HOW DECISION-MAKING CAN INFORM SUSTAINABLE DEVELOPMENT OF THE EXPANDING OIL INDUSTRY OF WESTERN KAZAKHSTAN

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Aigerim Kenzhebekova

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Aigerim Kenzhebekova

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SUPERVISORY COMMITTEE:

Jack Norland
Chair

Carolyn Grygiel

Christina Hargiss

Gary Goreham

Approved:

8/9/2012
Date

Carolyn Grygiel
Department Chair

ABSTRACT

This paper explores how decision-making under uncertainty can address opportunities, risks, and uncertainties for sustainable development; how decision theory, resilience thinking, and scenario planning approaches can assist the decision-making process. The paper will focus on decision-making for sustainable development under uncertainty associated with energy development in Western Kazakhstan. The main goal of this work is to demonstrate how different decision-making approaches under uncertainty can facilitate sustainable development of the oil industry in the region. Recommendations for sustainable development are examined for how the different approaches can be used to better inform the recommendations.

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INTRODUCTION

According to the Oxford Dictionary of Sociology **sustainable development,** is defined in *Our Common Future* (the Report of the 1987 World Commission on the Environment and Development), as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Rather than predicting greater environmental decay and hardship in a world of ever-diminishing resources, the Report foresees the possibility of a new era of economic growth, based on policies that sustain and expand the natural environmental resource base" (*Oxford*, 2007).

According to The World Conservation Union there are three pillars of sustainable development: economic growth, environmental protection, and social progress (Adams, 2006). The indicators of sustainable development are: unemployment, migration, demography, GDP per capita, the environment, human health, and indicators of industry and agriculture.

Western Kazakhstan has significant importance on sustainable development of Kazakhstan because of the concentrated and vast reserves of oil and gas along with the significant investments needed to develop the hydrocarbon resources. The region is located in the coastal zone of the Caspian Sea with closely intertwined ecological, economical, and social problems. The oil industry is one of the main industries in the region and has a large impact on the three main pillars of regional sustainable development (KazMunaiGas,2010). Ineffective environmental policies and uncontrollable oil extraction will lead to increased pollution of the marine environment and breaches in the state of the marine ecosystem, ultimately negatively impacting the well-being of the region.

The purpose of this paper is to present an in-depth analysis on how different approaches to decision-making can enhance the sustainable development of the target zone. The emphasis will be on how decision-making under uncertainty can address opportunities and risks for

sustainable development; how decision theory, resilience thinking and scenario planning can help inform decisions for sustainable development. This paper will focus on decision-making under uncertainty dealing with the impact of energy development on the social-ecological system in Western Kazakhstan including the Caspian Sea. The results from that analysis are used in an exercise where the different approaches are analyzed as to how they can be applied to different aspects of oil development that will influence sustainable development.

GENERAL DESCRIPTION OF THE REGION

The Republic of Kazakhstan (Figure-1) is a transcontinental country in Central Asia and Eastern Europe with the vast majority of its territory being located in central Asia. Ranked as the ninth largest country in the world, it has a territory of 2,724,900 square kilometers (1,693,174 sq. miles). It is neighbored clockwise from the north by Russia, China, Kyrgyzstan, Uzbekistan, Turkmenistan, and also borders on a significant part of the Caspian Sea (CIA, 2011).

Mangystau province is located in the southwest part of Kazakhstan. It was formed in 1973. The province's western border is the Caspian Sea. It also borders Turkmenistan and Uzbekistan. Mangystau borders two other Kazakhstani provinces, these being: Aktobe Province and Atyrau Province. The area of the province is 165, 600 square kilometers (Statistics, 2011). The capital of the province is Aktau city. Mangystau province consists of vast flatlands,

Figure. 1 Map of Kazakhstan. Source: [Map of Kazakhstan] (2008). Retrieved November, 2011, from:

http://www.anna.aero/2008/08/15/air-astana-plans-to-treble-fleet/

with some depressions, like the Batyr Depression, which is 130 m (425 feet) below the sea level (Universalium, 2010).

The population of the Mangystau region is 524,175, or 3, 25 % of the total population of Kazakhstan (Statistics, demography, 2011). The urban population is 275842 (52%), whereas the rural population is 248,333 (48%) (Statistics, demography, 2011).

The Caspian Sea is a large inland body of water bordered by the countries of Azerbaijan, Russia, Kazakhstan, Turkmenistan, and Iran. The measured surface area is 371,000 sq. km (143,244 sq mi), and the maximum depth is at 1025 m (3,363 ft) (Worldatlas: Caspian Sea, 2011).

According to information provided on the Caspian Sea web site of the "natural gas and oil production platforms are positioned along the shores of the Caspian Sea. Additionally, large numbers of sturgeon "*Acipenser*" inhabit its waters, and caviar produced with the eggs is an expensive commodity. It is widely believed that around 90 percent of all world sturgeons live in the Caspian. Seven subspecies and species of sturgeon inhabit the Sea and give it the widest diversity of sturgeon," (Nikitin, 2011).

The water level of the Caspian Sea has risen in last 25 years due to added municipal and industrial wastewater along with increased runoff from the river deltas. The rising sea level is projected to lengthen the coastline from 2400 km up to 2700 km, and to increase the amount of area that can be flooded to 2.2 million hectares. Oil fields on the northern and north-eastern coasts of the Caspian Sea are under the risk of flooding, which can cause environmental problems (Granovskii, 2003).

The Mangystau province along with the Caspian Sea is rich with oil, gas fields, borate, potassium and sodium salts. According to oil explorations, the Caspian Sea region contains the third largest reserve of oil and natural gas in the world, following the Gulf region and Siberia (Kazakhstan and Oil, 1997). In the early 1950s, geologists discovered rich deposits of uranium and rare earth elements, along with oil and gas *(History*, 2008).

The development of the oil industry in Kazakhstan has led to: 1) the creation of a new industrial field, 2) development of local infrastructure, and 3) affects on the social and cultural spheres of the region. Also, the development of the oil industry brought economical prosperity to Mangystau province and Kazakhstan (Granovskii, 2003). Kazakhstan has become one of the major oil-producing countries in the world. Currently, the area is carrying out intensive exploration of the Caspian Sea. According to estimates, oil production in 2011 will reach 55 million tons per year, and by 2030, 74-75 million tons per year (Granovskii, 2003). The government of Kazakhstan pays special attention to Mangystau province, as one of the most vulnerable provinces of Kazakhstan, where the favorable economic situation is complicated by serious environmental problems that affects the health, fertility, mortality, and well-being of the population.

Criteria and Indicators of Sustainable Development

There are many different definitions of Sustainable Development. One of them is "Sustainable Development is development that ensures that the use of resources and the environment today does not restrict their use by future generations" (UNEP, 2003). There are many more concise but slightly different definitions for sustainable development, including:

- "Economic activity or growth which does not reduce or deplete the resources available to future generations" (Robert Drislane, 2011).
- "Policy of promoting growth consistent with protection of environment, e.g., via shift to renewable resources and local community participation in development projects. Compromise reached in international negotiation, recognizing interests of developed and developing countries. Normative principle with mixed practical effect" (Lechner, 2001).

