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CHINA'S SOUTH-TO-NORTH WATER DIVERSION SCHEME: THE GEOGRAPHICAL DISTRIBUTION OF ENVIRONMENTAL AND SOCIOECONOMIC CONSEQUENCES

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ABSTRACT

In China, most resources are in the north, with the exception of water, which is predominantly in the south. Because of this unequal distribution of the resources, further economic development is restricted. In order to overcome this, China decided to execute a long distance water transfer project called the South-to-North Water Diversion Scheme, which will transfer water from the Yangtze River to the northern cities, especially, Beijing and Tianjin, which have been suffering from a severe water shortage problem.

Because of its unprecedented scale, the scheme may destroy the natural environment, and has created a heated debate among professionals globally. Possible costs and benefits regarding the scheme are considered and organized into a hierarchy for the AHP analysis that is used to determine the motives and values that are consistent with the decision, and the decision to build the scheme.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

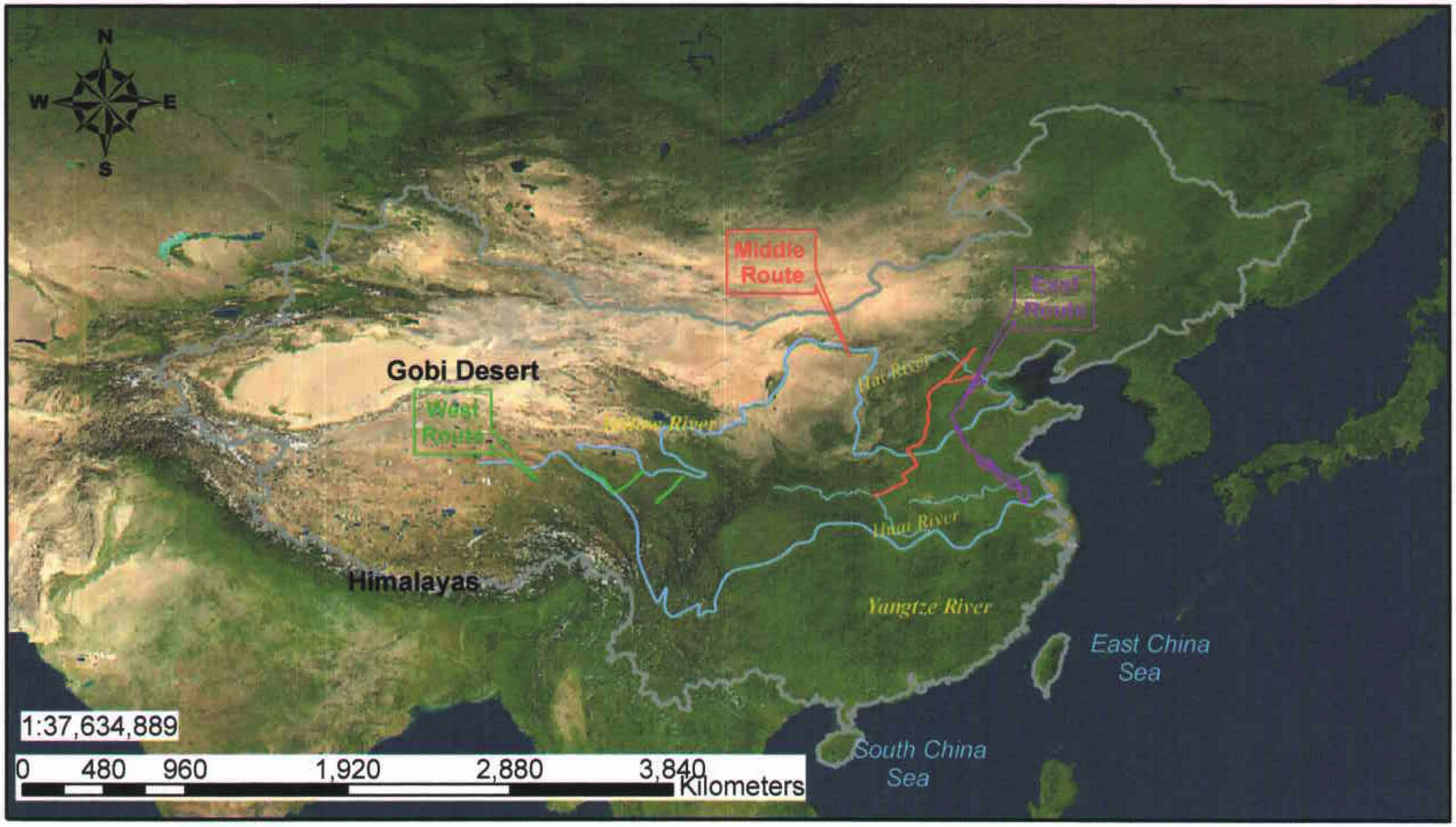
CHAPTER 1
INTRODUCTION

China's economy, politics, culture, and geographic characteristics are watched with keen interest internationally. China, the world's most populous country (Figure 1-2)[a], with 1.27 billion people, during the last decade of the 20^{th} century, has increased its Gross Domestic Product (GDP) by nearly 5 fold, from 1854.79 billion Yuan ($22.6 billion) in 1990 to 8940.36 billion Yuan ($1072.8 billion) in 2000 ("National," 2001) (Table 1-1). This growth has necessitated large-scale resource use and infrastructure development, including the development of the world's largest hydroelectric dam, known as the Three Gorges Dam, the South-to-North Water Diversion (Figure 1-1), the Qinghai-Tibet Railway Network, and the West-East Power and Gas Transfer ("Opinion," 2001). These colossal projects all address resource unevenness and economic development, and all have economic, social, and environmental consequences that have attracted international attention. One of those in the spotlight has been the South-to-North Water Diversion Scheme, as questions have arisen as to whether its benefits outweigh its costs.

China's water shortage could affect the entire world. In recent years, China's environmental deterioration has been reducing China's agricultural productivity. Entry into the World Trade Organization (WTO) in 2002 allows China to import agricultural products. The South-North Water Diversion Scheme is seen as China's desperate remedy to cope with pressing, economic, social, and environmental concerns. If the water

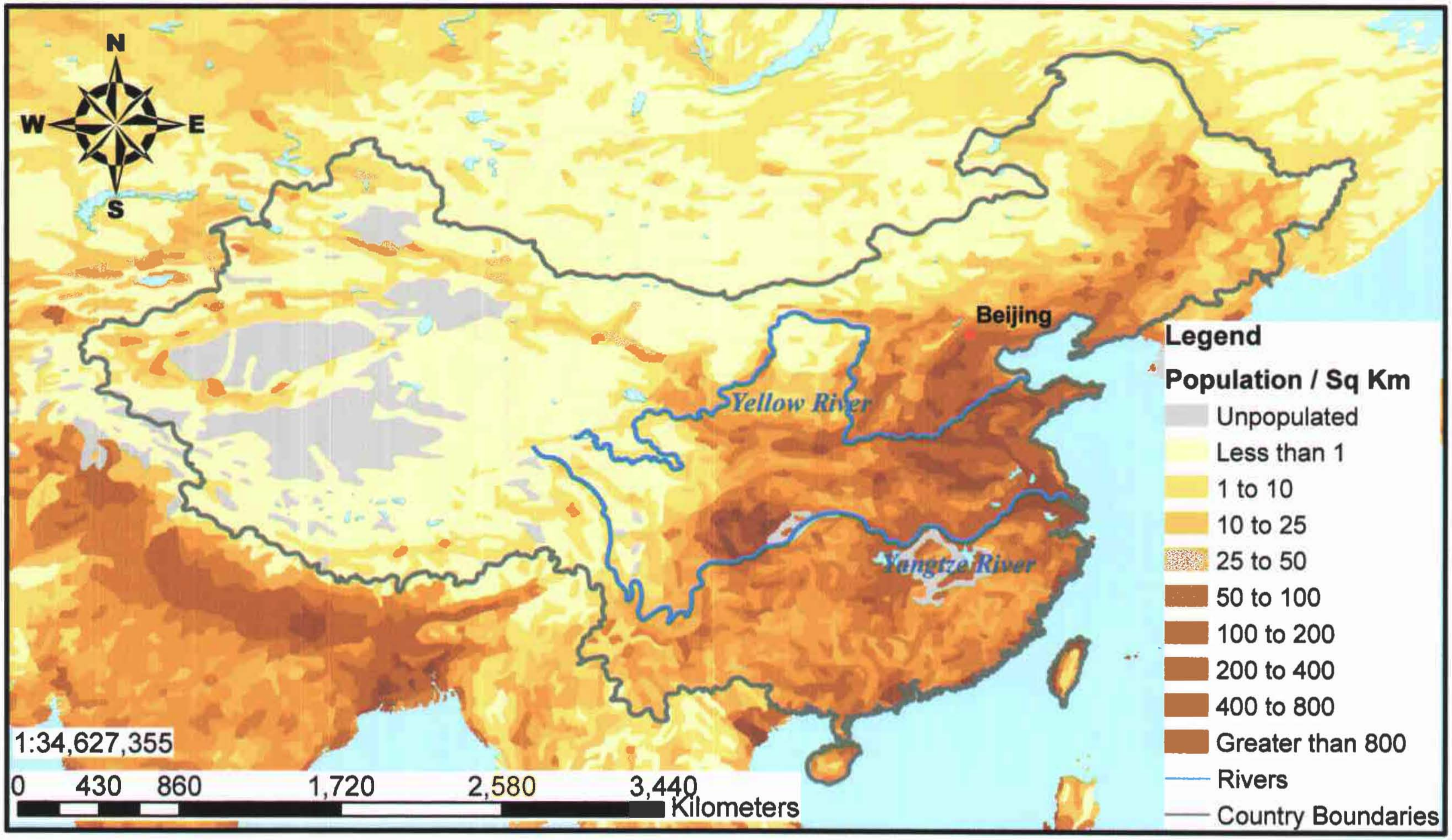
[a] China's total population 1.27 billion in 2000, 1.14 billion in 1990, 975 million in 1979.

Figure 1-1. The South-to-North Water Diversion Scheme and Satellite Image of China



Base Map Source: Environmental System Research Institute, Inc. ESRI_Satellite and ESRI_World.
Source: Modified from Ministry of Water Resources. P. R. C., 1995.

Figure 1-2. Population Distribution



Source: Modified from Environmental System Research Institute, Inc. ESRI_Pop.

transfer project were to fail, the repercussions of a faltering nation the size of China could have significant effects globally.

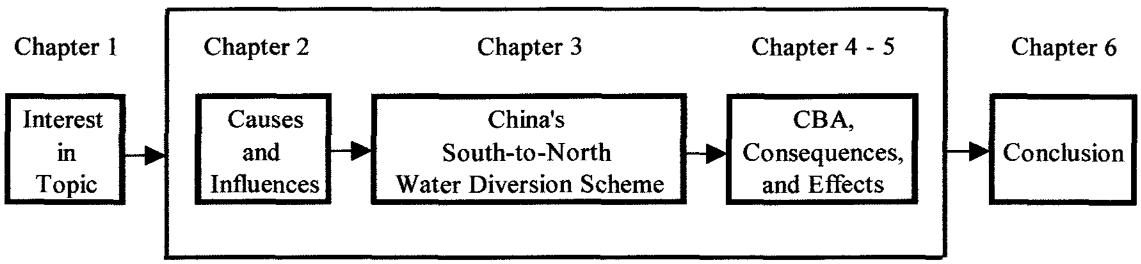
Table 1-1. GDP Growth for Selected Countries – percent (1996 - 2001)

	1996	1997	1998	1999	2000	2001
China	**9.6**	**8.8**	**7.8**	**7.1**	**8.0**	**7.3**
The United Sates	3.6	4.4	4.3	4.1	3.8	0.3
Japan	3.5	1.8	-1.1	0.7	2.4	-0.2
Korea	6.8	5.0	-6.7	10.9	9.3	3.0
Indonesia	7.8	4.9	-13.7	0.3	4.8	3.3
Malaysia	10.7	7.3	-7.4	5.8	8.5	0.4
The Philippines	5.8	5.2	-0.6	3.4	4.4	3.2
Singapore	7.7	8.5	-0.1	6.9	10.3	-2.0
Thailand	5.9	-1.4	-10.5	4.4	4.6	1.8
Viet Nam	9.3	8.2	5.8	4.8	6.8	6.8
Australia	3.2	3.6	4.3	5.1	3.2	2.7

Source: Modified from APEC Economic Committee, 2002

The objective of this study is to analyze the environmental and socioeconomic factors of the South-to-North Water Diversion Scheme in China. There are a few large-scale inter-basin water diversion projects around the world that have already been completed; however, these systems have yet to be fully analyzed and evaluated in terms of long-term social and environmental effects. This thesis aims to provide a cost-benefit analysis (CBA) regarding this scheme's likely environmental and socioeconomic consequences. Given the South-to-North Water Diversion Scheme, one can address three sets of issues regarding it. First, what are China's concerns? More specifically, what influenced China in its decision to execute the scheme? Second, what are the costs and benefits of the scheme? Given the fact that China has made the decision to go ahead and build the scheme, and given the dearth of significant impartial data available to the public with which one can verify whether or not the benefits outweigh the costs, how can one determine if the benefits are likely to outweigh the costs, and if they do not, what are the implications? Third, what are the choices for China's future course in water management? Figure 1-4 illustrates how the thesis is organized to address these issues.

Figure 1-3. Organization of the Thesis



This topic, China's South-to-North Water Diversion Scheme, is chosen because of the enormity of the scale and complexity of the project. My study will contribute to knowledge in three ways. First, this study increases awareness of the current situation of water resource scarcity in China. As part of this, I will draw attention to: 1) the enormous scale of construction involved, 2) the social, political and environmental impacts of the projects, and 3) a decision-making process to evaluate alternative water-transfer schemes. Second, my study will provide a general view of China's water-transfer scheme as a case study and guideline for future water-transfer endeavors. Water shortage is not only China's problem; most countries are facing similar problems. More water is needed to produce more food and goods in order to support an increasing global population. These agricultural and industrial activities require large amounts of water; therefore, good water management is directly related to a country's sustainable development. How China solves or addresses its problem may serve as a guide for other countries. Finally, my study will illustrate a procedure for decision-making through this water diversion project, but it should be noted that the decision making process used for this study does not necessarily represent the decision making process utilized by the China.

Water resources are essential for everyday life and furthering economic growth in China. Manufacturing, agriculture, transportation, and commerce all require water, as do electricity generation, recreation, the residential sector, and other uses. Given China's rapid population growth and economic development, the quality of water has deteriorated and the supply of water can no longer meet demand, due to flaws in the management of this resource and an outdated infrastructure (Brown, 1995; Johnson, Liu and Newfarmer, 1997; "Issues Surrounding," 2001; Murphy, 2003). In China, many resources are unevenly distributed, and water is not an exception. There is plenty of water but limited land for productive purposes in the south, while in the north, water resources are limited yet vast tracts of land lie unused. It seems there is a huge potential to increase agricultural and industrial production if China can alleviate the problem of unequal water and land distribution. In fact, a south-north water-transfer project was first proposed almost 50 years ago to address this problem, and after much heated political debate, it has finally met the technical requirements in order to start construction in 2002 (MacLeod, 2001; "Water Diversion," 2001).

Water and Related Resources in China

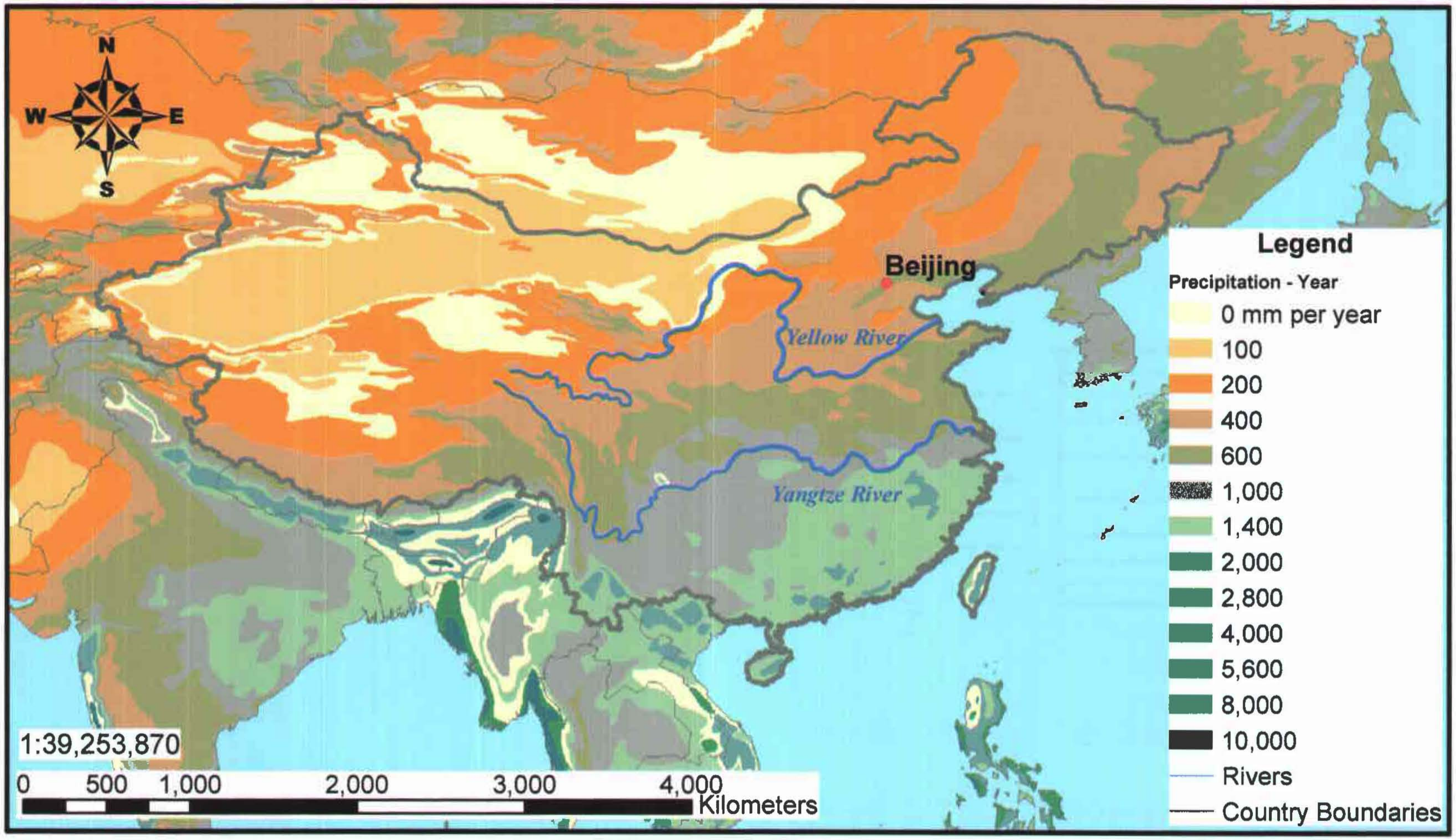
The biggest problem regarding natural resources is often summed up as unequal distribution. China's water resources can be assessed on three points: general condition, climatic conditions, and productivity conditions.

Freshwater resources in China are scarce relative to those of other nations. Although China is considered sixth in the world in regards to absolute quantity of total water resources with 2.8 trillion m^3 available, its per capita availability is only 2,249 m^3, one-fourth of the world's average (Li, 1999). In regards to the volume of water for agriculture, only 1,965 m^3 is available for an area the size of 1 *mu*[◊] (one-sixth of an acre), or 2.95m^3 per m^2, which is half of the world's average (Yan ed., 1999). By the year 2030, China is expected to have a population of 1.6 billion, thereby reducing the per-capita water supply to only 1760 m^3, and water available per *mu* will be down to 1900 m^3 (Ministry of Water Resources [MOWR], 2000). Therefore, without significant increases in water-use efficiency, China will almost certainly experience much greater water stress than at present.

China's precipitation is largely influenced by monsoonal winds, which generate uneven water resource distribution both spatially and temporally (Figure 1-3). Monsoons from the East and South China Seas produce a large amount of precipitation in the southern parts of China. The average annual precipitation in the south is more than 1000 mm, among which, the Yangtze valley receives an annual average of 1.93 trillion m^3, or 1.07 m^3 per m^2, which is 31.2% of the nation's total volume of water falling on an area

[◊] *Mu*: unit of area. (1*mu* = 667m^2)

Figure 1-4. Precipitation Distribution



Source: Modified from Environmental System Research Institute, Inc. ESRI_Precip_Yr.

that is only 18.8% of the total land in China (Qian and Zhang eds., 2001). In fact, monsoons have caused terrible flooding since ancient times in China.

In contrast, the climate in the north is very dry, with little precipitation, and high evaporation. The average annual precipitation is 303 mm in the northeast, 127 billion m^3 of water over an area of 960,000 km^2, or 0.13 m^3 per m^2, and the water surface evaporation rates at the three main rivers (Huai, Hai, and Yellow) fall between 800 - 1,200 mm, so only 26% of the precipitation will be available as ground water (Qian and Zhang eds., 2001). The average annual precipitation gradually decreases as one moves from east to west, with the northwest being the driest part of China. For example, in the Tarim Basin, it ranges from 200 mm at the rim of the basin, to 25 mm at the center of the basin (Qian and Zhang eds., 2001). The average amount of precipitation in the northwestern part of China is 50 – 70 mm annually. The annual average evaporation rate exceeds 2,000 - 3,000 mm in most parts of this area, so annual water scarcity reaches 50-200 mm depending on the area. Though northeast and north China are much closer to the seas than inland China in the northwest, since northeast and north China are located at high latitudes, the monsoon influence is restricted primarily to the southern parts, further contributing to the limited precipitation.

In regards to the temporal distribution, in the south, about 60% of the annual total precipitation occurs during the six to seven months of the summer season (Li, 1999). In the north, 70-80% of the annual precipitation comes during the two to three months of summer (July-October), and only 10% of it comes during the spring (Qian and Zhang eds., 2001). It prevents winter and spring agricultural productivity because of insufficiency of water. Therefore, the monsoon climate greatly affects China's water resource conditions. Summing up, the southern parts have a relatively bountiful supply of water resources, and the northern parts have a serious water shortage. Thus, there is a huge difference in water availability between north and south.

Other resources are also unequally distributed in China. With respect to land and mineral resources, the majority of arable and cultivated land, and minerals such as coal, iron, and oil are located in the northwest, northeast, and north China. According to Yan (1999), these areas are where 45% of the total population lives and have only 19% of the total water resources in China. Also, 63% of China's total area is in the north, and 64% of total cultivated land in China is located within this area. In addition, 52% of all coal, 29% of all iron, and 38% of all oil are produced in these regions (Yan ed., 1999). Most of the industrial energy use comes from coal in China. Due to the abundant coal production, the north became a popular industrial location. In turn, the serious water shortage in north China hinders industrial activities. Finally, northern China accounts for 43.4% of the country's GDP (MOWR, 2000). The conditions in the Yellow River, the Huai River, and the Hai River basins are even more alarming. The total area of these river basins contain 39.4% of the farmland, 34.7% of the population, and 32.4% of the GDP, but 7.7% of the nation's total water resources (MOWR, 2000). In contrast, south China contains 36% of the arable land and cultivated land (Yan ed., 1999). Of China's total production of coal, iron, and oil, the south accounts for 11%, 40%, and 1%, respectively, and the South's share of the GDP is 54.8% of the country (MOWR, 2000). The southern regions have 55% of the total population and 81% of the nation's total water resources (Yan ed., 1999). It is clear that more water is needed to exploit and harness the resources in the north.

Table 1-2. Resources Distribution Summary: North vs. South

	Population	Farmland	Coal	Iron	Oil	GDP	Water resource
North China (Yellow, Huai, Hai River)	45% (34.7%)	64% (39.4%)	52%	29%	38%	43.4% (32.4%)	19% (7.7%)
South China	55%	36%	11%	40%	1%	54.8%	81%

In brief, southern China is distinctive for a large population, relatively poor supply of mineral resources, and abundance of water resources. Northern China, on the other hand, is distinguished by vigorous economic activity and abundant natural resources, but very serious water-shortage conditions. This disparity is likely to impede China's further economic growth.

Conceptual Framework

The conceptual framework of this study derives from an evaluation of its benefits and costs, defined broadly. The resulting cost-benefit analysis (CBA) is executed through the Analytic Hierarchy Process, a more detailed description of which is provided in chapter 5. Such a cost-benefit analysis (CBA) builds on and borrows from a number of different intellectual currents in the discipline. In particular, it reflects the themes of regional geography and area studies, society-and-environment, spatial analysis, and resource allocation.

First, with respect to the regional geography and area studies, history has shown that for as long as organized civilizations have existed, people have attempted, with varying degrees of success, to understand their surrounding environment. In doing so, they noticed that some places and regions were so different from each other that they could be considered as defining fundamentally different landscapes, and that the Earth's surface was in turn composed of a "crazy quilt" of such landscape units. The phrase "areal differentiation" was first introduced by Sauer in 1925 to describe this view. This thesis furthers the description of one of those "landscape patches" — China.

Second, in the society-and-environment theme, geographers often attempt to focus on relationship between man and his environment, as opposed to either human or environmental phenomena alone. How people, from individuals to societies, interact with water — their attitudes towards it, the ways they conserve, exploit, and manage it — has received much attention in the geographic literature. For example, based on the ideology that rain water is given to people to use for free, since 1950s China's people have engaged themselves in extracting river water for the irrigation and industry, discharging wastewater into the river, exploiting new wells, and over pumping of groundwater, along with exploitation of forest resources, and many other economic activities as indirect uses of water (Liu, 1998; Vermeer, 1998; Huo, 2000; Brown, 2001; Qian and Zhang eds., 2001). As a result, China has serious environmental issues such as pollution, land subsidence, deforestation as well as social issues that relate to environment (MacLeod, 2001; Qian and Zhang eds., 2001).

Third, with respect to the spatial analysis theme, it focuses on the study of past, current, and potentially new or future spatial processes and structure in pursuit of quality, usefulness, and sustainability of landscape. In other words, the main objective of this theme is how to improve on existing spatial processes and structures through modification and improvement.

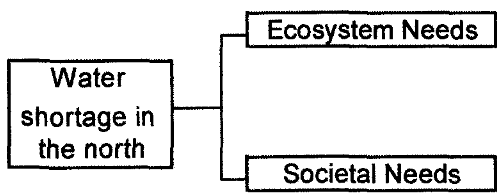
Finally, with respect to resource geography, the geographer's study of "resources" can be done from any or all of the aforementioned perspectives, areal differentiation, society-and-environment, and spatial analysis. In regard to this thesis, developed countries have already built and have been operating inter basin water diversion schemes, and obtained both positive and negative outcomes. In China during the 1950s, Chairman Mao came up with the idea of transferring water from the South to the North (Li ed., 1999; "South-North Water Diversion Project," 2001), and a societal and environmental assessment of this scheme based upon precedent instance is the main focus of this thesis. Therefore, geographers focus their studies on policy-making, decision-making, management of water efficiency and conservation in order to assess gigantism and techno-hubris with geographic and statistical analysis.

My study integrates these traditions of geographic inquiry and tries to expand their scope by examining the appropriateness of water management in China from various points of view. My "data" consists of empirical studies and expert assessments reported in the literature, and I link those assessments to a set of goals and criteria to which Chinese water management is thought to respond. That linkage is made through the Analytic Hierarchy Process (AHP), which helps one to assess the negative and positive societal and environmental consequences of China's SNWDS, and how they are distributed spatially and sectorally. In Chapter 5, I provide a more detailed description of AHP.

CHAPTER 2
A HIERARCHY OF WATER RESOURCE DISTRIBUTION PROBLEMS

Crystallizing China's concerns reveals the objectives of the South-to-North Water Diversion Scheme, which with regard to water resource management can be categorized in many ways. However, these problems ultimately boil down to conflicts between environmental protection and economic growth and which will get priority over the other. Therefore, following precedent, Ecosystem Needs and Societal Needs will be used (Figure 2-1). The dotted line represents the progression of the hierarchy.

Figure 2-1. Evolution of the Objectives Hierarchy: Ecosystem Needs and Economic Needs



Ecosystem Needs

With respect to ecosystem needs, the river system in North China gets into a critical situation. With the Yellow River running dry in recent years, a sense of urgency has arisen to solve the north's water shortage problems. Historically, the Yellow River in Northern China has presented chronic water problems. Traditionally, the river has overflowed its bank repeatedly since ancient times, because of the heavy load of the loess silt in its water that raised the riverbed and caused the river to flood. However, in recent years, the river water has been extracted mainly for the purposes of irrigation, industrial use, and household consumption, to the point that the river is drying up for part of each year (Huo, 2000; McCormack, 2001). The number of days that the river water failed to reach the Bohai has risen over the past three decades from 15 days in 1972 to 226 days in 1997 (Liu, 1998; Vermeer, 1998; Huo, 2000; Brown, 2001; Qian and Zhang eds., 2001). More detailed reports from a Chinese publication state that the average length the river has dried up was 242 km, 256 km and 438 km in the 1970s, 1980s,and 1990s, which has increased to 700 km as of 1997 (McCormack, 2001; Qian and Zhang eds., 2001). In turn, the amount of water that has flowed into the sea has decreased from 41 billion m^3 before the 1980s to only 1.5 billion m^3 in 1997 (Qian and Zhang eds., 2001). In order to maintain the flow of the Yellow River, it requires at least 6 billion m^3: 5 billion m^3 of water for the ecosystem and 1 billion m^3 for evaporation loss (Qian and Zhang eds., 2001). The river system in north China has deteriorated and shown environmental stress in various ways, which has resulted in inadequate flow.

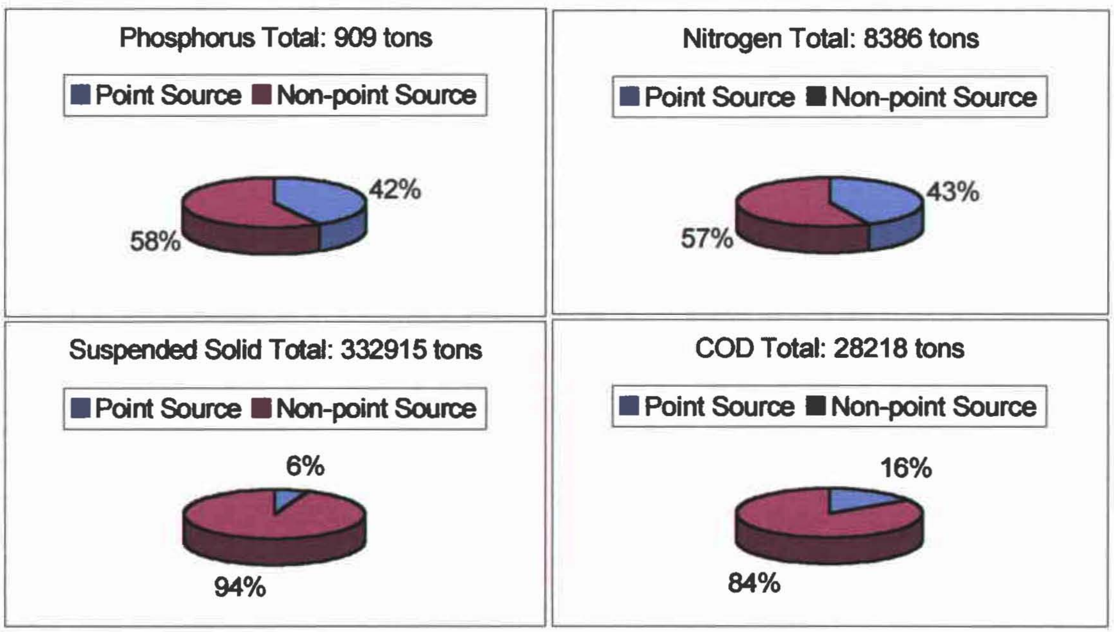
Within the river system, water pollution is a serious problem in China. Especially in the north, which has the majority of the population and human activities such as agriculture and an industrial nucleus, the surface water quality is poor (Zi, 2000). Johnson, Liu and Newfarmer (1997) reported that the Yellow, Huai, and Hai rivers in the urban areas were quite polluted and the water were unsuitable for the raw source of potable water. According to the five-grade fresh water quality standards that have been defined by government, it did not meet even the lowest standard (grade 5) for irrigation water, and only 8% of the water in the river system in the north met the standard for direct human contact (grade 3 or better) (Johnson, Liu and Newfarmer, 1997; Hu, 1998; Nickum, 1998; Qian and Zhang eds., 2001). Regarding organic contaminants, the water condition was reported thusly: "[t]he potable water for about 700 million people contained more *E. coli bacilli* than the state standards allow and about 170 million people are drinking water polluted by organic matters" (Hu, p.49, 1998).

The pollutants are coming from three main sources: industrial, agricultural, and municipal waste. Although industrial waste was somewhat regulated by suspending business if the factory did not meet the standard, large quantities of industrial waste were discharged into the river. The industrial waste discharged into the river, which contained a variety of major pollutants, exhibited COD and BOD concentrations 34 and 22 times higher than the average from developed countries (Qian and Zhang eds., 2001).

Agricultural wastes also account for significant water pollution. Multiple cropping has been achieved through increased use of chemical fertilizers, pesticides and herbicides, but excessive use of these chemicals for agricultural production threatens the ecological balance and water quality (Johnson, Liu and Newfarmer, 1997; Ash and Edmonds, 1998; Edmonds, 1998; Qian and Zhang eds., 2001). In fact, by 1995, 36 million tons of chemical fertilizer and 1 million tons of agricultural chemicals were used (Johnson, Liu and Newfarmer, 1997; Qian and Zhang eds., 2001). In addition to these magnitudes, China uses fertilizer of poor quality, which is cheap but easily washed out into the river system, accelerating the pollution problem in the river system. In China, much of the untreated sewage used to be collected and applied to the fields as agricultural fertilizer; however, now sewage is dumped into the river system (Banister, 1998). Only 13% of municipal wastewater is treated, and the rest is discharged into the river system without any treatment (Qian and Zhang eds., 2001). This non-point source pollution is becoming serious because the amount of municipal wastewater discharge has been increasing; in fact, it nearly tripled between 1981 and 1995 (Banister, 1998; Zi, 2000; Qian and Zhang eds., 2001). Figure 2-2 shows the main pollutants that flow into a lake called Dianchi in Yunnan Province in 1994 as an example.

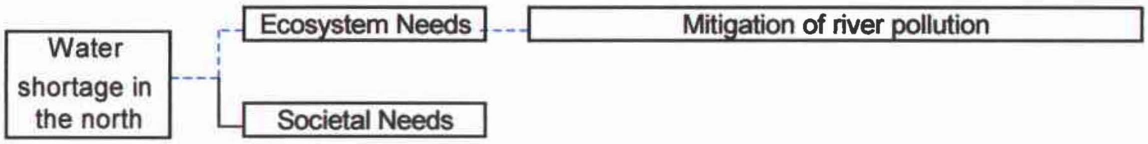
In short, China wants to send clean water to the north in order to sweep away the pollutants from the rivers, which have been drained dry and emit an "unbearable stink" from the residual sludge and deposit a slug of pollutants into the near ocean ("Beijingers," 2002). The clean water will also help repair the damage to the environment by restoring the natural dilution process (Figure 2-3).

Figure 2-2. One Example of Comparison Among Pollutants in the Lake Dianchi



Source: Qian and Zhang, eds. 2001.

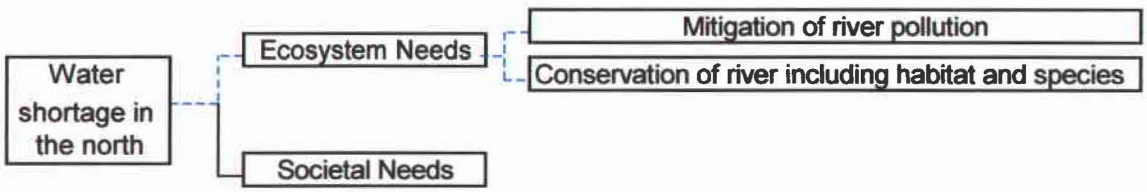
Figure 2-3. Evolution of the Objectives Hierarchy: Including "River Pollution"



Stagnant water in the river contributes by accelerating the building up not only of sediment, but polluted sludge in the dry riverbeds as well. To make matters worse, these conditions destroy living estuaries and nursery places for fish and plants in and along the rivers. China is well known as a country rich in biodiversity, in terms of both the number of different species and the genetic variety within species (Harkness, 1998). The value of the biodiversity historically has been incredibly important in China. Chinese used fish, birds, animals, and plants for food as well as for medicine, clothing, fuel and construction materials (Harkness, 1998). However, under Mao, wildlife conservation was deemed a lower priority than economic growth, so riparian life such as fish, birds, plants and animals in the north are in danger of extinction (Edmonds, 1999). For example, a report about fish that died off at the Guanting Reservoir in Beijing in 1971 aroused the environmental awareness to Chinese people (Harkness; 1998). Another example from a Chinese newspaper reported the sharp decline in the number of migratory birds and other species in the northern rivers over the past years due to habitat destruction ("More Rare Birds," 2003). In recent years, China recognized the importance of maintaining the natural ecological balance and the genetic diversity. They tried to protect riparian life; however, it was not easy without water (Hu, 1998).

In order to save habitats from deterioration of the surrounding river environment, China wants more water in the north to restore riparian habitats and the wildlife populations inhabiting there. Healthy ecological balance in the northern rivers would be maintained by a continuous flow of clean water to the sea throughout the year (Figure 2-4).

