. Continuous recording of these two parameters in both the injection and the target wells are strongly recommended. Accurate logging of wells to determine depth of connection could assist in estimating fracture inclination.

Well completion depends on different factors and may vary from site to site. Whenever structurally feasible, however, open-hole completion in the hydrofractured salt zone is recommended. Casing and perforating can be detrimental both to the injection well because perforations may induce fractures in undesired directions, and to the output well because the target area to the approaching frac is thus thoroughly limited.

Probably the factor most directly responsible for the success or failure of a frac job is the design of well location. When the geology, mechanical behavior, in situ stresses, or past experience related to a field are not well known there is not enough information to rationally plan well layout. This is, unfortunately, the case in most new salt fields, or new salt formations in old fields. One possible frac procedure to be followed in new fields is shown in Fig. 15. A group of wells (at least four) are drilled such that one is in the center and the others are evenly spread around it at reasonable distances for fracture connection. The central well is the fracturing hole. All wells are instrumented for pressure and fluid flow monitoring. As the hydraulic fracture is initiated and fluid is pumped in the instruments are carefully watched. At some point one of the circumferential wells will show a sudden pressure increase signaling a high-pressure connection. At a later stage another well may indicate connection. Continued pumping will finally yield a low-pressure communication with one or more of the wells. This entire sequence of events, diagramatically depicted in Fig. 15, would not only yield a successful connection at least between some of the wells drilled, but, in particular, will provide enough data on fracture and flow preferred directions to render a rational layout of future galleries in the field.

![Diagram of recommended hydrofracture procedure prior to brine field design.](image)
Ground-level Ozone

Ground-level ozone is a colorless, highly irritating gas created by photochemical reactions between nitrogen oxides and volatile organic compounds produced largely by fuel combustion, gasoline vapors and chemical solvents.

What Is the Environmental Issue?

Ozone ($O_3$) is a gas found in different parts of the atmosphere. Ozone in the upper atmosphere, or stratosphere, is an essential gas that helps to protect the earth from the sun's harmful ultraviolet rays. By contrast, the ozone found near the ground in the troposphere harms both human health and the environment. For this reason, ozone is often described as being “good up high and bad nearby.”

Ground-level ozone is produced when nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) react through photochemical processes in sunlight (see figure). Power plants, motor vehicle exhaust, industrial facilities, gasoline vapors, and chemical solvents are the major sources of these emissions.

Ozone is also formed at ground level from natural emissions of VOCs, $NO_x$ and carbon monoxide, as well as stratospheric ozone that occasionally migrates down to the earth’s surface. Natural sources of ozone precursors include emissions from plants and soils, forest fires, and lightning. High ozone concentrations are observed at many remote mid-latitude sites in late winter and spring, especially at high elevations. However, long-range transport and the winter buildup of $O_3$ precursors also contribute to these springtime levels, so it is not possible to attribute these high levels solely to natural sources.

How ground-level ozone is formed

\[ \text{VOCs} + \text{NO}_x + \text{Sunlight} = \text{Ground-level ozone} \]
Why Is This Issue Important to North America?

Ground-level ozone has deleterious effects on human and animal health and the environment. Despite reduction efforts by the three countries, it still exceeds national air quality standards in some areas of North America.

Effects of Ground-level Ozone

Ground-level ozone, a key component of smog, is considered a “nonthreshold” problem because even very small amounts in the air have deleterious effects on human health, especially the cardiovascular and respiratory systems. Exposure to ozone has been linked to premature mortality and a range of morbidity outcomes that include hospital admissions and asthma symptoms. After analyzing the air pollution and mortality data of eight major Canadian cities, Health Canada estimated that in these cities almost 6,000 deaths a year could be attributed to air pollution of which ground-level ozone is a major component. According to the Ontario Medical Association, air pollution costs Ontario citizens more than C$1 billion a year in hospital admissions, emergency room visits and absenteeism. In the United States, studies of 95 major urban areas by researchers at Yale and Johns Hopkins revealed that an increase in daily ozone levels was associated with more than 3,700 deaths each year from cardiovascular and respiratory illnesses.

Vegetation, crop productivity, flowers, shrubs and forests are also damaged by ground-level ozone. Moreover, it can deteriorate cotton and synthetic materials, produce cracks in rubber and accelerate the fading of dyes, paints and coatings.

Reducing Emissions

The 1970s saw the beginning of attempts to mitigate ground-level ozone concentrations across North America through directed reductions in precursor emissions. In response, both NO\textsubscript{x} and VOC emissions in the United States fell substantially, despite significant economic growth. In Canada, VOC emissions have decreased, but the trend in NO\textsubscript{x} emissions has been almost flat since 1990. Mexico has experienced reductions in emissions from vehicles, but increases in those from fixed or stationary sources for both NO\textsubscript{x} and VOCs. Overall, air emissions of ground-level ozone precursors in North America have declined since 1990, with releases of both NO\textsubscript{x} and VOCs falling over 20 percent (see graphs).

In all three countries, fuel combustion by mobile sources is a major source of both NO\textsubscript{x} and VOC emissions, with fossil fuel–fired power plants adding significantly to NO\textsubscript{x} emissions in the United States and Mexico. In Canada, upstream oil and gas production is the largest industrial contributor of NO\textsubscript{x}. In addition to fuels in the transportation sector, solvents are a major source of emissions of VOCs in all three countries, but oil and gas production is also a large contributor in Canada.

Monitoring Ozone Trends

At present, considerable ozone data for North America are available from various networks. Characterization of North American trends and patterns is limited, however, by the lack of consistency in these data sets and by the inconsistent methods for preparing and reporting results. It is also difficult to derive meaningful North American trends because conditions vary greatly on a regional basis. Nevertheless, existing monitoring reveals that ambient levels of ozone exceed national standards in certain areas of all three countries.

In Canada, trends for ambient ozone based on the Canada-wide Standard (CWS) remained largely unchanged over the 15 years ending in 2005. However, the Canadian indicator for human exposure to ozone rose by an average of 0.8 percent a year, for a total increase of 12 percent between 1990 and 2005. The national ozone exposure indicator for Canada, which is weighted by population, is driven primarily by the ozone concentrations and populations in Ontario and southern Canada.

Source: Bilateral Air Quality Committee.

Quebec. In 2005, communities in these areas recorded the highest ground-level ozone concentrations for both the CWS and seasonal averages. Many stations in Alberta also reported high seasonal average concentrations. In 2005, at least 40 percent of Canadians lived in communities with ozone concentrations above the ambient CWS target.

In Mexico, the frequency of days on which ground-level ozone concentrations exceed the standard has remained constant over time in most monitored cities. However, in Mexico City and Guadalajara, ground-level ozone remains a serious air quality problem. In 2005 at least 27.7 percent of Mexicans lived in municipalities in which ozone concentrations were above the national standard at least one day a year.

In the United States, national ozone concentrations averaged over one hour and eight hours fell by 12 percent and 8 percent, respectively, in the period between 1990 and 2005. Despite the decrease, in 2005, more than 10 percent of Americans lived in counties with air quality concentrations above the ozone one-hour National Ambient Air Quality Standard, and at least 33 percent lived in counties with concentrations above the eight-hour standard.

Transboundary Flows
Both field studies and computer models confirm that the ozone problem in various regions of North America is a result of the complex interactions between meteorological processes on various scales and precursor emissions and their chemistry. At times, ozone levels are predominantly the result of local emissions, with only minor contributions from upwind sources. And at other times, local ozone levels are dominated by the transport of ozone and its precursors from upwind sources.

State are not well resolved in the map shown, although they are lower than in the east. Between 1995 and 2004, there was a decrease in annual ozone levels within this border region, with trend lines on either side of the border tracking similarly.

Ozone concentrations in the US-Mexico border region remain a concern in some areas. Although in the Rio Grande Valley no days in 2005 exceeded the binational eight-hour ozone standard, other monitoring locations in border sister-city pairs demonstrated exceedances, including Ambos Nogales (1 day), Ciudad Juarez/El Paso (6 days), Tijuana/San Diego (11 days), and Mexicali/Imperial Valley (24 days). Although overall compliance with the ozone standard is generally improving, Mexicali/Imperial Valley and Tijuana/San Diego consistently remained above the applicable standard from 2001 to 2005.

Transport of ozone and precursor emissions extends beyond North America's borders. North America is a source of ground-level ozone for Europe just as Asia is for North America. More widely, ground-level ozone levels are rising across the planet and have created “background” ozone concentrations, even in remote areas that are not directly affected by human influence. Retrospective analysis of eighteenth-century data from Europe suggests that ozone concentrations in the Northern Hemisphere may have doubled over the past century in response to the massive

Analyses of ozone levels within 500 kilometers of the Canada-US border found higher ozone levels in the lower Great Lakes–Ohio Valley region and along the US East Coast.

