We Will Solve Problems Continuously: We Are Going To Open Up New Frontiers

Hydrological engineer Dr. Howard Chang closed the morning panel of the Pasadena NAWAPA conference Dec. 4, with his remarks on the history of water infrastructure in California, and in China, including his personal involvement in building China's Three Gorges Dam. (The video can be viewed at http://www.larouchepac.com/node/16798) Here is an edited transcript of his remarks.

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Dr. Howard Chang, a hydrological engineer, has worked on huge water projects, from California to China, including on the enormous Three Gorges Dam project.

Thank you. It certainly is my pleasure to share my first experience with you. What I said was the following: "What is the problem to solve? New problems are created by the solution. So, as engineers, we are going to solve problems continuously. We are going to open up new frontiers."

I'm going to talk about water engineering problems, not only in the United States, but outside the United States as well. The story must start from home, which is California, where we all call home, right? We have so many major engineering projects, water engineering projects in the state of California. I'm going to get into the details right after this.

FIGURE 1

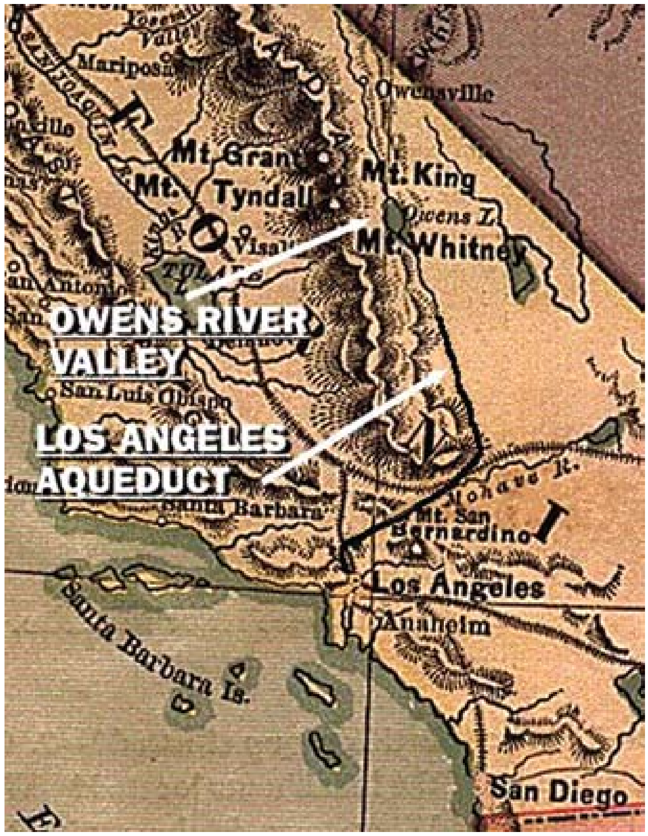
Let's start from the beginning; I'll give you the outline: We have the California Aqueduct, which diverts water from northern California, out to the Southland; we have the Los Angeles Aqueduct, which diverts water from Owens Valley to the Los Angeles area; we have the Colorado Aqueduct, which takes water from the Colorado River into southern California, including San Diego County; we also have the irrigation project that takes water to Imperial County.

You can see from this picture (**Figure 1**) parts of California are green: The Central Valley is green, the Imperial Valley is green. Now, that appearance is strictly due to irrigation projects. By the way, the irrigation project of Imperial County, now the All-American Canal, irrigates so many acres, that large-scale farming is so productive—you know that was desert area—that irrigation transformed that desert wasteland into the natural hotbed of the U.S.A. That large-scale farming is so productive, it can feed the entire population of California.

We also know the Central Valley: Now, irrigation for the Central Valley, irrigation for the Imperial Valley, the agriculture for California, can actually feed the population of the United States. California and Iowa are the most productive states in agriculture. Now, all these are because of irrigation and water-related projects.

You may or may not know that the water supply system for Southern California, supplies the water needs for 20 million people in seven counties. Now, in these seven counties, over 90% of the water used is actually imported from these two or three major aqueducts. Now, the water supply system for Southern California is one of the "Seven Wonders of the Modern World," seven wonders, including the Panama Canal.

FIGURE 2



Water for the San Fernando Valley

Let's think about how much has changed: Do you remember that story, when water was diverted from Owens County to Los Angeles, the San Fernando Valley, how land prices skyrocketed? When water was brought to the San Fernando Valley, it completely transformed the physical nature of Los Angeles and the San Fernando Valley.

I want to show you the details of this diversion project (**Figure 2**). That water comes from the back side of the High Sierras. That canal and diversion system feeds water to Los Angeles and San Fernando Valley. Now, this is a picture of the trunk canal for the All-American Canal, which diverts water from the Colorado River to Imperial County (**Figure 3**). This irrigates so much land, and by the way, the agricultural area can be greatly expanded, should there be more water available. Right now, they're actually sharing part of the water with San Diego County, because they sell that water which they got at a cheaper price, to San Diego County, at a much higher price. San Diego pays a much higher price per acre-foot of water, than Imperial County.

FIGURE 3

So, you see, water and power cannot be separated. Whenever you have water, you have power generation, hydropower generation at the same time. I'll give you one example, on the All-American Canal: That canal has a slope flatter than the natural terrain; therefore, it is built with a series of grade control structures, drop structures. The drop in water sur-

FIGURE 4

the hardest-working water in the world! That water is fully utilized! We built so many storage reservoirs; when we utilize water, transport water, water has to be stored, first, because rainfall does not come uniformly with time; it changes from season to season, it changes from year to year.

By the way, this year, last year, the last few years, we have had a drought in California. We are under water-use restrictions in San Diego County. You can only irrigate or water your lawn on certain days, with a limited amount of irrigation time. There's definitely a need of greater water supply, for this entire region.

I worked on a project a few years ago, for Pacific Gas & Electric, PG&E, a very large power company; they supply 50% of the energy for the state of California. They have all kinds of power plants: They have hydropower plants, they have nuclear power plants, such as Diablo Canyon; they have fossil-fuel-burning plants.

