神华集团
SHENHUA GROUP

Protection and Utilization of Water Resources in Coal Mining in Western China

Gu Dazhao

Deputy Chief Engineer

Shenhua Group Corporation Limited

Outline

Ⅰ. Introduction to Shenhua Group

Coal

Shenhua is the largest coal producer in China and the largest seller of coal in the world. In 2013, Shenhua's coal sales reached 654 Mt.

Coal-to-Liquids and Chemicals

Shenhua's businesses include coal, power, railway, port, shipping, coal-to-liquids and chemicals.

神华集团
SHENHUA GROUP

Shenhua's profits in 2013 were RMB 78.5 Billion, ranked 165th in the ***Fortune*** Global 500 in 2014.

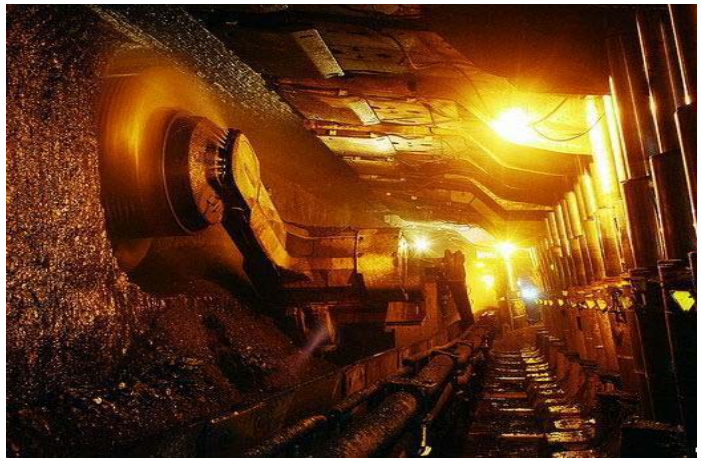
Power

Railway

Port and Shipping

Ⅰ. Introduction to Shenhua Group

- Shenhua has constructed the largest coal mines group in the world, each with a capacity over ten million tonnes per year.
- The fatality rate per million tonnes coal production was **0.004** in 2013, which is a world-class safety record.
- Today, vegetation coverage for Shenhua's major mining areas is over **80%** .



Large Mining-Height Longwall Face

Green Shendong Mining Area

Ⅰ. Introduction to Shenhua Group

- Shenhua is **the 5th largest coal-fired power company** in China with the total installed capacity of **65.7 GW** as of 2013.
- Shenhua has mastered the **600 MW (largest scale in the world) circulating fluidized bed boiler technology** and made the clean utilization of low-rank coal possible.

Shenhua Baima Circulating Fluidized Bed Boiler Power Station

Shenhua Zhoushan Coal-fired Power Station

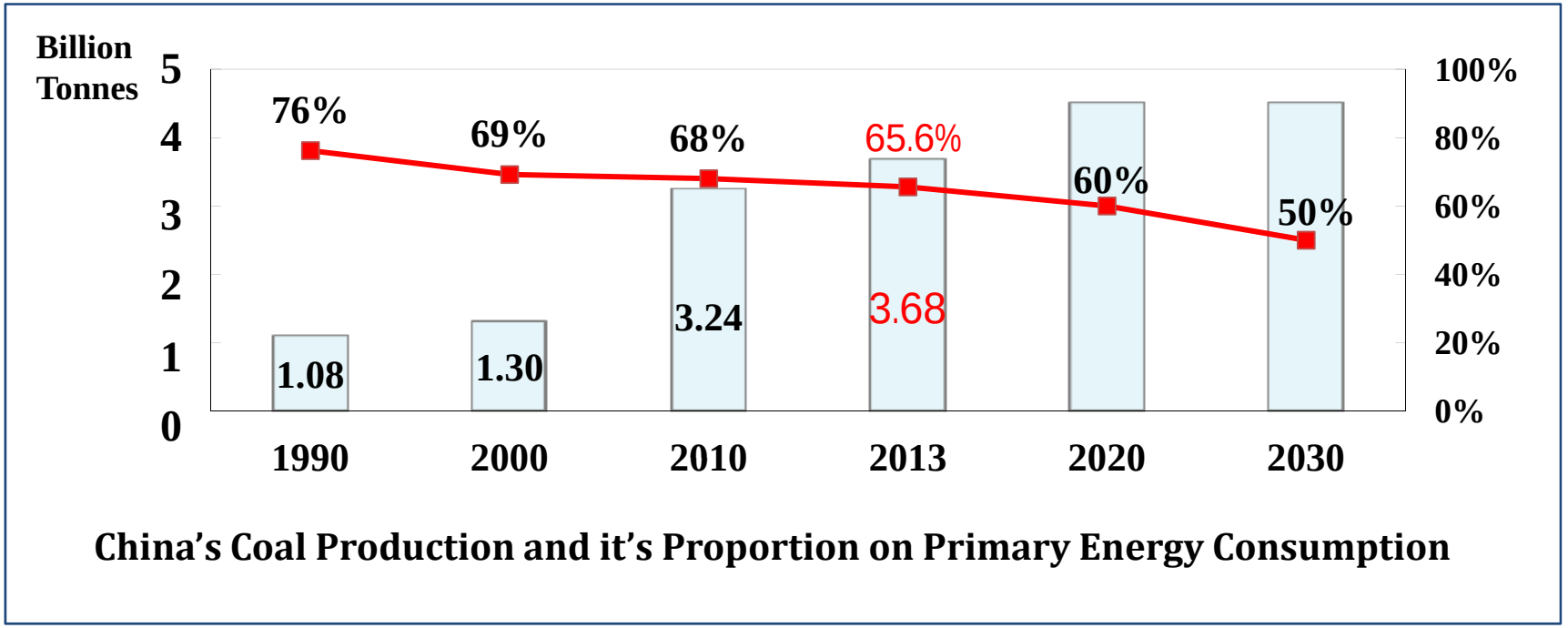
Ⅰ. Introduction to Shenhua Group

- Shenhua has developed the key technology of direct coal liquefaction (DCTL), constructed and operated the first DCTL plant, at a scale of **1Mt per year** liquid fuel production capacity in the world.
- The **4 Mt per year** indirect coal liquefaction Project in Ningxia Province is under construction now.

DCTL Plant in Ordos

Outline

Ⅱ. Background of Technology Development



China's Coal Production and it's Proportion on Primary Energy Consumption

- Coal is undoubtedly the most important primary energy fuel in China, accounting for about **70%** of the primary energy consumption.
- China's coal production and consumption accounts for about **50%** of global coal production and consumption.

Ⅱ. Background of Technology Development

- **Protecting and utilizing mine water resources is a strategically important task**

> ➢ Coal mining results in the loss of underground water and generates mine water. At present, **8 billion tonnes of mine water** is generated by coal mining every year, 75% of which is lost in China.

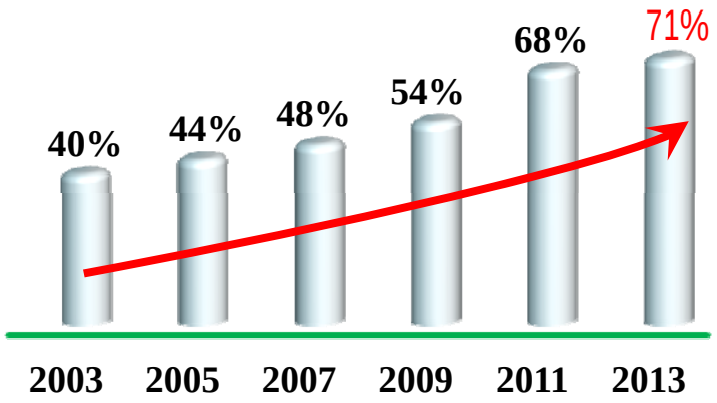
> ➢ China has a shortage of water resources. Today, there is a **10 billion tonnes** per year gap between consumption and demand for industrial and domestic water usages.

> ➢ If the loss of **6 billion tonnes** of mine water could be prevented and the water could be utilized efficiently, it could satisfy **60%** the water shortage for industry and domestic use every year in China.

