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June 14, 2019

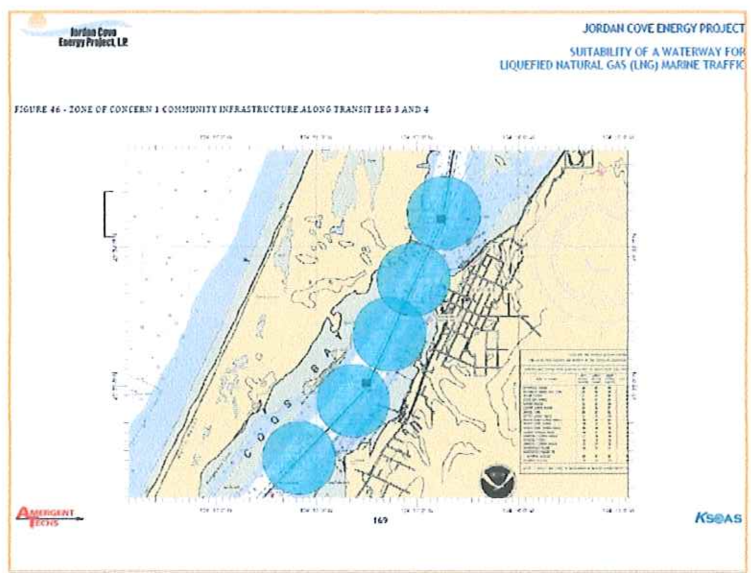
Andrew Stamp, Esq.,
Coos County Planning Department
Coquille, OR 97423

Re: County hearing on remand from the Land Use Board of Appeals in regards to 76 OR LUBA 346 (217), County file No. HBCU-15-05/CD-15-152/FP-15-09, regarding Jordan Cove LNG export terminal

Dear Mr. Stamp:

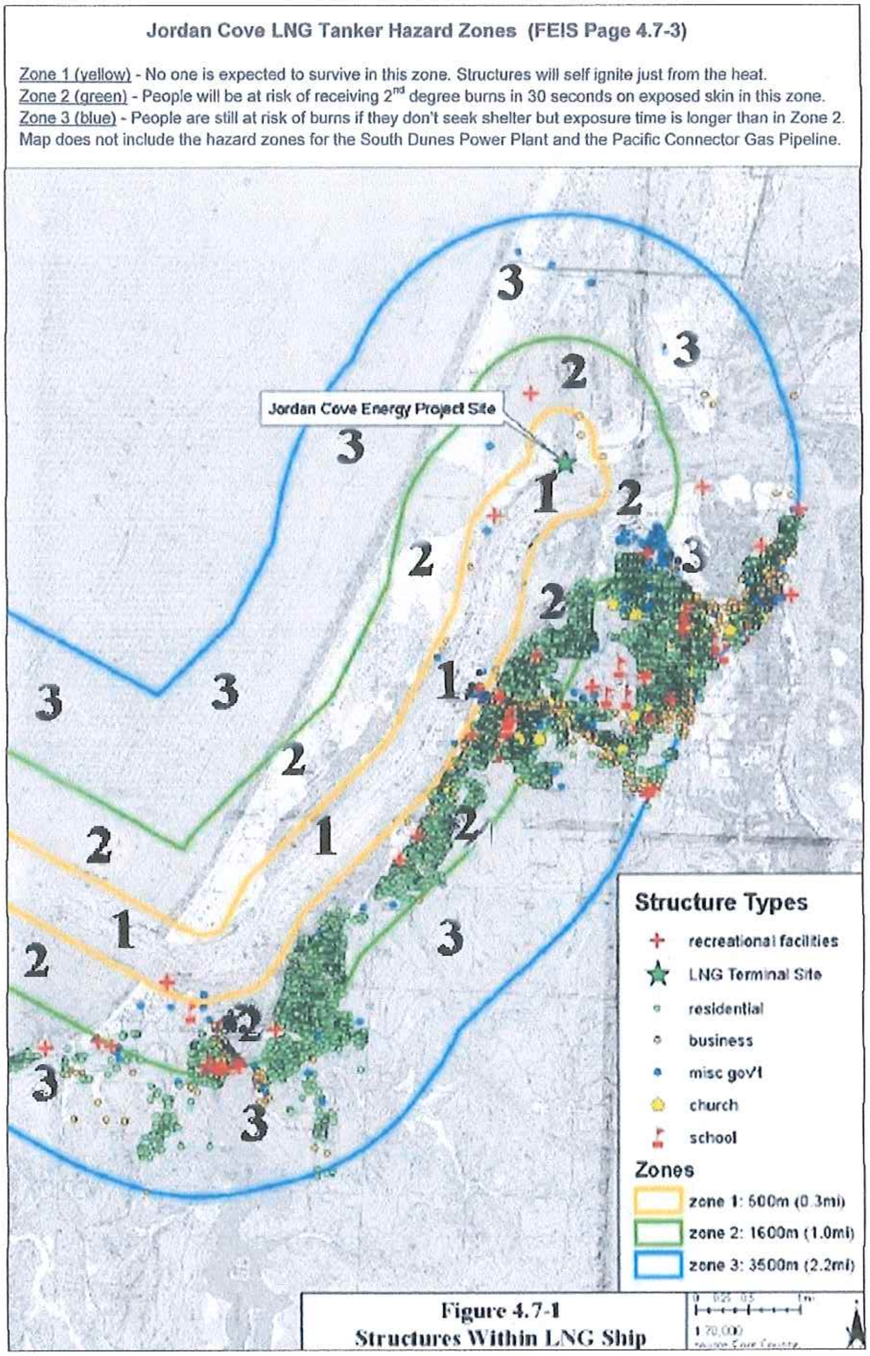
While looking over my earlier letters, of June 10 and June 11, I realized that my references to SIGTTO's recommendations to keep LNG facilities and ships "**remote**" from populated areas lacked specificity, meaning measurable distances. The short answer to that question is a distance of **2.2 miles**. This rest of this letter explains why.