Analyses of ozone levels within 500 kilometers of the Canada-US border found higher ozone levels in the lower Great Lakes–Ohio Valley region and along the US East Coast (see map). The lowest ozone values are largely found in the west and in Atlantic Canada. Levels are generally higher downwind of urban areas, such as in the western portions of lower Michigan. The locally higher levels in the complex terrain of the Georgia Basin–Puget Sound area of British Columbia–Washington industrialization that has taken place. Current “background” ozone concentrations in North America are about 30–40 parts per billion.

What Are the Linkages to Other North American Environmental Issues?

Ozone and its precursor pollutants are linked to particulate matter (PM), another component of smog, and to acidification, eutrophication and climate change.
Particulate Matter
When nitrate, an oxidation product of nitrogen dioxide (NO₂), is combined with other compounds in the atmosphere, such as ammonia, it becomes an important contributor to the secondary formation of fine particulate matter (PM₁₀). VOCs are also a precursor pollutant to the secondary formation of PM₁₀. Ozone and PM have some common precursor gases, and reductions in any one of these precursors can have complex, and at times negative, results for concentrations of ozone or PM. Efforts to address and reduce concentrations of ozone and PM are often integrated in air quality management programs to avoid negative air quality results.

Acidification
Nitrogen oxides are formed primarily from the nitrogen liberated during combustion processes. Nitrogen oxide emitted during combustion quickly oxidizes to NO₂ in the atmosphere. The NO₂ then dissolves in water vapor in the air to form nitric acid (HNO₃), and interacts with other gases and particles in the air to form particles known as nitrates and other products that may be harmful to people and their environment. Both NO₂ in its untransformed state and the acid and transformation products of NO₂ can have adverse effects on human health and the environment, harming vegetation, buildings and materials, and contributing to the acidification of aquatic and terrestrial ecosystems.

Eutrophication
Nitrogen releases not only contribute to the formation of acid depositions, but also can act as a nutrient in ecosystems, resulting in eutrophication or overenrichment of soils and waters.

Climate Change
When present in the upper troposphere, ozone is a very effective greenhouse gas. Strategies that reduce ozone concentrations on urban and regional scales probably help to limit the contribution of ground-level ozone to the greenhouse effect and global warming.
Risk Factor Analysis—
A New Qualitative Risk Management Tool

John P. Kindinger, Probabilistic Risk and Hazards Analysis Group, Los Alamos National Laboratory
John L. Darby, Probabilistic Risk and Hazards Analysis Group, Los Alamos National Laboratory

Introduction

Project risk analysis, like all risk analyses, must be implemented using a graded approach; that is, the scope and approach of the analysis must be crafted to fit the needs of the project based on the project size, the data availability, and other requirements of the project team. Los Alamos National Laboratory (LANL) has developed a systematic qualitative project risk analysis technique called the Risk Factor Analysis (RFA) method as a useful tool for early, preconceptual risk analyses, an intermediate-level approach for medium-size projects, or as a prerequisite to a more detailed quantitative project risk analysis. This paper introduces the conceptual underpinnings of the RFA technique, describes the steps involved in performing the analysis, and presents some examples of RFA applications and results.

Description of the Risk Factor Analysis Process

Overview of the Risk Factor Analysis Process

The objective of the RFA is to identify and understand the underlying factors that ultimately will drive the behavior of the top-level schedule, cost, and technical performance measures for a project. The primary steps involved in conducting a risk factor analysis are as follows:

1. List activities, tasks, or other elements that make up the project
2. Identify applicable technical risk factors
3. Develop a risk-ranking scale for each risk factor
4. Rank risk for each activity for each risk factor
5. Sum results across risk factors for each activity
6. Document the results and identify potential risk-reduction actions for evaluation by the project team

Each of these steps is described in the subsections that follow.

List Activities Modeled

The first step in RFA is the identification of the activities, tasks, or elements of the project to be evaluated. If available, the project work breakdown structure (WBS) and the baseline schedule can be used as the starting point for the identification of important activities. Using this information and data obtained from discussions with the project team, the analyst develops a project activity flow chart to help organize the RFA. The flow chart defines the tasks to be modeled and their interrelationships for the project schedule analysis. WBS and schedule tasks may be consolidated and/or expanded to explicitly highlight those tasks and influences that are expected to have a significant technical risk and/or significant uncertainty in schedule or cost performance. The flow chart is developed in sufficient detail to allow the items important to overall schedule and cost performance to be evaluated individually, yet it is simple enough for all key tasks and their interrelationships to be viewed easily.

Identification of Risk Factors

Risk factors are the issues, topics, or concerns that may ultimately drive the behavior of the top-level schedule and cost performance measures for a given activity. The aim of the RFA is to systematically search the selected project activities for the presence of such risk factors. To aid in the identification of relevant risks, the risk project spectrum first is divided into four broad categories of risk generally found to be relevant to all LANL projects.

1. Technical Risk. Technical risks are those events or issues associated with the scope definition, research and development (R&D), design, construction, and operation that could affect the actual level of performance vs. that specified in the project mission need and performance requirements documents. Examples of technical risks include new and changing technology and changing regulatory requirements.

2. Schedule Risk. Schedule risk is the risk associated with the adequacy of the time allotted for the planning, R&D, facility design, construction, and startup operations. Two major elements of schedule risk are (1) the reasonableness and completeness of the schedule estimates for the planned activities and (2) the risk that schedule objectives will not be met because of a failure to manage technical risks. An example of risk in this category would be schedule delays resulting from failure of the Department of Energy (DOE) to complete reviews and approvals of technical, safety, and management documents within the durations provided in the project schedule.

3. Cost Risk. Cost risk is the risk associated with the ability of the project to achieve the planned life-cycle costs. Thus, it includes both design/construction and operating costs. Two major elements of cost risk are (1) the accuracy and completeness of the...
Exhibit 1. Example Qualitative Risk Factor Ranking Criteria

Exhibit 1. Risk Categories and Generic Risk Factors for Risk Factor Analysis

<table>
<thead>
<tr>
<th>Risk Factor</th>
<th>Non/Low (0/1)</th>
<th>Medium (2)</th>
<th>High (3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology Maturity</td>
<td>Facilities &amp; equipment involve only proven technology or new technology for a non-critical activity.</td>
<td>Facilities or equipment require the adaptation of new technology from other applications to critical construction or operating functions for this project.</td>
<td>Facilities &amp; equipment require the development of new technology for critical construction or operating functions for this project.</td>
</tr>
<tr>
<td>Productivity Uncertainty</td>
<td>The planned rate of progress needed to reach completion as planned is conservative and well within benchmarks observed for similar tasks.</td>
<td>The planned rate of progress needed to reach completion as planned is aggressive but still within benchmarks observed for similar tasks.</td>
<td>The planned rate of progress needed to reach completion as planned is extremely aggressive or no benchmark experience is available to judge the reasonableness of the planned progress rate.</td>
</tr>
<tr>
<td>Equipment/ Material Cost Uncertainty</td>
<td>Equipment/Material costs are well established and regulated by contracts or competitive market forces.</td>
<td>Equipment/Material costs are not well established but should be regulated by competitive market forces.</td>
<td>Equipment/ Material costs are not well established and not subject to competitive market forces.</td>
</tr>
</tbody>
</table>

4. Funding Risk. Project schedule targets may not be met because the projected funding needed to conduct the planned activities is not available when needed. In turn, schedule delays caused by underfunding can produce a need for increased funds. Thus, a complete risk assessment must include an evaluation of
funding supply or budgetary risks. An example of this type of risk would be DOE failure to provide adequate funding or a change in priority for the project from DOE or the Congress.

Exhibit 1 shows the four risk categories and their interrelationships plus generic risk factors found to be broadly applicable to LANL projects for each risk category. The specific risk factors listed can be modified and supplemented with additional factors applicable to a specific project or program.

**Qualitative Risk Ranking Guidelines**

A method to systematically document the risk for each qualitative risk factor identified in Exhibit 1 is needed to perform a consistent evaluation of risk across the different project or program activities. To make this possible, qualitative definitions of risk for each of the risk factors are defined for three categories of risk (none, low, medium, and high). Some examples of these risk-ranking definitions are presented in Exhibit 2.

**Risk Factor Evaluation**

The identified project or program activities are evaluated systematically against the risk factors using qualitative risk factor rankings similar to the Exhibit 2 example. The evaluation can be performed by project personnel after training in the approach or by the risk analysis team based on interviews with the project team members. The results are recorded on worksheets prepared for each project activity. These worksheets document the risk ranking for each risk factor for each project activity using a system in which the qualitative categories from Exhibit 2 were given numerical values as shown below.