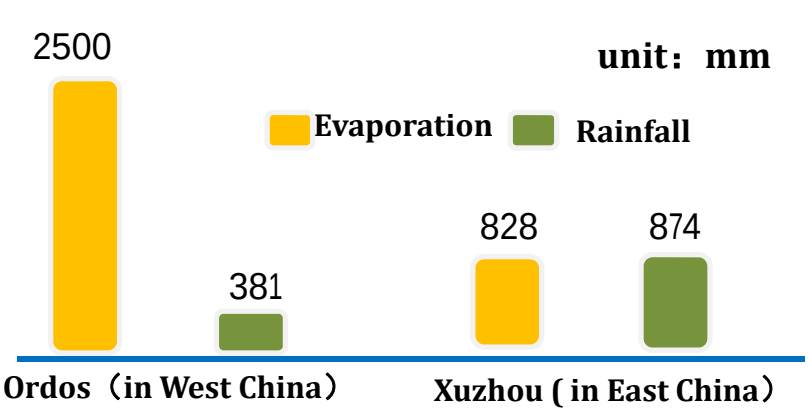
Ⅱ. Background of Technology Development

- **Mine water protection and utilization is very important for western China (Shanxi, Shaanxi, Inner Mongolia, Ningxia and Gansu)**

- The western area has rich coal reserves, which account for **63%** of China's coal reserves, its proportion in the country's coal production is now **71%**.
- However, in the western area, water resources account for only **3.9%** of China's total and the surface evaporation capacity is six times greater than rainfall.
- Large scale coal mining induces the loss of underground water and can increase the water shortages in western China.



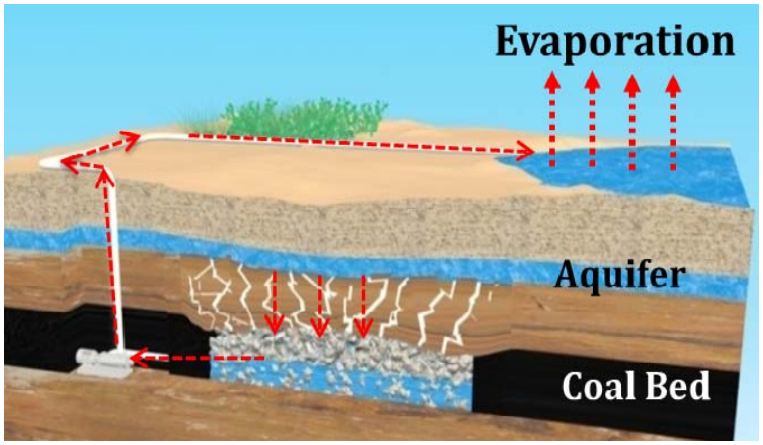
The Proportion of Western China's Coal Production in the Country's Total Production



Evaporation Capacity vs Rainfall in Different Areas of China

Ⅱ. Background of Technology Development

■ **The major reason for mine water loss in western area is the large capacity for surface evaporation after the mine water discharged to the ground**



Mine Water Loss in the Western Area of China

What induces the large mine water loss in coal mining?

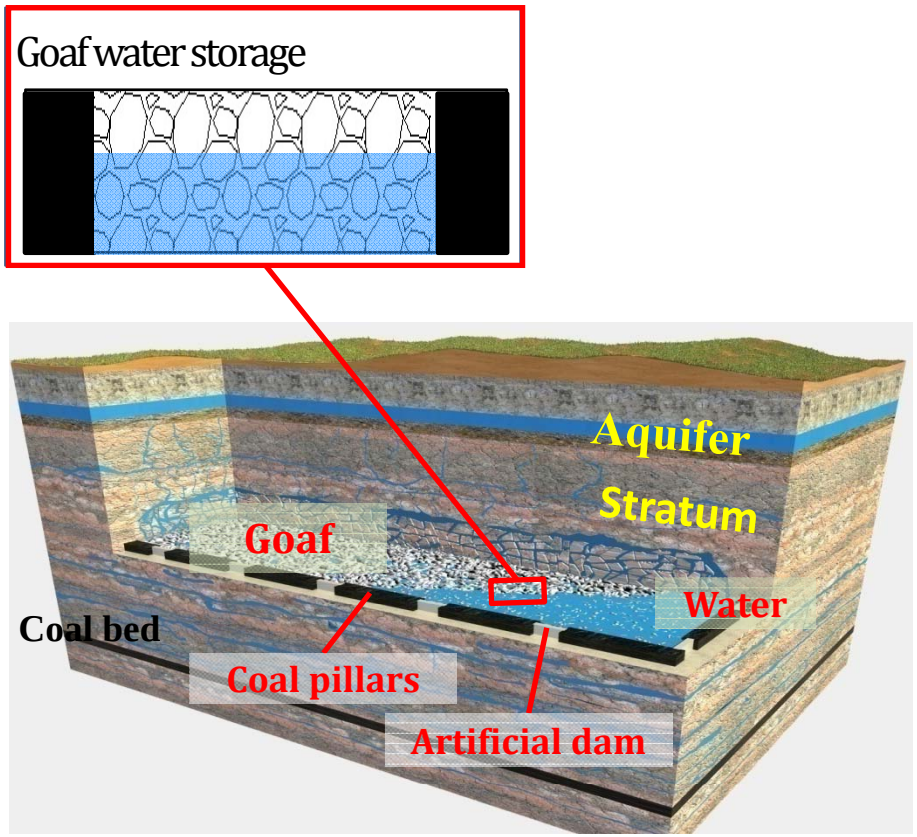
- Mine water is traditionally considered a harm and always **discharged to the surface to ensure mining safety**.
- Due to the **large evaporation capacity** in the western area, this discharged mine water can quickly evaporate and is, therefore, lost after being discharged.

- For Shenhua Group, over **80%** coal production is from western area where there are serious droughts and extreme water shortage.
- Shenhua has always had a strategic focus on develop the technology for protecting and utilizing the mine water in the recent 20 years.

Outline

III. Technology Innovation

- **Using the 200 Mt per year Shendong Mining Area as a research & development base, Shenhua Group developed the coal mine underground reservoir technology system.**



