# Progress and Prospect of Mined Land Reclamation in China


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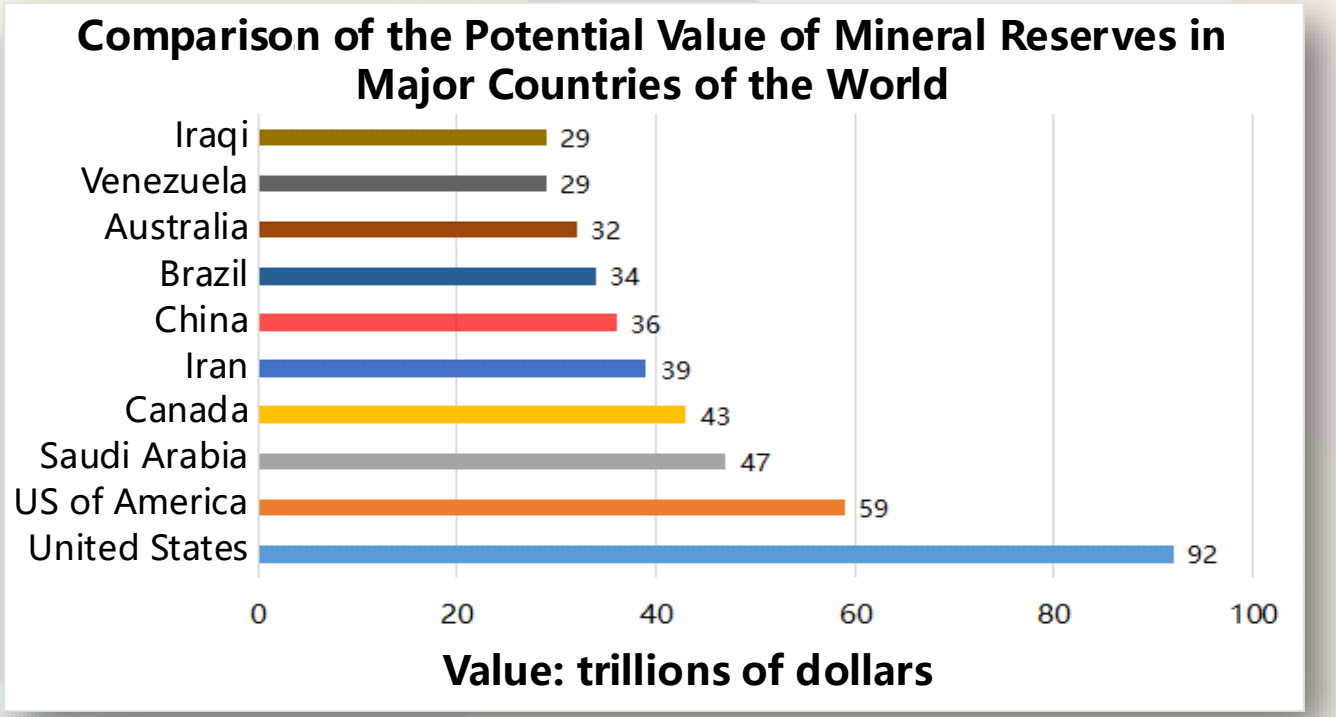
# CONTENTS

# 01 Background

# 1.1 The importance of mineral resources

- **Mineral resources are fundamental material basis for human beings' life and social and economic development.**
- **More than 92% of primary energy, 80% of industrial raw materials, and over 70% of agricultural production materials come from mineral resources.**

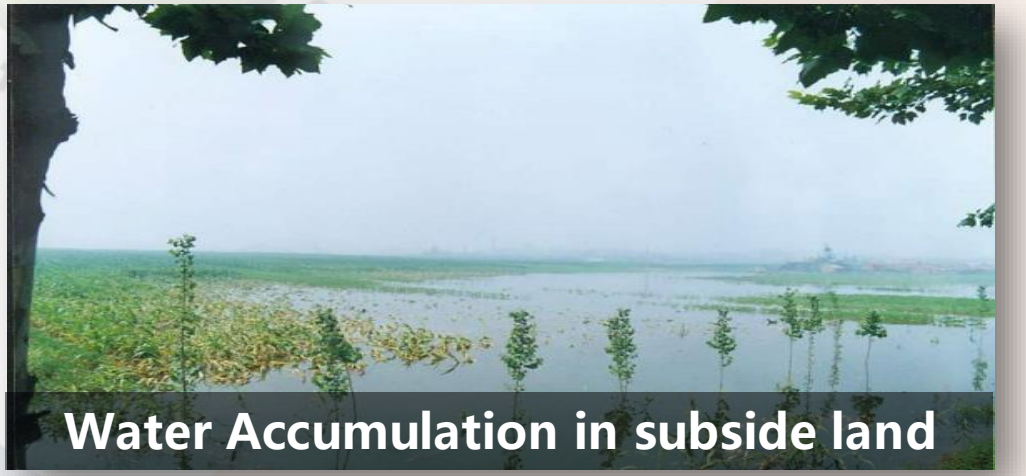


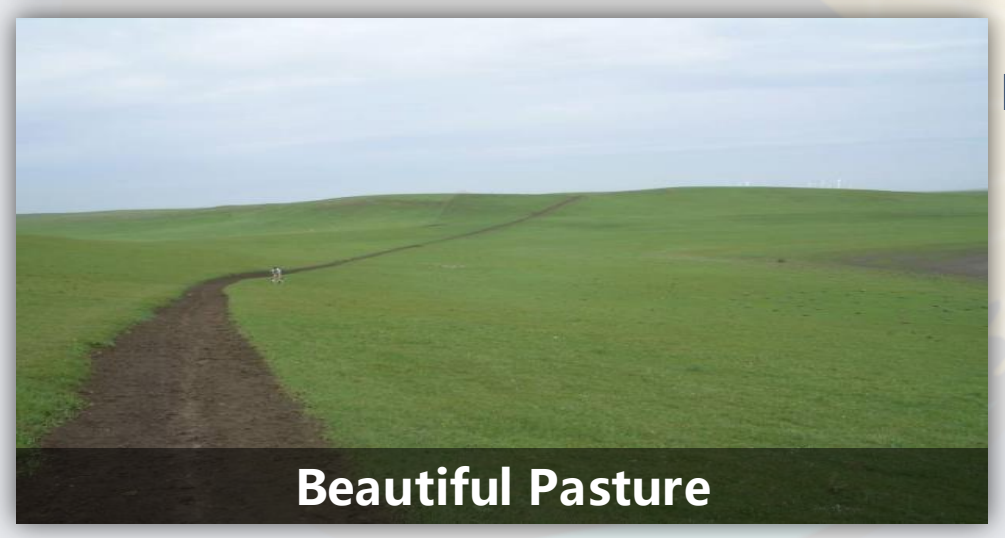
# 1.2 Mineral resources are buried deep underground, which extraction inevitably damages the environment


Rich Farmland

Mining Activity

Loss of farmland and grassland


Water Accumulation in subside land


Beautiful Pasture


Abandoned Open-pit

# Soil and water contamination

Acid Mined Drainage (AMD)

Brown Field-Abandoned Mine

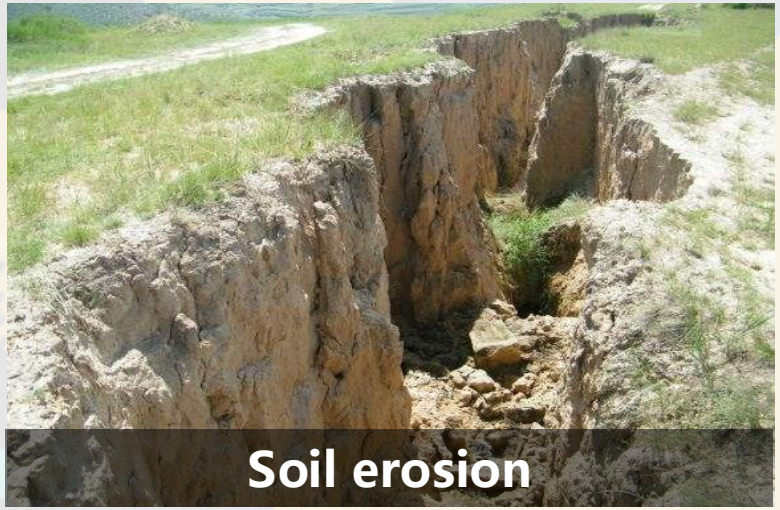
# Geo-environmental problems, soil erosion and air pollution

Dust from mining areas

Spontaneous combustion and explosion of coal gangue heaps

Surface cracks

Water resource destruction



Soil erosion

Mining-induced landslides

- Coal is the most important energy source in China.
- Damaged land and ecological environment.
- It affect directly ecological safety, food security, and the "Dual Carbon" goals.






**Loss of greenery, loss of carbon sinks, release of carbon dioxide**

# 1.3 The ecological and environmental issues have become a hard constraint for mining industry

- The national green development strategy and strict environmental regulations have led mine ecological and environmental issues being a hard constraint for mining industry.

- Chinese governments and leaders have gaven high priority to land and environment protection. —— 3 remediation engineering: blue sky, clear water and clean soil

- China has large population with shortage of farmland. The damage of farmland due to mining caused conflicts between farming and mining.