<table>
<thead>
<tr>
<th>Risk Ranking</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Low</td>
<td>1</td>
</tr>
<tr>
<td>Medium</td>
<td>2</td>
</tr>
<tr>
<td>High</td>
<td>3</td>
</tr>
</tbody>
</table>

In actual application, intermediate values such as 2.5 are used when appropriate. Numerical values are assigned to the qualitative risk-ranking categories to facilitate the later assembly of results and development of probability distributions. The risk-ranking worksheets also record the justification for the risk assignment and reference the appropriate documents or interviews.

A simple example of a completed evaluation is shown in Exhibit 3.

**Uses of Risk Factor Analysis Results**

RFA results have been used to aid LANL project management in three important ways. First, the qualitative risk factor rankings for each project activity provide a first-order prioritization of project risks before the application of risk-reduction actions. This general ranking process is shown by the project activity results given in the bottom row of Exhibit 3. This example shows that, in order, activity C represents the highest risk, followed by B and then A. A more robust example of RFA ranking results for an actual project at LANL is shown in Exhibit 4.
The second, and more meaningful, result from conducting an RFA is the identification of possible risk-reduction actions responding to the identified risk factors. Risk-reduction recommendations are often straightforward to make when the risk issue is identified. However, the value added from the RFA approach comes from the systematic and comprehensive nature of the RFA process and the confidence that is built in the project team and other stakeholders as a result of having performed the analysis. An example of risk-reduction recommendations identified through the RFA process is shown in Exhibit 5.

The final use to which RFA results have been applied at LANL is the development of input distributions for quantitative risk modeling. The integrated qualitative and quantitative risk analysis process is shown in Exhibit 6.

Note that in the RFA process, the potential effect of a risk factor on project performance is the focus of concern not its likelihood of occurrence. The issues identified in the RFA and the risk-reduction actions implemented in response to these issues now can be documented and weighed by the risk analyst to define defendable input distributions for quantitative risk modeling that account for both the consequence and likelihood of risk issues.

Conclusion

This paper has introduced a systematic qualitative project risk analysis technique called the RFA method. The RFA technique has been used at LANL as a tool for early, preconceptual risk...
Exhibit 5. Example Risk-Reduction Recommendations From RFA

<table>
<thead>
<tr>
<th>System Element</th>
<th>Critical Risk Factor</th>
<th>Discussion</th>
<th>Recommendation/Section Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>HYDOX</td>
<td>• Process technology</td>
<td>Process is undefined and unproven. Indicated cycle time would require multiple HYDOX reactors to achieve needed throughput. No alternative to HYDOX is available to make oxide from potential problem bonded pits. Two-step process will use hydrogen and oxygen. Three-step process being considered to avoid safety concerns. Plutonium oxide easily dispersible. Unique process not yet developed. HYDOX may be the most critical module in terms of downtime affecting production.</td>
<td>Consider eliminating HYDOX module; see recommendation 5.1.1.2. 5.1.2.2</td>
</tr>
<tr>
<td></td>
<td>• Scale-up concerns</td>
<td></td>
<td>Perform analysis of accident potential because of the ignition of hydrogen. Perform accident analysis for plutonium oxide dispersal. Develop contingency plans for maintenance on HYDOX module. Maintain long-lead-time replacement parts on site (e.g., heaters); consider maintaining full replacement HYDOX unit on site.</td>
</tr>
<tr>
<td></td>
<td>• Capacity potential</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Feed material</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Bad product</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Radiation accident</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Equipment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Equipment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Exhibit 6. Integrated Qualitative and Quantitative Risk Analysis at LANL

analyses, an intermediate-level risk analysis approach for medium-size projects, or as a prerequisite to a more detailed quantitative project risk analysis. The steps involved in performing the analysis and actual results from LANL projects have been used to illustrate the RFA process. It is the hope of the authors that the RFA technique may provide project risk analysts with a useful and cost-effective tool that can be applied to a broad spectrum of projects and programs.
Quantitative Risk Assessment to Site CNG Refuelling Stations

Naser Badri, Farshad Nourai, Davod Rashtchian
Department of Chemical and Petroleum Engineering, Sharif University of Technology
Azadi Street, Tehran, Iran

This study considers the application of quantitative risk assessment (QRA) on the siting of compressed natural gas (CNG) stations and determining nearby land use limitations. In such cases the most important consideration is to be assured that the proposed site would not be incompatible with existing land uses in the vicinity. It is possible by the categorization of the estimated levels of individual risk (IR) which the proposed site would impose upon them. An analysis of the consequences and likelihood of credible accident scenarios coupled with acceptable risk criteria is then undertaken. This enables the IR aspects of the proposed site to be considered at an early stage to allow prompt responses or in the later stages to observe limitations. According to the results in many cases, not only required distances have not been provided but also CNG stations are commonly located in vicinity of populated areas to facilitate refueling operations. This is chiefly because of inadequate risk assessment studies and ambiguities to define acceptable risk criteria.

Keywords: Quantitative risk assessment; Consequence analysis; Siting; CNG station.

1. Introduction

Siting is among the earliest steps in design, and is quite costly to modify once the site is constructed. Optimum siting must minimize material and construction costs, but more importantly, must minimize the risk of losses throughout the site’s life cycle. Siting provides a fundamental aspect of risk management. It separates sources of potential fire and explosion from adjacent areas that might become involved in the incident or be harmed by its potential consequences (CCPS, 2003 & Rigas et al., 2004). This is also a key component in inherently safer design. Inherently safer strategies can impact a potential incident at various stages. Inherently safer design can also reduce the potential for an incident to escalate. Lastly, an inherently safer strategy can limit the incident sequence before major impacts on people, property, or the environment by a proper siting (Cozzani et al., 2006). QRA is a measure to weigh up whether enough precautions have been taken or should be improved to prevent fatality, injury and destruction mainly in process industries. The need for QRA of process plants has become exceedingly critical due to the trend towards larger and more complex units. Moreover, the potential damage has been magnified by the proximity of many such operations to densely populated areas (Khan et al., 2002).
The flammable nature of methane (Cheremisinoff, 2000) high pressure condition and vicinity to densely populated areas are the most significant reasons which emphasize on importance of CNG station siting studies. This paper presents the QRA study carried out to evaluate a typical CNG station providing methane as a fuel for natural gas vehicles and the main purpose is to quantify the probable hazards and their consequences to estimate the risk to surrounding population.

2. CNG Stations Description

One of the largest CNG stations in Tehran (Figure 1a and 1b) selected as a case study to obtain required information. For this station fed by public distribution pipeline, five main components can be distinguished as follows:

Figure 1a. Top view of selected station Figure 1b. Layout of selected station.

**Metering Unit:** A metering unit is required at the CNG station inlet to record gas flow at low pressure (20 bar).

**Dryer:** The moisture content of CNG must be controlled at the filling station as it can cause operational problems in the station or the vehicle.

**Compressor:** This station uses two large reciprocating compressors which are electrically powered. These compressors are been designed to pressurize gas to 250 bar through three stages.

**Cylinders:** Compressed gas is stored in cylinders mounted vertically in each holding several cylinders. Gas is stored at three pressure levels; Low (160 bar), Medium (200 bar) and High (250 bar). There are 36 cylinders at Low, 27 cylinders at Medium and 12 cylinders at High pressure level.

**Dispensers:** The dispenser is the interface of the CNG filling station with the vehicles. In this station eight dispensers are connected to gas cylinders by pipeline conveying gas at three pressure levels.

3. Risk Assessment

The present study was aimed at following a systematic QRA procedure (Figure 2) to assess the imposed risk due to CNG station operation (CCPS, 2000).
QRA objectives and process description were discussed in former sections. Following sections complete the study.

3.1 Hazard identification and scenario selection

This step is so critical, because a hazard omitted is a hazard not analyzed. Scenarios usually result in the loss of containment of material from the process. Typical incidents might include the rupture or break of a pipeline and a hole in a cylinder or pipe (CCPS, 2007). Finally, after screening low frequency and low consequence scenarios the most credible ones in the selected CNG station have been determined as below:

- Sc-01: Rupture in dryer pipes.
- Sc-02, 03: 5mm and 25mm hole diameter in cylinders.
- Sc-04, 05: 5mm hole diameter and rupture in dispenser pipes.