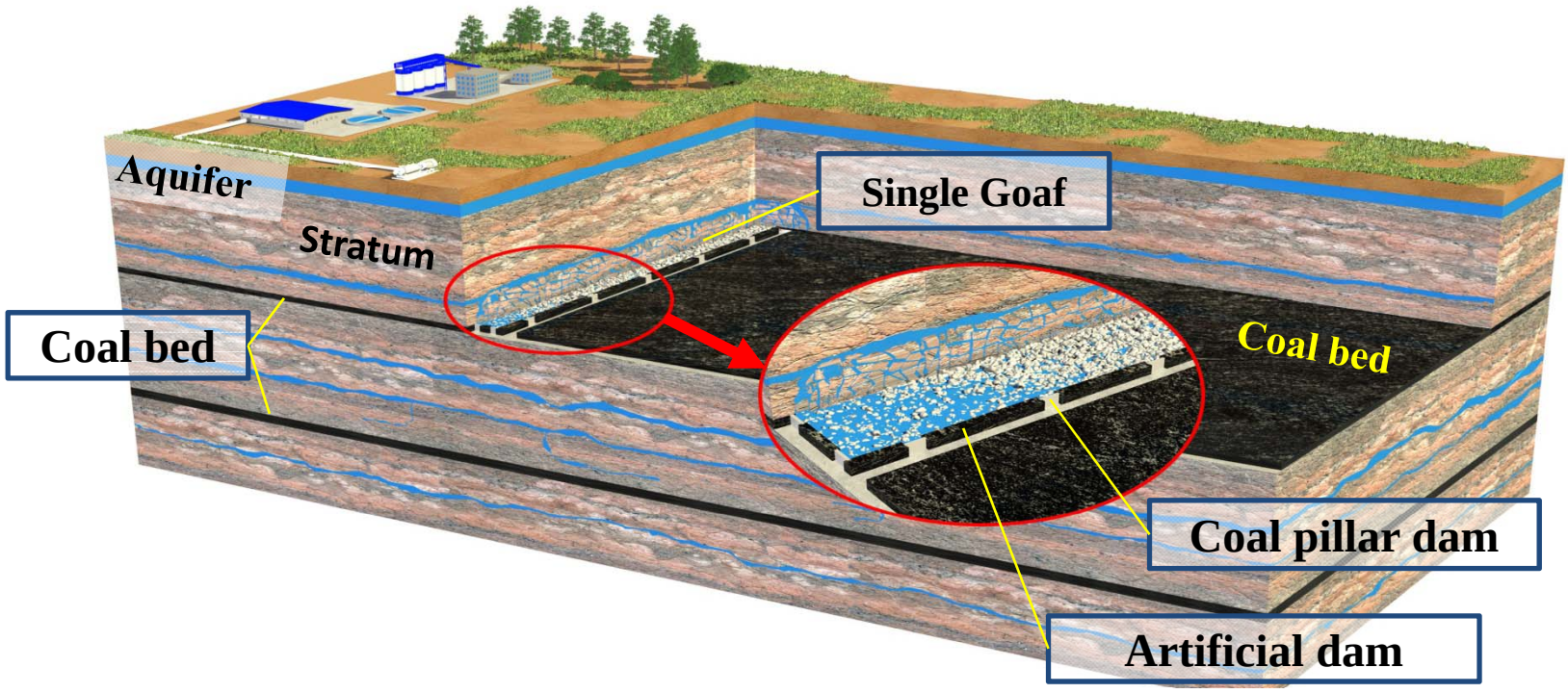
Coal mine underground reservoir

Three characteristics:

- Using caving rock masses in the goaf for water storage space
- Composing the dam by connecting the coal pillars with an artificial dam
- Mine water purification by rock masses

III. Technology Innovation: Technology Development

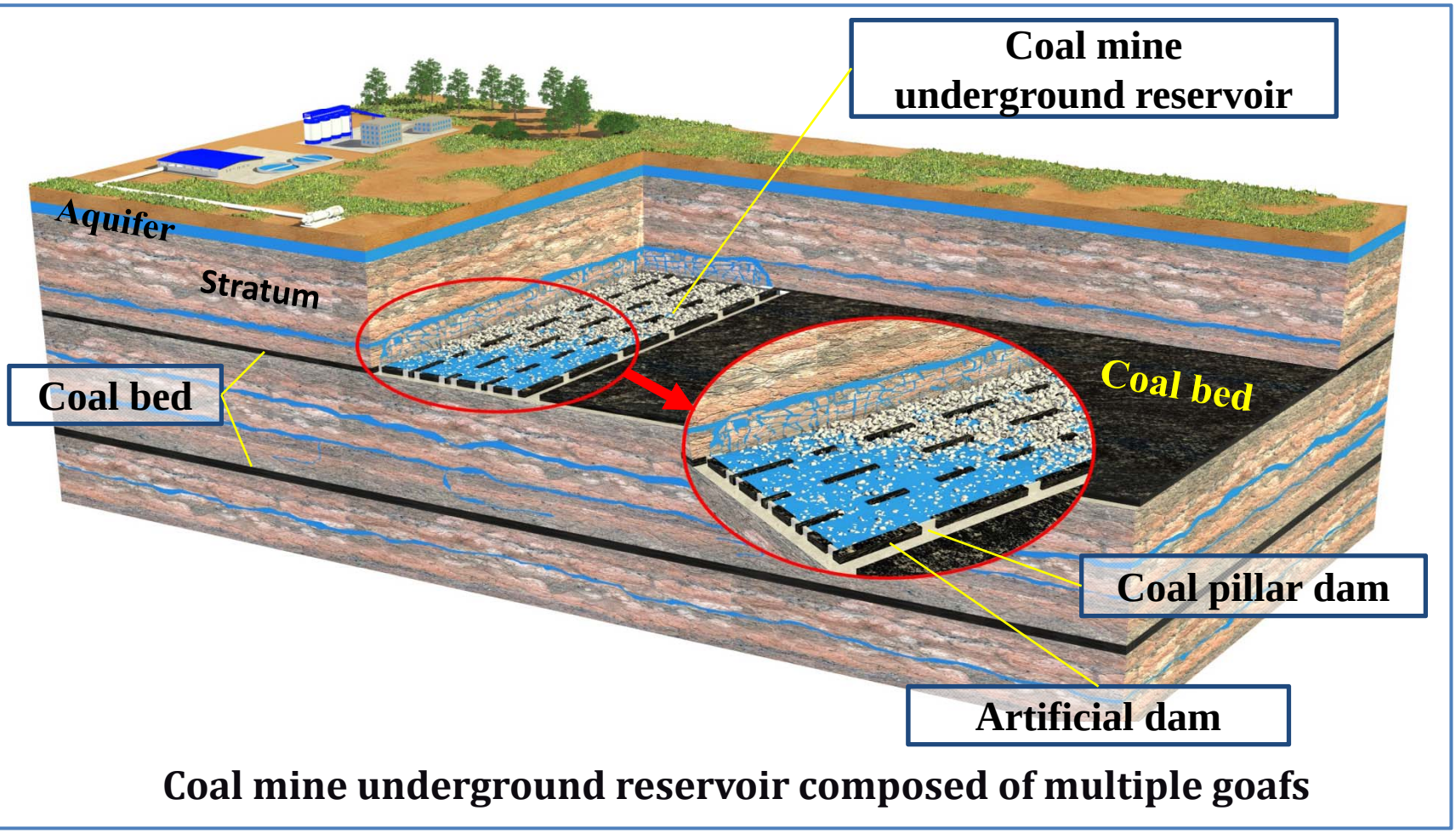
- **A three step route for technology development has been proposed. The first step is development of a single goaf facility for mine water storage to prove the feasibility of underground water storage.**



Water storage facility composed of a single goaf

III. Technology Innovation: Technology Development

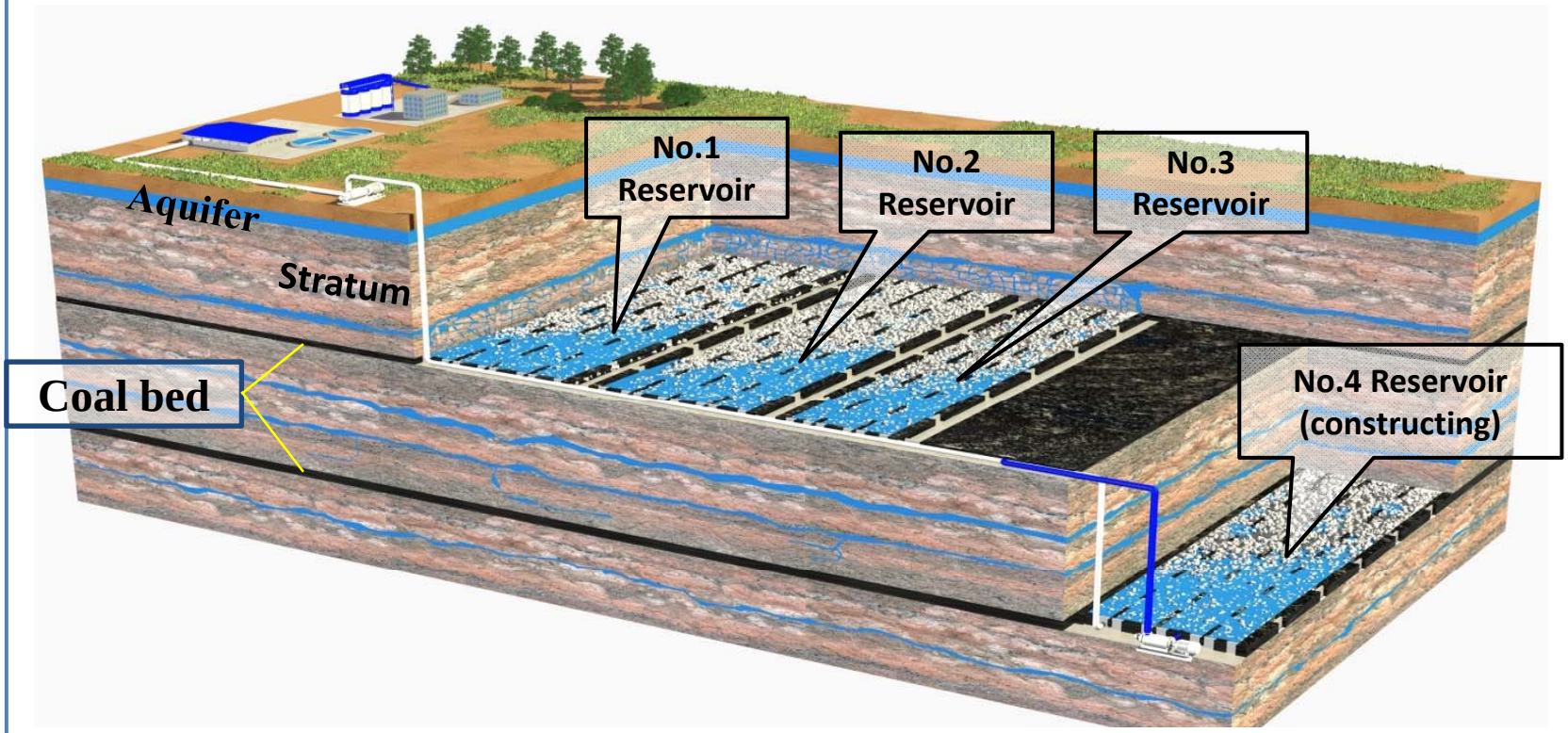
- **The second step is to develop coal mine underground reservoir composed of multiple goafs, in order to increase storage capacity**