Figure 2-4. The Evolution of the Objectives Hierarchy: Including "Habitat Destruction"



Geographically, China's forests are mainly located in the northeast, which are facing a serious water shortage and in the southwestern part of the nation (Shi and Xu, n.d.; Harkness, 1998). One of the most important functions of forests is to purify rainwater and enhance groundwater recharge. They also slow the rate of runoff, reduce flood hazard and soil erosion, and reduce drought potential during the dry seasons. Through their role in the hydrological cycle, forests moderate the flow of water through ecosystems. (Brown, 1995 and 2001). This chain of events is indispensable for all levels of water in circulation (hydrological cycle). However, the forest area in the northeast of China has been sharply reduced since the Mao years of the 1950s, even though it has been increasing after the 1970s due to significant afforestation and reforestation. The quality of the forest remains low, however (Nickum, 1998). In the declining period, this heavy exploitation of forest resources accompanied on increasing market demand due to population growth. Also, in the late 1960s and early 1970s, campaigns for local self-sufficiency in food production gave impetus to the deforestation of sloping land for cultivation and pastures (Nickum, 1998). As a result, land cover and land use changed within a short period of time, especially in the northeast, which has seen the most significant decline in forest area. (Shi and Xu, n.d.). Brown explained that there is a justifiable reason for the declining rainfall in the north, which was caused by deforestation resulting in the reduction of moisture transfer (2001). In other words, deforestation could also be responsible for changes in climate because it diminishes precipitation, so the atmosphere dries and becomes hotter (McCormack, 2001). As a result, deforestation leads to desertification, one of the most serious manifestations of environmental deterioration, which can have a variety of adverse environmental effects. Moreover, declining rainfall contributes not only to desertification, but also dust bowl conditions as well (Brown, 2001; "China Gripped," 2002). Joint research among China, Australia, and the United States verified that the desert in northern China expanded 300 km to the south (Li, 2002). Desert land has been expanding at the rate of 6.14 % annually since 1990s, and that 8,560 km^2 of grassland, which is about 6% has already become desert, and 6,507 km^2 of land has also been degraded into desert due to overgrazing, over cultivation, deforestation, and poor irrigation practices (MacLeod, 2001; "China Gripped," 2002; "Desertification," 2003; "Land Desertification," 2003). Because of the desertification problem, in 2002 alone an area of over 1,500 km^2 was so seriously eroded that it added 500,000 tons of sediment to the Yellow river and cut the water supply by 15% ("Desertification," 2003). There is a great deal of evidence that the forest system is no longer sustainable, so that it no longer fulfills its natural function properly. Another reason that northern China wants more water is thus to ameliorate environmental losses and help prevent further desertification (Figure 2-5).

Figure 2-5. The Evolution of the Objectives Hierarchy: Including "Desertification"

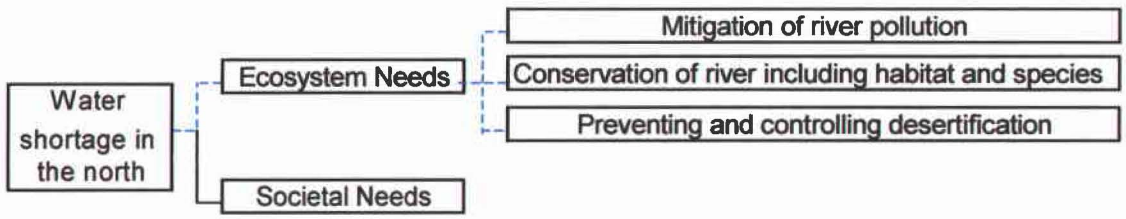


Figure 2-5 represents and summarizes the environmental reasons for China's water-transfer plans. In the following section, I will discuss the societal needs, which have also prompted the development of these plans.

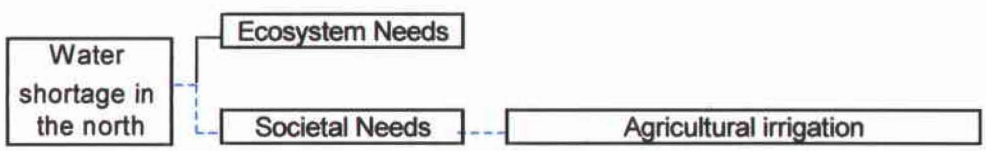
<u>**Societal Needs**</u>

China is a rapidly developing country with vigorous economic activity which requires a great volume of freshwater and electricity. This level of economic development is not restricted to China. A universal characteristic of the intensive stage of national economic modernization requires large quantities of water and electricity (Smil, 1998).

China is an agricultural country, and since 1980 it has been the number one producing nation of agricultural goods, although compared with other nations, its agricultural efficiency is much lower (Nickum, 1998; Qian and Zhang eds., 2001). More than 70% of the nation's freshwater is used for irrigation, and this water is wasted moreso in china than in developed nations because of the aging and disrepair of the irrigation infrastructures and facilities (Qian and Zhang eds., 2001; Pan and Meng, 2003). If China improves its efficiency to the levels of developed nations, nationwide the water used for irrigation could be reduced by more than 10 billion tons a year (Pan and Meng, 2003). This is important because around 2030, China's population will reach its forecast peak of 1.6 billion, and demand for both food and water are also expected to reach their highest levels (Qian and Zhang eds., 2001). In order to support 1.6 billion people, China needs about 700 million tons of food every year, and they need about 900 million *mu* (600 thousand km^2) to yield 700 million tons of agricultural product (Qian and Zhang eds., 2001). Currently, their agricultural area is 1.5 billion *mu* (1 million km^2 or 100 million hectares); therefore, China has enough agricultural land (Cheng and He eds., 1990). However, two-thirds of China's cropland is concentrated in the north, which has only has one fifth of the surface water. This regional imbalance between the distribution of the water and the cropland causes severe water scarcity in the north (Brown, 1995; Liu, 1998). For example, in the 500,000 km^2 of the North China Plain, which is 5.13 % of China's area, Beijing, Tenjin, Hebei, Shandong, Henan, have the most serious water shortage problems. The population of that area is 265 million, and there are 500 million *mu* (334 thousand km^2 or 33.4 million hectares) of cultivated land. This area produces 109.4 million tons agricultural products each year, which is about 22% of the nation's total output (Qian and Zhang eds., 2001). More specifically, their main products, wheat, corn, fruits, eggs, and meat and dairy products, represent 50%, 33%, 33%, 50%, and 25% of the nation's total output respectively (Brown, 2001; Qian and Zhang eds., 2001). Seventeen percent of the harvest, the equivalent of 66 million tons of grain, is lost each year because of the water shortage in China, and in the year 1997, the total loss was $16 billion (McCormack, 2001).

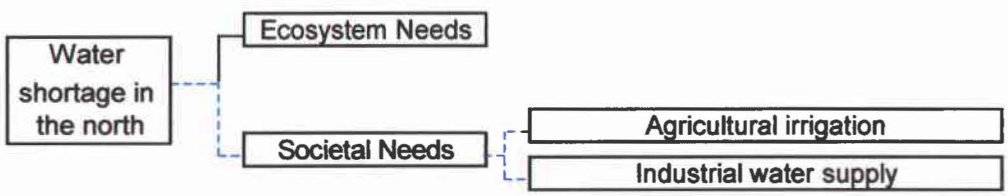
Thus, in order to have new agricultural land, maintain current agricultural land and increase its productivity, China wants more water to support its 1.6 billion people. Water scarcity for agriculture indirectly leads to food scarcity not only in China but perhaps also in the entire world if China is unable to support its people and needs to import more food. Farmers may also face a water distribution problem among other economic sectors. The economic values of water use do not favor agriculture because industry and urban areas can afford to pay 50 to 100 times as much for water as can farmers (Brown, 2001). Figure 2-6 thus shows one of the major societal needs to which the water-transfer scheme responds.

Figure 2-6. Evolution of the Objectives Hierarchy: Including "Irrigation"



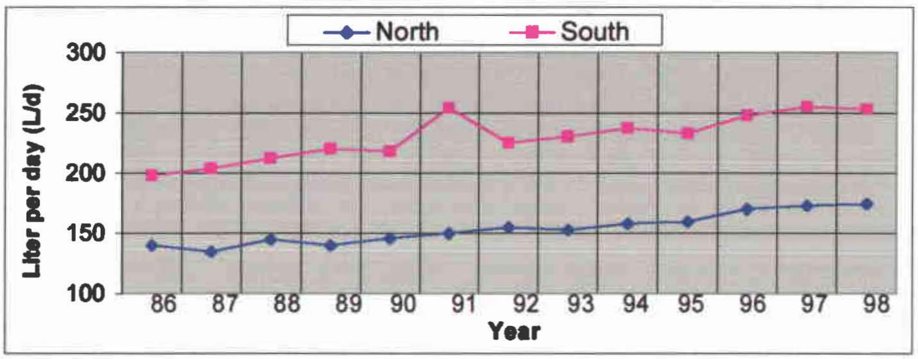
China's industrial water use reached its highest point of 31.4 billion m^3 in 1994. After that year, it has been decreasing due to the development of water recycling technology and increased efficiency (Qian and Zhang eds., 2001). However, China needs more water for industries. A recent Chinese newspaper reported that China lacks more than 30 billion m^3 of water, which inflicts a 230 billion yuan ($28 billion) loss on industrial output per year (Wang and Deng, 2001; "Water Shortage," 2003). Further, by the year 2010, China is expected to have 126 million more people and with this population growth, industrial water use is projected to increase by 62% from 127 billion m^3 to 206 billion m^3 (Brown, 2001). It is difficult to generalize China's industrial water use because, due to the vast size of the country, each area varies in its type of industrial water use. It depends on climate conditions, water resource conditions, population density, and levels and types of industrial development (Vermeer, 1988; Qian and Zhang eds., 2001). However, one general difference in industrial water use between the south and north is industrial water-recycling rates. In 1997, data showed that in the north, 76% of industrial water was recycled, but in the south, only 33% of it was recycled (Figure 2-9. A). From this fact, although there is considerable room for technological improvement, industrial activities continue to require large amounts of water. China's concerns about industrial water use are reflected in their quest to increase water efficiency as well as the absolute quantity of water needed (Figure 2-7).

Figure 2-7. Evolution of the Objectives Hierarchy: Including "Industry"



With respect to municipal water use, the data in 1997 showed that 17.6 billion m^3 of water went for municipalities in China (Qian and Zhang eds., 2001). The 17.6 billion m^3 of municipal water use breaks down into two main categories, households and public (city) use. Households account for 11.4 billion m^3 (65%), and public use is 6.2 billion m^3 (35%) (Qian and Zhang eds., 2001). Municipal water use in China is continuously increasing along with urbanization. It reflects improvements in the accessibility of water and sanitary facilities. For instance, between 1986 and 1997, municipal water use in China increased from 7.1 billion m^3 to 17.6 billion m^3, at an annual rate of 8.6 %, or 248 % over the eleven-year period. During the same period, population increased by about 6.1 %; thus, annual water use per capita increased by 2.3%. As a result, average daily water use per capita increased from 165 liters to 213 liters (Qian and Zhang eds., 2001).

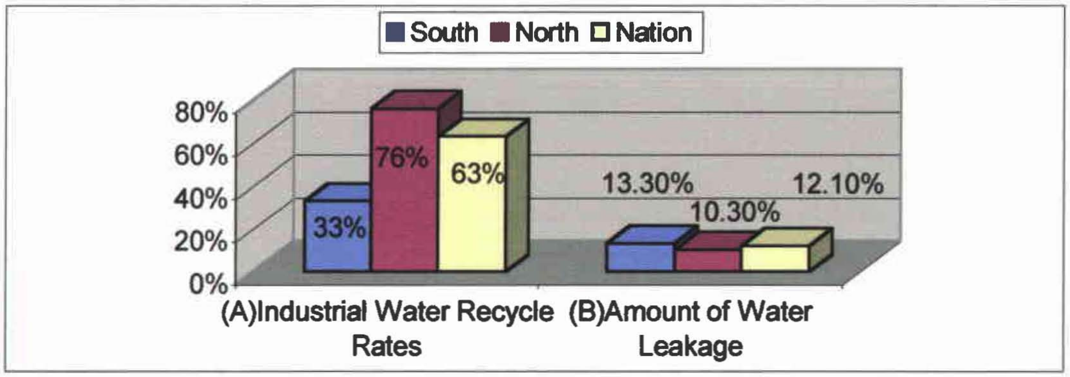
Figure 2-8. Changes in Per Capita Municipal Water Use Between Northern and Southern Cities

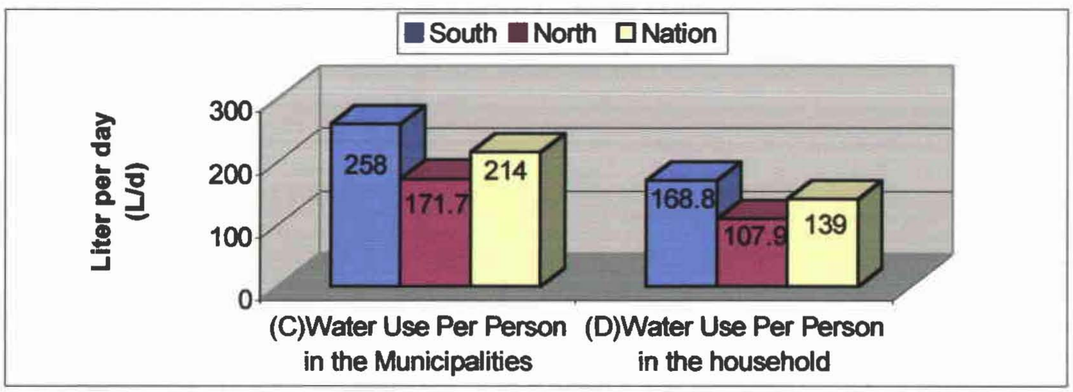


Source: Qian and Zhang, eds. 2001. p. 130.

Due to the climate and water condition differences, there are big differences in municipal water consumption between southern and northern China. Southern cities use more water than northern cities (Figure 2-8). Municipal (public and household together) water use per person is 50% higher (Figure 2-9. C), and household water use per person is 56% higher (Figure 2-9. D) in the south (Qian and Zhang eds., 2001). In addition, water leakage in the southern cities is 29% higher than in the northern cities, and there is an inverse relationship between the size of the city and the amount of water leakage (Figure 2-9. B) (Qian and Zhang eds., 2001). Therefore, since population growth and per-capita water consumption are expected to continue rising, China wants to transfer water to the north in order to meet its growing demand and increased living standards (Figure 2-10).

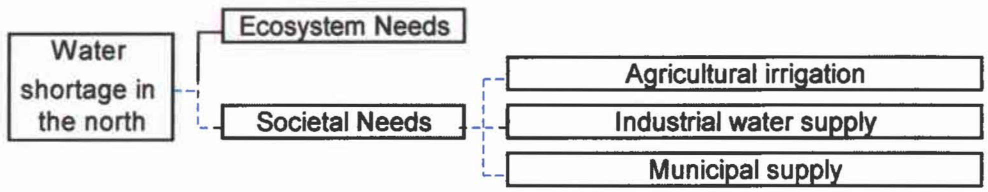
Figure 2-9. Water Use Comparison Between South and North





Source: Qian and Zhang eds., 2001

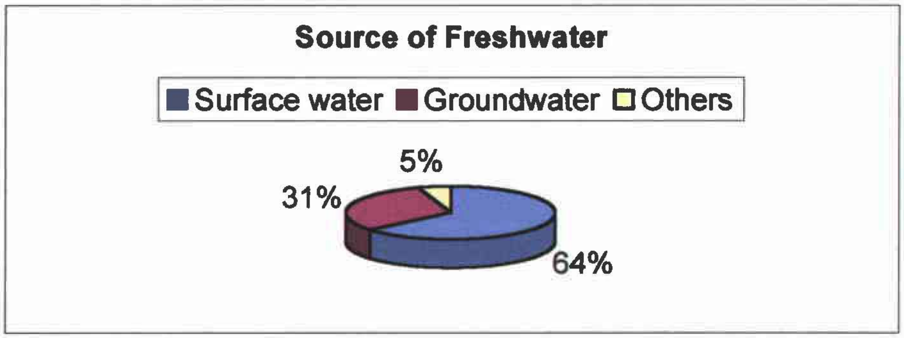
Figure 2-10. Evolution of the Objectives Hierarchy: Including "Municipality"

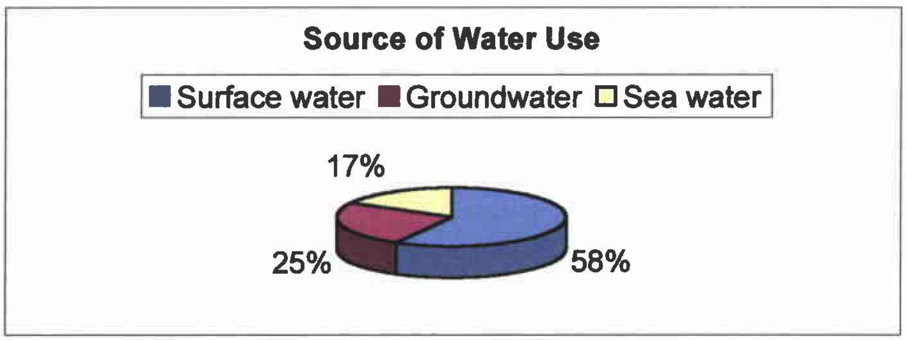


Over pumping causes other grievous problems. Land subsidence occurs in 30 cities and counties in northern China, and it not only damages buildings and other structures, but also reduces aquifer storage capacity (Liu, 1998; Nickum, 1998; Li, n.d.). For example, Tianjin, a port city near Beijing, has reported two meters of land subsidence due to the over pumping of groundwater (East-West Center, 1988; Brown, 1995; "South-North Water Diversion Project," 2001).

Generally speaking, groundwater has been widely developed, and its availability in northern China is relatively high (Zhang et al., n.d.). However, the water table of the aquifer has been dropping with frightening speed in the north because of over pumping (McCormack, 2001). For instance, the water table in the North China Plain, where 25% of grain in China is produced, is falling 1.5 meters per year, and in Beijing, it has fallen by 59 meters since the 1960s (Brown, 2001). The official data on the actual water supply situation in the north in 1997 disclosed that water use totals were 205.3 billion m^3, while the surface water totals were 140.4 billion m^3, 64% of the total supply, groundwater totals account for 64.3 billion m^3 or 31%, and 0.67 billion m^3 came from other sources (Figure 2-11) (Qian and Zhang eds., 2001).

Figure 2-11. Water Supply Situation in 1997



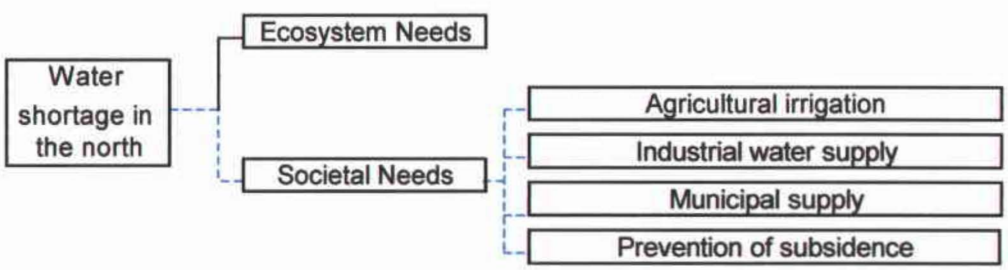


Source: Qian and Zhang, eds. 2001.

Each year, ground water in northern China, as a whole, is over extracted by approximately 8 billion m^3. The breakdown of this is 4 billion m^3 from the Hai River basin, which covers all of Hebei province including Beijing and Tianjin municipalities, 2 billion m^3 from the Huai River basin, and 2 billion m^3 from other parts of the north China plain (Johnson, Liu and Newfarmer, 1997; Brown, 2001; Qian and Zhang eds., 2001). Water is mainly used for irrigation in order to compensate for the lack of surface water. In the severely over pumped Hai River basin for example, 55 billion m^3 of water is used in the basin annually, but there is only 34 billion m^3 of sustainable water supply, so the 21 billion m^3 deficit comes from ground water mining although the ground water table has dropped by 100-300 meters in the basin (Brown, 2001). It shows that the natural sustainable yield of water, which is the recharge rate, cannot catch up with the rate of extraction from aquifers, and the gap between these two values widens. As a stopgap measure for the water shortage and decreasing water table, exploitation of new wells has been desperate. In fact, 221,900 new wells were drilled because 99,900 out of 2.6 million wells were abandoned due to their running dry (Brown, 2001). In addition, overpumped wells near the coast have suffered from seawater intrusion, and the damage reached an area 2,000 km^2, which is now below the salt water table (Liu, 1998; Nickum, 1998; Qian and Zhang eds., 2001). Intrusion increases salinity in the soil, and adversely affects agricultural productivity.

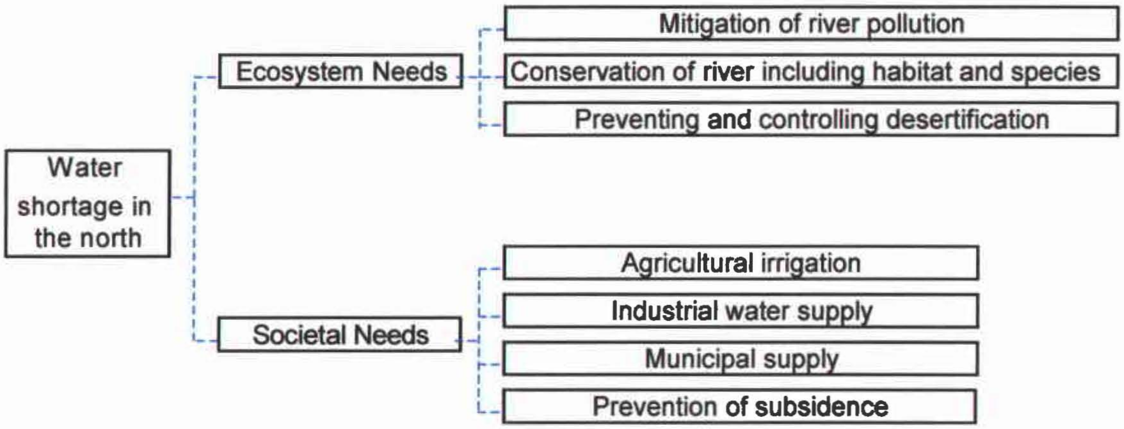
Therefore, in order to continue to utilize groundwater resources, China wants to have more river water so that they do not have to mine groundwater, and can maintain low salinity and pollution levels as well as prevent land subsidence (Figure 2-12).

Figure 2-12. Evolution of the Objectives Hierarchy: Including "Subsidence"



In this chapter, I have illustrated China's arguments in regards to the water resources from the ecosystem and societal needs, as summarized in Figure 2-13. China contends that the scheme can help meet each of these needs. China is now following a development path similar to that the developed nations have already have been experiencing. China needs to find a good balance between economic growth and environmental protection at the height of the nation's economic growth trajectory. In the next chapter, I will describe what China intends to do to mitigate the water shortage problem in the north: the South-to-North-Water Diversion Scheme.

Figure 2-13. Overview of China's Water Resource Needs



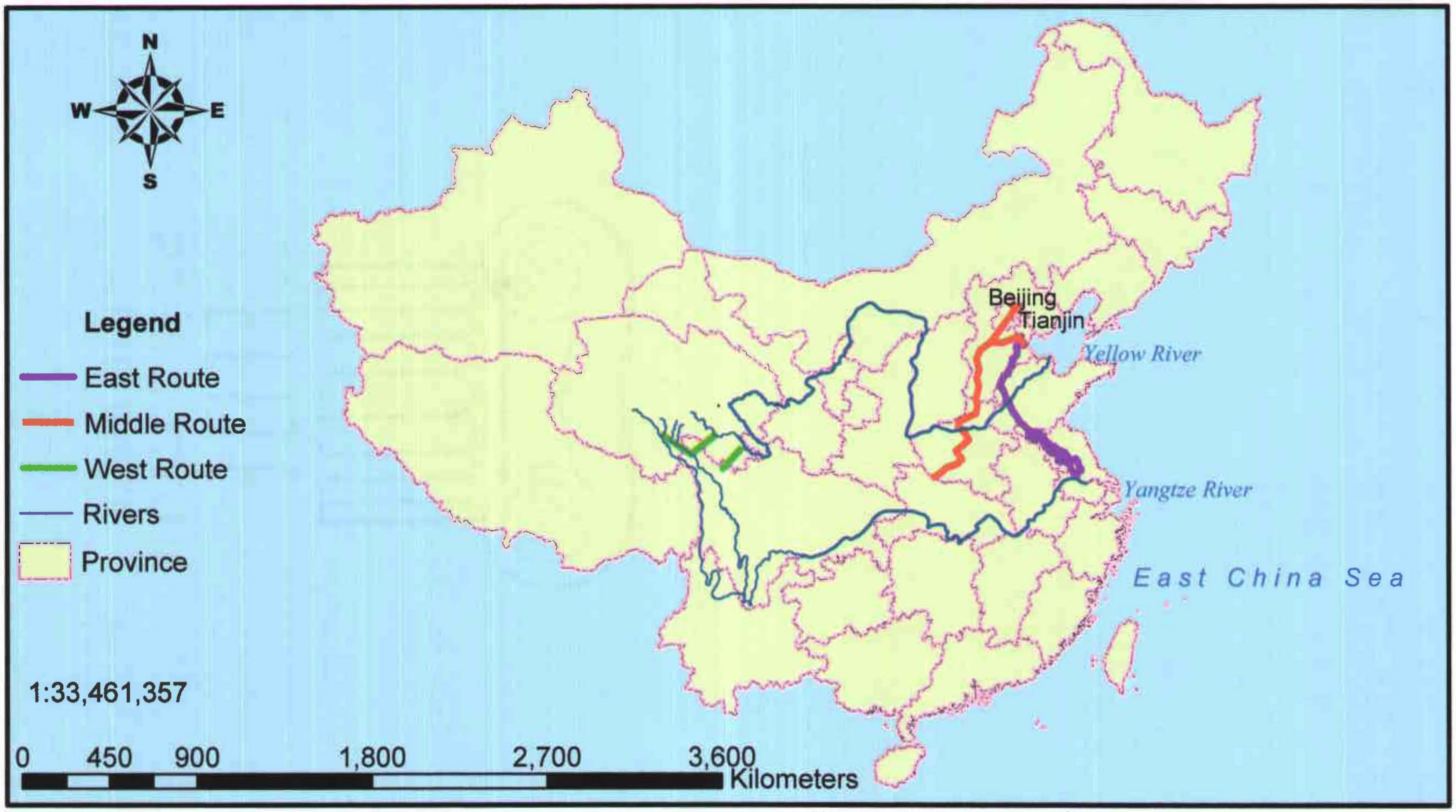
CHAPTER 3
DESCRIPTION OF THE SOUTH-TO-NORTH WATER DIVERSION SCHEME

Introduction

One solution for the water shortage problem in north China is to redistribute water from the south to the north. The plan is called the South-to-North Water Diversion Scheme (SNWDS). It redistributes water via three routes: East, Middle, and West (Figure 3-1). The late Chinese leader Mao Zedong commented during his inspection tour in 1952 to the Yellow River, "[t]he north of China needs water and the south has plenty; if possible, the north may borrow some water from the south" ("South-North Water Diversion Project," 2001). Since that time, investigation, planning, and research have been conducted by the Ministries and the Department of Municipalities. Scientific and research institutions based on the first written document "South-North Water Transfer" was established in 1958 (MOWR, 2000). According to the report from the Ministry of Water Resources, many organizations, institutions, and commissions participated in the General Plan and scientific research 2000 (MOWR, 2000)[c].

[c] Participants: the Chinese Academy of Science (CAS), Chinese Academy of Engineering (CAE), Chinese Academy of Social Science (CASS), Chinese International Engineering Consulting Corporation (CIECC), Development Research Center of State Council, Macro-Economic Research Institute, Urban Water Resources Center and Drainage and Water Supply Center from Ministry of Construction, China Agricultural Science Institute, China Environmental Science Research Institute, China Environment Planning Institute, Tsinghua University, Hohai University, Beijing Normal University, China Institute of Water Resources and Hydropower Research (IWHR), Nanjing Water Resources and Hydropower Scientific Research Institute, Nanjing Hydrology and Water Resources Institute, Design Institutes of the Yangtze River Water Resources Commission, the Yellow River Water Resources Commission, the Huai River Water Resources Commission, Hai River Water Resources Commission, Tianjin, and Shanghai Reconnaissance and Design Institute, Xinxiang Irrigation Research Institute.

Figure 3-1. Three Routes of the South-to-North Water Diversion Scheme



Base Map Source: Liu (SIESIN), Yao (CASM), and Lavely (CITAS), 1996 and Qin (SITAS), Lavely and Liu, 1996.
(Figurer 3-1, 3-2, 3-4, 3-5, 3-7, 3-8)
Source: Modified from Qian and Zhang eds., 2001.

The SNWDS called for three routes to transfer water from the lower, middle, and upper reaches of the Yangtze to the three largest rivers in the North China Plain: the Yellow, the Huai, and the Hai. The general characteristic of this framework is expressed as "Four Transverse Rivers and Three Longitudinal Routes" (MOWR, 2000). According to The People's Daily, "once it is completed in 5 to 10 years, about 38 to 48 billion m^3 of water will be transferred yearly to the area with a population of 300 million" ("South-North Water Diversion Project," 2001). Although there are some problems and the difficulties that China still continues to work out, it will certainly reduce the inequality of the south and north water distribution problem drastically, and relieve many of the water-related problems in the North.

Overview of the Routes

East Route

This route (Figure 3-2) will divert water from the lower reaches of the Yangtze, which has an annual mean of 956 million m^3 of water entering the sea, to the north via the previously constructed Grand Canal, rivers and lakes (Ministry of Water Resources. P.R.C. [MOWRPRC], 1995). In detail, from two diversion points on the Yangtze, Sanjiangying where the Huai River meets with the Grand Canal, and Liuyu where the Beijing-Hangzhou Canal meets with the Yangtze ("East Line Project," 2002), water travels to the Hongze Lake through four canals. Then, it moves through Zhong Canal and Xuhong River to get into Luoma Lake. From the lake, the water further moves to the north through three waterways: Zhong and Honzhuang canals, and Fangting River to get Nansi Lake. From Nansi Lake, the water continues to travel to the north, and empties

Figure 3-2. East Route

Source: Modified from Qian and Zhang eds., 2001.

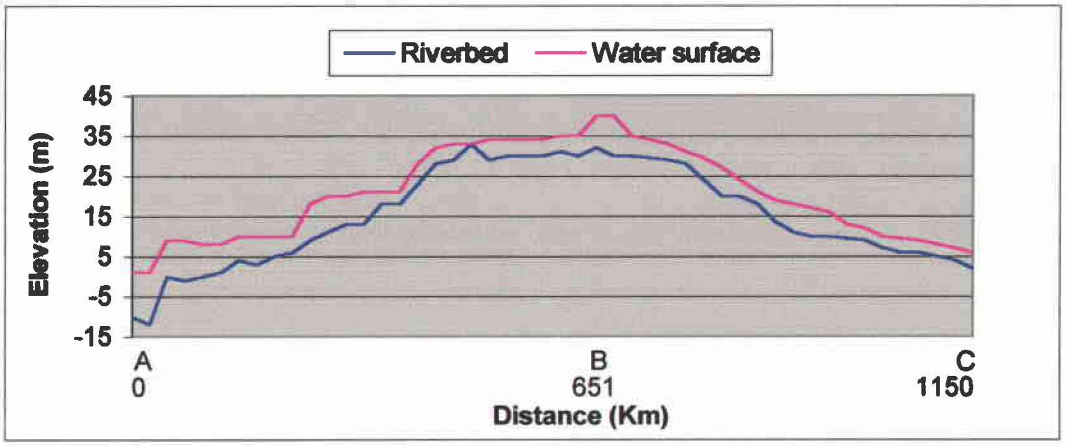
into Dongping Lake. From there, the water has to travel though excavated tunnels underground in order to cross the Yellow River to get to Weilin Canal at the northern bank of the Yellow river. From there, the water goes through Wei Canal via Lingqing, and South Canal via Dezhou. Finally, water reaches Beidagang Reservoir at Tianjin via Jiedi (Yan ed., 1999).

This total length from the Yangtze to Tianjin is 1150 km; including 490 km to the north of the Yellow River, 9 km as the part crossing the Yellow River, and 651 km to the south of the river.

One of the biggest difficulties of this route is how to cross the Yellow River. Not only does the river change water levels each season, but it also carries a great amount of loess (Yan ed., 1999). The Yellow River will send 100 million tons of silt a year to the north. In order to avoid disturbance to its natural flow, and a sedimentation problem in the north, they excavated and tunneled under the Yellow River bed. Three tunnels, each 9.3 meters in diameter, will be installed 70 meters under the riverbed, and the total amount of water transferred though these tunnels will be 700 m^3 per second (Yan ed., 1999).

Another big difficulty of this route is to convey the water uphill against gravity. Figure 3-3 shows that the cross section of the natural terrain along this route has the slope of gentle bell curve with the highest point at the Yellow River bank, and the ground at the Yangtze Basin is about 3-4 meter above the sea level, and the elevation at the Yellow River basin is about 40 meter above the sea level (Yan ed., 1999). Because of these elevation differences, water from the Yangtze needs to be pumped up to the southern bank of the Yellow River. In order to overcome this problem, the diversion route will need to be equipped with 30 pumping stations including the 7 existing ones and 23 newly built pumping stations to the south of the Yellow River (Yan ed., 1999; "East Line Project," 2002) (Figure 3-4). Once water gets to the north of the Yellow River, due to the difference in elevation, the water naturally flows to the Tianjin.

Figure 3-3. East Route Profile



Source: "East Line Project," 2002
A: Sanjiangying, B: Yellow River, C: Tianjin

Besides the two difficulties mentioned above, there is a big advantage to this route. There is a string of natural lakes of various size en route to the north, and these will be utilized as reservoirs. Generally speaking, impounding is very important for long distance water transference in order to coordinate and adjust timing of supply. The impounding capacity of the major lakes are: 3.15 billion m^3 for Hongze Lake, 590 million m^3 for Luoma Lake, and 1.13 billion m^3 for Nansi Lake. Total capacity of all of these lakes will be 9.058 billion m^3, or 4.87 - 7.57 billion m^3 to the south, and 0.66 - 1.488 billion m^3 to the north of the Yellow River (Yan ed., 1999).

Figure 3-4. Names of the Pumping Stations

Although the east route requires building 30 pumping stations along the southern part of the Yellow River (Figure 3-4), and excavating three tunnels to cross the Yellow River, this route will be the easiest and cheapest one compared with the other two routes. The expected budget for this route is about 25 billion Yuan ($3 billion) ("Issues Surrounding," 2001).

The implementation of the progression of work for the East route is divided into three stages. The first stage began around 2000, and is expected to take five years. The construction includes 22 new pumping stations, which will be equipped with a total of 87,600 kW of pumping power, and the 9.3-meter tunnels for Yellow river crossing. It will cost around 7.5 billion Yuan ($900 million) for this stage. Water will be taken from the Yangtze at a rate of 500 m^3 per second to the final destination of the Dongping Lake. It will increase an average of 3.7 billion m^3 of water annually. The second stage will take place before the year 2010, and will also take five years to construct. In this stage, total capacity of 87,600 kW will be expanded to 268,500 kW of pumping power at the 22 pumping stations.

Also, canals and reservoirs will be reinforced and expanded, and environmental treatment will be provided as well, especially after raising the water level in the reservoirs. It is expected to cost about 10.4 billion Yuan ($1.25 billion) for this stage of construction. The water will be taken from the Yangtze at 700 m^3 per second. The final destination, Tianjin, will receive 150 m^3 per second. It will increase by an average of 8.5 billion m^3 of water annually. The third stage will take place before year 2020, and also will take five years. In this stage, pumping capacity will be expanded to 278,200 kW at the pumping stations. Also, another Yellow river crossing underground tunnel will be installed. They will continue to expand, reinforce, and rebuild canal and reservoirs, and provide environmental care as well. It costs about 11.3 billion Yuan ($1.36 billion) for this stage of the construction. 1000 m^3 per second of water will be taken from the Yangtze River. 180 m^3 per second of water will reach Tianjin. It is planned to increase the annual water supply by 15.4 billion m^3 (Qian and Zhang eds., 2001).

Table 3-1. Summary of the Three Implementation Stages of the East Route

	Stage 1	**Stage 2**	**Stage 3**
Working plan	Around year 2000	Before year 2010	Before year 2020
Destination of Water Conveyance	Dongping Lake	Tianjin	Tianjin
Withdraw From the Yangtze (m^3 / second)	500	700	1,000
Water Flow to Tianjin (m^3 / second)	0	150	180
Main work	-build 22 pumping stations (total 87,600 kW) -build tunnel (9.3m diameter) -expand canal	-pumping stations (total 268,500 kW) -reinforce reservoir -management of lakes after raising the water level	-pumping stations (total 278,200 kW) -build other tunnel (same size) -expand canal -management of lakes after raising water level
Annual Average Water Supply Increase (billion m^3)	3.7	8.5	15.4
Investment Billion Yuan (Million Dollars)	7.5 (900)	10.4 (1,250)	11.3 (1,360)
Working period (Years)	5	5	5

Middle Route

This route (Figure 3-5) will divert water from Danjiangkou reservoir, which is located on the boundary between Hubei and Henan province, to Beijing, the capital of China, Tianjin, one of the biggest port cities, and other cities along the canal, which will be built. The primary uses of the transferred water will be for industry, cities, and irrigation.