3.2 Consequence analysis

Consequence analysis is supposed to be carried out through several steps to model the effect of each scenario. Once the scenario is defined, source models are selected to describe how materials are discharged. The source model provides a description of the discharge rate and the total quantity discharged. A dispersion model is subsequently used to describe how the material is dispersed to some concentration levels. Then, fire and explosion models convert the source model information on the release into hazard potentials such as thermal radiation and explosion overpressures (CCPS, 2000). All of the mentioned steps have been modelled using PHAST 6.5 software package developed by DNV. Finally, effect models convert results obtained by software into effects on people represented by probability of death. Probit equations (Equation-1) are commonly used to quantify the expected rate of fatalities for the exposed population.

\[
Y = k_1 + k_2 \ln(V) \tag{1}
\]

Where \(Y\) is probit variable, \(k_1\) and \(k_2\) are constants and \(V\) represents the dose of hazard (radiation and overpressure). A useful expression for performing the conversion from probit variable to probability of fatality (P) is given by Equation-2 (CCPS, 2000).
\[
P = 0.5 \left[ 1 + \frac{Y - 5}{|Y - 5|} \text{erf} \left( \frac{Y - 5}{\sqrt{2}} \right) \right]
\]  

(2)

All of the selected scenarios have been investigated in two different atmospheric conditions (Table 1) corresponding to day and night.

Table 1. Atmospheric conditions corresponding to day and night.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Day</th>
<th>Night</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wind velocity (m/s)</td>
<td>2.5</td>
<td>2.1</td>
</tr>
<tr>
<td>Atmospheric stability</td>
<td>A</td>
<td>D</td>
</tr>
<tr>
<td>Ambient temperature (°C)</td>
<td>27</td>
<td>3</td>
</tr>
<tr>
<td>Humidity</td>
<td>35%</td>
<td>70%</td>
</tr>
</tbody>
</table>

3.3 Frequency estimation

Frequency estimation is the methodology used to estimate the number of occurrences of a scenario through a year. Estimates may be obtained from historical incident data on failure frequencies or from failure sequence models, such as FTA (Less, 1996). Depending on scenario type both techniques have been used to estimate scenario frequencies (Table 2).

Table 2. Estimated frequencies of credible scenarios

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>Scenario description.</th>
<th>Estimated frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Rupture in dryer pipeline</td>
<td>7.5E-5</td>
</tr>
<tr>
<td>02, 03</td>
<td>5mm and 25mm hole diameter in cylinders</td>
<td>3.8E-5 and 1.0E-7</td>
</tr>
<tr>
<td>04, 05</td>
<td>5mm hole diameter and rupture in dispenser pipes</td>
<td>6.8E-2 and 1.7E-2</td>
</tr>
</tbody>
</table>

3.4 Risk estimation

One popular measure to risk monitoring is IR usually shown on a risk contour plot. The IR is defined as the probability of death at any particular location due to all undesired events. It can be expressed as the probability of a person at a specific location becoming a casualty within a year and analysed area. The calculation of IR at a geographical location near a plant assumes that the contributions of all scenario effects are additive. Thus, the total IR at each point is equal to the sum of the IR of all scenario effects at that point (Equation-3).

\[
IR(x,y) = \sum IR_i(x,y)
\]

(3)

Where, \(IR(x,y)\) is the total IR of fatality at geographical location \((x,y)\) and \(IR_i(x,y)\) the IR of fatality at geographical location \((x,y)\) from scenario \(i\) as Equation-4.

\[
IR_i(x,y) = F_iP_i(x,y)
\]

(4)
Where, \( F_i \) is the frequency of scenario \( i \) from frequency analysis and \( P_i(x,y) \) is the probability that scenario \( i \) will result in a fatality at location \((x, y)\) from the consequence and effect models (CCPS, 2000).

Figure 3 presents the IR contours of the selected CNG station to investigate in detail as a case study. For example, a person located within the 1.0E-6 IR contour for one year has one chance in a million of being fatally injured by the hazards associated with releases of methane in the CNG station.

![Figure 3. IR contours for selected CNG Station](image)

When considering proposals to site a process industry or any development in its neighbourhood, four general categories of development are distinguished: industrial, shopping, housing and sensitive. Within the Inner zone (where the IR is greater than 1.0E-5 yr\(^{-1}\)) UK HSE normally advises against all developments other than small or moderate industrial developments and limited numbers of other small developments. Within the Outer zone (where the IR is between 1.0E-6 yr\(^{-1}\) and 3.0E-7 yr\(^{-1}\)) only sensitive developments are advised against. Across the Middle zone (1.0E-5 yr\(^{-1}\) to 1.0E-6 yr\(^{-1}\)) and where developments straddle zone boundaries, each development proposal is considered on its own merits (Hirst et al., 2000). By comparing these general criteria with numerical results extracted from Figure-3, safe distances from CNG station borders can be determined for each zone (Table 3).

### Table 3. Safe and real distances from CNG station borders for each zone

<table>
<thead>
<tr>
<th>Safe distance from station borders (m)</th>
<th>Real distance from station borders (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner zone (18)</td>
<td>-*</td>
</tr>
<tr>
<td>Middle zone (30)</td>
<td>12</td>
</tr>
<tr>
<td>Outer zone (82)</td>
<td>0</td>
</tr>
</tbody>
</table>

* No industrial development is available
In present case study; Sensitive locations such as houses, recreational places and high traffic roads are located exactly adjacent to CNG station borders (Figure-1a) which are absolutely advised against and these areas must be out of the Outer zone characterizing by more than 82m as a safe distance. Shopping places are also located in close CNG station neighbourhood (Figure-1b) which are advised against too and they must be out of the Middle zone characterized by more than 30m as a safe distance.

4. Conclusion

As shown in Figure-3 and Table-3 there are such calculated distances between CNG station and general acceptable risk borders that usually are not followed (e.g. present case study), these distances usually are not intended more important in comparison with other aspects to determine proper distances such as site area value and accessibility for vehicles.

Obtained results obviously introduce many limitations to site a CNG station toward following all acceptable risk criteria for all construction developments, these limitations show that a large number of parameters should be considered to select optimal site for a CNG station in a populated city. This undesirable outcome is almost always present; to ignore these criteria means imposing unacceptable risk on people living and working in the neighborhood. The number of CNG stations and their close vicinity to populated areas, residential and office buildings and other reasons, especially in Iran, prove that enough studies have not been taken in this field. Thus, although CNG stations have an important role in the country’s economy and environment but it creates a source of hazard which its evaluation is still a challenging research. On the other hand, lack of studies to define acceptable risk criteria for different societies is clearly a deficiency.

References

Rigas, F., and Sklavounos, S., 2004, Major hazards analysis for populations adjacent to chemical storage facilities, Process Safety and Environmental Protection, 82 (4).
Quantitative Risk Analysis for
Amerigas Butane Storage Facility

Prepared in Consideration of:

Amerigas Propane L. P.

2110 North Gaffey Street
San Pedro, CA 90731

Prepared By:

Cornerstone Technologies, Inc.

Environmental Engineering & Construction

1650 Ximeno Avenue, Suite 210
Long Beach, CA 90804
Tel: (562) 494-9465
Fax: (562) 494-5296

September 2010
NOTICE

This report is designed to provide accurate and authoritative information with regard to the subject matter covered. However, it is provided with the understanding that the contents reflect the best judgment of Cornerstone Technologies, Inc. in light of the information available at the time of preparation.

Cornerstone Technologies, Inc. does not make any warranty, express or implied, or assume any liability with respect to use of, or damage resulting from the use of any data, information, and/or projections contained herein.
**TABLE OF CONTENTS**

**SECTION**

1.0 Introduction

2.0 Objective, Scope, and Methodology of Study

3.0 Facility Location and Site Description

4.0 Quantitative Risk Analysis Methodology

5.0 Hazards Posed by Amerigas Butane Storage Facility

6.0 Results of Quantitative Risk Analysis

7.0 Conclusions of the Study

**APPENDICIES**

Appendix 1: Release Scenario #1 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 2: Release Scenario #2 – Vapor Cloud Explosion (Distance <0.1 miles)

Appendix 3: Release Scenario #3 – Pool Fire (Distance 0.4 miles)

Appendix 4: Release Scenario #4 – Pool Fire (Distance 1.7 miles)

Appendix 5: Release Scenario #5 – Vapor Cloud Explosion (Distance 3.2 miles)

Appendix 6: Release Scenario #6 – Vapor Cloud Explosion (Distance 4.0 miles)

Appendix 7: Release Scenario #7 – BLEVE (Distance 5.2 miles)

Appendix 8: Release Scenario #8 – BLEVE (Distance 6.8 miles)
Quantitative Risk Analysis for
Amerigas Butane Storage Facility

Prepared in Consideration of:

Amerigas Propane L. P.