- "Continued economic and social progress that rests on four key principles: improved quality of life for both current and future generations; responsible stewardship of the natural resource base; broad-based participation in political and economic life; and effective institutions which are transparent, accountable, responsive and capable of managing change without relying on continued external support. The ultimate measure of success of sustainable development programs is to reach a point where improvements in the quality of life and environment are such that external assistance is no longer necessary and can be replaced with new forms of diplomacy, cooperation and commerce" (*Sustainable*, 2002).

There are three main pillars of Sustainable Development: 1) Economic growth (Economical), 2) Environmental Protection (Environment), and 3) Social Progress (Social) (Adams, 2006). There are various criteria used to assess Sustainable Development, as outlined in Table 1.

Table 1.
Criteria used to assess sustainable development. Source: Economic and Social Affairs. (2007). *Indicators of Sustainable Development: Guidelines and Methodologies*. (3rd ed.). New York, NY: United Nations.

	Social	
Theme	**Sub-theme**	**Indicator**
Equity	Poverty	Percent of population Living below the poverty line
Health		Gini Index of Income Inequality
		Unemployment Rate
	Gender Equity	Ratio of Average Female Wage to Male Wage
	Nutritional Status	Nutritional Status of Children
	Mortality	Mortality Rate Under 5 Years Old
		Life Expectancy at Birth
	Sanitation	Percent of population with Adequate Sewage Disposal Facilities
	Drinking Water	Population with Access to Safe Drinking Water
	Healthcare Delivery	Percent of Population with Access to Primary Health Care Facilities
		Immunization Against Infectious Childhood Diseases
		Contraceptive Prevalence Rate
Education (36)	Education Level	Children Reaching Grade 5 of Primary Education
		Adult Secondary Education
		Achievement Level
	Literacy	Adult Literacy Rate
Housing	Living Conditions	Floor Area per Person

Table 1. (Continued)

Theme	Sub-Theme	Indicator
Security	Crime	Number of Recorded Crimes per 100,000 Population
Population	Population Change	Population Growth Rate
Population	Population Change	Population Growth Rate
		Population of Urban Formal and Informal Settlements
Environmental		
Atmosphere	Climate Change	Emissions of Greenhouse Gases
	Ozone Layer Depletion	Consumption of Ozone Depleting Substances
	Air Quality	Ambient Concentration of Air Pollutants in Urban Areas
Land	Agriculture	Arable and Permanent Crop Land Area
		Use of Fertilizers
		Use of Agricultural Pesticides
	Forests	Forest Area as Percent of Land Area
		Wood Harvesting Intensity
	Desertification	Land Affected by
		Desertification
	Urbanization	Area of Urban Formal and Informal Settlements
Oceans, Seas and Coasts	Costal Zone	Algae Concentration in Coastal Waters
		Percent of Total Population Living in Coastal Areas
		Percent of Total Population Living in Coastal Areas
	Fisheries	Annual Catch of Major Species
Fresh Water	Water Quantity	Annual Withdrawal of Ground and Surface Water as a Percent of Total Available Water
	Water Quality	BOD in Water Bodies
		Concentration of Faecal Coliform in Freshwater
Biodiversity	Ecosystem	Area of Selected Key Ecosystems
		Protected Area as a % of Total Area
	Species	Abundance of Selected Key Species

Table 1. (Continued)

Theme	Sub-theme	Indicator
Economic		
Economic Structure	Economic Performance	GDP per Capita
		Investment Share in GDP
	Trade	Balance of Trade in Goods and Services
	Financial Status	Debt to GNP Ratio
		Total ODA Given or Received as a Percent of GNP
Consumption and Production Patterns	Material Consumption	Intensity of Material Use
	Energy Use	Annual Energy Consumption per Capita
		Share of Consumption of Renewable Energy Resources
		Intensity of Energy Use
	Waste Generation and Management	Generation of Industrial and Municipal Solid Waste
		Generation of Hazardous Waste
		Generation of Radioactive
		Waste
		Waste Recycling and Reuse
	Transportation	Distance Traveled per Capita by Mode of Transport

Regional Economy

Mangystau province is a unique industrial complex and its oil-rich region of Mangyshlak is often called "a treasure peninsula of Kazakhstan" (*Mangystau*, 2007). The priority areas of economic development of Mangystau are energy, agribusiness, and fishery sectors. The region's economy is highly concentrated in the oil and gas sector (*Fitch*, 2011). The main prospects for increasing oil production in the country are linked with development of the Kazakhstan sector of the Caspian Sea. History of oil operations in western Kazakhstan began in 1992 when reconnaissance was conducted in the Kazakhstan sector of the Caspian Sea. Starting from 1992, joint ventures were created in the oil and gas sector with foreign partners like the Kazakh-

Turkish JV "Kazakhturkmunai" (1993) and Kazakh-German enterprise "KazGerMunai" (KazMunaiGas, 2011), along with smaller partners.

The most important event of 2000 was the discovery of a large offshore oil field, the North Caspian in Kazakhstan, which has increased the total oil reserves in Kazakhstan by 35%. The same year, the "National Fund" was established in order to accumulate funds for future generations, as well as reduce the dependence of the economy from adverse external factors and market forces. The Fund's assets are derived from funds received from large businesses in Kazakhstan commodities (mainly oil companies), and payable on the amount of investment income. In 2009, direct taxes levied on oil sector enterprises (except for taxes to local budgets) to the National Fund amounted to 1,371,362.8 million tenge, or about 9,291.1 million USD (60% of all revenues), (Kazakhstan M. o., 2009).

According to information accessed in November 2011, provided by ECO Geosciences database, Kazakhstan's proven hydrocarbon reserves have been estimated between 9 and 29 billion barrels (ECO, 2011). Also, Kazakhstan recently updated a new assessment of its oil reserves and estimated oil reserves at approximately 29 billion barrels (Oil & Gas in Kazakhstan, 2011). Major prospects for increasing oil production in the country are linked with the development of the Kazakhstan sector of the Caspian Sea. According to the 2015 state program, the offshore fields located in the country will annually produce up to 100 million tons of oil. It is twice more than "today's production" for the territory of the Caspian Sea. There is a high environmental risk of disturbance of the natural environment, due to the extraction process (Kuanysheva, 2003). However, it is also important to consider that the developments of oil reserve projects are beneficial from several points of view: 1) they will develop local infrastructure, 2) they will increase technical and tanker fleet, 3) they will create jobs, 4) they will train staff, and 5) they will increase tax revenues (Kuanysheva, 2003).