SIGTTO itself does not specify safety distances, but LNG fire researchers have done so, by defining 3 "Hazard Zones" around a potential fire at the terminal or in the ship channel through which the LNG tankers travel. The clearest visual representation of these Zones was included in Jordan Cove's first Final EIS; you will find that one on the next page. In more recent EISs they have only shown graphs that, instead of showing 3 contiguous Hazard Zones, have round ones like the one below. These graphs' circles are meant to represent the extent of Hazard Zones around one stationary fire; the circles in the one below represent only Zone 1, where no one is expected to survive.



But such a representation is unrealistic in implying that, depending on the location of the fire, residents of Coos Bay's Empire district that are close to the bay may *suffer casualties, but only* those living inside a 500-meter, or 0.3 mile, radius around a stationary fire. This is unrealistic. If, for example, terrorists have struck a tanker sailing down the bay, breaching one of its

Exhibit: 14
Date: 6/14/19



LNG tanks (my letter of June 10 described several possible scenarios for such an attack), then that would not have stopped the tanker dead in the water. Even if its propulsion had been disabled, and its crew killed and likely cremated, its momentum would continue moving it down the bay for some distance, with a pool fire still raging near it. Incidentally, at that point the crews of the escorting tugboats and Coast Guard vessels would be dead too, unless they had raced away at the very moment the attack occurred.

It follows that while the exact shape of the fire is anybody's guess, it's quite unlikely to be a stationary circle. Much more likely it will be an elongated, intensely hot blaze moving south, much more in accordance with the Hazard Zones pictured in the graph above. As the unmanned vessel drifts down the bay, other tanks burst and spill more LNG, feeding the fire and eventually destroying the entire ship, which is what prominent fire scientist Jerry Havens expects. [1])

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[1]) Jerry Havens: "LNG and Public Safety Issues - Summarizing current knowledge about potential worst-case consequences of LNG spills onto water." *Proceedings (US Coast Guard)* Fall 2005. In 2007 it was reported that other experts also disagreed with the 3-tank scenario. See "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification," GAO for Department of Energy, February 2007; GAO 07-316 Maritime Security, p. 8.

On pages 6 and 7 of my letter of June 10 I mentioned that Jordan Cove has wrongly used petroleum standards for siting its facility, a grave error because gas off LNG burns ten to fifteen times hotter than petroleum. I should have added the reason for this difference:

> "LNG fires burn hotter because the flame burns very cleanly and with little smoke. In oil fires, the smoke emitted by the fire absorbs some of the heat from the fire and reduces the amount of heat emitted. Scientists measure the amount of heat given off by a fire ... in kilowatts per square meter (kW/m^2). Generally the heat given off by an LNG fire is reported to be more than 200 kW/m^2. By comparison, the [heat] of a very smoky oil fire can be as little as 20 kW/m^2." [2])

Simply put, at 200 kW/m^2 instead of 20 kW/m^2, LNG fires can burn ten times hotter than oil fires. According to Jerry Havens and James Venart, they can burn as many as fifteen times hotter, reaching more than 300 kW/m^2 [3])

And this explains why a burning oil tanker can be approached by people without much danger (as long as they stay upwind of the fire), as shown in the picture of the tanker Limburg hit in 2002, on page 7 of my June 10 letter. Nearby is a shot of one of the oil tankers attacked in the middle east, this very week.

The difference in burning characteristics also explains why in popular parlance Hazard Zone 1 around a burning LNG tanker is often described as the 'Death Zone'. (The text above the graph reproduced on page 2 states: ***"No one is expected to survive in this zone. Structures will self ignite just from the heat.")***

This is because, of the various fire scenarios projected by LNG fire scientists, a pool fire will produce the most extreme heat. A "pool fire" is a scenario in which LNG from a breached carrier spills onto water, quickly warms above its –265° F liquid temperature, and turns into an enormous gas cloud 600 times the volume of the LNG, which ignites almost immediately. Near-instant ignition is most likely if the breach was caused by a terrorist attack, in which explosives or sparks from the impact supply ignition. Compared to alternative scenarios of the gas cloud's behavior, which assume ignition later and further away (in Zone 2 or Zone 3), a pool fire will have the largest concentration of gas, and hence burn the hottest.

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[2]) "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification," GAO for Department of Energy, February 2007; GAO 07-316 Maritime Security, p. 9.

[3]) Jerry Havens and James Venart: *Regarding the Jordan Cove Export Terminal Draft Environmental Impact Statement, Docket No. CP13-483: UNITED STATES LNG TERMINAL SAFE-SITING POLICY IS FAULTY,* January 14, 2015, p. 27: "... radiant heat fluxes from large LNG fires on water, which burn without much smoke, can exceed 300 kW/m^2."

As already mentioned, thermal radiation at the center of a pool fire may reach 200 to 300 kilowatts per kW/m^2 but is expected to *drop*, at Zone 1's outer limit of 500 meters or 0.3 mile, to 37.5 kW/m^2. But this hardly means that people living just outside the 0.3 mile will be unharmed. The Hightower report mentions that heat radiation of 22.1 kW/m^2, less than the 37.5 kW/m^2 expected at that 0.3 mile outer edge of Zone 1, can weaken structural steel.[4]) When subjected to heat, people weaken much faster than steel.

Please note that in the graph reproduced on page 2, Hazard Zone 1 is delineated by yellow lines (I added the big numbers for clarity). Zone 2's outer green edge is 1 mile from the fire, and Zone 3's blue outer border is 2.2 miles away. It is generally held by the scientists that at 2.2 miles from the source, the gas will have dispersed enough so there won't be enough to keep the fire going (the gas must make up at least 5% of the air); this is known as the LFL, or Lower Flammability Limit of the gas cloud. [5])

In previous EIS's, Jordan Cove has acknowledged that an estimated 16,922 people live inside the 3 Hazard Zones.[6]) This means that all those will be exposed to some degree of danger. As already stated, anybody in Zone 1 will be dead. This is not guaranteed inside Zone 2, but if a pool fire occurs in Zone 1, then Zone 2's residents living near Zone 1's outer limit of 0.3 mile will have almost the same deadly heat exposure as if they were just inside it, which is the heat radiation of 37.5 kW/m^2 or slightly lower. Those people are numerous, and many are poor. With some exceptions, the neighborhoods of Empire, Barview and Charleston, from north to south along the bay, are low-income.