2110 North Gaffey Street
San Pedro, CA 90731

Prepared By:

Cornerstone Technologies, Inc.

1650 Ximeno Avenue, Suite 210
Long Beach, CA 90804
Tel: (562) 494-9465
Fax: (562) 494-5296

September 2010
NOTICE

This report is designed to provide accurate and authoritative information with regard to the subject matter covered. However, it is provided with the understanding that the contents reflect the best judgment of Cornerstone Technologies, Inc. in light of the information available at the time of preparation.

Cornerstone Technologies, Inc. does not make any warranty, express or implied, or assume any liability with respect to use of, or damage resulting from the use of any data, information, and/or projections contained herein.
TABLE OF CONTENTS

SECTION
1.0 Introduction
2.0 Objective, Scope, and Methodology of Study
3.0 Facility Location and Site Description
4.0 Quantitative Risk Analysis Methodology
5.0 Hazards Posed by Amerigas Butane Storage Facility
6.0 Results of Quantitative Risk Analysis
7.0 Conclusions of the Study

APPENDICES

Appendix 1: Release Scenario #1 – Vapor Cloud Explosion (Distance <0.1 miles)
Appendix 2: Release Scenario #2 – Vapor Cloud Explosion (Distance <0.1 miles)
Appendix 3: Release Scenario #3 – Pool Fire (Distance 0.4 miles)
Appendix 4: Release Scenario #4 – Pool Fire (Distance 1.7 miles)
Appendix 5: Release Scenario #5 – Vapor Cloud Explosion (Distance 3.2 miles)
Appendix 6: Release Scenario #6 – Vapor Cloud Explosion (Distance 4.0 miles)
Appendix 7: Release Scenario #7 – BLEVE (Distance 5.2 miles)
Appendix 8: Release Scenario #8 – BLEVE (Distance 6.8 miles)
1.0 Introduction

This report is intended to provide a quantitative risk analysis associated with butane at the Amerigas facility located at 2110 North Gaffey Street, San Pedro, California. The purpose is to provide the surrounding community with an informed evaluation of the potential health and safety risks that are inherent in this type of industrial setting.

Amerigas handles a number of industrial chemicals at this address. This report will focus exclusively on the butane storage and transport activities associated with the facility. Butane is usually received and/or distributed through a pipeline, railcar, or transport trucks. Based on the facility’s Regulated Substances Registration, two refrigerated storage tanks located on the western border of the facility are designated for butane storage, each with a capacity of 12.6 million gallons. Butane can additionally be stored in two smaller horizontal vessels, each with a capacity of 60,000 gallons. When considering all storage activities involving butane, this location can store approximately 25.32 million gallons of butane.

2.0 Objective, Scope, and Methodology of Study

The aim of the analysis is to assess the risk to safety of people living and working in the adjacent neighborhoods surrounding the Amerigas facility. The specific objectives of this analysis include:

- Identification of the typical hazardous incidents that relate to the operation of the facility;
- Assessing the significance of each incident that could occur in terms of its potential off-site impact;
- Assessing and quantifying the off-site levels of risk to people, property and the environment due to the proposed facility operations, using a quantitative risk analysis method; and
- Providing a clear, concise report of the analysis to determine the health risk associated with the operation of the facility.

In order to meet the necessary objectives of this study, the following items are included for consideration:

- Identification of the typical hazards present on the site and development of incident scenarios;
- Assessment of the consequences of the identified potential risk events;
- An assessment of the risk in relation to established risk guidelines.

The Quantitative Risk Analysis includes a systematic approach to the analysis of what potential hazards can occur within the storage facility. The normal conditions of
operation of the system are defined and the following questions are provided best-
approximation answers:

(1) What accidental events can occur within the storage system?
(2) What are the consequences of each accidental event?
(3) What is the significance of the calculated risk levels?

By objectively quantifying the potential risks from each part of the system, a quantitative
risk analysis enables identification of more effective measures to reduce such risks. The
methodology begins by defining the system through compiling and assimilating the
facility information that is readily available to the public domain. Following the
characterization of the facility, common hazards are recognized, in which internal and
external events are identified which may cause the release of hazardous materials. The
consequence and frequency of such events is modeled based on available information. A
risk assessment is conducted, which calculates the potential facility-wide risk and
compares the result to other accidental health risk hazards.

In this way, the facility is objectively defined, analyzed, and quantified in order to
provide a more accurate evaluation of its safety risk potential for the facility operators
and the general public.

3.0 Facility Location and Site Description

Location

The Amerigas facility located on Gaffey Street encompasses approximately 20 acres of
land and was previously owned and operated by Petrolane prior to Amerigas’ purchase of
the facility in 1993. The facility is connected via pipeline to a berth in the Port of Los
Angeles which has been used in the past to load ships with butane for export. The facility
provides access for vehicles and rail lines as alternative means of shipping or receiving
butane and other LPGs.

While the facility is predominantly surrounded by other industrial operations on the
north, south, and east sides, to the west across North Gaffey are very dense residential
areas and commercial buildings. Based on a survey of the available aerial maps for this
region, it is estimated that the nearest commercial receptor is roughly 0.13 miles (~675
feet) from the largest butane storage tanks. The nearest residential receptor is
approximately 0.24 miles (1,290 feet) from the largest butane storage tanks. The
relatively short distance between the largest butane storage tanks and areas where
civilians live and work has generated cause for alarm for the residents near the Amerigas
facility.
Geological Description

The facility is relatively level, and records indicate the land was used as a dump and fill area in the past. Numerous chunks of asphalt and concrete were present in the foundation, and the subsurface conditions are known to be relatively uniform for at least a depth of 35 feet. The fill materials that had been previously dumped in the subsurface varied between five and ten feet in thickness and had consistencies ranging from loose to medium-soft. After a depth of about 60 feet, it is postulated that the underlying geological materials consist of medium-firm clays and medium-firm to firm silts. Below this depth, it is estimated that the ground materials are dense deposits of sands and silts.

H. M. Scott and Associates of Rosemead, California, developed the site and excavated unsightly and problematic dump materials from the subsurface, consequently recompacting the area with earth excavated from a bluff at the back of the site. Grading work commenced in October 1972 and completed in December 1972.

The site was originally developed by Petrolane because of the geology of the subject site. It was determined that the large refrigerated tanks could be developed and installed on sand deposits by cutting into an existing slope. This would allow for the tanks to be stored on sturdy, natural foundations. Before development of the site, test borings and an earthquake engineering study were performed by Converse, Davis, and Associates of Pasadena, California. The evaluation included analysis of past statistical data and acceleration level-return period relationship, probability distribution of accelerations and earthquake magnitude, nature and activity of faults in the area of the site, and response spectra of various ground motions.

Facility Description

The facility is divided into two different parts. One portion is a storage facility on Gaffey Street, which includes two 12.6 million gallon butane tanks, transportation vehicles and pipeline and rail shipping capabilities. The second portion of the facility is a berth in the Port of Los Angeles which is used for the export of butane and other LPG products. A 16" pipeline, buried 10 feet below ground, connects the storage tanks to the export operations. At the time of preparing this report, it is our understanding that while the berth is not currently in use, Amerigas is negotiating with the Port for a new berth and renewed use of the pipeline from the tanks to the Port.

While most of the storage, transport, and rail car delivery is located farthest from Gaffey Street, the two largest butane storage tanks are located closest to the western boundary of the facility, which is closest to the nearest residential and commercial areas.
4.0 Quantitative Risk Analysis Methodology

By understanding the configuration of the facility and by describing the storage configuration of the liquid butane, a quantitative risk analysis can provide three primary conclusions:

(1) Determination of potential releases that could result in significant hazardous conditions outside the boundaries of the facility.
(2) For each potential release that is identified, the potentially lethal hazard zones can be defined.
(3) And using a consistent, accepted methodology, a measure of the "risk" posed to the public can be calculated.

It is assumed that a release of butane from the Amerigas storage facility could potentially result in one or more of the following health hazards:

(1) Exposure to thermal radiation, which is heat radiated by combustion of materials.
(2) Exposure to a blast wave from explosion of storage tanks from over-pressure or ignition of materials.

These possible health hazards can be divided more specifically to include pool, torch, and flash fires, vapor cloud explosions, and physical tank explosions. A more thorough description of these potential outcomes is discussed.

Release Risks and Modeling Assumptions

The physical consequences of a butane release are dependent on the quantity released, the rate of release, and for fire and explosion events, when ignition occurs. The quantity of the release will depend on the size of the release (equivalent hole diameter) and duration of release (how soon can the release be detected and isolated). The release rate from a hole will be assumed to be from a circular orifice and estimation is based on the maximum flow-rate from a given hole area.