The Han River is the longest tributary of the Yangtze, its basin covering 1.59 million km^2 (Yan ed., 1999). The area annually receives 897.2 millimeters of precipitation, with 55% to 65% of the total precipitation occurring from May to August. Consequently, the annual amount of water is 59.1 billion m^3, with 55.4 billion m^3 of the water entering the Yangtze (Yan ed., 1999). The intended water transfer route will be the following: the water in the Danjiangkou reservoir from the Han River will be discharged into the Taocha Canal. From the canal, the water will move towards the northeast to Fangcheng via Nanyang. Then, it will move northward to the southern bank of the Yellow River in the northwest of Zhengzhou. From Zhengzhou, the water will travel though excavated tunnels to get to the northern bank of the Yellow River called Gubaizui. After this, it will go further north along the eastern foot of the Taihang Mountain, and to the west of the Beijing-Guangzhou railroad through northern Tangxian via Anyang, Handan, and Shijiazhuang. Finally, the water will enter Beijing through northern Juma and Yongding rivers. This route will end at Yuyuan pool (Yan ed., 1999). Total length of this route will be 1241 km, including 466.1 km to the south of the Yellow River, 10.2 km for crossing the Yellow River, and 764.7 km to the north of the river

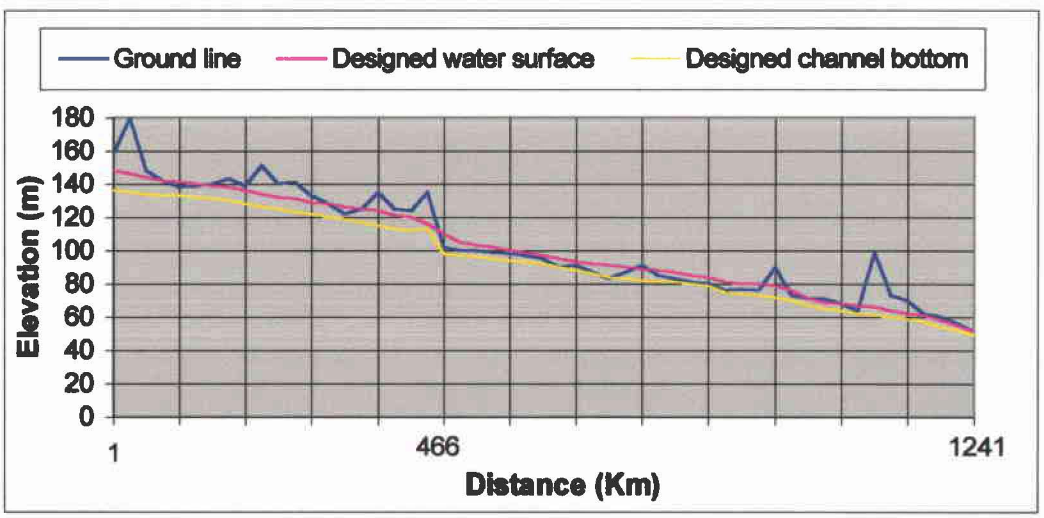
Figure 3-5. Middle Route

Source: Modified from Qian and Zhang eds., 2001.

(Huo, 2000). Also, some water will be diverted to Tianjin, with the total length of the canal set at 1,436 km (Yan ed., 1999).[d]

Just like the East Route, one of the difficulties of this construction is crossing the Yellow River due to the characteristics of the topography and other geographical features (Figure 3-6). The riverbed is very loose with either fine silt sand or medium granular sand (Yan ed., 1999). In order to cross the Yellow River, aqueducts and tunnel siphons are the two most feasible methods (Yan ed., 1999). After careful consideration to the location and conditions of the river, the tunnel siphon method was adapted. Two lines of piping 8.5 meters in diameter will be installed between 48.13 to 65 meters under the surface of water (Yan ed., 1999).[e] The total length of crossing section will be 7.2 km, and will need six years to complete with an estimated cost of 1.628 billion Yuan ($195 million) (Yan ed., 1999).

Figure 3-6. Middle Route Profile



Source: "Middle Line Project," 2002.

[d] The author also mentioned that the water will take 14 days from Danjiangkou reservoir to Beijing with 1389.2 meter.

[e] The space between the center of the pipes will be 20 meter.

The one biggest advantage of the route is that the water will flow through canals by gravity. The water level is gradually reduced from 147.2 meters at the head of the route, to 119.5 meters at the Yellow River, to 49.5 meters at the destination in Beijing (Yan ed., 1999). The slope of the incline to the south of the Yellow River is 1/25000, with a velocity of 1.2 – 1.5 meters per second (Yan ed., 1999). In order to utilize gravity to move the water, the water level at the Danjiangkou reservoir needs to be raised from 157 meters, with storage capacity of 17.45 billion m^3, to 170 m, with a storage capacity of 29.05 billion m^3 by the year 2020.[f] Unfortunately, this requires an additional area of 370 km^2 to be inundated (Yan ed., 1999; "Middle Line Project," 2002).

In regards to the resettlement issue, due to the Danjiangkou Reservoir the water table will rise displacing about 224 thousand people ("Middle Line Project," 2002).[g] Over 50 towns in three provinces — Hubei, Henan, and Shaanxi — will be submerged. Ninety-four percent of the people who are obliged to move make a livelihood from agriculture. The government still needs to work out the details for these people's new residences as well as new jobs. The estimated resettlement cost is 78-88 billion Yuan ($9.36 –10.56 billion), and the final cost of the Middle Route will be determined by the resettlement cost of more than 220,000 people ("Issues Surrounding," 2001).

The Middle Route will be the best of the three in terms of the quality of water diversion projects. In the first period of the construction of the middle route, 7.5 billion m^3 of water will be transferred to the north. Once the middle route is fully complete, it will convey 14.5 billion m^3 of good quality of water annually (Yan ed., 1999).

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[f] The Danjiankou reservoir was constructed in 1973.

[g] Qian and Zhang reported that 310 thousand people have already moved by 2002.

Table 3-2. Main Investment for the Middle Route

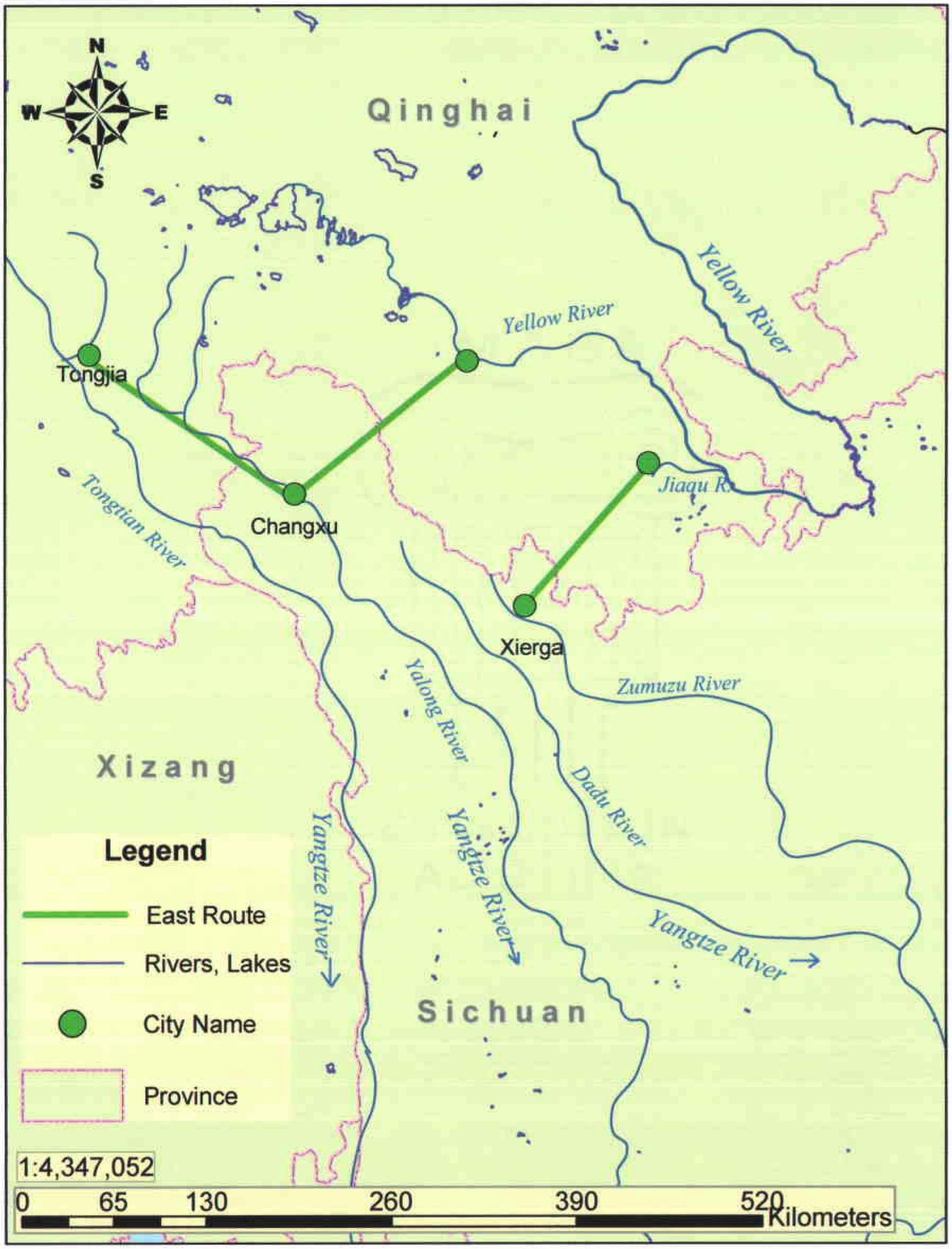
Item	Main Work	Investment Billion Yuan (Million Dollars)
Danjiangkou Dam	• Reinforcement • Heighten the wall to177.6 m	1.164 (140)
	• Resettlement	78 - 88 (9,360 -10,560)
Compensation for middle and lower leach of Han River	• Fix water level, depth of water for navigation • Reinforcement of riverside by the water extraction point	5.057 (606)
Canal	• 10 km^2 of canal construction • Tianjin Canal construction • Yellow River crossing section	14.5 (1,740)
	• Environmental Protection	0.85 (102)
Total		100 - 110 (11,950 - 13,138)

Source: Modified form Qian and Zhang eds., 2001.

West Route

This route will (Figure 3-7) divert water from the upper reaches of the Yangtze to the upper and middle reaches of the Yellow River. More specifically, water will be transferred from three major tributaries of the Yangtze, the Tongtian, Yalong, and Dalu Rivers, and supply the water deficit in the Yellow River in order to provide water to the northern inland and northwest parts of the country. Once this route is completed, four provinces (Qinghai, Gansu, Shaanxi, and Shanxi), and two autonomous regions (Ningxia Hui and Inner Mongolia) will be provided with 20 billion m^3 water, including 10 billion m^3 from the Tongtian River and 5 billion m^3 from the Yalong River and Dalu River.

Figure 3-7. West Route



Source: Modified from Qian and zhang eds., 2001.

This route will be the most difficult to construct compared with the two other routes because of its geographical conditions. The three rivers have their origins on the Qinghai-Tibet plateau at an altitude of 3,000-5,000 m. The geographical problem that engineers have to overcome is the Bayankala mountain range, which lies between the Yangtze and the Yellow Rivers, so the Yangtze River bed is about 80 - 450 m higher than the corresponding section of the Yellow River bed (Li ed., 1999; MOWRPRC, 1995). In order to divert water from the three tributaries of the Yangtze to the Yellow River, this route requires crossing the Bayankala (5,000 m) range, under harsh climate conditions and against the gravity. Long tunnels over 100 km and a 200m high dam will be constructed (MOWRPRC, 1995). The lowest annual temperature is about -37 - -25°C and the atmosphere is thin due to the high elevation. In addition, frequent earthquakes with high intensities of 6 - 9 degrees on the modified Mercalli scale occur in this region. Due to these reasons, the West Route still needs close investigation and study. However, based upon preliminary information, the most feasible plan for this route can be described.

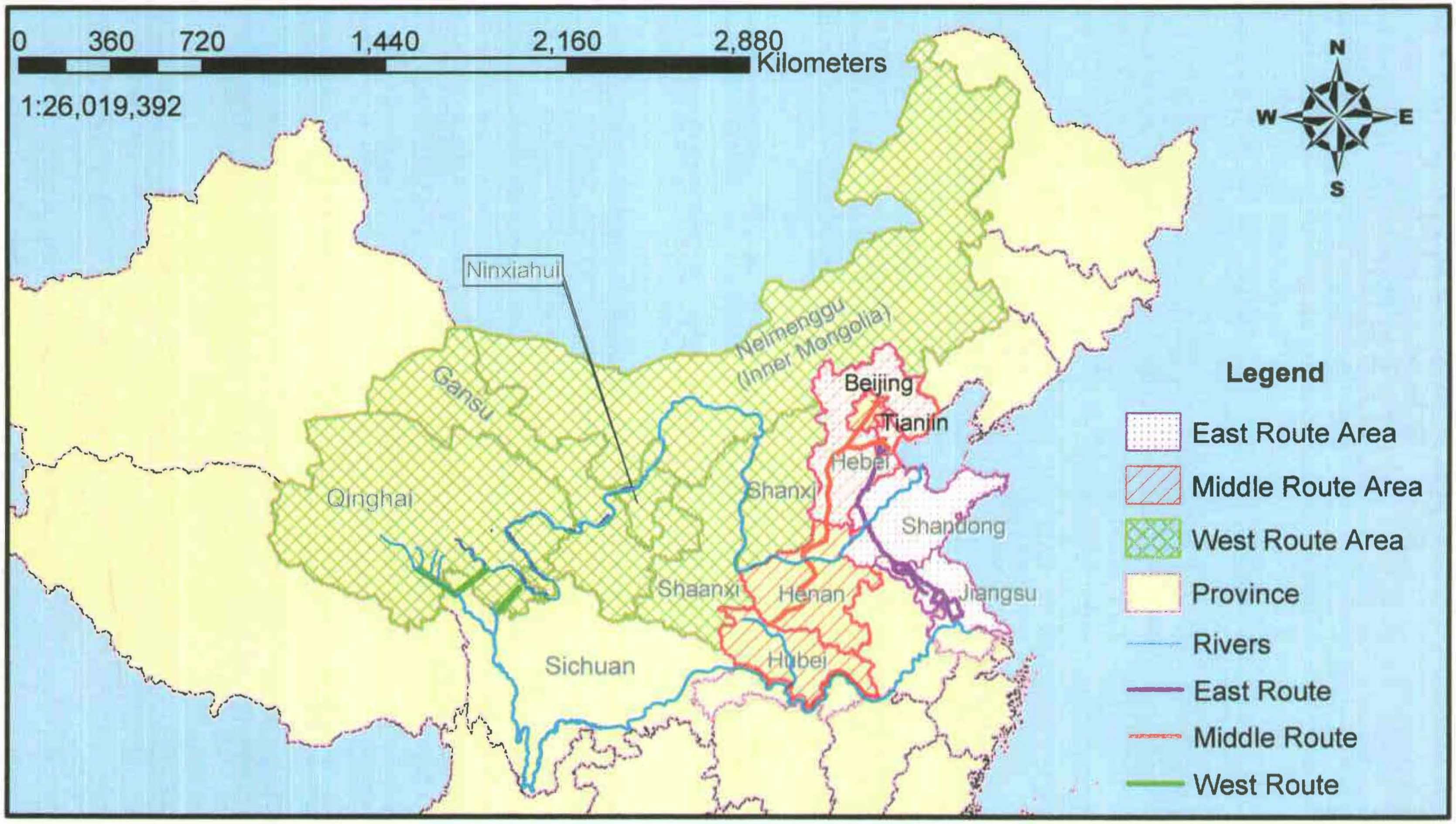
There are two separate parts to this route. The first part is a development plan combining the Tongtian River and the Yalong River. At a dam with a height of 300 m and capacity of 10 billion m^3 at the mainstream of the Tongtian River in Qinghai Province, the water level will be raised to 3860 m. From Tongjia, the water will travel by gravity through 158 km of an excavated tunnel to the Yalong River. From there, water will flow toward the lower reach of the Yalong River to Changxu (3,795 m above sea level). At Changxu, the water will be stopped again by a dam, in order to raise its level, and the second tunnel will be built in order to convey it by gravity into the upper stream of the Yellow River. From there, the water will flow into the main stream of the Yellow River. This route will be increased by 4.5 billion m^3 of water in the Yellow River per year.

The other part starts at the dam on the tributary of the upper reach of the Dadu River, called Xierga (2,920 m above sea level), on the Zumuzu River. The dam, 296 m in height, will be built at the Xierga. From there, the water will be diverted via pumping to the Jiaqu River (3,540 m above sea level), a tributary of the Yellow River. The length of the diversion route will be 30 km, including 28.5 km of tunnel. From there, the water will flow into the mainstream of the Yellow River. This route will increase water flow by 5 billion m^3 per year, and consume 7.1 billion kW for the pumping annually (Li ed., 1999).

The West Route needs to have dams, tunnels, and pumping stations of various sizes in the mountainous regions. The construction will start by the end of 2050s. Meanwhile, they may find alternative methods and technologies to modify this route.

The purpose of the SNWDS is to alleviate the water shortage in the north, and each route has specific purposes and rationale so that they not only do not conflict with each other, but also provide diverse benefits (Liu and Zheng, 2002). The Eastern Route will supply large quantity of low-quality water to the northern provinces, including Jiangsu, Shandong, Hebei, Tianjin, and Huai River basin by pumping, while the Middle Route will supply good quality water to the Hubei, Henan, and Hebei provinces, and at last to Beijing, Tianjin and western part of the North China Plain by gravity (Liu and Zheng, 2002) (Figure 3-8). The Western Route will supply water to northwestern China by a combination of pumping and gravity. However, this gigantic network comprising the water allocation plan may also create many undesired or unforeseen consequences. In the next chapter, I will discuss some of the positive and negative aspects of the SNWDS.

Figure 3-8. Areas Affected by Each of the Three Route



Base Map Source: Liu (SIESIN), Yao (CASM), and Lavely (CITAS), 1996 and Qin (SITAS), Lavely and Liu, 1996.
(Figurer 3-1, 3-2, 3-4, 3-5, 3-7, 3-8)

CHAPTER 4
THE SOCIETAL AND ENVIRONMENTAL CONSEQUENCES OF CHINA'S SOUTH-TO-NORTH WATER DIVERSION SCHEME

In the previous chapter, I described characteristics of each of the three routes of China's South-to-North Water Diversion Scheme (SNWDS). In this chapter, I will discuss how the scheme affects China's economy, society, and environment based on the literature that I have reviewed. To begin, I will first introduce some previous examples of water transferring schemes in order to illustrate some of the challenges China faces in undertaking the SNDWS. Next, I will address the expected benefits to each of the three sectors, distinguishing where possible three regions – *water-importing, water-transferring* and *water-exporting* under each of the three routes – *East Route, Middle Route* and *West Route* will be addressed. Then, the discussion will move on to address the *costs* of the scheme in the same fashion. Eight-character names in parentheses indicate the position of the criterion or objective within the hierarchy of concerns that evolves.

<u>Previous Instances of Long Distance Water Transfers</u>

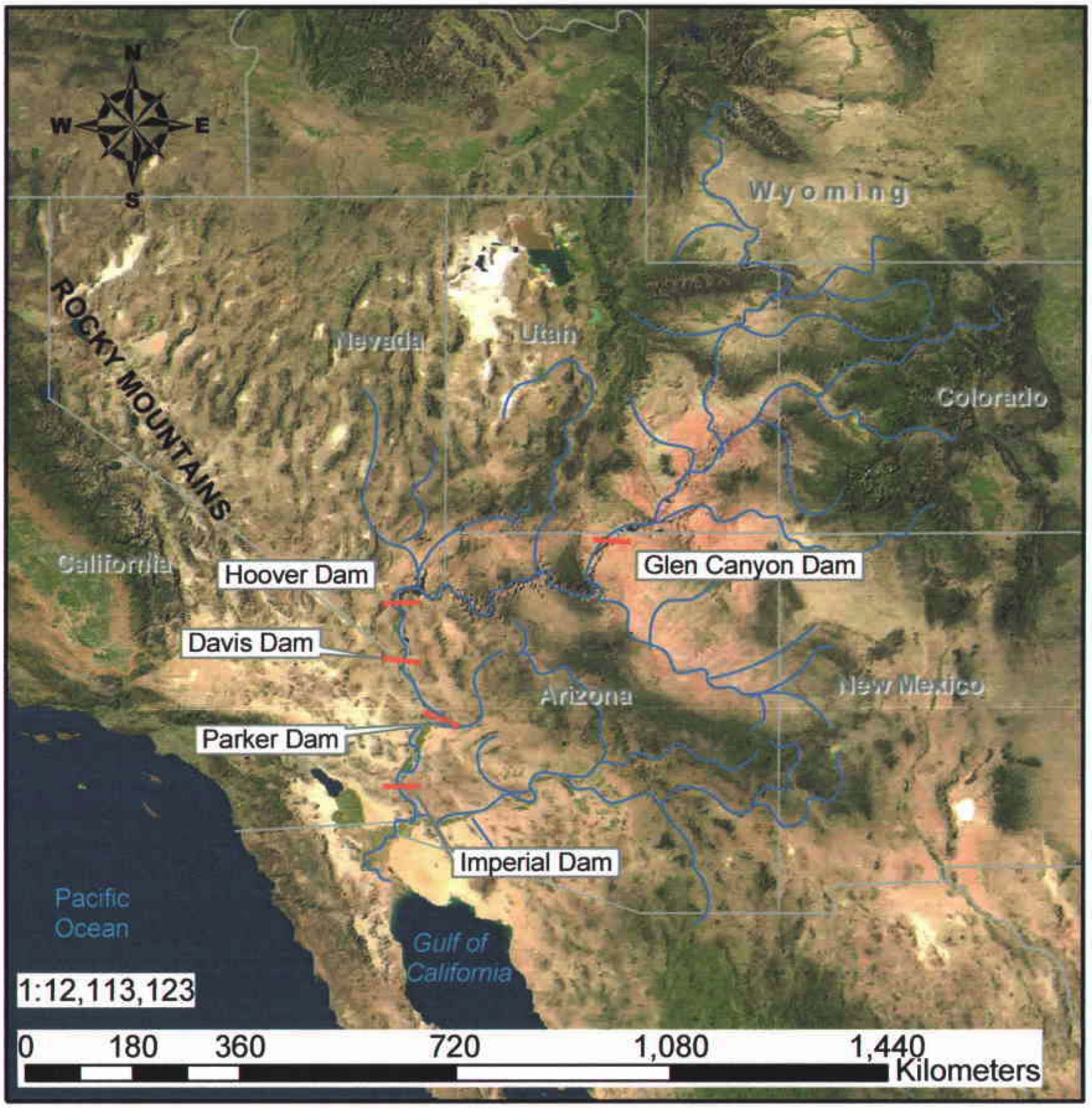
In this section, I will briefly introduce previous instances of water-transfer projects, including the Colorado River Basin in the United States, Snowy Mountains Scheme in Australia, and Ooi River Basin in Shizuoka, Japan, for the purpose of showing the general nature of water-transfer projects and to use them as comparisons with China's.

The idea of transferring water from water-sufficient regions to water-deficient regions has garnered people's attention since ancient times. The control of water for the purpose of farming was recorded around 4000 B.C. in the Tigris-Euphrates Valley (Postel, 1999). During the 20th century, developed countries carried out gigantic-scale water-transfer projects with the objective of improving their standard of living and increasing agricultural and industrial production, despite the fact that many of these large-scale water projects were and are often accompanied by environmental and social problems, and arouse a great deal of controversy. Obviously, large-scale water-transfer projects have both benefits and costs, as well as risks and opportunities, so it is beneficial to understand the outcomes from some of these other water-transfer projects, as models of what could potentially occur with the SNWDS.

Colorado River Basin in the United States

The Colorado River flows in a southwesterly direction, full of twists and turns, from the valley of the Rocky Mountain Range in the State of Colorado to the Gulf of California (Figure 4-1). Along its 2,320-km course, it crosses mountains and deserts, passing through seven states and Mexico (Hudson ed., 2000). It supplies water and hydroelectric power to over 25 million people and along the way provides water for irrigation to over 14 million km^2 within the 400 thousand km^2 of catchment basins ("Colorado River Project," 2000). The amount of water diverted from the Colorado River is the largest volume in the world. It is distributed to regions in all directions including the Salt Lake Valley in Utah and Cheyenne, Wyoming in the north; Phoenix, Arizona and the Rio Grande Basin in New Mexico in the south; over the Continental Divide to the city of Denver, Colorado to the east; and the southern coastal plain in

Figure 4-1. Colorado River Basin



Base Map Source: Environmental System Research Institute, Inc. ESRI_Satellite and ESRI_World.
Source: Dams within the Colorado River Watershed. (n.d.).

California west of the Colorado River ("Colorado River Project," 2000), with little to no water reaching the Gulf of California, its original destination (Brown, 2001).

Management of the Colorado River has a long history. As early as 600 A.D., Anasazi Indians first developed its water in northwestern New Mexico ("Colorado River Project," 2000). After many attempts to better manage the river water, Hoover Dam construction was started on the Colorado River in 1931. It was built in the Black Canyon, 530 km from the Mexican border and was completed in 1935. It was built during the depression era and was utilized as a provider of power for American's wartime industry. In addition, the construction of the Hoover Dam worked as a relief program for the unemployed in the early years of the depression. Availability of the consumable water and power enabled an increase in employment in various kinds of service and business, and provided more than 130,000 jobs (Committee on Water of the National Research Council [COWNRC], 1968). It set up a chain reaction to accelerate both a flourish in economic activity in the region and some negative impacts related to the development.

Today, it not only provides water for irrigation, flood control, and hydroelectric power to the surrounding states, but it also has become one of the major tourist attractions in America (Dunar and McBride, 1993). This multipurpose dam is seen as one of the engineering achievements of the twentieth century, although some newer dams are superior to its height, storage capacity, and power productivity. However, because of its enormity of scale, the dam both before and after the construction received a great deal of public criticism.

Geographic characteristics of the southwestern part of the United States are typical of an arid region, and before the completion of the Hoover Dam, the area was sparsely populated. Las Vegas, for example, grew from a small town with a population of just over 5,000 in the 1930s to a city of over one million by the end of the century. It may safely be said that Nevada's and Arizona's tremendous population growth were brought on by the availability of the water and power through the Hoover Dam. People enjoy having entertainment with glittering neon signs in Las Vegas and a swimming pool at their home. Clearly, the dam encourages people to consume more water and power in the desert.

Farmers are also able to access abundant water throughout the year by dint of the 32 million acre-feet (1.39 trillion cubic feet or 39.5 billion m^3) storage capacity of the reservoir (COWNRC, 1968). Although most of the region has less than 13 cm of precipitation throughout an average year, they cultivate high profit cash crops regardless of the consumptive use of water by the plants, and evaporation rates of the region (Hudson ed., 2000). Fruits and vegetables, rice, sugar and dairying are major products from the regions (Hudson ed., 2000). There is yet another instance of excessive use of water due to the engineering development from the Hoover Dam: it promotes further expansion of agriculture into the desert.

With respect to the environment and preservation of nature, scientists have come to realize various adverse effects within the basin. Because the dam altered the natural flow of the river, some native fish and plants were driven to extinction or otherwise threatened. In addition, the Colorado River naturally has a high load of salt, and the total salt load at the Hoover Dam is about 10.4 million tons per year (COWNRC, 1968).

However, salinity increases due to the discharge of additional pollutants from municipal, industrial, and agricultural wastes, and/or due simply to extracting water so that concentration increases. As a result, salinity tripled between 1917 and 1961 ("Moving Waters," 2001). Salt is one of the formidable problems for agriculture. In order to maintain agricultural benefits farmers must cut down on the amount of water for irrigation. Salt concentration in the soil is directly proportional to water consumption.

Among the twenty five million people in the seven states, thirty two American Indian tribal communities share the water in the Colorado River ("Moving Waters," 2001). They still attempt to engage in a traditional lifestyle on the same land as they have for millennia, although they suffer from the Western techno-centered way of life. In fact, many American Indians were forced to surrender their homes and traditional lifestyle for the nation's economic growth, giving up their tribal water rights. Due to government-imposed regulations, the results have been the loss of unique cultures and traditional ways of living that are closely tied to nature and the surrounding environment. The capitalistic ideology of consumption is firmly implanted in the people's minds, though we might have learned environmental management methods from their traditional lifestyle.

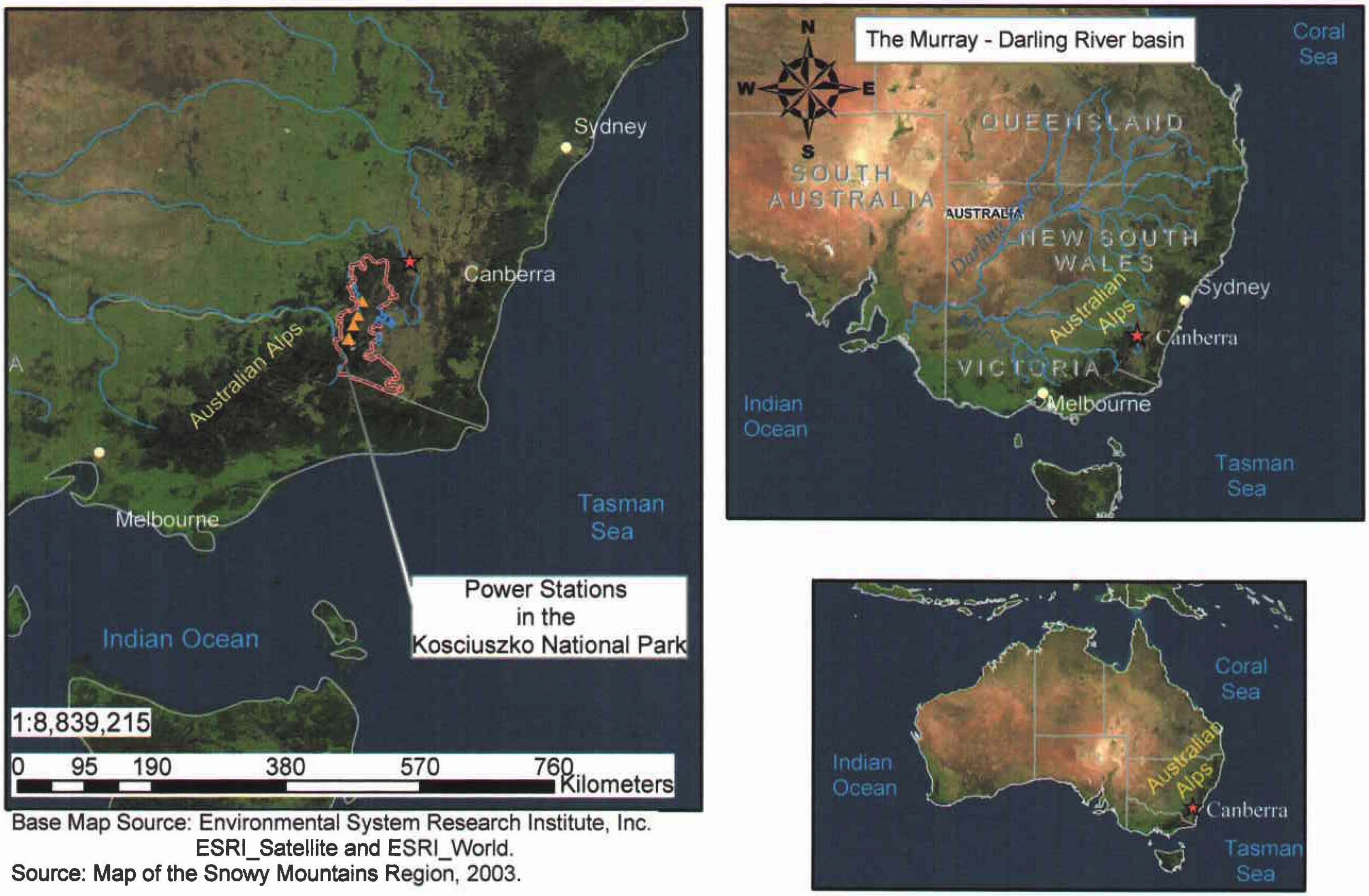
Hoover Dam can be seen as a utilitarian venture for water and power for the motivation of the national economic wealth, and is expected to promise 50 to 100 years of net benefits over the costs of construction, operation, maintenance and external effects (COWNRC, 1968). However, we now realize that the natural environment and the technology are not necessary and sufficient conditions for wealth. Good water management would be worthwhile in order to maintain the nation's sustainable development.

Snowy Mountains Scheme in Australia

The Snowy Mountains Scheme (SMS) is recognized as one of the greatest engineering works of the world in terms of water management. Also, from the geographer's point of view, the scheme is seen as a symbol of the alliance between man and nature, harnessing water for agriculture and power ("Snowy Mountains Scheme: People," 2001). From the post World War II period, the government found a new meaning in both agricultural and power demand for the nation's reconstruction and development ("Snowy Mountains Scheme: Water," 2001). Today, it is no exaggeration to say that the SMS successfully brought a significant contribution to the economic achievement of modern Australia.

Australia is the world's driest inhabited continent (Figure 4-2). Large portions of the continent are covered by desert, and average less than 50 mm of annual precipitation; the only places with more than 100 mm of annual precipitation are the northern and eastern coastal regions of the continent. Southeastern regions such as New South Wales and Victoria, where Australia's metropolitan areas are located not only suffer from droughts, but also suffer damage from flooding in the spring. In order to maintain stability and security of water supply, they needed to overcome erratic river flows caused by spring thaw from the Snowy Mountains ("Snowy Mountains Scheme: Water," 2001). The SMS was the overall solution for such water-related problems as flood control, water supply and hydroelectricity. It is designed to divert and harness the Snowy River,

Figure 4-2. Snowy Mountains Scheme in Australia



Base Map Source: Environmental System Research Institute, Inc. ESRI_Satellite and ESRI_World.
Source: Map of the Snowy Mountains Region, 2003.

swollen by snow melt from the Australian Alps, to generate and store electricity before sending water to irrigate the arid but fertile interior so that it can boost the food production.

The SMS is located in the Australian Alps, the southeastern part of the country between the two large cities, Sydney in New South Wales and Melbourne in Victoria, and the scheme took place within an area of 8,200 km^2 of Kosciuszko National Park (Good, 2000). Construction began in October 1949 and took 25 years to complete, at a cost of $1 billion (Good, 2000). It is a network of dams, diversion tunnels, and power stations. More specifically, it includes 16 major dams with a total storage capacity of 7 million m^3, 145 km of interconnected tunnels and 80 km of aqueducts, and 7 power stations that utilize 5.3 million m^3 of water for electric generation (Good, 2000). Through the SMS, collected, stored, and diverted water is available for a range of purposes and uses.

With regard to agricultural and hydroelectricity production, operation of the SMS is vital for a reliable water and power supply to southeastern Australia. Currently, diverted water from the Snowy River is shared between Victoria and New South Wales at 25% and 75% respectively (Good, 2000). The SMS assists in $3-8.5 billion of agricultural production in the Murray – Darling River Basin each year (Good, 2000). On average, the SMS diverts around 5.3 million m^3 of water each year to the Murray and Murrumbidgee irrigation systems, to the west of the Great Dividing Range, after utilizing the water for electricity generation. Approximately 16% of the total energy capacity of the southeastern part of the country is provided by the SMS (Good, 2000).

With respect to river management, the SMS provides on average approximately 8% of the flow of the Murray River, increasing to around 35% of the total flow during the dry period of the year. As with the Murray River, the SMS also provides on average 25% of the total flow of the Murrumbidgee River, with an increase to around 60% during the dry period ("Snowy Mountains Scheme: Water," 2001). This availability of water during the dry period in the river system contributes to the control of salinity in the Murray River, and in turn provides an advantage by protecting both the fauna and flora aquatic habitats.

Some of the reservoirs and lakes have turned into important locations for various kinds of recreation activities as well. People enjoy swimming, camping, sailing, trout fishing, and many other outdoor activities in the national park. Furthermore, its popularity is due to the high quality of water. To maintain the water quality, the government set up a water monitoring system within the power stations, and assesses the water simply by taking samples from the reservoirs on a regular basis throughout the scheme ("Snowy Mountains Scheme: Water," 2001).

Environmental protection and management within the SMS are essential for expanding its utility value. However, it is undeniable that the scheme has brought some physical changes to rivers and their riparian zone. Because the scheme changed the natural flow of the river, it appears to have caused some adverse effects to the environment.

Along with population growth, the expansion of residential areas has increased pressure on the river streams within the SMS. Effluent disposal increases nutrient loadings in the water, and contributes to the growth of algae, which accelerates the eutrophication process ("Snowy Mountains Scheme: Water," 2001). In turn, it may adversely affect riparian fauna and flora. Human activity such as vegetation clearing has also caused soil erosion problems ("Snowy Mountains Scheme: Water," 2001). As a result, silt accumulation and weed-infestation problems were seen at the lower reaches of the river system.

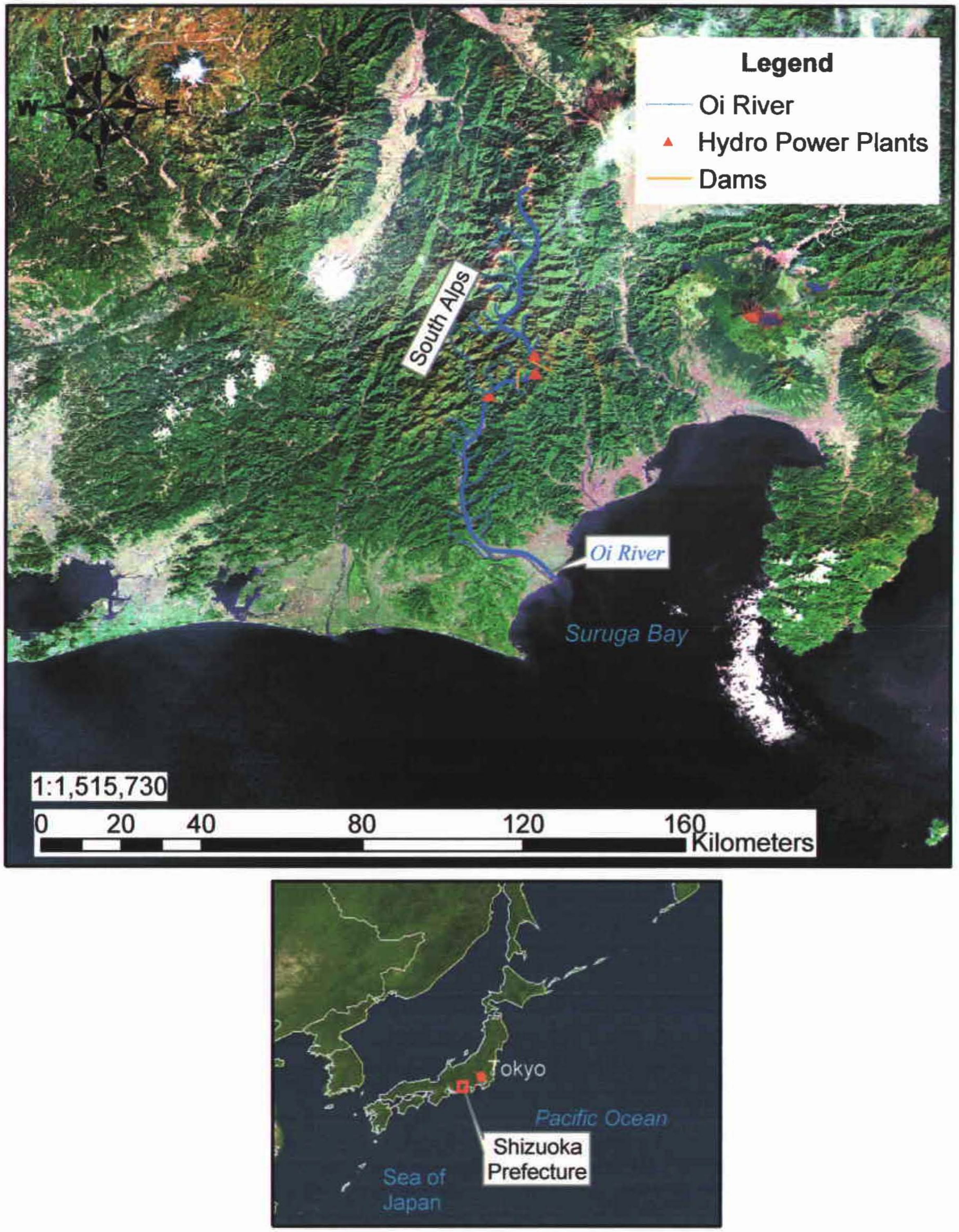
The SMS is a joint investment between the Governments of New South Wales and Victoria. Since the time of its conception, the Snowy Hydro-electric Authority has operated the scheme via agreements and acts. These laws appear to take an important role in order for sustainable development in the future. They may need to have new policies or need to reform old agreements in order to cope with new situations.