Clear water and green mountains are invaluable assets

**Mined land reclamation has become an important task in China!**

# 02 Progress

# 2.1 History of Mined Land Reclamation in China

- *The four stages of history for land reclamation and ecological restoration in China*

# 2.1 History of Mined Land Reclamation in China

## Sprouting Stage（1980-1989）

- Translation and introduction of foreign reclamation, e.g. Book “Surface mined land reclamation” published in 1982.
- **Project:** “Six-Five Science and Technology Research Project” - “Research on Comprehensive Reclamation for Coal Mining Subsidence Land”.
- **Academe:** The first MS student in the field of land reclamation in China graduated from China University of Mining and Technology in 1988.
- **Society:** “China Land Reclamation Society” was established in 1985.



**Milestone: The implementation of the "Stipulation on Land Reclamation“ in 1989 was the first milestone of land reclamation and ecological restoration in China.**

# 2.1 History of Mined Land Reclamation in China

## First reclamation research project and practice in China（1983-1986）

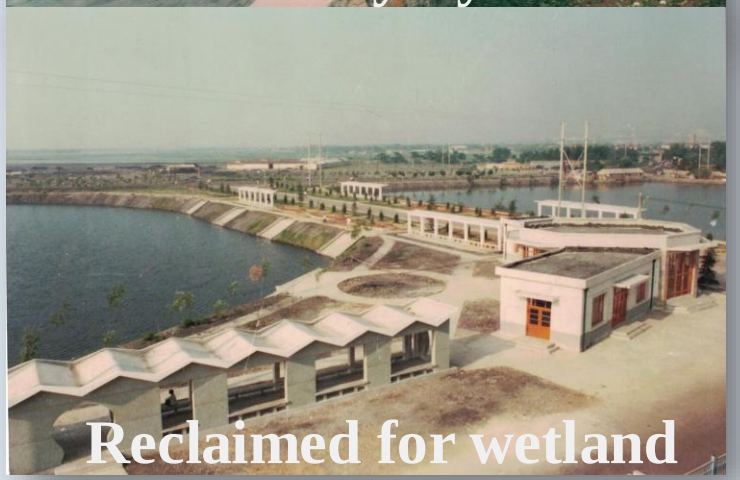

hydraulic dredge pump


Filled by coal gangue


Filled by fly ash


Reclaimed for construction


Reclaimed for buildings


Reclaimed for wetland

# 2.1 History of Mined Land Reclamation in China

## Initial Stage（1990-2000）

- **Focus:** On the exploration of the basic concepts and fundamental issues of the discipline. “On land reclamation science” and “The basic principles and methods of soil profile reconstruction for coal mine reclamation” were proposed in 1993 and1997.
- **Practice:** The large-scale reclamation practice and commended on excellent cases in China.
- **Technology:** Made in-depth study on coal mining subsidence land reclamation.
- **Academe:** The first Ph.D. student in the field of land reclamation in China graduated in China University of Mining and Technology in 1991 (China-USA Joint Training).

**Milestone: The First Beijing International Symposium on Land Reclamation was held in 2000, hosted by China Land Science. Secretary of the symposium was Dr. Hu.**

# 2.1 History of Mined Land Reclamation in China


**The first PhD in the field of land reclamation in China was trained by China University of Mining and Technology (China-USA joint training, 1991).**

# 2.1 History of Mined Land Reclamation in China

## Initial Stage（1990-2000）


The First Beijing International Symposium on Land Reclamation in 2000
Mr. William Plass, Dr. Shuman and Jack Nawrot attended this meeting

# •2.1History of Mined Land Reclamation in China

## Development Stage（2001-2007）

- **Focus:** On the research of the quality on the reclaimed soil and the concepts and methods of soil reconstruction (2005).
- **Technology:** Comprehensive and in-depth research to achieve technological breakthroughs in land reclamation in the east-central China. Got National Science and Technology Progress Award in 1994.
- **Hotspot:** Coal mining subsidence land reclamation and revegetation of coal waste piles.


**Milestone: Making land reclamation plan was required in mining permission and land use approvals in 2007.**

# Development Stage （2001-2007）


**Zhenqi Hu gave a presentation and met Mr. Plass at the ASMR meeting, Lexington, KY in 2002.**

# • Communications and Cooperation in Land Reclamation between China and the United States

## Development Stage （2001-2007）

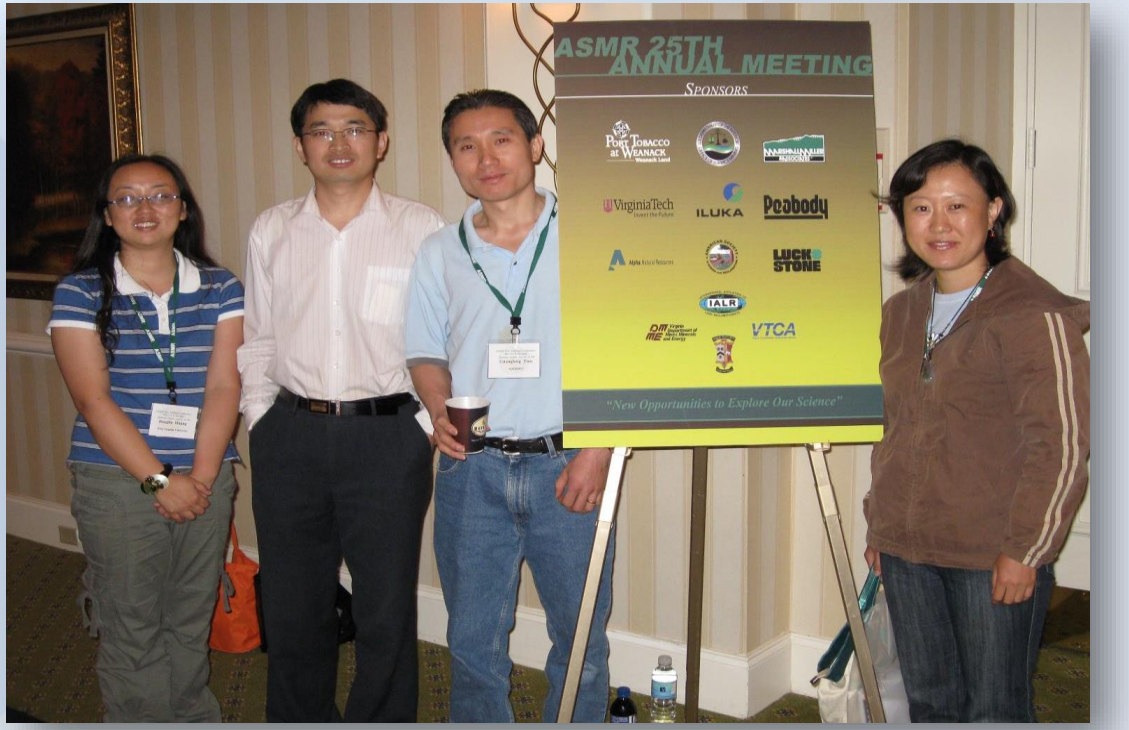

Prof. Barnhisel, Executive Secretary of ASMR, visited reclamation site in Jiawang, Xuzhou in 2002.

# Development Stage（2001-2007）



The 1st International Forum on Ecological Construction of Beijing in 2005.

# Development Stage （2001-2007）


**Zhenqi Hu's students, Mingliang Zhang Yu & feng Hao, and other Chinese students took part in the 25th ASMR Gillette, WY in 2007**

# Development Stage（2001-2007）


Group photo of Hu Zhenqi's research team with Louis Macdonald at CUMTB in 2007.

# 2.1 History of Mined Land Reclamation in China

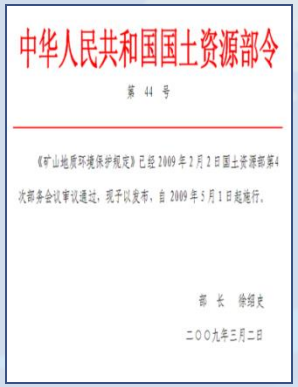
## Rapid Development Stage（2008-Pre）

- **Focus:** On the introduction of new concepts and technologies for land reclamation and ecological restoration.
- **Technology:** The breakthrough results of land reclamation and ecological restoration technologies in western ecologically fragile areas.
- **Laws and regulations:** the promulgation of the Regulations on Land Reclamation and the emergence of related standards and regulatory methods.

"Professional Committee on Land Reclamation and Ecological Restoration of Coal Mines"


试论井工煤矿边开采边复垦技术

Concurrent mining and reclamation for underground coal mining


中华人民共和国国土资源部令

第 44 号

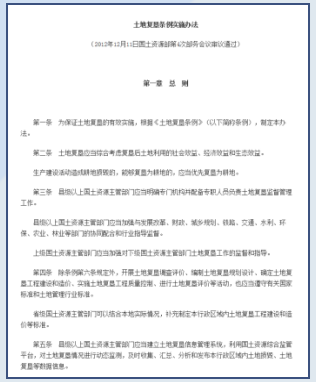
《矿山地质环境保护规定》已经2009年2月2日国土资源部第4次部务会议审议通过，现予以发布，自2009年5月1日起施行。

