Assessing and Controlling the Cost of Underground Space

Ray Sterling, Ph.D., P.E.
Professor Emeritus, Louisiana Tech University

Key Issues for Discussion

- Creating a suitable cost benefit analysis framework that will take into account the costs and benefits of building underground
  - Using the underground is typically a means of avoiding the impact of a surface facility.
  - For certain types of facilities, underground solutions are the only feasible or the cheapest options.
  - In others, it is a more expensive solution but provides a more livable environment.
  - This means that indirect benefits – often well into the future – must be valued either in financial terms or by political/planning leadership

Why use underground space?

- Location
  - We want to build a facility in a particular location and it creates problems if built on the surface
- Physical attributes
  - Aesthetic/environmental barrier
  - Isolation
  - Energy systems
- Topography and barrier crossings
  - Tunnels negate difficulties with topography
  - Crossings must go under or over

Not a "free" choice

- People general use the underground to solve problems or because it offers an advantage – not because they "prefer" it.
  - Underground metros
    - E.g. first London subway line
  - Underground street crossings
    - Avoids danger and delay in crossing at street level

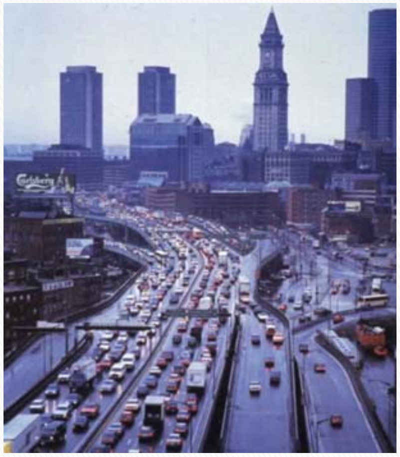
Economic Assessment

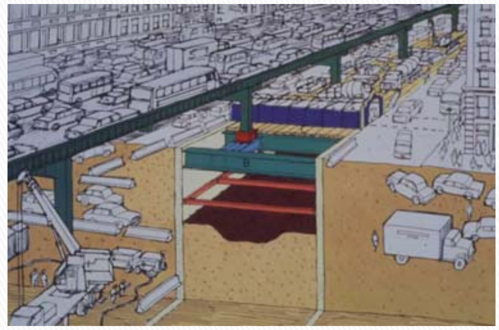
- Land cost
- Construction cost
- Savings in specialized design features
- Energy savings or extra costs
- Maintenance costs
- Replacement costs
- Hard costs versus social or indirect costs

Oslo Harbor Front

Created pedestrian-friendly waterfront spaces

Stimulated major waterfront commercial development

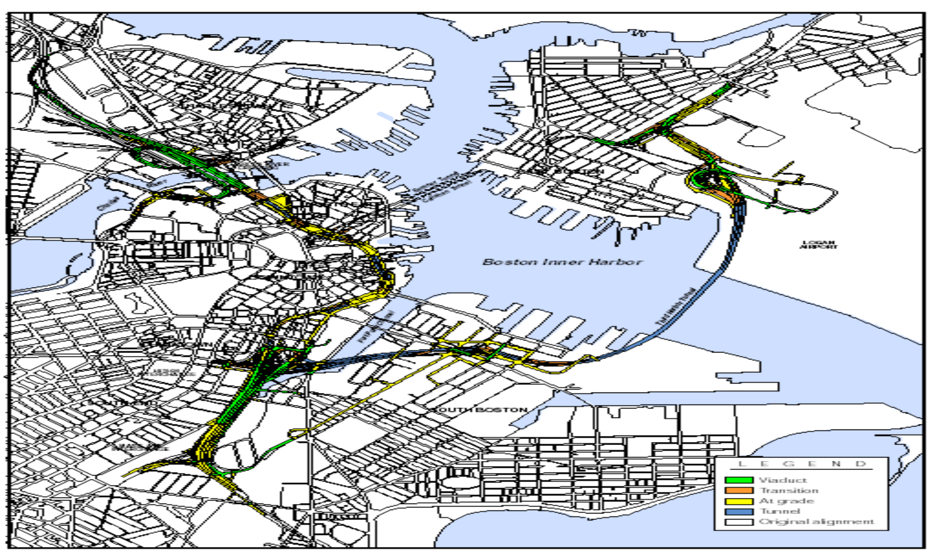




Boston Artery Project

$110 million in 1953
Underground option approx. 30% more expensive at that time
Total cost of 1992-2007 project: $14.3 billion
But, extensive project and extreme ground conditions

What is the Big Dig?



Source:http://www.bigdig.com

Central Artery: Before & After


Before: 2003


After: 2005

Source:http://www.bigdig.com

Real Estate Value Increase

- In 2004, along the one-mile strip of the "Greenway", the value of commercial properties had risen since the project began to $2.3 billion.
- This was a 79% increase compared to the citywide increase of 49% in the same period. (Palmer, Boston Globe, 2004)

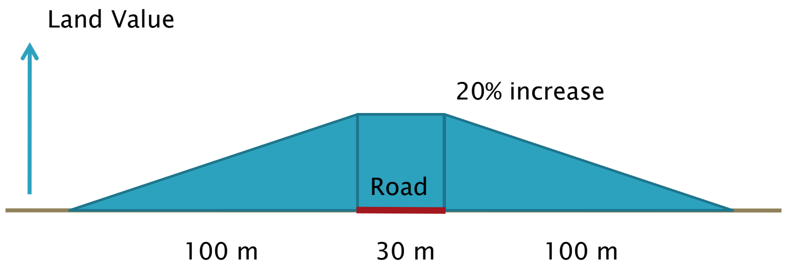
Seattle Alaskan Way Viaduct

Major controversy over replacement plans
Underground option, surface option, eliminate and redirect traffic
Boston Artery experience a major deterrent