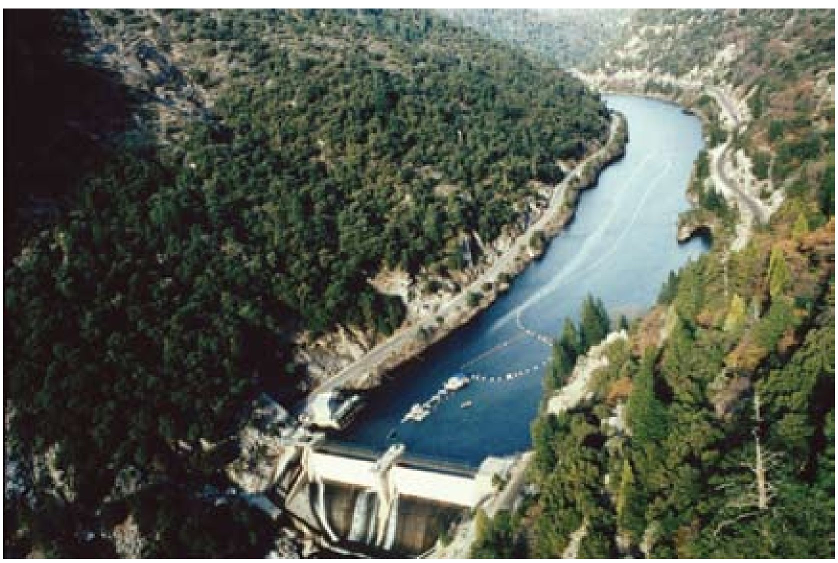
face elevation from upstream toward downstream is roughly 50 feet. Well, that 50 feet is the head that is used in generating hydropower. This one is a power plant (**Figure 4**). Water is fully utilized, for not only irrigation water supply, but also for power generation.

We're going to spend more time to talk about hydropower, especially the advantages and the benefits of hydropower, as compared with other sources of power.

Okay, let's go back, again, to California, to the High Sierras: We have so many small streams and larger steams. The waters of the High Sierras—this is

I want to show you the hydro plant on the Feather River. Here's the Feather River; here's the intake (**Figure 5**). That tunnel goes through the bedrock of the total length, exceeding 10 miles. They excavated tunnels through the bedrock for 10 miles, from this point, to a downstream area of the river, there's a drop of elevation of 700 feet; from the intake to the outlet, the drop in elevation is 700 feet. That is the head. And there's a constant flow of a few thousand cubic feet per second, of water going through the tunnel, and 700 feet plus the flow-rate is used to generate hydropower.

FIGURE 5



Well, there are three such stages along the Feather River, maintaining a constant flow rate. That total power capacity is 1 gigawatt. I would say 1 GW is the average capacity of one nuclear power plant. But think about this: If you want to have one nuclear power plant with the same capacity—a few years ago, I happen to know, 1 GW, the revenue for that energy, say is about $1 million a day; that energy is worth $1 million a day. Now, for these three power plants on the Feather River, the

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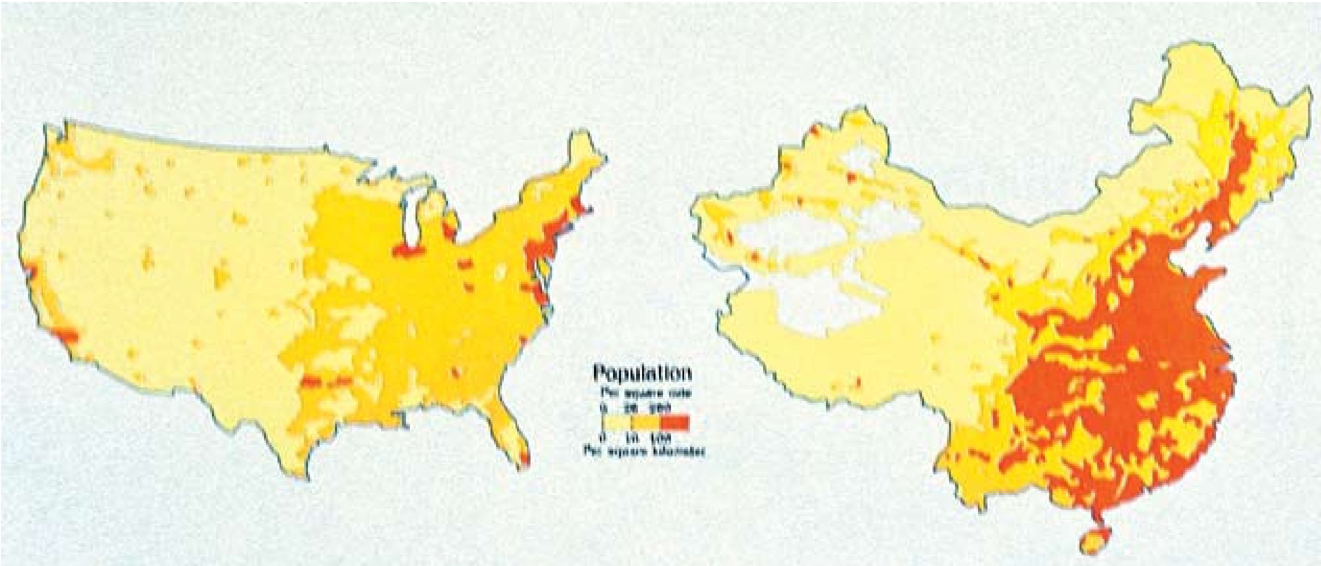


output in cost, is nearly zero! Because, hey! It burns no fuel, there's no fuel cost! There's no transportation cost for fuel. And also, they only hire 30 people in the entire canyon! So, the costs for generating hydropower are very low.

On the other hand, in a nuclear power plant, the operating costs to generate 1 GW are close to $1 million a day, so the profit for a nuclear power plant is very, very small, in comparison to a hydropower plant. Now, you can see the difference.

Well, one reason it's so expensive to operate a nuclear power plant is safety, the safety measures. There are so many regulations for operating a nuclear power plant. That's why they have a large staff at each nuclear generating station; that's why it's so expensive to operate a nuclear power plant.

The Hoover Dam—that's very important: In 1929, this country had a major depression, and one of the means for getting out of the Depression was the construction of Hoover Dam. Hoover Dam, of course, provides Lake Mead, for water and storage. Well, Hoover Dam, at the same time, generates hydropower: The capacity here, I know, is over 2 GW; it's almost like two nuclear power plants. Well, you see the importance of Hoover Dam: Lake Mead supplies the water used in Southern California. We need that water storage, for the water supply to Southern California; in fact, the very existence of the city of Las Vegas depends on the water supply from the Hoover Dam, from Lake Mead; depends on the power generated from the hydropower stations. Of course, the Western part of the United States, the very development of that, depends on the supply of water, and the power to this entire region, and the Hoover Dam is one such major project.

