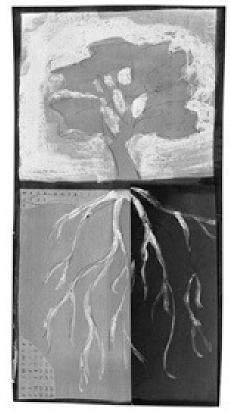
# Contents

# *Prologue*

# Industrialized Nature



In October 1948, loyal members of the Communist Party of the Soviet Union assembled in Moscow to decide the fate of their country's natural resources. For too long, climate and geography had played cruel tricks on the worker and peasant. Droughts and famine, floods and pestilence, energy shortfalls, long winters, and short summers were enemies of Soviet power no less than the capitalist nations that surrounded the country. Unanimously, the party loyal voted to adopt the Stalinist Plan for the Transformation of Nature. They would straighten rivers and shoals, dredge shallow areas to permit larger shipping vessels to use them, and build huge dams for irrigation, electricity, and municipal uses. They would plant thousands of kilometers of "forest belts" to protect the land from hot, dry winds. All of central Russia and Ukraine, from the European borders to the Ural Mountains, would become a mighty agricultural and industrial machine. Nature itself would operate according to plan. In the glorious paradise to follow, nature's bounty would serve the worker, not to mention the Communist Party elite, as never before in human history.

The massive effort to reconstruct nature began immediately with a series of projects. Among them were the construction of what was, for a time, the largest hydropower station in the world, the Kuibyshev dam; irrigation systems in the lower Volga River basin; and scores of forest defense belts. Joseph Stalin's successors in the 1950s through the 1980s—Nikita Khrushchev and Leonid Brezhnev—did not so much scale back the 1948 plan as overlay it with their own wildly ambitious transformative projects in Soviet Central Asia and Siberia, such as chemicalization of agriculture and diversion of rivers.

The result of Stalin's plans, and Khrushchev's and Brezhnev's, was not the taming of nature, however, but its devastation. In many places, river flows slowed to a crawl. Dams and reservoirs ruined spawning areas of sturgeon and other migrating fish. Heavy use of chemicals on collective farms, in conjunction with large scale irrigation systems, led to erosion and depletion of soils. Clear-cut forests never grew back. Industrial pollution—heavy metals, radioactive wastes from the military sector, petrochemicals, and so on—destroyed the ecology of rivers, lakes, and soil. In some regions, "industrial deserts" arose—tens of thousands of hectares of land where nothing, not even hardy grasses, will grow. In other regions, hundreds of towns and villages were inundated by waters backing up behind hydropower stations. At the center of all this devastation were human hands that guided large scale technologies—armies of scientists and engineers equipped with calculations, managers equipped with ideological certainty, and workers equipped with huge graders, bulldozers, and steam shovels, though more often merely hand shovels, pickaxes, and sledgehammers.

It is almost an article of faith that the dams, irrigation systems, highways, and other large scale technologies designed and built in the United States and elsewhere were far superior to anything the Soviet Union could muster. In the United States, the Tennessee Valley Authority illuminated the hollows of Appalachia and fought poverty through modern science. Dams along the Columbia River generated cheap electricity for residents of the Pacific Northwest. The irrigation systems of California's Central Valley have long provided a daily cornucopia of fresh fruits and vegetables, effectively ending the notion of "growing seasons." Americans are accustomed to reading about how the country's scientists and engineers work in the interests of democracy, how their work benefits the ordinary citizen, how they rarely get things wrong, and how, on the rare occasion when they do, they quickly find scientific solutions. We tend to believe that under communism, Soviet scientists and engineers were incompetent or overzealous or perhaps merely incapable of establishing the objectivity that would have enabled them to build dams, irrigation systems, and highways like ours. Our dams were bigger and better and provided more for citizens. As President Franklin Delano Roosevelt declared in 1937 on visiting the Grand Coulee hydroelectric power station in Washington State—soon to be the largest in the world—"It is so much bigger than anything that has ever been tried before. . . . We look forward not only to the great good this will do in the development of power but also in the development of thousands of homes. . . . It is a great prospect, something that appeals to the imagination of the entire country."[1]

Yet American engineers of nature have much more in common with their Soviet counterparts than is commonly assumed, as I have come to realize while working on this book. They shared faith in the ability of technology to change the face of nature for the better. My long-term affection for hydropower stations, canals, nuclear power plants, and other great "hero projects" that politicians promoted, engineers designed, and workers built has given way to the conviction that human beings have moved overzealously from scientific study of natural resources to political and economic decisions to exploit those resources. We risk a great deal when we assume that large scale applications of scientific knowledge in the form of armies of laborers and machines are better than small scale approaches to resource management. My joyous amazement at human hubris in building massive cultural artifacts, from pyramids to eight-lane highways, has been replaced by dismay at the great social, public health, human, and environmental costs of those artifacts. Construction of the Tucuruí hydropower station in the rain forest of the Amazon River basin inundated nearly 3,000 square kilometers (more than 740,000 acres) of land, destroyed fragile ecosystems, and nearly killed off the Parakana Indians. The U.S. Interstate Highway System, with rights-of-way 50, 60, even 150 meters (about 55–164 yards) wide, cut huge swaths of concrete and tar through the country's forests and plains. My nagging suspicion that in taking on these large scale projects we have bitten off more resources than we can chew has turned into the conviction that we must reevaluate the way we live in relation to the natural world, or at least the way in which we manage resources. The evidence overwhelmingly suggests that large scale projects to manage water, fish, and forest resources are both more wasteful and more destructive of human communities and ecosystems than are small scale projects.

This book is about the way science, engineering, policy making, finance, and hubris have come together to give great impetus to large scale technological systems that we use to manage natural resources.

These systems are not merely large technologies—graders, cement mixers, harvesters, genetically engineered crops—nor are they merely artifacts created by construction trusts and engineering firms, such as dams, canals, highways, railroads, and logging roads. The systems include the government bureaucracies that regulate and promote technology; the scientific researchers whose understanding of geology, geophysics, hydrology, marine fisheries, silviculture, and the like provide the basis for modern management techniques; the engineering firms that design technologies; the construction firms that erect them; and the multitudes of pourers, form builders, loggers, and sailors who gather, cut, channel, and transport the resources. The evolution of these technologies in the former Soviet Union, the United States, Norway, Brazil, and elsewhere provides a cautionary tale about the risks of large scale approaches to resource management problems, for these technologies leave environmental devastation in their wake.

In too many cases, these systems—what I refer to as brute force technologies—have taken on a life of their own. In each aspect of the management process—growing, harvesting, processing, storing, studying, understanding, buying, selling, importing, exporting, building, excavating, channeling, funneling, bulldozing, exploding, imploding, distributing, and consuming—we have gained extraordinary power to transform nature into something increasingly orderly, rational, and machine-like—in a word, industrial. The hydropower stations that turn the seasonality of rivers into a regulated year-round flow for agricultural irrigation, power generation, and transport; the railroads, roads, and highways that enable penetration of the so-called wilderness or frontier; the extraction of mineral wealth; the harvesting of wood, fish, fruit, and vegetable products and the transport of these raw materials to cities for processing and consumption; and the machines that repetitively grind, level, move, push, power, snip, cut, de-bark, prune, pulverize, grade, terrace, dig, drill, pump, open, close, puree, mix, seal, snip, behead, descale, and freeze have all contributed to the illusion—ultimately fleeting—of inexhaustibility of natural resources.

The best efforts of scientists and engineers who arm themselves with the most complete and current understanding of resource management techniques will be powerless to change this situation so long as they embrace brute force approaches. They build dams to power and irrigate, and coincidentally they destroy migrating fish populations. The fish physically cannot get beyond dams that rise 5, 10, even 200 meters. Engineers have designed fish ladders to help the fish return to their spawning areas upstream, but most fish refuse to climb ladders. The engineers have turned to aquaculture in various forms—hatcheries, for example—to replenish the stocks. But of the millions of fingerlings released into rivers to replace the destroyed stocks, only a few thousand manage to return, with most destroyed in the blades of turbogenerators or by natural predators—such as, apparently, humans. Dams and reservoirs have rarely functioned as long or as well as predicted. Scientists' self-consciously proclaimed hero projects have rarely met expectations and often have led to disastrous results.

For centuries, farmers strove to select the most productive and hardy from among their crops and farm animals. It was only natural for scientists at agricultural experiment stations around the world to seek a better way of reaching the same ends by creating hybrid crops and animals. They now use the techniques of genetic engineering to create even more productive crops and animals. But some scientists have discovered that there are limits to and dangers in their creative powers to produce hybrid monocultures, whether on the farm, in the forest, or at sea. For example, the industrial forest, pushed and pulled by pesticides, herbicides, and fertilizers to produce uniform softwoods for the pulp and paper industry, is at risk of various budworm infestations and of weakened soils that are greatly susceptible to erosion. Indeed, all monocultures are highly vulnerable to single predators, and they require intensive care and expensive chemical inputs to protect them.

One reason for these unexpected failures is that efforts to ensure adequate natural resources for present and future generations have come up against political pressures and economic interests that influence scientific understanding. Science and engineering are tied to the interests of nations and governments; to businesses and industries; to the interests of scientists' universities, institutes, and laboratories; and above all to the well-being of scientists' countrymen and countrywomen, however well-being is defined. The irreducible empirical facts that serve as the foundation of scientific knowledge find room for interpretation in the desires of governments for national security, public health, and economic prosperity; in the aspirations of entrepreneurs to profit handsomely; and in the hubris of specialists themselves that leads them to overlook gaps in knowledge that might slow efforts to develop sustainable silviculture, aquaculture, and agriculture. As one, public officials, entrepreneurs, and specialists presume that the bigger the technology, the better, the more effective, and certainly the more impressive. The confluence of scientific knowledge, political power, economic aspirations, and hubris has led to the creation of brute force technologies that overwhelm nature.

I began this project in concern over the environmental legacy of seventy years of Soviet power. As I visited Moscow, Kiev, Leningrad, Irkutsk, and Novosibirsk during various research trips in the late 1980s and early 1990s, I grew increasingly troubled, and I worried for the sake of friends both in the USSR and beyond its borders. Power stations, smelters, and mills of all sorts were built without a worry for the contaminants they spewed into the air. Hazardous waste was stored carelessly. Workers and officials knowingly tossed heavy metals, acids, petrochemicals, radioactive materials, batteries, and everything but the kitchen sink into rivers and lakes, or buried such material merely centimeters below the surface of the soils, where it leached into the water, or burned it in open piles. This was all in the name of the glorious proletariat; it started under Stalin, and it continued under Khrushchev and Brezhnev.

Later, in the Mikhail Gorbachev era, journalists, scientists, and even bureaucrats with a conscience began to fill newspapers, journals, and official reports with chapter and verse about past, present, and potential environmental disasters in the USSR. From the ruthless use of forced labor in constructing the Belomor (White Sea–Baltic) Canal to the radiation disaster at Chernobyl, from clear-cutting of forest in Arkhangel province to ruptured gas and oil pipelines in fragile arctic tundra to the spoiling of the Aral and Caspian Seas and Lake Baikal, seldom a day passed in the era of glasnost without yet another exposé on yet another disaster with still higher costs to people and nature.

I have never written about the USSR, or about the United States in comparison, out of hatred for communism, love of Lenin, excessive support for capitalism, morbid curiosity, or the desire to sit around the kitchen table with Russian friends until the wee hours, but merely in the naïve hope to understand, analyze, interpret, and report. Still, the end of the cold war provided an opportunity to consider not the uniqueness of Soviet environmental maladies but the fact that the Soviets, Japanese, Germans, French, Norwegians, Americans, Brazilians, and so many others share more than they can truly fathom when they embrace brute force technologies as a solution to such pressing problems as rational resource management, flood control, electric energy production, and irrigation for agriculture in the interests of increasingly urban populations. Societies only belatedly recognize these technologies' costs to their marginalized peoples, such as the American Indians, the Saami people of northern Scandinavia, the Chukchi of Siberia, and the Parakana of Brazil. In most cases, the economic and political systems, whatever form they may take, and nature itself matter less than the way in which brute force technology is embraced, developed, and diffused.

Are brute force technologies the central reason for worsening environmental conditions across the globe? Some analysts rightly point out that population pressures—whether from high natural growth rates or from immigration or migration—promote resource scarcity more than any other factor. Others argue that new conceptions of property and ownership that accompanied the rise of capitalism accelerated resource degradation by placing greed and profit at the forefront of individual desires, or by leading people to demonstrate their supposed superiority by undertaking "improvements" in the land. In a similar vein, these writers indicate that the very way most governments primarily measure their economic health—by increase in gross domestic product—contributes to the drain on natural resources, for these indicators ignore long-term costs of resource depletion, waste, income disparities, and marginalization of indigenous peoples while celebrating the current prosperity of the lucky. Still others point to the high levels of consumption achieved in Europe and, especially, the United States. There is no greater evidence of this than President George W. Bush's energy program, which aims at increasing production while ignoring conservation of nonrenewable resources—and this in a country where one-twentieth of the world's inhabitants consume one-fifth of its resources as some kind of manifest destiny.

Yet in addition to these factors, we need to consider how large scale approaches to transforming nature and managing resources ignore the concept of ecosystems and undermine environmental conditions. Brute force technologies require us to create human systems of order and structure that destroy boundaries and edges. They change the seasonality of natural processes. They necessarily lead to profligacy, for they are based on the illusion of inexhaustibility (or at least are based on the belief that humans will be able to produce ever more flora and fauna through scientific management). The question is this: What is inexhaustible, the resources or our hubris in believing we will always find a technological solution to problems we create through large scale approaches? We must also reexamine several assumptions embedded in the practice of modern science, including the belief that it is possible to pursue knowledge for its own sake independently of politics. The very notion of progress is political through and through. Politics necessarily accompanies the genesis of brute force technologies—in the governments that approve projects, the engineering organizations that design them, the banks that fund them, the construction firms that build them, and the people and ecosystems pushed aside for them.

At first glance, it would seem that science and technology, and the brute force technologies built upon them, must be apolitical. They are grounded in universal scientific facts and theories. The shared evidence and experience of scientists from Russia, Europe, and the United States, not to mention their colonial enterprises, reasonably led to a common belief that scientific understanding of plant respiration, fish migration and reproduction, water temperature and chemistry, and the like should guide plans to develop agriculture, silviculture, and aquaculture. This evidence suggested how to harvest flora and fauna only to the scientifically determined levels of natural replenishment and how to change natural topography with clear expectations of the environmental effects.

But a closer examination of the language of science, as revealed in journals and research papers, indicates the impossibility of divorcing the facts of how nature operates from the political decision to transform nature for the betterment of humankind. For example, by the turn of the twentieth century, European and American scientists writing in forestry and hydrology journals had begun to quantify the "duty" of water (a measure of its capacity to carry agricultural, fishing, municipal, and other burdens), not recognizing how strange it was to give water a moral obligation to humans. Industrial metaphors had supplanted biological ones in the journals of many resource management fields by the late 1920s and 1930s. From that point on, nature was industrial—in machine metaphors that supplanted biological explanations for vital functions of plants and animals and in the view of rivers, fields, and forests as closed systems that would operate as humans specified. Nature was industrial in the application of Taylorist and Fordist notions to resource management. Taylorism (the scientific management of human labor) was extended to forests, water, fish, and other resources. Fordism (mass production along the assembly line) found application in increasingly massive silvicultural, aquacultural, and agricultural enterprises through the effort to mass-produce standard products or monocultures. In a word, technocratic doctrines of efficiency found response in the effort to introduce modern technology into the creation, production, and harvest of natural resources.

Even when hot and cold wars prevented close cooperation, scientists and engineers familiarized themselves with the cutting-edge research of faraway colleagues that confirmed they were on similar paths. Not surprisingly, design institutes, national laboratories, businesses, and engineering firms throughout the world transformed their research to incorporate the tools, techniques, and technologies needed to move ahead with large scale research management practices. These tools and practices are now familiar in the agribusiness farms of monocultures that stretch to the horizon, producing, say, hybrid corn, soybeans, or grain. They are familiar in the seeds that, to reach maturity, require specific mass-produced chemical pesticides, herbicides, and fertilizers produced in industrial laboratories. They exist in the industrial forests; in the irrigation ditches and flood control facilities intended to permit water to do its duty; in the incubators and hatcheries built to increase animal populations; in the laboratories where hybrids of crops, birds, mammals, and fish are created; in the prefabricated concrete forms, slabs, and foundations made to stretch across rivers; and in the armies of workers wielding all these.