Coal mine underground reservoir composed of multiple goafs

III. Technology Innovation: Technology Development

- **The third step is to establish the distributed underground reservoir composed of several reservoirs, in order to achieve zero discharge of mine water when multiple coal seams are mined.**



Coal mine distributed underground reservoir

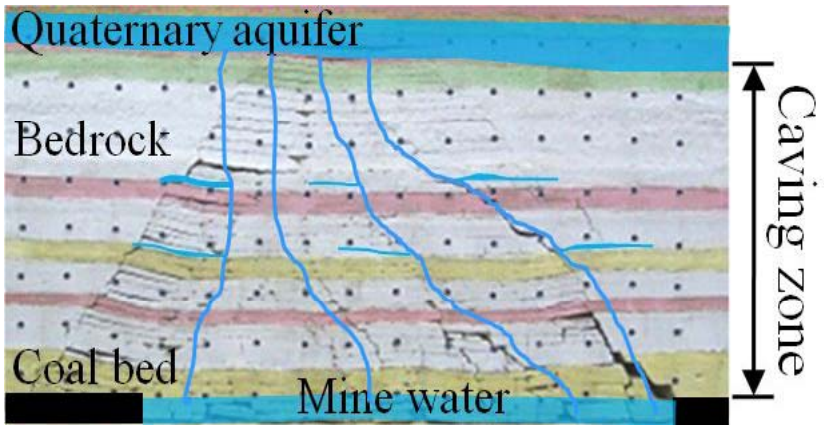
III. Technology Innovation: Technology System

- **The coal mine underground reservoir technology faces five technical challenges:**

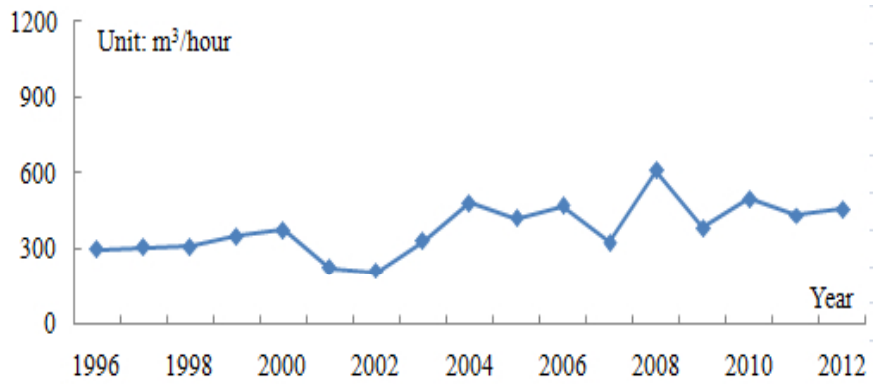
  - **Water production prediction**: How much mine water could be used for storing and utilizing?
  - **Reservoir capacity design**: How much mine water can be stored in the coal mine underground reservoir?
  - **Dam construction**: How best to ensure dam structure strength and avoid seepage?
  - **Safety Guarantee**: How can safety be ensured during operation of the coal mine underground reservoir?
  - **Water quality control**: How can water quality be made to meet users' requirements?

III. Technology Innovation: Water Production Prediction

- Studies have shown that the overburden rock fissures formed by coal mining induced migration of quaternary pore water and bedrock fissure water.
- Quaternary pore water is an important source of mine water in the initial stages of mining, while bedrock fissure water is a long-term stable source of mine water.



Physical Simulation of Mine Water Formation



Water Inflow in Daliuta Coal Mine in Shendong Mining Area

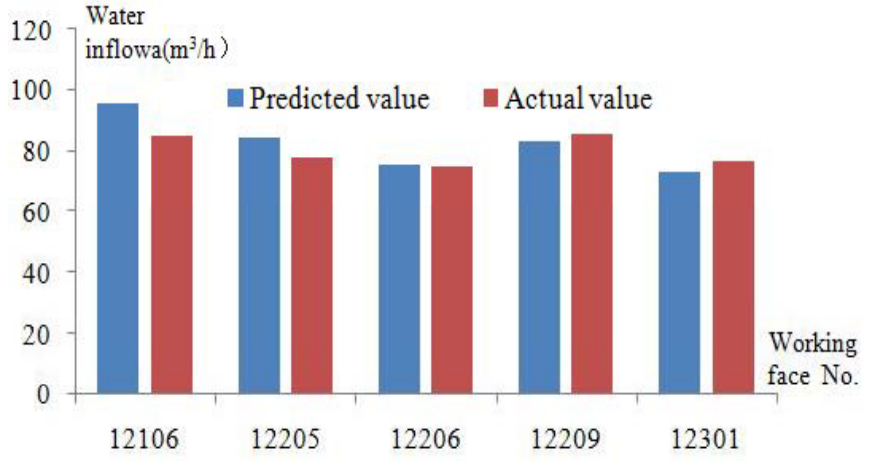
III. Technology Innovation: Water Production Prediction

- To predict the inflow rate of coal mine water, a prediction model was established, which was validated and then used to calculate a water production basis for the construction of underground reservoir.

$$Q = aS + bM + C$$

S-mining area; *M*-working face mining height; *a*-coefficient related to horizontal permeability; *b*-coefficient related to vertical permeability; *C*-empirical constant

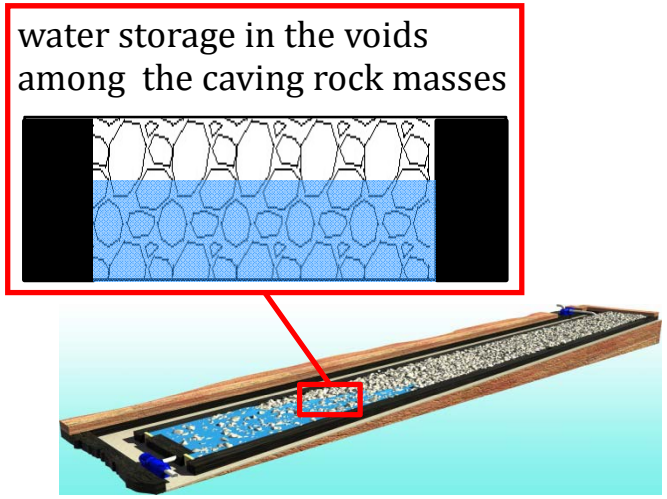
Coal Mine Water Inflow Prediction Model

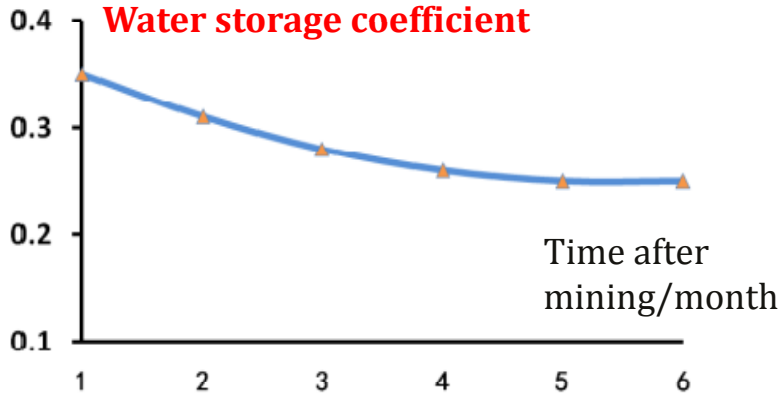


Comparison of Predicted Value and Actual Value of Water Inflow in Shangwan Coal Mine 1^{-2} Coal Seam