China and the U.S. Compared

I want to share some experience with you of major water projects in China, which I also got involved in. Let us now compare the geography of these two nations. These two countries are similar in size, similar in latitude, in climatic zones (**Figure 6**). However, this shows the population distribution: China has a population that is over five times the population of the United States. But in terms of water resources: The United States is number four in terms of water resources. Number one is Brazil, of course! Brazil is the most abundant nation in water resources, more than all the other nations. The United States is number four, and China is number six.

Think about it: With a huge population, with limited water resources, therefore, water utilization becomes a very important issue in China, but also, in many other developing nations, with the exception of Indonesia, which is abundant in water resources.

I want to show you the distribution of water resources in China. This map shows the rainfall distribution (**Figure 7**); the heavier the color, the greater the rainfall. I just mentioned that Indonesia is abundant in water resources—I believe Indonesia is number two in

FIGURE 7

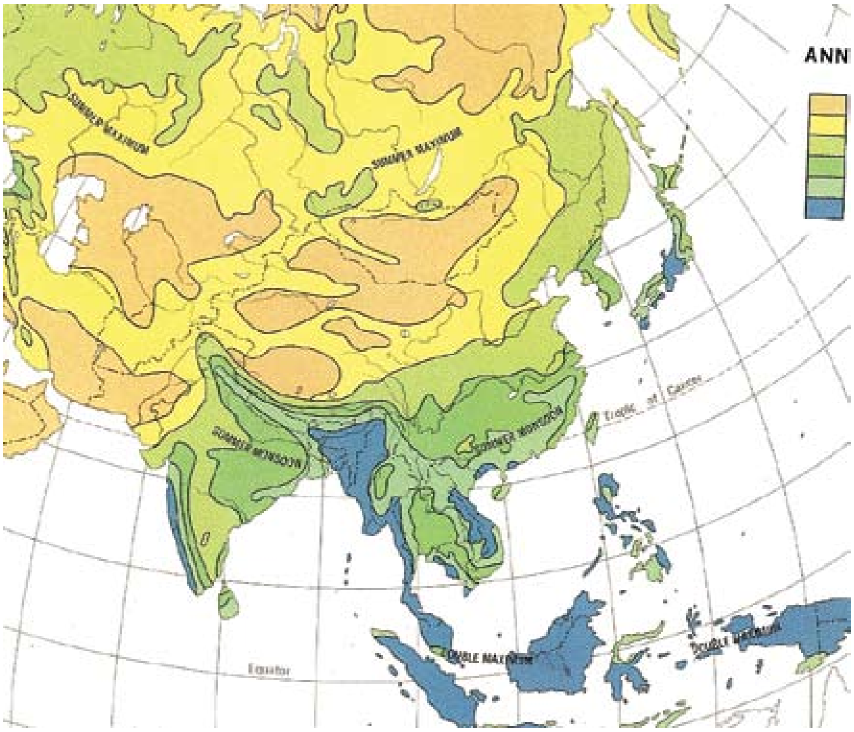
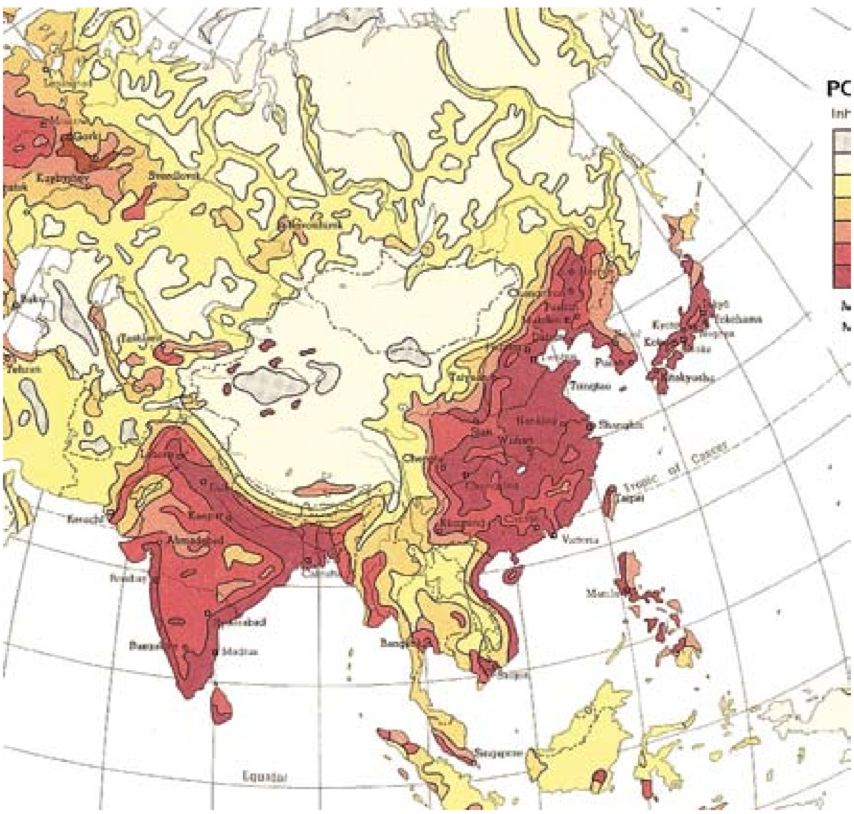


FIGURE 8



the world, second after Brazil. This area is fed by the water supplied by the monsoon. Monsoons feed 50% of the population of the world. But you can see the rainfall distribution is highly uneven. There's more rainfall in the South, and there's more rainfall in the North. The vast area of the Northwest is very dry.

Because of the uneven distribution of rainfall, to solve the water problem requires water redistribution, because of the population distribution (**Figure 8**). They also have a large population living in the North. They have a very sparse population living in the West. Therefore, water from the more abundant area needs to be transferred to the North. Therefore, water diversion becomes a very important task in that nation.

But before you can divert water, of course, water has to be stored, because the rainfall is not uniformly distributed in time. Well, there are years we have more rainfall; in the Summer, there's more rainfall; there's much less rainfall during the Wintertime. Well, with this basic understanding, we know the importance of water diversion, and water storage in this country.