National factors—ideology, politics, culture, economic systems—shape both scientific research and the brute force technologies that have been developed from it. We should thus expect these influences to mold the creation of hydropower stations, say, so that the Kuibyshev hydropower station on the Volga River will differ from the Grand Coulee Dam and both will differ from the Tucuruí dam on the Tocantins River in the Amazon. Climate, technological sophistication, and aesthetics will influence the design of roads, bridges, and power lines that stretch across the American West, down the Norwegian coast, and through Siberia and the Amazon. Perhaps engineered fish and trees will have specific national characteristics, even though they serve the same purpose of feeding and housing the masses and providing them with paper products.

The level of economic development, the degree of centralization of decision making and production, and the ideological importance of various artifacts to a country's leaders also shape the design and construction of brute force technologies. Think of how the Grand Coulee Dam served American leaders during the Great Depression in showing that the American system worked, and how the Kuibyshev hydropower station met the propaganda purposes of Joseph Stalin to demonstrate that only under Soviet socialism could dams transform nature for all citizens, not just wealthy capitalists. In all cases, in all countries, local knowledge—that of indigenous people, small fishing communities, yeoman farmers, and small scale enterprises regarding how, what, and when to harvest, process, consume, and distribute—is ignored and overwhelmed by national and international standards of what constitutes fact. Even more, universal beliefs about what constitutes the national interest predominate over local interest in being left alone. In many cases, being allowed to live as before means living a life of poverty on the fringe of subsistence. But being forced to conform to national facts, standards, politics, science, and technology means losing one's way of life, and it often means being forced to work to meet growing consumer demands in urban centers for various products of the forests, rivers, and oceans.

The true costs of the well-intended efforts to understand nature and transform it into readily available commodities, and to force nature to become more machine-like, more predictable, and a human construct more readily recognizable, are difficult to establish. One reason is that the tools we use to establish costs and benefits—technology assessment, cost-benefit analysis, and scientific knowledge—deal largely with categories of events and facts that are quantifiable. Justice, beauty, morality, and ethics often fall outside the scope of consideration. We can calculate how many tons of fish can be captured using deep-sea trawlers, but we are less able to quantify the costs to local fishing communities of their loss of livelihood to modern technology, which harvests cod, haddock, and the like so much more efficiently. We can determine the annual demand for board feet of lumber for new housing starts, but we cannot fix a price on the loss of habitat for any endangered species, let alone the joy of standing among the trees and smelling the forest. The result is that we give great store to immediate concerns and push ultimate responsibility for the true costs of our actions onto others, including future generations, almost always assuming that scientists and engineers will find ways to meet our growing profligacy. When balancing costs and benefits, so long as the benefits we can quantify are greater than the costs we cannot, we ignore the incalculables. Those who offer “go slow” approaches are seen as opponents of progress, perhaps Luddites, whereas supporters of the industrialization of nature are the prophets of a new era.

This book is based on the premise that we humans always have been a part of nature and always will be. We will attempt to modify it to meet our needs, harvesting what we will and discarding what is unneeded. This is only natural. Humans are powerful, filled with hubris, and it is thus no accident that we have pursued transformative projects using large scale technologies that entail quantifiable and seemingly predictable outcomes. What requires more understanding is how we have come to rely increasingly on science and technology to modify nature, yet fail to fathom the dangers in this approach.

Fortunately, many scientists and engineers have recognized that rarely, if ever, do they merely assemble facts into theories. They understand that they are part of the process by which humans acquire powerful tools to transform the landscape, alter the flow of rivers, and even create new forms of life. For this reason, they have urged us to adopt sustainable approaches to the transformation of nature that maintain biodiversity. I would add that we need also to consider how we can ensure reversibility of transformative projects. We must learn to question the belief among scientists, policy makers, and the general public that we can alter the face of nature substantially in one place without incurring substantial costs elsewhere. The engineers who built paper mills on the shores of Lake Baikal, for example, mistakenly assumed they could treat the wastewater and return it to the lake more pure than when it was removed. It is patent foolishness to allow in the name of progress the destruction of wetlands so long as developers "build" functioning wetlands elsewhere. Any child who has built a sand castle or dammed a stream knows how futile it is to assume permanence in nature. But this is precisely what the use of brute force technology assumes. The larger in scale a project is, the more it appeals to political leaders, the more its ideological content overwhelms its practicality, and the more it aspires to bring about permanent change in nature—regularity, order, predictability—the more we need to question it. Examples abound: the Siberian river diversion project, the Three Gorges Dam on the Yangtze River, the creation of an industrial forest, the taming of the Amazon River, construction of the Trans-Alaska Pipeline.

In the end, we must understand that the Stalinist plan for nature transformation was under way for much of the twentieth century, and not only in the USSR but also in Brazil, in China, in Norway, and above all in the United States. In the chapters that follow, I explore the genesis of brute force technology to develop fish, forest, water, and ore resources in the twentieth century. The notion of brute force technology takes its inspiration from E. F. Schumacher's 1973 classic, *Small Is Beautiful*. But it goes beyond Schumacher's criticism of capitalism in a search for universal attributes of large scale approaches to resource management that cut across economic systems. "Brute force technology" refers to overemphasis on unforgiving technologies of massive scale. This includes the premature search for monocultures based on incomplete understanding of the biological consequences of human activities. At times, the origins of brute force technology appear to be mass production gone wild in agribusinesses and industrial forests—what some have called "Fordism in nature." Brute force technologies often involve overuse of harsh chemical methods to protect these monocultures. In natural resource management, the driving force of brute force technologies is the effort to determine where production and biology meet.

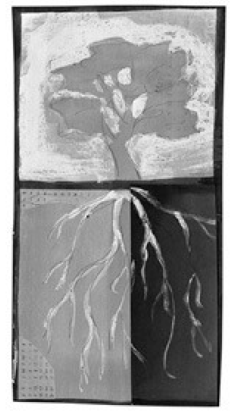
Brute force technologies are based on standard engineering practices applied to other areas of human activity with little or no consideration of potential external costs. For example, engineers moved from prefabricated forms for apartment construction to dams, canals, and hydroelectric and nuclear power stations with only modest modifications. Once they have established standard techniques on which to base such structures, engineers hesitate to introduce modifications because they may be costly or have unforeseen consequences. Yet this hesitation delays the incorporation of new knowledge about climate, geology, hydrology, and biology. The assumption is that climate and geology can be made to fit the technology, not the other way around. Even more, engineers often focus on the development of brute force technologies for harvest: deep-sea trawlers and tree feller bunchers, for example. The result of this focus—and the lesser attention paid to the creation of efficient processing equipment and infrastructure—is rapacious harvest, for it is a simpler matter to harvest seemingly inexhaustible natural resources than to harvest less and use it more efficiently.

In a word, brute force technologies have significant and irreversible environmental and social consequences. In chapter 1 of this book, I focus on the ideological roots of brute force technology by comparing the development of the Volga River and Columbia River basins, the former a good socialist river in the European USSR, the latter a good capitalist river in the Pacific Northwest of the United States. In chapter 2, I examine the effort to transform the pine forests of New England and Arkhangel province of northwestern Russia into factories for the mass production of wood products. In chapter 3, I take on questions of the development of the periphery for the benefit of the center. Specifically, I explore how corridors of modernization—roads, electric power lines, railroads, and the like—opened the interior regions of Brazil and the USSR, the Amazon basin and Siberia, respectively, regions whose resources were poorly developed to serve growing urban demands for agricultural products, aluminum, and electricity. In chapter 4, I consider the effects of brute force technology on the deep-sea fishing industries of the North Atlantic Ocean. On the basis of extensive oceanographic and marine fisheries research, Norway, Russia, Canada, and the United States all sought to turn the oceans, if not the fish themselves, into cold-blooded machines. In the epilogue, I return to the lessons that the history of brute force technologies should make clear.

My analytical tool—the notion of brute force technologies—may be applied with aplomb to resource management techniques and products throughout nature as it has been transformed worldwide. Consider the potato. In the Columbia River basin, the Bonneville Power Administration (BPA) built thirteen major hydropower stations. Many of these projects had roots in the Progressive Era at the beginning of the twentieth century but gained impetus for flood control and poverty abatement during the Great Depression. Engineers promised that the vast quantities of electricity the dams would generate could be used to irrigate the fertile but arid land of eastern Washington, Oregon, and Idaho, creating an agricultural wonderland. Farmers discovered that these soils were perfect for potatoes. Federally subsidized irrigation water was intended to serve the small family farmer. But scale is everything, and the forces of modern agribusiness are overwhelming. The BPA now provides subsidized irrigation water to huge agribusinesses that produce 60 percent of the frozen potato products in the United States, those same potatoes consumed in fast-food restaurants. The desire to transform nature begat hydropower and led to the industrial potato. But that is the story of chapter 1.

# I

# Pyramids of Concrete: Rivers, Dams, and the Ideological Roots of Brute Force Technology



> Look down in the canyon and there you will see
> The Grand Coulee showers her blessings on me;
> The lights for the city for factory, and mill,
> Green Pastures of Plenty from dry barren hills.
> —Woody Guthrie, "Pastures of Plenty"

FLOODS, STAGNANT POOLS, rapids, seasonal trickles, and hard freezes are the nature of a river's life. They also often disrupt natural human activities: commerce, transport, and fishing. For centuries, people have tried to regulate the flow of rivers to support those activities and prevent or diminish the effects of floods. They have dammed them to form reservoirs and to harness their power, employing at first simple water wheels and by the end of the twentieth century 500 megawatt turbogenerators.

Twentieth-century efforts to alter the flow of rivers commenced with the unquestioned wisdom that to dredge their shoals and straighten their banks in order to improve navigation, produce electricity, and store water for irrigation was always and everywhere good. Engineers were convinced that they understood the cycles of rain and drought, of summer warmth and winter ice, that affected river flow. They were confident that their sluices, canals, and irrigation channels would function as intended and that new agricultural land would be found to replace that inundated by the reservoirs. Above all, they believed that engineering of rivers was necessary to prevent once and for all the dangerous floods that periodically devastated towns and cities, killing hundreds of people and ruining valuable property. Engineers overlooked, underestimated, or did not anticipate the great costs of their projects, notably the destruction of ecosystems, of flora and fauna, and of the human cultures that were displaced.

In the mid-nineteenth century, the U.S. Army Corps of Engineers took it as a matter of faith that flood control by means of dams and levees along such rivers as the Mississippi would improve agriculture, commerce, and navigation, and the agency gained congressional approval and funding for its projects. The Swamp Land Acts of 1849 and 1850 encouraged the reclamation of millions of acres of wetlands, especially in the lower Mississippi River basin. Later, the Newlands Act of 1902 gave birth to the Bureau of Reclamation, which the United States Congress charged with advancing irrigation projects to expand the country's ability to farm—that is, to prosper regardless of the amount of water available, the aridity of the land, or the presence of competing demands for this scarce resource. Cattlemen, lumbermen, farmers, and miners in the American West all needed water, and specialists concluded that rational planning based on modern science was the way to provide it.[1] Yet flood control and land reclamation accelerated urbanization and activities such as farming on floodplains. Technologies of transport and communication along the rivers—highways, bridges, and railroads—led to the covering of floodplains by structures of cement, tar, wood, and other materials, leaving less and less area for runoff and absorption of water. Before long, hundred-year floods became fifty-year floods. Fifty-year floods became twenty-five-year floods, and twenty-five-year floods became ten-year floods.

Indeed, massive floods on the Mississippi in 1912 and 1927, and disastrous floods in 1935 and 1936, should have indicated that all was not well with river engineering. Either flood control was not working or it was drawing too many people into dangerous regions. The 1936 floods in Johnstown and Pittsburgh, Pennsylvania, though not as devastating as the region's 1889 flood, which killed more than 2,200, caused $100 million in property damage. This gave further impetus to regulation of inland waterways and promoted still larger projects employing many thousands of workers armed with ever more powerful earthmoving equipment, dynamite, and federal money. Never lacking for confidence, civil engineers, hydrologists, and other specialists believed that with additional study they would understand the interaction of climate, geology, and river "improvements" and be able, once and for all, to transform rivers into machines that operated according to human dictates.

From past centuries to the present, a number of major geo-engineering projects have moved steadily ahead on the confluence of engineering certainty, government action, and human hubris. These include centuries-long Dutch efforts to reclaim land from the ocean; various canal and river diversion projects, from the Panama Canal in the nineteenth century to the Suez Canal in the twentieth; and such noteworthy efforts to change the landscape—even if simultaneously to obliterate history—as the Aswan High Dam on the Nile and the Three Gorges Dam on the Yangtze River.[2] But two stand out for their scale, their irreversible effects on human and other biological communities, and their importance as symbols of high statecraft in the mid-twentieth century: the reconstruction of the Columbia River basin in the Pacific Northwest region of the United States and the transformation of the Volga River basin in the European USSR. These massive, unified river engineering projects are the epitome of modern, state-sponsored brute force technologies—and their unintended and devastating social and environmental consequences.

Although everyone knew of the pitched battle between the USSR and the United States during the cold war for ideological and military supremacy, few noticed how intense this battle was in the 1930s. Soviet leaders pronounced capitalism bankrupt, pointing to the long lines of hungry workers waiting for handouts during the Great Depression. As examples of the advantages of emergent socialism they held up new hydropower stations, steel mills, and subway systems being built in the USSR that were transforming the nation into an industrial superpower while keeping its workers contentedly employed. Many Soviet engineers and political leaders realized that the United States had a far more developed technological culture, but under Joseph Stalin they could not risk openly saying so. Instead, they insisted their technologies were better in all respects: they would be built more quickly, treat the worker with respect, end unemployment, facilitate the control of nature, and create an industrial power greater than that of the United States, all within fifteen years. The steel mills in Gary, Indiana, were nothing, propagandists argued, next to those in Magnitogorsk, a steel city at the southern end of the Ural Mountains built in the 1930s from virtually nothing.[3] On the river front, until the early 1950s Soviet engineers and workers focused their energies on reconstructing the Volga, Don, and Dnepr River basins in the European part of the country, establishing a unitary system for transportation, agriculture, and power generation to serve Moscow and what was euphemistically called proletarian power.

No less explicitly, business and political leaders in the United States spoke about the Tennessee Valley Authority and the Bonneville Power Administration, about their dams and cheap electricity, and about successful flood control, illumination, and clean water as evidence that the capitalist system was more just and more efficient than the Soviet system. The nations were locked in a battle of hydroelectric envy, each side touting each successive dam it built as more powerful, requiring more excavation and more concrete. Hoover Dam and the Grand Coulee Dam in the United States and the Kuibyshev and Tsimliansk dams in the USSR were not just hydropower stations but symbols of the might and right of the capitalist and socialist systems. The tragedy is that political leaders, engineers, and planners, in part because they were so blinded by ideology, typically overlooked or dismissed the great human and environmental costs—some in plain view early on, others quite unanticipated—of their concrete pyramids.

Neither socialism nor capitalism produced dams, fish ladders, or irrigation systems that lived up to their rhetoric. In both the United States and the Soviet Union, families were forcibly removed from their homes to make way for progress—many churches, schools, and cemeteries were inundated. In both countries, dozens of workers were injured, maimed, or killed in the huge construction projects. In both, crucially, engineers underestimated, indeed did not understand, the significant effect brute force technologies would have on the environment.