部 长 徐绍史

二〇〇九年三月二日


土地复垦条例

中国法制出版社


土地复垦条例实施办法

（2012年12月1日国土资源部部务会议审议通过）

第一章 总 则

第一条 为保证土地复垦的有效实施，根据《土地复垦条例》（以下简称条例），制定本办法。

第二条 土地复垦应当综合考虑复垦后土地利用的社会效益、经济效益和生态效益。

生产建设活动造成耕地损毁的，起码复垦为耕地的，应当优先复垦为耕地。

第三条 县级以上国土资源主管部门应当明确有关机构和配备专职人员负责土地复垦监督管理工作。

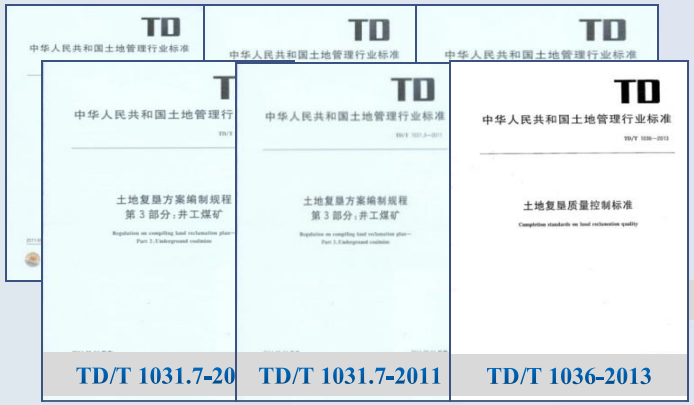
县级以上国土资源主管部门应当加强与发展改革、财政、城乡规划、铁路、交通、水利、环保、农业、林业等部门的协同配合和行业指导监督。

上级国土资源主管部门应当加强对下级国土资源主管部门土地复垦工作的监督和指导。

第四条 除条例第六条规定外，开展土地复垦调查评价，编制土地复垦规划设计，确定土地复垦工程建设和验收、实施土地复垦工程质量控制、进行土地复垦评价等活动，也应当遵守有关国家标准和土地管理行业标准。

省级国土资源主管部门可以结合本地实际情况，补充制定本行政区域内土地复垦工程建设和造价等标准。

第五条 县级以上国土资源主管部门应当建立土地复垦信息管理系统，利用国土资源综合监管平台，对土地复垦情况进行动态监测，及时收集、汇总、分析和报告本行政区域内土地损毁、土地复垦等的基础信息。



# Rapid Development Stage（2008-Pre）







Zhenqi Hu and his research team attended ASMR meetings in USA.

# • *Communications and Cooperation in Land Reclamation between China and the United States*

## Rapid Development Stage（2008-Pre）





**Foreign scholars attended international symposium on land reclamation in China.**

# • Communications and Cooperation in Land Reclamation between China and the United States

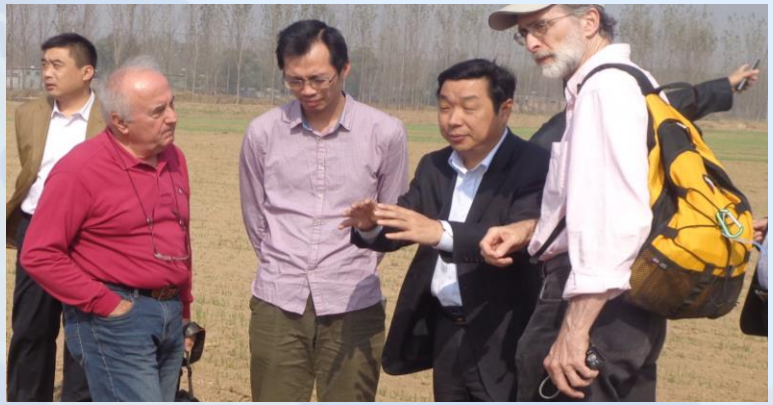
## Rapid Development Stage（2008-Pre）

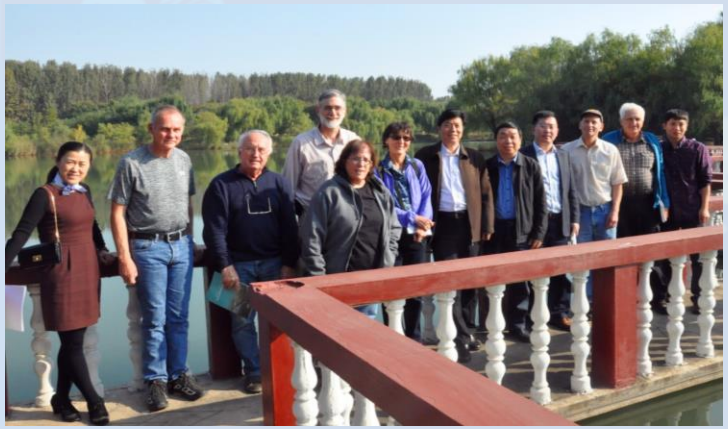



Foreign scholars gave lectures in China.

# • Communications and Cooperation in Land Reclamation between China and the United States

## Rapid Development Stage（2008-Pre）



Foreign scholars visited experiment plots of subsidence land reclamation in China.

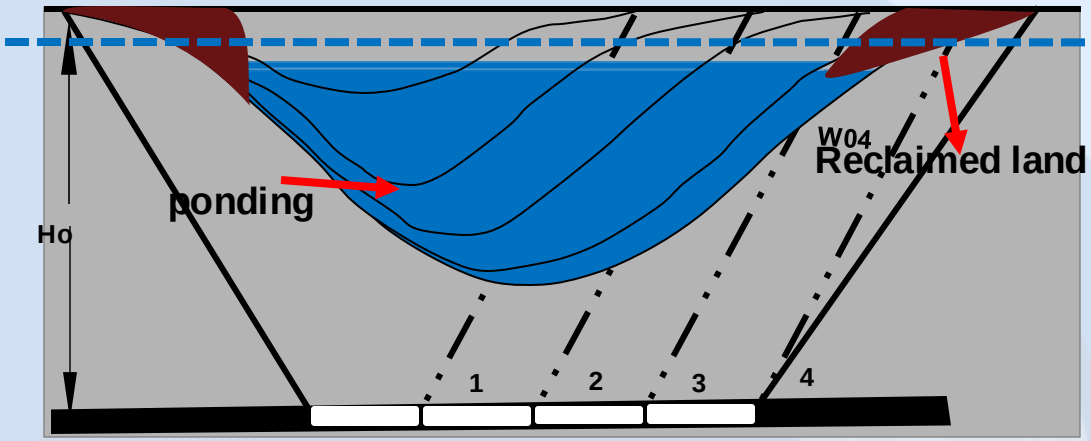
# 2.2 Progress of subsided Land Reclamation in China

- About 80% coal output and 94% coal mines are underground mining.
- Underground coal mining in China always use longwall mining method, which produced a lot of subsided land. So far, more than 2 million hectares land have been subsided, and an annual increase of subsided land is 70,000 hectares.
- There are many types of subsided land, especially in the eastern China with high underground water level， a lot of farmland lost due to water accumulation in subsidence trough. It is the difficulty and focus of land reclamation for farmland.

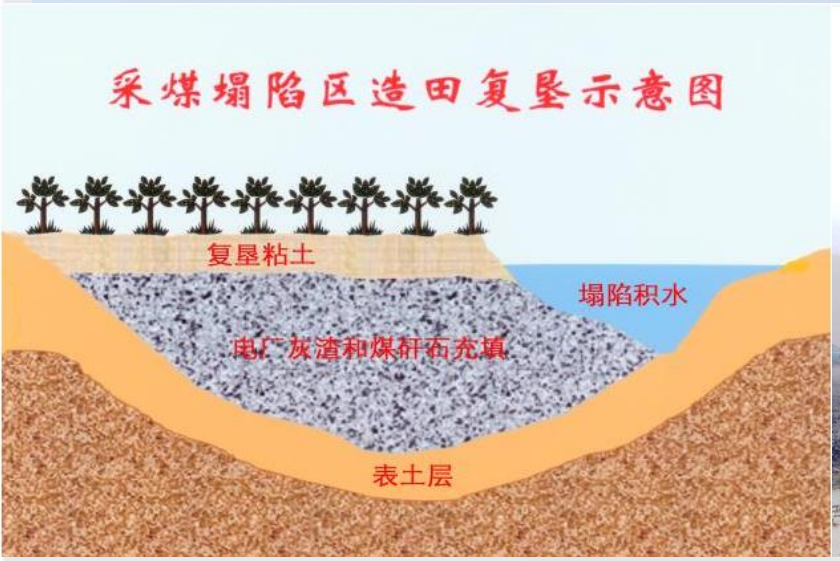
**Restoring subsided land with high underground water level to prime farmland is the most critical challenge for subsidence land reclamation.**