Let's use the population distribution, more detailed population distribution. You see a lot of people living in Asia; China and India have the largest populations in the world; and the rainfall distribution is concentrated in the South, and much less in the vast area of the West.

I want to take you to the far western province of China, Xinjiang province (**Figure 9**). I was out there about five years ago. I want to show you a picture I took, showing the desert area (**Figure 10**). I would say that 80% of the province is basically a huge desert, the Gobi Desert, one of the largest in the world, after the Sahara. We tried to stabilize

FIGURE 9

FIGURE 10

the drifting sand, we used drip irrigation. I understand they learned this technology from Israel. Well, Israel's very advanced in irrigation, because of the need, and also because of the desalination. With drip irrigation, they tried to stabilize the drifting sand—they have highways, and for different reasons, the drifting sand must be stabilized.

The Yellow River: Part of the Yellow River flows through the arid region of China. I happened to be out there four years ago; I took this picture (**Figure 11**). Along the river valley, you could see oases, because water was taken from the river, for irrigation purposes for the farmland, so this area is very green. But as soon as you go away from the river, you see a very dry landscape. They have really developed *a lot* of irrigation projects along the river. I want to show you some examples.

For people living in the arid area, they have their measures for storing water. Say, for example, here is the roof, here's the pavement (**Figure 12**). During the rainfall, water is not drained away; water actually is collected into underground cells. This underground storage—they actually built an underground storage tank: Water is collected from rainfall from the roof, from the pavement area, into the groundwater storage, and that water is used, of course, when it is in need, during the dry season.

Let's look at some of the irrigation projects: They took water from the Yellow River, they built *huge* pumping stations! See the lift, the total lift—this is a three-stage lift, taking water from the Yellow River, the total lift exceeding 1,000 feet (**Figure 13**), taking

FIGURE 11

FIGURE 12

FIGURE 13

water from a much lower area into the high plateau area. I want to show the interior of the pumping plant (**Figure 14**); Here are the electric motors that pump water up, three-stage pumping, over 1,000 feet to irrigate a *huge* amount of land. I understand there are 30,000 people living in that area, where the water is strictly supported by the pumping system.

I want to show you the facilities, a small irrigation facility (**Figure 15**), small canals, man-made canals, control gates for distributing water; and also small canals that go directly into the farmland (**Figure 16**). You can also use aqueducts across the valleys to distribute water (**Figure 17**). You can look at the landscape, how dry the landscape is, in a way, much like California and Arizona: We all live in arid regions.

FIGURE 14

FIGURE 16

FIGURE 15

FIGURE 17

FIGURE 18

FIGURE 19

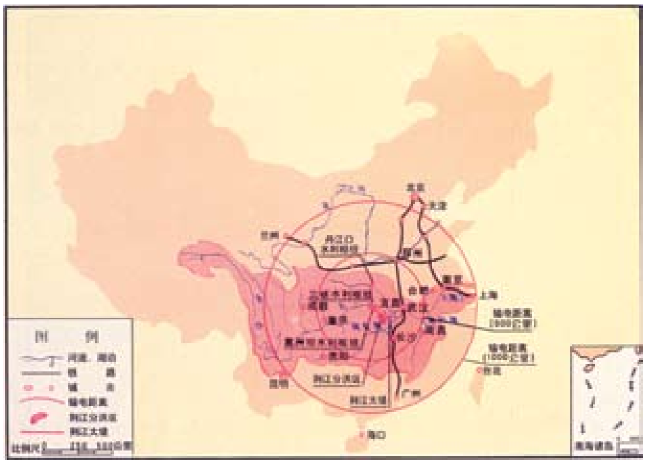
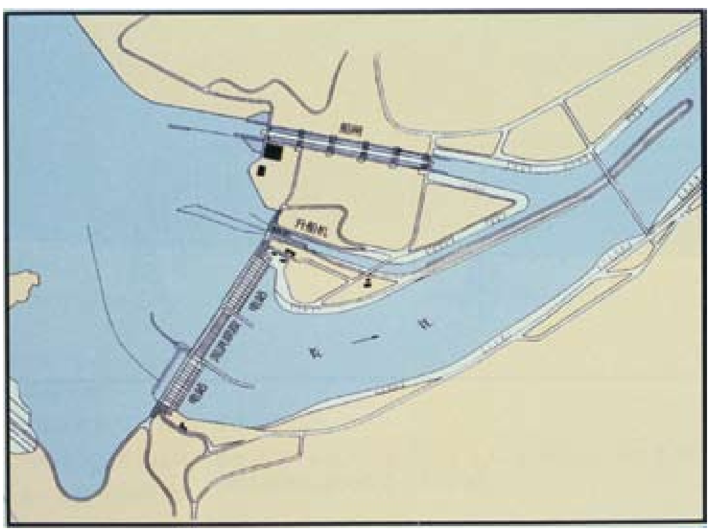


FIGURE 20



The Three Gorges Dam

A major project, the Three Gorges Dam was built on the mighty Yangtze River. The color here shows the drainage basin (**Figure 18**), the watershed of the Yangtze River, which accounts for 50% of the water for that entire region. That's the drainage basin of the Yangtze River (**Figure 19**). And here is the city of Shanghai; that's the city of Beijing; Taiwan is right here.

Let's see how they're going to utilize the water of the Yangtze River for power generation, water storage, and so forth. Here is the drainage basin of the Yangtze River: Three Gorges is located somewhere here, a small gorge, but it controls roughly two-thirds of the drainage basin of the river, therefore, there must be a *lot of water* flowing through the gorge!

The Yangtze River is very similar to the Mississippi River in size, and also, in the amount of water. The average flow rate for both rivers, is roughly 1 million cubic feet per second. There's 1 million cubic feet of water flowing through the river cross-section per second: You can see the abundance of water flow for these two major rivers; the Mississippi River and the Yangtze River are very similar in size, and also, in capacity. And the Three Gorges controls at least two-thirds of the drainage basin—there is so much water that would have flowed through the gorge.

Power generation depends on two factors: It depends on the discharge, it depends on the flow rate, and it depends on the head; it depends on the drop in the water-surface elevation—that's what we call a "head" in hydraulic engineering. In fact, the power is equal to the product of the discharge and to the head. So the greater the discharge, the greater the power; the greater the head, the greater the drop, the greater the power. Let's keep that in mind. So, they can build a dam where there is the huge discharge, a large drop in water-surface elevation; and a lot of power can be produced, based upon these two conditions.

