Professor H. Kazemi Letter to:

House Committee on Natural Resources

Oversight Field Hearing

Re: Examining the Natural Gas and Oil Shale Opportunities in Western Colorado

Honorable Committee:

I am a professor of Petroleum Engineering at Colorado School of Mines. I worked in the petroleum industry for thirty-seven years in three major U.S. technology centers before becoming a full time professor at Colorado School of Mines.

I was invited to make a short presentation at the oversight field hearing of Friday, June 1, 2018 on the topic: Examining the Natural Gas and Oil Shale Opportunities in Western Colorado. Specifically, the hearing pertains to the following items:

- The potential to export natural gas from the Piceance Basin for use in a proposed **Jordan Cove LNG project**
- The **oil shale opportunities** in Colorado and the neighbor states
- **Technical advances** that could lead to increasing the oil and gas yields of the low-permeability, hydrocarbon-bearing sediments in Western Colorado

I am honored to present my views on the above topics; however, they are re-structured as follows:

- Natural Gas Production Potential in Western Colorado, Wyoming and Utah
- Jordan Cove Proposed Project for Import of LNG to Asia Pacific markets
- Future Potential for Oil Shale Development in Western Colorado and Neighboring States of Utah and Wyoming

(1) Natural Gas Production Potential in Western Colorado, Wyoming and Utah

Colorado produces about 1.6 TCF/year (primarily from the **Piceance and DJ Basins**), Wyoming 1.8 TCF/year (predominantly from the **Pinedale** and **Jonah** Fields in the **Uinta** and **Green River Basins)**, and Utah about 0.30 TCF/year mostly from the **Three Rivers Area**. The total gas production from the Western Colorado could amount to about 0.8 TCF/year.

John Harpole (2017), in his publication on Piceance Basin to the Pacific, the "Economic Advantage the Piceance Bas Has over Other North American Shale Plays", states that: "The Piceance Basin is one of the more mature producing basins in the U.S., with a mixture of vintage natural gas production out of the Williams Fork formation (lower member of the **Mesaverde** formation) and new natural gas production out of the **Mancos Shale** formation. It is the combination of those two natural-gas-bearing reservoirs -- one old, one new -- that should be of particular interest to any party looking for an investment in long-term natural gas reserves."

Typically, the gas bearing formations in the Western Colorado are very low-permeability sandstones and require hydraulic fracturing to make them economical. An early attempt to alleviate the low-permeability problem was the **Rulison Project**, an underground 40-killoton nuclear test, on September 10, 1969, eight miles southeast of town of Parachute in Colorado, at 8400 feet below ground. The Rulison Project did not provide a workable solution; thus, a new approach, the Multiple Well Field

Experiments (**MWX)** by Sandia National Laboratories, was instigated to assess the viability of massive hydraulic fracture stimulation. These pioneering experiments provided new insight on hydraulic fracturing and produced a wealth of new knowledge which paved the way to the invention of **multi-stage hydraulic fracturing**. This technology simply **rubblizes** the low-permeability, hydrocarbon-bearing sediments; thus, releasing hydrocarbons from the tight pores.

An **example of the multi-stage hydraulic fracturing success** is a one-square-mile section in the Wattenberg Field in the DJ Basin of Northern Colorado (Ning et al., Paper SPE-190226-MS presented at the SPE IOR Conference, April 2018). This one-square-mile section was stimulated using eleven horizontal parallel wells using 335 hydraulic fracture stages. While the project was very successful, the ultimate recovery of the very light oil from the section has been projected to be six to eight percent of the hydrocarbon in place. This points to the difficulty of producing a large percentage of oil and gas from such tight formations.

(2) Jordan Cove LNG Project

A proposed pipeline (the Pacific Coast Connector) from **Malin Hub** to **Jordan Cove,** in the port of **Coos Bay** in the **Pacific Coast of Oregon,** is a 229-mile long, 36-inch diameter, 1600-psi natural gas pipeline. The natural gas will be converted to **LNG** at **Coos Bay** for shipment to the growing **Asia Pacific** market. The projected plan is to covert **1.2 BCF/D of natural gas** to **LNG**. This amounts to **7.8 million tons per year of LNG. One ship load** will be 3.6 BCF or 170,000 m^3 of LNG, and the projected annual LNG shipping is **110 to 120 LNG ship loads per year.**

"Colorado is to supply 25% of all LNG for export for at least 20 years—most of it from Piceance Basin (Bob Braddock, the Daily Sentinel; March 16, 2018)." This amounts to 0.30 BCF/D, which is physically attainable, but from the economics point of view it depends on the market forces.

(3) Future Potential of Oil Shale Development in Western Colorado and Neighboring States

Oil shale is a fine-grain, organic-rich sedimentary rock containing **kerogen** with an approximate chemical formula $C_{200}H_{300}SN_5O_{11}$ **.** This formula has been proposed by Professor Milind Deo of the University of Utah. The formula simply demonstrates the molecular complexity of Kerogen--composed of algae and woody plant matter from which liquid hydrocarbon can be produced.

Based on the history of oil shale development in the last sixty years, I believe **Oil from Oil Shale** is not a viable economic commodity for commercial development now and in foreseeable future because oil from shale can be obtained only by high temperature pyrolysis (in absence of oxygen) followed by hydrotreating to upgrade the fuel quality for aviation use. The efficiency of producing **crude oil** from **oil shale** is very low; thus, continued laboratory research and field pilot test programs to improve the efficiency of crude oil extraction from oil shale, enhancing its economic viability, and minimizing the environmental concerns should be pursued vigorously.

Conclusions:

1. Western Colorado is projected to provide 0.3 BCF/D to the proposed Jordan Cove LNG project. This **should be attainable** with a minimum gas price of $4.00 per Mscf in the current market conditions. To further improve gas production flow rates, one can resort to horizontal wells in

addition to placing a small number of multi-stage hydraulic fractures in the horizontal section of each well.

2. The USGS has estimated that Colorado's technically feasible producible **gas-in- place** is about 66 TCF. However, the amount of **producible gas reserves** associated with this resource is constrained by the price of gas—the higher the price of natural gas, the greater is the likelihood of increasing the producible gas reserves. Fortunately, application of the new improved production technologies, as used in unconventional shale reservoirs, can further increase the producible gas reserves.

3. Oil from **Oil Shale** is not economically viable yet. Research and field pilot testing should continue vigorously.