## Lenin, Stalin, and Hydroelectricity

Since the first years of the Russian Revolution, large scale technologies were at the center of Soviet economic programs. Economics of scale seemed to make them preferable. The centralizing and controlling ethos of Bolshevism gave them impetus. They were justified for their role as both workplace and venue in which overly superstitious and religious peasants could be turned into atheists and communists. And Vladimir Ilich Lenin, Russia's leader, embraced electricity in particular as a panacea for the country's backwardness. Lenin asked a colleague, engineer Gleb Krzhizhanovskii, to compile a program for the electrification of Russia. The state program, known usually by its acronym, GOELRO, served as the basis of Soviet electrification efforts for decades.[4] Approved by the 8th Congress of Soviets in December 1920, the plan was popularized by the Bolsheviks through posters emblazoned with lightbulbs intended to supplant religious icons and carrying the famous slogan "Communism equals Soviet power plus electrification of the entire country!" GOELRO was as important for its revolutionary symbolism as for its concrete results. Indeed, Lenin called GOELRO "the second party program," foreshadowing the centrality of brute force technologies in government development programs.[5]

The GOELRO plan, modest in generating capacity by today's standards, proposed the construction over a fifteen-year period of thirty stations of all sorts, with a total capacity of roughly 1.2 million kilowatts (kW). Soviet Russia lagged considerably behind Germany, England, the United States, and other industrializing nations at this time in per capita consumption of fuel and energy resources. In GOELRO, planners emphasized power derived from coal, peat, and oil (and also wood) because of the country's extensive fossil fuel reserves. Hydroelectricity made up one-third of the total fifteen-year forecast of additional capacity. Stations were to be built at Volkhovsk, Sversk, and Dnepropetrovsk by 1925 or so, with six others to follow soon thereafter in Ukraine, the Urals, the Altai, and Uzbekistan. These goals for hydroelectricity are not surprising, given the poor state of the tsarist coal industry in the Kuznetsk Basin of Ukraine, the backwardness of the oil industry in the Caspian Sea near Baku, Azerbaijan, and the cost of extraction of oil and coal. By comparison, hydroelectric power seemed less costly and could be developed wherever there was a sizable river. Engineers identified scores of sites.[6]

GOELRO engineers quickly established hundreds of experiment stations to measure the level and flow of rivers in the USSR. Increased study meant increased potential capacity. In 1916, the tsarist minister of agriculture, I. O. Moskvitinov, released the "White Coal" report showing potential water resources in the Russian Empire of 14.6 million kW; the GOELRO plan of 1921 indicated 44.5 million kW; and a report three years later found another 3.2 million kW of electric energy. By 1935, planners had concluded that roughly 280 million kW of potential existed, with the Lena River providing 50.6 million kW, the Enisei 46.8 million kW, the Amur 31.8 million kW, and the Volga 11.8 million kW.[7]

In true Bolshevik fashion, Krzhizhanovskii used hyperbole and metaphor to describe the work of GOELRO. Electricity was a "powerful lever for the creation of the cultural conditions of socialist labor by guaranteeing the rapid increase in its productivity and its rational organization."[8] Hydroelectric power stations on the Volga were crucial links in the plan to build the material-technological basis of communist society. They showed clearly the advantages of the Soviet system over those of capitalist countries and symbolized the qualitative difference between peaceful Soviet electricity and imperialist, militaristic capitalist energy.[9] Under Stalin, the share of hydroelectric generation capacity indeed grew rapidly.

The tsarist government had not developed these resources in the least. From 1872 to 1916, Russian industry manufactured slightly more than 3,000 turbines with total capacity of 101,000 horsepower (hp), and the country had a total of 55,000 water power plants of all sorts, mostly grist mills, with total capacity of 513,000 hp.[10] Soviet engineers lacked the modest goals and aspirations of their predecessors: by 1939 they planned to install aggregate capacity of 2.5 million kW. They focused on development of the Volga, Sevan-Zanga, and Dnepr Rivers while commencing installation on the Angara, upper Irtysh, and other Siberian rivers. All projects involved power generation, improvements in river transport, irrigation, and water supply. "Big Volga" and "Big Dnepr" centered on the most developed, densely populated districts with basic industrial and agricultural services, high and continually increasing demand for electric power, and dense interregional freight traffic. Limited local fuel resources demanded rapid construction of dozens of stations. On the Volga, the Uglich, Rybinsk, and Ivankovo stations were already under construction in 1932, with stations planned at Gorky, Cheboksary, Kuibyshev, and Kamyshin (later to be Stalingrad).[11] If in 1928 hydropower stations produced 4 percent of Soviet electricity, by 1937 they produced 8 percent and by 1950, 15.2 percent.[12]

Like Lenin and many other Bolshevik officials, Stalin saw technology as a panacea for the USSR's economic and political problems. Even before becoming the nation's leader, Stalin called for expansion of irrigation systems and an increase in the role of GOELRO in bringing workers and peasants—the countryside and the city—closer together. Stalin proposed irrigation programs to end droughts in the southern Volga River basin near Samara, Saratov, and Astrakhan. In his eyes, technology was a mighty political tool; it would force the peasants to abandon their antiquated culture and bring them psychologically into the workers' state.[13]

Once he became leader, in the late 1920s, he embraced large scale projects as the centerpiece of an officially proclaimed "Great Break" with previous policies to transform the country's political, social, and geophysical maps. In political terms, this meant abandoning the New Economic Policy, which had permitted small scale trade and a money economy, for a centralized, top-down economy. He pushed industrialization hard and forced peasants into collective farms to produce a steady source of food for growing urban centers, at the same time subjugating them to Bolshevik political institutions. The human costs were great: millions died of famine, millions perished in purges, and engineers and managers whose projects failed to reach targets were arrested. The secret police executed many of the technological experts for "wrecking" plans to use resources rationally. In this case, "rational" meant state, not consumer, preferences and breakneck speed.

Stalin forced the cities and countryside to adopt a socialist face. For the cities, this meant large scale projects that reveled in the state's, and Stalin's, glory. Buried in the projects was supposed to be a collectivist ethos: handsome, spacious buildings that housed the worker, broad thoroughfares that admitted light and moved traffic with ease, well-illuminated and safe factories, and a subway whose ornate stations, replete with marble facades and socialist realist murals, deified the worker.[14] The reality was something else. Peasants streamed into urban centers, becoming workers overnight with only barracks for shelter, and overburdened public transport—broken-down trams—moved them to factories and home again.

The Great Break signaled changes in all areas of Soviet life, most of them for the worse. During collectivization, builders irrigated millions of hectares* of land and built ponds, and then they turned to carving out canals and reservoirs to improve municipal water supply and transport. To the leaders, it mattered little if construction of the "magnificent" Belomor (White Sea–Baltic) Canal[15] and Moscow Canal resulted in the deaths of tens of thousands of slave laborers, or that the former was poorly designed and built and never functioned as intended, for symbolic meaning was more important than physical function.[16] Because of the emphasis on heavy industry, the Communist Party starved the countryside, requisitioning grain from the peasants for the cities. Rather than join the collective farms, the peasants slaughtered half of their farm animals. The highly touted electrification programs failed to reach the countryside, and there was no counterpart to the United States' Rural Electrification Administration. Hydroelectric, wind, thermal, gas generator, and locomotive power all lagged in the countryside, as did provision of even modest goods and services, until the end of Soviet power. Granted, between 1940 and 1948 the power of agricultural electric stations grew by 226 percent, from 275,000 to 622,000 kW. But electricity served only modest local irrigation systems and low-level mechanization, not domestic (home) purposes, and power remained human-, animal-, or peat-generated, the latter usually in units of no more than 20 to 40 kW. The capacity of the few existing rudimentary hydropower stations in the countryside was only about 1,000 to 2,000 kW.[17] Electricity for agriculture, irrigation, and the countryside would be a reality only with the big technology projects of the Nikita Khrushchev era.

A number of engineers came into conflict with the Communist Party over industrialization policies even before Stalin's rise to power. As Loren Graham discusses, they criticized the growing tendency of the state to manifest "gusher psychology"—an emphasis on spectacular short-term achievements at the expense of more economical long-term use of resources. For them, Belomor and Magnitogorsk demonstrated that Soviet planning ignored local geological conditions; emphasized large scale projects at the expense of handicrafts, office materials, tableware, and clothing industries that might have been more efficient, owing to their small scale; and stressed the value

*A hectare is equivalent to 2.47 acres.

of capital while abusing humans and the environment in the process. Political pressures made it impossible for individual engineers to practice the profession with integrity. Inevitably, political judgments predominated. The engineer was responsible for raising production at any cost. The "human" factors in production that might be encouraged by higher pay, good housing, and good nutrition and health care and that might lead to sensible environmental considerations within the limits of scientific uncertainty were ignored.[18] Yet it was precisely gusher psychology and the emphasis on short-term achievements that made the rebuilding of the Volga River basin possible and desirable.

Stalin wanted to order engineers to work as the state saw fit, not as independent thinkers. The Communist Party demonstrated its resolve by charging engineers who failed to cooperate—and many who did cooperate—with "conspiracy" and "wrecking" in a series of show trials. Ultimately, perhaps 30 percent of the 10,000 engineers in the Soviet Union were arrested; few of these survived.[19] In fact, many engineers welcomed the Bolshevik approach to planning and technology, especially because of the state's willingness to fund their projects, many of which had been proposed in the tsarist era but languished for lack of funds. But there was a major difference in their worldview. They were not the generalists of the tsarist period but rapidly trained specialists with foci on narrow aspects of production, such as engines, machine tools, or ball bearings. When individuals trained as narrow specialists replaced the generalists who favored a more circumspect approach to industrialization, conditions were ripe for the focus on "hero" technologies, which carried such high human and environmental costs. They saw only obstacles to increasing production in their areas of expertise, not the entire picture. This was to be expected, for nature transformed served the cities, their proletariat, and especially Moscow, where the majority of high party officials lived.

In 1926 at Volkhovsk on the Volga, at their first large hydroelectric project, the Soviets used Swedish turbogenerators complemented with several Elektrosila Factory 7,000 kW models. Sergei Kirov, secretary of the Leningrad party organization, declared at the festive opening of the station: "Leningrad workers today celebrate a new victory, but to us [the Volkhovsk station] already means very little. . . . We must learn to build so that we can escape the need to buy equipment abroad. Our government is doing all it can so that everything—from the first brick to the complex machines—is manufactured by our own hands in our factories. And we will achieve this." Through economies of scale, engineers forecast decreasing costs of electricity production. They commenced manufacture of 12,000, 25,000, 50,000, and 100,000 kW turbines and generators at the country's own Elektrosila Factory as Russia abandoned its reliance on equipment produced by the General Electric Company, Siemens AG, and other western manufacturers. Already at the Dnepr hydroelectric power station there were four Elektrosila units, each with a capacity of 62,000 kW. In the 1930s, Elektrosila produced more than fifty turbogenerators, some of which were among the world's largest, and ended dependence on the West.[20] By 1976, total installed Elektrosila turbogenerator capacity had surpassed 30,000 megawatts (MW).

Just as in the United States, hydropower in the Soviet Union had its roots in Enlightenment notions of nature and the desirability of man's dominion over it. Since the late eighteenth century, Western scientists had unquestioningly accepted the view that humans ought to study nature in order to control it and improve on it. This view took hold in tsarist Russia no less than in Europe and North America in various irrigation, canal, harbor improvement, forestry, and other projects.[21] With respect to the belief of dominion over nature, there was no revolution when the USSR was formed, for scientists already accepted the view that it was their place to secure human supremacy. Now, however, a state-sponsored modernization ideology vigorously supported their efforts. But in a war-torn country with industry remaining at pre-1914 production levels until after 1926, with the economy lagging far behind that of Europe and the United States, and with an ongoing struggle to deal with revolutionary catharsis of lawlessness, migration, famine, and class war, it was difficult for engineers to gain sufficient resources to build modern waterworks. In the absence of private capital, any project would have to be funded by the state. Nevertheless, GOELRO engineers somehow succeeded in bringing 100,000 kW worth of hydroelectric power stations on-line between 1920 and 1928. This was the prelude to development of Soviet gigantomania under Stalin, the first manifestation of which was the Dnepr hydroelectric power station.

## Learning in the Field at Dneprostroi and Beyond

Enlightenment visions, political backing, economic support, and Marxian ideological certainty came together first in construction of the Dnepr hydroelectric station, best known as DneproGES (the station itself—GES is the Russian acronym for "hydroelectric station") or Dneprostroi (the construction organization and site). Begun in 1928, Dneprostroi had become, at its completion five years later, one of the largest hydroelectric power stations in the world. Its three locks made the Dnepr River navigable from central Ukraine to the Black Sea.

The decision to build the 560,000 kW station diverted resources from such projects as the Volga–Don Canal, which supporters claimed would be less expensive to build and of more immediate benefit to agriculture.[22] But form was more important than content in showcasing socialist technological verve. Dneprostroi became a symbol of what centralized economic planning and political will could accomplish in the face of such daunting obstacles as illiterate and unskilled peasant laborers, outdated and decrepit machinery, and constant attacks on engineers for their perceived bourgeois leanings.

The delay of one project, the Volga–Moscow Canal, was particularly costly for new residents of Moscow. By the 1930s, the city was receiving twice the water it had before the revolution. But demand far outpaced supply as hundreds of thousands of workers and peasants migrated to the cities. Party leaders had learned at Dneprostroi that they could force the pace of construction through coercion, exhortation, and fear. Using similar rhetorical devices and an army of workers equipped with rudimentary tools, they began the 128 kilometer* (km) Volga–Moscow Canal in 1934 and completed it in less than three years. A centerpiece of the project was the 327 square kilometer ($km^2$) Moscow reservoir for municipal water supply. It involved 240 artificial objects—locks, pumping stations, dams, bridges, tunnels, and a 30,000 kW hydropower station. Like the socialist Moscow metro, this was a self-proclaimed hero project. At about the same time, construction began on the Uglich (100,000 kW) and Rybinsk (200,000 kW) hydropower stations on the upper Volga River. The 4,550 $km^2$ Rybinsk reservoir was fourteen times

*A meter is equivalent to 39.37 inches; a kilometer (1,000 meters) is 0.62 mile.

larger than the Moscow reservoir but reached full capacity only in the last days of World War II.

The early canals and dams on the Dnepr and Volga Rivers provided the theoretical and practical foundation for the postwar "Big Volga" project. In the early 1930s, scientists and engineers convened a series of conferences to determine how best to use the country's still vast, untapped natural resources, including the Volga River. At a planning session of the Soviet Academy of Sciences in 1933, scholars delivered more than five dozen papers and project proposals on problems of the Big Volga—from energy resources to shipping, water supply for industrial centers, fishing, and the transformation of the Caspian Sea into a fish farm for valuable sturgeon and other anadromous fish. Projects were also proposed to divert the supply of several northern rivers into the Volga through massive transfer canals. Hydrologists and engineers debated the best way to distribute water among competing interests. Some argued for small hydroelectric power stations with reservoirs that limited inundation of farmland. Others, representing the side that ultimately prevailed, proudly demanded that "cascades" of huge hydropower stations be built, with massive reservoirs to regulate the water for year-round flow. This would inundate good farmland along the Volga but would permit irrigation to compensate with newly developed agricultural land elsewhere.

Stalin's hydroelectric power stations resulted in tremendous human dislocation. Tens of thousands of square kilometers of towns, homes, cemeteries, farmland, and forest were submerged. During the first five-year plan of forced industrialization and collectivization (1928–1932, completed one year early), construction organizations built the Nizhne-Svirsk, Rionsk, and Gizeldon hydropower stations. Including the Dnepr station, by 1933 construction organizations had completed new stations with a total capacity of 345,000 kW. In the second five-year plan (through 1937), another 745,000 kW of capacity was added, and by the eve of World War II, more than 10 percent of the country's electric energy was being generated by hydroelectric facilities.[23] These projects inundated 663 cities, villages, and towns, setting a pattern of irreversible loss of homes and history that was repeated throughout the Soviet era at a greater scale.

Still, Stalin could not get enough electricity, especially after World

War II, for it was needed to rebuild the country after the war and to engage the United States in the cold war. The result was plans for the construction of six more stations on the Volga River, several of them larger in capacity than the combined total of the first thirty-seven stations in Big Volga.

## Stalinist Transformation of Nature: The Big Volga

The Volga River is 3,700 km long and flows through thirteen regions and autonomous republics in central Russia. It flows southward from its source near Tver to its mouth at Astrakhan on the Caspian Sea. Its drainage basin of 1.4 million $km^2$ has 108,500 named creeks, streams, brooks, and rivers, which total 200,000 km in length. The Volga—the Mother, the heartland, the symbol and roots of Russia—with an annual flow of 256 billion $km^3$, is the largest river in Europe; among Soviet rivers, only the Siberian Enisei, Ob, Lena, and Amur Rivers have greater flow. Eighty cities sit along its shores, including (going downstream) Iaroslavl, Nizhnii Novgorod (earlier Gorky), Kazan, Kuibyshev, Saratov, Volgograd (formerly Stalingrad), and Astrakhan. Its molecules of water rank among the most studied, catalogued, pushed, and pulled of any twentieth-century river. Like the Mississippi River in the United States, the Volga became an object of nature improvement after World War I. Many projects had antecedents in tsarist times as Moscow's need for water grew. Russian engineers traveled to the United States at the turn of the century to study the water and sewage systems of, for example, Boston. On the basis of this study, during the civil war that followed the Russian Revolution they built 17 km of water tunnels from the Volga to Moscow to quench the city's thirst.