I want to show the schematic of the layout (**Figure 20**): Here is the dam, and there's the spillway. These are the turbines, these are the areas where turbines are installed on both sides of the spillway, and they have a lift, a ship lift—ships and boats can be lifted from the lower side to the upstream side. The lower side is the downstream side; the up side, is the upstream side. Of course, there's a huge difference in water-surface elevation; it also has locks and dams, because large ships would have to sail up and down the river. In fact, ships as large

FIGURE 21

FIGURE 21

as 10,000 tons can sail through the gorge. You have a series of locks and dams.

We have many such facilities in the United States. The Panama Canal has many such facilities, locks and dams, because of the changing water-surface elevation; and the ships would have to go through from one elevation to the other, by going through a series of locks and dams.

This one is a satellite view of the Three Gorges Dam (**Figure 21**), after its completion. Here is the dam, here is the lift, here are the locks and dams for ship passage. We will see a closeup (**Figure 22**): This, again, is a schematic view of the project. And here is a satellite view, when water was released from the control gates (**Figure 23**). And you can see a closeup (**Figure 24**), from the downstream side. Now, you can really see the scale of this dam!

FIGURE 23

By the way, the total project cost, was US$30 billion, including the resettlement of 1.2 million people! Wow! Well, there's a big political question here: Resettle 1.2 million people to different parts of the country, to higher elevations. People ask me, "What if we want to build such a project elsewhere in the world?" Say, if we wish to settle 12,000 people in the United States, I'm sure what your answer is: It's out of the question. Well, they have to take very ambitious measures, because they want to solve a big, big problem: The water problem far outweighs so many other problems.

And, by the way, this project is the largest project in modern times. This project surpassed all the seven wonders of the modern world, of the Western world, by a

FIGURE 24

FIGURE 25

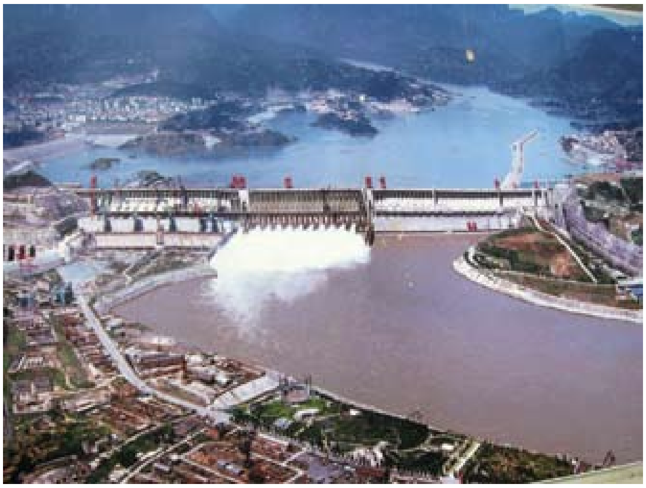
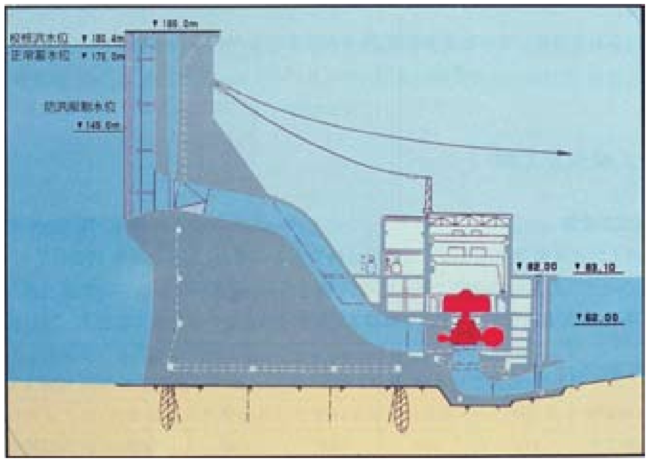


FIGURE 26



very, very large margin, in terms of the magnitude, in terms of the cost, in terms of the total effort.

U.S. Government Withdraws Support

You see, water was released from the control gates during a recent storm (**Figure 25**). A big question arose: During the planning stage of the project, there was much opposition. The Chinese government contacted the U.S. government for technical and financial support. The U.S. government designated the U.S. Bureau of Reclamation, which is the water-engineering institute in the United States, to look into technical cooperation and support for the project. It was the determination of the U.S. government, that the Chinese Environmental Impact Report for this project, does *not* meet the U.S. standard; therefore, *the U.S. government withdrew the support of this project.*

FIGURE 27

Well, that was the bad news. The good news is that they no longer used the engineers from the U.S. Bureau of Reclamation. Hey! I got the job! To work as a consultant.

You know what the major issue was? There was opposition, not only outside the country, but also inside China. The president of the Chinese Academy of Science was opposed to the project! He said, eventually, the reservoir created by the dam, will be *completely* filled up with sediment. That's what he said; because, he said, that impact cannot be mitigated. And, so the reservoir of that big project eventually will become a waterfall! He said, that's going to be a sorrow for China in the long run.

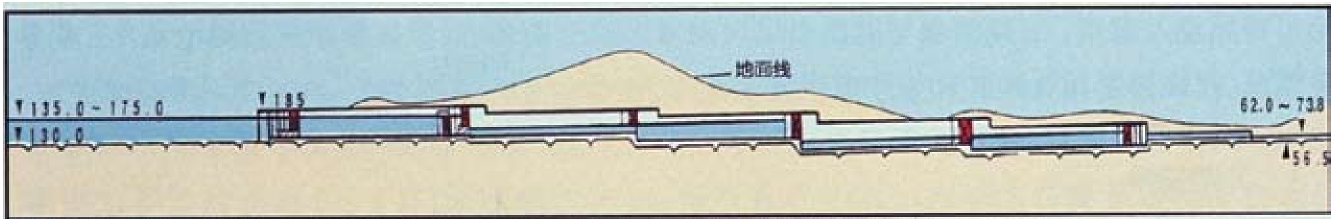
So, the number-one issue in this case, is the reservoir sedimentation. I'm going to address that subject, because I happen to be the person who worked on the research and development, looking for solutions to the problem for reservoir sedimentation. That's the most important issue which I'll discuss.