Since 2007, the economic development of the region has been characterized by the rapid growth of the Gross Regional Production (GRP) in current market prices, amounting to a 6.2% increase in 2009 for the Mangystau region. Increases in oil production have affected the growth of the GRP (Mangistau, 2011). The regional GRP depends in large part on the extractive industries of the region, and this sector of the local economy makes 58.6% of the GRP. The growth of the GRP is accompanied by an increase in number of employees that are employed in large and medium enterprises in the region and demonstrates an active business development along with the emergence of new enterprises.

According to Profinance.kz, one of the financial periodicals in Kazakhstan, the Mangystau region holds one of the leading places in investment policy in the country (profinance.kz, 2011). The oil and gas sector has 14 investment projects with a half billion dollars in operations within the region. In just 5 years, the region attracted 1.6 trillion tenge in direct investments (U.S. $ 11 billion), with 2010 attracting 370.5 billion tenge (U.S. $ 2.5 billion), a 12% increase compared to 2009 (Mangistau A. o., 2011)

Ecological Situation in the Region

Increased human pressure has negatively affected the regional and Caspian Sea ecosystem. The major influences that have negatively affected the ecosystem are: 1) regulation of river flows, 2) construction of reservoirs, 3) intensive offshore oil field development, and 4) chemical pollution along with several other issues (Granovskii, 2003). The Caspian Sea is a very sensitive ecosystem. The offshore regional oil industry has contributed to the chemical emissions in the Caspian Sea. Currently, the ecosystem of the Caspian Sea is estimated to be in a pre-crisis state and may worsen because of the large-scale planned development of shallow northeastern part of the sea for oil (*The first*, 2009). There are several conditions that could, if not well-managed, contribute to high levels of pollution in the Caspian Sea, such as: 1) the

existence of significant hydrocarbon reserves under the seabed, 2) high population density and industry, 3) intensive agricultural development in the river valleys, 4) the lack of the clearly defined geochemical barrier "river-sea", and 5) the sea is a closed basin (Isuev, 2009).

Mangystau province is undergoing environmental degradation due to increased oil and gas extraction, as well as highly aggressive extraction methods that add pollution to the atmosphere, surface water, ground water, soil, and vegetation cover, where heavy metals and oil wastes are accumulated. The ecological situation is shaped by natural and anthropogenic factors, the most important of which is the rapid development of the oil and gas industry (Umbetpaev AT, 2008).

The main types of impacts on the soil during drilling operations are mechanical disturbances and chemical pollution. An example of this first impact is that the drilling operations require the movement of a large volume of soil, which removes the fertile horizons. Soil contamination with heavy metals is due to the construction of oil and gas wells, collection and transportation of oil through pipelines, oil preparation for processing, refining infield, and storage. For example, the Tengiz oil field in the province exceeded the maximum permissible concentration of lead concentration in soil twice during oil production (Umbetpaev AT, 2008). According to information provided by Sellenreik constructions “Directional boring, commonly called horizontal directional drilling, is a steerable trenchless method of installing underground pipes, conduits, and cables in a shallow arc along a prescribed bore path by using a surface-launched drilling rig, with minimal impact on the surrounding area. Directional boring is used when trenching or excavating is not practical. It is suitable for a variety of soil conditions and jobs including road, landscape, and river crossings. Directional boring is not practical if there are voids or incomplete layers in the rock. It is used for crossing waterways, roadways, shore approaches, congested areas, environmentally sensitive areas, and areas where other methods are

costlier. It is used instead of other techniques to provide less traffic disruption, lower cost, deeper and/or longer installation, no access pit, shorter completion times, directional capabilities, and environmental safety" (Safety, 2011).

Economic development has had adverse effects on the regional water-ecosystem. The oil industry is a relatively water-intensive production, and therefore the water management and conservation of water resources from contamination is an important task in the development of oil fields. Dumping of polluted wastewater in rural communities from agribusiness and large oil-producing facilities is a major source of water pollution (Granovskii, 2003).

The particular problem of the Caspian Sea is the proximity of oil fields. There is a systematic accumulation of large oil slicks in the waters of the Caspian Sea due to imperfect systems and equipment in oil-producing complexes, as well as increasing volumes of crude oil transport and oil tankers (Granovskii, 2003). Contamination of the sea also comes from the Volga and Ural rivers. For example, the Volga River annually discharges 77 thousand tons of petroleum hydrocarbons to the sea (Kenzhebegaliev, 1997) . According to many researchers, the ecosystem in the region is threatened from the failure of protective measures which could have dire consequences not only for the area, but on a global scale.

Another particular concern is the rapid development of *Mnemiopsis*, a warty comb jelly or sea walnut. According to recent data, it was introduced into the Caspian Sea in 2001 from the ballast tanks of ocean-going vessels. It actively feeds on the marine flora, resulting in reduced food for sturgeon, which leads to a decrease in the sturgeon population. Scientists from Caspian State University stated that if the system reacts similar to the Azov and Black Seas, the total loss of the Caspian Sea fishery will take place in just five years. Moreover, arguments about the cessation of fishing sturgeons in the Caspian may not make any difference to the conservation of their populations due to new environmental conditions (Prohorov, 2011). Potentially there are

many diverse environmental consequences that, in combination, would have a harmful impact on the environment of the Caspian region.

Social Situation in the Region

Most of the population of the Mangystau region lives in close contact with oil and refined products, as well as with other toxic and carcinogenic chemicals that are released into the environment that can have harmful effects on workers as well as the general population (Granovskii, 2003). The oil industry development in the North Caspian Sea brought increased emissions of air pollutants and a growing number of sick people. The study "the dynamics of morbidity in Mangystau region," conducted from 2001-2009, shows that the predominant diseases are respiratory diseases, digestive system disruption, diseases of blood-forming organs, and complications of pregnancy, childbirth, and the postpartum period (Kunitsei, 2010).

According to data provided by the Agency of Statistics of the Republic of Kazakhstan, at http://www.eng.stat.kz/digital/Population/Pages/default.aspx, the total population of the Mangystau region was 446 thousand people (Kazakhstan T. A., 2009). The analysis of population dynamics over the period 2005-2009 (*The analysis*, 2009) shows a positive trend of population growth. In general, fertility rates have a positive trend leading to increased regional population. It should be noted that this region has high rates of fertility and mortality.

The region is very attractive to job seekers and has experienced an influx of population. Current immigration trends show that the influx of population in the region exceeds the outflow of population from the region. The inflow of migrants is due to the actively developing oil fields. The main driving force behind the influx of people from other regions is high wages. According to official data, the number is three to four times higher than in the agro-sector and two times higher than in manufacturing (*Income*, 2010).

The Caspian region's increased gross regional product is accompanied by increased employment (or reduced unemployment). The region's economic development provides new jobs in industry, construction, transportation, communications, and trade. There were 209 thousand economically active people and 194.1 thousand employed people in 2009 in Mangystau region (Kazkhshtan, 2010). Most of the employed population in Mangystau region works in industry (27.6%), construction (10%), trade (10%), transport and communications (11%), and real estate (10.3%) (*The structure*, 2010). The economically active population and employment increased over the past five years, because of migrants and increase of the "working age" population. Even the financial crisis of 2008 has not affected the statistics of employment and unemployment (Kunitsei S. , 2011).