# 2.2 Progress of subsided Land Reclamation in China

## ◆ Traditional subsided land reclamation – end-of-pipe treatment

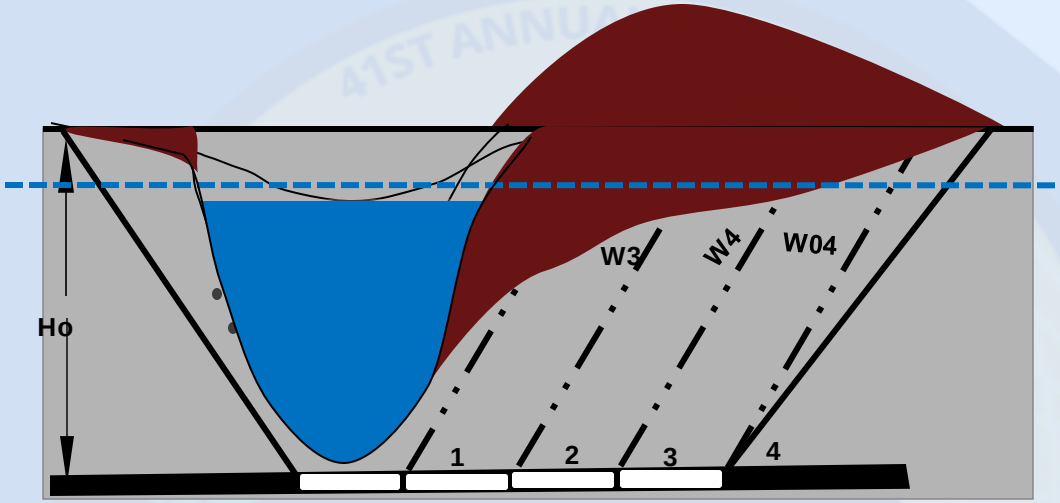








# 2.2.1 New Technology 1 —— Concurrent Mining and Reclamation




CMR reclamation

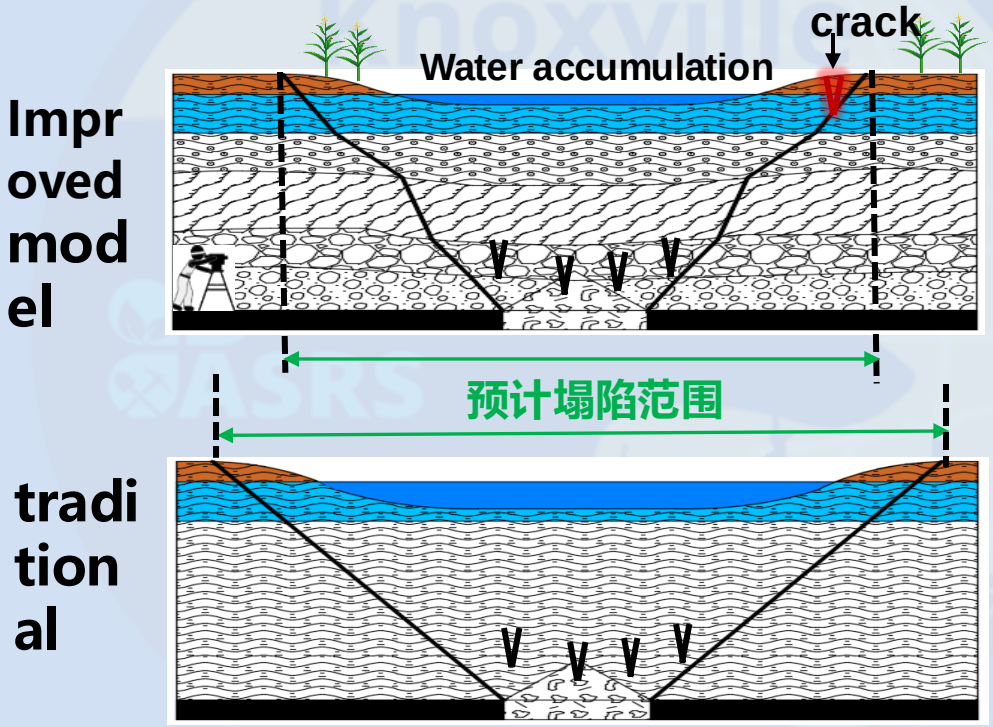
much more farmland could be restored, could increase more than 10%~40% farmland

**Keys of the technology**

- Predicting subsidence damage accurately
- Optimizing post mining land-use plan
- Determining the optimum reclamation time for CMR
- Making dynamic reclamation construction scheme, optimizing the elevation of reclaiming land

# 2.2 Progress of subsided Land Reclamation in China

**Key 1: Construction of a heterogeneous quantitative prediction model for layered deformation transfer from underground mining to the surface based on probability integral method, and establishment of a surface damage diagnosis model with underground-surface coupling.**




**Model for predication of subsided depth for any point**

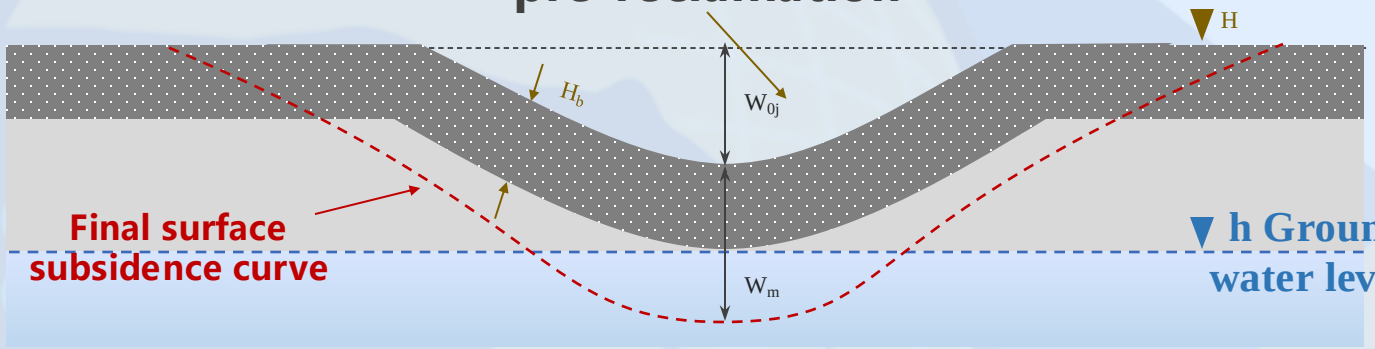
$$W_n(x) = q_n W_{n-1}(\infty)\left(\frac{1}{2}erf\left(\frac{\sqrt{\pi}x}{r_n}\right)+\frac{1}{2}\right)$$

**Prediction error reduced from over 20% to below 10%.**

# 2.2 Progress of subsided Land Reclamation in China

## ◆ Key 2: Optimum time for reclamation

Surface subsidence curves at the start of dynamic pre-reclamation



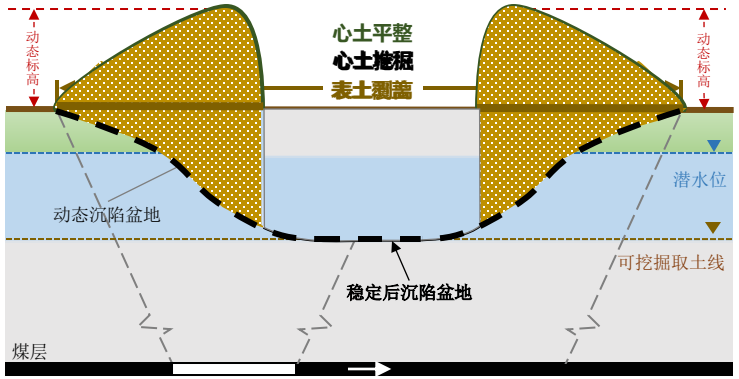

$$T \leq \frac{2H_0\left(1.03\frac{H-H_b-h_{潜水位}}{mq\cos\alpha}+0.08\sqrt{1.03\frac{H-H_b-h_{潜水位}}{mq\cos\alpha}-0.4}-0.4\right)}{tg\beta v}+t'$$

Reclamation timing preference method based on a critical waterlogging threshold plus constraints

# 2.2 Progress of subsided Land Reclamation in China

## ◆ Key 3: The dynamic elevation calculation model

### Dynamic Construction Process




### Subsoil Accumulation Elevation

$$H_d(x,y,td)=\begin{cases} H_0(x,y)-W(x,y,td)+\dfrac{1+Kd}{1+Kz}\left[H_R-h_B-H_0(x,y)-W(x,y,td)\right] \\ \quad +\dfrac{1+Kd}{1+Kz}\dfrac{6\iint_{D_C} W_0(x,y,tz)\text{-}W(x,y,td)dydx}{D_C+D_{CZ}+4D_{C0}} & (x,y)\in D_{CZ} \\ H_0(x,y)-W(x,y,td)+\dfrac{1+Kd}{1+Kz}\left[H_R-h_B-H_0(x,y)-W(x,y,td)\right] \\ \quad +\dfrac{1+Kd}{1+Kz}\dfrac{6\iint_{D_C} W_0(x,y,tz)\text{-}W(x,y,td)dydx}{D_C+D_{CZ}+4D_{C0}}\cdot\tan\theta\cdot\mathrm{d}(x,y) & (x,y)\in D_{CW}\cup D_{CN} \end{cases}$$

### Subsoil Accumulation Elevation

$$\begin{aligned} H_P(x,y,tp) &= H(x,y,tp)+\frac{1+Kp}{1+Kz}\left[H_R-h_B-H_0(x,y,tz)\right] \\ &= H_0(x,y)-W(x,y,tp)+ \\ &\quad \frac{1+Kp}{1+Kz}\left\{H_R-h_B-\left[H_0(x,y)-W_0(x,y,tz)\right]\right\} \end{aligned}$$

### Leveling Elevation After Topsoil Covering

$$H_{PB}(x,y,tp)=H_P(x,y,tp)+\frac{1+Kb1}{1+Kb2}h_B$$

**Overcame the dynamic elevation calculation model and construction technology considering future subsidence**

# 2.2 Progress of subsided Land Reclamation in China

## Engineering Application Results

**No reclamation measure**

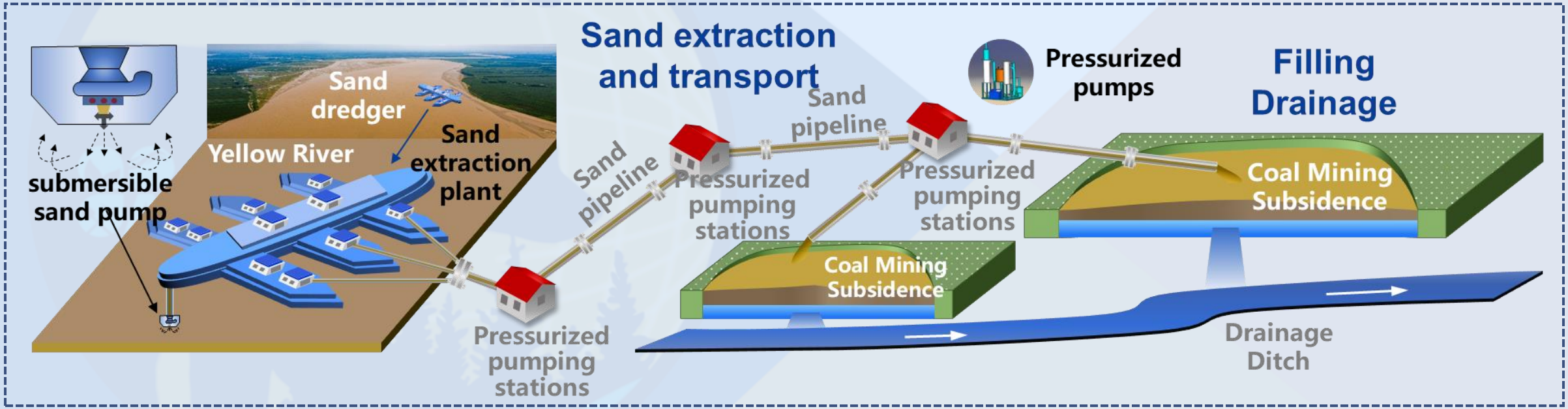
**Concurrent mining & reclamation**

Water region after reclamation  Arable land after reclamation

Compared to end-of-pipe treatment, it **restores 15% to 40% more arable land.**
This reclamation technology achieved “more arable land restoration”.