Going back to the sketch (**Figure 26**): From the upper reservoir to the lower river channel, you see the drop in elevation is roughly 100 meters, 320 feet, that is the head. The water flows through the penstock, which is the huge pipe, and it drives the turbine at a downstream dam. So, it's the flow-rate and the head that determine the power capacity of the generator. Here's the turbine, which is driven by the flow; and the turbine drives the generator. The generator is right above the turbine (**Figure 27**).

By the way, those turbines are huge. Each turbine has a capacity close to one-third of a nuclear power plant.

The total capacity of this project is 18 gigawatts;

FIGURE 28



that is equivalent to 18 nuclear power plants. Now, you can think about the magnitude of this project. Then we're going to compare the difference between hydropower and other sources of energy, as well.

Let's look at lock and dams (**Figure 28**). Going from the downstream side to the upstream side, the difference in elevation is 100 meters. Ships and boats would have to go through many stages, the locks and dams. And this is a view of the locks and dams along the ship channel, an aerial view of that (**Figure 29**).

FIGURE 29

Let's discuss important aspects of the project: First of all, it is the cheap energy in the long run.

About the Feather River project: Because you have water storage, it has the benefit for flood control, because the storage capacity of the reservoir can reduce the flood peaks. Flood peaks are the most damaging to the downstream areas. The flood peaks can be reduced because of the capacity for water storage, because you have control of the water release, thereby reducing the flood peaks. That's the advantage for flood control.

And then, navigation: There's a very interesting development. There's a very big city on the upstream side of the Three Gorges Dam, which is called Chongqing. That city right now has 20 million people. That city can now reach the ocean, by major ships, because of water transportation; that is a very important factor of the development of that major city.

What about navigation before that? There were rapids! Very shallow water, very high-speed water, going through the Three Gorges area, so large boats simply could not sail up and down the river. But now, even oceangoing ships can sail up and down the river. I would compare Chongqing right now to the city of Chicago. Chicago, of course, is connected with the ocean, by the St. Lawrence Seaway. Now, the city of Chongqing is connected to the ocean because of the Three Gorges Dam and the improved navigation, through the Three Gorges Dam.

And of course, water storage of the previous water ponds, is going to benefit fishery products.

The Benefits of Hydropower

And what is most important: *Hydropower* is renewable energy! We are talking about low-carbon energy nowadays. There are different ways for generating low-carbon energy, and the most important way happens to be hydropower. There's wind energy, there's solar energy: Right now, there are many such projects going on in the United States. There are two solar energy projects, one in Imperial County; the other one just south of Barstow. They're still at the development stage. There are so many wind energy projects in development in the United States, because we know, we hope, someday, 10% of energy produced in this country will be from renewable energy sources. And hydropower happens to be the most important renewable energy.

And why? We know the importance of energy. In fact, we have energy crises! Not only in this country, but all over the world. Why? Because energy is the foundation for *economic development*. If we are going to enhance the livelihood, the economic activities of this nation, make this country wealthier and stronger, of course, we have got to have a good supply of energy.

So, what is energy? I've listed coal—that's a fossil fuel; oil, nuclear, hydropower, solar, wind, etc. And hydropower is an ideal source of energy for the following reasons: First of all, there is no fuel cost: You don't have to buy coal, you don't have to buy oil, you don't have to buy uranium. There's no fuel cost. Secondly, no shipping cost for the fuel. You don't have to ship coal to the power plant; you don't have to ship oil to the power plant—there's no shipping cost for the fuel! And nonpolluting, because there's no carbon generated, and then, no waste produced!

That waste is a very big issue for nuclear power plants. Nuclear waste will remain radioactive for thousands of years. We have found out that nuclear waste disposal is a big headache. Where do we store it? We store it underground, thousands of feet underground; we dig very deep tunnels. That is very expensive, as well.

Well then, high initial installation cost: Of course, it takes a lot of money to build a hydropower plant. I have calculated that the cost of generating 1 GW of power from a hydro plant is very similar to a nuclear power plant. In other words, the initial cost is very similar, for the amount of energy produced. However, afterwards, your operating cost for hydropower is very, very small, extremely small. But, for a nuclear power plant, the operating cost is very high, because of the safety regulations. Even for fossil-fuel-burning plants, the operating cost is also very high, because they're required to buy the fuel, shipping costs for fuel, plus all kinds of other costs.

The Three Gorges installation is equivalent to 50 million tons of coal per year—think about it! Fifty millions tons of coal. Let us now make a comparison: The major hydropower generating stations of the world, Three Gorges is the giant among the giants. These are the radiant capacity, these are the power dams in the country. Three Gorges, I say is 17.7 GW—17.7 nuclear-power-plant capacity. The next one is in Venezuela. The next one is Itapú, Brazil.

I happen to know a story of Itaipú. That was built something like 30 years ago in Brazil. That was supposed to be a *huge* hydropower plant, and Brazil didn't have the money to build it. You know how they raised the capital for doing that? They built a hole by using a charge card, either Visa, American Express, whatever—they charged it—charge, charge, charge! By the time they finished the project, there was inflation in Brazil, 1,000% a year. That is the consequence of borrowing. You're going to see the consequence if you borrow too much money.

We better pay attention to our country, the United States.

Well, the Grand Coulee Dam in the State of Washington, on the mighty Columbia River, is the largest hydropower-generating station in this country, 6.5 GW. The Columbia River has a lot of flow, in comparison to the Colorado River. That one doesn't have very much head, but the discharge is huge. Then we have Oak Creek, 3.6 GW.

Hoover Dam, unfortunately, does not make the list, because its capacity is less than 3 GW. But you know, Hoover Dam supplies so much energy, a good portion of energy for our region.

The Problem of Reservoir Sedimentation

A very important issue here, reservoir sedimentation. That's why so many people were opposed to the construction of the Three Gorges Dam. I have sailed on the Yangtze River; I sailed the Yangtze River in the Summer; I sailed on the Yangtze River in the Wintertime. It was muddy in the Winter, it was muddier in the Summer. Do you know what the difference was? The only difference between Summer and Winter, is between muddy, muddier, and the muddiest! Because the water was muddy all year round! The water has a high sediment content: That is a major concern. If you build a dam, create a reservoir, you're slowing down the flow-velocity, which will induce sediment deposition in the reservoir; that's something everybody understands. Then the big question is: Is that going to mean, eventually, the reservoir will become completely silted up with sediment? Well, that is the most important issue to address.