Unfortunately, most of the Volga's flow occurs in late fall and in spring with snowmelt; only 20 percent of the flow occurs when it is needed most, in the summer growing season. Like engineers on the Columbia River, as we shall see, struggling to produce electricity, facilitate river transport, and make use of spring runoff, Soviet engineers set out to build dams, reservoirs, and other huge structures to regulate the flow more evenly year-round, to keep channels at least eight meters deep for shipping, and to open the way with canals to the Don and other rivers. Through canals, engineers, planners, and policy makers intended to make Big Volga the largest inland waterway in the world, with a basin of 9 million $km^2$, 25 percent larger than the Amazon.[24] Soviet technological propagandists put it this way: "The question is natural: is it possible to capture a huge quantity of water, which is uselessly carried off in the spring into the Caspian sea? Is it possible to redistribute the yearly flow of the Volga, to divert the ruinous spring run-off of the river and turn summer slackening into a so-called intermediate period? 'Quite so!' answered Soviet hydrological engineers."[25]

Most of Ukraine, the Soviet breadbasket, fell to the Nazis during World War II. German armies destroyed bridges, factories, and hydropower stations—much of what the Soviets had built up before the war. The German forces took special glee in dynamiting the Dnepr station. Eager to eradicate evidence of the hated enemy, Stalin and the party decided at the close of the war to transform the nation on a scale never before imagined in any country. The crowning event in the all-out Soviet commitment to this idea was the party's promulgation in October 1948 of the Stalinist Plan for the Transformation of Nature. Having vanquished the German armies, Stalin unleashed a war on nature with tens of thousands of soldiers—that is, workers—tens of thousands of pieces of equipment, and millions of metric tons* of building materials. Having been near defeat at the hand of man, they went to war not on man but on nature, with engineers in the advance group of soldiers. To build a series of locks, canals, and irrigation systems, the Soviets developed one of the largest hydraulic shovels the world has ever seen. They planted "defense belts" of trees 100 km long to protect newly reclaimed farmland from drought and wind. Ignoring European and American achievements, Stalin asserted that only under socialism had the worker mastered the laws of nature to direct them for the good of society—through electrification, irrigation, recreation, reclamation, elimination of erosion, drainage of swamps, and the creation of green zones around cities and industrial centers, along rivers, canals, and reservoirs, and so forth.[26]

Postwar reconstruction was one part construction and two parts ideology, with cold war competition with the United States and Stalin's ego

*Unless otherwise noted (as here), tons are short tons (2,000 pounds), equivalent to 0.91 metric ton. A metric ton equals 1.1 short tons.

FINLAND
Lake Ladoga
Lake Onega
Northern Dvina
Sukhona
URAL MOUNTAINS
ESTONIA
St. Petersburg
LATVIA
Rybinsk Reservoir
Rybinsk
Gorky Reservoir
Perm
Tver
Yaroslavl
Nizhnii Novgorod
Moscow Canal
Oka
Kazan
Kama
Moscow
BELARUS
Kuibyshev Reservoir
Simbirsk
Samara
Volga
Ural
Saratov
Volgograd Reservoir
Don
UKRAINE
KAZAKHSTAN
Volgograd
Volzhskii
Aral Sea
Volga–Don Canal
Rostov-na-Donu
Sea of Azov
Astrakhan
Caspian Sea
UZBEKISTAN
Black Sea
0
500
Miles

the ideological components. Stalin would leave as his legacy thirty hydropower stations on the Volga and Syr Daria Rivers and on rivers of the Ural and Caucasus regions. By 1947, the Dnepr station had been rebuilt and upgraded. Then, in 1950, a new series of government resolutions advanced the Big Volga program in earnest, in part to belittle U.S. efforts in the Columbia and Tennessee River basins. The resolutions called for construction of the massive Kuibyshev, Stalingrad, and Kakhovsk hydropower stations, with hundreds of kilometers of canals (the Main Turkmen, the South Ukraine, the North Crimean, the Volga–Don, and several smaller ones) to be built, and hundreds of thousands of kilometers of irrigation channels to complement them. Construction began in 1951 and was expected to be completed by 1957.[27] The reservoirs—of course, the largest in the world—would provide water for agriculture, industry, and municipalities on demand, not as capricious nature had offered in the past. Within a decade, the hero projects would create twenty new reservoirs with a total surface area of 2.2 million hectares (ha), three times the previous total. For engineer Aleksandr Vinter, who had served well his two masters, electrification and Soviet power, the hero projects of late Stalinism reflected "a scale and tempo of economic and cultural construction hitherto unseen in human history." The rebuilding of nature "had turned the USSR from a backwards, poverty-stricken nation into an unbeatable industrial socialist power."[28]

Upon its completion, Big Volga was a unified transportation, hydroelectric power, and irrigation network. It served as a paradigm for future large scale economic development projects, and it contributed to the particular technological style standard for Soviet construction projects that I call proletarian aesthetics. Prodded by national and local party organizations, engineers turned as rapidly as possible to standard designs that employed mass-produced prefabricated concrete forms, turbogenerators, pumps, conduits, piping, and the like in a reasonable effort to cut construction costs and time. Then divisions of workers armed with massive graders, excavators, bulldozers, and suction dredges were assembled, their every movement scrutinized to ensure they remained in lockstep with Stalinist plans. These workers were joined in construction firms that rapidly grew from five to ten thousand and then from ten to fifty thousand employees—firms such as Kuibyshevgidrostroi, Stalingradgidrostroi, and others that all too often resembled Dneprostroi in terms of labor skills, access to modern equipment, and worker comforts.

The large scale approach to large scale tasks was intended to eliminate the chance of worker error (or slacking) in the field while treating nature as an enemy to be subjugated unconditionally. Learning experience on one project rarely led to significant innovations on the next, for it seemed less expensive and faster to stick with traditional standards for forms, motors, excavation procedures, and labor organization patterns than to seek a new way. Stalin's engineers often preferred proven—and party-approved—methods and technologies over the risk of a failed innovation. The latter might result in a charge of incompetence or even "wrecking." The result was a gray, uniform countryside; a gray, uniform series of dams; and a gray, uniform quality of life for workers and engineers alike.

In completing Big Volga, the construction trusts assembled twelve major hydroelectric power stations on the Volga River that produce approximately 60 billion kilowatt-hours (kWh) annually. Several smaller stations complement them. Each required massive excavation that was increasingly mechanized but labor-intensive by Western standards and seldom accompanied by reclamation. Each inundated thousands of square kilometers of land, displacing perhaps a half million people and destroying homes, churches, and schools, not to mention productive farmland. People whose families had lived for generations near the Volga were moved into unfamiliar, poorly constructed prefabricated homes. They barely had time to remove the icons from their churches before Stalin's icons, the hydropower stations, submerged them. For example, the Rybinsk reservoir, once the largest artificial lake in the world, covers an area of 4,550 $km^2$ and submerged 663 inhabited areas, including six cities. In 1948, construction trusts began work on the upper Volga—the Gorky hydropower station. The workers poured the first concrete for the Gorky station in April 1951. On November 2, 1955, the first turbine there produced electricity. Another 280 towns and villages were inundated. In all, Soviet dams flooded 2,600 villages and 165 cities, almost 78,000 $km^2$—the area of Maryland, Delaware, Massachusetts, and New Jersey combined—including nearly 31,000 $km^2$ of agricultural land and 31,000 $km^2$ of forestland.[29]

Major Hydroelectric Power Stations on the Volga River

| Name of Station | Year Construction Began | Year Full Power Established | Capacity (1,000 kW) | Reservoir Area (km²) |
|---|---|---|---|---|
| Uglich | 1937 | 1947 | 110 | 249 |
| Shcherbakov | —[a] | 1941 | — | — |
| Gorky | 1948 | 1957 | 530 | — |
| Cheboksar (upgraded in 1968 to 1.5 million kW) | 1952 | 1955 | 800 | 2,182 |
| Kuibyshev | 1951 | 1958 | 2,100 | 5,600 |
| Saratov | 1955 | 1970 | 1,290 | — |
| Rybinsk | 1935 | 1941 | 330 | — |
| Volgograd (previously Stalingrad) | 1950 | 1957 | 2,300 | — |
| Volgograd 2 | 1951 | 1962 | 2,540 | — |

*Sources:* P. S. Neporozhnii, ed., *Gidroenergetika i kompleksnoe ispol'zovanie vodnykh resursov SSSR* (Moscow: Energiia, 1970), 312–317; M. M. Davydov and M. Z. Tsunts, *Ot vokhova do amura* (Moscow: Sovetskaia rossiia, 1958), 66, 81–82, 98–99; A. V. Vinter and A. B. Markin, *Elektrifikatsiia nashei strany* (Moscow: Gosenergoizdat, 1956), 84–90; E. Kasimovskii, *Velikie stroiki kommunizma* (Moscow: Gosizdatpolit, 1951), 50–52.

[a]Dashes denote that information is not available.

For each of these major stations, a dam roughly 5 km long was constructed across the river, including 1,000 meters (m) or so of reinforced concrete 70 m high with spillways and locks.[30] Serially produced Elektrosila turbogenerators, often at 105,000 kW and later with units up to 500 MW, were fitted with three-phase 400,000–500,000 volt transmission lines hundreds of kilometers long. The transmission lines inevitably fed Moscow's growing hunger for energy. Ministry of Power and Electrification personnel directed the electric power from their control rooms in Moscow. This highly centralized approach, which benefited Moscow at the expense of the rest of the country, was in fact a source of pride because it made the Moscow energy region "the largest in the world."[31] For the Kuibyshev station, engineers had to build a 400,000 volt "electric highway" stretching 869 km over hills, through forests and swamps, and over thirty bodies of water; this was "not only the longest in our country" but also, when built, "the longest in the world."[32]

From the standpoint of competition between the United States and the Soviet Union, the single most important project in the Big Volga was the Kuibyshev hydroelectric power station. By 1950, Stalin must have recognized his mortality. He had begun to tire more easily and was no longer capable of outlasting all other officials by working into the wee morning hours. He had become irritable. He hatched the "Doctors' Plot," in which physicians, many of them Jewish, who catered to the Kremlin elite were accused of setting out to poison the party leadership. Clearly, another nationwide purge was brewing. But Stalin wanted more. He wanted tangible concrete temples attesting to the glory of his leadership—the hero projects of the century, such as the seven gaudy neoclassical wedding-cake skyscrapers that dot Moscow's horizon. The biggest monument to Stalin's enlightened rule, built in the same architectural style as his skyscrapers, was the 2.1 million kW Kuibyshev station. Kuibyshev would fire a burgeoning petrochemical industry, power a nuclear arms industry, and jump-start the Togliatti (Fiat) automobile factory. Most important, the dam would beat America's Grand Coulee in capacity. This was hydropower envy at work, pure and simple.

Some variant of the Kuibyshev station had been in the minds of tsarist and Soviet engineers—often the same individuals—for decades before the Soviet Council of Ministers approved the project in the summer of 1950. It was the USSR's Grand Coulee Dam in word and deed. In word, socialism, country, Stalin, and nature were of a piece. An editorial in *Bolshevik* on the significance of the "magnificent" construction projects of the Stalin era noted that the dams on the Volga fulfilled Stalin's "sage" plans for creation of the material basis for communist society and the transformation of nature. The massive projects were clear evidence of the firmness and correctness of the Stalinist political line.[33] An editorial in *Pravda* emphasized that the Stalingrad and Kuibyshev stations guaranteed the "unprecedented growth" of the socialist economy, at the same time serving as "an expression of the peaceful labor of the Soviet people who with certainty moved toward communism under the great leadership of Stalin."[34] Spokesmen for the construction trust Stalingradgidrostroi added their two kopeks in praise of concrete and steel as tools of the transformation of steppe and desert into fertile crescents of agriculture.[35]

The Kuibyshev station, the largest in the world at its completion in 1955, was 3.9 km long, of which 1.2 km was poured concrete (a total of 6 million cubic meters [$m^3$], or 7.8 million cubic yards, of concrete) and 2.7 km was earthen dam. Workers excavated more than 150 million $m^3$ of earth. A huge reservoir of 5,600 $km^2$—approximately one and one-quarter the size of the Great Salt Lake—extended upstream to Cheboksary, about 600 km north. The Kuibyshev station generates roughly 11.4 billion kWh annually. If each turbine at DneproGES sipped 200 cubic meters per second ($m^3$/sec.) of water, Kuibyshev gulped 700 $m^3$/sec. The closing of the dam was technically challenging, but engineers were prepared for flows of as much as 12,000 $m^3$/sec. Workers armed with 100,000 $m^3$ of stones and boulders, hundreds of cement pyramids, each weighing ten metric tons, and millions of metric tons of soil—perhaps even the kitchen sink and bedsprings—closed the dam without misstep. It took years to fill the lake with 50 billion $m^3$ of water; to fill it more quickly to prepare to generate power, workers drew water from Rybinsk and Kamsk reservoirs. The first generator produced electricity on December 29, 1955. Over the next twenty-two months, nineteen others came on-line, each at 105,000 kW.

Engineers thus had turbines running within five years of the decision to build the dam. Party officials gleefully pointed out that in the 1930s, the United States had taken ten years to get all the states through which the Colorado River flows to agree on construction of Boulder Dam, and completion of the Grand Coulee Dam took nearly twenty years. Yet there was no resting on laurels and Lenin prizes; ten days after the resolution to build the Kuibyshev station, the Communist Party passed a resolution to build another massive hydropower station on the Volga at Stalingrad (now Volgograd). Soviet communism tolerated no obstacles from nature, petit bourgeois politics, or squeamish engineers.

In 1957, Khrushchev visited Elektrosila, where he complimented the factory for making the production of electric energy possible up and down the Volga: “The country and the party are proud of your work, Comrades!”[36] The following year, Khrushchev, future Soviet leader Leonid Brezhnev, and other party functionaries visited the Kuibyshev hydroelectric project. The facade of the station had been decked out in banners to welcome them and included a huge, multistory portrait of Lenin. The portrait served to tie Khrushchev to Lenin and GOERLO while pushing Stalin into the shadows. The leaders mingled with workers and then awarded Kuibyshevgidrostroi, the construction trust, an Order of Lenin. They attended a ribbon-cutting ceremony for the seventeenth turbine and then boarded a steamship, the *Dobrynia Nikitich,* for a tour of the reservoir, the locks, the spillways, and other concrete icons. By the time of the visit, the station had already generated 15 billion kWh.[37]

Construction at the Volgograd and "Volga" stations (at Zhiguli, a wooded mountain range rising 680 m in the Samara bend of the Volga) began even before the Kuibyshev station opened. After all, the authorities had gathered fifty thousand workers in massive construction trusts who were looking for earth to move and dreaming about pouring concrete. They set their sights on Zhiguli, one of the most scenic places on the Volga, a region important in songs, fairy tales, and legends. But if the Zhiguli Mountains had cultural significance, they were more important for their limestone, phosphates, gypsum, sulfur, and crude oil production. Hence, party officials and engineers decided to build (and inundate) at Zhiguli. The hydropower station led to the birth of a new town, Stavropol, which became a center of the chemical, automobile, and construction industries. In 1964 the town was renamed Togliatti, after the Italian Communist Palmiro Togliatti, and shortly thereafter it became the site of a joint Fiat–Volga Automobile Works venture.

GOELRO engineers had noted the Zhiguli site in their first studies. By the time construction began, some three decades later, expectations had changed from modest energy production to massive Soviet scale. To meet this scale, workers toiled seven years, day and night, in rain and snow. They used ten thousand machines, including gigantic cranes weighing 450 metric tons, excavators, and a flotilla of pumping and dredging devices. The workers excavated 190 million $m^3$ of earth and poured 7.4 million $m^3$ of concrete and reinforced concrete. The resulting earthen dam of Volga sand and soil is 2,800 m long. The concrete edifice contains 38 spillways carrying 55,000 $m^3$/sec. The Zhigulev reservoir was of similar scale, at 6,500 $km^2$ and holding 60 billion $m^3$ of water. To move past the dam, ships and barges entered locks with gates weighing 700 metric tons. The station, which opened officially in August 1958, had a capacity of 2.3 million kW, or the equivalent of 6 Gorky, 7 Rybinsk, 21 Uglich, or 77 Ivankovo stations. One Soviet author said that the Volga station was a symbol of "human reason, a true technical masterpiece, one of the greatest engineering works of our time."[38]

The next hydropower station took the name of the party and therefore was bigger still. The Volgograd 22nd Party Congress station (called the Stalingrad station until Khrushchev removed his predecessor from the Kremlin wall and from dozens of places bearing his name) was the work of Sergei Iakovlevich Zhuk. A hydrologist, Zhuk was deputy chief engineer of the Belomor (White Sea–Baltic) Canal project, which saw the death of thousands of laborers, and head of the Moscow canal, Uglich, and Rybinsk hydropower station projects, followed by work at Kuibyshev. During World War II, Zhuk became director and head engineer of the Zhuk Gidroproekt Institute, part of the Ministry of Electrification. The major hydroelectric engineering institute therefore came from Stalin's notorious labor camps. After the war, his institute and armies of workers assigned to him by Stalin turned to the Kuibyshev and Stalingrad hydropower stations.