# 2.2.2 Reclaiming subsidence land with Yellow River Sediments

## Technological Processes



# *The technical process of filling reclamation of mining subsidence land with Yellow River sediment.*

Topsoil stripping

Prepare Filling strip

Taking sediment

Filling and drainage

Consolidation

Sediment leveling

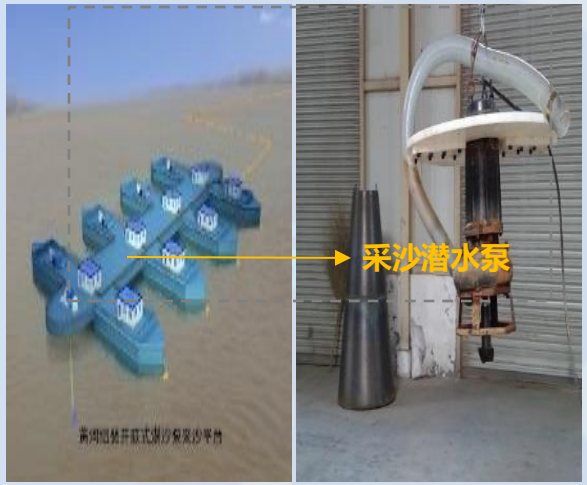
Topsoil covering

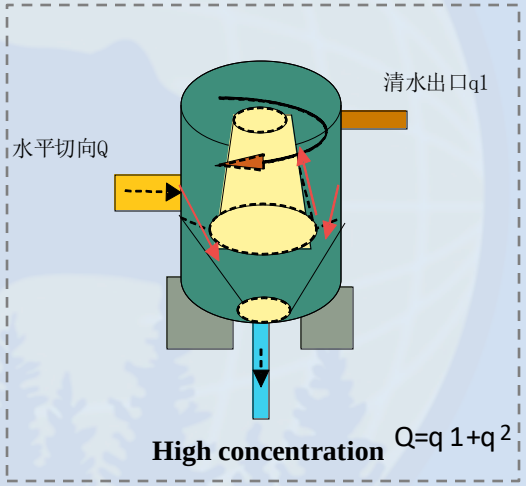
Land leveling

# 2.2 Progress of subsided Land Reclamation in China

## Key 1: The technology of sand extraction and transportation

**Extraction from the flowing water** → **Concentrator** → **Pressurised pumps for high concentrations** → **Pipeline transportation**

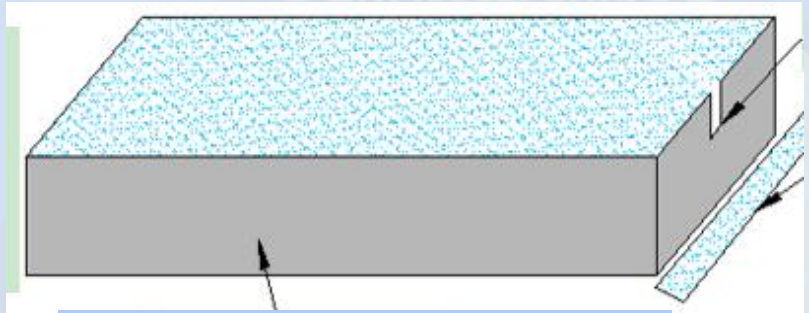



**Integrated approach on "submersible sand pump-concentrator-pressurised pump-pipeline"**

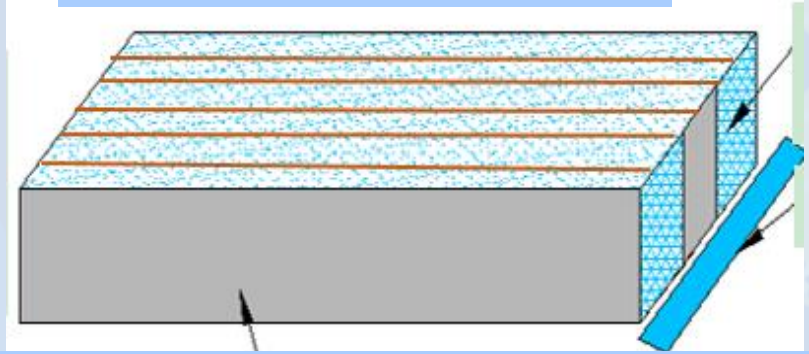
# 2.2 Progress of subsided Land Reclamation in China

## Key 2: New method on rapid separation, consolidation &drainage



Traditional filling in large area and drainage

Shallow and small drainage outlet,



new filling model by strips and drainage with geotextile

Full profile and big drainage outlet

# Key 3: New soil profile for reclaimed land filled with Yellow river sediments

Wheat field(normal control farmland )

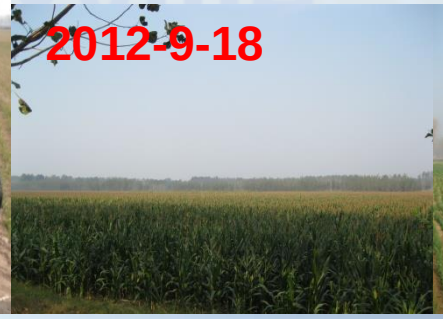
Grow well

Wheat field(reclaimed farmland )

Grow bad (not enough thickness of covering soil)

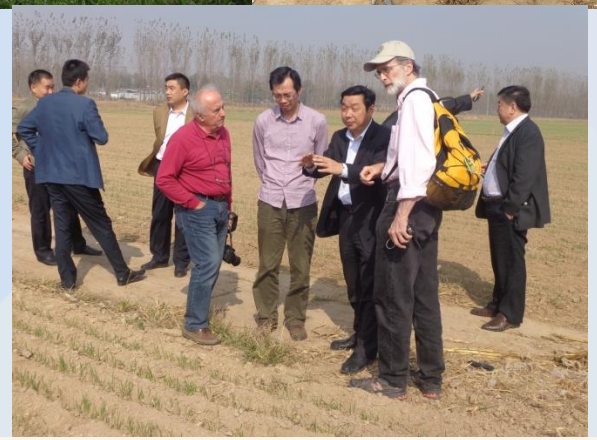
# 2.2 Progress of subsided Land Reclamation in China

## Key 3: New soil profile for reclaimed land filled with Yellow river sediments

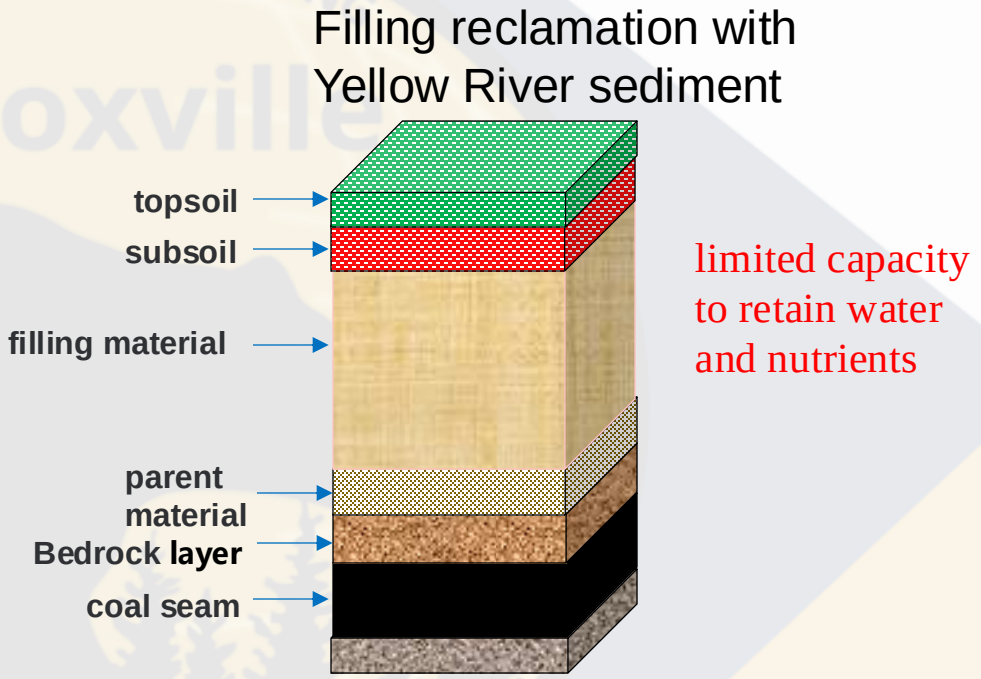






***Traditional filling reclamation method was: 1) stripping the soils to be reclaimed land; 2) filling the subsided land materials at once; 3) backfilling the soils. This kind of simple soil profile is an unfavorable profile type in pedology, resulting in poor productivity.***