ANALYSIS AND DISCUSSION

"The decisions that humans make are important drivers of change, including changes in biogeochemical cycling, land use changes, emergent diseases, invasive species, biodiversity loss, and social change. It is important then to consider not only the future impacts of current decisions, but also the potential for learning from decisions that can help inform future decisions" (Stephen Polasky, 2011) . In this section, I apply and discuss several approaches that address the application of existing knowledge to decision-making under uncertainty. The application of decision theory, scenario planning, and resilience approach are demonstrated in this section.

Decision Theory

Decision theory is the "Systematic approach to making decisions especially under uncertainty by using analytical techniques of different degrees of formality designed to help a decision-maker choose among a set of alternatives in light of their possible consequences" *(ITS*, 2005).

Using this definition, if the decision-maker does not know with certainty which state of nature will occur, then he/she is said to be making a decision under uncertainty.

The three commonly used criteria for decision making under uncertainty are:

- the optimistic approach (Maxi-max)
- the conservative approach (Maxi-min)
- the mini-max regret approach (Mini-max Regret)

"A decision problem is categorized by decision alternatives, states of nature, and resulting payoffs. The decision alternatives are the different possible strategies the decision-

maker can use. The states of nature address possible future events that are not under the control of the decision-maker, which will affect the outcome" (Lightner, 2010).

Applying Decision Theory to the TCO Case

The company "TCO" is the largest oil producer in Kazakhstan located on the shore of the Caspian Sea. The Tengiz oil field was discovered in 1979 and is one of the deepest and largest oil fields in the world (Tengizchevroil, 2011). Starting from 1993, there were numerous oil spill cases caused by TCO, resulting in damage that amounted to 116 million US dollars (Protection M. O., 2011). Application of the method is based on data on oil spills by oil companies on-site. The data was taken from the website of the Ministry of Environment of the Republic of Kazakhstan at http://en.government.kz/structure/org/m09 (Protection M. O., 2011). The objective for this decision analysis is to use oil spill data with the three different approaches: 1) optimistic approach, 2) conservative approach, and 3) mini-max regret. I have established three main states of nature or variations of damage based on the data on oil spills, these being: 1) Zero, 2) Low, and 3) High. The damage from the oil spills can be controlled using three different decision alternatives, these being: 1) Lax, 2) Moderate, and 3) Stringent.

The different damage control alternatives have different costs. Costs include penalty costs and the costs of the actual damage (Table 2). These different control alternatives have associated with them the three possible states: Zero, Low, and High damage, but it is uncertain which will occur in the future. The optimistic approach, maxi-max, assumes that there is some way to gauge the probability of the most likely state, with the optimal choice being the control alternatives with the maximum benefit or, in this case, the least cost. If zero damage is the most likely state, then Lax control would be the maximum or the minimum cost ($0 > -3.8; -35$); conversely if High damage is most likely, than Stringent control is the optimistic choice. If all three states or damages can equally occur, a 1/3 probability, then the expected net benefit from

all three controls with the lowest cost would be optimal. Under this case the Moderate control is optimal (-26 > -38; -51).

The conservative approach, maxi-min, is the one where the benefit is the highest or the least cost in this situation (i.e. the maximum minimal value) among the three controls over the different damage levels. So, the conservative approach would have Stringent control being the conservative choice since -42 is the least unfavorable choice over the three damage stages compared to Moderate (-54) and Lax (-116).

Table 2.

Combined costs of environmental damage and abatement from oil spills under different control and damage states. Expected net benefits is calculated by summing all costs over the different damage states for each alternative and multiplying by the probability of each state (ex. Moderate control, ((-3.8)+(-19)+(-54))*1/3)).

	Zero Damage	Low Damage	High Damage	Expected Net Benefits
Stringent control	-35	-38	-42	-38
Moderate control	-3.8	-19	-54	-26
Lax control	0	-38	-116	-51

The next step is to use the mini-max regret approach, which was done by calculating for each control level and damage type the difference between each benefit and the highest benefit (lowest cost) for that damage level (Table 3). In this situation, the choice under mini-max regret would be Moderate control because the maximum minimum is (-12) as opposed to Lax which is (-74) and Stringent at (-35).

Table 3.

Regret table for the different control and damage levels. Regret is calculated by taking the difference between the benefits (cost in this case) of a certain control and the highest benefit (lowest cost) within the state irrespective of control.

	Zero Damage	Low Damage	High Damage
Stringent control	-35-0= -35	-38-(-19)= -19	-42-(-42)= 0
Moderate control	-3.8-0= -3.8	-19-(-19)=0	-54-(-42)= -12
Lax control	0-0= 0	-38-(-19)= -19	-116-(-42)= -74

The conservative and mini-max regret approach do not need probabilities. Comparing the different approaches together finds that if there is confidence in the probabilities of different states, then using the optimist choice will result in the highest benefit (least cost), but if there is uncertainty in the probabilities, then using the other methods that do not require probabilities will result in informed decisions under uncertainty. By accepting uncertainty in the outcomes, these decision theory methods help to address different aspects of decision-making and promote forward-looking learning. Decision-makers in the Mangystau region can use this analysis to initially select a control. If the control of damage is the goal, then selecting the conservative approach of stringent control would result in the least damage. However, Stringent control comes with a high cost due to prevention. Choosing the mini-max regret choice of Moderate control would be the choice if the cost of prevention is an issue. Moderate control was also the optimistic choice when all states have equal probability. Given that Moderate control was the choice of both the optimistic and mini-max regret, this choice would make a good initial

compromise for decision-makers. As time goes by and knowledge is gained as to what level of damages are occurring, decision-makers could reanalyze using the gained knowledge, leading to adjustments in the level of control and cost reduction. Using decision theory in this instance would allow for decision-makers to make an informed decision initially that would allow for energy development while reducing the cost of prevention and damages from oil spills. With time, more information and learning will be occurring on spills and their control, which will allow for refinement of the inputs used in the decision theory making process, resulting in decisions that have the highest benefits given the evolving conditions.

Applying the decision theory approach can be difficult in some cases, due to: 1) lack of information on the different states and their benefits (no quantifiable information, nothing to calculate), 2) lack of knowledge about how alternatives and states work together, and 3) what calculation method to choose among i.e. decision trees, the optimistic approach, the conservative approach, the mini-max regret approach, equally likely, or Criterion of Realism.