The foundation pit for the Volgograd station—now called Volga II—was 50 ha in size and was once described as "an entire industrial city with an armada of different machines." As with other brute force projects, the entire nation was involved in building it. The Leningrad region alone requisitioned the services of seventy enterprises and research institutes. The first turbine produced power on December 23, 1955. Only three years later, the twenty-first turbine came on line. The workers had excavated 144 million $m^3$ of earth and poured 5.5 million $m^3$ of concrete. They planted 65,000 trees and 5,000 bushes to restore some aesthetic beauty to the riverbanks.[39]

Zhuk and his colleagues were hardly finished with dam building, however. Accelerating the competition with the Bureau of Reclamation and the Army Corps of Engineers, they built three more stations on the Volga. With completion of these projects, installed capacity was more than eighty times what it had been in the 1930s. Zhuk belittled the American achievements at Boulder and Grand Coulee, where granite made construction easier and the head of the river—the distance it fell at a given point—enabled high power production. Soviet engineers produced power with a smaller head and still managed to use larger turbines than the Americans. Was it superior knowledge, superior ideology, or both? And if American workers had established a world record in 1939 at Grand Coulee by pouring 15,700 $m^3$ of concrete in one day, then Soviet laborers beat this at the Volga station on August 15, 1955, pouring 16,020 $m^3$ of concrete, and again a few days later, pouring 19,050 $m^3$ of concrete.[40] Ah, the proletarian aesthetics of it all!

So centralized was Soviet engineering and economic planning that one organization could serve as the sole source of expertise—the Zhuk Gidroproekt Institute, for example, or, in the case of turbogenerators, Elektrosila, one of the largest electric motor and component enterprises in the world.[41] Elektrosila could marshal the authority of the party and tens of thousands of workers behind production of the world's largest turbogenerators. Plant managers enthusiastically leaped from the modestly sized generators used at DneproGES to standard 500 and 800 MW units that found homes on Siberian rivers.[42]

To be sure, specialists in other fields criticized the technological enthusiasm of the dam builders. Not only ichthyologists attacked the engineers of nature; forestry specialists also criticized the huge waterworks. They worried openly that the scale and speed of construction of the hero projects on the Volga, the Kama, the Dnepr, and Siberian rivers had destroyed valuable lumber. The reservoirs were largely in steppe and forest-steppe regions where forest had been preserved precisely along the floodplains of rivers. The reservoirs thus sharply reduced the forested areas of those regions. For the Kuibyshev station, 18,500 ha disappeared under water before the trees were felled; under the Tsimliansk, 14,000 ha; in the Saratov region, which was only 5 percent forested, the reservoirs destroyed nearly 70,000 ha of forest-steppe; and in the Stalingrad region, 33,000 ha. Gidroproekt specialists apparently did not understand the need to remove lumber more systematically, prepare the bottom, and cart off the rubble of homes.

Even more, the reservoirs frequently caused significant erosion, created huge ravines, triggered landslides, and precluded use of the land for farming or other purposes. They were so poorly constructed that they often had whitecap waves 2 m tall and higher. As a result, for example, along the Tsimliansk Sea, they were losing millions of cubic meters of soil annually. On the Ob River reservoir, built in the late 1950s, scientists observed waves 2 m tall moving along for 20 to 30 km, destroying the shoreline. A railroad along the shore had to be moved inland. Forest plantings provided a modest defense. The forest industry recommended an extensive program of planting projects of 5,000–10,000 ha along denuded shores of reservoirs to fight erosion and landslides and reclaim the area for agriculture.[43]

Lest there be any doubt that this criticism of the Soviet experience, let alone the Brazilian, Egyptian, Chinese, or American, had dampened the enthusiasm of the diverters, inundators, and regulators, specialists in Russia advanced a proposal for a second Volga–Don Canal in 1987, when glasnost opened the project to public scrutiny, which previous endeavors had avoided. Engineers associated with the new canal argued that another 64 km canal was required to bring 2 $km^3$ of water into the Don annually, with three-fourths of that going for irrigation. Operation of canals, locks, and irrigation systems would require 0.7 billion kWh annually but would irrigate 274,000 ha in the Volgograd and Rostov regions and the Central Black Earth Region. Leading environmentalists opposed the project, pointing out that high cost, inadequate water in the Volga, and migration of organic chemicals from agriculture into the Don made it too risky. Ultimately, the government abandoned Volga–Don II as too expensive only when the Russian economy went into free fall in 1991.[44]

What the Soviet Union lacked in technological sophistication, its engineers and policy makers made up for in unbridled enthusiasm. Without the impediments of public opposition or the legal requirements of environmental impact statements, they quickly moved to change forever the face of the Volga River basin, with serious human, economic, and ecological costs that will be felt for many decades to come. These costs have been well documented. They include the destruction of fisheries through construction projects or extensive pollution. Entire regions of the former Soviet Union are "industrial deserts" formed by hazardous waste that seeps, blows, and flows everywhere, with little effort made to filter it or prevent it. Most of the rivers in Russia have become, in their own way, dead zones, where only the very strong survive.

Rather than examining endless tables to understand the scale of devastation, we can employ historical analysis to consider the great cost to the fishing industry of the dams on the Volga. After the Russian Revolution, social turmoil, poaching, and lack of regulation ruined inland fisheries. They might have recovered, but the growing claims of engineers on the Volga for power and irrigation completed the destruction of the fish industry before World War II. Nikolai Mikhailovich Knipovich, the founder of Russian oceanography and scientific fishery research,[45] was active in fisheries studies for thirty years before he turned his attention to the rich fisheries in the Volga delta, the Caspian Sea, and the Sea of Azov. He noted that the Russian Revolution had nearly destroyed the anadromous fish industry—bream, sazan (a kind of freshwater carp), and sheatfish. At the end of the war, several large fish combines usurped the fishing rights of local residents, fishing where they should not have, even in *zapovedniki* (nature preserves), especially after anarchy erupted in the countryside and famine hit regions of the country. Then, as war and civil war escalated, Reds (Communists and their supporters) and Whites (monarchists and others who opposed the Bolsheviks) alternated fishing and overfishing. Nature preserves were essentially sacked. As troops came and went, confiscating what they could, the fishing industry overfished to stay afloat. Knipovich lamented Russia's poor understanding of the extent of its natural resources and how to use them. Industrial demands on the waters of the Volga, pollution, and rapacious harvest would destroy Volga and Caspian fish resources, he warned: "All kinds of violations of fishing laws were a common matter in the Caspian Sea itself and in the rivers, especially on the most important of them—the Volga." The violations included illegal catch, illegal equipment, and catch at forbidden times and in forbidden places, where spawning takes place—and all this "on a great scale." As limits had evolved in the Soviet period, it was cheaper to pay the fines and keep on fishing. In the 1930s, in connection with the development of huge hydroelectric projects on the Don and Volga Rivers, Knipovich helped study the effects on the Caspian and Azov as a member of special government investigative commissions. Unfortunately, the dam projects went ahead. Together with pollution and overfishing, they essentially destroyed the Volga fishing industry. Pond aquaculture and seeding of fish in reservoirs in postwar decades have done nothing to change the situation.[46]

The state of inland fisheries deteriorated further with promulgation of the Stalinist plan for nature transformation. Seawater levels dropped in connection with all the new dams, river flow slowed, and spawning areas were destroyed. Scientists sought artificial propagation of sturgeon, Caspian inconnu, common carp, and bream. By 1959, sturgeon hatcheries at the Kura and Volga Rivers were in operation and, at peak, produced about 100 million fry annually. This was inadequate to prevent destruction of stocks, for sturgeon fishing was an industrial enterprise that earned the Soviet Union hard currency. Further, sturgeon are a slow-growing fish, reaching maturity after fifteen or twenty years, too long for planners impatient to harvest. The sturgeon is now so rare, with only about 100 fish caught annually, that it seems only a complete ban on fishing in the Caspian Sea can save it. However, economic pressures will make it difficult for the five countries bordering the sea to agree to a ban.

Although the scale and aesthetics of Stalinist nature transformation were unique in the twentieth century, the effort to transform was not. The Columbia River basin in the Pacific Northwest underwent similar radical transformation, with thirteen massive dams added between 1933 and 1973, complemented by huge irrigation systems and fish ladders that fundamentally altered the river's shape and flow. Often, construction moved ahead with explicit reference to Soviet hydropower efforts to demonstrate that the American way of life, its science, technology, and economic system, was better—more efficient and morally superior—than Soviet communism.

## The Best Damn Capitalist Dams

The development of the Columbia River basin paralleled that of the Volga basin in temporal, ideological, and psychological senses. Planning, alteration, and construction began in the 1930s. Engineers and policy makers touted reconstruction of the basin as possible only in America, with the masses to benefit and the nation to become measurably more powerful. The rebuilt modern capitalist river would solve the problems of terrible floods and the economic crisis of the Great Depression. One of the last major floods, in May 1948, destroyed Vanport City, the second largest city in Oregon, and gave impetus to the construction of more dams for flood control even as the finishing touches were being put on the exemplars of New Deal planning and ideology, Bonneville Dam and the Grand Coulee Dam.[47] And brute force technology with unrivaled grandeur was the tool for the river's transformation. In response to plans advanced decades earlier, the Army Corps of Engineers and Bureau of Reclamation turned earnestly to building dams on the Columbia River during the New Deal era. The dams would easily provide enough electricity for the entire Pacific Northwest and enough water to irrigate eastern Washington, Oregon, and Idaho. Like the Volga, the Columbia held significant historical and cultural meaning for local people, in this case Indians, but this fact was not taken seriously by settlers of European descent who were eager to overrun any obstacles to the generation of wealth in the Columbia's great drop and huge volume of flow.

The 1,250 mile long (2,012 m) Columbia has some 150 tributaries, many of them major rivers, that drain semi-arid land, areas of heavy rainfall, and mountains whose snowpack melts into the river in spring. The Snake River, one of the tributaries, is more than 1,000 miles long. The Columbia drops 2,400 feet (731.5 m) along its length, in some places charging through narrow canyons and over magnificent falls—Great Falls (Celilo), Long Narrows (The Dalles), and the Cascades—before spreading to a width of two and a half miles at its mouth. The river's flow fluctuates considerably, with its heaviest coming in late spring and early summer with snowmelt. Before the dams were built, the river rose 50 feet from low to high water at Celilo Falls, a traditional Indian fishing site several hundred miles from the Columbia's mouth but now under waters of The Dalles Dam.

When explorers Meriwether Lewis and William Clark traveled down the Columbia to the coast in the autumn of 1805, they encountered a wild river and many Indians who gave them food and assistance as they tried to negotiate the rapids, with their "swels and boils." Often the rapids tossed members of the expedition into the water, or they hit rocks, the canoes sank, and they lost "many things including shot and powder." There was no problem with provisions, however: deer, elk, sea otters, geese, grouse, ducks, and pheasants "as large as [turkeys]" were everywhere to be seen. But it was the salmon that astounded them the most. "The river is remarkably clear and crowded with salmon in maney places," they wrote. "The number is incredible to say—and at this season [the Indians] only have to collect the fish split them open and dry them on their scaffolds which they have great numbers."[48] The Indians had established hundreds of drying lodges the length of the river, Lewis and Clark discovered. Wherever they went, hundreds of Indians—notably the Cho-pun-nish, or Nez Percé—came to meet with them, to sit at fires all night to talk, smoke, and eat salmon.

The Indians caught salmon with weirs, harpoons, dip nets, and long nets of seine and gill-net type made of wild hemp, flax, or grass, and they trolled for the fish from canoes. They exercised close control over fishing sites in their area, trading fishing privileges and offering reciprocal rights to other groups. Before the white man invaded, the Indian population probably consumed one pound of salmon per person on a daily basis—for a total of perhaps 18 million pounds per year—more than is caught today by commercial and sport fishermen. This level of consumption did not destroy fish stocks, for the Indians did not overfish; perhaps they did not have the numbers to do so, but they certainly did not participate in commercial fisheries that inevitably led to pressure to overfish. Nor did they destroy spawning areas by building dams.[49] The effects on the salmon population of the incoming settlers, dams, and pollution were another matter.

The natural wealth of the Pacific Northwest attracted fortune seekers and settlers and drew them into early contact with the Indians, many of whom perished from smallpox and other epidemics. By the time Lewis and Clark traveled down the river, smallpox and malaria had already killed 90 percent of the Indian population on the lower Columbia. Many whites saw the destruction of the Indians as God's will, for they, unlike the Indians, intended to turn the land into productive gardens. To entrepreneurs such as John Jacob Astor, who established the American Fur Company in 1808, Indian suffering mattered little. Extensive missionary activities to convert or displace the Indians accompanied disease and economic exploitation. The newcomers' agricultural settlements—both crop- and cattle-based—spread rapidly through inland valleys after a brief gold rush in the 1850s. Soon, fences and cultivation moved along the Yakima, Walla Walla, and Grand Ronde River valleys. By 1870, settlers and developers had reached the upper Columbia in western Washington, where experimental wheat and barley fields on the high prairies attracted farmers. The harvest of Douglas fir, yellow pine, and cedar facilitated the clearing of fields. The economic and cultural marginalization of the Indians was all but complete, and it remained only to introduce brute force technologies to transform the Columbia into what Richard White has called an "organic machine."[50]

As in Russia and other places, the railroad in the Pacific Northwest was a crucial ingredient in the pace of settlement. Rails came to the river floodplains in the 1860s and 1870s, and later tracks were laid over the mountains. Railroad owners first conceived of a Pacific Northwest route to join the two coasts. They secured financial backing in the 1880s and set about to build a roadbed, using dynamite to obliterate rock bluffs and tunneling through others. The first railroaders pushed ahead too quickly, building curves too sharp and roadbeds too weak, and much of the construction had to be rebuilt in later decades. The railroads were crucial for portage around the rapids at the Cascades and The Dalles and were important in their own right as an alternative to river transport. Reconstruction of the river itself through brute force technology, with dams and locks and canals, would complete a revolution in transportation.

By the turn of the century, commerce with paper and wood mills stimulated further improvements in railroads and in the river channels and contributed to the creation of a steam shipbuilding industry in the years leading to the Great War. Congressional delegations and businessmen from the region were persistent and successful lobbyists in getting federal funds. They secured funds for a highway at an extravagant (for that time) $48,000 per mile, but the new highway enabled a new industry, tourism, to feed the prosperity of the region. Fifteen thousand automobiles used the highway the first day it opened. Today, the ecology of the region has changed so much that tourists visiting the dams outnumber the fish they come to see swimming upstream to spawn.[51]

The farming, logging, mining, and other activities had a negative effect on the fisheries long before the great dams were erected. As the leading ethnographer of salmon, Anthony Netboy, describes it, these activities changed habitat for fish overnight. Clearing and plowing led to erosion and increased silt loads in rivers and streams. Irrigation in arid areas reduced flows of some streams below levels necessary to support fish. Grazing reduced ground cover. Lumbering activities destroyed land, and frequent and devastating forest fires added to the silt in streams. Sawmills, plywood mills, and pulp and paper mills dumped their waste into streams. Logjams stopped fish migrations. Dredging removed "vital transition zones" for the fish. Road and railroad construction both contributed to erosion and caused the loss of spawning areas as sand and gravel operators removed vast quantities from the rivers.[52]

For businessmen, adventurers, and many settlers, the transformation of the Pacific Northwest into a utopia of economic growth and American democratic ideals was an unavoidable process tied to technological advance. Progressive changes in transportation, from canoe to bateau, flatboat, sailing vessel, and steamboat and thence to railroad and automobile, left no doubt about the promise of the region's future productive capacity. The construction of canals and locks, the removal of rock and reefs, the deepening and straightening of channels, and the engineering of rapids would make the Columbia a major thoroughfare of local, national, and international commerce. Those who were eager to transform the river into a tool amenable to human activities justified their actions as part of the human compunction to improve on nature and engage in economic activities. They insisted that worries about destruction of nature through canals, locks, railroads, and highways were unfounded. In 1917, William Lyman, a biographer of the Columbia River, acknowledged that there might be "an inrush of population with its common place conveniences and contrivances, but it is only just that the world enjoy these scenes, and we have faith that not even civilization can spoil them," for this was a land "abounding in resources and filled to the brim with hope and enthusiasm."[53]

As in Soviet Russia, advocates of progress became convinced that electricity, more than the railroad, was the key to further economic development of the region. Engineers opined that the electric potential of the Columbia River was nearly limitless, and by the 1920s they had proposed nearly 100 sites for dams. Almost no bend in the Columbia River or its tributaries lacked that potential. One such engineer, Carl Edward Magnusson, proposed in 1925 building massive reservoirs "in order that the stream flow may be made more nearly uniform than the monthly precipitation." He called for study throughout the basin to ensure a scientific foundation for site selection. A patriot of his state, Magnusson anticipated the day when Washington would assume its rightful place as the country's leading producer of hydroelectricity.