Ōi River Basin in Shizuoka, Japan

The discussion here of this case is based upon the videotape recording, *River Without Water: Journey to Oigawa River* (Sakurai prod., 1990). How interactions between water and society have shaped the nature and human environment in the Ōi River area was condensed and illustrated in this video. Dams are seen as a symbol of human control over water. The Ōi River region in Japan is not an exception (Figure 4-3). However, people pay the penalty for having dams for electricity, and it seems that the solution to one problem creates new problems.

From the post World War II period, for the purpose of economic growth, dams were built along the Ōi River in Shizuoka prefecture, Japan. Shaped by nature, the river flows 168 km through the middle of the Shizuoka prefecture, from 3,000 m high in the South Alps, and flows down to Suruga Bay and on to the Pacific Ocean. An abundant flow produced by 3,000 mm annual rainfall at the higher reaches of the river, and steep inclines through the mountains, make for optimum conditions for the dam sites. For

Figure 4-3. Oi River Basin in Shizuoka, Japan



Base Map Source: Environmental System Research Institute, Inc. ESRI_Satellite and ESRI_World.
Source: CHUBU and KANTO Dstricts, 1997.

example, Ikawa dam, which is 103 m high, was one of the biggest dams in Japan when it was built in 1953. Everyone believed that dams and lakes bring prosperity to the villages along the river. All together, 18 dams and 11 power stations were built along the Ōi River, and its total annual output is 700,000 kW, which is equivalent to ¥40 billion ($350 million) of electricity. Nowadays, the river water is diverted from its natural course. It is conveyed by 6 m pipelines through a tunnel in the mountain to dams and power stations before reaching Suruga Bay. The total length of the pipeline is 65 km, which accounts for a third of the river. These dams create hydroelectric power, but at the same time they create many problems as well.

Because dams do not allow natural flow of the river, the river does not carry silt to the mouth of the river. Silt builds up behind the dam, and it shortens the life span of the reservoir. Sand also piles up along the riverbank and riverbed. In fact, the riverbed has risen about 2 meters, and it creates flood problems when it rains hard, and dust pollution when it is dry. Moreover, for these reasons, the beautiful coastline of Suruga Bay has been gradually but clearly eroded by the waves, since the replenishing silt has been cut off from the bay. The shoreline has receded more than 100 m in the thirty years since the completion of the Ikawa dam.

Lack of water in the river also affects local tea production. Tea is cultivated along the slopes of the valley. Mist formerly formed in the gorge, and that is essential to producing good tea because it helps to produce soft new leaves. However, this no longer occurs and the tea leaves are covered by dust. What is more, the farmers need to wear masks for insecticide spraying in order to avoid dust, and there are health problems whenever they work in the field during the dry season.

Trout farms too are having difficulty because of the great quantity of gravel flowing into the farm when it rains hard. Trout are particularly sensitive to changes in the amount of silt in the water and need clear water in order to thrive; therefore, flows carrying large amounts of earth and sand into the farms can be fatal and potentially lead to the complete destruction of the industry along the river.

Forestry used to be a major industry in the area, and timber was transported by the river. However, the Ōi River no longer has enough water for timber transport. Gradually, the timber industry disappeared. Instead, the forest labor union provided jobs for the people who worked in the forest. They now collect gravel from the Ōi River and convert it to building materials, such as making tetra pods. However, collection and transportation costs for moving the gravel down to the mouth of the river in order to reduce the rate of shoreline erosion are getting expensive, which nature could do for free if the dams were not in place. Ironically, the tetra pods are used to combat the coastal erosion problem.

Furthermore, people who are engaged in the coastal fishery have also suffered from an unfavorable catch in the Suruga Bay. To illustrate the problem, a fish-finder on one of the fishing boats showed coasts and the ocean floor with concrete tetra pods, but not fish. Also, fishermen complained about tetra pods because they tear their fishing nets.

Ironically, the dams were constructed in order to provide electricity to the growing population of the surrounding area; however, their adverse side effects, such as pollution, clogging of the dam, and coastline erosion, are driving people away and the population is declining. It seems they not only lost the beauty of nature, but also traditional ways of life, which money cannot replace. Ōi River is just one example. According to John Peet (2003), 90 % of river water is under some sort of infrastructural control in Japan.

Other countries have similar problems. For example, several hydropower dams in the state of Washington have been removed in order to counter some of the damage. Those dams not only decreased the flow of water and created sedimentation problems, but also reduced the number of salmon and trout. They adversely affected the local fishing industry.

The brief reviews of these three precedents disclose many characteristics in common. Each took control over spatially and temporally unsteady water resources for the purpose of increasing hydroelectricity and agricultural production. Each one also caused harmful side effects to the environment, which in turn affect or are related to other human activities. China cannot afford to repeat the same mistakes of these earlier cases, because its proposed water-transfer scheme is of a much larger scale and could have significantly worse side effects.

Benefits and Costs of the Project: Economic System

There are arguments both for and against the scheme in regards to the *economic system*. The benefits from the SNWDS from the economic perspective are great both in the water-transferring and water-importing regions. These regions have been experiencing rapid economic development, but they suffer from severe water scarcity, so the scheme would further promote development of industry and agriculture there (Liu, 1998). On the other hand, the total cost of the scheme is estimated to be roughly $59 billion, which is much higher than the Three Gorges Dam project, the other major water project in China.

Economic Benefits in Water-exporting Region Along the East route

This route does not require building a new water transfer canal because of the previously constructed Grand Canal is used for this route. However, it still needs some modifications and repair in order to send water 500 m^3 per second to the north. The modifications include expansion and reinforcement of the canal and *THE CONSTRUCTION INCREASES REVENUES* (CONSTINC).

Economic Benefits in Water-transferring Region Along the East route

It will take over 15 years and cost over $3.51 billion to complete the East Route. Thus, *THE CONSTRUCTION INCREASES REVENUES* (CONSTINC).

A recent Chinese newspaper reported that the East Route will pour 110 million m^3 of water into the Nansi Lake, which is the largest lake in northern China, and will be capable of handling a statistical 100-year drought ("For the First Time," 2002). It will save the water-transferring region from frequent drought damage. Therefore, another benefit is the improved *ECONOMIC STABILITY ACCOMPANYING DROUGHT PREVENTION* (DRTPRVNT).

Economic Benefits in Water-importing Region Along the East Route

The benefits from the scheme will be great in water-importing regions. It will not only ameliorate water demand for industries, irrigation, and domestic water use, but also dissolve the causes of the 230 billion Yuan ($28 billion) of annual losses in hindered industrial output due to the water shortage ("Water Shortage," 2003). Thus, benefit signals the objective of *INCREASING AGRICULTURAL AND INDUSTRIAL PRODUCTIVITY* (PRODINCR).

The lakes and reservoirs along the East Route work as places for impounding, and it will save the water-importing region from frequent drought damage and stabilize economic activities. Therefore, another benefit is the increased *ECONOMIC STABILITY DERIVED FROM DROUGHT PREVENTION* (DRTPRVNT).

The East Route facilitates economic development of the Bohai rim and part of the North China Plain, and it will expand job opportunities there ("East Line Project," 2002). Another objective is thus *TO EXPAND BUSINESS OPPORTUNITIES* (BUSIOPTY) through an increase in the water supply.

A vast water supply provided by the scheme ensures the navigability of the Beijing-Hangzhou Canal between Jining and Xuzhou ("East Line Project," 2002). Therefore, *INCREASED SHIPPING TRADE* (SHIPTRAD) is expected due to reestablishing a stable trade route.

Economic Benefits in Water-exporting Region Along the Middle Route

The economic loss from natural disasters, such as flooding, is enormous. For example, the Yangtze River flood in 1998 alone caused $30 billion in damage and killed thousands of people (Becker, 2004). The estimate of the annual benefit from flood control will be about 250 million yuan ($30 million) ("China's Middle Route," n.d.). For the Middle Route construction, the storage capacity at the Danjiangkou Reservoir will be

29.05 billion m^3 after construction, so the flood-control capacity at the reservoir will be increased ("Middle Line Project," 2002). *REDUCED FLOOD LOSSES* (FLOODLOS) is viewed as a major benefit in this area.

Economic Benefits in Water-transferring Region Along the Middle Route

Constructing the Middle Route itself generates economic benefits. Another one objective therefore is to *INCREASES CONSTRUCTION REVENUES* (CONSTINC).

Economic Benefits in Water-importing Region Along the Middle Route

The estimated annual benefits from the Middle Route would be about 18.5 billion yuan ($2.3 billion), the breakdown of which are 15.88 billion yuan ($2 billion) for industrial and domestic water supply, 2.38 billion yean ($290 million) for irrigation and other water supply needs, and 0.25 billion yuan ($30 million) for flood control ("China's Middle Route," n.d.). Therefore, benefits can be seen as *INCREASED AGRICULTURAL AND INDUSTRIAL PRODUCTIVITY* (PRODINCR) due to increase water supply, and *NEW BUSINESS GROWTH* (BUSIGROW) due to increase water supply.

Economic Benefits in Water-exporting Region Along the West Route

Constructing the West Route itself generates an economic benefit in the form of *INCREASESD CONSTRUCTION REVENUES* (CONSTINC).

Economic Benefits in Water-transferring Region Along the West Route

As with the previously mentioned exporting region, construction of the West Route along the transferring region also generates similar economic benefits; therefore, *CONSTRUCTION INCREASES REVENUES* (CONSTINC).

Economic Benefits in Water-importing Region Along the West Route

The northwestern region, has rich energy, mineral, agricultural, forestry and livestock resources. Therefore, this region has great potential for economic development stimulated by the importation of water via the Western Route ("Suggestion," 2002). Currently, the region is significantly underdeveloped due to the water shortage problem, which is caused by a desertic climate having sparse precipitation and high evaporation rates ("Suggestion," 2002). Thus, benefits corresponding to this area are expected to be *INCREASED AGRICULTURAL AND INDUSTRIAL PRODUCTIVITY* (PRODINCR), and *NEW BUSINESS GROWTH* (STIMBUSI) due to increased water supply.

Economic Costs in Water-exporting Region Along the East Route

Saltwater intrusion of the Yangtze estuary has occurred due to the reduction of fresh water at the base of the Eastern Route. The saltwater intrusion in the Yangtze estuary has already affected industrial and agricultural production in Shanghai (Zuo, 1983). This concern is reflected in the following cost: *REDUCED AGRICULTURAL AND INDUSTRIAL PRODUCTION* (REDSPROD) due to saltwater intrusion.

Because of environmental changes such as saltwater intrusion, a loss of species will occur at the mouth of the Yangtze as a result of the extraction of water for the

Eastern Route, affecting the fishing industry in the vicinity of the Yangtze estuary (Liu, 1998; Liu and Zheng, 2002). This concern is reflected in the criterion *FISHERY LOSSES* (FISHLOSS).

Economic Costs in Water-transferring Region Along the East Route

The East Route will utilize the preexisting Grand Canal. However, this route needs to have 23 new pumping stations built along the route and underground tunnels constructed for Yellow River crossing section. The pumping stations will require electricity to operate, and the installed capacity will be 1.02 million kW. This route is not associated with the hydroelectric dam project, so electricity must be sent to the transferring regions. The electricity is a hidden cost for the operation of this route. These concerns are reflected in the following criteria: *CONSTRUCTION COST FOR PUMPING STATIONS* (COSTPUMP), *CONSTRUCTION COST FOR YELLOW RIVER CROSSING SECTION* (COSTCROS), and *ELECTRICITY FOR THE PUMPING STATIONS* (COSTELEC).

Economic Costs in Water-importing Region Along the East Route

Along the Eastern Route, the water pollution problem is severe. Although clean water will be sent from the exporting region, after flowing through the East Route, which has several big cities along the coast that generate billions of cubic meters of polluted water, this large volume of polluted water will need to be treated at great expense before it can be used in the north (Liu, 1998). This concern is reflected in the criterion *COST FOR TREATING TRANSFERRED WATER* (TREATWTR).

As mentioned before, the quality of the water transferred through the East Route will be very poor, so water treatment facilities must be built in order to use that water. Building the facilities will be beneficial to the environment, but will also be very expensive to construct and operate. The investment required for water pollution control and prevention along the Eastern Route will exceed the construction and refurbishing costs for the Eastern Route ("Issues Surrounding," 2001). In fact, the cost for the facilities is estimated to be 30 - 35 billion Yuan ($3.7 - 4.3 billion), which brings the total cost for the Eastern Route to over $7 billion ("Issues Surrounding," 2001). This concern is reflected in the criterion *CONSTRUCTION COST FOR TREATMENT PLANTS* (COSTPLNT).

Economic Costs in Water-exporting Region Along the Middle Route

The cost of building the Middle Route not only includes the canal, it also includes heightening the wall of the Danjiangkou reservoir, resettlement costs, which account for majority of the total cost, and reinforcement of the riverside by the water extraction point. These necessary expenses are reflected in the following criteria: *COST FOR DANJIANGKOU RESERVOIR UPGRADE CONSTRUCTION* (RESUPGRD), *COMPENSATION FOR DISPLACEMENT OF PEOPLE* (MOVEPEOP), and *COMPENSATION FOR MIDDLE AND LOWER REACHES OF HAN RIVER* (HANRIVER).

Cutting down the flow of water at the Han River will not only adversely affect the environment, but also have an impact on economic activities as well. According to Liu, the amount of water left in the river, which will only be two-thirds of the original flow, may disrupt the economic activities there such as navigation, irrigation, and many other purposes (1998; Liu and Zheng, 2002; "Issues Surrounding," 2001). This concern is reflected in the following criterion: *LOSS OF NAVIGATIONAL AND ECONOMIC TRADE ROUTES* (LOSTRADE).

4.794 million m^2 (or 4.794 km^2) of urban development and 0.235 million mu (156.7 km^2) of farmland will be inundated because of the elevated water level at the Danjiangkou Reservoir ("Middle Line Project," 2002). This region has a long history of agriculture because the region is ideal for agricultural development (Guo and Xu, 1983). According to Guo and Xu, the region has a flat and thick soil layer with temperate conditions both in light and heat (1983), so the inundation of this region is not just loosing land, it is the loss of very productive food-producing farmland. This concern is reflected in the following criterion: *LOSS OF FARMLAND AND ITS PRODUCTION* (LOSSFARM) due to inundation.

Economic Costs in Water-transferring Region Along the Middle Route

The building of the canal for the Middle Route is expected to cost about $1.74 billion, which includes the main canal, the Tenjin Canal, and the Yellow River crossing section. These expenses are reflected in the cost criterion *CONSTRUCTION COST FOR MIDDLE ROUTE* (CSTMIDRT).

Economic Costs in Water-importing Region Along the Middle Route

THERE ARE NO SIGNIFICANT COST EFFECTS.

Economic Costs in Water-exporting Region Along the West Route

The primary cost for this region will be the expense incurred in order to construct the water diversion route; therefore, it is reflected in the following criterion: *CONSTRUCTION COST FOR BUILDING WEST ROUTE* (CSTWSTRT).

Economic Costs in Water-transferring Region Along the West Route

The total cost of this route is still unknown, but this route is the most expensive compared with the other two routes. It will include a combination of dams, tunnels, and pumping stations. This expense is reflected in the cost criterion *CONSTRUCTION COST FOR BUILDING WEST ROUTE* (CSTWSTRT).

Economic Costs in Water-importing Region Along the West Route

THERE ARE NO SIGNIFICANT COST EFFECTS.

Benefits and Costs of the Project: Environmental System

There are arguments both for and against the scheme in regards to the *environmental system*. As with the *economic system*, the discussion will begin with the *benefits* in the *water-importing, water-transferring* and *water-exporting* regions under all three routes. Then, *costs* of the scheme will be addressed in the same way.

Environmental Benefits in Water-exporting Region Along the East Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-transferring Region Along the East Route

The scheme adopts modern operation systems so that water pollution control will be strengthened (MOWR, 2000). At least 13 new water treatment facilities will be constructed along the East Route ("Issues Surrounding," 2001). Also, the Chinese government claims it will enforce water pollution regulations upon local authorities along the East Route transferring regions ("Issues Surrounding," 2001). Therefore, *A DECREASE IN WATER POLLUTION* (DCRSPOLL) will be due to an increase in the number of water treatment plants and through pollution regulation enforcement.

Environmental Benefits in Water-importing Region Along the East Route

Liu reported that the Eastern route of the SNWDS would mitigate seasonal water flow stoppage in the Yellow River (1998; Liu and Zheng, 2002). Especially, in the wet years, excess water could be diverted to the north and flow along the natural river course, supplementing ecological water and helping ensure a continuous flow of water throughout the year (MOWR, 2000). Therefore, beneficial outcomes are *IMPROVED ECOLOGY FROM POLLUTANT DILUTION* (POLDILUT) and *RIPARIAN LIFE REPOPULATION* (LIFREPOP) due to increased water flow.

Environmental Benefits in Water-exporting Region Along the Middle Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-transferring Region Along the Middle Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-importing Region Along the Middle Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-exporting Region Along the West Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-transferring Region Along the West Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Environmental Benefits in Water-importing Region Along the West Route

With respect to the West Route, northwestern regions including Qinghai, Gansu, Shaanxi, Shanxi, Ningxia Hui, and Inner Mongolia will receive 20 billion m^3 of water, and the SNWDS will improve ecological conditions there. These water-importing regions located above latitude 33° N have a potential evaporation rate that exceeds precipitation (Liu, 1998; Liu and Zheng, 2002). Therefore, the SNWDS will *IMPROVE THE ECOLOGICAL ENVIRONMENT* (IMPRVECO) in the northwest because the transferred water flow rate will exceed the evaporation rate.

Environmental Costs in Water-exporting Region Along the East Route

The water-exporting region for the East Route at the lower Yangtze River, which has one of China's most highly developed economic cities, such as Nanjing and Shanghai, may experience negative environmental impact from the SNWDS. One of the biggest concerns is seawater intrusion due to the decline in flow to the estuary of the

Yangtze (Zuo, 1983). Thus, this concern is reflected in the following criteria: *LOSS OF ESTUARY* (LOSESTRY) and *DAMAGE TO AGRICULTURAL LAND* (HARMFARM).

Environmental Costs in Water-transferring Region Along the East Route

Along the East Route, water from the Yangtze crossing many lakes, ponds and rivers can cause changes to local ecological environments, which in turn may adversely affect the fish and other riparian life (Zuo, 1983; Liu and Zheng, 2002). This concern is reflected in the cost criterion *ALTERATION IN LOCAL RIPARIAN LIFE* (ALTRLIFE).

Environmental Costs in Water-importing Region Along the East Route

In the north, water-importing regions will have sufficient water available for households, industry, and irrigation from the scheme, but this increased water supply would also generate an increase in the volume of wastewater since per-capita water use is expected to rise (Liu and Zheng, 2002; Xie, Guo and Ludwig, 1999). This concern is reflected in the cost criterion *INCREASE IN WASTEWATER DISCHARGE AND PRODUCTION* (INCWASTE).

As mentioned regarding the economic system, sewage pollution is common along the East Route. Although there will be the transfer of clean water, several large cities lie along the transfer route, which generate billions of cubic meters of polluted water. Hence, the environment in the importing regions will end up getting polluted as well (Liu, 1998). This concern is reflected in the cost criterion, *TRANSFERRED WATER POLLUTES ENVIRONMENT* (POLLENVR).

As in the transferring region, the transferred water may adversely affect fish and other riparian life due to introduced species from the exporting and transferring regions along the East Route (Zuo, 1983; Liu and Zheng, 2002). This concern is represented by in the criterion *RISK OF INTRODUCED SPECIES* (ALIENSPC).

Environmental Costs in Water-exporting Region Along the Middle Route

Water transference will reduce the velocity of the river along the middle and lower reaches of the Han River, and it could have a significant impact on the ecosystem in the basin. The Middle Route will divert as much as one third of the annual flow of water from the Han River ("Issues Surrounding," 2001). This concern is reflected in the criterion *ALTERATION OF ECOSYSTEM* (ALTERECO).

Another environmental issue stemming from methane production from submerged and slowly decaying forests will be the release of a far more powerful greenhouse gas than carbon dioxide (McCormack, 2001). This is significant since the heightening of the Danjiangkou Dam will require 370 km^2 of additional area to be inundated for this route. We thus have the cost criterion *METHANE EMISSION FROM SUBMERGED REGIONS* (METHEMIT).

Environmental Costs in Water-transferring Region Along the Middle Route

The natural geological conditions along the Middle Route are composed of thick coarse sand, gravel or sand pebbles (Wei and Zhao, 1983), allowing water loss due to canal seepage. In order to overcome this problem, engineering measures will be taken. Concrete will be used as a lining for the sake of preventing seepage and reducing roughness along the canal (Liu, 1998; Liu and Zheng, 2002; "Middle Line Project," 2002). This process of creating a new artificial waterway significantly changes the surrounding ecology, a concern reflected in the criterion *ALTERATION IN LOCAL RIPARIAN LIFE* (ALTERECO) due to canal seepage prevention.

Building the Middle Route will also destroy the natural environment by excavating 600 million m^3 of earth and 0.6 million m^3 of rock ("Middle Line Project," 2002). The large amount of excavation materials will need a place for disposal (Xie, Guo and Ludwig, 1999). Thus, this concern is reflected in the following criterion: *PRODUCTION OF EXCAVATION MATERIALS* (EXCAVATE).

Furthermore, emissions from fossil fuels used during the construction of the Middle Route, such as for the production of concrete, steel and other materials, will be harmful to the surrounding environment (McCormack, 2001). It will contribute to local air pollution and its related negative environmental problems such as acid rain. Thus, this concern is reflected in the following criterion: *AIR POLLUTION* (AIRPOLLU) due to construction.

Environmental Costs in Water-importing Region Along the Middle Route

The Middle Route transfer of 14.5 billion m^3 of water will generate more than 10 billion m^3 of wastewater due to increased use of water. This concern is reflected in the criterion *TRANSFERRED WATER POLLUTES ENVIRONMENT* (POLLENVR).

Generally speaking, large-scale inter-basin water transfer such as the SNWDS would negatively affect the environment because it could alter the natural hydrological process, and is likely to create a new hydrological cycle (Liu, 1998; Liu and Zheng, 2002). Thus, this concern is represented by the criterion *ALTERATION OF ECOSYSTEM* (ALTERECO) due to transferred water.

Environmental Costs in Water-exporting Region Along the West Route

Constructing the West Route in a little disturbed environment will be destructive. The West Route requires building a combination of tunnels, dams and reservoirs, and pumping stations in the mountainous area. This concern is reflected in the following criterion: *DESTRUCTION OF FOREST* (DESTFRST) due to construction.

The dams and reservoirs built along the West Route will submerge forested land. Methane production from submerged and slowly decaying forests will produce far more powerful greenhouse gas than carbon dioxide (McCormack, 2001). This concern is reflected in the aforementioned criterion, *METHANE EMISSION FROM SUBMERGED REGIONS* (METHEMIT).

With regard to construction of the West Route, just as with the construction of the Middle Route, emissions from fossil fuels used for the production of cement, steel and other materials will be harmful to the local environment (McCormack, 2001). Thus, this concern is reflected in the following criterion: *AIR POLLUTION* (AILPOLLU) due to construction.

Environmental Costs in Water-transferring Region Along the West Route

As mentioned in the preceding paragraph, the emission from the fossil fuels used during the construction of the West Route along the transferring region will be harmful to the local environment (McCormack, 2001). We thus have the same criterion, *AIR POLLUTION* (AIRPOLLU) due to construction, associated with this region as well.

As with the exporting region, the natural environment in the transferring region will be destroyed along the route and will also produce large quantities of excavation materials, a concern reflected by the criterion *CONSTRUCTION PRODUCES EXCAVATION MATERIALS* (EXCAVATE).

The West Route also crosses many rivers along the transferring route before reaching the Yellow River. This action will not only negatively affect the environment because it could alter the natural hydrological process, and therefore be likely to create a new hydrological cycle (Liu, 1998; Liu and Zheng, 2002), but it can also introduce foreign species to the water-transferring regions. Thus, we have the cost criterion *RISK OF INTRODUCED SPECIES* (ALIENSPC) due to transferred water.

Environmental Costs in Water-importing Region Along the West Route

As with East route and Middle Route, sufficient available water from the West Route leads to increased use and hence an increase in wastewater, reflected in the criterion: *INCREASE IN WASTEWATER DISCHARGE OR PRODUCTION* (INCWASTE).

Finally, the water transferred through the West Route would likely introduce foreign species to the water-importing regions, reflected once again in the criterion *RISK OF INTRODUCED SPECIES* (ALIENSPC) due to transferred water.

<u>Benefits and Costs of the Project: Social System</u>

This final section will illustrate the benefits and costs to the Social System. As with the two previous systems, social *benefits* will first be analyzed, followed by the *costs*.

Social Benefits in Water-exporting Region Along the East Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Social Benefits in Water-transferring Region Along the East Route

The scheme further contributes to perceived improvements in quality of life, for the transferring regions, including; achieving higher living standards due to the local urbanization, public health improvement, recreation opportunities (Biswas, 1983; Xie, Guo and Ludwin, 1999; MOWR, 2000). The benefit criteria are thus: *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased domestic water supply.

Along with the economic development accompanying the sufficient water supply, job opportunities will increased in the water-transferring regions, and unemployment will decline. This will lead to intrapersonal gains, such as the satisfaction of having a job, being able to contribute to society, and being able to provide for one's family and so forth. Therefore, one objective is *INCREASED EMPLOYMENT* (INCREMPL).

Social Benefits in Water-importing Region Along the East Route

The scheme further contributes to improvements in quality of life, for the water-importing regions as well. Thus, benefits are: *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased domestic water supply.

For the same reason as found in the water-transferring regions, along with economic development due to increasing water supply, job opportunities will be increased at the water-importing regions as well, yielding the benefit criterion *INCREASED EMPLOYMENT* (INCREMPL).

Liu (1998; Liu and Zheng, 2002) also argues that maintaining year-round river flow will prevent silt and sedimentation problems in the estuaries, which will in turn lessen flood hazards. The Yellow River has overflowed and shifted course in the past, and it can return to its normal pattern along this stretch (Wei and Zhao, 1983). Therefore, with sedimentation control, the objective *DECREASE FLOOD HAZARD* (DECFLOOD) can be attained.

Furthermore, sufficient water supply through the SNWDS will reduce the current dependence on groundwater extraction. This will give the groundwater aquifers time to recharge and help to avoid groundwater depression as well as salt intrusion (Mei and Dregne, 2001). As a consequence of this, it *AMELIORATES LAND SUBSIDENCE* (NOSUBSID) and *PROTECTS AQUIFERS FROM SALTWATER INTRUSION* (NOSEAWTR) caused by over pumping (Liu, 1998).

Social Benefits in Water-exporting Region Along the Middle Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Social Benefits in Water-transferring Region Along the Middle Route

The scheme will contribute to improvements in quality of life for the transferring regions just as it will in the water-importing regions. As before, those benefits are *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased domestic water supply. For the same reason as for water-transferring regions along the East Route, *INCREASED EMPLOYMENT* (INCREMPL) is an expected benefit.

Social Benefits in Water-importing Region Along the Middle Route

The scheme further contributes to improvements in quality of life, for the importing regions. Thus, objectives are: *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased domestic water supply. As in the East Route's water-importing regions, *INCREASED EMPLOYMENT* (INCREMPL) is also anticipated.

Social Benefits in Water-exporting Region Along the West Route

THERE ARE NO SIGNIFICANT BENEFICIAL EFFECTS.

Social Benefits in Water-transferring Region Along the West Route

As with the East and Middle Routes, the scheme further contributes to improvements in quality of life in the transferring regions. Thus, benefits will be *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased water supply. As in the water-transferring regions along the East and Middle Routes, job opportunities will be increased. *INCREASED EMPLOYMENT* (INCREMPL) is thus an expected benefit.

Social Benefits in Water-importing Region Along the West Route

The scheme further contributes to improvements in quality of life for these importing regions as well. Thus, objectives are *PUBLIC HEALTH IMPROVEMENT* (HLTHINCR), *RECREATION OPPORTUNITIES* (RECOPPTY) due to the increased water supply. For the same reason as in the Middle and Eastern Routes, importing regions along the West Route will see the benefit of *INCREASED EMPLOYMENT* (INCREMPL).

Social Costs in Water-exporting Region Along the East Route

Loss of fishing and other jobs may occur due to environmental changes and alterations in the local ecology. This concern is reflected in the criterion *UNEMPLOYMENT LEADS TO PERSONAL DISSATISFACTION* (UNEMPLOY).

In regard to water rights, conflict between upstream and downstream provinces will be seen in the water-exporting regions of the south (Liu and Zheng, 2002). Conflict will also be likely between water-exporting and water-importing regions, and it will be seen even among the water-importing regions themselves. Since a large-scale water-transfer project implies the transfer of an economic resource, it will lead to a conflict of interest among the various parties (Liu, 1998). Therefore, this concern is reflected in the cost criterion *INTERREGIONAL DISCORD AND ANIMOSITY BETWEEN SOUTH AND NORTH* (INTERREG).

The water-exporting region for the East Route at the lower Yangtze River may experience negative environmental impacts from the SNWDS, and this change will affect society as well. One of the biggest concerns is seawater intrusion due to the decline in flow to the estuary of the Yangtze (Zuo, 1983). Thus, this concern is reflected in the following two criteria: *LOSS OF ESTUARY* (LOSESTRY) and *DAMAGE TO AGRICULTURAL LAND* (HARMFARM).

Social Costs in Water-transferring Region Along the East Route

Due to changes in the environment, unemployment from loss of fishing jobs, declining fish processing industries, and fishing equipment markets may occur as species disappear. The concern is reflected in the cost criterion *UNEMPLOYMENT LEADS TO PERSONAL DISSATISFACTION* (UNEMPLOY).

The scheme may also cause public health issues to both water-importing and transferring regions. The scheme increases the risk of spreading disease of both enteric and insect vector forms due to the development of water resource projects (Zuo, 1983; Xie, Guo and Ludwin, 1999; Becker, 2004). Therefore, this concern is reflected in the following criterion: *INCREASE THE RISK OF DISEASE TRANSMISSION* (RISKHLTH).

Social Costs in Water-importing Region Along the East Route

Critics claim that transferred water to the importing region will be too expensive for the public to afford because the scheme itself is too costly. Transferred water which will be used for irrigation will raise the price of agricultural products as well (World Wide Fund for Nature, 2001). The cost criterion *HIGH WATER PRICES* (WTRPRICE) reflects those concerns.

In addition, the same type of public health issues mentioned in the previous section need to be considered, and this concern is reflected in the criterion *INCREASED RISK OF DISEASE TRANSMISSION* (RISKHLTH) (Zuo, 1983; Xie, Guo and Ludwin, 1999; Becker, 2004).

Social Costs in Water-exporting Region Along the Middle Route

The foremost negative social issue of the SNWDS will be the displacement of people at the exporting region for the Middle Route due to the raising of the Danjiangkou Reservoir water level, which is anticipated to displace about 224 thousand people ("Issue Surrounding," 2001; Liu and Zheng, 2002). They will have to sacrifice their ancestral homes, jobs, and way of life including sites of archeological, historical, and cultural value in order for the SNWDS to go through (Xie, Guo, and Ludwing, 1999; Becker, 2004). Therefore, this concern is reflected in the following criteria: *POPULATION DISPLACEMENT* (POPMOVED) due to the Danjiangkou Reservoir expansion, and *LOSS OF CULTURE AND HERITAGE* (LOSCULTR) due to inundation of cities and villages.

As elsewhere, changes in the environment resulting from lower water flow will result in loss of jobs that depend on the condition of the river, such as fishing jobs, because fish populations, and maybe entire species, will disappear. The criterion *UNEMPLOYMENT LEADS TO PERSONAL DISSATISFACTION* (UNEMPLOY) represents this concern.

Social Costs in Water-transferring Region Along the Middle Route

Similar to the public health issues of the East Route, health issues along the Middle Route need to be considered, and this concern is reflected in the following criterion: *INCREASE THE RISK OF DISEASE TRANSMISSION* (RISKHLTH) (Zuo, 1983; Xie, Guo and Ludwin, 1999; Becker, 2004).

Social Costs in Water-importing Region Along the Middle Route

As in the water-importing region from the East Route, personal hardships stemming from the expenses incurred for the transferred water in this region are also expected. Therefore, this concern is reflected in the following criterion: *HIGH WATER PRICES* (WTRPRICE).

Again, the public health issues need to be considered, and this concern is reflected in the criterion *INCREASE THE RISK OF DISEASE TRANSMISSION* (RISKHLTH) (Zuo, 1983; Xie, Guo and Ludwin, 1999; Becker, 2004).

Social Costs in Water-exporting Region Along the West Route

In order to build the West Route, swaths of untouched forest will need to be leveled. The social implications are a loss of natural resources and beauty; therefore, this concern is reflected in the following criterion: *DESTRUCTION OF FOREST* (DESTFRST).

Social Costs in Water-transferring Region Along the West Route

The public health issues need to be considered although they are considered to be less serious than along the East Route or Middle Route since the water is expected to suffer little contamination. This concern is reflected in the criterion *INCREASE THE RISK OF DISEASE TRANSMISSION* (RISKHLYH).

Social Costs in Water-importing Region Along the West Route

As mentioned in the water-importing region from the East and Middle Routes, this route will also experience similar social problems related to the costs of the transferred water. Therefore, the criterion: *HIGH WATER PRICES* (WTRPRICE) reflects this concern. Finally, as with the transferring region along the West Route, the public health issues need to be considered, and is reflected in the following criterion: *INCREASE THE RISK OF DISEASE TRANSMISSION* (RISKHLTH).

The entire set of concerns – Economic, Environmental, and Social – are separated into two categories, one reflecting merits, advantages, payoffs, or other "benefits" of the diversion scheme, and the other reflecting drawbacks, disadvantages, or "cost". Each subset can be structured hierarchically, with Figure 4-1 thus depicting the benefits hierarchy, and Figure 4-2 representing the costs hierarchy. These provide the framework from which the overall evaluation of the scheme will be carried out in the next chapter.