**Topsoil is not good. Thickness of soil cover is not enough.**




limited capacity to retain water and nutrients

**Innovation needed**

Diagram of Traditional filling soil-sediment profiles

# Optimum thickness of soil cover?

*traditional profile "Yellow River sediment covered by soil*

Laboratory experiment ——The optimal thickness of soil in filling reclamation with Yellow River sediment

**Planting corns in laboratory:**

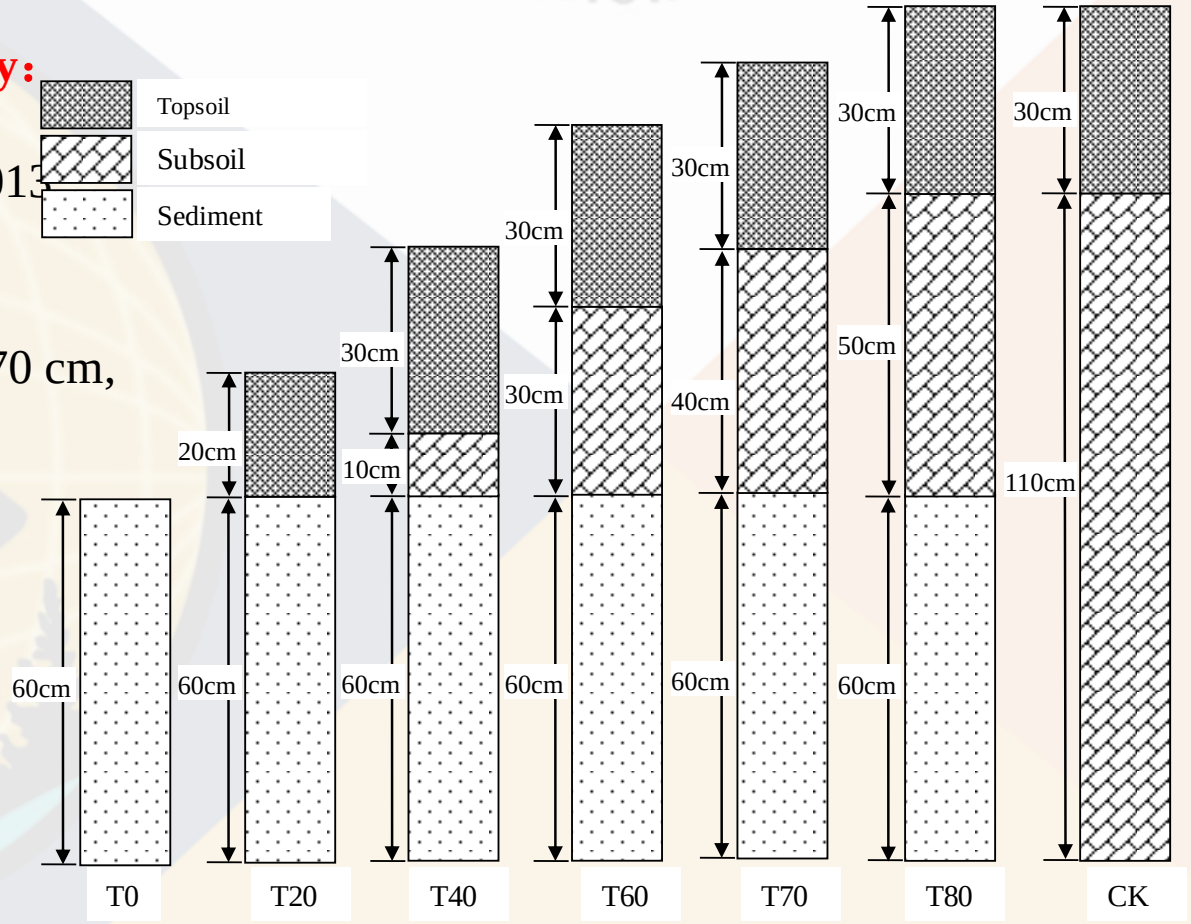
Form 04/25/2013 to 07/05/2013

**Soil thickness:**

0 cm, 20 cm, 40 cm, 60 cm, 70 cm, 80 cm, CK

**Stages:**

Seedling stage;
Elongating stage;
Flare opening stage;
Tasseling stage;
Flowering stage,
Then, stop the experiment.

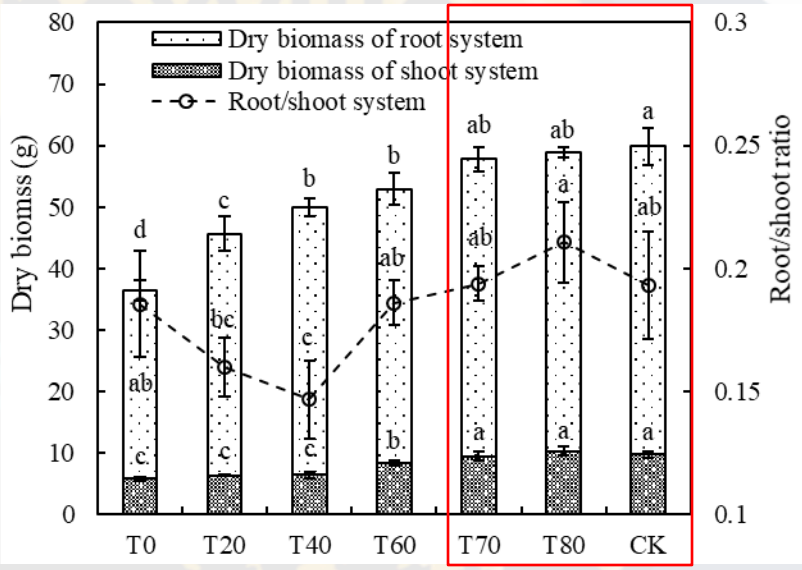



CK soil profile

# Optimum thickness of soil cover?

*traditional profile "Yellow River sediment covered by soil*

Laboratory experiment ——The optimal thickness of soil in filling reclamation with Yellow River sediment




T0 has the min dry biomass of root and shoot system is 30.72 g, 5.67 g, respectively.
CK has the max dry biomass of shoot system is 50.21 g.
T80 has the max dry biomass of root system is 10.24 g。

**If no enough soil for cover? How to handle this problem?**

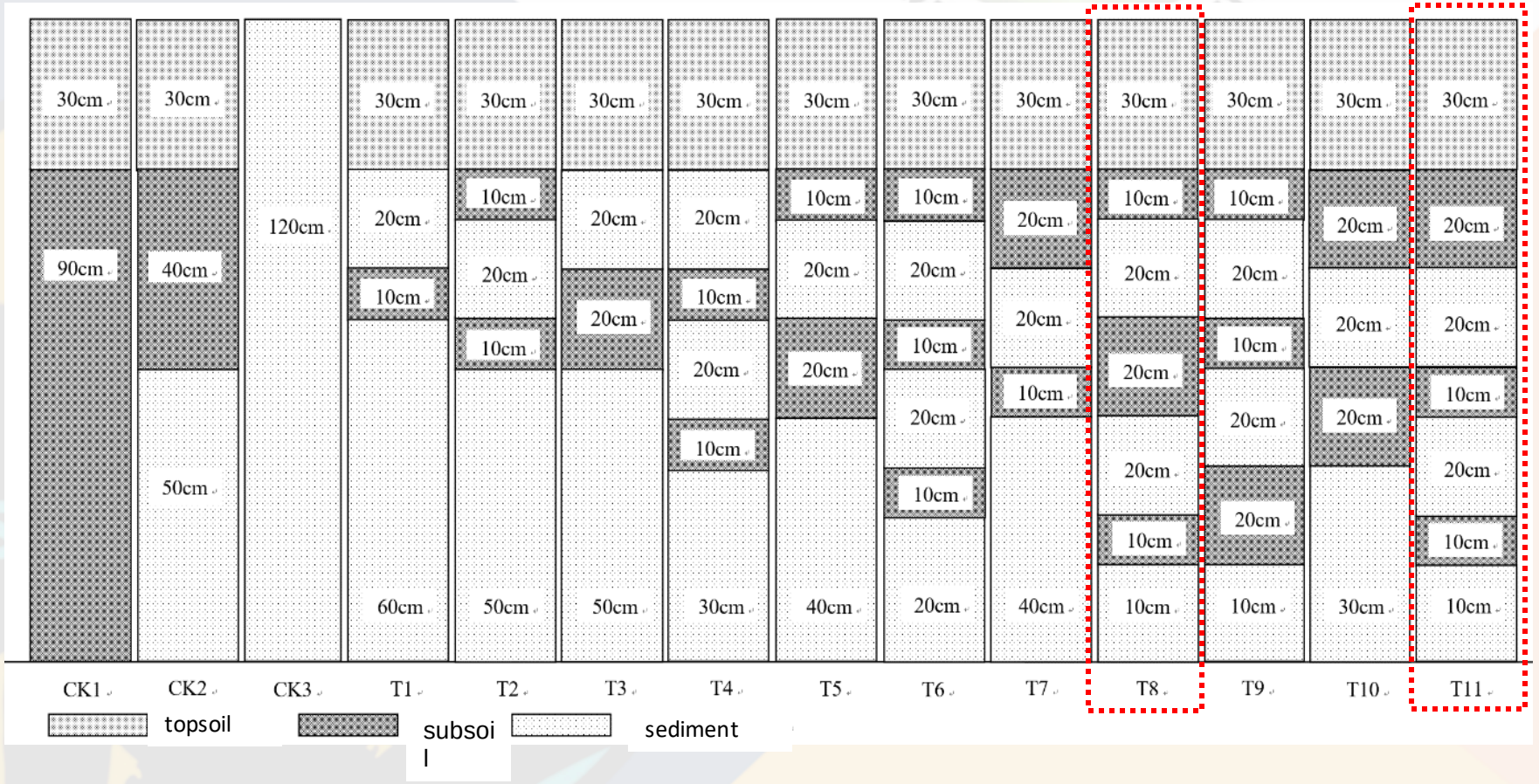
# A new reconstruction method for reclaiming subsided land with Yellow River Sediments