Scenario Planning

"Scenario planning is a systemic method for thinking creatively about possible complex and uncertain futures. The central idea of scenario planning is to consider a variety of possible futures that include many of the important uncertainties in the system" (Peterson, 2003). The purpose of this scenario planning exercise is to develop information about the future of oil development in western Kazakhstan (Tengizshevroil, 2011). Scenario planning starts with identifying forces of change that can impact the future of a region, such as: no action, pollution effects, oil demand, introduction of new legislation on "limiting the oil production" or "new environmental regulation." Once identified, the forces were grouped into "best case" trends and "worst case" trends. The last step is identification of key transformations, such as social-economical, ecological, and health issues. The scenarios were based on a literature review—local

people's interviews, including professionals in various fields, which were conducted by regional periodicals (*Development*, 2008).

The scenario question is "How would an increase in oil extraction affect the social-ecological system of the Caspian Sea in the next 10 years?"

Scenario 1: The Tengizchevroil is planning to increase the oil production from 26 to 36 billion tons starting in 2012. What are the different projected effects of such an increase in production?

1. Social-economical: Atyrau is a donor region, serving as a source of income. Oil profits are flowing to the capital, Astana, and the state budget and State Oil Fund of Kazakhstan. This forces the population of Atyrau to endure the social, economic, and environmental impacts of the project without full compensation. Further increases in oil extraction would continue the lack of full compensation affecting the local economy, since all income goes to the Republic budget and other funds, and does not go through the local budget. Only about 10% of the population is working in the oil sector. However, according to local NGOs, when the construction phase of the new oil infrastructure is finished, the number of jobs will be drastically reduced, leaving much of the local population out of work.
2. Ecological: Due to the presence of different chemical components and burning of excess gas, which is scheduled at Kashagan, certain negative impacts to the local and global environments would occur on biodiversity, along with leading to increased CO_2 emissions. Pollution would increase with a sharp decline of fish stocks. Local residents have reported a substantial reduction in fishing for the last decade, both in Mangystau and in Atyrau. Such declines occurred from 2002-2005, where in May 2006 over 2,000 sturgeon and other fish species and over 300 marine mammals were found on the shores of the Caspian Sea. There is an imminent threat of extinction for Caspian sturgeon

"*Acipenser*", white sturgeon "*Acipenser transmontanus"*, and others. Obviously, the decrease in fish populations would have a significant socio-economic impact, as reflected in the dependence of the local population on fishing (for example, local fishing cooperatives employ up to 45% of the population in certain areas).

Production of sulfur is the main cause of environmental problems and threats to human health in the Kashagan project. In fact, Northern Caspian oil is characterized by high levels of reactive sulfur (18% of the Kashagan field), which may become toxic under certain climatic conditions encountered in the region. One ton of oil extraction in Kashagan will be accompanied by 110 kg of sulfur, which is not dangerous in its crystalline form, but can become extremely dangerous if transformed, which can occur in the Tengiz field due to the influence of weather conditions and extreme temperatures.

Northern Caspian oil contains toxic pollutants that may exert a strong influence on the environment and on human health. Mercaptans (methyl mercaptan and ethyl mercaptan) are among the most dangerous pollutants contained in the Kashagan oil. Removal of mercaptans from crude oil after its extraction is the most important issue. A concentration of 0.001mg/m^3 mercaptan can be deadly to humans. The mercaptan rich deposits and its extraction would affect human demographics and health.

3. Impact on Health: Health problems of the local population will be increased due to the expanding industrial complex. The location of industrial facilities away from local population centers may reduce the potential growth of the region's infrastructure, which causes additional problems and costs associated with the local industry or residential buildings.

Scenario 2: No action taken to increase production or special governmental regulations are enacted that limit the oil extraction at the site. What are the different projected effects of such a limit to the increase in production?

1. Ecological: With conservative legislation control over oil production, the ecology of the region will remain the same or improve. However, it is important to note that this scenario covers only 10 years and that the affect on the global environment may not be significant.
2. Health issues: New regulations in Standard and Maximum Allowable Concentrations and enforcement of penalties would minimize mercaptans and other pollutants, leading to little change for human health. Standard and Maximum Allowable Concentrations set performance levels that are favorable to human life and health of the environment and natural resources. The purpose of environmental regulation is the regulation of environmental quality and the establishment of permissible exposure to ensuring environmental safety, conservation of ecosystems, and biological diversity (*Environmental*, 2012).
3. Economics: The new regulations would affect the oil industry in the region by prohibiting or limiting oil extraction resulting in: 1) reduction of investment, 2) reduction in extraction affecting the local economy, such as reduction of work places and employment, and 3) decreased regional development affecting the national economy.

These two scenarios, based on literature and interviews, may give the impression of oversimplification. Overall, however, the method is practical and takes into account many different possibilities, whereas I have used only two in order to build short and relevant scenarios. Given that the scenario was based on judgments on previous trends (highlighted by local people) and events that had taken place, the probability of which scenario will occur in the

future is unknown and even the form of the future may not follow these scenarios closely. The utility of scenarios for decision-makers is considered by examining the possible future trends, challenging the official future, and identifying the signals to scan that will indicate what trends are occurring. Some of the signals from the scenarios to watch are: 1) the response of the government to health problems and environmental damage and whether regulations are being enacted that will reduce oil development, 2) the flow of the proceeds from the oil development and whether they are being redistributed to the Atyrau region, and 3) how the marine environment and important fish populations are responding to the oil development in light of other environmental stresses.

Resilience Approach

F. Stuart Chapin discusses resilience in his text, aptly named *Resilience*, indicating as follows:

> "Resilience is the capacity of a socio-ecological system to absorb a spectrum of shocks or perturbations and to sustain and develop its fundamental functions, structure, identity and feedbacks thorough either recovery or reorganization in a new context. It is important to emphasize that resilience is a concept that embraces change as a basic feature of the way the world works and develops, and therefore is especially appropriate at times when changes are prominent feature of the system. One of the key contributions of resilience theory is the recognition that complex adaptive systems are constantly changing in the ways that cannot be fully predicted or controlled, so decisions must always be made in an environment of uncertainty" (F. Stuart Chapin G. P., Resilience, 2009).

According to Resilience based Natural Resources Management

"Resilience based socio-ecological system stewardship shifts the philosophy of

resource management from reactions to observed changes to proactive policies that shape change for sustainability, while preparing for the unexpected. A central approach to both reducing the vulnerability and enhancing resilience is to enhance the adaptive capacity of social-ecological systems to both expected changes and unanticipated occurrences" (F. Stuart Chapin G. P., Resilience, 2009).

There are four approaches to enhancing resilience by fostering:

1) A diversity of options,
2) A balance between stabilizing feedbacks and creative renewal,
3) Social learning and innovation: the capacity to adapt, communicate, and implement solutions,
4) Experiment and innovate to test understanding,
5) Adapt governance to changing conditions. (Chapin, Resilience, 2009)

Foster Biological, Economic, and Cultural Diversity

The Caspian Sea region's economy is highly concentrated in oil production and this concentration is expected to continue and even increase. The concentration of economic activity in the oil sector can dominate the regional situation, resulting in a reduction of diversity for different economic activities, which can then affect the social and environmental diversity in the region. In response to this, Chapin states "To counteract this dominance and the possible lower diversity it is therefore important to identify, protect, and legitimize latent sources of diversity that may be underrepresented in the current system," (Chapin, Resilience, 2009). Possible options to increase underrepresented diversity in the region can be the promotion and subsidizing of other sectors of the economy such as tourism, eco-tourism, agriculture, and aquaculture. The region has a long cultural relationship to the marine resource and continuing to protect and

legitimize this connection through tourism and eco-tourism along with innovation in the form of aquaculture would contribute to the diversity of the region. It is important to note that policy makers at the national level should address this issue and consider using the National Fund derived from oil proceeds to fund these initiatives.