Table 4-1. Hierarchy of Criteria for the Scheme: Benefit

- Economic System
  - East Route Benefits
    - Exporting region
      - construction increases revenues (CONSTINC)
    - Transferring region
      - construction increases revenues (CONSTINC)
      - economic stability accompanying drought prevention (DRTPRVNT)
    - Importing region
      - increased agricultural and industrial productivity (PRODINCR)
      - economic stability derived from drought prevention (DRTPRVNT)
      - expand business opportunities (BUSIOPTY)
      - increased shipping trade (SHIPTRAD)
  - Middle Route Benefits
    - Exporting region
      - reduced flood losses (FLOODLOS)
    - Transferring region
      - construction increases revenues (CONSTINC)
    - Importing region
      - increased agricultural and industrial productivity (PRODINCR)
      - new business growth (BUSIGROW)
  - West Route Benefits
    - Exporting region
      - construction increases revenues (CONSTINC)
    - Transferring region
      - construction increases revenues (CONSTINC)
    - Importing region
      - increased agricultural and industrial productivity (PRODINCR)
      - new business growth (STIMBUSI)

- Environmental System
  - East Route Benefits
    - Exporting region
    - Transferring region
      - decrease in water pollution (DCRSPOLL)
    - Importing region
      - improved ecology from pollutant dilution (POLDILUT)
      - riparian life repopulation (LIFREPOP)
  - Middle Route Benefits
    - Exporting region
    - Transferring region
    - Importing region

Table 4-1. (Continued) Hierarchy of Criteria for the Scheme: Benefit

- West Route Benefits
  - Exporting region
  - Transferring region
  - Importing region
    - improve the ecological environment (IMPRVECO)

- Social System
  - East Route Benefits
    - Exporting region
    - Transferring region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)
    - Importing region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)
      - decrease flood hazard (DECFLOOD)
      - ameliorate land subsidence (NOSUBSID)
      - protect aquifers from seawater intrusion (NOSEAWTR)
  - Middle Route Benefits
    - Exporting region
    - Transferring region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)
    - Importing region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)
  - West Route Benefits
    - Exporting region
    - Transferring region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)
    - Importing region
      - public health improvement (HLTHINCR)
      - recreation opportunities (RECOPPTY)
      - increased employment (INCREMPL)

Table 4-2. Hierarchy of Criteria for the Scheme: Cost

- Economic System
  - East Route Costs
    - Exporting region
      - reduced agricultural and industrial production (REDCPROD)
      - fishery losses (FISHLOSS)
    - Transferring region
      - construction cost for pumping stations (COSTPUMP)
      - construction cost for Yellow River crossing section (COSTCROS)
      - electricity for the pumping stations (COSTELEC)
    - Importing region
      - cost for treating transferred water (TREATWTR)
      - construction cost for treatment plants (COSTPLNT)
  - Middle Route Costs
    - Exporting region
      - cost for Danjiangkou reservoir upgrade construction (RESUPGRD)
      - compensation for displacement of people (MOVEPEOP)
      - compensation for middle and lower reaches of Han River (HANRIVER)
      - loss of navigational and economic trade routes (LOSTRADE)
      - loss of farmland and its production (LOSSFARM)
    - Transferring region
      - construction cost for Middle Route (CSTMIDRT)
    - Importing region
  - West Route Costs
    - Exporting region
      - construction cost for building West Route (CSTWSTRT)
    - Transferring region
      - construction cost for building West Route (CSTWSTRT)
    - Importing region

- Environmental System
  - East Route Costs
    - Exporting region
      - loss of estuary (LOSESTRY)
      - damage to agricultural land (HARMFARM)
    - Transferring region
      - alteration in local riparian life (ALTRLIFE)
    - Importing region
      - increase in wastewater discharge and production (INCWASTE)
      - transferred water pollutes environment (POLLENVR)
      - risk of introduced species (ALIENSPC)

Table 4-2. (Continued) Hierarchy of Criteria for the Scheme: Cost

- Middle Route Costs
  - Exporting region
    - alteration of ecosystem (ALTERECO)
    - methane emission from submerged regions (METHEMIT)
  - Transferring region
    - alteration of ecosystem (ALTERECO)
    - construction produces excavation materials (EXCAVATE)
    - air pollution (AIR POLLU)
  - Importing region
    - transferred water pollutes environment (POLLENVR)
    - alteration of ecosystem (ALTERECO)
- West Route Costs
  - Exporting region
    - destruction of forest (DESTFRST)
    - methane emission from submerged regions (METHEMIT)
    - air pollution (AIR POLLU)
  - Transferring region
    - air pollution (AIR POLLU)
    - construction produces excavation materials (EXCAVATE)
    - risk of introduced species (ALIENSPC)
  - Importing region
    - increase in wastewater discharge or production (INCWASTE)
    - risk of introduced species (ALIENSPC)

Social System

- East Route Costs
  - Exporting region
    - unemployment leads to personal dissatisfaction (UNEMPLOY)
    - interregional discord and animosity between south and north (INTERREG)
    - loss of estuary (LOSESTRY)
    - damage to agricultural land (HARMFARM)
  - Transferring region
    - unemployment leads to personal dissatisfaction (UNEMPLOY)
    - increase the risk of disease transmission (RISKHLTH)
  - Importing region
    - high water prices (WTRPRICE)
    - increase the risk of disease transmission (RISKHLTH)
- Middle Route Costs
  - Exporting region
    - population displacement (POPMOVED)
    - loss of culture and heritage (LOSCULTR)
    - unemployment leads to personal dissatisfaction (UNEMPLOY)

Table 4-2. (Continued) Hierarchy of Criteria for the Scheme: Cost

Transferring region
  increase the risk of disease transmission (RISKHLTH)
Importing region
  high water prices (WTRPRICE)
  increase the risk of disease transmission (RISKHLTH)
West Route Costs
  Exporting region
    destruction of forest (DESTFRST)
  Transferring region
    increase the risk of disease transmission (RISKHLTH)
  Importing region
    high water prices (WTRPRICE)
    increase the risk of disease transmission (RISKHLTH)

CHAPTER 5
THE DECISION MAKING PROCESS

The uncertainty of the South to North Water Diversion Scheme (SNWDS) is considerable because of its scale. Scientists, engineers, and decision makers are aware of the potential costs and benefits of the scheme, but these people have different opinions about it (Biswas, 1983). These differences are important because they underscore the range of potential solutions available to cope with those various effects. Chapter 4 highlighted these complexities, illustrating many different criteria and effects. However, in order to put this all together, a method is needed in order to interpret, distinguish, and combine the more "factual" judgments pertaining to the effects themselves, and the more value-laden judgments as to the importance of those effects. In other words, given the criteria in figures 4-1 and 4-2, from the previous chapter, how can one assess the overall costs and benefits of the diversion scheme, or of any alternative plan, including the sectoral and spatial distribution of those cost and benefits? The way I will conduct such an assessment here is through the application of the Analytic Hierarchy Process (AHP). After describing this methodology, I will first discuss the development of scenarios in order to conduct a cost and benefit analysis (CBA), and then present the CBA of the SNWDS itself.

The Assessment Methodology: The Analytic Hierarchy Process (AHP)

The AHP is a method for prioritizing and measuring intangible criteria and other elements of a decision problem. Prioritization is always developed with respect to a particular goal, purpose, objective, or criterion. In order to describe the AHP method, I will divide the process into two main steps – structuring the set of criteria to guide the prioritization, and conducting the prioritization itself.

An "analytic hierarchy" has at least three levels: an apex, or top level, defining the overall goal of the analysis; a second level of evaluative criteria; and the lowest level defining a set of discrete alternatives. It is often necessary for a criterion to be divided into subcriteria representing dimensions or facets of it, which together define the criteria in question. This is the case here, as the benefits and costs hierarchies of Tables 4-1 and 4-2 indicate. The alternatives to be prioritized ("evaluated") in this study are two mutually exclusive actions: DO the project, or DO NOT do the project. The evaluation conducted here will use two analytic hierarchies, one for benefits and one for costs, each consisting of an apex, four levels of criteria, and the same two alternatives. An analytic hierarchy is thus a structured set of attributes or characteristics ("criteria") thought relevant to a situation, that situation or problem represented by the overall goal at the apex.

The second part of the AHP is the assessment phase, in which the prioritization of criteria and alternatives is executed. Every prioritization on the AHP is conducted through pairwise comparison of elements at one level with respect to their "parent" element at the level immediately above them: alternatives with respect to the lowest-level subcriteria, subcriteria with respect to their parent criteria, and highest-level criteria with respect to the overall goal. Comparison is made in terms of relative dominance in achieving or manifesting the parent element, where "dominance" is in terms of importance, preference, or likelihood, as the case warrants. Thus alternatives are related by preferences—i.e., with respect to a given *impact* (criterion), one *prefers* alternative X over alternative Y—and criteria are related by importance—i.e., with respect to a given criterion, one believes subcriterion X to be more important than subcriterion Y. Comparisons are quantified in the AHP through use of a 9-point positive integer scale (Table 5-1), with such comparisons made graphically, verbally, or numerically. A set of such comparisons of the "children" elements of each criterion (and of the overall goal) yield a positive reciprocal matrix, each entry of which is the dominance of the row element (alternative or criterion) over the column element. Although such human, subjective judgments are almost invariably inconsistent, Saaty (1980) has shown the normalized maximum eigenvector of that matrix to be the best approximation of the "true" relative dominance ("weight" or "priority") of each element. He further showed that these priorities exist on a new ratio scale, meaning that they can be multiplied and divided by each other. This is important because it allows priorities at each level to be aggregated through multiplication up through the hierarchy. The overall priority of each alternative is thus determined by summing the corresponding products. While this process yields an additive value function, since the number of terms in each product increases with the number of criterion levels in the hierarchy, the function has a multilinear form. For two or more criterion levels, it is thus a nonlinear value function. For a more detailed discussion of the entire process, one can refer to Saaty (1980). It should be noted that the AHP software used was Expert Choice Version 9.50A05.

CBA with the AHP forms ratios based on the multiattribute formula benefit multiplied by cost (B x C). Although any ratio is itself a relative measure, recall that individual priorities themselves are relative measures. AHP-based CBA prioritizes and ranks alternatives based on this B x C ratio, whereas the economist would rank them on the basis of net benefits, or benefits minus costs (B-C). The difference is due to the fact that the economist deals only with identical monetary units on the same ratio scale, while the AHP deals with multiattributed benefits and costs measured on different ratio scales.

Table 5-1. The Pairwise Comparison Scale

Intensity of Importance	definition	explanation
1	Equal dominance	Two elements contribute equally to the priority
3	Moderate dominance	Experience and judgment slightly favor one element over another
5	Strong dominance	Experience and judgment strongly favor one element over another
7	Very strong dominance	An element is strongly favored and its dominance is demonstrated in practice
9	Extreme dominance	The evidence favoring one element over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgment	Compromise is needed between two judgments
Reciprocals	When activity i compared to j is assigned one of the above numbers, then activity j compared to i is assigned its reciprocal.	

Source: Modified from Saaty, 1990. p.78.

Notice that for the B x C metric to make sense, pairwise comparisons must be made such that higher cost priorities reflect higher costs, that is "better" on costs, i.e. lower real costs, or in other words higher real costs leads to decreased attractiveness, which results in lower prioritization.

"Value" Judgments: Development of Scenarios

The judgments at the upper levels of the hierarchy are considered more "value"-laden than those made nearer the bottom. This is because those upper levels deal with the importance of the effects. I first consider three different viewpoints – conservationist, socialist, and technocratic– in order to capture a wide range of perspectives. Second, since the primary purpose of this thesis is to conduct a cost and benefit analysis of the SNWDS, I will also be weighting the variables *Cost* and *Benefit* to reflect different attitudes regarding them. Finally, since the problem of the water shortage in China originates from an unequal distribution of resources between southern and northern China, I have included weighted values for northern and southern China as the final variable set, for the development of the prioritization of alternatives DO or DO NOT execute the SNWDS.

Discussion of the Scenarios

In order to cover a broad spectrum of perspectives, three main viewpoints were generated from the multitude of viewpoints and opinions presented in the literature reviewed. The first perspective, the conservationist, represents the environmental concerns, leans heavily towards protecting the environment, not only through the prevention of additional habitat destruction and pollution, but through the restoration of damaged ecosystems as well. Criteria that meet these beliefs, are weighted more heavily, that criteria that do not. Such criteria are: decreasing water pollution, riparian life restoration, etc. The second perspective, the technocratic, represents the economic concerns, leans heavily towards industrial or technological progress, the production of physical products. Criteria that meet these values—e.g., new business growth, increased agricultural growth and industrial productivity, reduction of financial losses through flood prevention, etc.—are weighted more heavily than those that do not. The final perspective, what I refer to as the "welfarist" view, which represents the social concerns, leans heavily towards the overall wellbeing and improvement of individuals, families and communities. This perspective is the most difficult to quantify as a whole, because while there are certain attributes which can be directly measured, such as changes in annual income, employment rate, or rates of particular illnesses, there are many attributes that are difficult to quantify, such a personal satisfaction or community cohesiveness. However, with the other two perspectives, criteria that meet these values are more heavily weighted than those that do not. These criteria are improvements in public health, increased employment, etc.

The second set of values deals with the general categories of *cost* and *benefit* themselves. For some, the adage "the ends justify the means," represents the perspective that as long as the goal is reached, the benefits from reaching the goal outweigh the cost of reaching that goal. This implies that benefits are weighted more heavily than costs. For others, the first rule of ethics is "do no harm". For them, "harms" (i.e., "costs"), cannot be compensated by gains in other areas (i.e., other benefits). For such people, costs are implicitly weighted higher than benefits. A balanced perspective is presented giving equal weight to both cost and benefit. These three different views give rise to three different value scenarios.

The final value set is weighted with respect to the unequal distribution of resources between northern and southern China. Both sacrifices and gains are anticipated for both northern China and southern China; therefore, consideration is given to the people and resources located in either area. For this thesis the exporting and transferring regions are considered southern China and the importing region is considered northern China. Two scenarios will be presented with one having the North heavily outweighing the South and the other with the South outweighing the North.

Utilizing all of the perspectives previously mentioned, a series of eight scenarios have been developed in order to effectively assess the impact of each in regards to prioritizing the alternatives with respect to whether or not to execute the SNWDS.

Scenario 1:
- Socialist Welfarist, Conservationist, and Technocratic each given equal weight
- Benefit and Cost each given equal weight

Scenario 2:
- Socialist Welfarist, Conservationist, and Technocratic each given equal weight
- Cost outweighs Benefit

Scenario 3:
- Socialist Welfarist, Conservationist, and Technocratic each given equal weight
- Benefit outweighs Cost

Scenario 4:
- Conservationist outweighs both Social Welfarist and Technocratic equally
- Benefit and Cost each given equal weight

Scenario 5:
- Social Welfarist outweighs both Conservationist and Technocratic equally
- Benefit and Cost each given equal weight

Scenario 6:

- Technocratic outweighs both Conservationist and Social Welfarist equally
- Benefit and Cost each given equal weight

Scenario 7:

- Social Welfarist, Conservationist, and Technocratic each given equal weight
- Benefit and Cost each given equal weight
- Southern China outweighs Northern China

Scenario 8:

- Social Welfarist, Conservationist, and Technocratic each given equal weight
- Benefit and Cost each given equal weight
- Northern China outweighs Southern China

"Factual" Judgments

"Factual" judgments, which are what the actual effects are expected to be, are located in the lower part of the hierarchy. These assessments were done by me the author, based on the literature reviewed. All of these judgments are located in appendix section. Undoubtedly there will be disagreement with "my" judgment of these effects, just as many experts themselves would disagree on the relative magnitudes of the effects of such a complex project. However, the AHP allows for such different judgments to be made explicit and the sensitivity of final decisions to them to be evaluated (Ridgley and Rijsberman, 1992).

Table 5-1. Summary of Scenarios with Weights and Resulting Rankings

	Scenario1	Scenario2	Scenario3	Scenario4	Scenario5	Scenario6	Scenario7	Scenario8
Environmental	0.33	0.33	0.33	0.8	0.1	0.1	0.33	0.33
Social	0.33	0.33	0.33	0.1	0.8	0.1	0.33	0.33
Economic	0.33	0.33	0.33	0.1	0.1	0.8	0.33	0.33
Benefit	0.5	0.75	0.25	0.5	0.5	0.5	0.5	0.5
Cost	0.5	0.25	0.75	0.5	0.5	0.5	0.5	0.5
North							0.2	0.8
South							0.8	0.2
DO	0.234	0.175	0.058	0.045	0.236	0.414	0.218	0.244
DO NOT	0.245	0.061	0.183	0.384	0.23	0.051	0.267	0.235

Note: Numbers in black for DO and DO NOT represent rank 1, while the light gray numbers indicate rank 2.

Results and Summary of the CBA

With respect to the valuation of the perspectives presented in the eight scenarios, at a quick glance one can see that the resulting priorities were evenly split between the alternatives of DO and DO NOT execute the SNWDS. This becomes even more evident looking at Scenario 1, which is considered the balanced perspective. There is only a small margin between *DO* and *DO NOT* execute the scheme, with DO execute the scheme having a weighted value of 0.234 and DO NOT having a weighted value of 0.245. When taking into account the value of benefit versus cost in Scenario 2 and 3, the weighted values are almost exactly reversed. This reflects that there is a small margin between the alternatives of DO and DO NOT execute the scheme. However, cost receives an overall weighted priority that is slightly greater that benefit therefore, giving a lean towards DO NOT execute the scheme. However, when considering the three main points of view conservationist, welfarist, and technocratic in Scenarios 4, 5, and 6, two of the three, the technocratic and welfarist, result in a higher priority for DO execute the SNWDS. Finally, with respect to the division of northern China versus southern China in Scenario 7 and 8, the overall priority ranking slightly favors northern China with respect to DO execute the scheme. This analysis demonstrates clearly that, given the unavoidable value-ladenness of the decision neither of the alternatives examined here is clearly superior to the other in any objective sense. The choice to proceed or not with the transfer scheme depends on one's values.

CHAPTER 6
CONCLUSION

Analysis of China's Decision to Proceed with the SNWDS

Based on the results of the CBA, while four scenarios support executing (DO) the scheme and four scenarios suggest not proceeding with it (DO NOT), the conclusion reached would be not to proceed with the SNWDS only by a slight lead based on both the balanced perspective and when comparing all eight scenarios together. However, there are four main reasons that highlight the motives and the decision to execute the SNWDS.

First, the overall decision comes down to either DO NOT, maintain the status quo, and the water shortage remains, or DO, execute the scheme, the water shortage problem is significantly reduced, and all other factors related to Cost and Benefit basically cancel each other out As a result, in order to reduce the water shortage problem for the nation as a whole, it would not be prudent for China to follow the decision of maintaining the status quo, because in any case, China needs to deal with the situation.

Second, the results of the CBA present an overall priority of DO NOT execute the scheme when comparing the value of northern China versus southern China. However, with the decision to proceed with the SNWDS this decision appears to give little consideration for the south and those who live in the water-exporting and transferring regions. As a result, this is one of the main reasons why the scheme is controversial. People who want development of the nation as a whole tend to support the scheme, but people who want to consider the costs to those in the south oppose the scheme. However, those who are in the position of decision makers believe that the scheme promotes economic growth in north, which would in turn contribute to improvements in the nation's standard of living as a whole by increasing the average household income, and per capita water use. This is based on the perspective that as a result of the potential prosperity in the north, the scheme will eventually help to pay for environmental costs incurred in the south, the water-exporting and transferring regions (Edmonds, 1998). Therefore, the rapid economic growth could generate the funds for both poor people who hope to fulfill their basic needs and protect or even clean up the environment (Vermeer, 1998). As a result though, China's attitude was understood as "pollute first and pay later" (Edmonds, 1998, p.4). Thus, the Chinese viewpoint gave rise to public censure from other parts of the world, since this has been seen as a continuation of the Maoist mode of thinking, progress at the expense of the environment.

However, this mode of thinking was not China's intention at all. In fact, alleviating environmental problems and raising the quality of life are the foremost demands of the Chinese people (Hu, 1998). Chinese leaders clearly stated that China must coordinate economic development with population growth, resource use, and environmental protection in order to avoid following the path of wasting resources or polluting the environment first and then taking belated actions to fix them (Hu, 1998). In order to grant the Chinese people's foremost request, the Chinese government sought the solution for the water shortage problem in the north, which was the SNWDS. Therefore, the SNWDS is just one of China's responses to water scarcity in the north.

Eventually, the SNWDS will help to improve the entire nation's standard of living, which is currently about US$1,000 per capita per year. This economic information correlates with China's decision to move forward with the scheme. Edmonds referred to the relationship between changes in environmental values and economic growth pointed out by the Overseas Economic Co-operation Agency, was that "guaranteeing water supply seems to be the primary pollution concern in countries with annual GNP per capita of up to US$1,000. Once a society has reached the US$3,000 level, sewerage becomes a consideration, whereas waste disposal does not become a major concern until a GNP per capita US$10,000 level is reached" (1998, p. 1). Water supply is certainly China's primary present day concern. Finally, since the 1990s, China has experienced a surge in economic growth; however, China's current situation of water resources has already not only posed a great threat to its sustainable development, but has also inflicted a great loss on agricultural and industrial production (Zhang, 2000). Through the scheme, at least China will be able to mitigate water shortage in the north. From this viewpoint, China is a developing country and there is nothing for it to do but to (DO) execute the scheme.

The third main issue regarding the SNWDS is its scale. The scheme has been seen as an appropriate example of gigantism and technocentrism, which are considered as outdated and mistaken modes of technology by scientists and engineers in developed nations (McCormack, 2001). Through their experiences, they have realized that there are a lot of things in nature that defy human ingenuity to control. The scientists have come to realize that these centralized systems can provide low-cost water, but the system not only costs a great deal for the construction, but also can lead to a vicious cycle in which damage to the environment can require more money to remedy the situation (Cosgrove and Rijsberman, 2000). As a result, developed nations' scientists and engineers assume that the SNWDS will create a negative impact on China's society. While it is true that the SNWDS is a colossal national project, which was proposed in 1950s, China is trying to build the scheme utilizing modern techniques, and attempting to avoid the mistakes made by developed nations. For instance, if there is a correlation between scale of the scheme and impact on the environment, reduction of scale will minimize the impact on the environment. Based on this assumption China is trying to reduce the scale by establishing three stages for the construction so that they can stop building if it meets demand. Another example is that China is trying to adapt western technology to improve the efficiency (Boxer, 2002). In addition, more and more young people in China are learning about science and technology ("News Scan," 2004) from institutions in North America, Western Europe, and Japan, so they are aware of the situation that a technological fix can be the cause of other environmental problems such as those being raised in regards to the scheme (Edmonds, 1998). Therefore, while the SNWDS is a colossal project as a whole, efforts can be taken to reduce the possibility that the scheme will not be outdated and become a mistaken project, and that the scale of the scheme and impact on the environment can be minimized. Through the scheme, the Chinese government needs to bring its ability into full play, because solving the water situation in north China raises complicated environmental, economic, and social problems, and only the Chinese government has the capability of taking command of this project (Zhang, 2000).

The final issue deals with China on an international level in how it relates to other nations and how other nations relate to China. The SNWDS supposes to accelerate energetic economic activity in northern China, and it has aroused great concern from the international community. China has already affected the environment of neighboring countries and other parts of the world, so other nations can no longer accept China's methods for economic development to continue. In fact, China is the world's second largest producer of greenhouse gases, generating one eighth of the global total (Smil, 1998). This is due to China's industries, which heavily rely on burning coal as an energy source, and its technological efficiency, including its coal-cleaning capacity, which is low compared with the level of other developed nations. As a result, it causes global environmental problems such as climate change resulting in global warming, and water pollution by acidification of the surface water from the acid rain due to air pollution.

In accordance with addressing these international concerns for environmental protection and reducing pollution, "encouraging cleaner production, and environmental protection has recently been elevated to the status of 'national fundamental policy'" for China (Vermeer, 1998, p.229) by trying to develop a compromise between the nation's economic growth and environmental protection. Although China is trying cleaner production techniques for the benefit of the environment and more importantly, for the people's health, it is hard to answer the calls for quick progress. China is having a difficult time balancing the two major concerns of trying to afford the expensive latest technology in order to address the environmental concerns and the heavy reliance on coal for energy for the nation's economic growth, while at the same time, dealing with a pronounced water shortage. With this in mind, China is placed in a difficult situation, and as a result, "to some degree China is forced into international accords out of fear of isolation" (Edmonds, 1998, p.4). They are caught in a dilemma of whether to give up economic growth and a higher standard of living for the poor people or protect the environment and people's health. Therefore, it seems apparent, that since China cannot choose one priority over the other, they will execute the scheme and cooperate with other nations in order to meet international standards regarding environmental issues.

Based on these main issues, China has made the decision to execute the SNWDS. By following through with their decision, it shows that China is trying hard to improve its citizens' standard of living by eliminating the water shortage in the north through the development of the scheme. Yet, China is acknowledging to some degree the criticism and concerns voiced by the international community. However, these efforts and changes are sometimes hard for foreigners to see because not only can China sometimes not afford the technologies necessary for their applications, but also the fact that the newest technologies do not fit Chinese traditional culture and historical legacy of water engineering knowledge (Boxer, 2002). At the same time though, it is also true that it is hard to change people's attitude. Many of the older leaders still believe the notion from the Maoist era that technology can fix everything (Edmonds, 1998). In this respect China has the challenge of reworking its ideological framework and moving from an isolationist nation to participating with the international community, while retaining its cultural heritage.

Findings and Future Issues

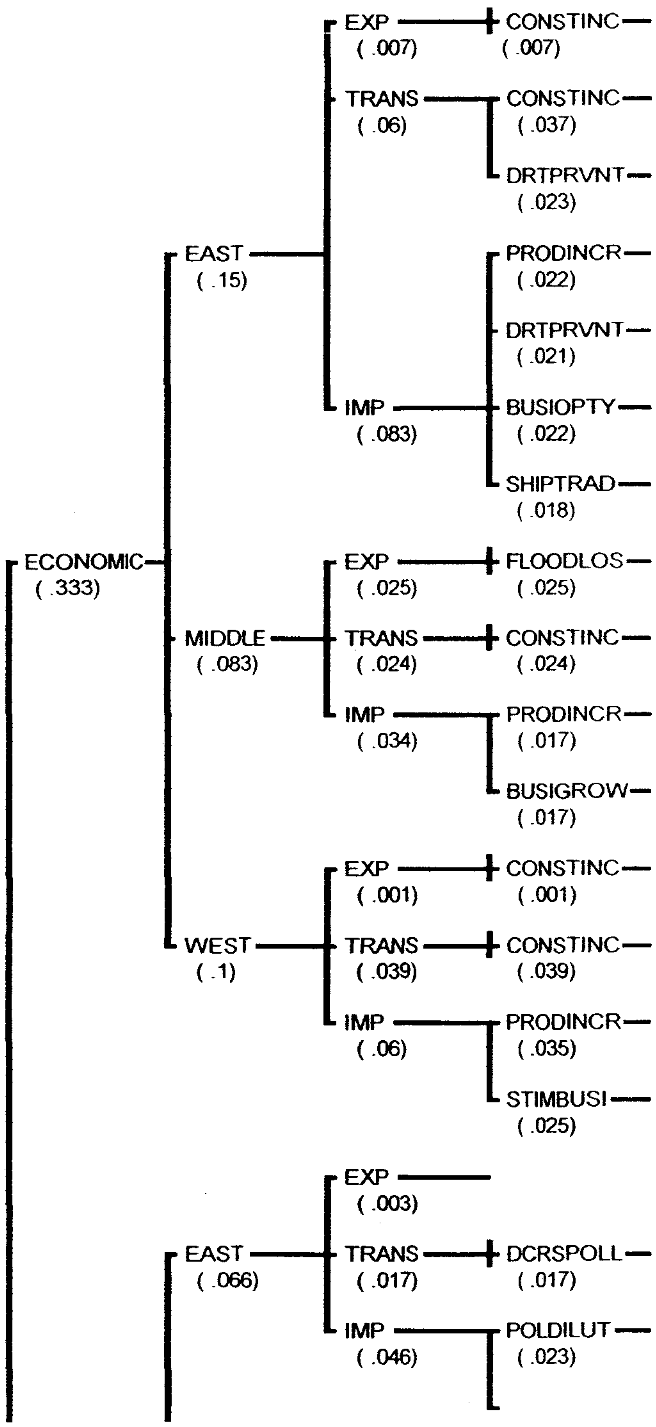
Notwithstanding some of the cost-benefit arguments against the SNWDS, China feels the water situation in the north has already become too serious to be effectively addressed by local government and non-government organization intervention alone; the north needs the SNWDS as an initial step in mitigating the crisis. It is understood that the SNWDS is just a necessary remedy for partially solving the water shortage problem in north China. In order to eradicate the problem at hand it will be necessary to develop a combination of other available methods. In turn, cooperation and input from local, regional, and national governmental levels will need to be considered, so that the most appropriate water management for China can be developed and implemented. The reason for this is because the national government can develop and implement projects on the scale of the SNWDS, but local governments can only apply small scale and low-tech projects, which are very practical and easy to implement to the water shortage problem (Murphy, 2002). The management plan also needs to work with concerted effort in controlling both demand and supply simultaneously. The biggest challenge that China is facing is to seek the best modern technologies that address China's water problems by applying internationally accepted strategies and methods, but which meet the unique Chinese values and specific culture (Boxer, 2002). In addition to that, Vermeer commented on what a Chinese society should be: "modern society require[s] public participation based on adequate information, open exchange of views, transparency of the decision-making process and early involvement of interested parties" (1998. p.234). China is apparently focusing its untiring effort towards water management. China's problem is no longer only China's problem. If China is going to proceed, then the developed countries should help it do so in a way that minimizes the adverse effects that they anticipated and know how to mitigate as a result of their past experience. This way, the challenges that China is experiencing now may provide very beneficial lessons for many developing countries in the future.

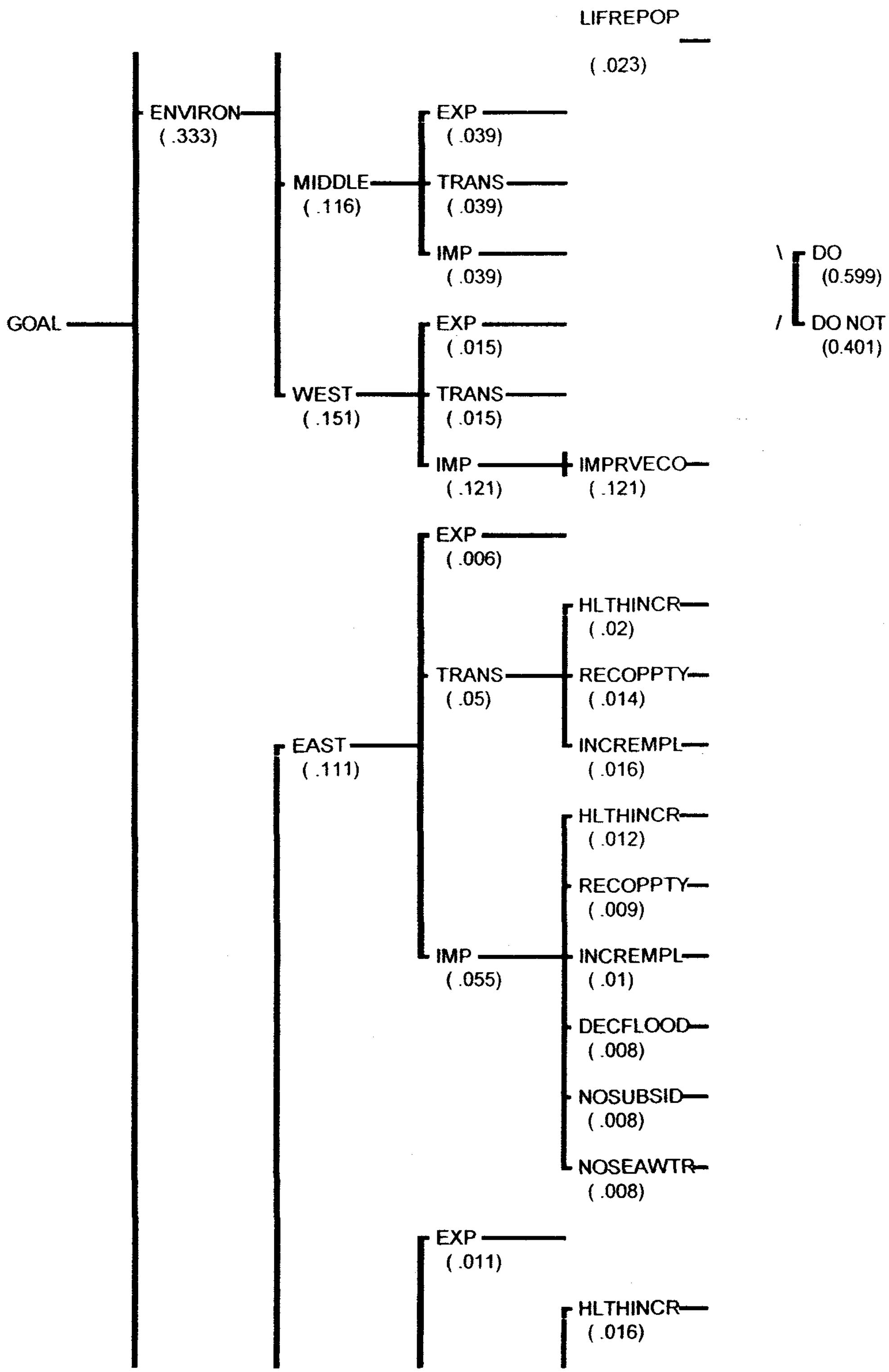
Finally, the following comments are directed towards China's future issues regarding effective water management, and thoughts for future study. First, China needs to continue to conduct research. This thesis has integrated a number of studies and views in an overall assessment. Of course China conducted various feasibility studies before it set about construction, but a real study of the scheme requires direct surveys, observations, and experimental data. Liu commented that "Resorting to ideas from abroad or from the past may lead to fallacious results, due to the specific nature of the contemporary natural, social and economic conditions of the areas affected" (1998, p.182). Study of the SNWDS needs to be conducted continuously, and China will receive accolades if the project lasts for a long time, not for the scheme itself but what they did with it.

Second, China needs to be flexible in constructing the scheme, since technology is rapidly changing and improving, so that new technologies can be incorporated into the SNWDS. However, they also need to take responsibility in operating the scheme appropriately and efficiently.

Finally, China needs to exchange information. Vermeer pointed out that very little has been written by China about its national project's environmental issues beyond impacts on animals such as pandas, white dolphins, golden monkeys, and cranes (1998). In fact, the result of a grading test of "freedom of the press" is very low, China ranked 161 out of 166 countries ("Majority of Asian Countries," 2003). For the purpose of uniting efforts in meeting the agreements made with the international community in order to protect the environment both on a national and international level, China needs to exchange information actively and freely, not only because China plays a strategically important global role, but also because being a more transparent nation and developing a willingness to accept constructive criticism more readily will produce better results and generate benefits for China that it will miss otherwise.