As butane liquid may be released, it may pool and generate vapors. Ignition of the vapors arising from the butane pool could result in a flash back or a pool fire, both of which may cause intense thermal radiation around the burning pool. If the evaporating pool does not ignite immediately, then the evaporated vapor may form dispersions within the ambient air. These dispersions are affected by the atmospheric conditions, weather, and wind speed during the occurrence. Vapor will remain close to the pool at first, since the vapor is heavier than ambient air, but as time progresses and mixing occurs, the vapor is assumed to more readily disperse. Ignition of such a dispersion could create a flash fire or a vapor cloud explosion. Areas of confinement or congestion are most vulnerable to the impact caused by a vapor cloud explosion.
Most of the representative release scenarios are summations of many individual events (e.g. a tank rupture can occur at various locations, and have varied release outcomes). The frequency of each possible outcome is normally derived using event tree analysis. Starting with an initial butane release, the event tree follows various possible outcomes such as ignition, exposure of persons within the impact radius, and types of injury. Probability of such occurrences are further defined and quantified by considering the detection and mitigating protocols which may decrease or prevent exposure to such incidents. Other factors, such as ambient air conditions, wind flow rates, puncture location, etc., can alter the release scenarios either beneficially or detrimentally.

The prediction modeling thus makes some assumptions to evaluate generalized occurrences and outcomes, since specific modeling data and outcomes are difficult to quantify. The failure modeling assumptions are as follows:

(1) All releases are assumed to be oriented horizontally (parallel to the ground) in the direction that the wind is blowing. All other release orientations would result in smaller hazard zones. Thus, this assumption would allow for a conservative prediction of hazards and their associated risks.

(2) If a release does not immediately ignite upon release, it is assumed to grow to its full extent before ignition. This conservative estimation of the risk would not consider intermediate, smaller ignitions which would create smaller hazard zones.

(3) A very conservative estimate is provided in consideration of tank rupture due to earthquakes, since detailed knowledge of the seismic reinforcements of these tanks is not available. Furthermore, there are limited studies and historical data on how refrigerated butane tanks respond to catastrophic earthquake events. Thus, the analysis provides a very conservative tank failure rate in light of the difficulty in predicting a tank’s response to such a geological impact.

Additional assumptions must be made concerning the emergency systems in place at the facility:

(1) It is likely that the facility has installed required mitigation technologies, such as fire control systems, including the fire sprinkler and fire deluge systems. However, the modeling scenarios assume that these mitigation technologies will not immediately reduce the potential of a fire-induced explosion due to catastrophic malfunction, human error, or other worst-case scenario influences.

(2) All significant release events are assumed to occur for at least five minutes before the emergency mitigation and abatement systems are capable of maintaining the situation to full capacity. This considers the probability that some emergency response systems may fail due to unforeseen circumstances associated with accidental releases.
Since the risk analysis also must consider the human factor during evaluation, the following assumptions are made regarding the surrounding population and neighborhoods:

(1) The area surrounding the storage facility is assumed to be occupied by members of the general public at all times. This means that accidental risk hazards could impact the nearby population 365 days a year, 24 hours a day. This is a conservative approach toward the risk analysis, as population density and prevalence will vary considerably based on the time of day and day of the week. However, given the relatively close residential proximity to the facility, the assumption that individuals will be near the release incident at anytime is justifiable.

(2) No external ignition sources (vehicles, spark-ignition equipment, etc.) were assumed to cause any accidental release hazards, given the storage tanks’ proximity to nearby receptors and the probability that a release cloud could travel such a distance before combusting.

Influence of the Palos Verdes Fault Zone of Failure Analysis

The potential of a catastrophic earthquake occurring, which would cause rupture of the significant storage tanks at the facility, is estimated based on presently available information on the Palos Verdes fault zone, which is the nearest fault zone to the facility. The fault zone is estimated to extend over 100 km from Lasuen Knoll in the south, across the San Pedro Shelf, along the northeastern base of the onshore Palos Verdes Hills, and cross Santa Monica Bay. The fault zone has been shown to have a maximum exhibited slip rate of about 3.0 mm per year, but has been known to exhibit slip as low as 0.2 mm per year.

The probability of a moderate or major earthquake along the Palos Verdes fault is low when compared to the potential for movements on either the Newport-Inglewood or San Andreas faults. However, this fault is capable of producing strong to intense ground motion and ground surface rupture. The Palos Verdes fault zone has not been designated as an Alquist-Priolo Special Studies Zone by the California Geological Survey; however, the segment of the fault zone that extends through the harbor area has been identified as a Fault Rupture Study Area by the City of Los Angeles General Plan, Safety Element. During a survey conducted in 1996, it was concluded that Los Angeles region of the fault zone could anticipate a >7.0 magnitude earthquake resulting from the fault zone every 400 to 900 years. More recent approximations set the maximum possible magnitude around 7.3.
5.0 Hazards Posed by Amerigas Butane Storage Facility

Hazardous Properties of Butane

Butane inherently presents a human health risk due to its physical properties. Butane vapor is very flammable, and when ignition of vapors occurs, the combustion will flash back to the liquid surface. Butane vapor is colorless and non-toxic, with a potential for asphyxiation at high concentrations due to depletion of ambient oxygen. Asphyxiation is not as common of a health risk, since the risks associated with combustion of the butane are much more likely to occur under normal circumstances.

Heat radiation or direct fire burns occurring from instances of jet fire, pool fire, or flash fire, are also possible during butane leaks. Jet fire occurs when combustion of butane vapor is released from an orifice in the storage tank, which creates a powerful stream of flame as the evacuated butane vapor is rapidly combusted. A pool fire occurs when butane liquid is released and ignited on the surface of the ground or other area. A flash fire occurs when concentrations of released butane vapors mix with ambient air, disperse, and then are later ignited. The ignition can cause the gas cloud to burn back to the source of the spill or leak, and can cause a very rapid, unexpected onset of injury or even death.

Injuries from butane can result from overpressure of the storage tank due to rapid phase transition, resulting in vessel explosion. Overpressure from a vapor cloud explosion or an explosion in a confined space likewise present a risk of severe injuries or death.

Radius of Overpressure Blast Wave

Materials stored at the Amerigas facility may allow overpressure to be generated in two ways. The first type of occurrence is generated as a result of rapid burning (deflagration) of a vapor cloud, which could result in a low overpressure value (~0.15 psig) that could result in windows and glass materials shattering for open, unconfined spaces. Overpressures reaching over 1 psig are commonly associated with the boundary where building structural damage can begin to occur. Overpressure explosions occurring in confined spaces, or in areas where obstructions exist, can achieve such potentially damaging values.

The second type of mechanism by which damaging overpressure can occur results when a blast wave is created by failure of a pressure vessel. When storage tanks fail due to the buildup of vapor pressure from fire or from the absence of the cooling mechanisms, the internal energy of the butane can be converted to a pressure wave. A conservative estimate considers all the internal energy of butane converted to a pressure wave. This is unlikely to ever occur, but provides a worst-case scenario for a blast wave occurrence.
Radius of Fire Radiation Generation

It is assumed that the largest credible hazard that would extend beyond the facility boundaries of the Amerigas facility is the thermal radiation that could be released as a result of the combustion of vapor originating from pooled butane that may have escaped during accidental or catastrophic failure of the storage tank. This calculation considers the worst case scenario whereupon an earthquake could cause catastrophic failure of the largest butane storage tanks simultaneously. Vapor released from such an event would disperse and travel downwind until a combustion source ignited the vapor. It is likely that the flash fire would travel back to the pool source, igniting the dense concentration of vapor within that region and producing a tall column of flames capable of subjecting the immediate vicinity to hazardous amounts of thermal radiation. Other possible fire events are possible, but would result in a potentially smaller hazard zone with decreased exposure of individuals to harmful fire radiation.

6.0 Results of Quantitative Risk Analysis

Eight separate, distinct release scenarios were considered when evaluating the different types of hazards that could occur as a result of a release incident from the butane storage tanks. The scenarios ranged from minor release scenarios where a puncture was made in the walls of the storage tank, to catastrophic release events caused by severe earthquakes, whereupon the entirety of the butane stored in the largest tanks were to release and combust. For purposes of this risk analysis, EPA’s RMP*Comp Ver 1.07 was used to calculate the projected release scenarios. A detailed explanation of each release scenario is presented as follows.