Associated with the cultural relationship to the marine resource is illegal fishing. In this case, there is danger of losing some valuable species in the region, which would be a noticeable reduction in biological diversity, but also a reduction in the social aspects dependant on those species. Regulations that protect the fish species could be enacted to preserve the diversity of fish species, but these regulations could also result in the reduction of those social and cultural sectors that are dependent on the fish species. To make up for this loss, options such as tourism, eco-tourism, and aquaculture could be promoted and encouraged to act as a substitute for illegal fishing. The successful implementation of these options would work to preserve existing diversity while allowing for innovation in the form of aquaculture to increase diversity. These options could be subsidized with some of the profits derived from the increased oil production.

Foster Innovation and Social Learning

Innovation and social learning are the core processes that build the adaptive capacity and resilience of a social-ecological system (F. Stuart Chapin G. P., Resilience, 2009). In this case, scenario planning, as detailed earlier in this paper, and the accompanying analysis provided opportunities to explore the consequences of alternative policy options, building social learning, and setting the stage for innovation. This approach is useful for decision-makers, as it allows them to see the range of possible future outcomes and what signals should be monitored to determine what trends are occurring. Scenario planning broadens the context of the problem, helping explore different perspectives to accommodate new values and options which can help drive innovation.

According to Carl Folke (Chapin, 2009), “much has been learned through comparative studies on the social factors that promote sustainable use of common pool resources,” like the Caspian Sea in this case. For example, concentration of toxic hydrocarbon elements in the marine environment can cause thresholds to be crossed, resulting in partial or complete loss of biological species or affecting the habitat and population of species. In this case, oil spills have already affected the sturgeon population, and further oil spills that exceed thresholds would cause further environmental damage to the habitat and to the sturgeon populations. Comparison with other social-ecological systems that have had changes caused by toxic hydrocarbons, such as the Deepwater Horizon oil spill in the Gulf of Mexico in 2010, would prompt social learning in this situation, along with being a starting point to discussions on innovative approaches to dealing with hydrocarbon concentrations in the environment. Decision-makers should keep in mind that each social-ecological system is "unique"; it is very rare that socio-ecological systems are identical and this can be a challenge for decision-makers.

Adapt Governance to Changing Conditions

Governance structures that are adaptable and flexible are better able to deal with change and are essential to social-ecological resilience (F. Stuart Chapin G. P., 2009). Changing legislation to be more flexible and using rules that promote the changing of rules can be ways to bring flexibility to resource use governance. It has been suggested that “Devolving the powers and resource of government to local scales can also enhance the responsiveness and adaptability to change in ways that sustain opportunities instead of constraining options, as long as it comes with the resources that needed to navigate change and good systems of accountability,” (F. Stuart Chapin G. P., Resilience, 2009)(Chapin, 2009). To this end the following strategies should be encouraged: 1) allow leadership and trust to develop at all levels of governance, 2) promote

networking that increases accountability and communication at all levels of governance, and 3) allow for some duplication and overlap among organizations so there is some redundancy among levels for governance (F. Stuart Chapin G. P., Resilience, 2009).

Marine pollution and the waste products from oil development are responsible for environmental and health problems in the region, which demands that some sort of governance structure be used to deal with these problems. The governance structure should not only be sensitive to the national and regional impacts, but also pay particular attention to the needs of the disadvantaged segments of society, which tend to be the local indigenous peoples of society dependent on traditional resources (the marine environment) that are under stress due to oil development. Such problems can be solved in different ways but should include different levels of governance, from the national emergency response team, to traditional local governance systems, to non-governmental organizations (Coordination, 2010). At all governance levels, there should be an increased effort to promote networking among the groups along with allowing some redundancy in governance at different levels. Recommendations for making flexible legislation and enacting flexible legislation should come from and occur at all levels.

Transformability

"Transformability is the capacity to conceptualize and create a fundamentally new system with different characteristics. Transformations are fundamental changes in a social-ecological system that result in different control variables defining the state of the system, new ways of making a living, and often changes in scales of critical feedbacks." The main phases of the transformation process are: "Building a resilience of a new regime and Navigating the Transition," (Chapin, 2009). These phases include the following approaches:

- "Enhance diversity, adaptation and resilience
- Identify potential future options and pathways to get there

- Enhance capacity to learn from crisis
- Create and navigate thresholds to transformation," (Chapin, 2009).

In the context of ecosystem stewardship, "transformations involve forward-looking decisions to convert the system to a fundamentally different, potentially more beneficial system," (Chapin, 2009). For example, continued oil spills and overfishing may lead to the reduction of biodiversity. Crossing the threshold would bring the transition to an alternate state and pose risks to biodiversity, fishing industry, human health, and the local economy.

Unintended transformations can also occur when management actions to prevent damage cause adjustments in other parts of the system, forcing a transformation (F. Stuart Chapin G. P., 2009). For example, using different extraction methods in order to decrease the toxic emissions into the sea can lead to new types of emissions on land that can migrate to coastal areas, causing a transformation of the coastal zone. The example would be considered as unintended transformation to a new state (often degraded) that happened due to the inability to recognize the new vulnerability that was accompanied by the failure to adapt.

As the region transforms, new interactions frequently become important and social-ecological processes become sensitive to different stressors. Decision-makers will need to be aware of how transformation can be responsible for this change in interaction and flexibility, which, along with adaptation, will need to be emphasized so new solutions are sought. For example, specialized interdisciplinary departments at local universities can address the different economic, social, and environmental issues exploring the complexities of the issues helping to inform the decision-makers on how to navigate the transformation (F. Stuart Chapin G. P., 2009).

Much of the success in navigating transformations relies not just on identifying the problems associated with the transformation while maintaining flexibility and transparency

across the various stakeholders and levels of decision-makers, but also on the need to build resilience into the system at the start (F. Stuart Chapin G. P., 2009). Many of the recommendations in navigating transformation in this region require a high level of innovation and development of new structures and institutions that may not be possible given the existing system. Bridging organizations can be a significant part of navigating a transformation (F. Stuart Chapin G. P., 2009). They can provide a base for collaboration, identification of common interests, and conflict resolution. Various organizations can act as bridging organizations in Western Kazakhstan, such as an "emergency oil spill response organization" and an "ecological monitoring organization," both of which cooperate with local oil companies and governance in the region. These organizations can "filter external threats and redirect into opportunities and help to transform social ecological systems" (Chapin, 2009). Barriers due to change and lack of will due to fragmentation among the different levels and institutions may prevent the transformation to a beneficial state. In the end, without the effort of building resilience into the new regime, the system may continue to degrade (Chapin, 2009).