APPENDIX A
SCENARIO 1 BENEFIT

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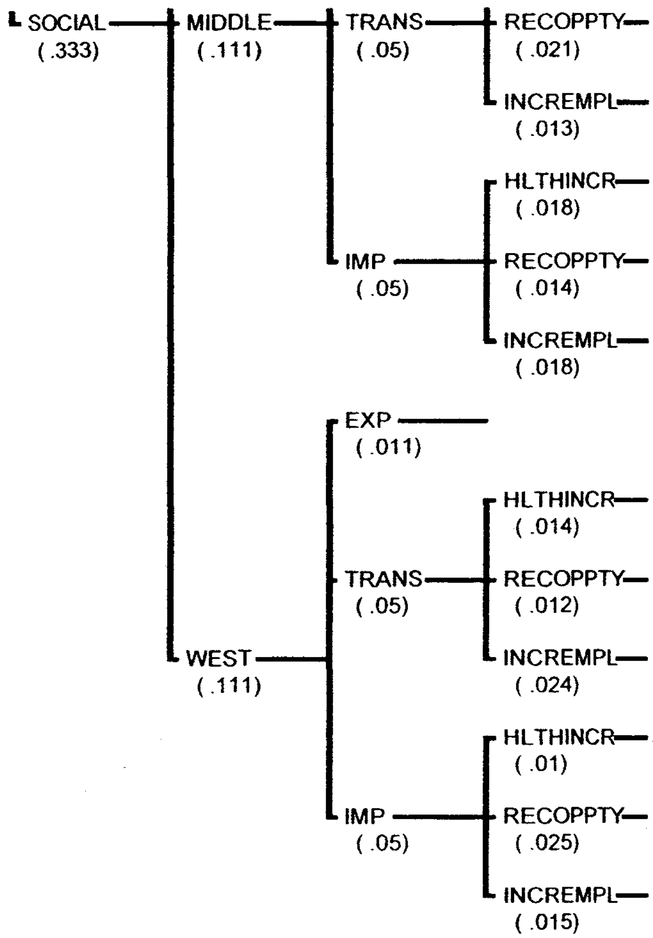
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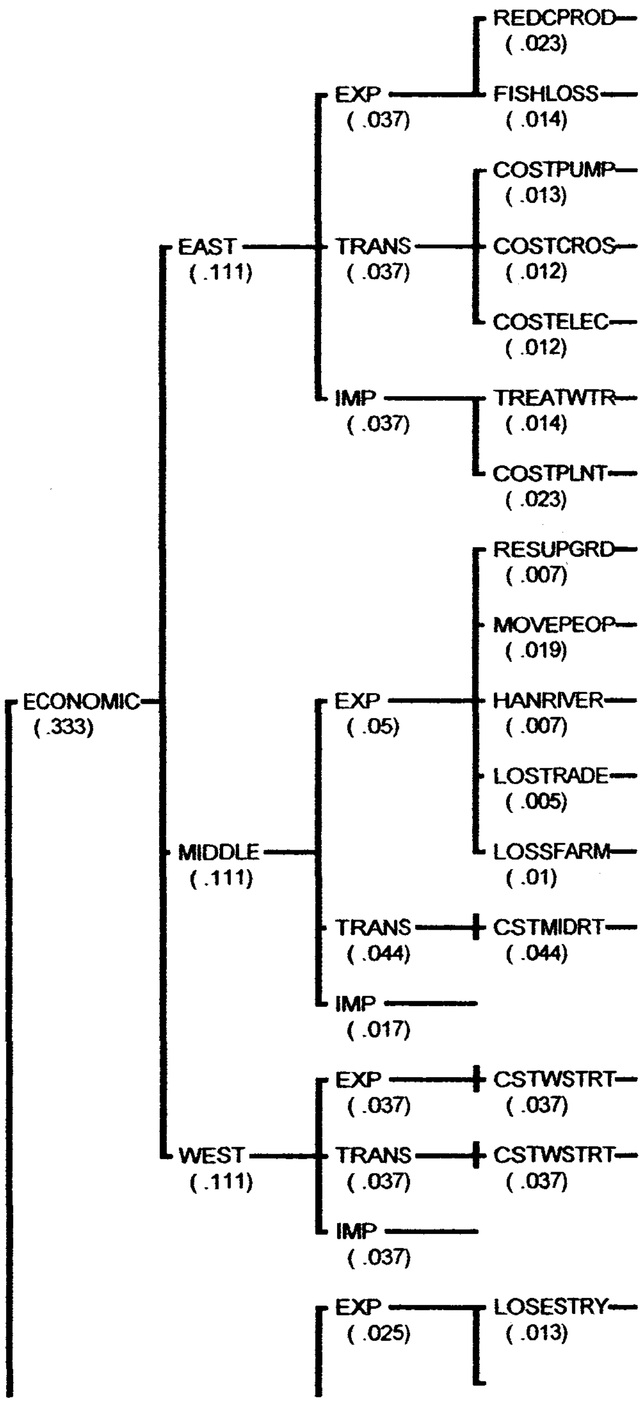
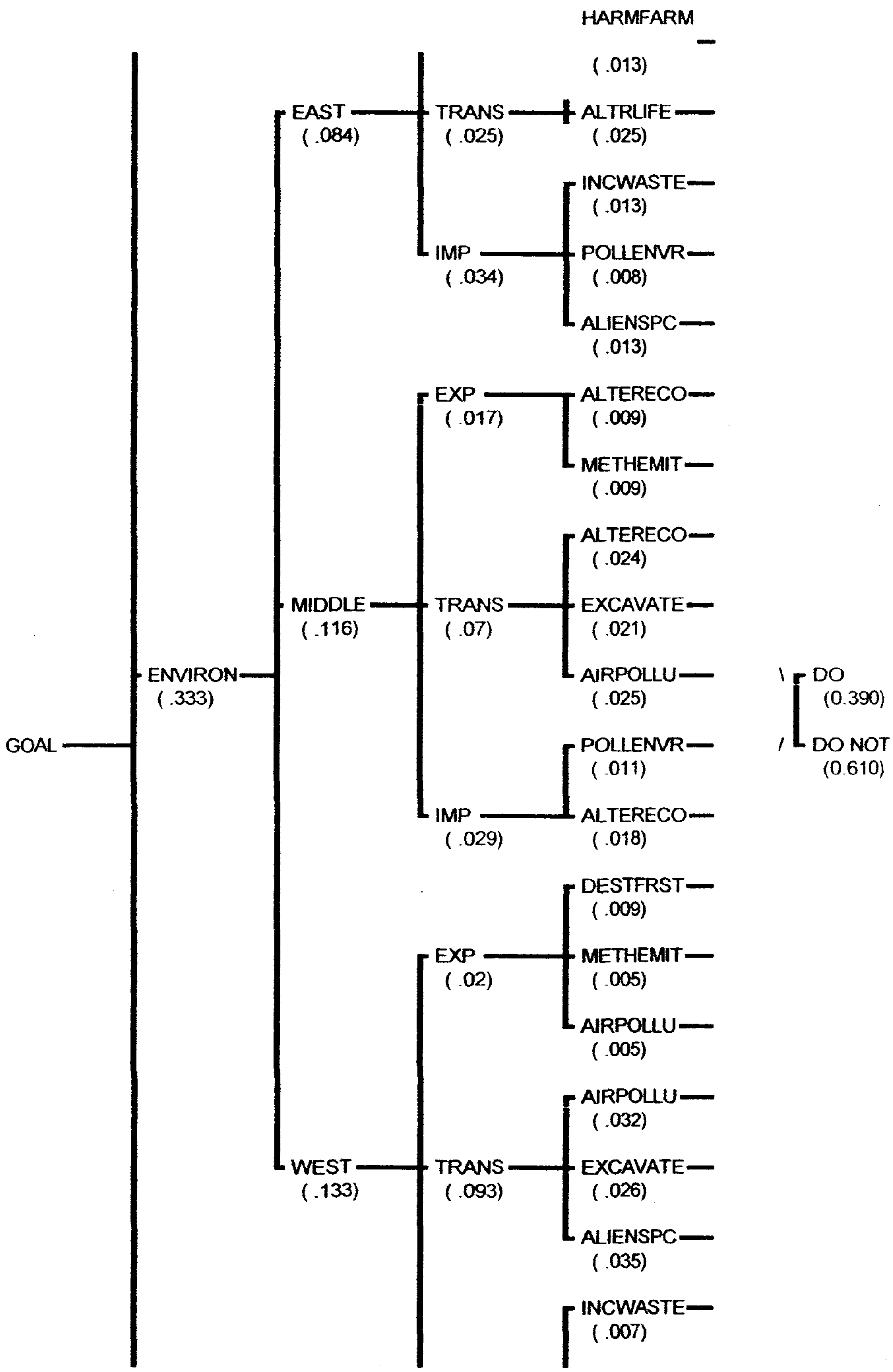
APPENDIX B
SCENARIO 1 COST

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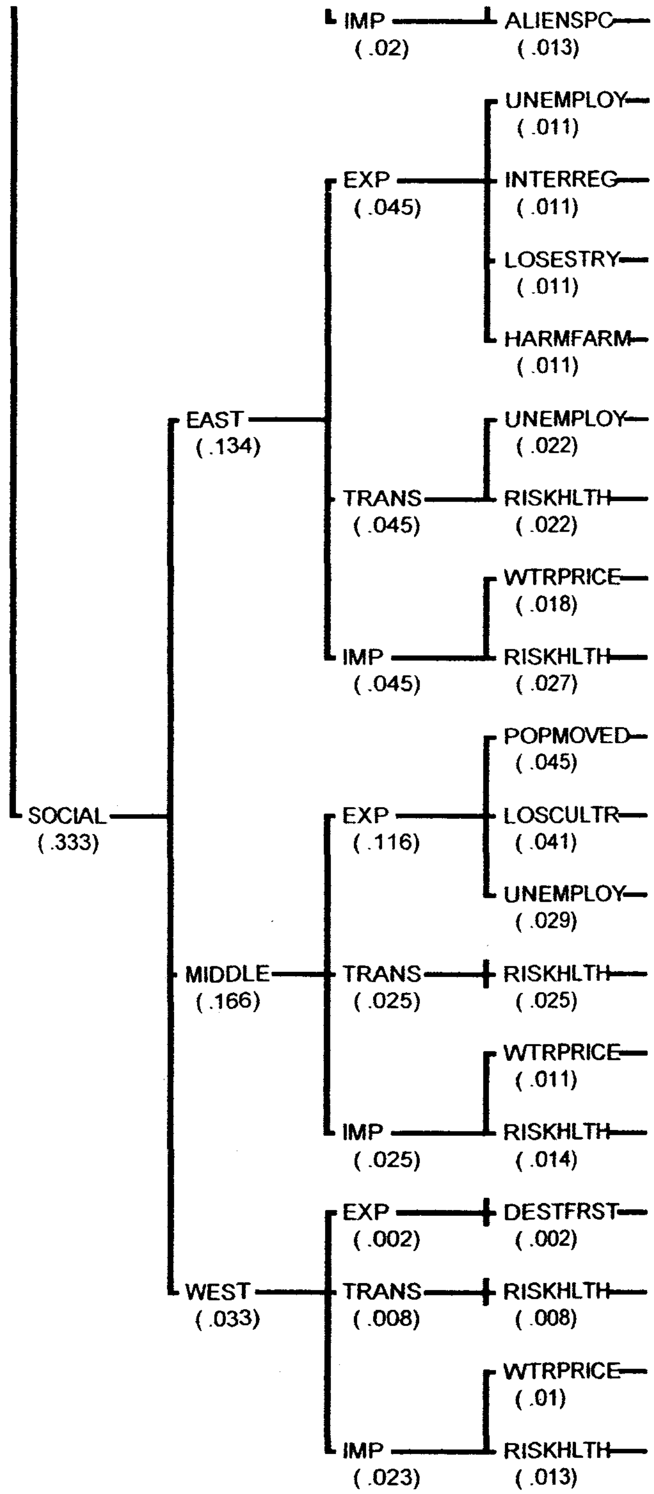
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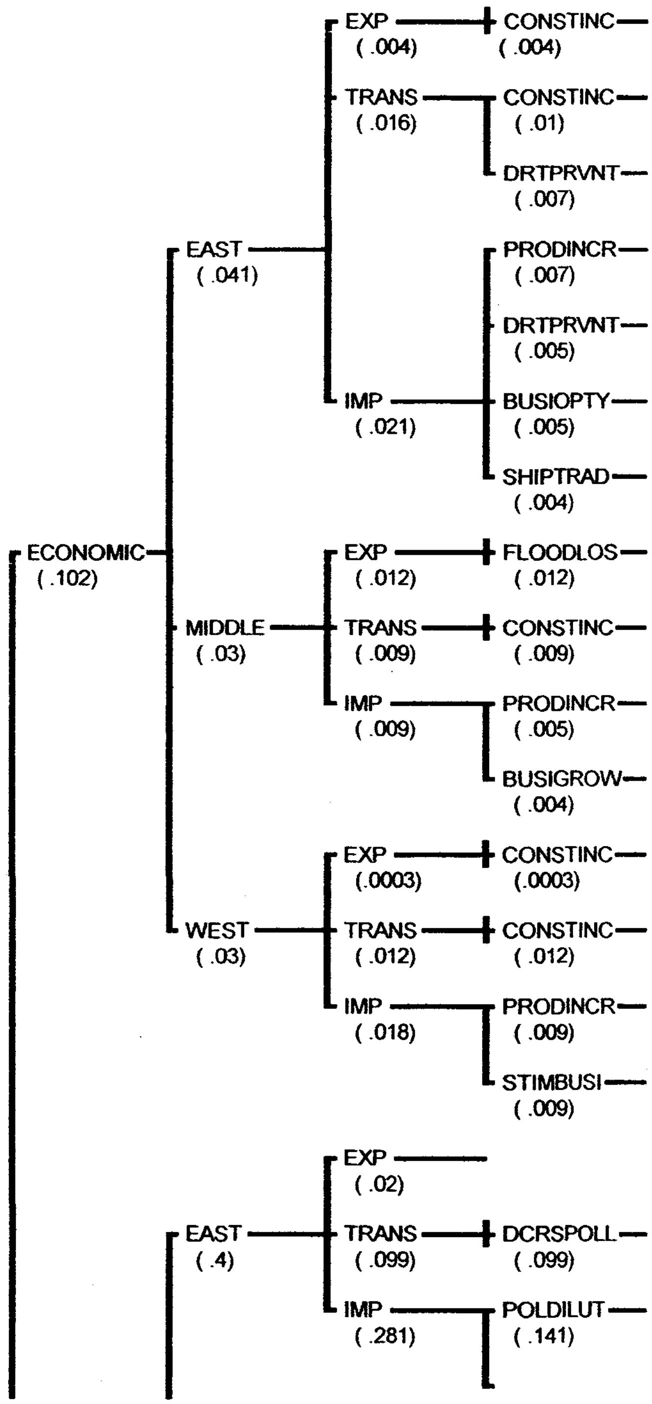
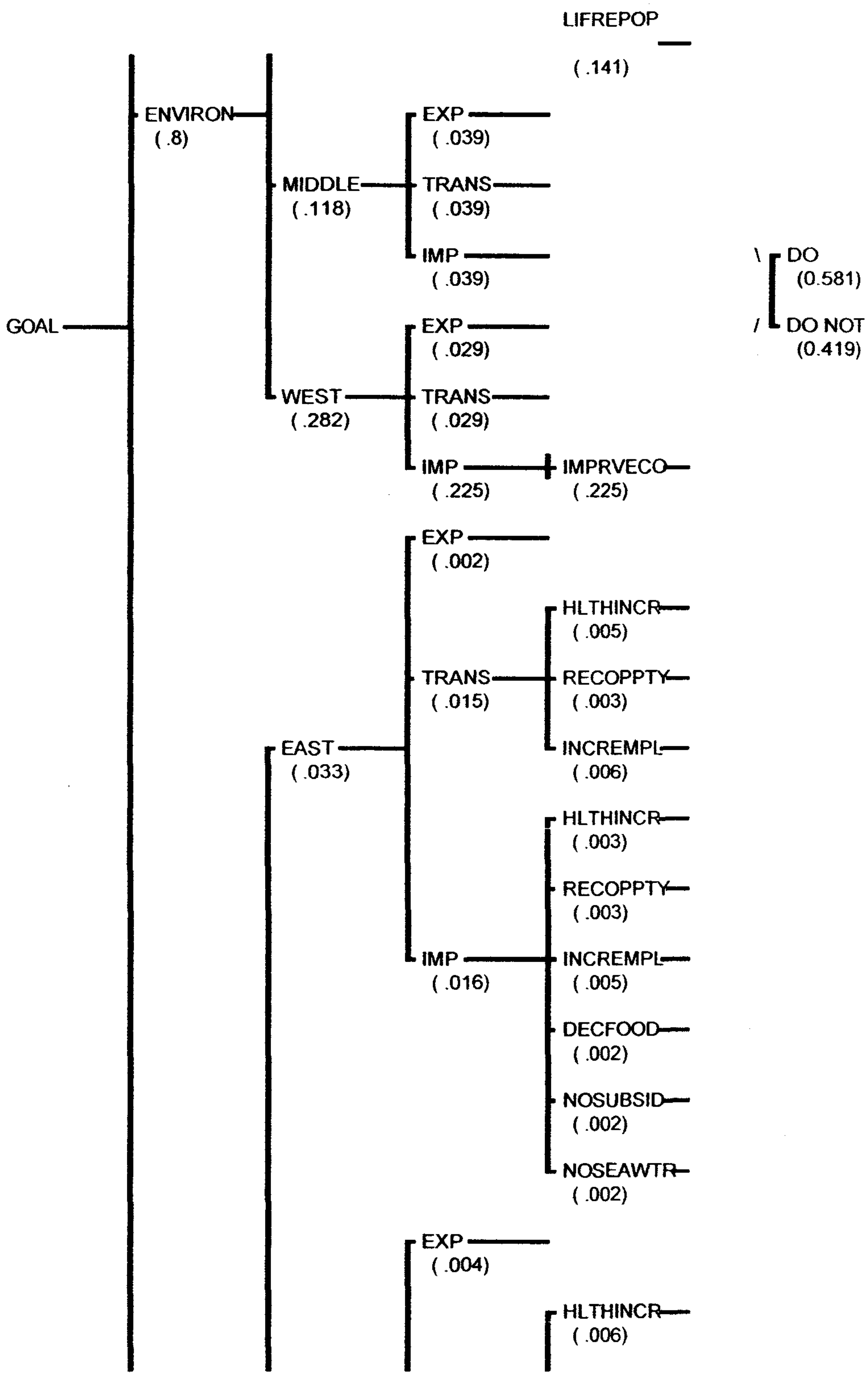
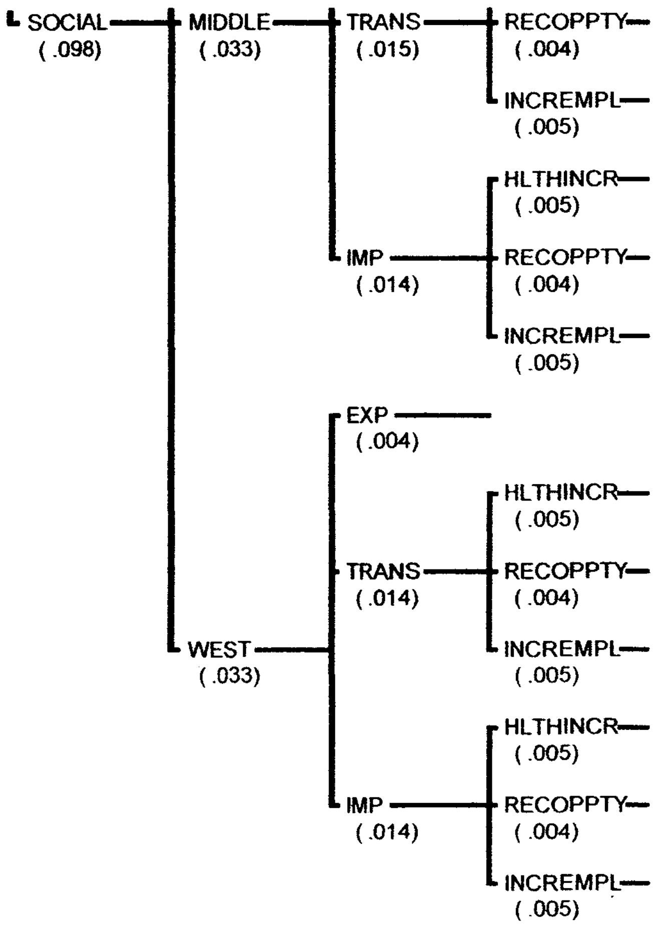
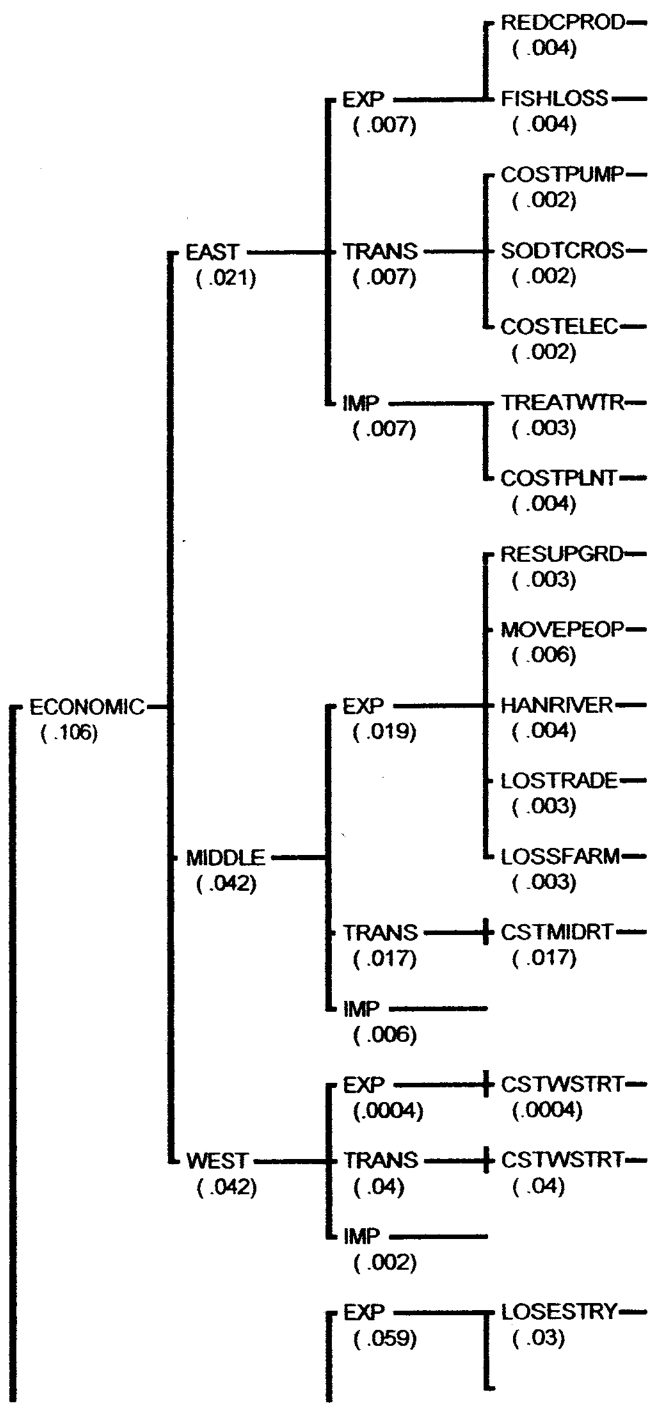
APPENDIX C
SCENARIO 4 BENEFIT

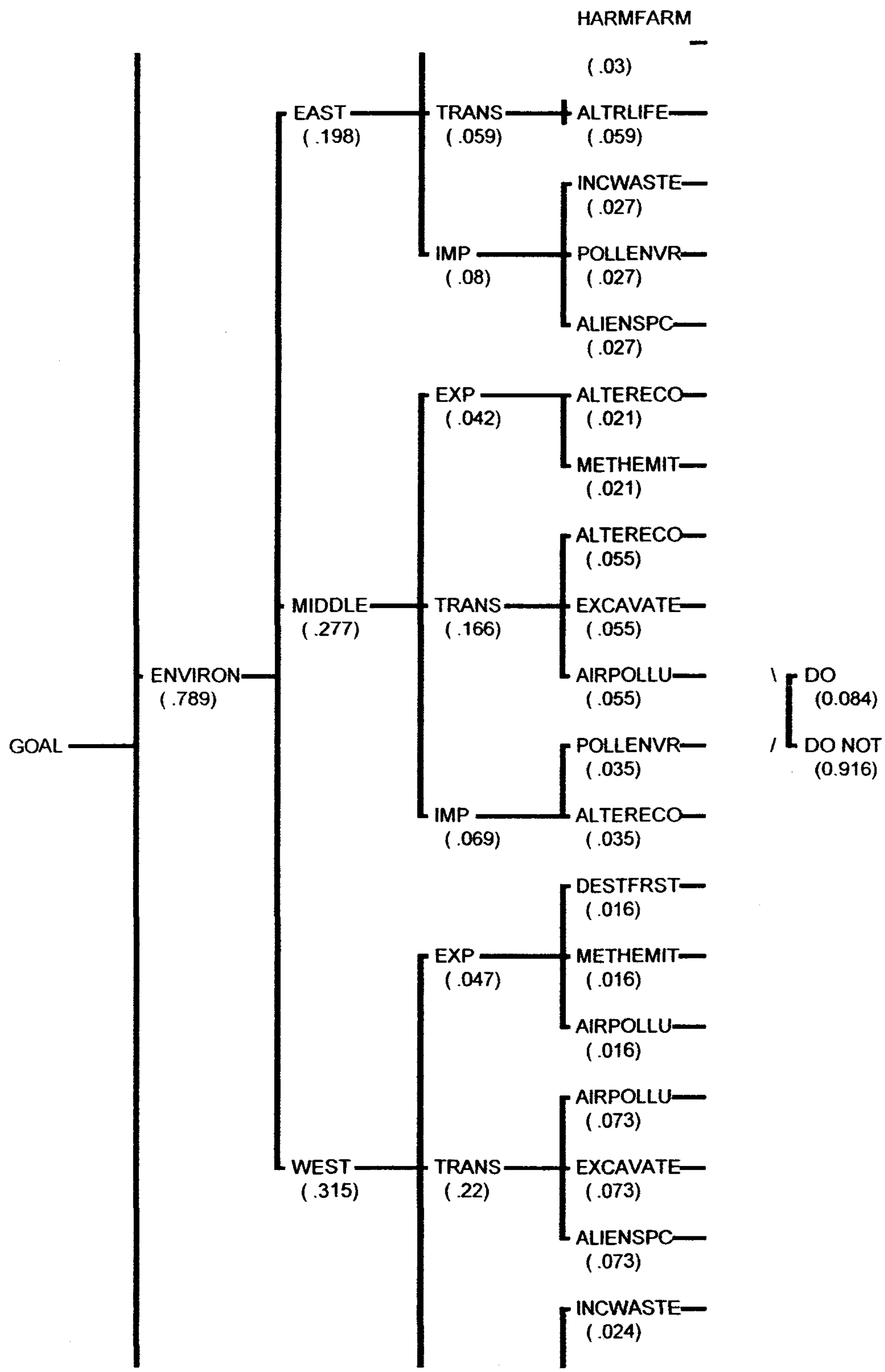


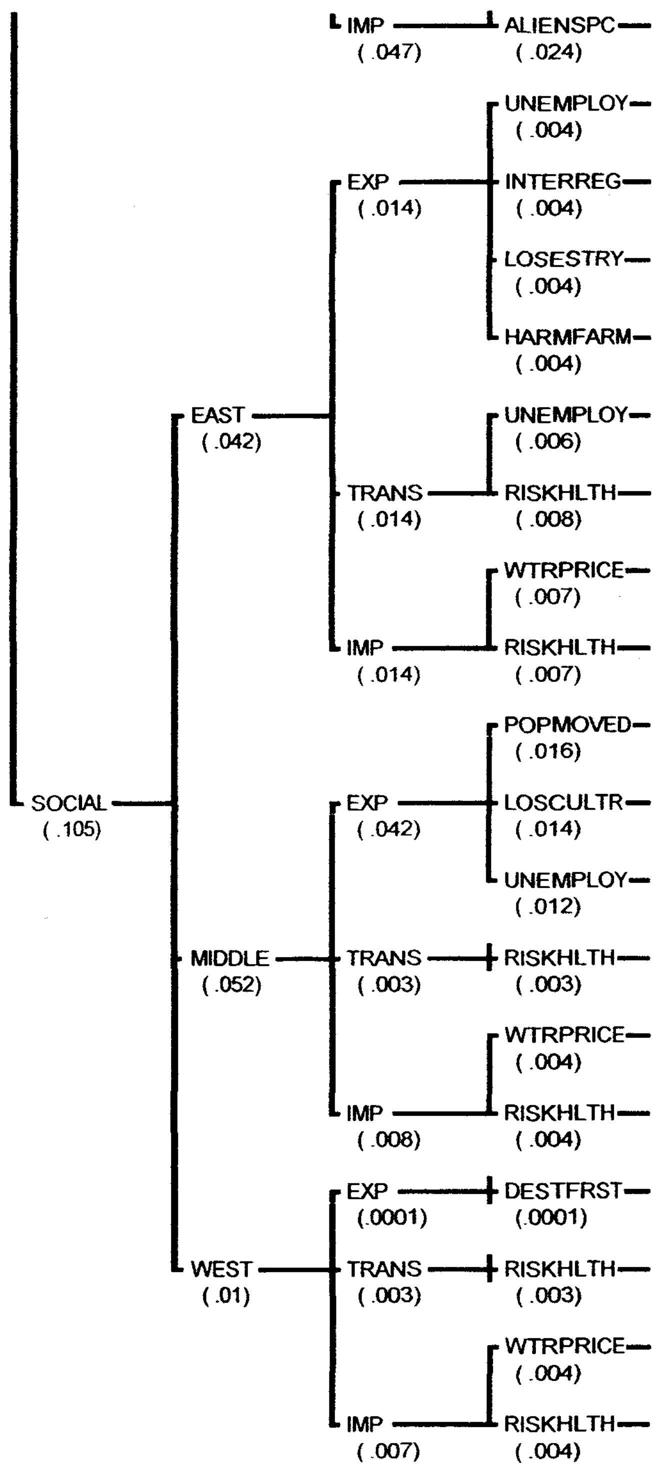

GOAL
ENVIRON
(.8)
MIDDLE
(.118)
EXP
(.039)
TRANS
(.039)
IMP
(.039)
WEST
(.282)
EXP
(.029)
TRANS
(.029)
IMP
(.225)
IMPRVECO
(.225)
LIFREPOP
(.141)
DO
(0.581)
DO NOT
(0.419)
EAST
(.033)
EXP
(.002)
TRANS
(.015)
HLTHINCR
(.005)
RECOPPTY
(.003)
INCREMPL
(.006)
IMP
(.016)
HLTHINCR
(.003)
RECOPPTY
(.003)
INCREMPL
(.005)
DECFOOD
(.002)
NOSUBSID
(.002)
NOSEAWTR
(.002)
EXP
(.004)
HLTHINCR
(.006)


SOCIAL (.098)
MIDDLE (.033)
TRANS (.015)
RECOPPTY (.004)
INCREMPL (.005)
IMP (.014)
HLTHINCR (.005)
RECOPPTY (.004)
INCREMPL (.005)
WEST (.033)
EXP (.004)
TRANS (.014)
HLTHINCR (.005)
RECOPPTY (.004)
INCREMPL (.005)
IMP (.014)
HLTHINCR (.005)
RECOPPTY (.004)
INCREMPL (.005)

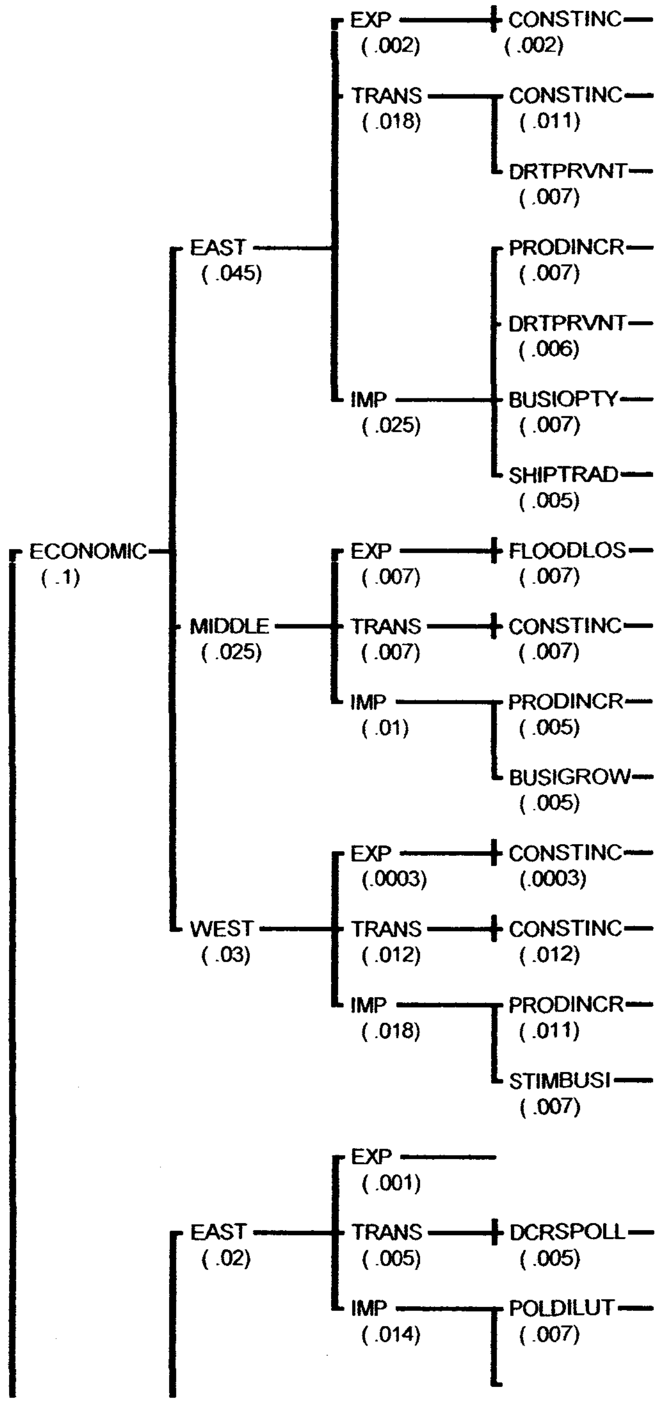
APPENDIX D
SCENARIO 4 COST

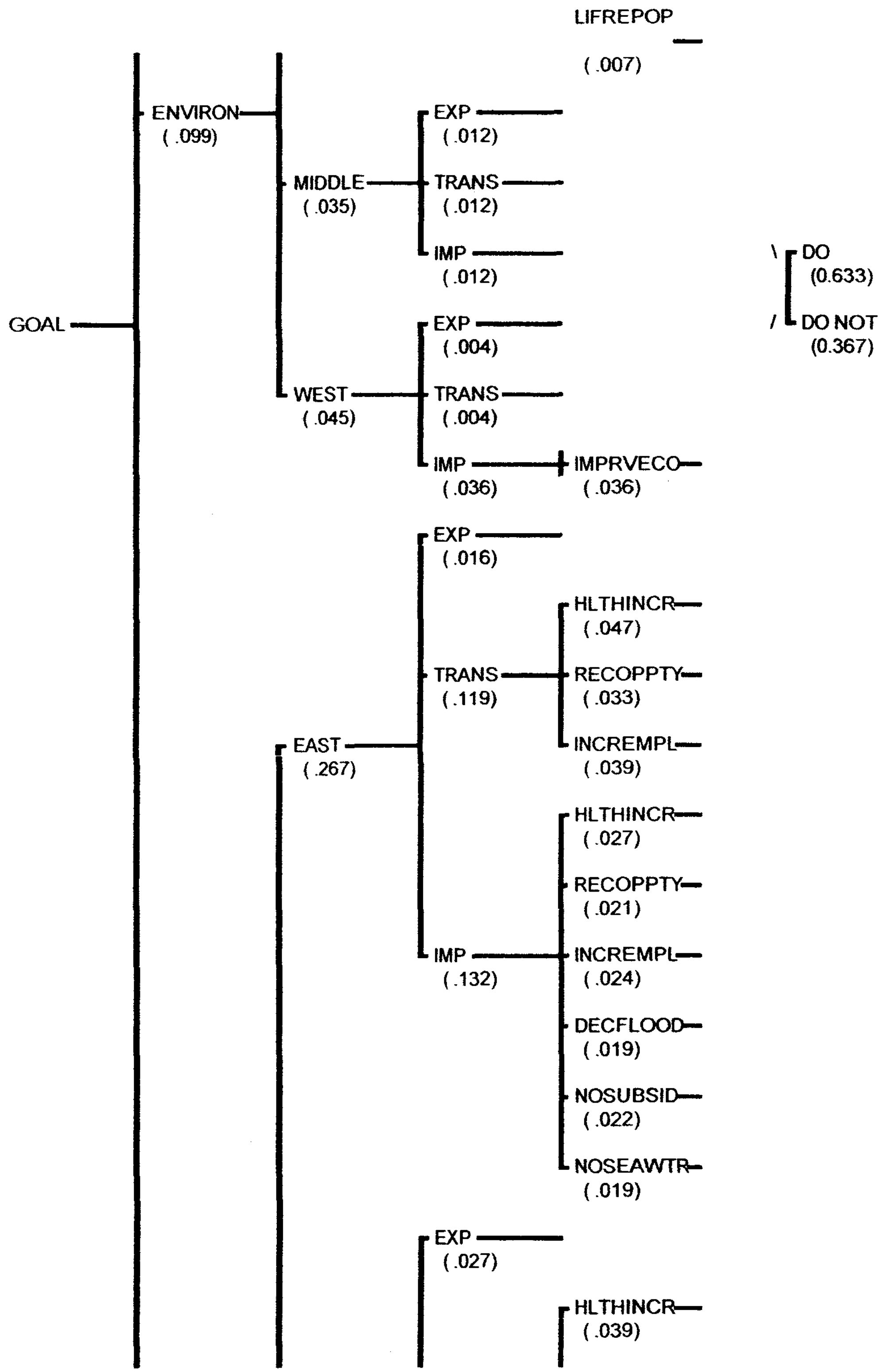


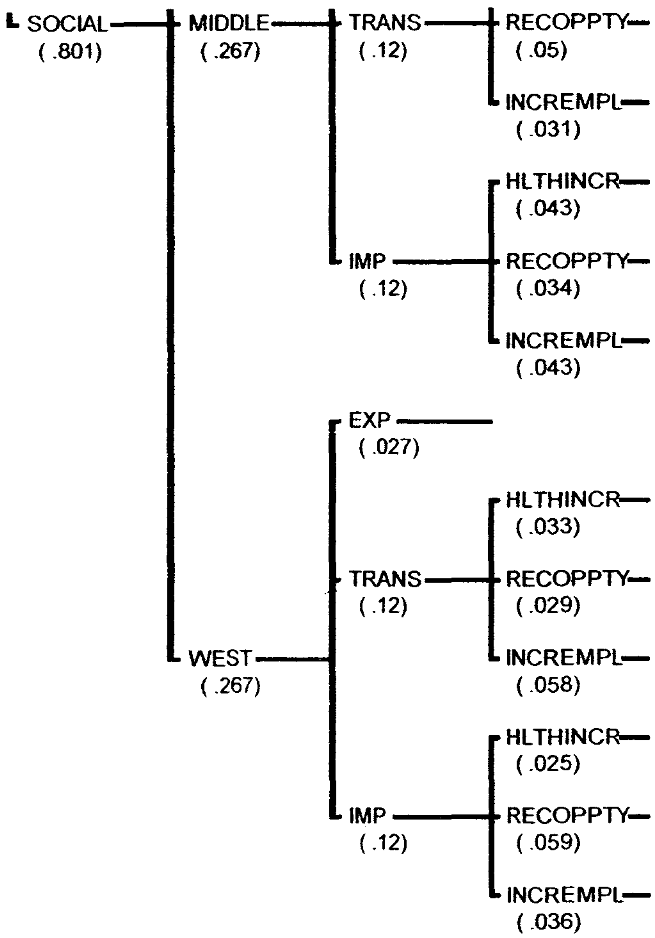

HARMFARM
(.03)
EAST
(.198)
TRANS
(.059)
ALTRLIFE
(.059)
INCWASTE
(.027)
IMP
(.08)
POLLENVR
(.027)
ALIENSPC
(.027)
EXP
(.042)
ALTERECO
(.021)
METHEMIT
(.021)
ALTERECO
(.055)
MIDDLE
(.277)
TRANS
(.166)
EXCAVATE
(.055)
ENVIRON
(.789)
AIRPOLLU
(.055)
DO
(0.084)
GOAL
POLLENVR
(.035)
DO NOT
(0.916)
IMP
(.069)
ALTERECO
(.035)
DESTFRST
(.016)
EXP
(.047)
METHEMIT
(.016)
AIRPOLLU
(.016)
AIRPOLLU
(.073)
WEST
(.315)
TRANS
(.22)
EXCAVATE
(.073)
ALIENSPC
(.073)
INCWASTE
(.024)


IMP (.047)
ALIENSPC (.024)
UNEMPLOY (.004)
EXP (.014)
INTERREG (.004)
LOSESTRY (.004)
HARMFARM (.004)
EAST (.042)
UNEMPLOY (.006)
TRANS (.014)
RISKHLTH (.008)
WTRPRICE (.007)
IMP (.014)
RISKHLTH (.007)
POPMOVED (.016)
SOCIAL (.105)
EXP (.042)
LOSCULTR (.014)
UNEMPLOY (.012)
MIDDLE (.052)
TRANS (.003)
RISKHLTH (.003)
WTRPRICE (.004)
IMP (.008)
RISKHLTH (.004)
EXP (.0001)
DESTFRST (.0001)
WEST (.01)
TRANS (.003)
RISKHLTH (.003)
WTRPRICE (.004)
IMP (.007)
RISKHLTH (.004)