***New idea: sandwich profile***

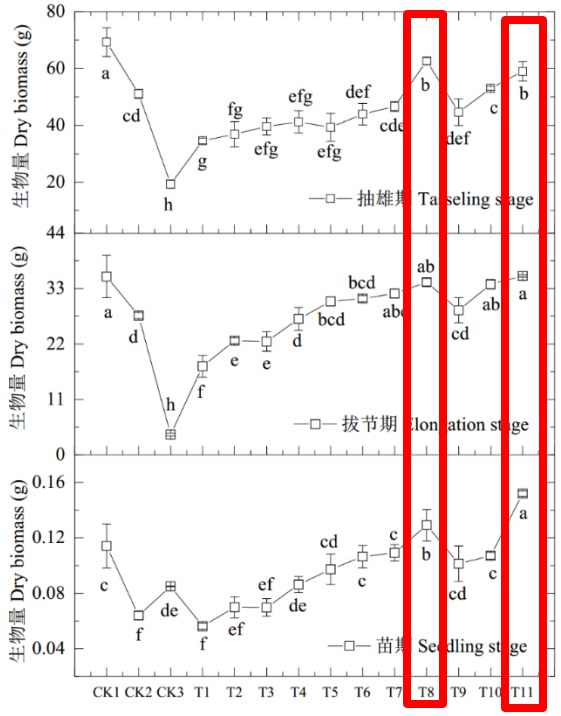
Multilayered soil profiles were favorable for maize growth, water-holding and storage capacity and nutrient preserving capability.

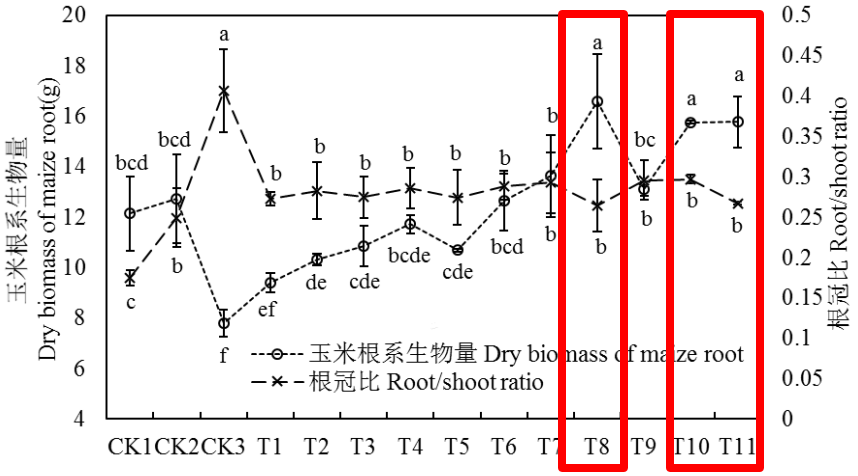

Diagram of multilayered soil-sediment profiles

# Laboratory simulation test




laboratory simulation test design of different multilayered soil-sediment profiles




Compared to CK1, T8, T10, T11 had an increase of dry biomass of root system at 36.64%, 29.78%, 29.96%.

**Results and Discussion：** Compared to CK2 (traditional soil reconstructed profile, i.e. filling materials of Yellow river sediment cover with 70cm soil), **T8 and T11 had an increase of 22.60%, 15.50% for plant growth, respectively**.

**The results illustrate that multilayer soil profiles were favorable for maize seed germination and root growth.**

# There was no difference between filling reclamation and normal farmland for the landscape.

Before filling reclamation

After filling reclamation

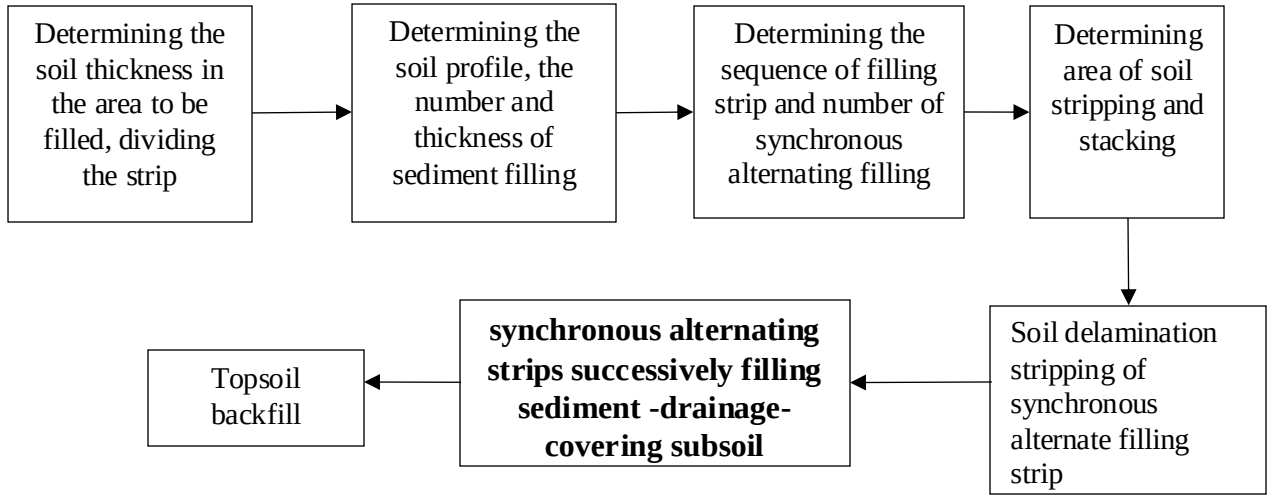
Achievement of more than 95% recovery of arable land without risk of pollution.

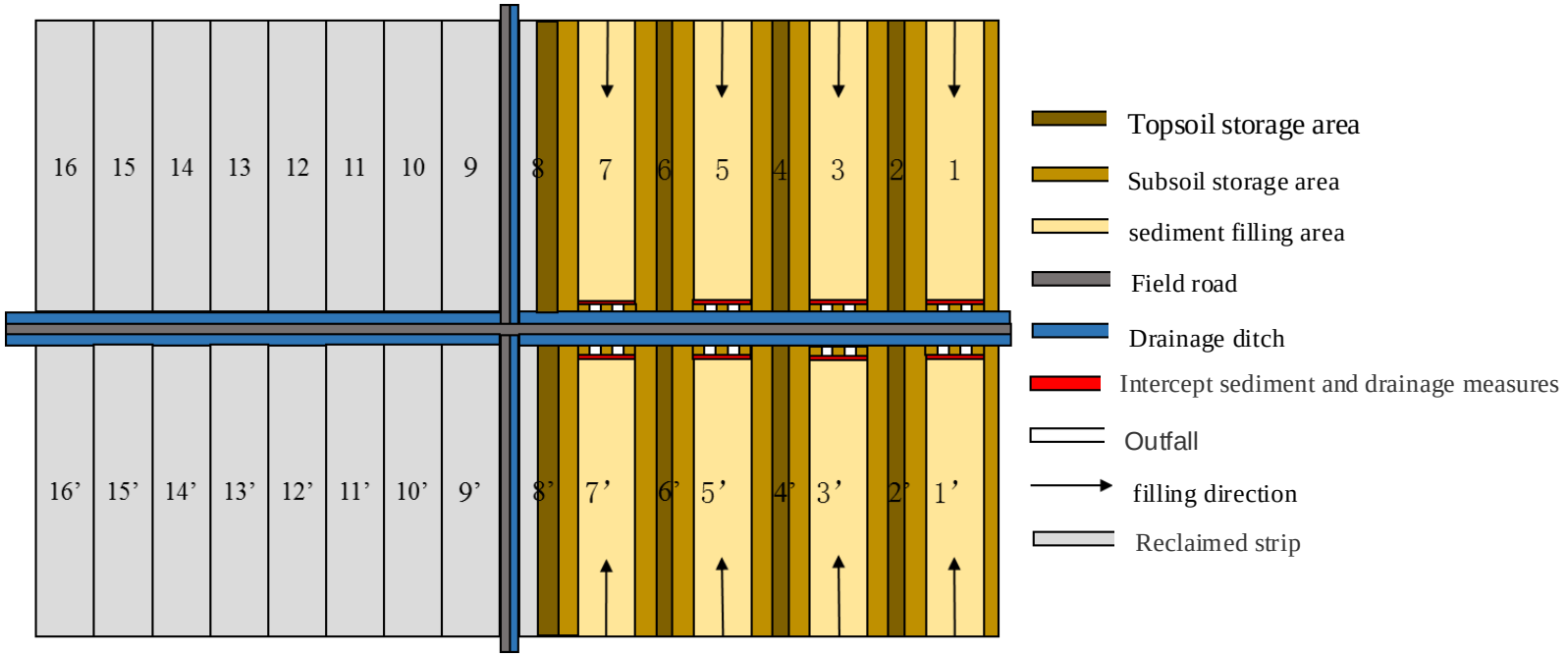
Productivity reaches its original level at least 3 years ahead of schedule

## How to implement the sandwich soil profile?

# *Process of multiple filling reclamation of mining subsidence land with Yellow River sediment.*

This technology focus on soil stripping, multiple filling, multiple drainage, multiple backfill, leveling and other links



# 2.3 Ecological Restoration of Coal waste piles in China

- Coal gangue is an inevitable product.
- More than 10 thousand coal waste piles with more than 6 billion tons scatting around whole China, and over 700 million tons was produced every year.
- More than 60% revegetated coal waste piles with spontaneous combustion were reburn, resulting reclamation failure.