> **"You're an old-timer if you can remember when setting the world on fire was a figure of speech."**
>
> *Franklin P. Jones*

Heat radiation in Zone 2 is expected to decline from the quoted 37.5 kW/m^2 at its 0.3 mile inner limit to '*only*' 5 kW/m^2 at its 1-mile outer limit, and the latter has often been taken to apply throughout Zone 2. But as already pointed out, this is a misrepresentation or a misunderstanding. And even at Zone 2's 1-mile outer limit where 5 kW/m^2 heat is predicted to prevail, anyone on either side – just inside Zone 2 or just inside Zone 3 – will still be at serious risk of burns, because the Hightower report states that radiation only slightly lower than 5 kW/m^2, of 4.73 kW/m^2, can cause second degree skin burns after just 30 seconds of exposure.[7]) As LNG fire scientist Jerry Havens has pointed out:

> ... the use of a thermal flux criterion that would result in second-degree burns in 30 seconds is not necessarily appropriate to ensure public safety, as such exposure essentially ensures that serious burns will occur at that distance to persons who cannot gain shelter within 30 seconds. Aside from questions about

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[4]) Hightower, Mike, and 11 other researchers: "Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) spill over Water", *Sandia Report SAND 2004-6258*, produced for the US Department of Energy, p. 85.

[5]) In order to ignite with the oxygen in the air, natural gas needs to make up between 5 and 15% of the surrounding air. Once its concentration falls below that 5% it is expected to dissipate without burning.

[6]) This number is mentioned in Jordan Cove's 2015 FEIS, page 4-1031 (= p.1381 in the 7891-page pdf).

[7]) Hightower, *"Guidance on Risk Analysis and Safety Implications"*, op. cit., p. 85.

the ability of even the most able to gain shelter in such a short time, questions are also raised about the safety of those less able.[8])

To recap: people on either side of the 500 meter or 0.3 mile boundary between Hazard Zones 1 and 2, but close to it, will suffer roughly similar deaths. The heat radiation of 37.5 kW/m^2 at that location will decline to 5 kW/m^2 at Zone 2's 1-mile outer limit, so people on either side of that 1-mile limit, but close to it, will still be subject to the 2nd degree/30-second rule – and that will be the best possible prospect facing thousands inside Zone 2. Many others inside Zone 2 but closer to that Zone's inner border may incur 3rd degree or fatal burns, and at its outer border many others unable to seek shelter within that very short interval will not fare well either.

Incidentally, two schools of the Coos Bay School District are inside Zone 2.

Early morning, when pupils arrive at Madison elementary school. The school's 400 children will be only ⅓ mile from the Coos Bay waterfront and ⅔ mile from future passing LNG carriers.

About the hazards in Zone 3, between Zone 2's 1-mile outer limit and Zone 3's 2.2 mile outer limit, the scientific literature says that they will diminish to none if the gas cloud has ignited before reaching Zone 3. But they may be worse if, as is possible but much less likely, the gas cloud doesn't ignite until reaching Zone 3.

In summary, the numbers show that rather than causing only minor harm, an LNG spill in the bay can cause many deaths and burns in Zone 2, and Zone 3 is not exempt. This is why a scientifically-based application of SIGTTO's "remote" advice would apply the **2.2 mile outer limit** of Hazard Zone 3. Jordan Cove may well object that applying such a rule would make siting its terminal anywhere in Coos Bay impossible, but that would just show their incurable irresponsibility.

> "Most people sell their souls, and live with a good conscience on the proceeds."
>
> *Logan Pearsall Smith*

[8]) Jerry Havens: "LNG and Public Safety Issues - Summarizing current knowledge about potential worst-case consequences of LNG spills onto water," *op. cit.*

I have attached copies of the sources cited in all the footnotes of this letter.

Sincerely,

Wim de Vriend

United States Government Accountability Office

GAO

Report to Congressional Requesters

PAGE 2 - NOTE 1

February 2007

MARITIME SECURITY

Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification

GAO

Accountability * Integrity * Reliability

GAO-07-316

GAO Accountability·Integrity·Reliability

Highlights

Highlights of GAO-07-316, a report to congressional requesters

MARITIME SECURITY

Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification

Why GAO Did This Study

The United States imports natural gas by pipeline from Canada and by tanker as liquefied natural gas (LNG) from overseas. LNG—a supercooled form of natural gas—currently accounts for about 3 percent of total U.S. natural gas supply, with an expected increase to about 17 percent by 2030, according to the Department of Energy (DOE). With this projected increase, many more LNG import terminals have been proposed. However, concerns have been raised about whether LNG tankers could become terrorist targets, causing the LNG cargo to spill and catch on fire, and potentially explode. DOE has recently funded a study to consider these effects; completion is expected in 2008.

GAO was asked to (1) describe the results of recent studies on the consequences of an LNG spill and (2) identify the areas of agreement and disagreement among experts concerning the consequences of a terrorist attack on an LNG tanker. To address these objectives, GAO, among other things, convened an expert panel to discuss the consequences of an attack on an LNG tanker.

What GAO Recommends

GAO recommends that the Secretary of Energy ensure that DOE incorporates into its LNG study the key issues identified by the expert panel.

In reviewing our draft report, DOE agreed with our recommendation.

www.gao.gov/cgi-bin/getrpt?GAO-07-316.

To view the full product, including the scope and methodology, click on the link above. For more information, contact Jim Wells at (202) 512-3841 or wellsj@gao.gov.