III. Technology Innovation: Reservoir Capacity Design

- The water storage space of coal mine underground reservoir is made of the voids among the caving rock masses in the goaf.
- To calculate the reservoir capacity, a water storage coefficient was introduced, which can be defined as the water reserve in the goaf per unit volume.
- The water storage coefficient is affected by the overburden rock structure, mining factors, rock pressure, rock mass lumpiness and other various factors. The effect of these factors have been studied.





Water Storage Coefficient Change as Time

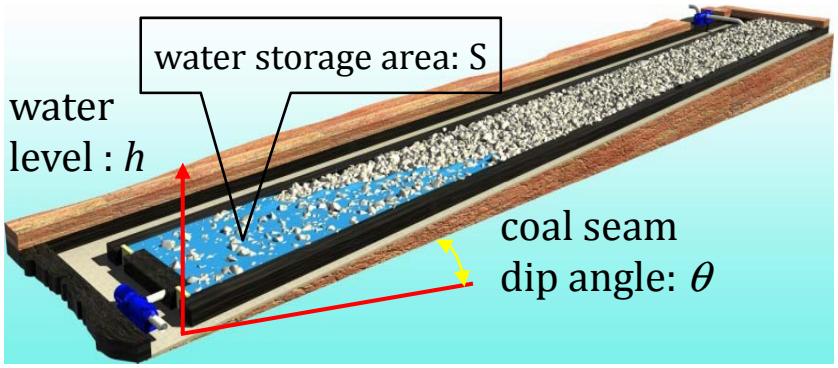
III. Technology Innovation: Reservoir Capacity Design

- Based on a similar material model and field test research, a water storage coefficient calculation method was established. **The water storage coefficient was 0.2~0.3** in Shendong mining area.
- Based on the water storage coefficient and other parameters, a coal mine underground reservoir **capacity calculation model**, which can provide a foundation for reservoir capacity design, was developed.

$$V(h,t)=\int_0^{h\cos\theta} s(z)\,R(z,t)\,dz$$

V-water reserve/m^3; h-water level /m; θ-coal seam dip angle; $s(z)$ - water storage area/m^2; $R(z, t)$- water storage coefficient changed along with time and water level.

Coal mine underground reservoir capacity calculation model

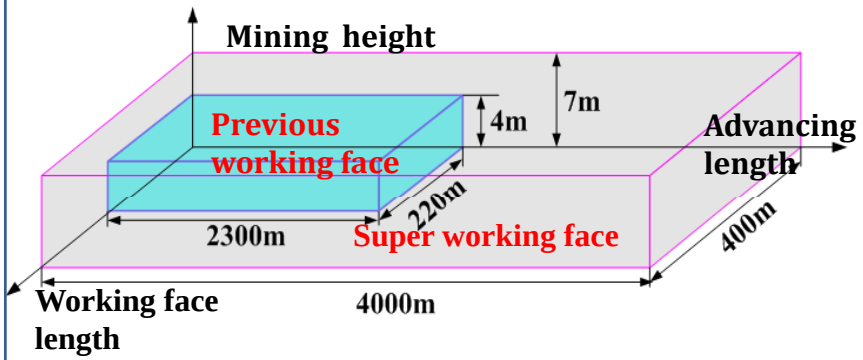


Calculation of coal mine underground reservoir capacity

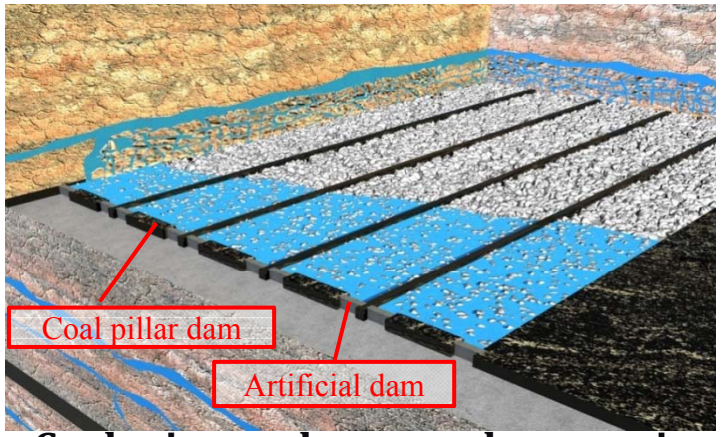
III. Technology Innovation: Reservoir Capacity Design

- **A technology for increasing coal mine underground reservoir capacity was developed.**

  - Mining technology for the super working face has been developed, which can increase reservoir capacity by a factor of **2–3.**
  - Multiple goafs can be combined to form the coal mine underground reservoir, which can increase reservoir capacity by a factor of **4–8** compared to a single goaf storage facility.



Sketch for Super Working Face

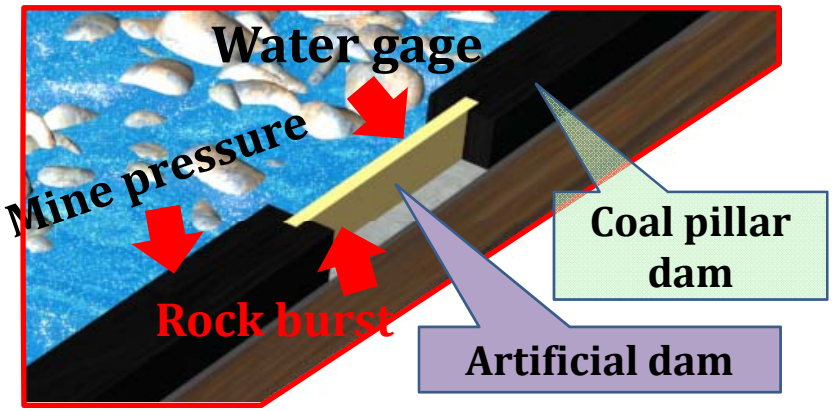


Coal mine underground reservoir composed of multiple goafs

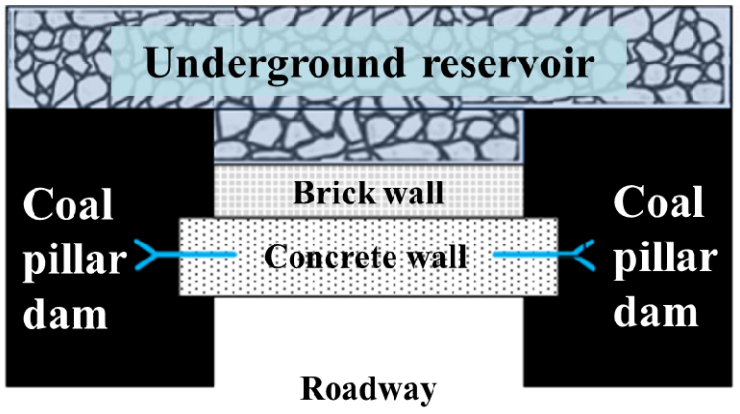
Ⅲ. Technology Innovation: Dam Construction

■ Dam construction technology was developed

- Underground reservoir dams are composed of the **coal pillar dam** and the **artificial dam**, which is **not continuous, heterogeneous, varies by section**, and is affected by rock pressure, water pressure, mine vibration and other factors.
- In order to ensure safety at the joint, a coal pillar and artificial dam **cutting and connecting process** and specialized equipment were researched & developed.