Building General Resilience as Opposed to Specific Resilience

General resilience "includes all kinds of shocks, including completely novel ones" while specified resilience "involves particular aspects of a system that might arise from a particular set of sources or shocks" (Folke, 2010). In the Western Kazakhstan case, general resilience strives to cope with all the shocks and problems like human health, oil spills, economic transformation, and pollution by toxic elements, among others. In contrast, specific resilience considers particular aspects, such as reductions in biodiversity of marine environment or pipeline oil spills. When considering the implications of using either specific or general resilience "there is a danger of becoming too focused on specific resilience because specific resilience relies on being resilient to just a particular part of a system" (Carl Folke 1, 2010). This over-reliance on being

resilient to just one specific disturbance may in turn cause the system to lose resilience in other ways (Carl Folke 1, 2010). For example, emphasizing being resilient to oil spills in the marine environment and building systems just for that contingency could draw attention and resources away from responding and being resilient to other disturbances like invasive species, or promote diversity by preserving the traditional fishing resources used by the local culture, or the need to innovate through the building of aquaculture. By directing attention to general resilience instead of specific resilience, aspects such as innovation, learning, adaptation, openness to novelty, and transformability will be responses to building resilience to the all the changes and disturbances being brought about by the oil development.

Comparison of the Different Approaches

This section is devoted to a discussion of how the three different approaches, decision theory, scenario planning and resilience approach, compare in their ability to inform decision-makers. The section provides an overview of how the three approaches work in different situations (Table 4).

Table 4.
Comparison of how the three approaches scenario planning, decision theory, and resilience approach work under different situations in Western Kazakhstan.

Scenario Planning (SP)	**Decision Theory (DT)**	**Resilience Approach (RA)**
Pipeline spills		
The SP approach can help in problem identification, identification of the forces of change, and how the joint effect of many factors can affect pipeline spills in the long term. SP allows policy-makers to examine how different pathways can develop and what trends to monitor that contribute to the different pathways. SP allows for decision-makers to examine options and to make adjustments due to uncertainty and change without risking career-limiting failures in real life.	The DT approach is preferable for pipeline spills since the outcomes of spills are known to a certain degree and are controllable. The DT approach can provide the decision-maker with different options (solutions) to dealing with spills and can help identify what decision to make, whether it is conservative, optimistic, or balanced with regret.	Resilience thinking generates a comprehensive, inclusive view of the entire system that aims to include all relevant factors for a decision, even if they are ambiguous or not quantifiable. In our case, the central idea of the resilience approach was to reduce the vulnerability of pipeline spills by monitoring trends in indicators of stresses and their ecological impact. The resource managers can gauge changes from some historic reference point and take appropriate actions to reduce the stress (chronology of oil spills), paying particular attention to disadvantaged segments of society (local population). The comprehensive view can help to develop long-term action plans.

Table 4. (continued)

Scenario Planning (SP)	Decision Theory (DT)	Resilience Approach (RA)
Pollution		
The SP approach focuses directly on the factors and drivers of risk that affect pollution. This approach helps to identify forces of change with the inclusion of factors that are difficult to formalize and focuses on the joint effect of many factors. It opens the picture from different sides and aspects and can help deal with the complexity of the situation. It also helps policy-makers to anticipate hidden weaknesses.	The DT approach gives understanding of the decision in numbers. It offers ways to help decision-makers analyze problems and make a rational choice with several alternative courses of action. In our case, the DT approach can help to make rational decisions about the control of damage. The approach allows decision-makers to make an informed decision initially that would allow for energy development while reducing the cost of prevention and damages from pollution.	The RA can generate a comprehensive, inclusive view of the entire system, of which pollution is just one part. The RA can be useful to enhance the adaptive capacity of the social-ecological system to deal with the pollution that conceivably happens. The RA uses comparisons to other systems with similar, but not identical, pollution problems, which can give insight into ways to be resilient to pollution while informing decision-makers on options dealing with pollution.
Health Problems		
The SP approach can consider the health problems during the scenario building or put the health issue as a focal question of the scenario building process. Overall, the approach can help to broaden possible outcomes of health problems in the region. The main challenge of SP is to find out the real needs of policy-makers, when policy-makers may not themselves know what they need to know, or may not know how to describe the information that they really want.	DT provides a more precise and systematic study of the formal or abstract properties of decision-making, with cost-effectiveness being an entrenched part of health services. With the identification of different possibilities comes the problem in determining the values (positive or negative) and the probabilities that recommend the best course of action. In terms of health, it is often hard to determine the level of health desired given the resources available.	The RA, with its inclusive nature and emphasis on change and uncertainty, works well with health problems that are emerging and not well known. With the RA paying particular attention to the needs of the disadvantaged segments of society, there is a higher chance that health for these segments will be part of the decision-making process. The interconnection of the local population to the marine environment as a source of food and livelihood responsible for health will be emphasized in the RA placing a focus on well being from that resource.

Table 4. (continued)

Scenario Planning (SP)	Decision Theory (DT)	Resilience Approach (RA)
Changes in oil production		
The SP approach would be recommended in this case, since it can consider different variations and give insight into how change will affect future sustainability. Relevant and plausible scenarios can show possible outcomes of each storyline and factors that drive each particular storyline.	The DT would not be recommended for this problem since this approach works with concrete numbers and does not take into account the possible changes in oil production. It would be hard to inform decision-makers with DT since the uncertainties would be so great and virtually immeasurable.	Overall, the RA is designed to deal with changes such as in oil production. An analysis of how to be resilient to changes in oil production would inform decision-makers on what it would take to be sustainable in the face of changing production and the changing revenues and associated problems that accompanying disruptions would incur. Changes would affect not just local but national and regional sustainability and RA would be informative on how the various levels would interact and how innovation, diversity, and adaptability would work within all those levels in response to the changes. The RA would show how fostering other sectors of the economy (tourism, eco-tourism, and agriculture) would contribute to sustainability.

Table 4. (continued)

Scenario Planning (SP)	Decision Theory (DT)	Resilience Approach (RA)
Introduction of new legislation/policy		
The SP approach can take into account the introduction of new legislation/policy as a focal question of the scenario or as the driver of change. The SP approach can help in the identification of hidden weaknesses in legislation/policy and how legislation/policy can incorporate greater flexibility. This approach can help with how legislation/policy can affect sustainability by the different storylines that will follow when certain courses are chosen because of the particular paths that legislation/policy encourages.	The DT approach can be used for the introduction of new legislation/policy when outcomes are identifiable and some level of certainty and controllability are present in the alternatives. The DT approach can be limited in that legislation/policy often plays out as being highly uncertain and experimental.	RA can contribute to sustainability through legislation/policy by fostering innovation and social learning through experimentation and innovation. The RA promotes the exploration of the consequences of alternative policy options with the inclusion of factors that are difficult to formalize.