What GAO Found

The six unclassified completed studies GAO reviewed examined the effect of a fire resulting from an LNG spill but produced varying results; some studies also examined other potential hazards of a large LNG spill. The studies' conclusions about the distance at which 30 seconds of exposure to the heat (heat hazard) could burn people ranged from less than 1/3 of a mile to about 1-1/4 miles. Sandia National Laboratories (Sandia) conducted one of the studies and concluded, based on its analysis of multiple attack scenarios, that a good estimate of the heat hazard distance would be about 1 mile. Federal agencies use this conclusion to assess proposals for new LNG import terminals. The variations among the studies occurred because researchers had to make modeling assumptions since there are no data for large LNG spills, either from accidental spills or spill experiments. These assumptions involved the size of the hole in the tanker; the volume of the LNG spilled; and environmental conditions, such as wind and waves. The three studies that considered LNG explosions concluded explosions were unlikely unless the LNG vapors were in a confined space. Only the Sandia study examined the potential for sequential failure of LNG cargo tanks (cascading failure) and concluded that up to three of the ship's five tanks could be involved in such an event and that this number of tanks would increase the duration of the LNG fire.

GAO's expert panel generally agreed on the public safety impact of an LNG spill, but believed further study was needed to clarify the extent of these effects, and suggested priorities for this additional research. Experts agreed that the most likely public safety impact of an LNG spill is the heat hazard of a fire and that explosions are not likely to occur in the wake of an LNG spill. However, experts disagreed on the specific heat hazard and cascading failure conclusions reached by the Sandia study. DOE's recently funded study involving large-scale LNG fire experiments addresses some, but not all, of the research priorities identified by the expert panel. The leading unaddressed priority the panel cited was the potential for cascading failure of LNG tanks.

LNG Tanker Passing Downtown Boston on Its Way to Port

Source: GAO.

as freeze burns and asphyxiation, do not pose a hazard to the public. Experts disagreed with the heat impact and cascading tank failure conclusions reached by the Sandia National Laboratories' study, which the Coast Guard uses to prepare WSAs. Specifically, all experts did not agree with the heat impact distance of 1,600 meters. Seven of 15 experts thought Sandia's distance was "about right," and the remaining eight experts were evenly split as to whether the distance was "too conservative" or "not conservative enough" (the other 4 experts did not answer this question). Experts also did not agree with the Sandia National Laboratories' conclusion that only three of the five LNG tanks on a tanker would be involved in a cascading failure. Finally, experts suggested priorities to guide future research aimed at clarifying uncertainties about heat impact distances and cascading failure, including large-scale fire experiments, large-scale LNG spill experiments on water, the potential for cascading failure of multiple LNG tanks, and improved modeling techniques. DOE's recently funded study involving large-scale LNG fire experiments addresses some, but not all, of the research priorities identified by the expert panel.

We are recommending that DOE incorporate into its current LNG study the key issues identified by the expert panel. We particularly recommend that DOE examine the potential for cascading failure of LNG tanks.

Background

Natural gas is primarily composed of methane, with small percentages of other hydrocarbons, including propane and butane. When natural gas is cooled to minus 260 degrees Fahrenheit at atmospheric pressure, the gas becomes a liquid, known as LNG, and it occupies only about 1/600th of the volume of its gaseous state. Since LNG is maintained in an extremely cooled state—reducing its volume—there is no need to store it under pressure. This liquefaction process allows natural gas to be transported by trucks or tanker vessels. LNG is not explosive or flammable in its liquid state. When LNG is warmed, either at a regasification terminal or from exposure to air as a result of a spill, it becomes a gas. As this gas mixes with the surrounding air, a visible, low-lying vapor cloud results. This vapor cloud can be ignited and burned only within a minimum and maximum concentration of air and vapor (percentage by volume). For methane, the dominant component of this vapor cloud, this flammability range is between 5 percent and 15 percent by volume. When fuel concentrations exceed the cloud's upper flammability limit, the cloud cannot burn because too little oxygen is present. When fuel concentrations are below the lower flammability limit, the cloud cannot burn because too little methane is present. As the cloud vapors continue to warm, above

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Report to Congressional Requesters

February 2007

MARITIME SECURITY

Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification

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GAO-07-316

minus 160 degrees Fahrenheit, they become lighter than air and will rise and disperse rather than collect near the ground.

If the cloud vapors ignite, the resulting fire will burn back through the vapor cloud toward the initial spill and will continue to burn above the LNG that has pooled on the surface. This fire burns at an extremely high temperature—hotter than oil fires of the same size. LNG fires burn hotter because the flame burns very cleanly and with little smoke. In oil fires, the smoke emitted by the fire absorbs some of the heat from the fire and reduces the amount of heat emitted. Scientists measure the amount of heat given off by a fire by looking at the amount of heat energy emitted per unit area as a function of time. This is called the surface emissive power of a fire and is measured in kilowatts per square meter (kW/m^2). Generally, the heat given off by an LNG fire is reported to be more than 200 kW/m^2. By comparison, the surface emissive power of a very smoky oil fire can be as little as 20 kW/m^2. The heat from fire can be felt far away from the fire itself. Scientists use heat flux—also measured in kW/m^2—to quantify the amount of heat felt at a distance from a fire. For instance, a heat flux of 5 kW/m^2 can cause second degree burns after about 30 seconds of exposure to bare skin. This heat flux can be compared with the heat from a candle—if a hand is held about 8 to 9 inches above the candle, second degree burns could result in about 30 seconds. A heat flux of about 12.5 kW/m^2, over an exposure time of 10 minutes, will ignite wood, and a heat flux of about 37.5 kW/m^2 can damage steel structures.

Four types of explosions could potentially occur after an LNG spill: rapid phase transitions (RPT), deflagrations, detonations, and boiling-liquid-expanding-vapor-explosions (BLEVE).[7] More specifically:

- An *RPT* occurs when LNG is warmed and changes into natural gas nearly instantaneously. An RPT generates a pressure wave that can range from very small to large enough to damage lightweight structures. RPTs strong enough to damage test equipment have occurred in past LNG spill experiments on water, although their effects have been localized at the site of the RPT.
- *Deflagrations and detonations* are explosions that involve combustion (fire). They differ on the basis of the speed and strength of the pressure

[7]Generally, an explosion is an energy release associated with a pressure wave. Some explosions are large enough that the pressure wave can break windows or damage structures, while others are much smaller.