Alternative Release – Vapor Cloud Explosion #1

This scenario considers the release incident that may occur from a small puncture in a butane storage tank near the ground level of the tank. Such a puncture could be caused by improper operation of forklifts or other transportation vehicles. In such a situation, the release of butane from the punctured area would be initiated by the pressure of materials above the puncture area. In this model, the puncture area is assumed to be nine (9) square inches, 75 feet below the maximum fill height of the storage tank. The release rate is assumed to be 7,790 pounds per minute based on puncture conditions. Assuming a vapor cloud explosion to be the most likely ignition of the released materials, the impact distance is calculated to be roughly <0.1 miles in radius. In such a scenario, the explosion diameter would reach North Gaffey Street and slightly extend past Westmont Drive to the south. A summary of the projected conditions and represented aerial impact map are shown in Appendix 1.
Alternative Release – Vapor Cloud Explosion #2

This scenario considers the incident that may occur from any general release from the storage tank that is caused by the formation of a vapor cloud. The release can occur from the pressure release valve during instances where excess venting may be required due to tank overpressure (due to refrigeration failure, for instance). Other causes may result from improper tank construction and maintenance, which could cause leaks due to material fatigue. In this type of instance, the release rate is lower than an accidental puncture incident. The release rate is assumed to be 1,000 pounds per minute or less. Assuming a vapor cloud explosion to be the most likely ignition of the released materials, the impact distance is calculated to be roughly <0.1 miles in radius. Like the first vapor cloud explosion scenario caused by a puncture, the explosion diameter would reach North Gaffey Street and slightly extend passed Westmont Drive to the south. This indicates that the resulting release incident caused by a puncture or small leak result in equivalent damage scenarios. A summary of the projected conditions and represented aerial impact map are shown in Appendix 2.

Alternative Release – Pool Fire #1

This scenario considers a pool fire that may occur when liquid butane is released from a storage tank due to a general release. This may result from improper tank construction and maintenance, which could cause leaks due to material fatigue. The release rate is assumed to be 500 pounds per minute or less. This scenario considers the impact a pool fire would have on the surrounding area. The pool fire would occur once ignition of vapor returned to the dispersed butane liquid collecting near the release point. The consequent ignition of the liquid would result in a large plume of flames fueled by the pooled liquid. The amount of butane present will cause a larger plume of flame, which increases the possibility of exposure to fire radiation. The outer boundary of the projected area of such an event is the furthest area where an individual would suffer second degree burns if exposure to the fire radiation were to exceed thirty seconds.

Assuming a release duration of 360 minutes, occurrence of a pool fire under this scenario would cause an impact radius of 0.4 miles in radius from the source. This release would extend to the west past North Gaffey Street, impacting some residential areas to the west and southwest of the facility. A summary of the projected conditions and represented aerial impact map are shown in Appendix 3.

Alternative Release – Pool Fire #2

This scenario considers the incident that may occur when liquid butane is released from a storage tank due to a rupture, similar to an incident postulated in the first vapor cloud explosion scenario. The release rate is expected to be larger than the scenario addressed in “Pool Fire #1” for this study. It is assumed to be 7,790 pounds per minute or less. This scenario considers the impact a pool fire would have on the surrounding area.
Assuming a release duration of 360 minutes, occurrence of a pool fire under this scenario would cause an impact radius of 1.7 miles from the source. This release would extend to the west as far as South Western Ave. (Highway 213), to the north as far as Ken Malloy Harbor Regional Park, and to the south as far as Highway 47 (Vincent Thomas Bridge), causing a devastating impact to residential and commercial centers. To the east, the impact area includes several major container terminals in the port of Los Angeles. A summary of the projected conditions and represented aerial impact map are shown in Appendix 4.

Worst-Case Scenario – Vapor Cloud Explosion #1

Worst-case scenario assumes that a catastrophic earthquake would cause complete tank failure and instant release of the stored butane. In this model, only one butane tank is considered to completely fail under such a circumstance. The model assumes instantaneous and rapid release of butane vapor from the collective 63 million pounds that would be present at the time of failure. The scenario considers that the vapor cloud will disperse its maximum distance before ignition by an external, uncontrolled source. The model assumes vapor cloud explosion, whereupon the entirety of the butane is in vapor form and is instantly ignited upon full dispersion.

In this scenario, the impact radius would be 3.2 miles. The impact would cause large scale structural and physical damage due to rapid overpressure caused by the explosion. The explosion is shown to extend east into predominant shipping yards in the Long Beach harbor, to the north towards West Carson, to the south towards the coast of San Pedro, and to the west as far as the boundary of Rancho Palos Verdes. The impact would encompass terminals in Long Beach and includes nearly all the Port of Los Angeles terminals, as well as the visitor serving areas of the new Wilmington Waterfront project, the proposed San Pedro Waterfront project, and the Los Angeles Cruise Terminals. A summary of the projected conditions and represented aerial impact map are shown in Appendix 5.

Worst-Case Scenario – Vapor Cloud Explosion #2

Worst-case scenario assumes that a catastrophic earthquake would cause complete tank failure and instant release of the stored butane. In this model, all of the butane tanks on-site are considered to completely fail under such a circumstance. The scenario assumes instantaneous and rapid release of butane vapor from the collective 126.5 million pounds that would be present at the time of failure. The scenario considers that the vapor cloud will disperse its maximum distance before ignition by an external, uncontrolled source. The model assumes vapor cloud explosion, whereupon the entirety of the butane is in vapor form and is instantly ignited upon full dispersion.

In this scenario, the impact radius would be 4.0 miles. The impact would cause large scale structural and physical damage due to rapid overpressure caused by the explosion. The explosion is shown to extend east into predominant shipping yards in the Long
Beach harbor, to the north towards Carson, to the south towards the coast of San Pedro, and to the west as far as the boundary of Rancho Palos Verdes. A summary of the projected conditions and represented aerial impact map are shown in Appendix 6.

**Alternative Release – BLEVE #1**

This model is another worst-case scenario like the previous two scenarios, though the resulting release type is considered alternative to the more common type of release mode vapor cloud explosions. BLEVE (Boiling Liquid Expanding Vapor Explosion) occurs when a sudden drop in pressure inside a container causes violent boiling of the liquid, which rapidly liberates large amounts of vapor. The pressure of this vapor can be extremely high, causing a significant wave of overpressure (explosion) which may completely destroy the storage vessel and project fragments over the surrounding area. The harm involved with such an incident can include injury from shrapnel, explosion, and fire radiation.

The first model assumes catastrophic failure of only one butane storage tank due to an earthquake. Again, this represents roughly 63 million pounds of butane released. If BLEVE were to occur, the projected release radius is approximately 5.2 miles. This would expand to the east towards downtown Long Beach, to the north near the 405 Freeway, to the west into central Rancho Palos Verdes, and to the south past the coastline and over the Pacific Ocean. The projected impact covers nearly half of Palos Verdes Hills. A summary of the projected conditions and represented aerial impact map are shown in Appendix 7.

**Alternative Release – BLEVE #2**

The final BLEVE model assumes catastrophic failure of all the butane storage tanks on-site due to an earthquake. Again, this represents roughly 126.5 million pounds of butane released. If BLEVE were to occur, the projected release radius is approximately 6.8 miles. This would expand to the east past downtown Long Beach, to the north towards Gardena, to the west towards Redondo Beach, and to the south past the coastline and over the Pacific Ocean. A summary of the projected conditions and represented aerial impact map are shown in Appendix 8.

Though this is a worst-case scenario projection, it is highly unlikely to occur, and contains some considerations that may not occur in practicality.

First, a large magnitude earthquake from the Palos Verdes fault zone (up to 7.3 magnitude), is only expected to occur once every 400-900 years. Likewise, the probability this would be centered near the Amerigas facility is moderate, since the fault zone extends nearly 100 kilometers. Similarly, it is not confirmed that such a large earthquake would rupture the tanks, since historical and test data is limited for such an occurrence.
Second, it is highly likely that the vapor cloud will distribute and ignite before reaching its maximum radius, so BLEVE may not occur. The numerous electrical sources in the area will likely ignite the vapor cloud before this can occur. When considering an earthquake failure, exposed electrical sources are anticipated to be more abundant and will likely act as instantaneous ignition sources.

Finally, weather conditions along the harbor are anticipated to generate consistent yet variable wind speeds that would disperse the butane vapor more rapidly to prohibit dense, overpressure conditions upon ignition.

### 7.0 Conclusions of the Study

In the event of unexpected release of butane from the Amerigas storage facility, a variety of accidental risks can occur, which include types of combustion (pool, flash, and jet fires) and types of overpressure explosions (overpressure in storage tank, BLEVE, etc.). The worst case scenario of a large-scale release hazard is projected to occur during the night when population density of the nearest receptors is highest. Low wind velocity is considered, as this would cause a dense vapor cloud of evaporated butane to collect within the facility, producing a powerful blast wave upon ignition. The largest combustion incident is projected to occur, whereupon BLEVE will occur as the result of simultaneous tank failure due to catastrophic earthquake, creating an intense overpressure that would result in a large-scale explosion, projectile shrapnel, and fire radiation exposure.