Unlike his Soviet colleagues who ignored transmission lines in their capital cost calculations to keep estimates down, Magnusson acknowledged them as a crucial cost,[54] but this did not dampen his enthusiasm.

Washington engineers, like their Soviet counterparts, spoke about the huge dams in unbounded metaphor. In the new "power age," they wrote, electric energy "serves most of our needs. . . . It brings the radiance of sunshine to our hours of darkness; it gives motion to our machines, waters our deserts, fertilizes our fields and transforms our crops." It would create a new economy that tamed natural resources "on the basis of almost unlimited supply of electrical energy." Products drawn from the earth's core, such as aluminum and cadmium; the farms; space heating; regulated river flow; and a host of other things meant "a new civilization of mankind" based on electricity.[55]

The Columbia, like the Siberian rivers, the Amazon, and the Volga, was indeed a river of superlatives. Its flow was twice that of the Missouri River and ten times that of the Colorado—at least before water interests turned the latter into a trickle by siphoning off much of its flow for agriculture, desert lawns, and industry in Arizona and California. American hydrologists calculated that one-fifth of the world's hydroelectric potential was to be found in North America and one-third of that in the Columbia basin. Before 1933, there was not a single dam on the main stem of the Columbia River, but in the ensuing forty years, thirteen of the world's largest concrete structures would be put up in its path. By 1957, Bonneville, Shasta, McNary, Chief Joseph, Grand Coulee, and The Dalles Dams were on-line. The Pacific Northwest had 28 percent of the country's total hydroelectric capacity, with 115 plants in the Columbia River basin at a capacity of 6 million kW, or 82 percent of the Pacific Northwest total.

The federal government was the only institution in the United States capable of running the gauntlet of landownership, regulation, and capital investment challenges to build massive dams. Progressive Era thinking about the need for national stewardship of forest and water resources provided the context, although progress itself on hydroelectricity was slow. The first federal installation was the Theodore Roosevelt Dam and power plant on the Salt River in Arizona, begun in 1906; in 1920 the total federal capacity nationwide was still only 54,000 kW. By 1930, that had grown to 1.8 million kW, and by 1940, to 6.5 million kW; in the 1950s, 5.5 million kW was added, with another 5.5 million kW under construction. Hydroelectricity, as in the USSR, was therefore large scale state technology.[56] Interestingly, growth rates in hydroelectric capacity in the United States and the USSR mirrored that in the rest of the world. Total world capacity doubled between 1920 and 1930, growing from 18 million kW to 36 million kW, and it had increased by another 50 percent by the eve of World War II.[57]

To build these dams, federal authorities required more than potential and more than the justification of flood control. The crisis of the Great Depression supplied the final push. New Deal enthusiasm, "emergency" economic action through the Public Works Administration and the National Industrial Recovery Act, feasibility studies by the Army

Total Hydroelectric Capacity and Generation in the United States by River Basin, 1957

| Drainage Area | Capacity ($10^6$ kW) | Average Annual Generation (1,000 kWh) |
|---|---|---|
| Total United States | 26.5 | 132.5 million |
| Ohio River basin (includes the Tennessee River) | 4.2 | 18.8 million |
| Pacific Northwest (includes the Columbia River basin) | 7.4 | 47.6 million |
| Columbia River basin (includes the following) | 6.1 | 41.9 million |
| Columbia River (main stem) | 4 million | 30.8 million |
| Lewis River | 199,000 | 720,000 |
| Willamette River | 393,604 | 1.5 million |
| Sandy River | 21,000 | 93,000 |
| John Day River | 1,100 | 3,600 |
| Snake River | 434,105 | 2.8 million |
| Yakima River | 23,130 | 103,600 |
| Chelan River | 48,000 | 400,000 |
| Spokane River | 147,260 | 1.05 million |
| Clark Fork River | 805,038 | 4.03 million |

*Source:* Federal Power Commission, *Hydroelectric Power Resources of the United States* (Washington, D.C.: Federal Power Commission, 1957), 1–17.

Corps of Engineers, recognition that grandiose projects had cultural significance in addition to whatever practical value they had, and an ideological contest with the USSR were now all in place. Marc Reisner wrote: "In a slip of time, the mantle of achievement passed from private enterprise to public works. The dams announced that America could still do remarkable things; they also said that the country would never be the same."[58]

In the American East, the Tennessee Valley Authority (TVA), a government-owned utility, was instrumental in advancing public works efforts to improve on nature. One of the most ambitious projects of the New Deal in its overall conception, and one of President Franklin Delano Roosevelt's favorites, TVA built a series of dams to promote flood control, conservation, and agriculture and to bring electricity to thousands of people—especially poor people of Appalachia—at an affordable price. Roosevelt supported federal entry into the utility business, reversing the veto of his predecessor, Herbert Hoover, who opposed efforts to create public utilities such as the Tennessee Valley Authority. On February 2, 1933, the newly elected president announced the formation of the Tennessee Valley Authority to create 200,000 jobs, overriding concerns about "socialism" in the Tennessee River basin. TVA also aided the national defense by establishing government facilities to manufacture nitrate and phosphorus at Muscle Shoals and, later, by providing power for uranium separation plants at Oak Ridge. According to its charter, TVA had the mandate to improve "the economic and social well-being of the people living in said river basin."

Fears of socialism, of state ownership of the means of production, and of Soviet-style communism had delayed the passage of bills and allocation of funds for projects in the Tennessee and Columbia River basins in the 1930s. Many objections were based on free-market, anti–New Deal concerns that downplayed the federal government's potentially positive role in stimulating regional economic development, in distributing income and services more fairly, and in taking on costly or risky ventures the private sector could not or would not. Free-market critics of TVA and the Bonneville Power Administration (BPA) claimed that these projects prevented greater or equal amounts of goods and services from being produced in the private sector by siphoning taxpayers' money—hundreds of millions of dollars—away from factories and jobs, denying Americans “more work and more happiness.” They attacked the inherent centralization of the projects for abrogating common law and states’ rights.[59] But supporters easily pointed to the contributions of federal hydroelectric projects to navigation, fertilizer, electricity, and flood control purposes, to job creation, to pest control, and to wildlife and fish culture, as well as the recreational, scientific, and training functions of the dams. In fact, as it turned out, the similarities between the Grand Coulee Dam and the Kuibyshev dam were greater than either subsequent defenders or detractors of New Deal public works projects cared to admit. Both promised salvation for agriculture based on rational planning and scientific study; both supported burgeoning war industries; both inundated areas of historical and cultural importance; and both had significant deleterious environmental effects on ecosystems, habitat, flora, fauna, and people.

## Kuibyshev Meets Grand Coulee

Modern hydropower stations were not only symbols of America’s might. They were above all else the culmination of the vision of engineers and businesspeople to transform nature into an orderly, well-oiled machine. The Army Corps of Engineers reported to Congress as early as 1927 that twenty-one dams might be built on the Columbia River for flood control, electricity, navigation, and, especially, irrigation. Projects to build dams in any number gained impetus from the convergence of meteorological, economic, and political factors. A huge dust storm in April 1931 at Big Bend, Washington, not far from the farming community of Richland, provided the Corps the opportunity to report to the Bureau of Reclamation and the Federal Power Commission that a dam powering a regional irrigation effort would prevent any future dust storm. Many local agricultural, energy, forestry, and other interests opposed the dam, however, fearing higher taxes, loss of land, and little market for the excess electricity produced. The severity of the Great Depression largely derailed opposition, enabling President Roosevelt to gain congressional approval to establish the BPA in order to tame the Columbia. In December 1935, workers poured the first concrete for the Grand Coulee Dam, the flagship of the project, eighty miles west of Spokane, Washington.[60]

When he visited the Grand Coulee construction site two years later, on October 2, 1937, President Roosevelt emphasized that it was jobs and farming as much as electricity and flood control that lay behind the provision of federal money for the project: "There are thousands of families in this country who are not making good because they are trying to farm on poor land, and I look forward to the day when the valley is dammed up to give the first opportunity to these American families who need some good farm land in place of their present farms. They are a splendid class of people, and it is up to us as a Nation to help them to live better than they are living now. So, in a very correct sense, it is a national undertaking and doing a national good."[61]

The Grand Coulee Dam was the Kuibyshev dam, the Tsimliansk reservoir, and the lower Volga irrigation project wrapped into one. According to reclamation engineers, it would irrigate a vast tract of rich desert and dry-farming land in central Washington by spreading water from the reservoir through a series of canals and irrigation channels that covered an area sixty miles east to west and eighty-five miles north to south, bringing "life-giving waters" to more than 1.2 million acres, or 485,600 ha. Mean annual precipitation in the region was roughly eight inches, or about twenty centimeters, with less than half of that falling in the growing season. Soil and climate were suited to temperate zone crops; the Grand Coulee would provide the water. When the Bureau commenced the Grand Coulee irrigation projects, there were hundreds of abandoned farm buildings scattered over the area, "mute reminders of farm families that settled on the land years ago, when a succession of wet years made the area appear to be adapted to dry farming." Settlers, the Bureau assured them, "will benefit from the most comprehensive planning investigations ever undertaken for an irrigation project." The Bureau, the Corps, the U.S. Department of Agriculture, University of Washington agricultural experiment stations, and the state highway and conservation departments all participated in planning studies. The studies determined how many acres a competent farmer needed to earn a suitable living for an average family, what type of farm economy he should embrace, how to develop the land and maintain its productivity, how to transport and market his produce, how much water to use, what kind of financial assistance was available, and so on.[62] The studies provided assurances that American vision and American technology would enable irrigation farming and at the same time support the small family farmer.

In the eastern part and some of the northern parts of the Columbia basin project, livestock fed on alfalfa and other forage crops seemed promising for land use, with perhaps 20 percent of land to be used for cereals and 5 percent for other crops. In regions with lighter soils, 50 percent would be for forage crops, 25 percent for cereals, and 25 percent for fruits, nuts, beets, and potatoes. The studies, the Bureau warned, could not do away with risk, hardship, or long hours of work: the land must be leveled and cleared, and buildings, fences, and irrigation ditches would have to be constructed. But Americans do work hard. The Bureau expected that 50,000 acres would be developed annually in the first few years after the land was opened to irrigation in the late 1930s, and by 1965 or 1970 all the land, millions of acres of it, would be irrigated.[63] The government sought to promote individual small farmers, not corporate farming or speculation. Congress stipulated a maximum number of family-size farm units at noninflated prices and limited the amount of water to which one owner was entitled to that needed for a family-size tract. In the end, by the 1960s, agribusinesses dominated anyway,[64] for over time, laws changed and corporations learned how to manipulate them, and the corporations had the wherewithal to acquire the farms as they came up for sale.

Among its various benefits, the Grand Coulee created the perfect French fry potato. Beginning in the 1950s, low-cost publicly subsidized irrigation water and energy provided by the Bureau of Reclamation (some of the lowest kilowatt-hour rates in the country) enabled rich, arid soil to turn out the highest potato yields in the world. The region's soil and climate are perfect for growing the Burbank russet and similar potato varieties. But this productivity is achieved at no small cost. A few major potato processors located on Washington, Oregon, and Idaho lands irrigated largely with Columbia River water account for 80 percent of frozen potato products in the United States; they use millions of gallons of water a day; and their profligate use of pesticides and fertilizers has contributed to dangerously high nitrate levels in alluvial aquifers.[65] Approximately 8 million acres are under irrigation for all agricultural purposes in the Pacific Northwest (including 1.6 million acres in Washington, 1.9 million in Oregon, and 3.6 million in Idaho). Some 35 million acre-feet of surface water are pumped out for agriculture, and less than 2 percent of total water consumption is for nonagricultural uses. Most farms in the region are large: in Washington, a potato farm averages 227 acres. Fertilizers account for more than 50 percent of potato production costs. Much of the potato itself is wasted; the large processors seeking to produce plain stick French fries throw away, or use as fertilizer or cattle feed, as much as 40 percent of the potato.[66]

Before the farms began production, before the irrigation canals filled with water, the engineers, workers, and government officials gathered to build the Grand Coulee Dam. Grand Coulee technology was simple, if massive.[67] As with other brute force projects, Grand Coulee encompassed not one single technology but scores of them, from the dam itself to turbogenerators, pumps, pipes, canals, electric substations, power lines, and so on. It consisted of construction firms, engineering organizations, universities, and government bureaucracies. By the summer of 1937, as the base of the dam neared completion, more than 7,000 people were at work at Grand Coulee, from engineers to the construction workers themselves. To reach this stage, they had to construct a thirty-mile railroad from the Northern Pacific Railway line at Odair and a thirty-mile power transmission line from the Washington Water Power Company lines near Coulee City, relocate and hard-surface highways, erect a 950 foot steel highway bridge, hang telephone and telegraph systems, and raise two towns for the workers.

At the site itself, the builders poured nearly 12 million cubic yards (yd.$^3$) of concrete, or about 48,000 boxcar loads. The cement was produced at five modern cement plants with electric controls for blending the mix, shipped in bulk in boxcars, unloaded through hoses and pipelines by pumps, and stored in eleven steel silos with a capacity of 55,000 barrels. During construction of the base of the dam, the cement pipeline crossed the river on a suspension bridge, which also carried a conveyor belt supplying sand and gravel to a mixing plant. The engineers transferred the concrete to four-yard bottom-dumping buckets. Diesel-electric locomotives weighing ten tons hauled the buckets to huge cranes with a reach of 115 feet.[68]

The Grand Coulee Dam was also a series of settlements. On the eastern side of the river, the contractors built Mason City, a temporary city with a large mess hall, office buildings, a hospital, a hotel, a laundry, churches and schools, 280 residences, and sixty bunkhouses to accommodate more than 1,200 workers. The government village, known locally as Engineers' Town, separated the workers from their masters, the engineers and managers. The engineers, government employees, and senior contractors were blessed with indoor plumbing and shade trees. They lived in mass-produced but very pleasant houses designated by letter grades that indicated their—and their inhabitants'—stature. "Dry laws" kept the engineers sober. The "working stiffs" lived in Grand Coulee, a town that had all the features of Hollywood's Wild West: gambling, prostitution, murder, and syphilis. The workers lived in boarding houses, tents, cars, caves, and the boxes in which supplies for the project—including pianos for the managers and engineers—were shipped.[69] The government paid Woody Guthrie $3,200 to write and perform serenades to the dam. For thirty days, he and his government chauffeur drove up and down the river between Grand Coulee and Bonneville while he wrote lyrics for twenty-six songs, none of them referring to syphilis.

On its completion in 1942, the Grand Coulee Dam, at a height of 550 feet and a length of 4,173 feet, was, the Bureau of Reclamation proclaimed, "the largest man-made structure in the world." Power plant capacity was 1,890,000 kW, with Westinghouse generators rated at 117,000 kW. Maximum annual output was 8.3 billion kWh, with another 2.3 billion kWh for irrigation. Until the Kuibyshev dam was built, it had the highest electric energy capacity in the world. At each side of the 1,650 foot centrally located spillway section was a powerhouse and abutment section, each more than 1,000 feet long. The Grand Coulee Dam is a straight-gravity type dam, depending entirely on the weight of the structure to resist the pressure of water behind it. It transforms water into electricity through sixty 8.5 foot gate-controlled outlet tunnels with a combined length of 2.5 miles, carrying 253,000 cubic feet ($ft.^3$) per second. The average annual rate of flow of the Columbia River would fill the reservoir in about two months, but the flow in June or July would fill it in less than one month. Silt from the Columbia is extremely fine, and practically all of it is carried in permanent suspension, so engineers expected the silt to have no detrimental effect on the reservoir, and they have been correct in this estimation. The dam's base is 500 feet wide, covering thirty acres, and 30 feet wide at the crest, covered with a highway. Jackhammers and dynamite moved a million yards of rock to make a firm, clean footing for the dam. In all, workers excavated 19 million yd.$^3$ of earth for the dam and 25 yd.$^3$ of sand and gravel for the concrete.