PAGE 3 NOTE 3

Submitted by

Jerry Havens
Distinguished Professor of Chemical Engineering
University of Arkansas

James Venart
Professor Emeritus of Mechanical Engineering
University of New Brunswick

Regarding the
Jordan Cove Export Terminal
Draft Environmental Impact Statement
Docket No. CP13-483

January 14, 2015

UNITED STATES LNG TERMINAL SAFE-SITING POLICY IS FAULTY

We have commented repeatedly to the Federal Energy Regulatory Commission (FERC) and the Department of Transportation (DOT) that we believe FERC is approving variances to the requirements of 49 CFR 193, Liquefied Natural Gas Facilities: Federal Safety Standards, that have not been subjected to adequate science based review and appear to provide inadequate fire and explosion exclusion zones to protect the public.

This submission focuses on the *Draft Environmental Impact Statement (DEIS)* for the Jordan Cove Export (JCE) Terminal Project. We believe the JCE DEIS fails to provide for protection of the public from credible fire and explosion hazards. The conversion of the Jordan Cove facility for export, including provision of gas treatment technology utilizing mixed hydrocarbon refrigerants for liquefaction and removal of heavy hydrocarbons from the natural gas feed to the plant, presents hazards to the project more serious (on a unit weight basis) than with LNG. We believe these additional hazards have been discounted without sufficient scientific justification in spite of multiple international reports during the last decade of catastrophic accidents involving unconfined (hydrocarbon) vapor cloud explosions. It is clear that the increased hazards due to the presence of significant amounts of heavier-than-methane hydrocarbons, for which there is considerably more extensive research and accident experience than for LNG-ONLY projects, and which are "game-changing" in importance, have been seriously under-estimated in this DEIS. We believe the hazards attending the proposed operations at the Jordan Cove export facility could have the potential to rise, as a result of cascading events, to catastrophic levels that could cause the near-total and possibly total loss of the facility, including any LNG ship berthed there. Such an event could present serious hazards to the public well beyond the facility boundaries.

We also believe there remains significant potential for cascading fire and explosion events attending "LNG only" storage and handling that have not been sufficiently addressed, particularly regarding the worst-possible case events that should be considered on the shore side storage tanks and marine side (ship related), either by accident or terrorist activity. Instead of considering the findings of extensive LNG Safety research conducted at the direction of Congress during the last decade that might influence the judgment of the acceptability (to the public) of the worst case *of LNG spilled, key LNG fire properties, and environmental conditions, such as wind and waves. Three of the studies also examined other potential hazard of an LNG spill, including LNG vapor explosions, asphyxiation, and cascading failure. All three studies considered LNG vapor explosions unlikely unless the LNG vapors were in a confined space. Only the Sandia National Laboratories' study examined the potential for cascading failure of LNG tanks and concluded that only three of the five tanks would be involved in such an event and this number of tanks would increase the duration of the LNG fire.*

Our panel of 19 experts generally agreed on the public safety impact of an LNG spill, disagreed with a few conclusions reached by the Sandia National Laboratories' study, and suggested priorities for research to clarify the impact of heat and cascading tank failures. Experts agreed that (1) the most likely public safety impact of an LNG spill is the heat impact of a fire; (2) explosions are not likely to occur in the wake of an LNG spill, unless the LNG vapors are in confined spaces, and (3) some hazards, such as freeze burns and asphyxiation, do not pose a hazard to the public. Experts disagreed with the heat impact and cascading tank failure conclusions reached by the Sandia National Laboratories; study, which the Coast Guard uses to prepare WSAs. Specifically, all experts did not agree with the heat impact distance of 1,600 meters. Seven of 15 experts thought Sandia's distance was "about right," and the remaining eight experts were evenly split as to whether the distance was "too conservative" or "not conservative enough" (the other 4 experts did not answer this question).

As a result of the GAO report, Congress directed further research to be conducted by the Sandia National Laboratory. That research (thus far) concludes that the radiant heat fluxes from large LNG fires on water, which burn without much smoke, can exceed 300 kW/m^2, and that there are potential failure modes regarding LNG carriers that could lead to a ship being at risk of sinking. The ship-safety-research continues.

PAGE 4, NOTES 2 + 7

SANDIA REPORT

SAND2004-6258
Unlimited Release
Printed December 2004

Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water

Mike Hightower, Louis Gritzo, Anay Luketa-Hanlin, John Covan, Sheldon Tieszen, Gerry Wellman, Mike Irwin, Mike Kaneshige, Brian Melof, Charles Morrow, Don Ragland

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550
Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Sandia National Laboratories

Table 24: Model Results (Quest Study)

WIND SPEED (m/s)	WAVE HEIGHT (m)	MAXIMUM LNG RADIUS	TOTAL TIME TO BURN SPILL (min)	DISTANCE TO:		
				22.1 kW/m^2	12.6 kW/m^2	4.73 kW/m^2
1.5	0.575	78 m (257 ft)	14.3	226 m (740 ft)	309 m (1,015 ft)	497 m (1,630 ft)
5.0	0.672	73 m (239 ft)	16.6	270 m (885 ft)	351 m (1,150 ft)	531 m (1,740 ft)
9.0	1.24	55 m (180 ft)	28.6	281 m (920 ft)	349 m (1,145 ft)	493 m (1,615 ft)

At these radiant flux levels, the following occur:

Table 25: Impact of Radiation (Quest Study)

22.1 kW/M^2	Structural steel weakens after prolonged exposure to this flux level.
12.6 kW/M^2	Vapors evolving off of a wooden structure might ignite after several minutes of exposure to this flux level if ignition source is present
4.73 kW/m^2	Second-degree skin burns are possible after 30-seconds exposure to this flux level.