A summary of the release scenarios and statistics is shown in the following table:

<table>
<thead>
<tr>
<th>Release Description</th>
<th>Wind Speed (m/s)</th>
<th>Air Temperature (°F)</th>
<th>Release Rate (lb/min.)</th>
<th>Impact Radius (miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vapor Cloud Explosion</td>
<td>3.0</td>
<td>77.0</td>
<td>7,790</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Vapor Cloud Explosion</td>
<td>3.0</td>
<td>77.0</td>
<td>1,000</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>Pool Fire</td>
<td>3.0</td>
<td>77.0</td>
<td>500</td>
<td>0.4</td>
</tr>
<tr>
<td>Pool Fire</td>
<td>3.0</td>
<td>77.0</td>
<td>7,790</td>
<td>1.7</td>
</tr>
<tr>
<td>Vapor Cloud Explosion</td>
<td>1.5</td>
<td>77.0</td>
<td>Instantaneous</td>
<td>3.2</td>
</tr>
<tr>
<td>Vapor Cloud Explosion</td>
<td>1.5</td>
<td>77.0</td>
<td>Instantaneous</td>
<td>4.0</td>
</tr>
<tr>
<td>BLEVE</td>
<td>3.0</td>
<td>77.0</td>
<td>Instantaneous</td>
<td>5.2</td>
</tr>
<tr>
<td>BLEVE</td>
<td>3.0</td>
<td>77.0</td>
<td>Instantaneous</td>
<td>6.8</td>
</tr>
</tbody>
</table>

It is important to note that the analysis is conducted based on a number of assumptions. This may result in an over-conservative conclusion in regards to toxic and flammable hazard zones. These assumptions were necessary, however, due to the lack of historical data and lack of access to facility-specific data.
While the probability of larger-scale release scenarios is very low, the smaller incidents that may occur from ruptures or leaks still pose a threat to the local communities surrounding the facility. Thus, while incidents resulting from large magnitude earthquakes are not likely, factors such as accidental release or rupture can still pose an inherent risk to surrounding residential and commercial areas.
Appendix 1

Release Scenario #1 – Vapor Cloud Explosion  
(Distance <0.1 Miles Radius)
Appendix 2

Release Scenario #2 – Vapor Cloud Explosion (Distance <0.1 Miles Radius)
Appendix 3

Release Scenario #3 – Pool Fire
(Distance 0.4 Miles Radius)
Appendix 4

Release Scenario #4 – Pool Fire
(Distance 1.7 Miles Radius)
Appendix 5

Release Scenario #5 – Vapor Cloud Explosion (Distance 3.2 Miles Radius)
Appendix 6

Release Scenario #6 – Vapor Cloud Explosion (Distance 4.0 Miles Radius)
Appendix 7

Release Scenario #7 – BLEVE
(Distance 5.2 Miles Radius)
Appendix 8

Release Scenario #8 – BLEVE
(Distance 6.8 Miles Radius)
Appendix 1

Chemical: Butane
CAS #: 106-97-8
Form: Liquefied by Refrigeration
Category: Flammable Gas

Scenario: Alternative Release
Storage Parameters: Tank Under Atmospheric Pressure
Hole or Puncture Area: 9 square inches
Height of Liquid Column Above Hole: 75 feet
Release Rate to Outside Air: 7790 lbs/min (based on the condition of punctured area)
Release Type: Vapor Cloud Fire
Release Duration: 360 Minutes
Mitigation Measures: None
Lower Flammability Limit: 36 mg/L

Assumptions about this scenario
Wind Speed: 3 meters per second (6.7 miles/hour)
Atmospheric Turbulence: D Class (Neutral)
Air Temperature: 77 degrees F (25 degrees C)

Estimated Distance to Lower Flammability Limit: < 0.1 miles radius ( < 0.16 kilometers)
Appendix 2

Chemical: Butane
CAS #: 106-97-8
Form: Liquefied by Refrigeration
Category: Flammable Gas

Scenario: Alternative Release
Storage Parameters: Tank Under Atmospheric Pressure
Release Rate to Outside Air: 1000 lbs/min
Release Type: Vapor Cloud Fire
Release Duration: 360 Minutes
Mitigation Measures: None
Lower Flammability Limit: 36 mg/L

Assumptions about this scenario
Wind Speed: 3 meters per second (6.7 miles/hour)
Atmospheric Turbulence: D Class (Neutral)
Air Temperature: 77 degrees F (25 degrees C)

Estimated Distance to Lower Flammability Limit: < 0.1 miles radius (< 0.16 kilometers)
Appendix 3

Chemical: Butane
CAS #: 106-97-8
Form: Liquefied by Refrigeration
Category: Flammable Gas

Scenario: Alternative Release
Storage Parameters: Tank Under Atmospheric Pressure
Release Rate to Outside Air: 500 lbs/min
Release Type: Pool Fire
Release Duration: 360 Minutes
Mitigation Measures: None
Topography: Urban Surroundings (many obstacles in the immediate area)

Assumptions about this scenario
Wind Speed: 3 meters per second (6.7 miles/hour)
Atmospheric Turbulence: D Class (Neutral)
Air Temperature: 77 degrees F (25 degrees C)

Estimated Distance to Heat Radiation Endpoints (5 kilowatts/square meter): 0.4 miles radius (0.7 kilometers)
Appendix 4

Chemical: Butane
CAS #: 106-97-8
Form: Liquefied by Refrigeration
Category: Flammable Gas

Scenario: Alternative Release
Storage Parameters: Tank Under Atmospheric Pressure
Hole or Puncture Area: 9 square inches
Height of Liquid Column Above Hole: 75 feet
Release Rate to Outside Air: 7790 lbs/min (based on the condition of punctured area)
Release Type: Pool Fire
Release Duration: 360 Minutes
Mitigation Measures: None
Topography: Urban Surroundings (many obstacles in the immediate area)

Assumptions about this scenario
Wind Speed: 3 meters per second (6.7 miles/hour)
Atmospheric Turbulence: D Class (Neutral)
Air Temperature: 77 degrees F (25 degrees C)

Estimated Distance to Heat Radiation Endpoints (5 kilowatts/square meter): 1.7 miles radius (2.7 kilometers)
Appendix 5

Chemical: Butane  
CAS #: 106-97-8  
Form: Liquefied by Refrigeration  
Category: Flammable Gas  

Scenario: Worst-Case  
Quantity Released: 62,958,773 Pounds  
Release Type: Vapor Cloud Explosion  
Mitigation Measures: None  

Assumptions about this scenario  
Wind Speed: 1.5 meters per second (3.4 miles/hour)  
Atmospheric Turbulence: F Class (Stable)  
Air Temperature: 77 degrees F (25 degrees C)  

Estimated Distance to 1 psi overpressure: 3.2 miles radius (5.1 kilometers)
### Appendix 6

<table>
<thead>
<tr>
<th>Chemical:</th>
<th>Butane</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS #:</td>
<td>106-97-8</td>
</tr>
<tr>
<td>Form:</td>
<td>Liquefied by Refrigeration</td>
</tr>
<tr>
<td>Category:</td>
<td>Flammable Gas</td>
</tr>
<tr>
<td>Scenario:</td>
<td>Worst-Case</td>
</tr>
<tr>
<td>Quantity Released:</td>
<td>126,517,153 Pounds</td>
</tr>
<tr>
<td>Release Type:</td>
<td>Vapor Cloud Explosion</td>
</tr>
<tr>
<td>Mitigation Measures:</td>
<td>None</td>
</tr>
</tbody>
</table>

**Assumptions about this scenario**

- Wind Speed: 1.5 meters per second (3.4 miles/hour)
- Atmospheric Turbulence: F Class (Stable)
- Air Temperature: 77 degrees F (25 degrees C)

**Estimated Distance to 1 psi overpressure:** 4.0 miles radius (6.5 kilometers)
Appendix 7

Chemical: Butane
CAS #: 106-97-8
Form: Liquefied by Refrigeration
Category: Flammable Gas

Scenario: Alternative Release
Quantity Released: 62,958,773 Pounds
Release Type: BLEVE (boiling liquid expanding vapor explosion)
Mitigation Measures: None

Assumptions about this scenario
Wind Speed: 3 meters per second (6.7 miles/hour)
Atmospheric Turbulence: D Class (Neutral)
Air Temperature: 77 degrees F (25 degrees C)

Estimated Distance at which exposure may cause second-degree burns: 5.2 miles radius (8.4 kilometers)