The Grand Coulee's reservoir is fifty-one miles long and averages 4,000 feet in width, with a maximum depth of 375 feet, and extends up the Columbia River toward the Canadian border. It has a total area of 128 square miles and a capacity of 10 million acre-feet of water. The dam eliminated 1,100 linear miles of salmon spawning grounds, mostly in British Columbia, by flooding and stilling the waters.[70] No one questioned whether land was more valuable than salmon, for there were too many superlatives associated with the dam.

In addition to Grand Coulee and the eleven other major Columbia River structures, there are scores of other dams in the Columbia River basin. They do provide cheap electricity year-round, turn desert into farmland, regulate floods, and create jobs in the aluminum, logging, and nuclear industries. The calculations the government made about the river itself—about its volume flow, turbidity, silt, and temperature, on the basis of which they built the dam—were quite close to the mark.

But the river, any river, is more than water molecules. In altering the river on such a scale, the engineers altered human culture and history and flora and fauna, underestimating or ignoring their value, for history and culture cannot be quantified. They did not calculate the cost of destruction of local history, geophysical monuments, and fish. Dams displaced thousands of people along the Columbia. Eleven towns large enough to have post offices disappeared under reservoir water. The dams destroyed the Indians' burial grounds and their chinook salmon runs at Kettle Falls, which had been protected by treaty. Kettle Falls and its rapids also vanished so that no water would be "wasted." There were no more obstacles to navigation or farming, nor to progress and democracy. Salmon have no right to vote, and the question is whether new home appliances, plutonium, and potatoes are worth destruction of river ecology.

## Nuclear Salmon

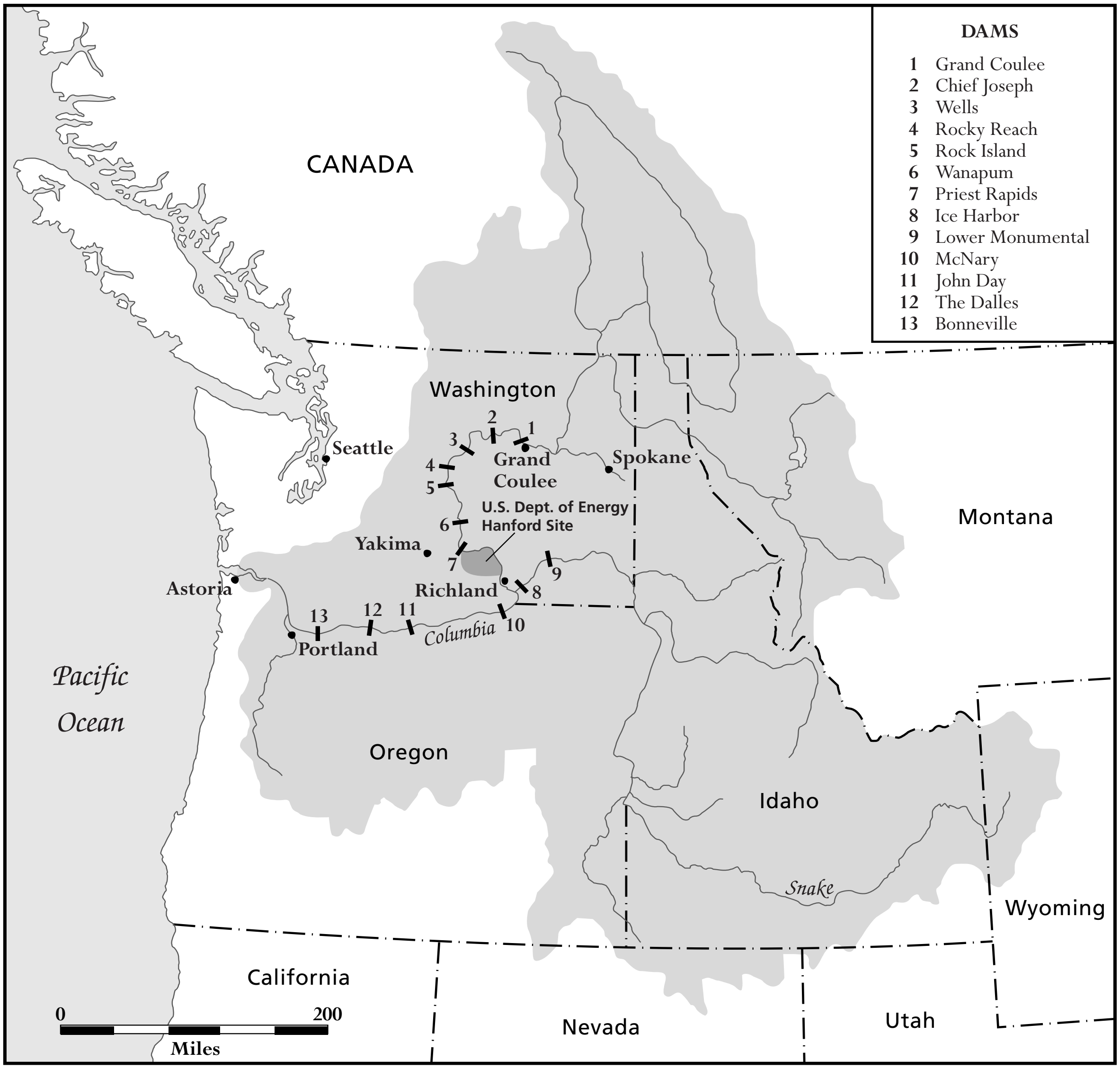
On the eve of the New Deal dam construction projects, several observers noted the human influence on the coveted salmon population. Once there had been "hordes" of chinook (king), sockeye (red), silver (coho), dog, and humpback (pink) salmon fighting their way upriver past natural and human-made obstacles. The Indians had speared and netted them. Later, sportsmen shot them with rifles and pistols, beat them with clubs, hooked them with gaffs, even dynamited them, and trapped them for canneries. People learned the species' spawning and life cycles in order to maximize, but in no way to moderate, their rapacious harvest. When settlers first reached the upper Columbia River, they observed that royal chinook salmon ascended as far as Windermere Lake in British Columbia. By the 1920s, they were rarely seen above Kettle Falls, 100 miles downstream.

Even before the building of the great dams, technological change had given the fish little chance: steam engines had replaced oars and sails in fleets, mechanized seiners had supplemented gillnetters, internal combustion engines had replaced steam engines, and mechanized canneries had replaced manual ones. First, more efficient harvesting technology took a toll. The fisheries took salmon when they were still "fresh and unmarred," at the start of the upstream migration, before they had weakened or had been bruised and discolored, but also before they had spawned. The first businesses used fish wheels, erected on shores or on movable scows, with wire mesh arms that revolved with the current, intercepting the fish and scooping them onto platforms. A single large fish wheel might harvest eight tons in one day. These so decimated the fish population that they were outlawed in the 1930s. Fish traps and gill nets, which were pulled ashore by horses, augmented the wheels. By midcentury, a huge canning, packing, and shipping industry had developed. In 1873, there were eight canneries on the Columbia. By 1883, there were fifty-five canneries at Astoria, some as far upstream as The Dalles, that packed 630,000 cases, roughly 43 million pounds, mostly of chinook. The "mechanical chink," a racist reference to a new canning device that replaced Asian laborers to fill, seal, and label cans automatically, put additional pressure on the fisheries.[71] Gasoline boats that used drift gill nets and seines took to trolling in the open sea with hook and line techniques. Commercial fishing was without limit, and by World War I, many runs were "showing signs of exhaustion."[72] Only twenty-one canneries remained on the Columbia, mostly in Astoria, in 1921. To prevent complete annihilation of the fish stock, the states began to regulate the fisheries in various ways: postponing the time of the catch, controlling the methods and equipment, and limiting the amount. But the agencies responsible for regulation rarely had the personnel or budgets to enforce laws, and they had to watch the catch decline as the fish did.[73]

In the concrete visions of the Army Corps of Engineers, the salmon had little importance. The original design of the Grand Coulee Dam in fact had no provisions for anadromous fish (those that migrate upstream to spawn). Only after public consternation on the part of ichthyologists and local fishing interests were fish ladders, locks, elevators, and bypass canals included in the final plan for the dam. At first, the salmon largely figured out how to move past the coffer dams to spawning areas, with 1 million salmon and steelhead passing upstream in 1938. Once construction of the big dams was completed, fewer and fewer fish made it upstream. By 1942, the number of salmon making it past Grand Coulee had dwindled to 625,000. Clearly, there was sizable mortality of fingerlings going downstream and adults going upstream. But the numbers were good enough for the engineers who asked, If the ladders work this well, why not build more dams? By 1947, dams and associated construction had destroyed about 40 percent of the original spawning areas of the Columbia River watershed.

In the 1950s and 1960s, the Washington and Oregon congressional delegations succeeded in securing funds to build several more dams, which ensured the demise of the salmon. The power, industrial, and river navigation interests, along with local chambers of commerce, lobbied with their delegations for more dams. General Claude H. Chorpening, chief of the Army Corps of Engineers, testified before Congress that, judging by the success of Bonneville Dam, there would be no difficulty in getting fish beyond other dams the Corps intended to build, even though there were losses of at least 15 percent at Bonneville. But how could salmon climb 88 feet at The Dalles, 132 feet at John Day, 100 feet at McNary (finished in 1953), 100 feet at Ice Harbor (1961), 93 feet at Lower Monumental (1969), 100 feet at Little Goose, and 82 feet at Lower Granite (1973)?[74]

Fishways had been around for nearly 300 years when scientists set to moving the salmon beyond Bonneville, and the scientists hesitated to admit that they poorly understood how to build them. A fish ladder, the most common type of fishway, is merely a series of concrete steps over



DAMS
1 Grand Coulee
2 Chief Joseph
3 Wells
4 Rocky Reach
5 Rock Island
6 Wanapum
7 Priest Rapids
8 Ice Harbor
9 Lower Monumental
10 McNary
11 John Day
12 The Dalles
13 Bonneville
CANADA
Washington
Seattle
Grand Coulee
Spokane
U.S. Dept. of Energy Hanford Site
Yakima
Richland
Astoria
Portland
Columbia
Montana
Pacific Ocean
Oregon
Idaho
Snake
Wyoming
California
Nevada
Utah
0
200
Miles

which dam water flows. Elevators and locks have also been used. But construction in and around river basins occurred so rapidly during eighteenth- and nineteenth-century settlement and industrialization that fishways were often an afterthought—in many cases after industrial development had already interfered with or destroyed large populations of migrating fish. Specialists remained convinced that fishways based on scientific research and management would help preserve and even increase species that had survived, especially since creation of the legal framework to ensure obstruction-free passage or to require fishways for migrating fish had become standard in many countries by the mid-twentieth century. Shockingly, by 1940 there appears to have been only one study that considered the actual performance of fish in relation to a number of different fishways, and this study was limited to fish that were native to streams of Iowa.[75]

Engineers designed dams with fishways, but a Canadian fisheries specialist acknowledged that their approach to developing them was "haphazard" and that "progress was slow." On Bonneville Dam in 1937–1938, he noted that "perhaps for the first time, sufficiently large numbers of salmon were involved to warrant large expenditures on designs incorporating the latest ideas of experienced engineers and fisheries biologists." The design employed such new principles as large quantities of pouring water ("attraction water") to attract the fish to upstream entrances away from spillways and powerhouse effluent. Bonneville Dam also incorporated fish locks. The U.S. Fish and Wildlife Service reported that the effort was not entirely successful, with only one-sixth of the annual run making it past the dam in 1948.[76]

Experience at Bonneville Dam led to increasing awareness of the complex nature of fish passage problems and eventually to basic research on the problem of downstream passage over dams as well as the efficiency of facilities for moving fish upstream. Only then did scientists ask certain basic questions: What are the hydraulics of fishways? What are the mechanics of swimming fish? How must spillways be designed and their flow regulated to encourage fish to enter fishways? What influence do eddies, boils, and upwellings have on migration? They recognized that careful study was not enough. Provision of fishways did not "insure the continued existence at their original level of abundance of the migratory fish for which the facilities were designed." This was because dams changed the physical characteristics of the river: water temperatures, normal patterns of seasonal flow, settling of silt above the dam, levels of oxygen and nitrogen. So a fishway is only a partial solution to one of many problems created by dam technology. No matter the effort, design flaws seemed to be the rule, for, the specialist concluded, "actual counts in the Bonneville fishways failed to reach the totals assumed."[77]

Belatedly, it became clear that fish passage facilities did not ensure the livelihood of the fish. With changes they caused in water temperature, oxygen and nitrogen loads, and seasonal flow patterns, the dams effectively prevented natural behavior, and humans were incapable of overcoming human-made problems. In the 1960s and especially in the 1970s, after passage of the National Environmental Policy Act of 1969, those same fans of dams, now pushed and harassed by environmentalists, fish scientists, and various Indian nations, asked for funds for fishery development, including artificial propagation; removal of stream obstructions such as logjams, waterfalls, and small, abandoned dams; construction of fishways; and establishment of fish refuges. The fish ladders at these facilities cost approximately $0.5 billion, but this did not prevent an estimated $6.5 billion loss of fish between 1960 and 1980. To keep the fish from passing through turbines downstream, dam operators have covered the intakes with plastic screen to shunt the fish to a juvenile collection, a holding and transportation facility, and a system of pipes, tanks, and vats to enable anadromous behavior, leading to expensive and surreal carting by truck, barge, or airplane. Of the fish that manage to pass through turbines, few survive. For example, those that get beyond Ice Harbor Dam on the Snake River, ten miles before its confluence with the Columbia River, are so disoriented or exhausted that they are easy prey for birds and other fish. Moving through water that is placid and warmer than normal by as much as 4 degrees Fahrenheit (2.2 degrees Celsius), salmon prematurely begin their transformation to saltwater physiology or, once again, fall prey to predators. The water also carries more nitrogen and less oxygen. Gone is the Columbia, gone are the rapids, gone are the netsmen and the Indians; gone, essentially, are the salmon.[78]

The effect of expanded hatchery facilities that raise and then release upstream from the dams millions of fingerlings and smolts has been minimal. Scientists at the Idaho National Engineering and Environmental Laboratory, those same folks who developed reactors for electric energy production and nuclear airplanes, apparently wanted to contribute more than nuclear technology to society. They came up with the idea for a flexible 350 mile Kevlar fish tube eight feet in diameter, with a estimated cost of $1.4 billion, to bypass the dams entirely. But this project, abandoned as too costly, would have been a losing battle. Because of changes in water chemistry, speed, and other characteristics, Idaho rivers will not support salmon in spite of "enormous hatchery releases." For example, in 1983, 3 million smolts were introduced, but only 2,000 adults returned to spawn. To figure out what is going on in such a situation, fish managers inject the smolts with a passive integrated transponder, a computer chip the size of a rice grain that lodges in the salmon's belly and enables high-tech tracking, sorting, and study. The Army Corps of Engineers produces millions of salmon annually in its hatcheries. Today's salmon travel in style, but transponder or not, the number of fish getting upstream declines almost every year.[79]

Another plight of the salmon is in fact connected with nuclear scientists working at another brute force technology along the Columbia River, the Hanford Atomic Reservation. Cheap, plentiful hydroelectricity, as in the Amazon and Siberia, copious amounts of water, and the seclusion of the desert made the region of the Columbia River near Richland, Washington, appropriate for Hanford. Just as with the dams themselves, the nuclear enterprise developed on the foundation of scientific uncertainty even as the engineers assured the public that their activities were safe, effective, and predictable.

In December 1942, Lieutenant Colonel Franklin Matthias scouted eastern Washington for an area suitable for construction of plutonium production reactors. His requirements were secrecy, space, and water. His superior, the head of the atomic bomb's Manhattan Project, General Leslie R. Groves, had first considered the Argonne Forest, just outside Chicago, and Oak Ridge, Tennessee, as locations. Since physicists were not yet clear about the risks of plutonium production, the former location was eliminated because it was so close to a major metropolitan area; the latter's weak point was that the TVA dams near Oak Ridge produced electricity that was largely spoken for in uranium separation, aluminum production, and other purposes. When Matthias flew over Hanford, an area of 0.5 million acres and only about 2,000 people, he knew he had found the right spot. The Columbia River provided all the water needed, and the Grand Coulee Dam supplied the electricity through 20,000 kilovolt (kV) lines. There were few roads and no railroad to bring curiosity seekers.[80]

When the Army Corps of Engineers selected Hanford for the production of plutonium, the agency gave thirty days' notice to local fruit growers and farmers to get out. The Corps bought up 600 square miles of land and sealed it off behind barbed wire and armed guards. Over the years, the Hanford facility produced the plutonium for thousands of nuclear weapons, including Fat Man, the bomb used on Nagasaki, Japan, in August 1945. Hanford accepts scrapped submarine reactors, barged up the Columbia from Puget Sound Naval Shipyard, a disposal process far superior to the Soviet practice of dumping reactor carcasses in the Arctic Ocean. That is small consolation to living things. The radioactive waste began to leach within a few years, not the 180 years the engineers had assured everyone it would take.