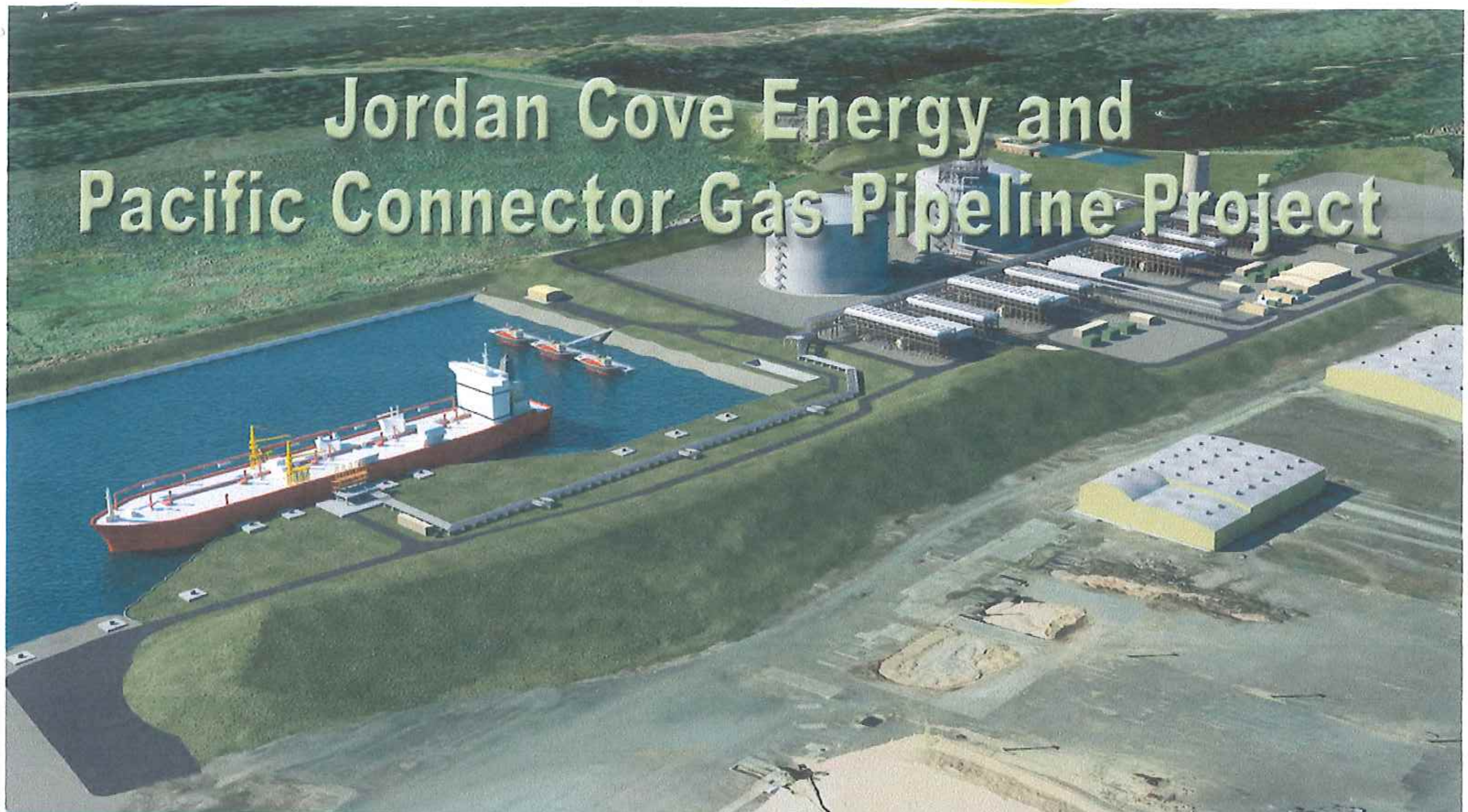
For the dispersion calculations of the vapor cloud:

Table 26: Dispersion Calculations (Quest Study)

WIND SPEED (m/s)	STABILITY CLASS	MAXIMUM LNG RADIUS	DISTANCE TO LOWER FLAMMABILITY LIMIT	
			Canary	Degadis
1.5	F	80 m (261 ft)	4,030 m (13,220 ft)	3,400 m (11,155 ft)
5.0	D	73 m (239 ft)	1,050 m (3,445 ft)	1,900 m (6,230 ft)
9.0	D	55 m (180 ft)	340 m (1,115 ft)	1,100 m (3,610 ft)

PAGE 4 NOTE 6

Jordan Cove Energy and Pacific Connector Gas Pipeline Project



Final Environmental Impact Statement

Jordan Cove Energy Project, L.P.
Docket No. CP13-483-000

Pacific Connector Gas Pipeline, L.P.
Docket No. CP13-492-000

DOE Docket No. FE 12-32-LNG ■ DOE/EIS-0489

FERC/EIS 0256F
September 2015

Cooperating Agencies
USDA Forest Service, Pacific Northwest Region
Department of the Army, Corps of Engineers, Portland District
US Department of Energy
US Environmental Protection Agency, Region 10
US Department of Homeland Security Coast Guard, Portland
US Department of Transportation, Pipeline and Hazardous Materials Safety Administration
US Department of the Interior Bureau of Land Management, Oregon State Office
US Department of the Interior Bureau of Reclamation, Klamath Basin Area Office
US Department of the Interior Fish and Wildlife Service, Oregon State Office

Federal Energy Regulatory Commission
Office of Energy Projects
Washington, DC 20426

navigation channel. At this point, one tug would drop lines, and the remaining two tugs would assist the LNG vessel throughout its transit of the Coos Bay navigation channel through the breakwater and offshore. If conditions are deemed not appropriate to leave the facility, the LNG vessel would remain at the pier. For most deep draft vessels, a speed of 4 to 6 knots is maintained while they transit the Coos Bay navigation channel. The total distance an LNG vessel would travel from the entrance of the ship channel to the end of the jetties is approximately 1.7 nmi. LNG vessels would require a minimum depth and width in the Coos Bay navigation channel. The present channel depth and width would be acceptable for the safe transit of a nominal size/capacity 148,000 m^3 LNG vessel with the aid of high tides.