Dam Structure and Stress

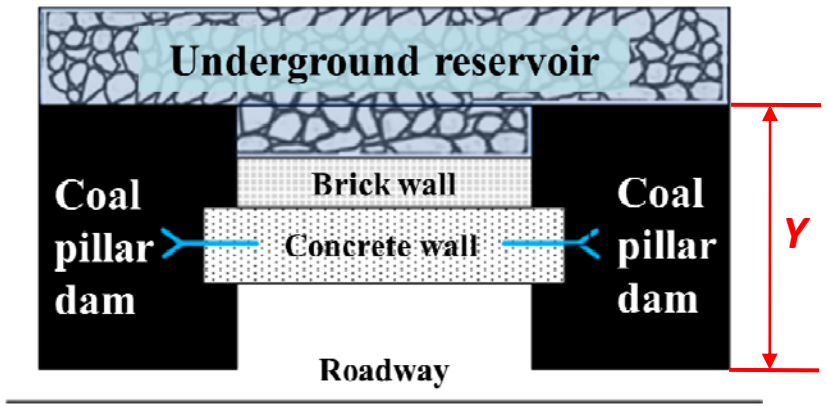


Artificial Dam Construction

III. Technology Innovation: Dam Construction

■ Three major dam parameters have been put forward

- The first is the establishment of a calculation method for the coal pillar dam width.
- The width of coal pillar dam is **20~30 m.**



Dam Parameters: Coal Pillar Dam Width

$$Y = X_0 + KM + X_1$$

X_0,X_1-plastic zone

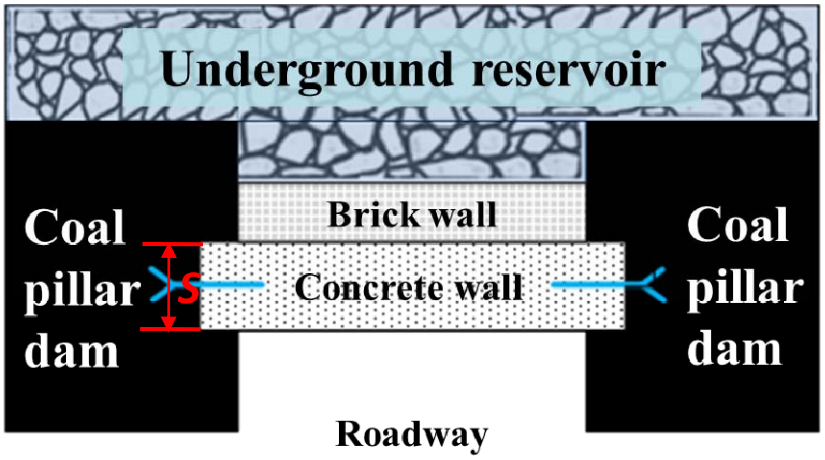
K-adjustment coefficient

M-coal seam thickness

Coal Pillar Dam Width Calculation Model

III. Technology Innovation: Dam Construction

- The second is the calculation method of the thickness of artificial dam.
- The thickness of artificial dam is about **1m** in the Shendong coal mining area.



Dam Parameters: Artificial Dam Width

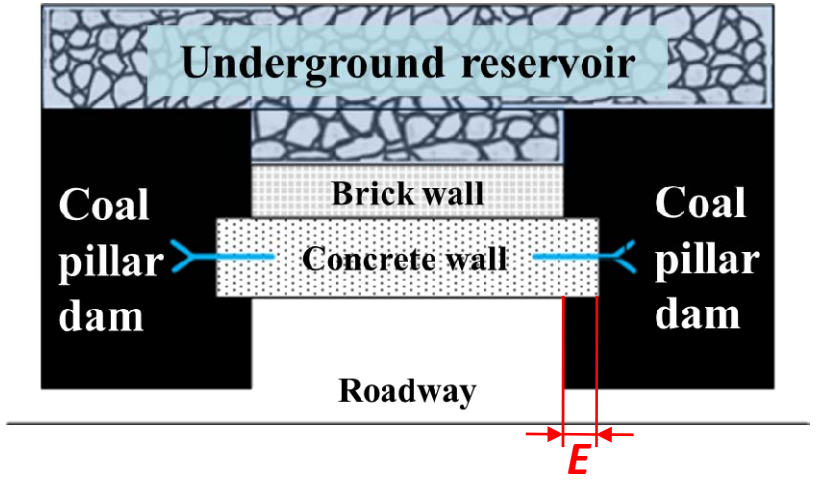
$$S = \frac{K_1 P F}{\tau L}$$

S-artificial dam thickness (m);
K_1-adjustment coefficient;
P-anti-water pressure strength (MPa);
F-dam sectional area (m^2); τ-shearing strength (MPa); L-cut perimeter (m)

Artificial Dam Width Calculation Model

III. Technology Innovation: Dam Construction

- The third is the calculation of the depth of the artificial dam and the coal pillar dam connecting chute
- The depth is **0.3–0.5m** in the Shendong mining area



Dam Parameters: Connecting Chute Depth

$$E = \frac{K_2 PF}{\delta L}$$

E-depth of wall embedded into the surrounding rock (m); K_2-adjustment coefficient; P-water pressure resistance (MPa); F-dam sectional area (m^2); L-cut perimeter (m); δ- lower artificial dam and coal pillar dam ant-pressure strength (MPa).

Connecting Chute Depth Calculation Model

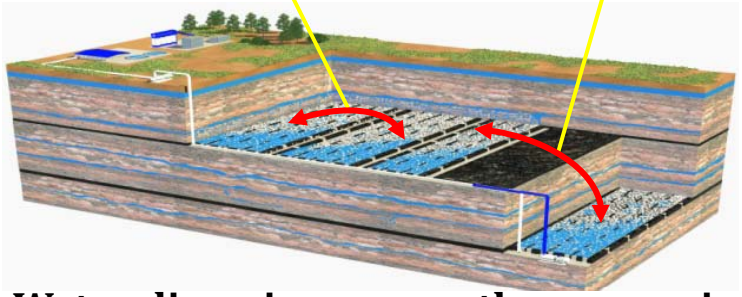
III. Technology Innovation: Safety Guarantee

- An coal mine underground reservoir **safety triple-prevention and control technology** has been researched & developed.

> - The first safety step in prevention and control is to control the water levels of the reservoirs through **water diversion among the reservoirs.**

Water diversion among the reservoirs on **same coal seam**

Water diversion among the reservoirs on **different coal seams**



Water diversion among the reservoirs to guarantee reservoir safety

Safety control center for the underground reservoir

III. Technology Innovation: Safety Guarantee

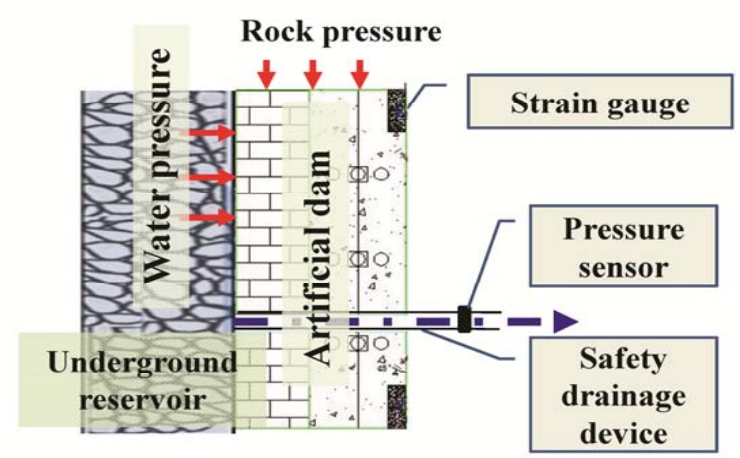
- The second safety step in prevention and control is to **monitor any stress and deformation** of the dam weak link to ensure the dam safety.