How would the river and salmon fare? The Army Corps of Engineers and contractors built Hanford in record time during the war; they believed they had to do so to beat German physicists to the bomb. True, they worried about some aspects of safety. The reactors and separation facilities had extensive shielding to protect the workers from radioactivity. But they designed some of the reactors to take cooling water directly from the Columbia and then send it, warmer and with some radioactive additions, back into the river (a "single pass" process). The U.S. government closed the last single pass reactor only in 1971. To deal with the heightened levels of radioactivity in the water, the engineers decided to dilute it and hold it temporarily in ponds, to allow the radionuclides with short half-lives to decay, and then release the water back into the Columbia. The releases were premature, however, for the levels of radiation remained high. Compounding the problem, they buried the highly radioactive waste, it turns out, haphazardly. This included billions of gallons of contaminated radioactive sludge stored in sandy soil, some of it only 100 yards from the Columbia River. General Groves claims that army personnel told him Hanford would not harm a single salmon, and he was convinced this was the case. Yet almost immediately after it was built, officials testing the river downstream from Hanford found water—and the fish in it—carrying high levels of radioactivity. Some of the very same water was used to irrigate fields of alfalfa, lima beans, potatoes, and corn. There have been cancers and birth defects among the Washington residents who live downwind and downstream at rates significantly higher than those for the rest of the population. The government never issued a public health warning, and only recently has the Department of Energy declassified data indicating the extent of this severe public health problem. In any event, the cooling water effluent raised the temperature of the Columbia River by 2 degrees Fahrenheit, giving the salmon another obstacle with which to contend.[81]

Salmon and other living creatures in the area ran up against perhaps the most dangerous, most highly polluting human activity, the production of nuclear weapons. It requires separation of various radioactive isotopes and the use of acids to remove metal cladding from fuel rods. It creates millions of gallons and tens of thousands of tons of low- and high-level radioactive waste that remains lethal for tens of thousands of years. At Hanford, the PUREX (plutonium uranium extraction) facility is the major culprit. Hanford engineers built huge concrete canyons at PUREX for the acid baths and isotope separation. To produce 1 kilogram of plutonium, they generated 2.5 million gallons of wastewater for evaporation ponds, 55,000 gallons of low- to mid-level waste for dirt trenches, and 340 gallons of high-level waste destined for underground steel tanks, some of which almost immediately sprang considerable leaks. A PUREX accident in September 1963 released four to five times more iodine 131 than did the partial meltdown at the Three Mile Island facility. Only in 1990 were data about exposures declassified to enable studies of illness and death rates. According to one estimate, 200 workers have died or will die from cancer as a result of exposure to low levels of radiation.[82]

Documents from the Atomic Energy Commission, E. I. du Pont de Nemours and Company, and General Electric reveal that officials had worried since the 1950s about the release of radionuclides in the Columbia River. Local residents—eventually called "downwinders," like their compatriots downwind of the Nevada nuclear weapons test site—were exposed to radiation in water, fruit, vegetables, and fish. Over time, some residents noticed that more and more of their number seemed disproportionately afflicted with various diseases, including cancer. Then they learned that late in 1949 the Hanford managers had intentionally released radioactivity into the atmosphere in the so-called green run. The purpose of the release was to provide a baseline for analyzing traces of radioactive isotopes from Soviet facilities picked up in atmospheric samples. The samples would enable scientists to gauge the direction of the USSR's weapons programs. Because of the weather patterns during the green-run release, the radioactivity spread much farther than managers had anticipated, exposing tens of thousands of Americans downwind of Hanford. But to them it seemed a small cost to pay for national security, and they convinced themselves the exposures were at safe levels.[83]

When exposure hit home—the engineers themselves rather than the fish or downwinders—there was higher concern. An engineer at Hanford was accidentally exposed to a relatively large radiation release. A married man, he wished to know the consequences for his reproductive choices. The Atomic Energy Commission enlisted prisoners at Oregon and Washington State penitentiaries in a study of the effects of testicular radiation on spermatogenesis. Doctors took multiple biopsies of testicular tissue and then vasectomized the subjects. The results showed that reproduction would be possible for the engineer, but not so for the vasectomized prisoners. These experiments, carried out over eight years, eventually led enlightened medical personnel to conclude that prisoners ipso facto cannot give informed consent for their participation in such studies, for they are already coerced by their incarceration.[84]

Recent studies indicate that salmon and people exposed to radiation in less dramatic fashion also suffer serious health consequences. In the 1990s, after the cold war ended, the federal government finally supported studies of the amount and types of radiation to which people were exposed during the four decades when Hanford produced plutonium. Indians may have eaten more fish than others living in the area, and they prepared it in such a way that their radiation exposure was increased. Initial studies assumed that Indians ate about 90 pounds of fish annually. In fact, as Lewis and Clark had discovered, the amount was much higher, perhaps 1.5 pounds daily.[85] Hanford and Grand Coulee will continue to affect Indians for decades to come.

For the salmon, worst of all were not so much the radiation effects but the dams and irrigation systems. Many of these were the smaller dams put up by private utility companies without ladders or other fishways. Dams built by the Army Corps of Engineers put an end to the fisheries as the salmon knew them. Anthony Netboy has described in disturbing detail the effects of the "megalithic dams" on the salmon migrations; the initial hesitance of designers to include fish ladders, so as not to be "nursemaids" to the fish; the challenges of building ladders that induced salmon to go upstream beyond the Bonneville Dam, which required them to climb 70 feet; the use of locks and elevators to lift salmon, shad, and sturgeon; and the dangers to the fingerlings going downstream of the crushing spillway waters or through the turbine blades. When it came to Grand Coulee, at 550 feet, the salmon could no longer reach their spawning grounds. So biologists tried catching salmon and relocating them to holding ponds and incubators at three new hatcheries. The program was not successful. Studies showing the dams' destructive effect on salmon populations, however, did not diminish the enthusiasm of the builders or the certainty of many fish scientists that they might somehow keep the fisheries going as before the dams.[86]

## The Legacy of Hydropower Envy

When asked to think about state-sponsored big science of the 1950s and 1960s, most people envision space and nuclear technologies. But the postwar decades were also an era of hydropower projects larger than those imagined only fifteen years earlier, when the first wave of giant dams were built in the United States and the USSR. In the United States, construction accelerated on the Columbia River in the 1950s and continued in the Tennessee River basin. In the USSR, on the Siberian rivers Ob, Lena, Angara, and Enisei, engineers commenced design and construction of what would become the world's largest stations; in Gamal Abdel Nasser's Egypt, the Aswan High Dam was built. Only later did the project engineers recognize that the dams had colossal negative effects and that their understanding of hydrology, ichthyology, and geology was incomplete at best. From the start, local organizations and citizens fought hydropower, from the Tennessee River valley to the Angara River in Siberia and from the Alta River in Norway to the forests of Brazil, but they were powerless against the forces of industry and defense and the ideology of modernization and progress.[87]

Like their Soviet counterparts, American engineers and politicians recognized the symbolic meaning of large scale technologies, especially in competition with the USSR for supremacy in ideological jousting. Franklin D. Roosevelt pushed the Grand Coulee Dam to remind the public of America's great economic and scientific potential, not just to put thousands of people back to work. There was no difference between getting Woody Guthrie to pen songs about the Columbia and getting writers in the USSR such as Maksim Gorky to glorify water projects through their prose. Employees of the Bureau of Reclamation at the Grand Coulee visitors' center have long touted American engineering authority when describing the dam's majesty, size, and power, with numbing numerical chapter and verse.[88]

Like their American counterparts, Soviet planners and engineers justified their transformationist visions by pointing to dedicated workers toiling for socialism and to nature channeled to operate according to plan. Similar to U.S. efforts on the Columbia, the Stalinist plan for nature transformation involved geological engineering to maximize productive capabilities on a scale never before imagined. Visionaries proposed turning nature itself, its lakes, ponds, rivers, forests, and plains, into a giant factory. Stalin insisted that all natural "aberrations" from the planned norms be eliminated. A centrally managed, unitary system would cover the socialist countryside. One Soviet scholar asserted that complete mastery of nature was simply impossible under capitalism. A socialist order was required to ensure "complex rational utilization of resources." The anarchic distribution of property and monopolies under capitalism, he explained, interfered with large scale transformation of nature.[89]

Soviet engineers and planners embraced universal practices in industrial design intended to minimize risk, economize on materials, and maximize the immediate utility of natural resources. These practices resulted in proletarian aesthetics. Put simply, Soviet engineers developed a technological style noteworthy for bland, functional designs in which safety and comfort played a secondary role and in which environmental issues were only belatedly a concern. Soviet engineers, perhaps like many engineers throughout the world, had come to believe that what they designed was inherently safe or perfectible. They viewed public involvement in decisions about whether to proceed with the diffusion of a new technology as at best a necessary evil; as for the environment, it was simply something to be managed. Almost without exception, hydrologists, limnologists, geophysicists, and others—so-called engineers of nature—who studied virtually every aspect of Soviet natural resources read conservation as "intensive utilization."[90]

Proletarian aesthetics reflected the primacy of state programs for resource development over local, historical, and ecological concerns. The United States was not immune to proletarian aesthetics—the spirit of each dam remains the same even when the architecture is different. The essential sameness of the Columbia River dams—the way they were built, the speed with which they were built, the joy of the engineers over how much concrete they poured, the uniformity of their negative effects on the environment, and the typical addition of fishways as an afterthought—reflects the primacy of the interests of engineering organizations and big businesses over the long-term concerns of salmon, Indians, downwinders, and indeed all of us. The Army Corps of Engineers, the Bureau of Reclamation, and the contractors and utilities who worked with them in the Columbia River basin strove to put standardized technologies in use as early as practicable. They also viewed nature in mechanistic terms, perhaps as an "organic machine," when they applied their knowledge to the control of nature.[91] And before environmental impact statements were required, they built dams and canals rapidly; seemingly no obstacle other than the occasional shortage of capital stood in the way of dam construction on the Columbia.

Soviet plans never lacked enthusiasm for the belief that engineers could improve on nature's gifts. They assumed they could take advantage of the unanticipated payoffs of their hubris. But though unbounded designs on nature had their birth under Stalin, they grew to epic proportions after Stalin's death and the rebirth of constructivist visions for the communist future under Khrushchev and Brezhnev. In the absence of market forces, which might have damned fiscally and environmentally expensive projects, and vocal public opposition, which might have drawn attention to those costs, the engineering organizations responsible for water melioration projects in the USSR seemed only to gain in hubris. In each year of Soviet power, the quantity of manipulated water increased, from 70 billion $m^3$ in 1937 to 125 billion in 1957 and to 450 billion by 1967. Said one Soviet writer, "To possess such great volume of controlled water means to be able to eliminate desert, decisively change climate just like that, and forever be done with poor harvests."[92]

The technologies of the Army Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration have national mystique. Rarely did opposition to these projects materialize, and once the projects commenced, opposition, especially at the local level, was powerless. The language of Corps directors and publicists demonstrated the agency's omnipotence. There would be "no slackening," and there ought to be "optimum development" of "basin wide" and "project oriented" goals.[93] The dams were symbols of the New Deal rebuilding of America. Through the Rural Electrification Administration, they would bring electricity to the poor, enabling them to purchase modern conveniences, including illumination. Cheap electricity, it was said, demonstrated that democracy worked well, for the common man and woman had indeed secured a path out of the Great Depression.

The large scale approach to large scale problems requires large scale surveying, engineering, and construction organizations. In the United States, a series of fortuitous political and economic factors came together in the twentieth century to give the Army Corps of Engineers and Bureau of Reclamation seemingly unlimited power in their efforts to build canals, dams, and irrigation systems across the American West. The Central Valley Project in California (to replace groundwater "pumped relentlessly" out of the Sacramento and San Joaquin River valleys with river water brought in by canal), the proposed Klamath Diversion (wherein engineers imagined reversing the flow of the Klamath River, the second largest river in California, in order to get the water to Los Angeles, hundreds of miles away), and the damming of the Columbia required billions of dollars, hundreds of thousands of workers, and tens of thousands of managers. Melded together by a belief that humans ought to improve on nature, these organizations brooked no obstacles and searched out new projects as older ones neared completion.[94]

Similarly, the large scale, centrally planned projects that were paradigmatic for the USSR were characterized by technological momentum. They grew from Stalin-era efforts to force the pace of industrialization, carried out by construction and industrial trusts with a relatively narrow profile, into megaprojects that left, literally, no stone unturned. The experience at DneproGES, Magnitogorsk, and the Moscow metro foreshadowed the technological momentum the Volga basin development projects would acquire. For example, crews totaling 70,000 workers and 5,000 engineers from Dneprostroi, Magnitostroi, and the Kuzbass coal combine joined together to build the Moscow subway. Bratskgesstroi, formed in 1954 to tame the Angara River in central Siberia, had 6,000 employees by 1955 and 35,000 by 1961, by which time the town where most of its workers lived had grown to 51,000. Hundreds of Soviet organizations responsible for the scientific, design, and construction activities surrounding transformationist projects acquired technological momentum seemingly greater than that of, say, the Army Corps of Engineers or the Tennessee Valley Authority in the United States.[95]

The Soviet system gave impetus to questionable projects through the need to keep workers who were employed by construction trusts somehow occupied in the towns built to house them for the initial project. In part, this led Soviet engineers of the late 1950s to calculate the potential energy of the 1,500 largest rivers of the USSR at an impressive 300,000 MW. Engineering organizations thus proposed building another 1,800 hydroelectric stations, with perhaps another 20,000 small hydropower stations for electrification of agriculture. Under Khrushchev and Brezhnev, they turned to the Siberian rivers with a vengeance.

Was the American system any better? Did it consider the social costs of brute force technology? Planners of the Columbia River projects either assumed the workers would migrate to jobs elsewhere or conveniently ignored relocation costs, including those of social displacement. What happened to the crews of the Grand Coulee Dam after construction ceased? And what of the town of Grand Coulee, the headquarters for construction activities, Electric City, and Coulee Dam, towns of several thousand people? There had been a boom in these towns for eighteen years, until 1950, and then a 50 percent decline in population over three years. The trade and service outlets were twice what the towns' purchasing power could justify. Carrying out economic rehabilitation through federal aid would have been the just thing to do, but demolishing the towns or selling them off to the private sector, letting the workers fend for themselves in search of uncertain jobs, was the American way. The Bureau of Reclamation had failed to answer its assigned question: What was the "rational, long-range" economic basis to which investment values and population could reasonably adjust so that "institutions of local government and property ownership" would fall "into patterns more nearly harmonic with the values of American life"? Nature improvement, not environmental study or social costs, was its concern. The Bureau's final recommendations were to make the towns self-governing municipalities, transfer all private use buildings and land to private ownership, give title to highways to the state of Washington, and provide some funds to utilities and municipal facilities but not to individuals for permanent housing.[96] Let the workers and salmon look out for themselves.

The cascades of hydropower stations and irrigation systems on the Volga and Columbia Rivers required extensive capital investment, unbounded organizational reach, and scientific certainty. They required a vision of nature that was at once utopian and utilitarian. The former came from the belief that nature ought to be controlled—indeed, could be controlled—through the melding of scientific study, large scale technology, and appropriate government structures. The utilitarian aspect grew out of cold war competition between the United States and the Soviet Union to build eternal artifacts of capitalist and socialist culture. They also came from a deeply ingrained belief among specialists in both countries that water had an obligation to humanity, indeed a moral duty, to fulfill many missions before it flowed wastefully into the sea. A stream, a brook, a river all had a "duty"—a strictly quantifiable term—to irrigate the land and to produce electricity.[97] Vision, power, and funding hence enabled the transformation of nature, but at great human and environmental costs.

In *Farewell to Matyora,* Siberian writer Valentin Rasputin describes an island town in the middle of a turbulent river whose residents must pack up and move away. The waters beyond a newly completed hydropower station will soon cover the island, obliterating their homes, land, businesses, churches, schools, and memories. They must move to mass-produced prefabricated boxes—apartments—typical of the Soviet era. Matyora is fictional, but the dams and rivers are not. *Farewell to Matyora* could describe the human consequences of the Grand Coulee Dam just as well as those of the Kuibyshev and later stations. How much longer must we say farewell to nature itself?