APPENDIX E
SCENARIO 5 BENEFIT

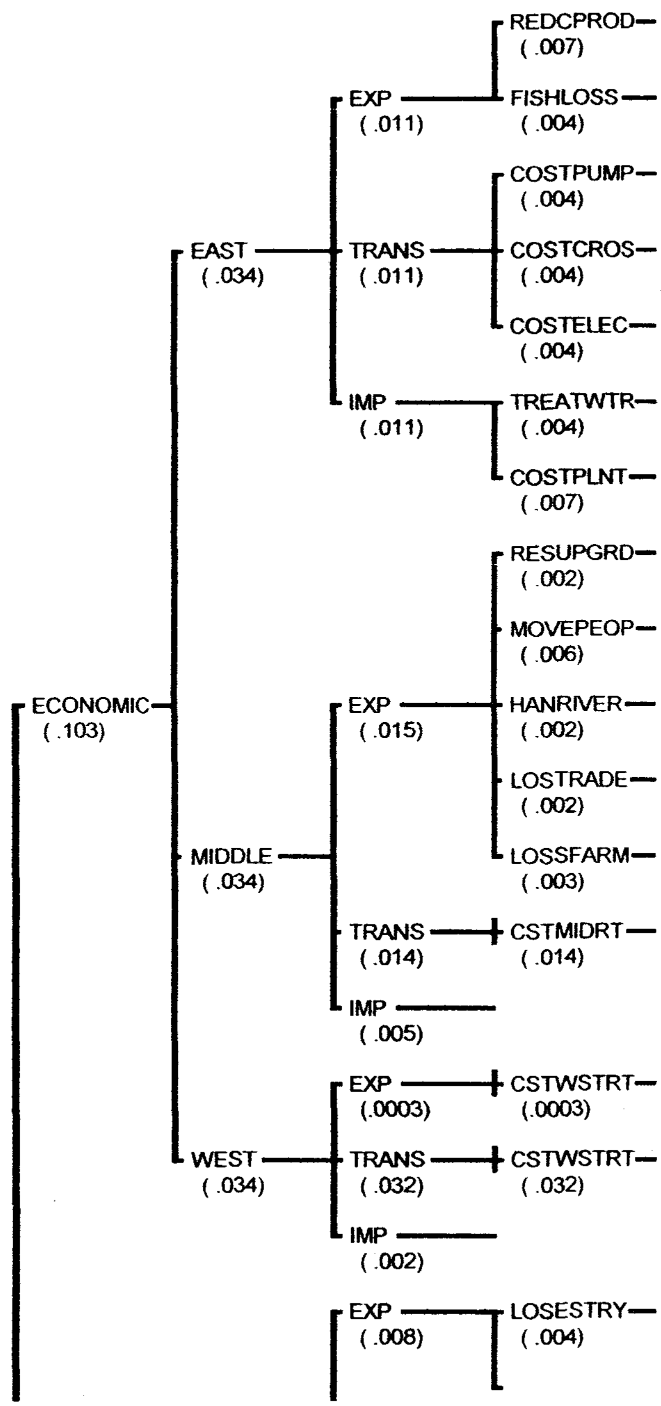


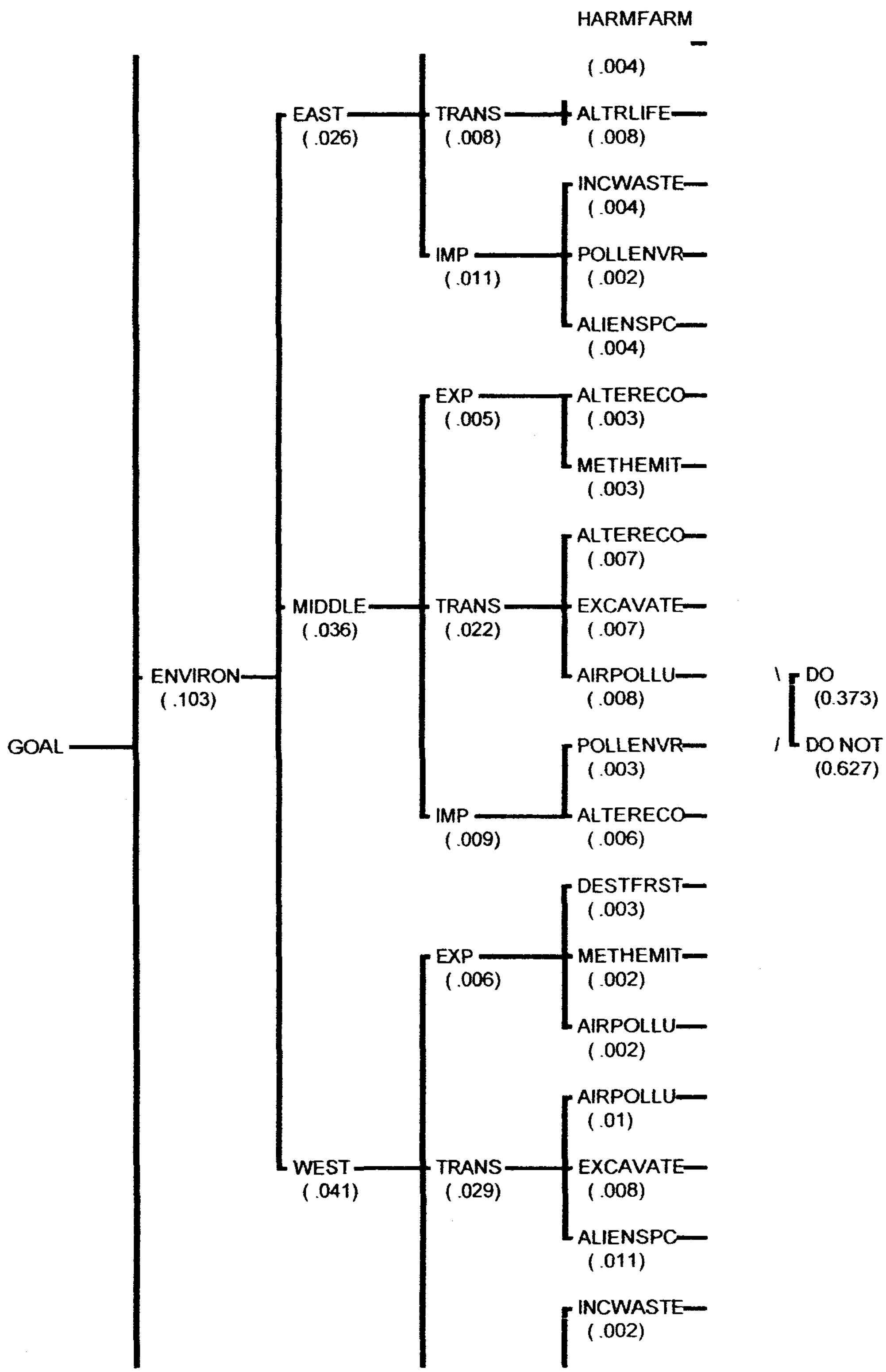

LIFREPOP
(.007)
GOAL
ENVIRON
(.099)
MIDDLE
(.035)
EXP
(.012)
TRANS
(.012)
IMP
(.012)
DO
(0.633)
DO NOT
(0.367)
WEST
(.045)
EXP
(.004)
TRANS
(.004)
IMP
(.036)
IMPRVECO
(.036)
EAST
(.267)
EXP
(.016)
TRANS
(.119)
HLTHINCR
(.047)
RECOPPTY
(.033)
INCREMPL
(.039)
IMP
(.132)
HLTHINCR
(.027)
RECOPPTY
(.021)
INCREMPL
(.024)
DECFLOOD
(.019)
NOSUBSID
(.022)
NOSEAWTR
(.019)
EXP
(.027)
HLTHINCR
(.039)

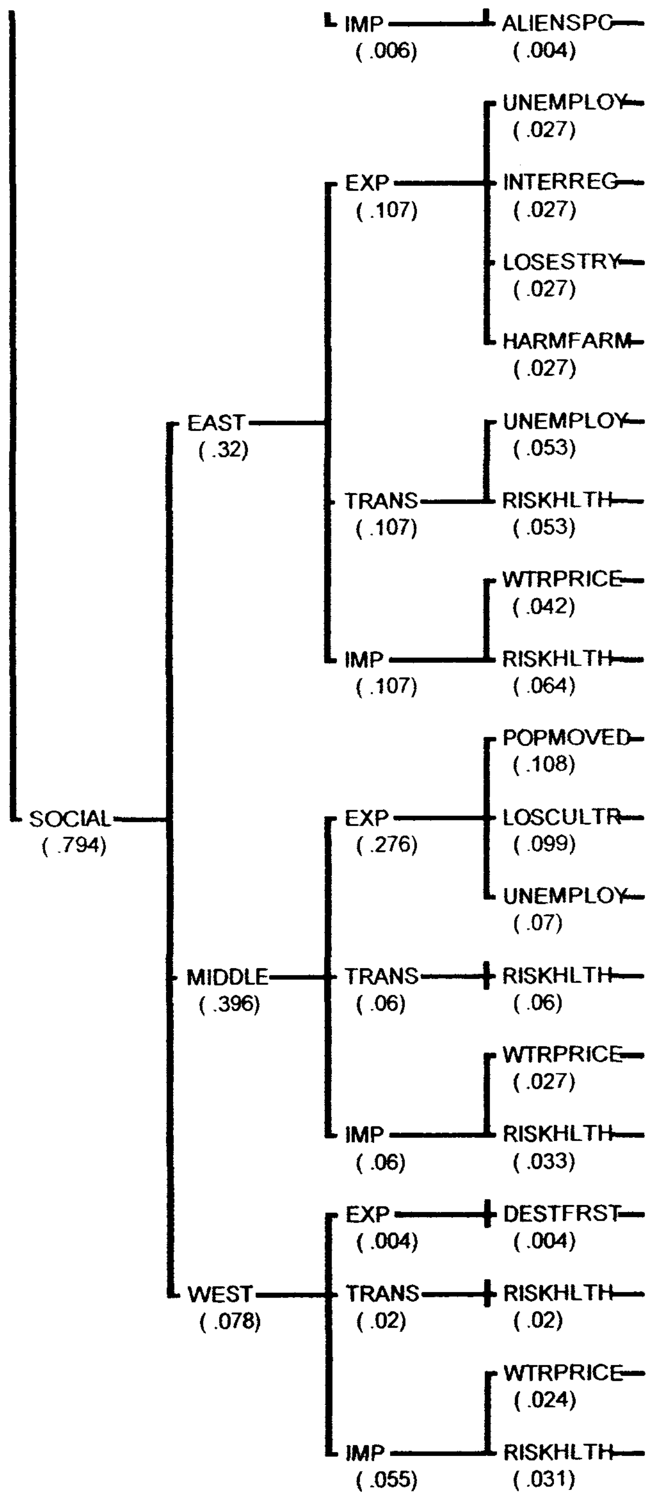


SOCIAL
(.801)
MIDDLE
(.267)
TRANS
(.12)
RECOPPTY
(.05)
INCREMPL
(.031)
HLTHINCR
(.043)
IMP
(.12)
RECOPPTY
(.034)
INCREMPL
(.043)
EXP
(.027)
HLTHINCR
(.033)
TRANS
(.12)
RECOPPTY
(.029)
WEST
(.267)
INCREMPL
(.058)
HLTHINCR
(.025)
IMP
(.12)
RECOPPTY
(.059)
INCREMPL
(.036)

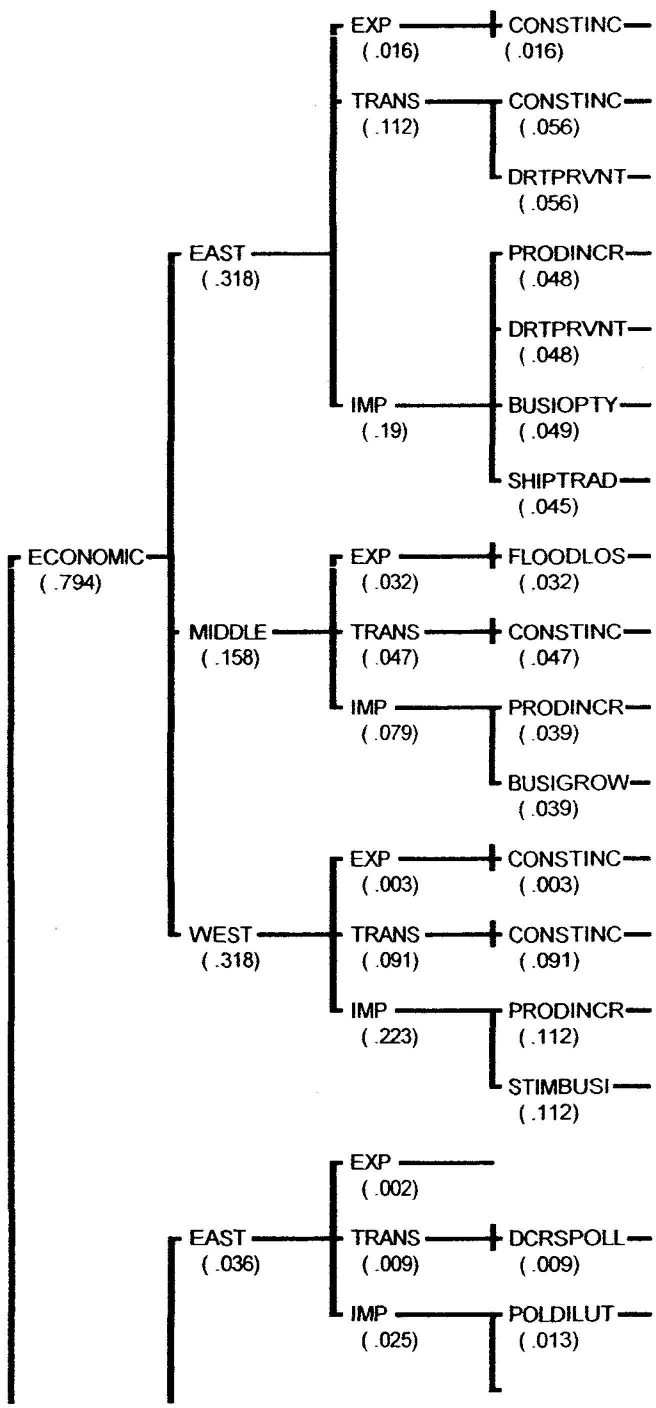
APPENDIX F
SCENSRIO 5 COST

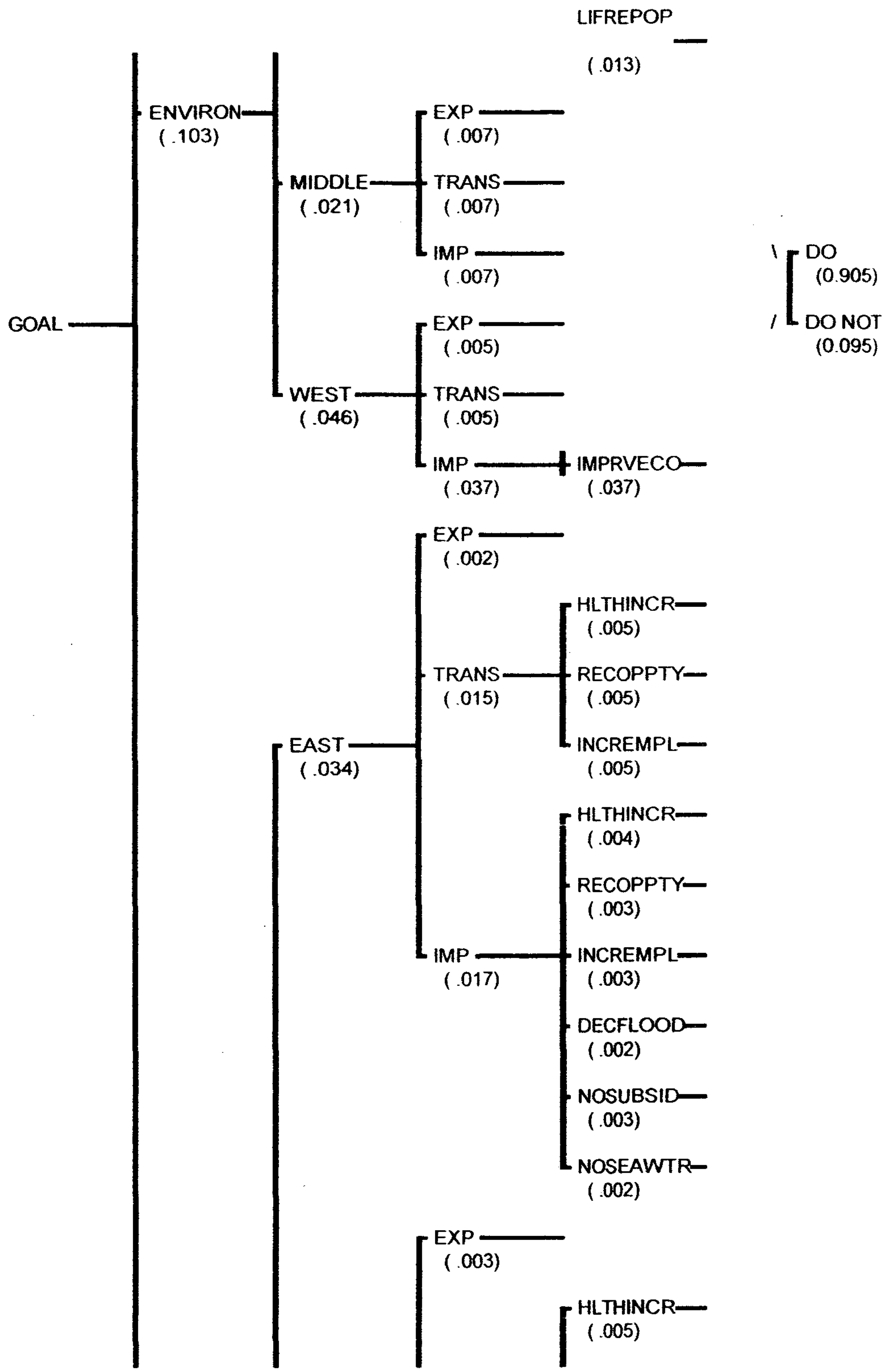



GOAL
ENVIRON
(.103)
EAST
(.026)
MIDDLE
(.036)
WEST
(.041)
TRANS
(.008)
IMP
(.011)
EXP
(.005)
TRANS
(.022)
IMP
(.009)
EXP
(.006)
TRANS
(.029)
HARMFARM
(.004)
ALTRLIFE
(.008)
INCWASTE
(.004)
POLLENVR
(.002)
ALIENSPC
(.004)
ALTERECO
(.003)
METHEMIT
(.003)
ALTERECO
(.007)
EXCAVATE
(.007)
AIRPOLLU
(.008)
POLLENVR
(.003)
ALTERECO
(.006)
DESTFRST
(.003)
METHEMIT
(.002)
AIRPOLLU
(.002)
AIRPOLLU
(.01)
EXCAVATE
(.008)
ALIENSPC
(.011)
INCWASTE
(.002)
DO
(0.373)
DO NOT
(0.627)

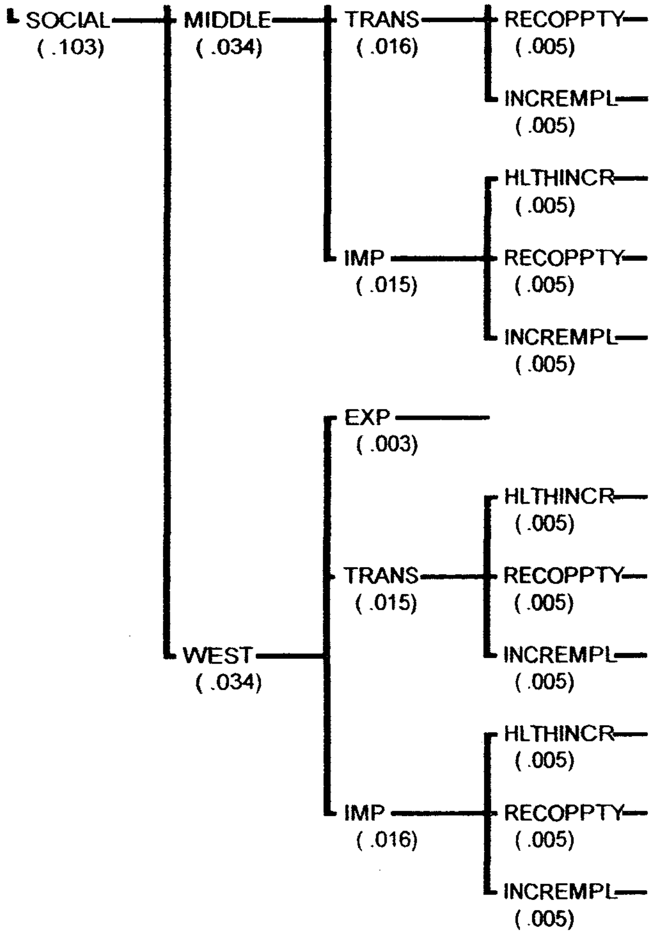

SOCIAL
(.794)
EAST
(.32)
MIDDLE
(.396)
WEST
(.078)
IMP
(.006)
ALIENSPC
(.004)
EXP
(.107)
UNEMPLOY
(.027)
INTERREG
(.027)
LOSESTRY
(.027)
HARMFARM
(.027)
TRANS
(.107)
UNEMPLOY
(.053)
RISKHLTH
(.053)
IMP
(.107)
WTRPRICE
(.042)
RISKHLTH
(.064)
EXP
(.276)
POPMOVED
(.108)
LOSCULTR
(.099)
UNEMPLOY
(.07)
TRANS
(.06)
RISKHLTH
(.06)
IMP
(.06)
WTRPRICE
(.027)
RISKHLTH
(.033)
EXP
(.004)
DESTFRST
(.004)
TRANS
(.02)
RISKHLTH
(.02)
IMP
(.055)
WTRPRICE
(.024)
RISKHLTH
(.031)

APPENDIX G
SCENARIO 6 BENEFIT

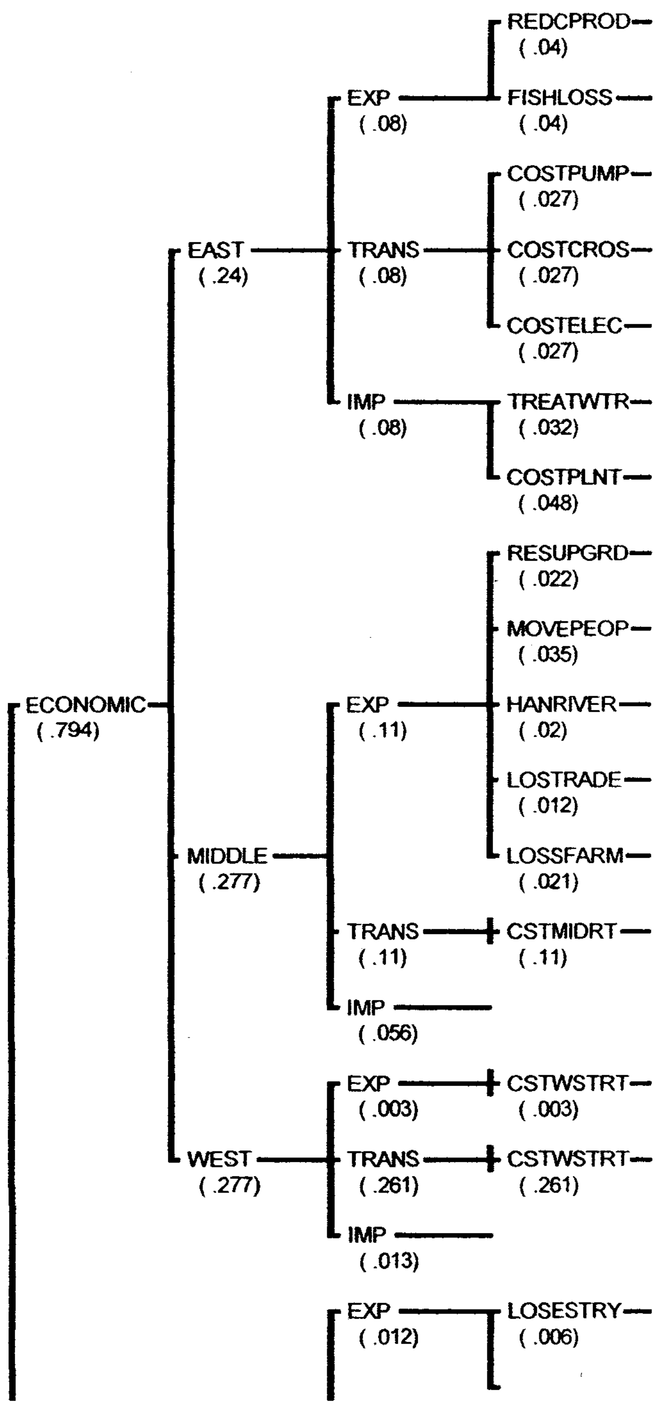


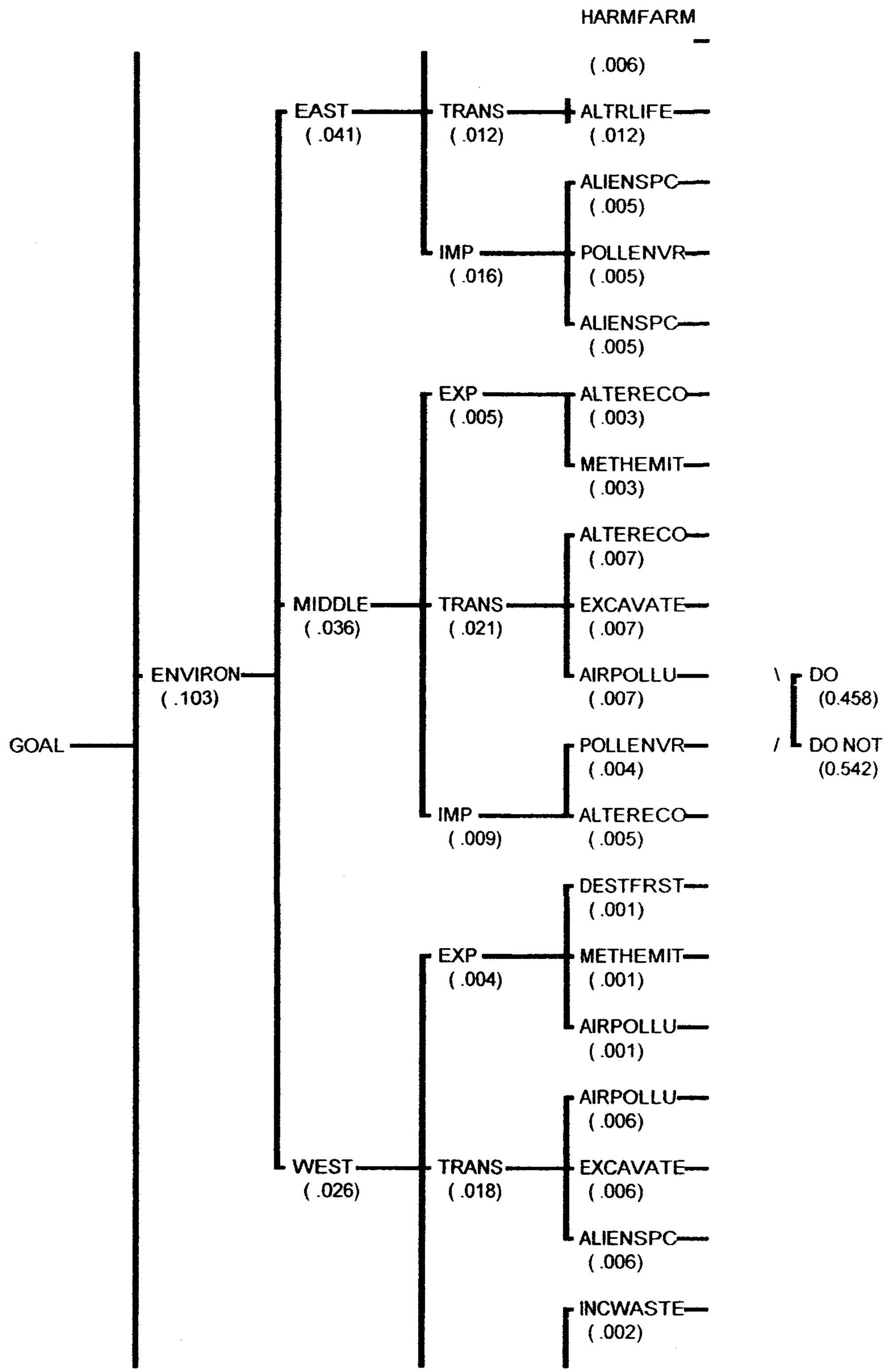


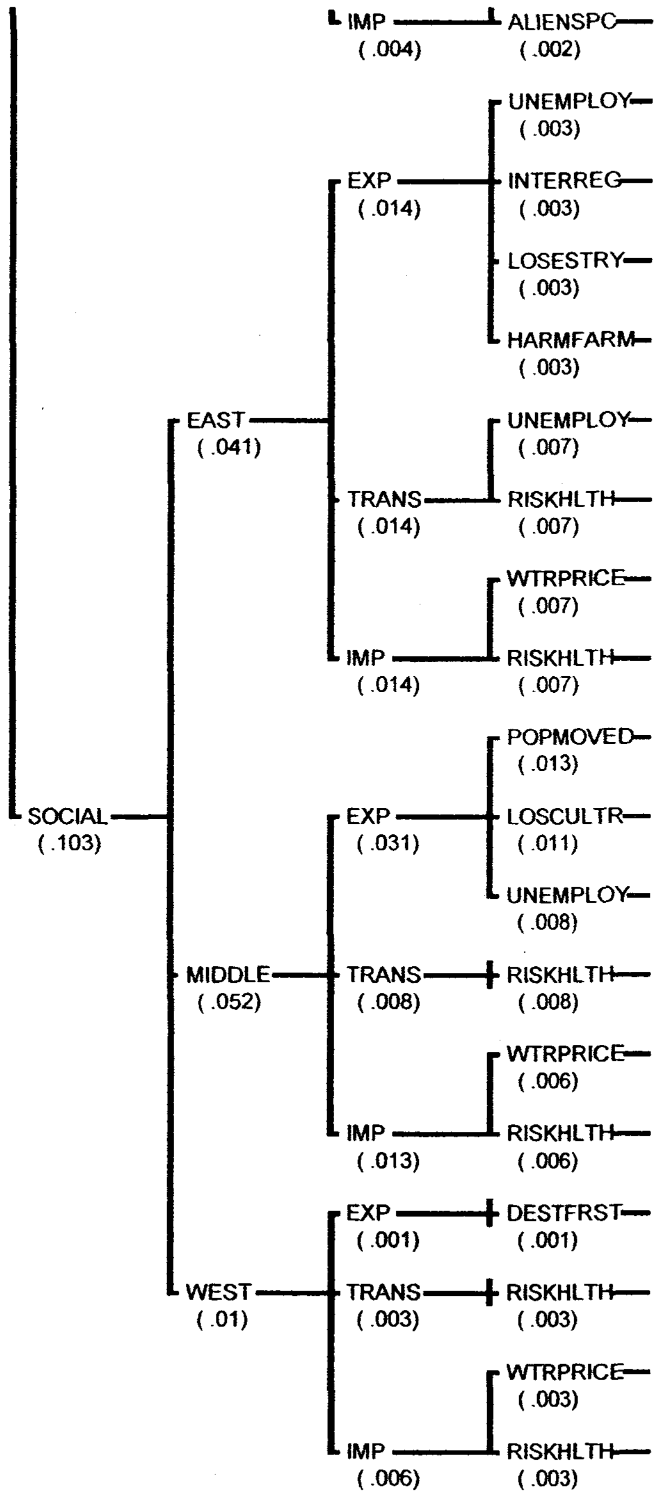
GOAL
ENVIRON (.103)
LIFREPOP (.013)
MIDDLE (.021)
EXP (.007)
TRANS (.007)
IMP (.007)
WEST (.046)
EXP (.005)
TRANS (.005)
IMP (.037)
IMPRVECO (.037)
EAST (.034)
EXP (.002)
TRANS (.015)
HLTHINCR (.005)
RECOPPTY (.005)
INCREMPL (.005)
IMP (.017)
HLTHINCR (.004)
RECOPPTY (.003)
INCREMPL (.003)
DECFLOOD (.002)
NOSUBSID (.003)
NOSEAWTR (.002)
EXP (.003)
HLTHINCR (.005)
DO (0.905)
DO NOT (0.095)


SOCIAL
(.103)
MIDDLE
(.034)
TRANS
(.016)
RECOPPTY
(.005)
INCREMPL
(.005)
IMP
(.015)
HLTHINCR
(.005)
RECOPPTY
(.005)
INCREMPL
(.005)
WEST
(.034)
EXP
(.003)
TRANS
(.015)
HLTHINCR
(.005)
RECOPPTY
(.005)
INCREMPL
(.005)
IMP
(.016)
HLTHINCR
(.005)
RECOPPTY
(.005)
INCREMPL
(.005)

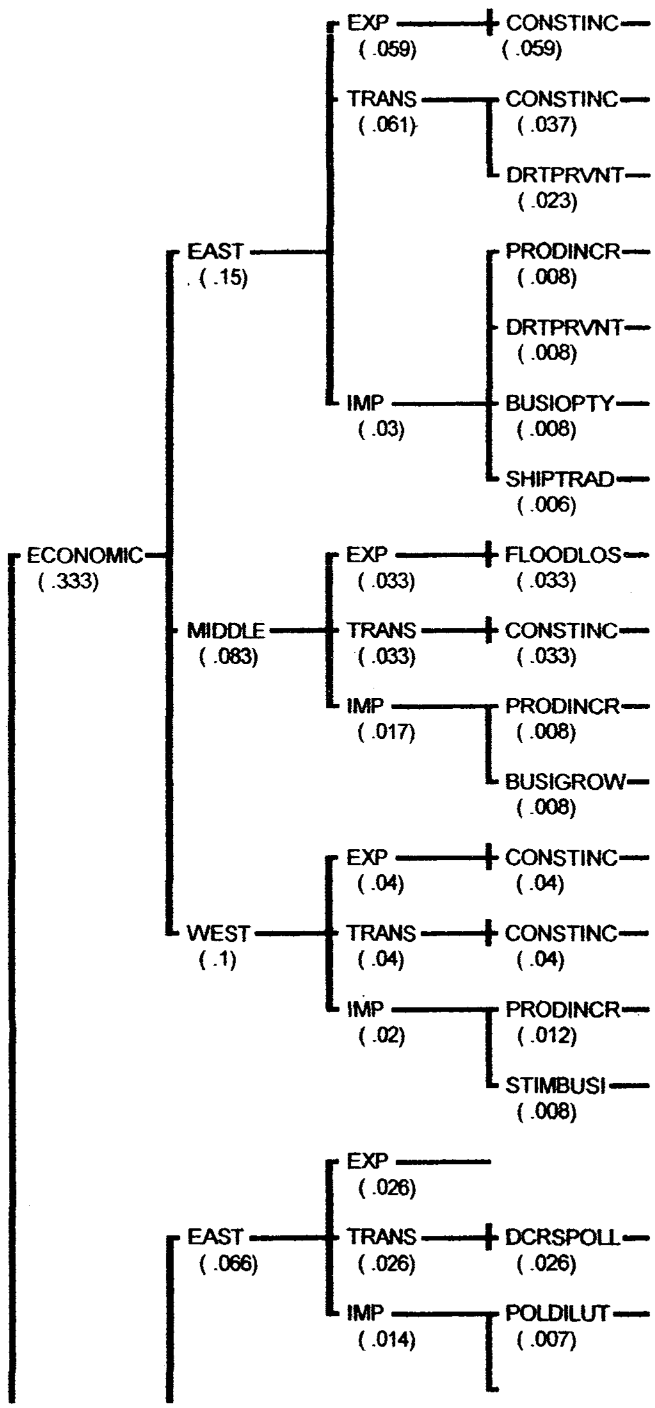
APPENDIX H
SCENARIO 6 COST

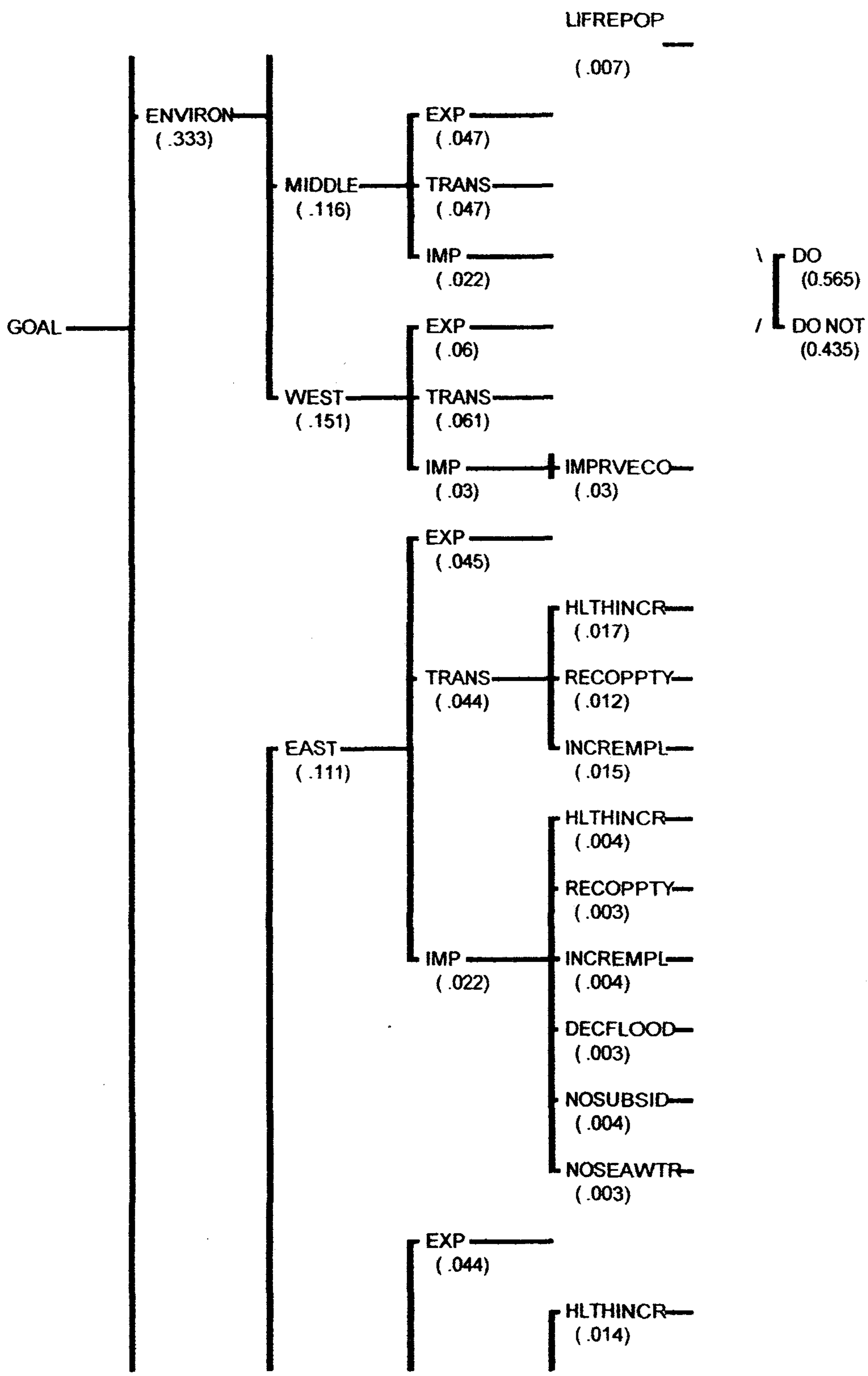


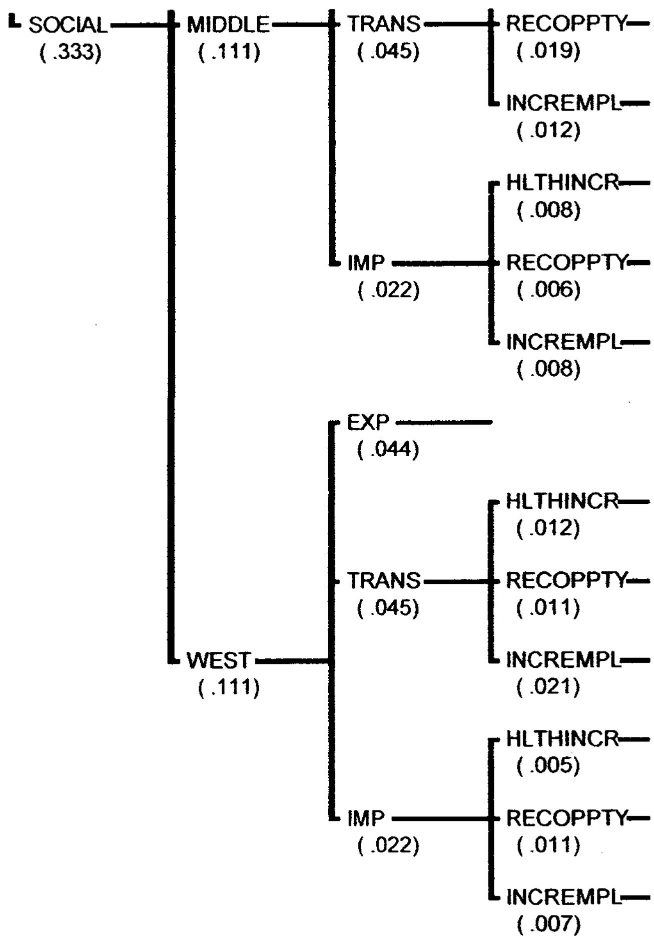

HARMFARM
(.006)
EAST
(.041)
TRANS
(.012)
ALTRLIFE
(.012)
ALIENSPC
(.005)
IMP
(.016)
POLLENVR
(.005)
ALIENSPC
(.005)
EXP
(.005)
ALTERECO
(.003)
METHEMIT
(.003)
ALTERECO
(.007)
MIDDLE
(.036)
TRANS
(.021)
EXCAVATE
(.007)
ENVIRON
(.103)
AIRPOLLU
(.007)
DO
(0.458)
GOAL
POLLENVR
(.004)
DO NOT
(0.542)
IMP
(.009)
ALTERECO
(.005)
DESTFRST
(.001)
EXP
(.004)
METHEMIT
(.001)
AIRPOLLU
(.001)
AIRPOLLU
(.006)
WEST
(.026)
TRANS
(.018)
EXCAVATE
(.006)
ALIENSPC
(.006)
INCWASTE
(.002)