During its approximately eight-mile transit, the LNG vessel would pass by the Southwest Oregon Regional Airport and the neighborhoods of Empire, Barview, and Charleston to the east and the uninhabited North Spit to the west. The LNG vessel would cross Southwest Oregon Regional Airport's main runway designed for instrument landings. The issue of an LNG vessel passing through the flight path of the airport's main runway was discussed between Jordan Cove and the FAA airport authority during the development of the WSA. The current height limitation imposed on marine traffic in the Coos Bay navigation channel by the FAA is 137 above ground level. This equates to a height of 167 feet AMSL. The FAA indicated that as long as vessels did not exceed the maximum height of 167 feet AMSL, they would not have any objections to vessels passing through the flight path of the main runway. In its development of the WSA, Jordan Cove verified the highest height to the mast of existing LNG vessels with a capacity of 148,000 m^3 is 139 feet above mean sea level. Since the development of the WSA, newly constructed LNG vessels could exceed the 167 feet AMSL. In response to a FERC data request on July 21, 2015, Jordan Cove reviewed the global inventory of the LNG vessels that could call on the LNG terminal and all of the LNG vessels would have a maximum height of 167 AMSL or less. Jordan Cove has agreed to amend the FAA's Form 7460 to reflect the change in LNG vessel height. If the FAA agrees with this change to the height of the LNG vessels, there would no longer be a NPH pertaining to the height of LNG vessels.

Hazard Zones Associated with the Proposed Route

The only area of land that would be overlapped by Zone 1 in the LNG vessel's transit to the proposed terminal would be a small portion of the western side of Empire and a small portion of the eastern side of the uninhabited North Spit. During transit, Zone 2 would overlap portions of the neighborhoods of Charleston, Barview, and Empire to the east and most of the North Spit to the west. Near the proposed terminal, Zone 2 would overlap the Roseburg Forest Products site and a portion of the Southwest Oregon Regional Airport's main runway. During transit, Zone 3 would overlap portions of the cities of Coos Bay and North Bend.

Estimates for the number of structures and the population within the Zones of Concern were provided in sections 4.7.1.2 and 4.8.1.1 of the FEIS the FERC issued in May 2009 for the previously proposed Jordan Cove LNG import terminal in Docket No. CP07-444-000. No residential structures, hotels, or motels were identified within Zone 1 (within 1,640 feet of the waterway). There are about 11 hotels or motels, and about 5,457 residential structures, including single family homes, apartments, and mobile homes, within Zones 2 and 3 combined, between 0.3 and 2.2 miles outside of the waterway. We estimated that there are approximately 16,922 people total residing within the Zones of Concern.

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LNG and Public Safety Issues

Summarizing current knowledge about potential worst-case consequences of LNG spills onto water.

by Jerry Havens
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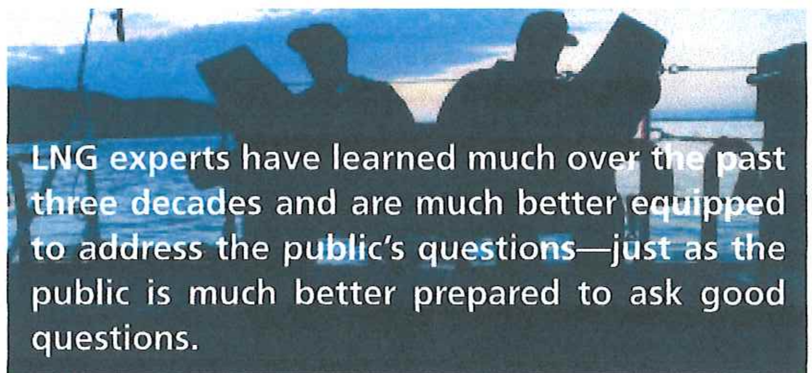
In 1976 Coast Guard Admirals were being called to Capitol Hill to answer the question: If 25,000 m^3 of liquefied natural gas (LNG) were spilled on water without ignition, how far might a flammable cloud travel before it would not pose a hazard? As technical advisor to the Office of Merchant Marine Safety in the Coast Guard's Bulk Hazardous Cargo Division, I was assigned to provide an answer on the LNG vapor cloud issue within a couple of weeks. Although no longer with the Coast Guard, I am still working on the problem 30 years later.



Past Lessons

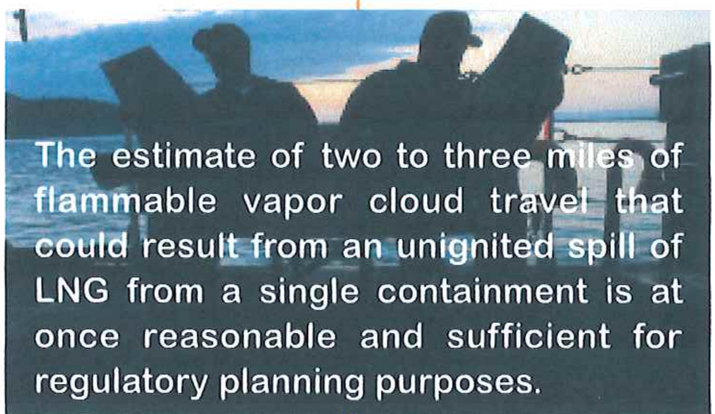
The tragic events of September 11, 2001, changed everything. Watching the World Trade Towers fall sharply focused my research of LNG spills on water. It is understood now that the towers fell because the insulation was knocked off the steel, which could then not withstand the extreme fire exposure. The lesson from this is to understand the consequences of such events, not only in planning for decisions that are within our control, but in planning for events over which we may have little or no control.

LNG experts have learned much over the past three decades and are much better equipped to address the public's questions—just as the public is much better prepared to ask good questions. For space constraints this discussion sidesteps many important issues in the LNG debate; however, it summarizes what is currently known about potential worst-case consequences for public safety of LNG spills onto water.

The description of current LNG knowledge is aided by reference to reports prepared in 2004 by the ABS Shipping Group for the Federal Energy Regulatory Commission[1] and by the Sandia National Laboratory for the Department of Energy.[2] These two reports, which appear to be largely accepted by all of the regulatory agencies involved, emphasize for their analyses one scenario of the consequences of LNG marine spills—spillage onto water of 12,500 m^3 of LNG, which is representative of approximately one half of a single tank on a typical LNG ship. While the Sandia report does provide some consideration of multiple-tank spills, it suggests that such occurrences would not involve more than three tanks at one time. The choice of spillage of only half a tank appears to be the result of the report's consideration of the extreme implausibility of the rapid spillage of the entire tank as an initial result of a terrorist attack. However, limiting discussion to the initial results of a terrorist attack is not necessarily sufficient.