**How to achieve the success of revegetation of coal waste piles with spontaneous combustion is the focus of research activities.**

# 2.3 Ecological restoration of Coal waste piles in China

- **Technology for ecological restoration of coal waste piles with spontaneous combustion**

**Keys of the technology**

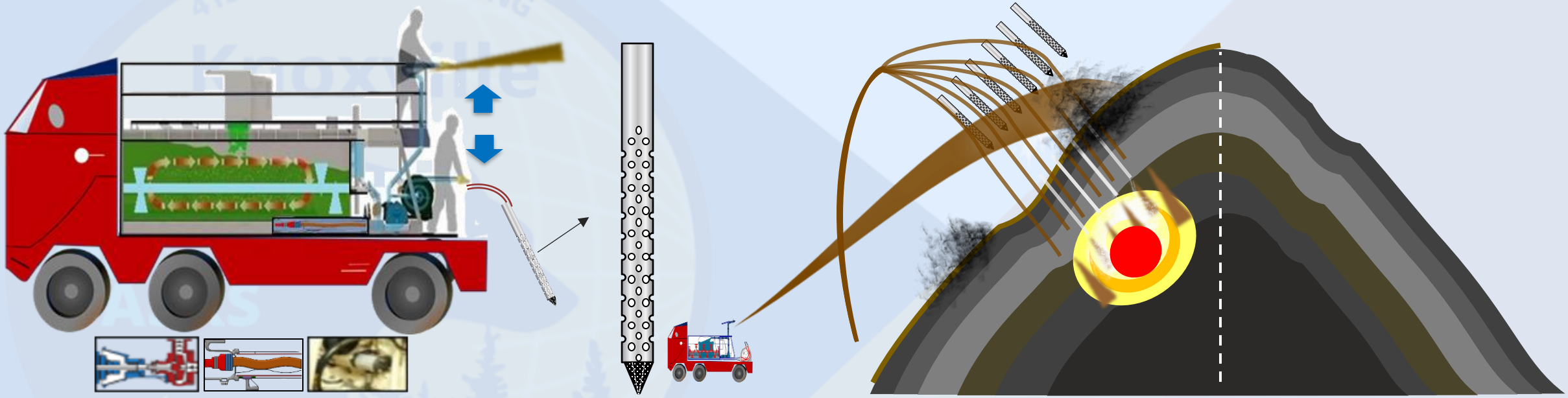
- Safely Fire Extinguishing
- Long-lasting prevention of fire


国家科学技术进步奖
证 书
为表彰国家科学技术进步奖获得者，特颁发此证书。
项目名称：煤矸石山自燃污染控制与生态修复关键技术及应用
奖励等级：二等
获 奖 者：胡振琪
2019年12月18日
证书号：2019-J-231-2-03-R01

**National science and technology progress award, 2019**

# 2.3 Restoration of Coal waste piles in China

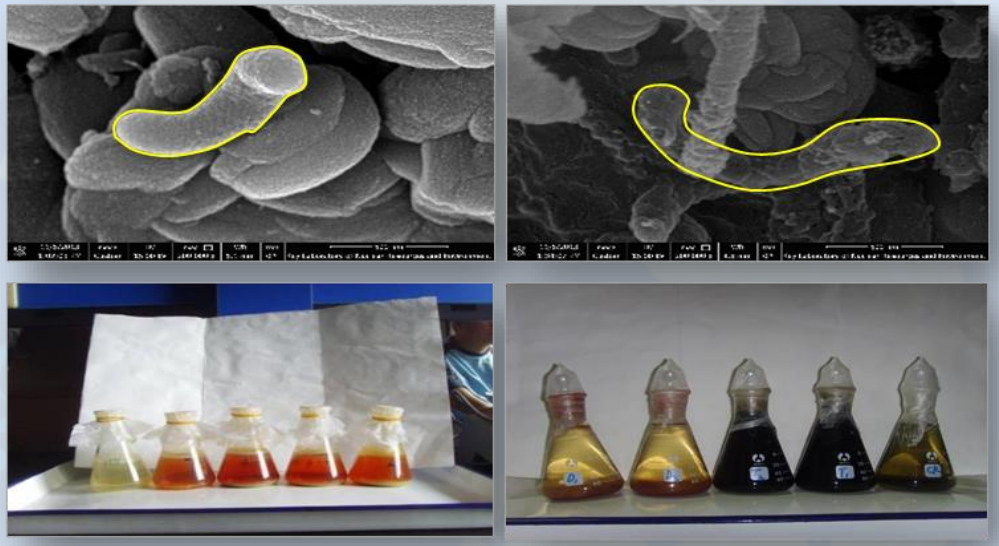
## ◆ New Technology for safely fire extinguishing



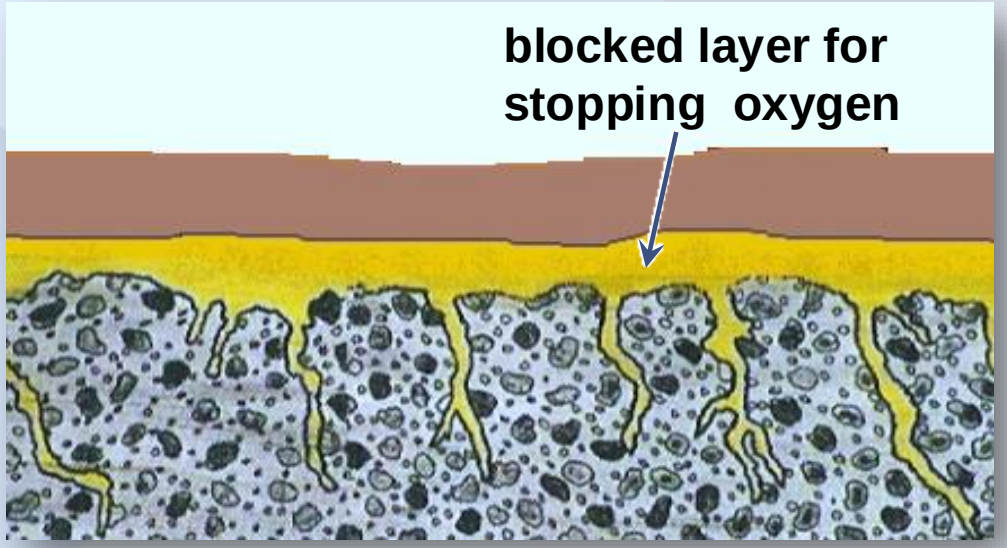
Invented this technology: surface slurry spraying and deep borehole grouting;
For every fire area, grouting from edge to the center of the fire area
Specific slurry materials and equipment

# 2.3 Restoration of Coal waste piles in China

- **New Technology: prevention of fire**



Coupling materials of biocide & sulfate reducing bacteria (SRB)




soil cover with blocked layer

**This technology enables long-lasting prevention of reburn**
**Inhibiting oxidation process and stopping oxygen**

# 2.3 Restoration of Coal waste piles in China

## ◆ New Technology for prevention of fire

### Engineering Application Results


Vegetation coverage rate over 80%, transforming pollution sources into ecological parks.

# 03 Prospects

# • *Future focused directions*

- Systematic reclamation strategy—comprehensive, full-region, full life circle; diversity, stability, and sustainability.
- Concurrent mining and reclamation concept—based on the concept of "source and process control," rather than "end-of-pipe treatment."
- Soil reconstruction technology—based on the theory of "niche of soil layer" and the construction core of "critical layer of soil."
- Dual carbon goals—exploring key technologies and solutions for carbon sink-increasing mine ecological restoration to support the national green development strategy: peak carbon dioxide emission and carbon neutrality
- International cooperation——regulation, technology, administration, implementation, case study

# Welcome to the 4th International symposium on Land Reclamation and Ecological Restoration (LRER) in Shenyang, China on Aug 23-26, 2024!


**Major topics covered by the Conference, but not limited, are as follows:**

- Monitoring and assessment of the mining damage and effect of land remediation
- Mining methods and measures to mitigate damage
- Policies, regulations and standards for land reclamation and ecological restoration
- Reclamation and ecological restoration of coal mining subsidence land
- Land reclamation and ecological restoration of open-pit mines
- Mine solid waste management and ecological restoration of waste rock piles
- Generation and treatment of acidic water in mines
- Contaminated land remediation
- Mine ecosystem resilience
- Transitional development of closed mines
- Geology and Environmental Disaster Prevention and Control for Mine
- Mechanisms of water environment disasters in abandoned mining areas and the theory of groundwater system balance control
- Assessment of the far-field effect of mining earthquake and protection technology
- Industrialization of land reclamation and ecological restoration
- "Belt and Road" and ecological restoration of mining areas
- Reclamation education, technology exchange and diffusion and internati

**Conference Theme:** Ecological Smart Reclamation, Green Low-Carbon Homestead

**Register Website:** https://cloud.yiyum.com/?sid=3873&mid=987&v=100

**Welcome to attend the meeting**

# Thanks!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