Ensuring dam safety

Monitoring device for the dam

III. Technology Innovation: Safety Guarantee

- The third prevention and control step is to **install the emergency drainage devices on the artificial dams**. The installed emergency drainage device is used for drainage and pressure reduction under emergency situations, such as mine earthquakes, ground pressure impacts, etc. to ensure the reservoir safety.

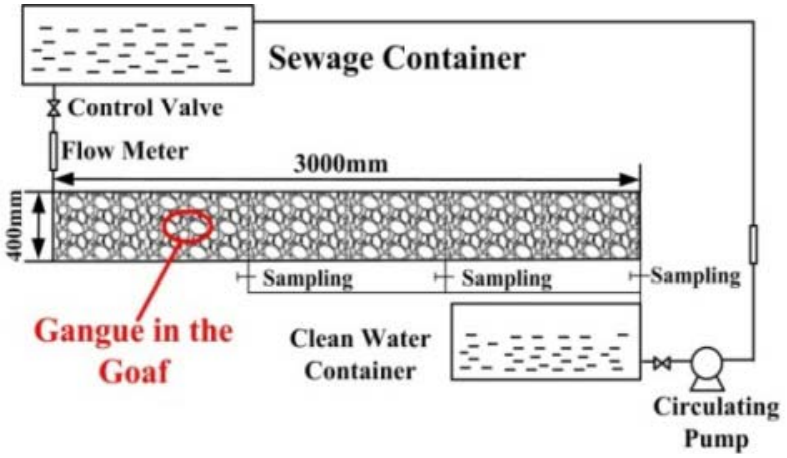


Guarantee of the reservoir safety under exceptional circumstances

Emergency discharge controller

III. Technology Innovation: Water Quality Control

- The purification mechanism of mine water has been developed, which is carried out by rock masses in the goaf, **including filtering and precipitation, rock mass adsorption, ion exchange**, etc.
- Principal pollutants are clearly removed through purification by the rock masses.



Test Device for Mine Water Purification

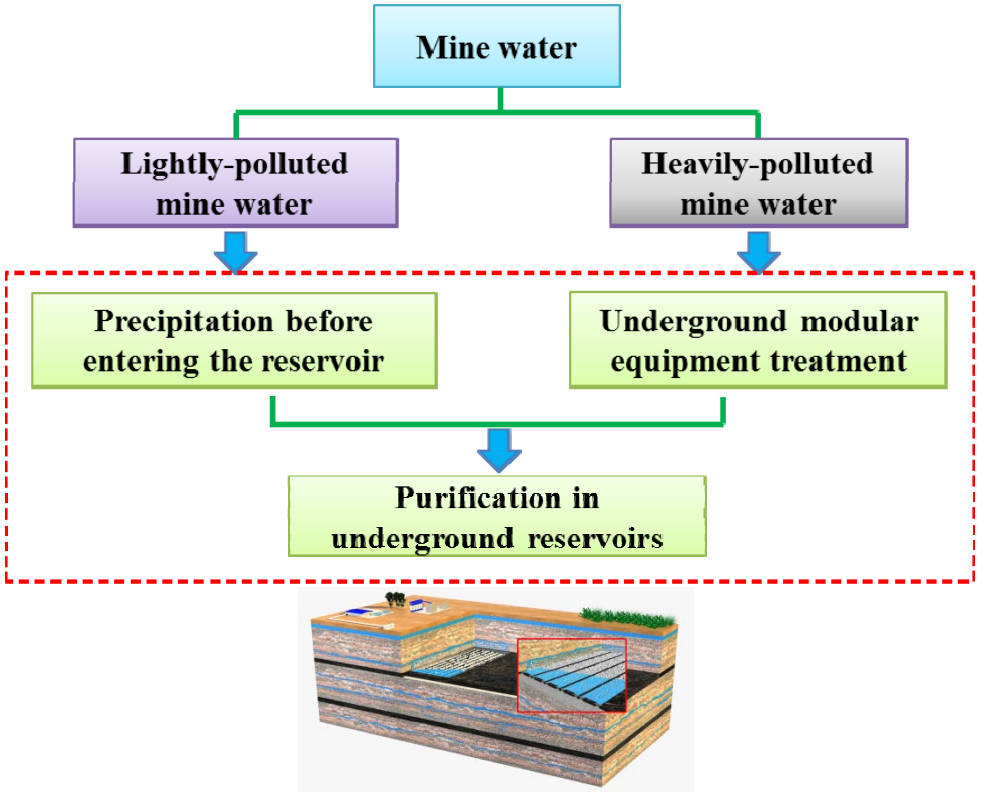
Removal Effect of Main Pollutants

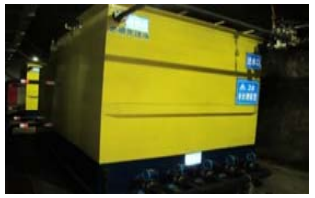
	Effluent Quality	Standard	Removal
Suspended (mg/L)	5–15	≤30	60–95%
COD (mg/L)	7.8–31	≤50	60–86%
Hardness (mg/L)	206–334	≤450	8–40%

III. Technology Innovation: Water Quality Control

- A coal mine underground reservoir **"three-in-one" technology** has been researched & developed. This includes filtering and precipitation before the mine water enters the reservoirs, natural purification in the reservoirs, and downhole modular processing.

Precipitation before the mine water enters the reservoir





Underground modular processing

"Three-in one" Mine Water Quality Control Technology

Outline

Ⅳ. Demonstration and Commercialization

■ **The development process of the mine water underground storage technology in Shenhua Group**

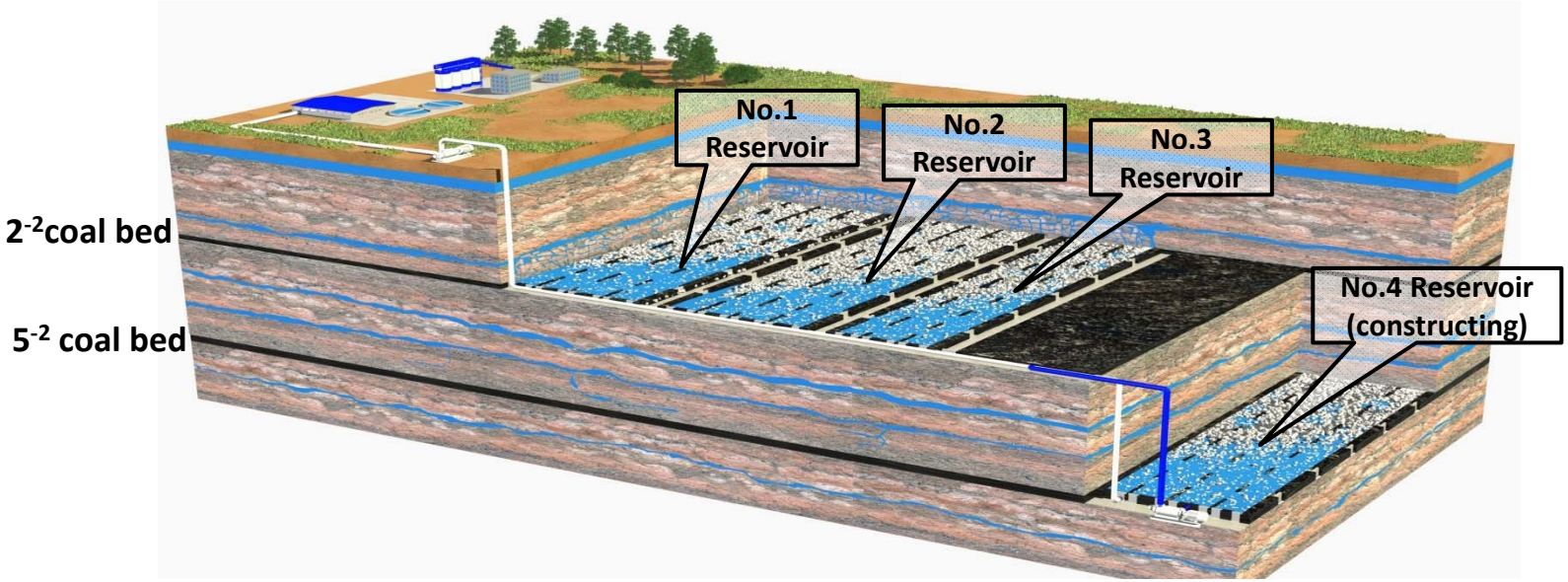
■ The mine water underground storage technology has developed step by step and the volume of stored has increased continuously over the last 20 years.