Comparing the effectiveness of the three approaches in the presence of different levels of controllability and uncertainty demonstrates that Decision Theory is the least effective when controllability is low and uncertainty is high (Table 5). For the set of selected problems (see Table 4), only one problem, pipeline spills, has the same properties of uncertainty (low) and controllability (high) that match Decision Theory when it is most effective. As for the rest of the selected problems, Scenario Planning matched the invasive species problem, while the Resilience Approach matched two problems, changes in oil production and loss of biodiversity. Three of the problems did not match any of the approaches since no approach is most effective when controllability and uncertainty are both high. Even though the Resilience Approach is most effective with low uncertainty and controllability, in some ways general resilience is capable of dealing with high controllability and uncertainty. General resilience, as opposed to

specific resilience, "focuses on adapting to and shaping the coming changes to enhance sustainability" (Carl Folke 1, 2010). This strategy followed by general resilience would match those problems that have high controllability and uncertainty. General resilience would be able to respond to the uncertainty (change) and would not be hampered by high controllability, since it will encourage all sorts of proactive adaptations that would prepare for future shocks. Therefore, this analysis would find that Scenario Planning and Decision Theory would be restricted to certain situations while the General Resilience Approach would be able to play a role in most all problems that affect sustainability.

Table 5.
Comparison of the three different approaches, decision theory, scenario planning, and resilience, as to the levels of uncertainty and controllability under which the different approaches work effectively (Peterson, 2003) along with how the selected problems from Table 4 relate to the levels of uncertainty and controllability.

Sustainability Approach	Uncertainty		Controllability	
	Low	High	Low	High
Decision Theory	+			+
Scenario Planning		+	+	
Resilience Approach	+		+	
Selected Problems				
Pipeline spills	+			+
Pollution		+		+
Health problems		+		+
Changes in oil production	+		+	
Introduction of new legislation/policy		+		+
Invasive species		+	+	
Loss of biodiversity due to pollution and illegal/over fishing	+		+	

Analysis of UN Recommendations

Based on a UN study of sustainable development, there are many potential actions that can be taken to increase sustainability (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992). Unfortunately, there is uncertainty as to which of the approaches analyzed in this paper should be undertaken in the region to help inform sustainability. Below, the prior analysis of the different approaches to decision-making under uncertainty will be applied to the recommendations to determine which approach would be useful in informing decision-makers on these recommendations. After each recommendation, the decision-making approach that would inform whether the action would be effective for sustainability is discussed.

"Coastal States commit themselves to integrated management and sustainable development of coastal areas and the marine environment" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992). To this end, it is necessary for the region to, inter alia:

(a) "Provide for an integrated policy and decision-making process, including all involved sectors, to promote compatibility and a balance of uses" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992) This recommendation is closely connected with scenario planning and resilience thinking, since both of them are inclusive and promote integration.

(b) "Identify existing and projected uses of coastal areas and their interactions" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas,

& Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992). This recommendation assumes a scoping of projects and their interaction. In such cases, scenario planning and the resilience approach will be useful to assess the current and future conditions and make the preliminary forecasts. Both approaches would be useful for assessing the interactions.

(c) "Concentrate on well-defined issues concerning coastal management" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992) Decision theory would be useful for the analysis of well-defined issues.

(d) "Apply preventive and precautionary approaches in project planning and implementation, including prior assessment and systematic observation of the impacts of major projects" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992) Decision theory would be useful for impact analysis.

(e) "Promote the development and application of methods, such as national resource and environmental accounting that reflect changes in value resulting from uses of coastal and marine areas, including pollution, marine erosion, loss of resources and habitat destruction" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992). Data from this recommendation would be used in the decision theory approach.

(f) "Provide access, as far as possible, for concerned individuals, groups and organizations to relevant information and opportunities for consultation and participation in planning and decision-making at appropriate levels" (Protection of the Oceans, all

Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992). Under the resilience thinking framework, experience shows "that complex problems can often be better addressed by a diverse team of competent experienced individuals and gathering information and opinion from many independent sources about highly plausible outcomes, because such actions expand the scope of use" (Polasky, 2011).

Under the framework of recommendations, local authorities can use scenario planning for contingency plans for human induced and natural disasters, including likely effects of potential climate change and sea level rise, as well as contingency plans for degradation and pollution of anthropogenic origin, including spills of oil and other materials. Also, scenario planning can be used prior to environmental impact assessment, systematic observation, and follow-up of major projects, including the systematic incorporation of results in decision-making. Implementation of integrated coastal and marine management and sustainable development plans and programs at appropriate levels could be done under the scenario-planning framework.

Under the resilience approach framework, local authorities should: 1) conduct "periodic assessment of the impacts of external factors and phenomena to ensure that the objectives of integrated management and sustainable development of coastal areas and the marine environment are met" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992); 2) "conduct the conservation and restoration of altered critical habitats" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992); 3) "conduct infrastructure adaptation and alternative employment" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection,

Rational Use & Development of their Living Resources, 1992); and 4) work on "promoting environmentally sound technology and sustainable practices" (Protection of the Oceans, all Kinds of Seas, Including Enclosed & Semi-enclosed Seas, & Coastal Areas & the Protection, Rational Use & Development of their Living Resources, 1992).

The authorities should consider other recommendations related with sustainable development under the framework of the different approaches, such as: 1) using preventive and proactive approaches and assess their impact on the environment, 2) using "clean" production methods, 3) recycling and, 4) constructing and improving wastewater treatment plants in order to prevent degradation of the marine environment (Lagutov, 2003).

CONCLUSIONS

Sustainable development is continually confronted with situations in which decisions must be made in the face of uncertainty. The appropriate response to uncertainty depends on the degree of uncertainty and the degree to which a system can be controlled. This paper represents an analysis of decision-making under uncertainty and which approaches can inform sustainable development of Western Kazakhstan and the Caspian Sea.

The paper uses new and challenging decision-making approaches in environmental management, such as scenario planning, resilience thinking, and decision theory. The use of these approaches can help decision-makers address new environmental issues or issues related to sustainable development expanding the application of the approaches. In situations of uncertainty, scenario planning and resilience thinking can be useful ways to expand the scope of what is considered, thereby reducing the risk of unintended consequences and organizing complex materials focusing on key factors and boundaries.

Using such approaches helps to assess the problem as broadly as possible and can generate a richer understanding of complex system dynamics and more accurate and comprehensive assessment of uncertainties. Scenario planning and resilience thinking are ways of expanding the frame. These types of analyses are useful for identifying gaps in understanding that should guide future research efforts. It is important to note that the above approaches have been rarely applied in combination, but using these combined approaches can help in solving complex environmental problems. This is a completely new approach for problem solving for the future of Western Kazakhstan and the Caspian Sea.

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