IMP
(.004)
ALIENSPC
(.002)
UNEMPLOY
(.003)
EXP
(.014)
INTERREG
(.003)
LOSESTRY
(.003)
HARMFARM
(.003)
EAST
(.041)
UNEMPLOY
(.007)
TRANS
(.014)
RISKHLTH
(.007)
WTRPRICE
(.007)
IMP
(.014)
RISKHLTH
(.007)
POPMOVED
(.013)
SOCIAL
(.103)
EXP
(.031)
LOSCULTR
(.011)
UNEMPLOY
(.008)
MIDDLE
(.052)
TRANS
(.008)
RISKHLTH
(.008)
WTRPRICE
(.006)
IMP
(.013)
RISKHLTH
(.006)
EXP
(.001)
DESTFRST
(.001)
WEST
(.01)
TRANS
(.003)
RISKHLTH
(.003)
WTRPRICE
(.003)
IMP
(.006)
RISKHLTH
(.003)

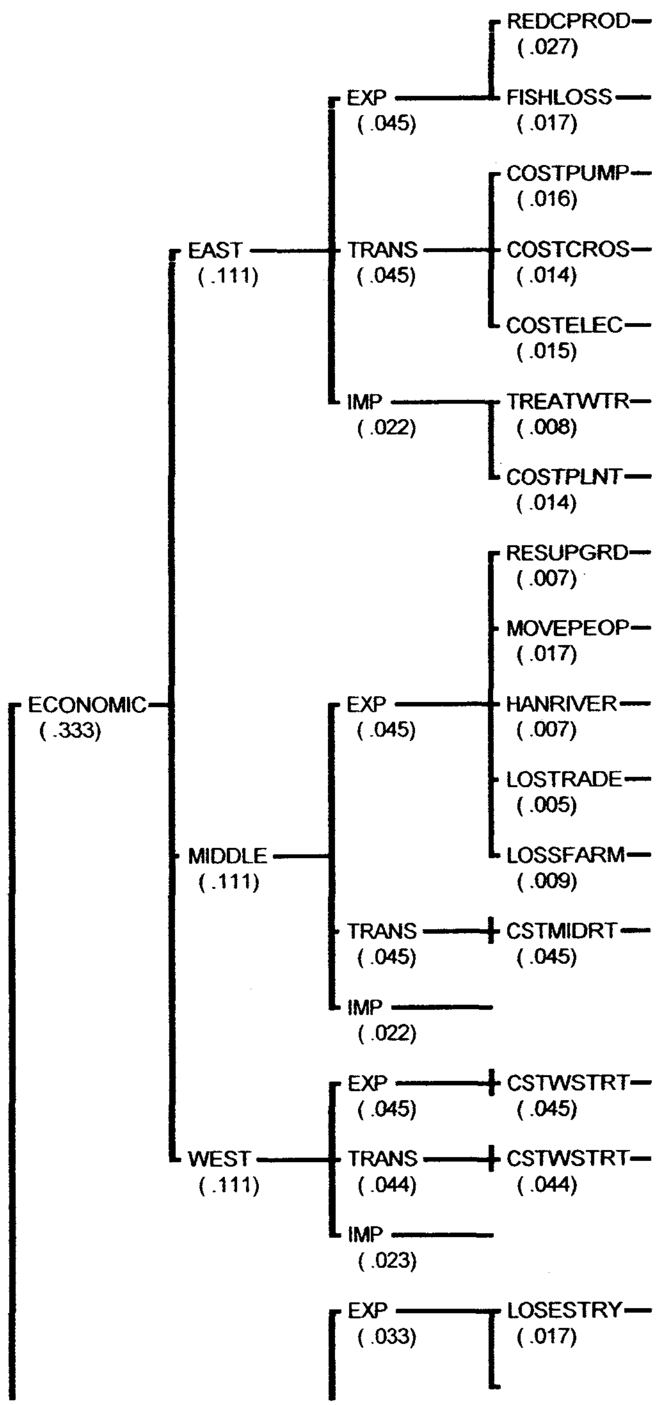
APPENDIX I
SCENARIO 7 BENEFIT

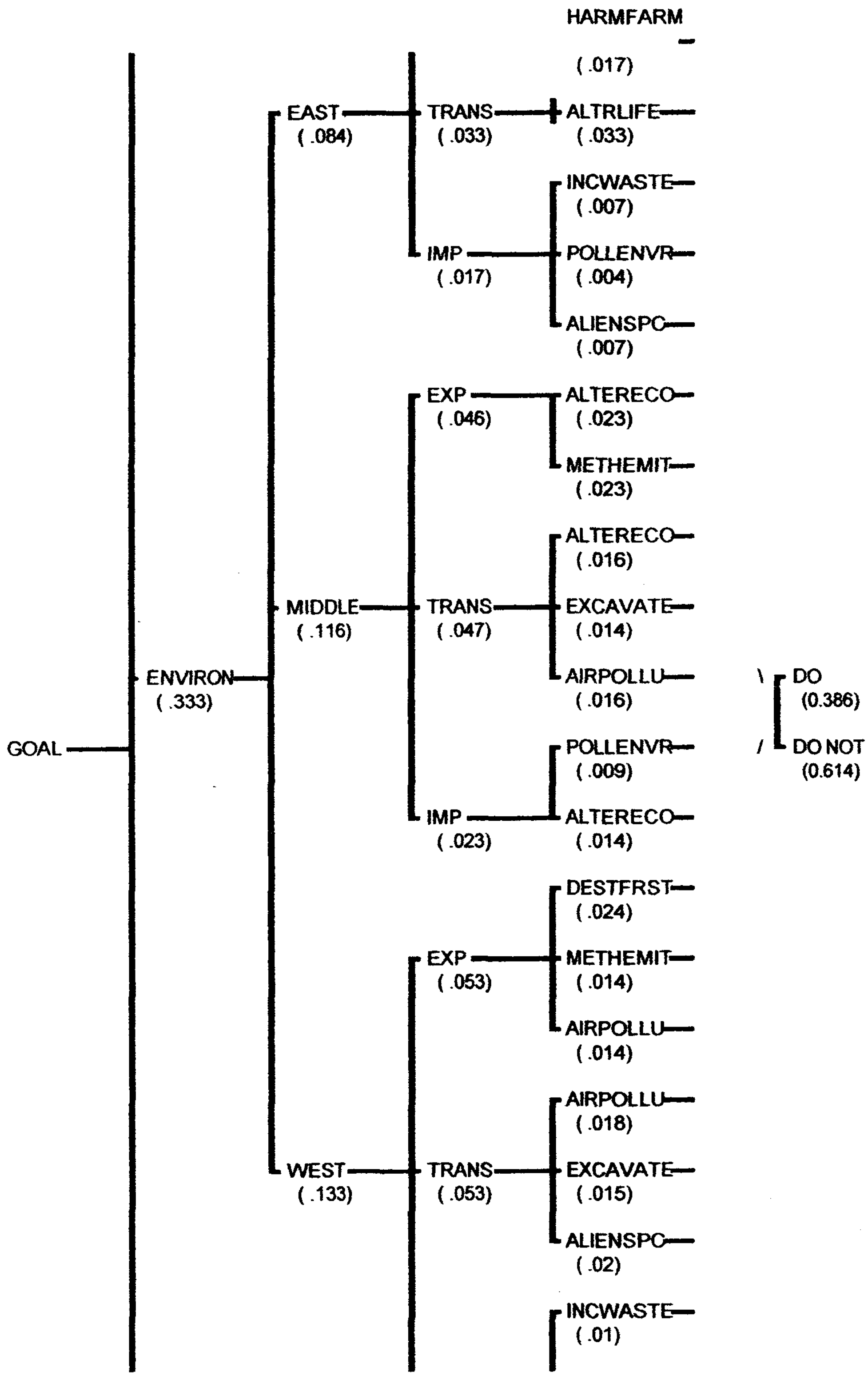


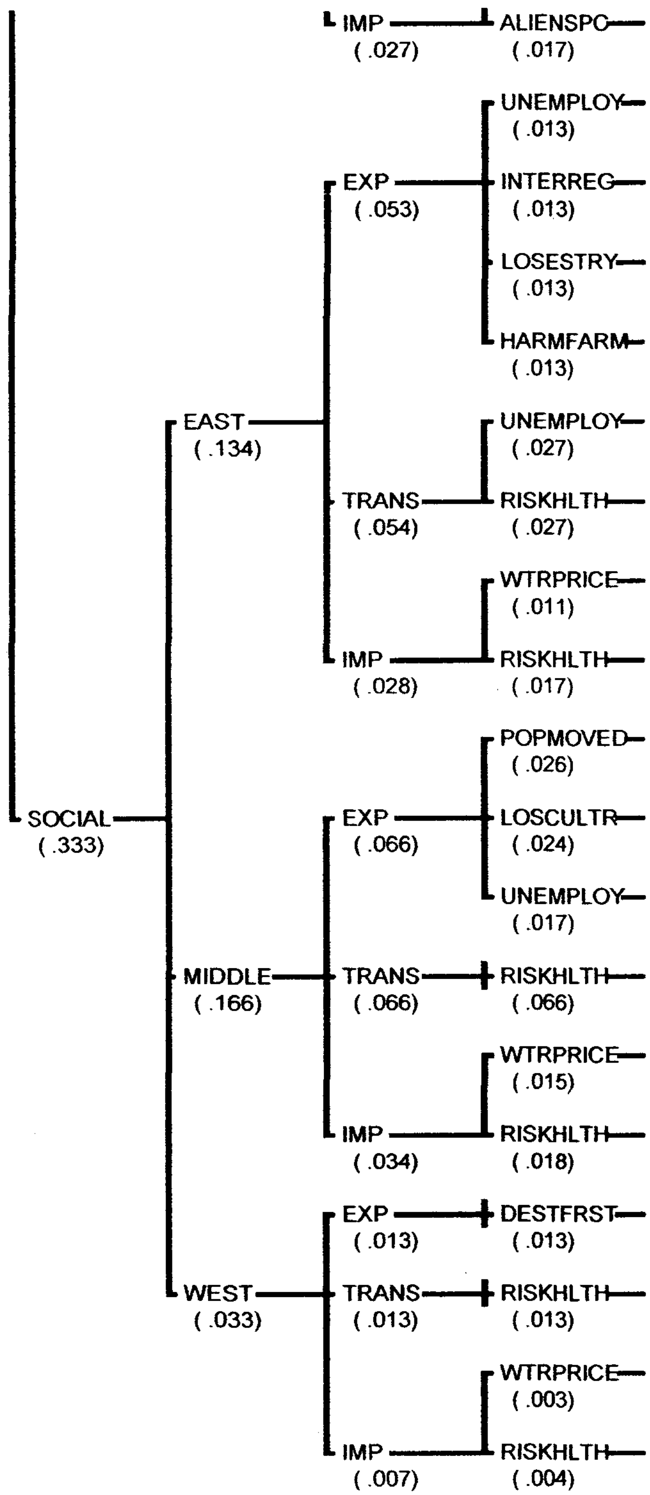

LIFREPOP
(.007)
GOAL
ENVIRON
(.333)
MIDDLE
(.116)
EXP
(.047)
TRANS
(.047)
IMP
(.022)
WEST
(.151)
EXP
(.06)
TRANS
(.061)
IMP
(.03)
IMPRVECO
(.03)
DO
(0.565)
DO NOT
(0.435)
EAST
(.111)
EXP
(.045)
TRANS
(.044)
HLTHINCR
(.017)
RECOPPTY
(.012)
INCREMPL
(.015)
IMP
(.022)
HLTHINCR
(.004)
RECOPPTY
(.003)
INCREMPL
(.004)
DECFLOOD
(.003)
NOSUBSID
(.004)
NOSEAWTR
(.003)
EXP
(.044)
HLTHINCR
(.014)


SOCIAL
(.333)
MIDDLE
(.111)
TRANS
(.045)
RECOPPTY
(.019)
INCREMPL
(.012)
IMP
(.022)
HLTHINCR
(.008)
RECOPPTY
(.006)
INCREMPL
(.008)
WEST
(.111)
EXP
(.044)
TRANS
(.045)
HLTHINCR
(.012)
RECOPPTY
(.011)
INCREMPL
(.021)
IMP
(.022)
HLTHINCR
(.005)
RECOPPTY
(.011)
INCREMPL
(.007)

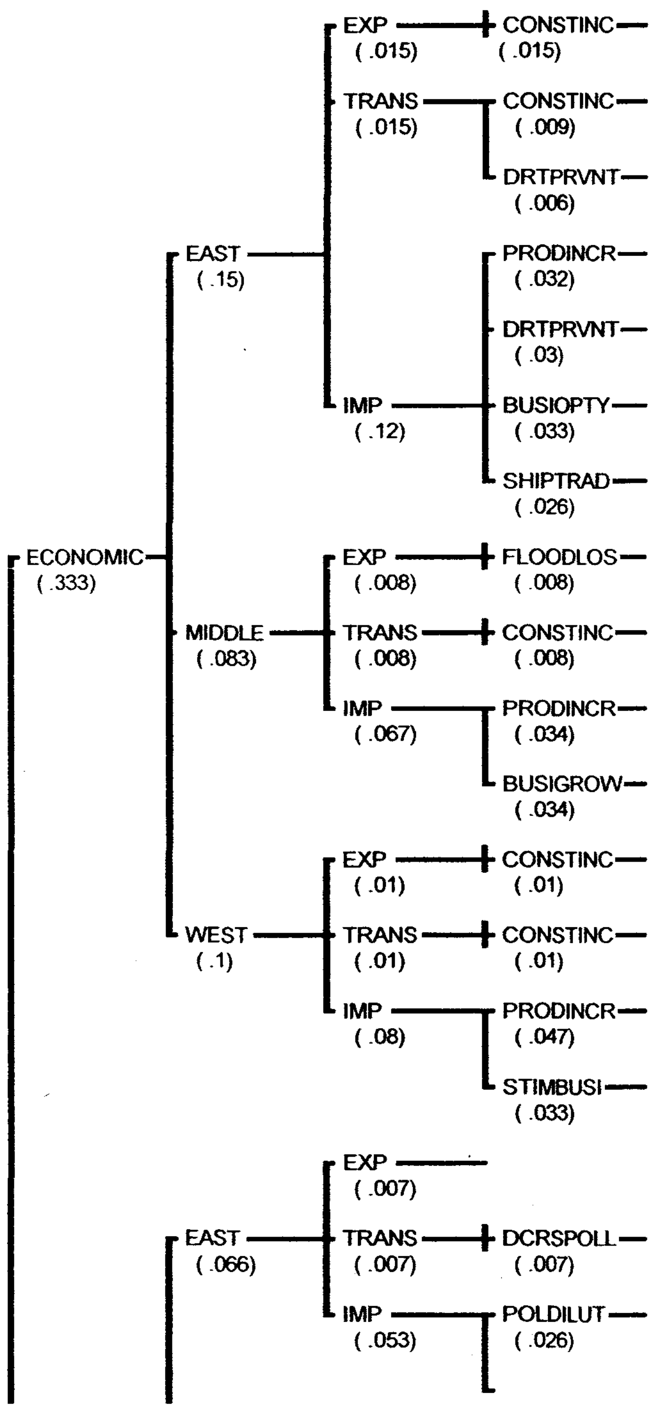
APPENDIX J
SCENARIO 7 COST

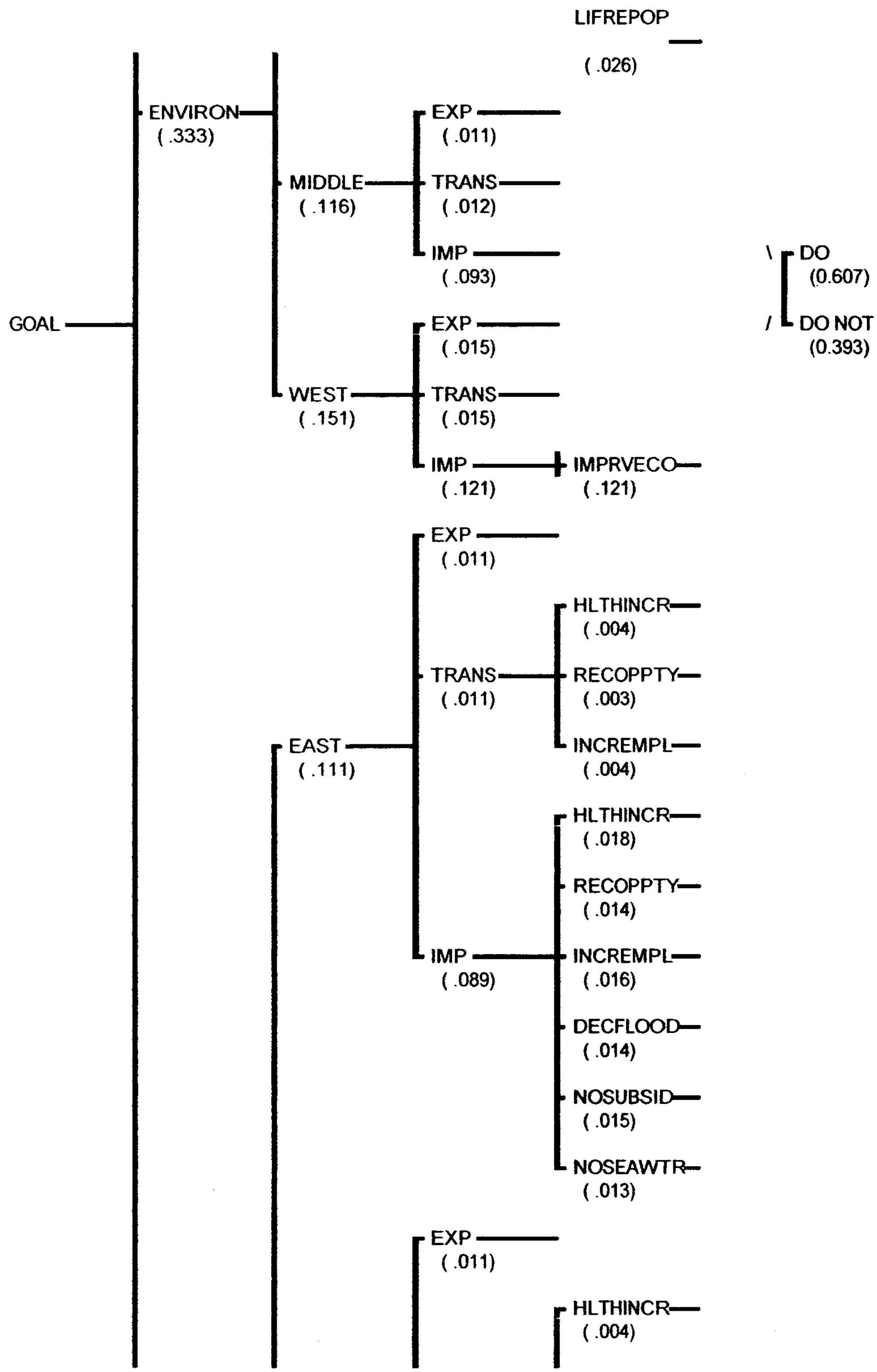


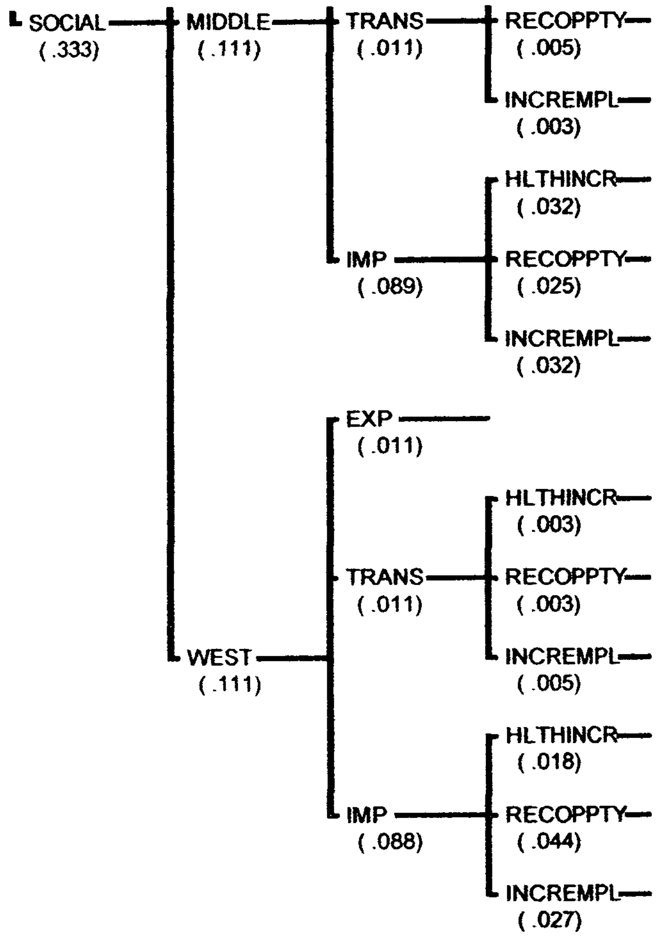

GOAL
ENVIRON (.333)
EAST (.084)
MIDDLE (.116)
WEST (.133)
TRANS (.033)
IMP (.017)
EXP (.046)
TRANS (.047)
IMP (.023)
EXP (.053)
TRANS (.053)
HARMFARM (.017)
ALTRLIFE (.033)
INCWASTE (.007)
POLLENVR (.004)
ALIENSPC (.007)
ALTERECO (.023)
METHEMIT (.023)
ALTERECO (.016)
EXCAVATE (.014)
AIRPOLLU (.016)
POLLENVR (.009)
ALTERECO (.014)
DESTFRST (.024)
METHEMIT (.014)
AIRPOLLU (.014)
AIRPOLLU (.018)
EXCAVATE (.015)
ALIENSPC (.02)
INCWASTE (.01)
DO (0.386)
DO NOT (0.614)


IMP (.027)
ALIENSPC (.017)
UNEMPLOY (.013)
EXP (.053)
INTERREG (.013)
LOSESTRY (.013)
HARMFARM (.013)
EAST (.134)
UNEMPLOY (.027)
TRANS (.054)
RISKHLTH (.027)
WTRPRICE (.011)
IMP (.028)
RISKHLTH (.017)
POPMOVED (.026)
SOCIAL (.333)
EXP (.066)
LOSCULTR (.024)
UNEMPLOY (.017)
MIDDLE (.166)
TRANS (.066)
RISKHLTH (.066)
WTRPRICE (.015)
IMP (.034)
RISKHLTH (.018)
EXP (.013)
DESTFRST (.013)
WEST (.033)
TRANS (.013)
RISKHLTH (.013)
WTRPRICE (.003)
IMP (.007)
RISKHLTH (.004)

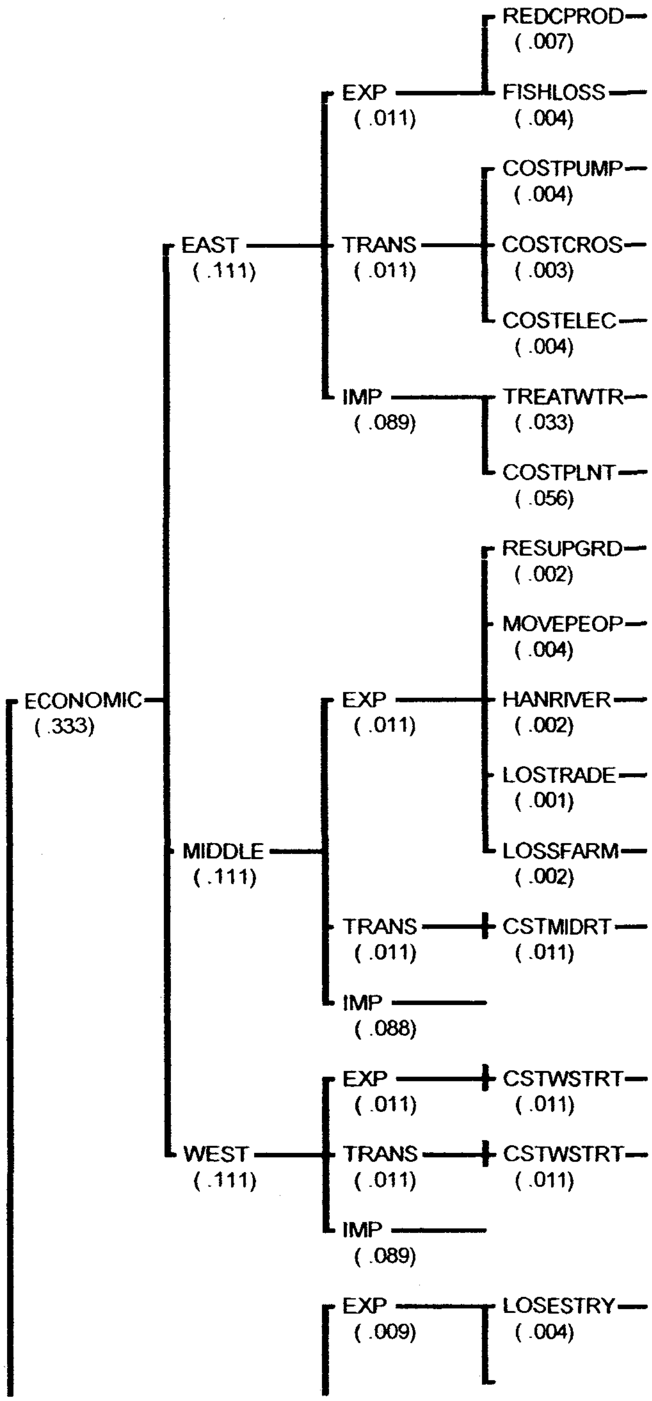
APPENDIX K
SCENARIO 8 BENEFIT

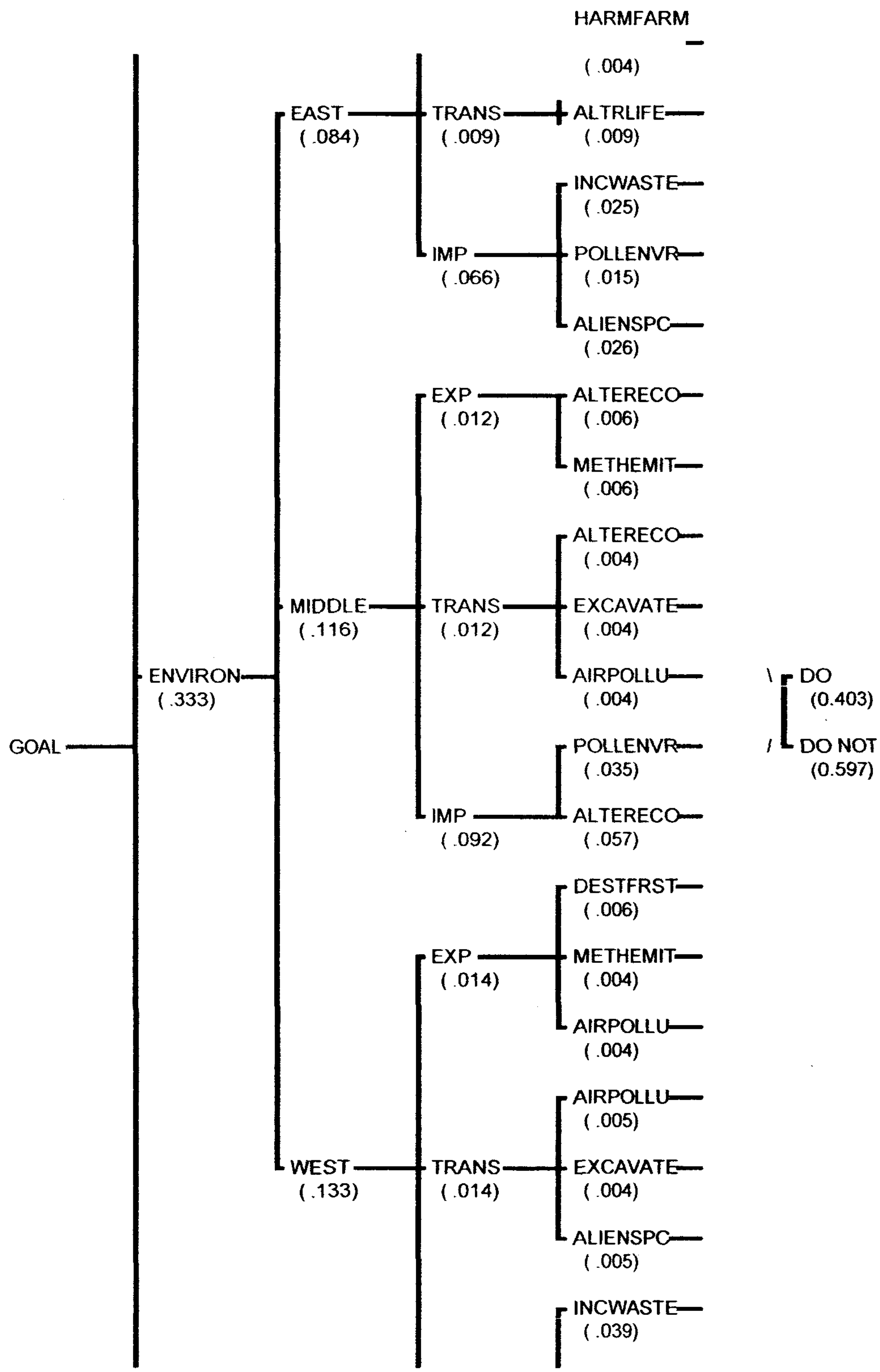


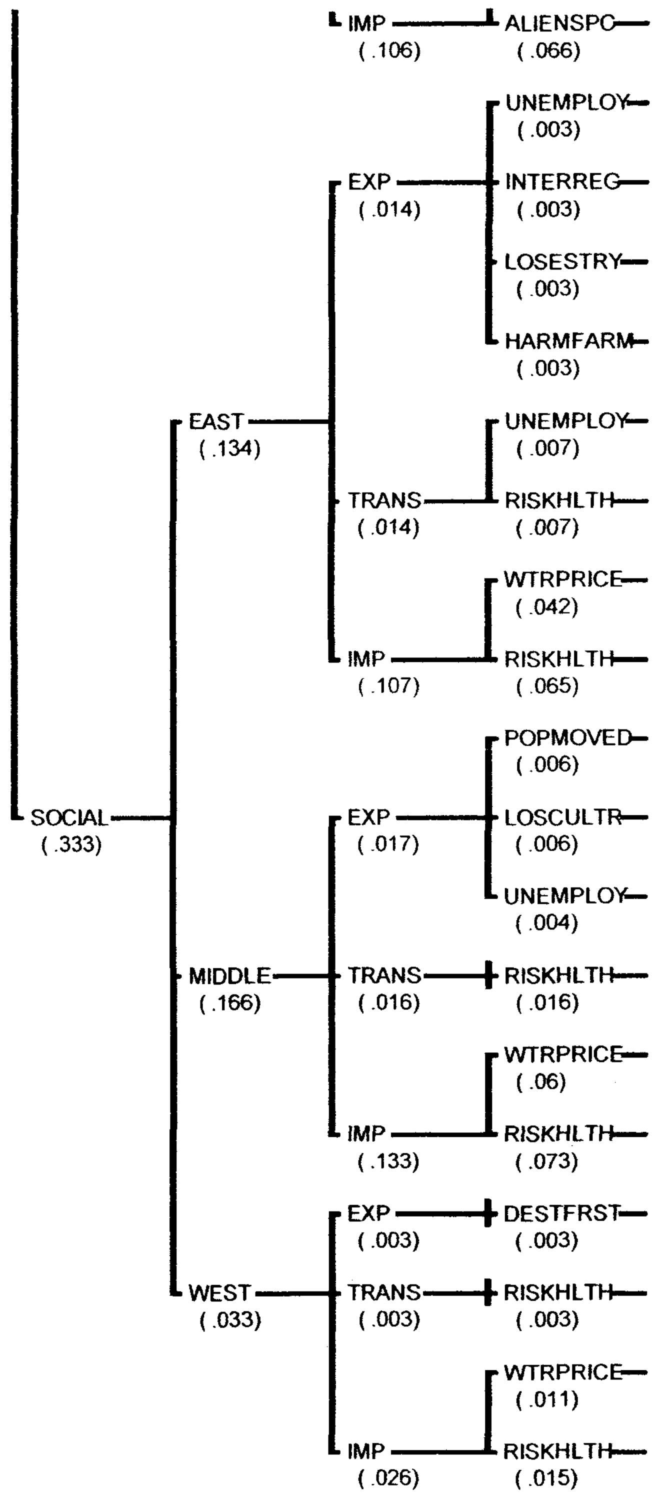

LIFREPOP
(.026)
GOAL
ENVIRON
(.333)
MIDDLE
(.116)
EXP
(.011)
TRANS
(.012)
IMP
(.093)
WEST
(.151)
EXP
(.015)
TRANS
(.015)
IMP
(.121)
IMPRVECO
(.121)
DO
(0.607)
DO NOT
(0.393)
EAST
(.111)
EXP
(.011)
TRANS
(.011)
HLTHINCR
(.004)
RECOPPTY
(.003)
INCREMPL
(.004)
IMP
(.089)
HLTHINCR
(.018)
RECOPPTY
(.014)
INCREMPL
(.016)
DECFLOOD
(.014)
NOSUBSID
(.015)
NOSEAWTR
(.013)
EXP
(.011)
HLTHINCR
(.004)


SOCIAL (.333)
MIDDLE (.111)
TRANS (.011)
RECOPPTY (.005)
INCREMPL (.003)
HLTHINCR (.032)
IMP (.089)
RECOPPTY (.025)
INCREMPL (.032)
EXP (.011)
HLTHINCR (.003)
TRANS (.011)
RECOPPTY (.003)
WEST (.111)
INCREMPL (.005)
HLTHINCR (.018)
IMP (.088)
RECOPPTY (.044)
INCREMPL (.027)

APPENDIX L
SCENARIO 8 COST




HARMFARM
(.004)
GOAL
ENVIRON
(.333)
EAST
(.084)
TRANS
(.009)
ALTRLIFE
(.009)
IMP
(.066)
INCWASTE
(.025)
POLLENVR
(.015)
ALIENSPC
(.026)
MIDDLE
(.116)
EXP
(.012)
ALTERECO
(.006)
METHEMIT
(.006)
TRANS
(.012)
ALTERECO
(.004)
EXCAVATE
(.004)
AIRPOLLU
(.004)
IMP
(.092)
POLLENVR
(.035)
ALTERECO
(.057)
WEST
(.133)
EXP
(.014)
DESTFRST
(.006)
METHEMIT
(.004)
AIRPOLLU
(.004)
TRANS
(.014)
AIRPOLLU
(.005)
EXCAVATE
(.004)
ALIENSPC
(.005)
INCWASTE
(.039)
DO
(0.403)
DO NOT
(0.597)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