We built so many reservoirs in this country. I stood on Hoover Dam several times. I look at Lake Mead: I see *clear* water in Lake Mead! You know what message I get? Well, your message and my message are different, because I happen to be a hydraulic engineer. I see clear water in Lake Mead; is what you saw in Lake Mead, clear water? Muddy water? Clear water! You know what message I get? No sediment can escape Lake Mead! Which means, Lake Mead eventually will be filled up with sediment! Except, that timespan is very long, measured in thousands of years. Because there are several other dams, Glen Canyon Dam, that also retain more sediment. Glen Canyon Dam has a lot more sediment deposition than Hoover Dam.

But! The Yangtze River is so muddy—even in this country, and all over the world, the average rate of siltation is 1% per year, for reservoirs in the world. Without proper sediment control, a dam will eventually become a waterfall! Well, that is the most important

FIGURE 30

FIGURE 31

issue. That's why the president of the Chinese Academy of Science was opposed to the project. He wrote a letter to Deng Xiaoping [leader of the P.R.C., 1978-92]. He said, "I strongly oppose the construction of the Three Gorges Dam project," and gave all kinds of reasons.

Of course, there was research and development before construction started. I happened to be a part of the ballgame, on the very subject of the reservoir sedimentation. The question is, will the reservoir eventually be totally filled up with sediment?

Well, of course, when you do research, you know what you do? There are different ways of doing research in hydraulic engineering. There's one that will become a physical modeling, and there's mathematical modeling. Physical modeling is where you build a physical model, to simulate what happens when the dam is finished: How much sediment would actually accumulate in the reservoir? The mathematical model is what you do, using a computer. You use a computer to simulate what happens in the reservoir. Of course, the part I did was the computer simulation of reservoir sedimentation.

I want to show you, when I said muddy water—this was before the construction of the dam (**Figure 30**). See, the water was quite rapid, because the water was flowing through the gorge, quite shallow. This ship has a very shallow draft, by the way, otherwise you could not sail on that river. The water is muddy. The water was muddy, very muddy, and very shallow. It's very clear in this picture (**Figure 31**). And the Colorado River is in much better shape in terms of sediment content. So sedimentation was a serious concern—here's the gorge.

This picture shows reservoir sedimentation (**Figure 32**). This is a small reservoir in the northern part of China. The thing about the reservoir is, it's almost totally silted

FIGURE 32

FIGURE 33

up. Even if you drain all the water from the reservoir, you're not going to flush the sediment—you only cut a small gully! Most sediments stay in the reservoir.

However, the Three Gorges reservoir is different, because it is a river reservoir instead of a storage reservoir. A river reservoir is long and narrow. With a river reservoir, therefore, a certain speed of flow can be accomplished. And besides, the dam has a low-level outlet to pass the sediment: The dam is *built* with a low-level outlet, to pass sediment. Then the reservoir level can be drawn down—you can raise the water level and lower the water level. During the Summertime, there's more flow: They lower the water level, to increase the speed.

And, reservoir operations are made during floods. During floods, you have a lot more flow; you lower the reservoir level, you achieve the flow velocity to flush the sediment, to pass the sediment through the reservoir.

And research was done. In the physical modelling study, here's a physical model they built indoors, to see what happens (**Figure 33**). And you would think sediment would settle in the reservoir bed, to make the reservoir shallower, and shallower, and shallower, right? Not so! Because there's a flow, because there's a river flow! Sediment actually settles along the banks, not necessarily along the bed, because there's a river flow (**Figure 34**). The river flow will always create a channel. That river flow would actually become faster, with the sediment deposition along the banks, to establish a narrower channel.

Our conclusion's the same: That reservoir will un-

FIGURE 34

FIGURE 35

FIGURE 36

dergo siltation. Forty percent of reservoir capacity will eventually be lost to sedimentation. But, the remaining 60% will be preserved, in perpetuity. So that reservoir will never be filled up, because there's a river flow. The river flow will always pass the sediment through the reservoir.

70 Million People Will Benefit

What is most important? For that country, it's the water diversion project, from the South to the North. Because there's much more water in the South, than in the North, so they are going to build *three* diversion channels, from the Yangtze River, to the Yellow River, and further north (**Figure 35**). Here's the eastern route; here's Shanghai; that is Beijing. That is about 700 miles in distance. Here is the eastern route, along the ancient canal. Here is the central route: It takes water from a tributary of the Yangtze River to the city of Beijing; and this takes the water to the city of Tianjin, and there's a branch to the tip of the peninsula. These are the major water diversion projects. And there's the western route.

The three routes combined will divert so much water, 7% of the water of the Yangtze River, to the north. How many people are they going to benefit? I'd say, at least 70 million people, who will actually benefit from the diversion project. That's got to be the largest diversion project ever undertaken by man.

And by the way, you may not know, the city of Beijing, right here, is on the edge of a huge desert! The annual precipitation in Beijing is less than 20 inches. And there are 20 million people living in that big city. The local drainage simply will not supply the water needs for such a huge population.

So, with the water diversion to the city of Beijing, the city of Beijing would benefit so much from the water diversion project. And you will see the way we've built, between Tianjin and the coastline (**Figure 36**): That city becomes the second Shanghai. That's going to be the third-largest economic zone in China. Before that, the city could not be developed. That's wasteland, and because of the freshwater supply, they are going to build a second Shanghai outside the city of Tianjin. That water comes from the Yangtze River; the Yangtze River to the Yellow River, and then the Yangtze River to the city of Beijing: These are *huge* diversion projects!

And this is the canal, the ancient canal; in its current state, it's out of repair (**Figure 37**). And this canal will be deepened, enlarged, and then dredged. You would

FIGURE 37

also improve the navigation from the South to the North. And the new canal will be built—that shows they're actually working on the project (**Figure 38**). You can see the construction of the new canal.

By the way, from the Yangtze River to the Yellow River, there are going to be 13 pumping stations, locks and dams (**Figure 39**). Boats would have to pass. And from the Yellow River to the city of Tianjin, that's strictly by gravity flow, that's dropping elevation, so water will flow by gravity. For the central route, the difference in elevation from the source water to the city of Beijing is 100 meters; water will flow strictly by gravity, no pumping stations in between.

Of course, the water's going to cross the Yellow River, *under* the Yellow River, by huge tunnels (**Figure 40**). This one doesn't show the size, but the Yellow River is a huge river! You can see the tunnel, the size of the tunnel intake; an underground tunnel going through the Yellow River and going north to the city of Beijing. The water flows strictly by gravity; there are no pumping stations in-between.