- **In 1998**, we built the first goaf water storing facility and proved the feasibility of storing mine water underground.
- **In 2006**, we built the first coal mine underground reservoir composed of several goafs and increased the reservoir capacity significantly.
- **In 2010**, we built the first distributed coal mine underground reservoir and realized zero discharge of water from the mine.
- **In 2014**, there were 32 coal mine ground reservoirs in Shendong Mining Area with the total water reservoir capacity of 31 million m^3 .

Ⅳ. Demonstration and Commercialization

■ The distributed coal mine underground reservoir demonstration project

- The first distributed coal mine underground reservoir project, which is composed of 4 reservoirs with water reserve of 2.35 million m^3, was built in Daliuta coal mine in 2010.
- The water storage for the distributed coal mine underground reservoir has now reached 7.1 million m^3 and zero discharge of mine water has since been realized.

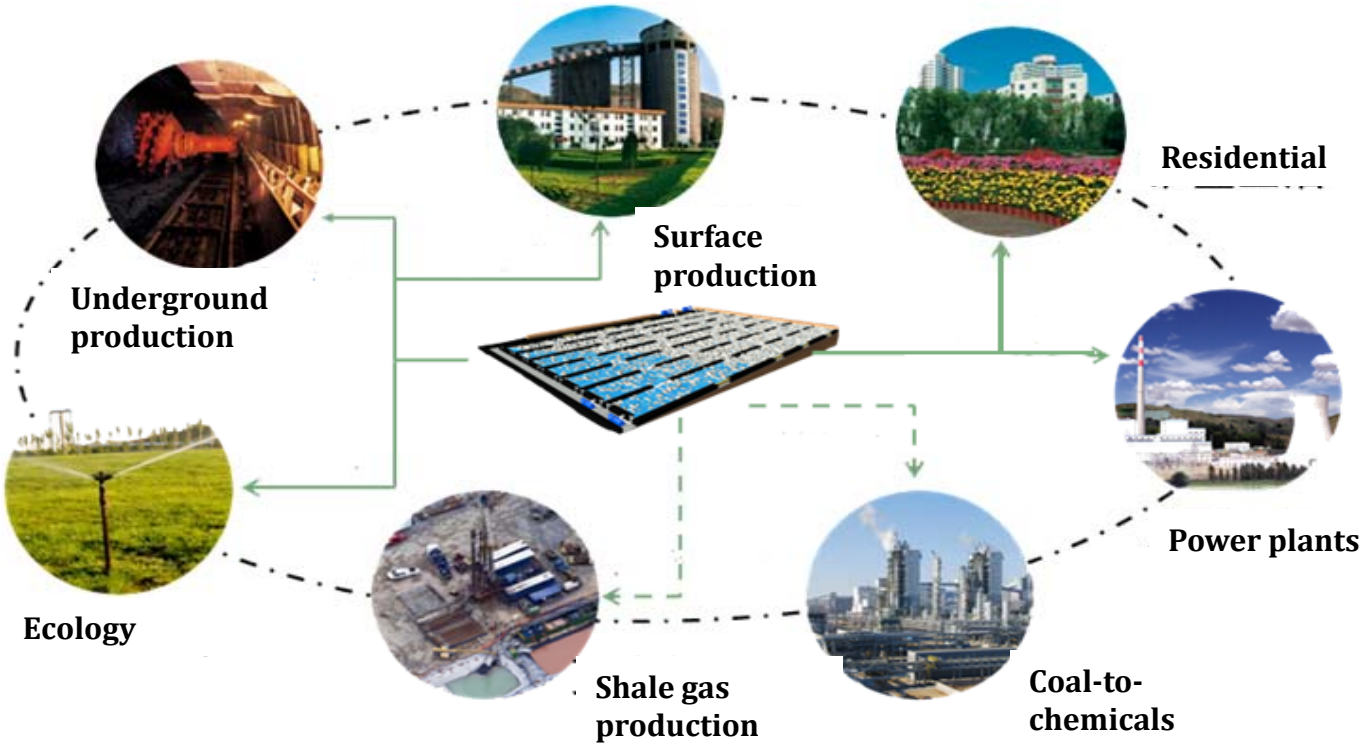


The distributed coal mine underground reservoir in Daliuta Mine

Ⅳ. Demonstration and Commercialization

■ Coal mine underground reservoirs in Shendong coal field

- The underground reservoirs provided over 40 million m^3 water in 2013 and met over 95% of the total water demand in the Shendong Mining Area.
- The underground reservoirs also supplies water for the power plants nearby and is about to supply the water for the coal–to-liquids project (35,000 m^3 /d).



The mining area has transitioned from being a water consumer to a water supplier.

Ⅳ. Demonstration and Commercialization

- **The Chinese Ministry of Land and Resources has listed the coal mine underground reservoir as a technology recommended for commercialization.**

中华人民共和国国土资源部
Ministry of Land and Resources of the People's Republic of China

首 页 | 要闻播报 | 领导活动 | 政策解读 | 图片新闻 | 视频新闻 | 政府会议 | 部委动态 | 地方动态 | 直属单位
评 论 | 通知公告 | 土地新闻 | 地质调查 | 地质勘查 | 地质环境 | 矿业新闻 | 海洋新闻 | 测绘新闻 | 科技新闻

当前位置:政务公开 > 通知公告

国土资源部关于《矿产资源节约与综合利用先进适用技术推广目录和汇编（第二批）》的公告

2013-07-12 | 来源：矿产资源储量司 | 【大 中 小】【打印】【关闭】

2013年第11号

为推广矿产资源节约与综合利用先进适用技术，提高矿产资源开采回采率、选矿回收率和综合利用率，促进矿产资源合理开发利用，加快矿业发展方式转变，提升生态文明建设水平，国土资源部组织制订了《矿产资源节约与综合利用先进适用技术推广目录和汇编（第二批）》，现予以公告。

2013年7月2日

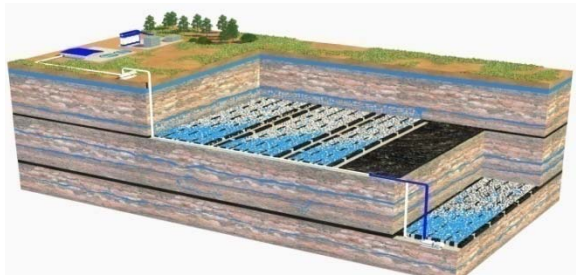
附件：

1、矿产资源节约与综合利用先进适用技术推广目录（第二批）.xls

2、矿产资源节约与综合利用先进适用技术汇编（第二批）.doc

Coal mine underground reservoir technology

矿产资源节约与综合利用先进适用技术汇编（第二批）



Ⅳ. Demonstration and Commercialization

■ International peer comments

"Water is a precious resource especially in arid regions. Shenhua has implemented an innovative solution to water scarcity at its coal mines by storing billions of litres of water in underground facilities. Water that would otherwise be lost to evaporation is instead available for local industry and agriculture. This is an excellent example of sustainable development in practice in the coal industry."

Harry Kenyon-Slaney

Chairman, World Coal Association

Chief Executive, Rio Tinto Energy

- The technology was presented at the WCA workshop in May, 2014 and received many positive comments.
- WCA has made a decision to carry out a case study and help with global commercialization.

Outline

Ⅴ. Conclusions

- Water resource protection and utilization is strategically important for sustainable coal mining in western China.

- The theory framework and technology system for coal mine underground reservoir have been built based on 20 years of research and development.

- According to the practice of Shenhua Group, it has been proven that coal mine underground reservoir technology is an efficient way to protect and utilize mine water with large social and economic benefits with potential for wider application.

Thanks for your attention