LNG Vapor Cloud Dispersion

My year-long look at the LNG vapor dispersion issue for the Coast Guard produced a report[3] in 1978 that reviewed several predictions by leading authorities of the vapor cloud extent, following spillage of 25,000 m³ LNG onto water. Those estimates ranged from 0.75 mile to a little over 50 miles. The range was narrowed by showing the errors in reasoning underlying the lowest and highest estimates, but the uncertainty range could not be tightened closer than three to 10 miles.



The estimates, which range between approximately two and three miles, presented in the Sandia and ABS Group reports are endorsable. Note, though, that these estimates are for the spillage of 12,500 m³ of LNG, half the amount considered in the Coast Guard report produced in 1978. Nonetheless, the estimate of two to three miles of flammable vapor cloud travel that could result from an unignited spill of LNG from a single containment is at once reasonable and sufficient for regulatory planning purposes. Indeed, given the uncertainties involved, the point of diminishing returns has been reached on this scenario for vapor dispersion from a 12,500 m³ LNG spill on water.

Thermal Radiation from LNG Pool Fires

For thermal radiation from pool fires, the findings of the ABS Group and Sandia reports are also endorsable. Both reports appear to provide estimates of approximately one mile as the distance from a pool fire on a 12,500 m³ spill on water to which unprotected persons could receive second-degree burns in 30 seconds (based on a thermal flux criterion of 5 KW/m²). Although this estimate is reasonably representative of the best available estimates of the distance to which the public could be exposed (to this damage criterion), the endorsement is qualified as follows.

First, the use of a thermal flux criterion that would result in second-degree burns in 30 seconds is not necessarily appropriate to ensure public safety, as such exposure essentially ensures that serious burns will occur at that distance to persons who cannot gain shelter within 30 seconds. Aside from questions about the ability of even the most able to gain shelter in such a short time, questions are also raised about the safety of those less able. Lower thermal flux criteria (~1.5 KW/m²) are prescribed in other national and international regulations designed to provide safe separation distances for the public from fires. Since such lower thermal flux level criteria could increase the distances prescribed in the ABS Group and Sandia reports by as much as one and a half to two times, this end point criteria for ensuring public safety from LNG fires should be reconsidered, especially if the goal is to provide for public safety.

Second, the mathematical modeling methods in the reports that predict the various levels of thermal radiation intensity from a massive LNG pool fire are not on as firm scientific ground as are the methods for predicting vapor cloud dispersion. The vapor cloud question has been more extensively studied to provide data for the models' verification. The physical basis for extrapolation from small-scale experimental data is better understood for vapor dispersion than are the methods in present predictions of thermal radiation extent from pool fires. Sandia and others are considering the need for further large-scale LNG fire testing. Such tests should be conducted with appropriate scientific planning and for the purpose of obtaining experimental data that could be used to verify mathematical modeling methods; this additional testing is advised to provide a better understanding of large LNG fires on water.

However, the Sandia report states that cascading events, resulting either from brittle fracture of structural steel on the ship or failure of the insulation that results in LNG vaporization at rates exceeding the capability of the relief valves, cannot be ruled out. Foamed plastic insulation, widely used on LNG carriers, would be highly susceptible to failure by melting or decomposition. It is a cardinal safety rule that the pressure limits on tanks carrying flammable or reactive materials should not be exceeded, as such excess portends catastrophic rupture of the containment. While the Sandia report concludes that such cascading events would be very unlikely to involve more than three of the five tanks on a typical LNG carrier, the report's optimism in this regard is unexplained. Once cascading failures begin, what would stop the process from resulting in the total loss of all LNG aboard the carrier? More research is required.

Other Hazards

Other hazards associated with spilling LNG onto water include oxygen deprivation, cold-burns, rapid phase transitions, and explosions in confined spaces, as well as the potential for unconfined vapor cloud explosions (UVCEs) if the LNG contains significant heavies. As the hazards of oxygen deprivation and cryogenic burns are not expected to affect the public, they will not be considered further here.

Explosions in confined spaces, either combustion events or events of rapid phase transition, may have the potential for causing secondary damage that could lead to further spillage of LNG. Unconfined vapor cloud explosions cannot be dismissed if the cargo contains significant amounts—perhaps greater than 12 to 18 percent, based on Coast Guard-sponsored tests at China Lake in the 1980s—of gas components heavier than methane. Enrichment in higher boiling point components of LNG remaining on the water can lead to vapor cloud concentrations that pose a UCVE hazard, even if the concentration of liquid initially spilled does not. LNG contact with ship structural steel, rapid phase transitions, and gas explosions in confined spaces on the ship are not expected to pose hazards to the public, except as they may relate to the ship's vulnerability to further damage following the cryogenic cargo spillage onto ship structures, with or without ignition.

Vulnerability Issues

Coast Guard Navigation and Vessel Inspection Circular No. 05-05, "Guidance on Assessing the Suitability of a Waterway for Liquefied Natural Gas (LNG) Marine Traffic," incorporates requirements for a vulnerability assessment that identifies the exposures that might be exploited to ensure the success of an attempted terrorist attack.[4] Two types of vulnerabilities are considered: system and asset. System vulnerabilities consider the ability of the terrorist to successfully launch an attack; asset vulnerabilities consider the physical properties of the target that may influence the likelihood of success of a terrorist attack.

Worst Case?

The hazards of brittle fracture, rapid phase transitions, and explosions in confined ship spaces, as well as cascading events that may result from the extreme fire exposure a ship would experience if a nominal 12,500 m^3 spill on water around the ship was ignited, will require careful consideration. The definition of the worst case event that could be realized as a result of a terrorist attack is likely to hinge on the assessment of the asset vulnerabilities that is required to be considered in NVIC 05-05. This is largely where our unfinished work remains.

References

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