FIGURE 38

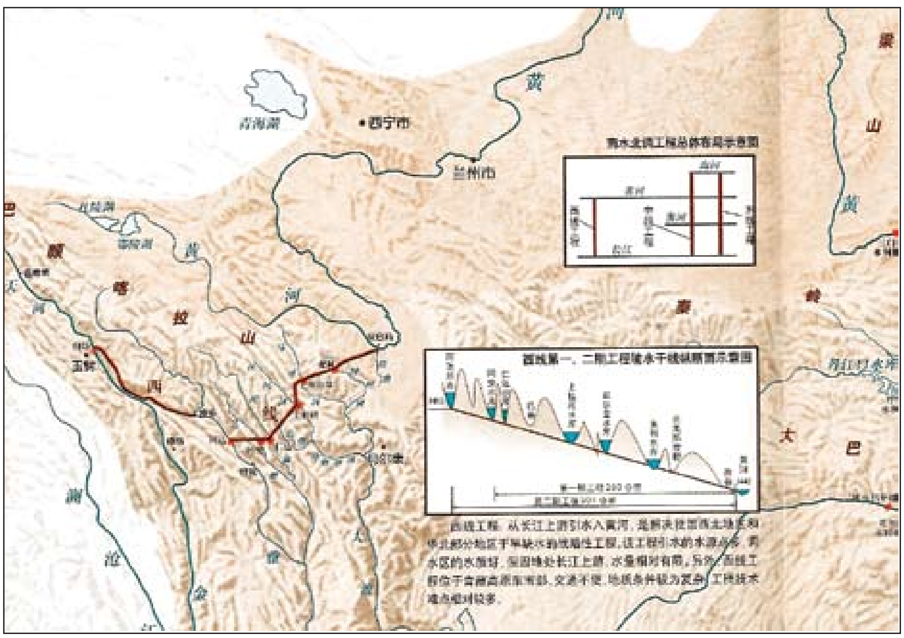
The Western Route

I want to show you the Western route (Figure 36). The Western route is the most difficult; it's going to take *tremendous* investment. They're going to take the water from the Yangtze River to the Yellow River, to the *upper reaches* of the Yellow River, through very rugged country, high mountain areas, deep valleys. From the source, from the Yangtze River to the Yellow River, the drop in elevation is only a few meters: water tunnels going through a huge series of huge tunnels (Figure 39).

By the way, 90% of the diversion system is tunnels. *Huge* tunnels, that takes huge investment to build that project. That is the only part, the only route, where the construction has not started.

You can see the Western route, on the edge of the Tibetan Plateau (**Figure 41**). So you're crossing all the mountains, crossing all the valleys. There's going to be a series of dams to be built in the valleys; there's going to be a series of tunnels going through the mountains

FIGURE 39



(Figure 36), going from the Yangtze River to the Yellow River, to supply water from the producing area to the consuming area.

So, 7% of the Yangtze River water will be diverted to the north. But how are they going to replenish the water for the Yangtze River? Well, I'll tell you what. There are three parallel rivers: Here's China; here's Myanmar—that's Burma—that's India. There are three rivers which are parallel. Here's the Yangtze River; here's the center river that flows into the Mekong River in Vietnam; and there's another river, the Salween, very close to it, that goes into Burma. These three rivers are so close to each other, they are going build 12 high dams on these rivers. Water from the other rivers can be transferred to the Yangtze River.

But, that brings up an international issue, *of water rights.* It was an issue for the Colorado River. We use most of the water inside the United States; when the Colorado River flows into Mexico, it's a trickle.

So, they have to solve the water rights issue, because those two rivers are *international rivers*. The United States is very fortunate: The Mississippi River is *not* an international river. The MacKenzie River and Yukon River are international rivers, but fortunately we have an agreement with Canada to solve the international issues.

But, people actually predicted, that there are going to be more international issues, perhaps even wars, because of the water conflict. Also Mesopotamia, the Mesopotamian civilization, depended on the water supplies of the Tigris and Euphrates. The source of water is where? In Turkey, where the rainfall occurs, and Turkey is in the process of building two huge dams and water storage. So the waters flowing into Iraq, would actually be controlled by Turkey. So, that is an international water issue.

Well, I've used up most the water! I wonder if you have time for questions.

FIGURE 40

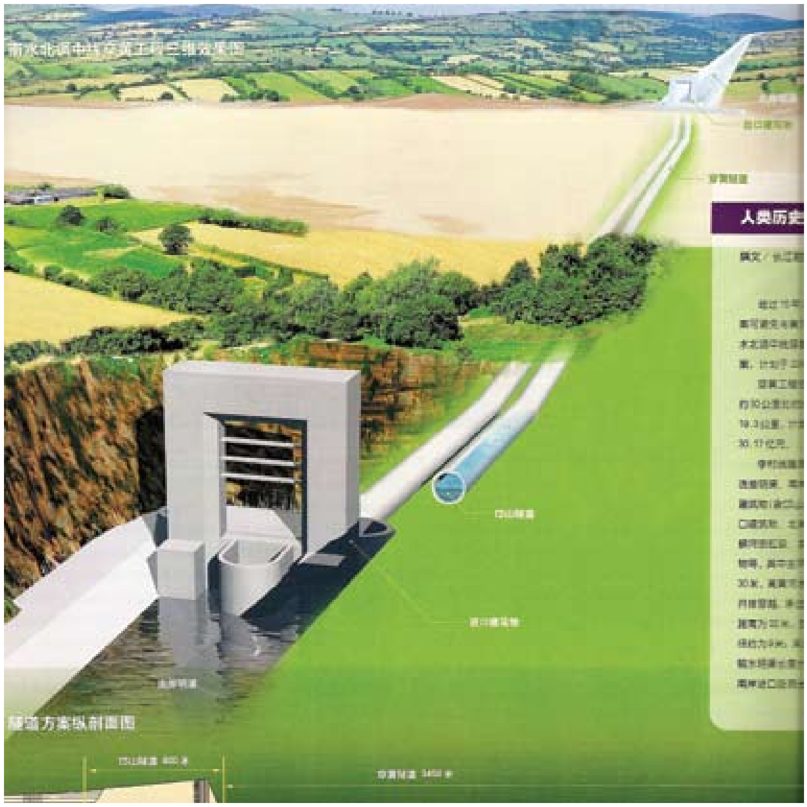


FIGURE 41