Other examples

- San Francisco Embarcadero Freeway (removed following 1989 Loma Prieta earthquake)
- Toronto (private proposal in 1989 to move underground the Gardiner Expressway in return for development rights)
- Dusseldorf riverfront
- Madrid M30 riverfront

Land Value Increase Assumptions



Studies have been carried out in relation to land value increases adjacent to parks

Land Value Impacts (Conceptual)

- Construction cost €200 million per km
- Land cost €10,000 per sq m
- Right-of-way width 30 m
- Land value of ROW €300 million per km
- Assume 20% increase = €60 million
- Add for adjacent rise in land value (tapers to zero over 100 m each side) = €200 million
- Total land value change = €260 million
- I.E. the land value change can be of a similar order to construction costs (value in relation to differential costs (elevated:underground) would be much higher.

Use of Land Beneath Public R.O.W.

- Does the fact that public agencies and utilities do not have to pay for utilizing the public space beneath rights-of-way mean that the space should be administered as if it has no value and no impact on the long-term development of the urban area?

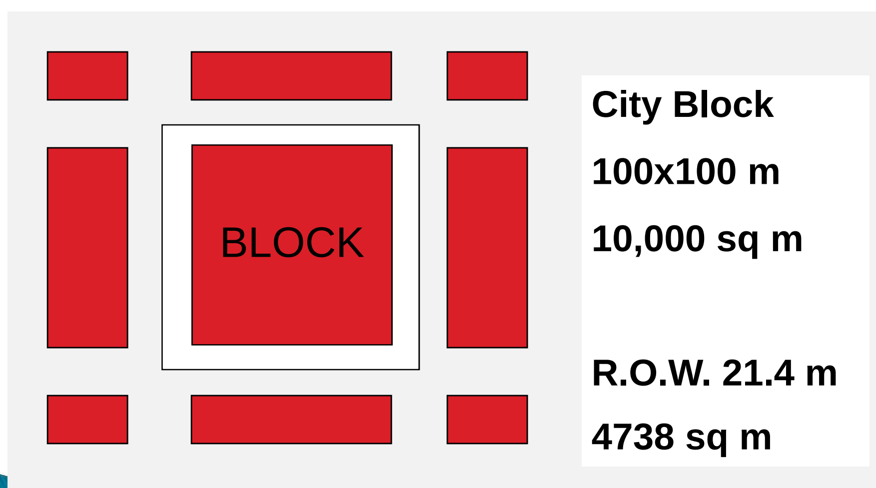
Underground Land Value

- Proper land valuation assists an efficient allocation of space
- Should not be treated as a “free good”
- Waste of land carries a “loss of opportunity” cost
- Land is non-reproducible
- Land should be employed in its most valuable use

Assessing Land Value

- In small parcels, the value of public right-of-way should approximate that of adjacent land.
- Over large areas, the value cannot be maintained without the access provided by public rights-of-way and value should be assessed lower.

Comparative Areas



Comparative Value

- Value of Associated Right-of-Way may be up to 47% of value of block
- For land worth US$1000 per sq m, the block would be worth US$10 million and the Right-of-Way US$4.7 million
- For a city, the value of the public R.O.W. can be billions of $

Trenchless Technology Center

Determining Value of Underground Space

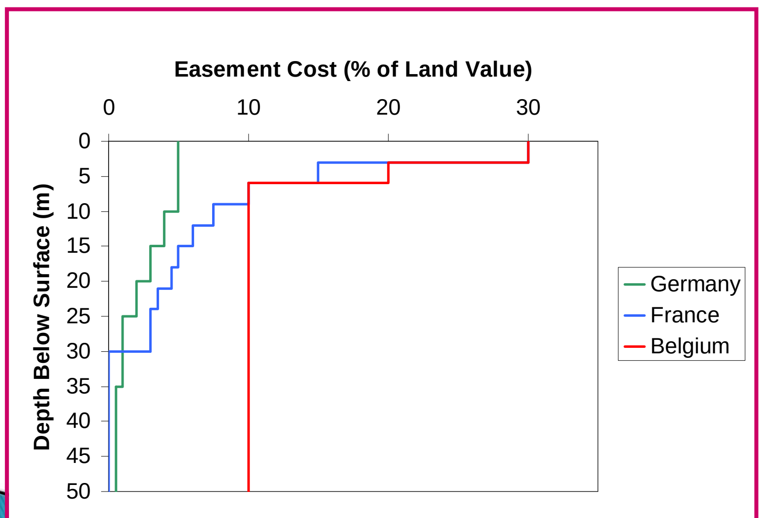
- Mineral resources of value?
- Normal surface use affected?
- Future structures affected?
- Accessibility of underground zone?
- Current owner may develop?
- Reserves extra space for stability?
- Psychological impact on buyer?

Trenchless Technology Center

Value Versus Depth

- Value typically decreases with increasing depth
- If particular geological strata have favorable characteristics, these layers may have a higher unit land values even at larger depths

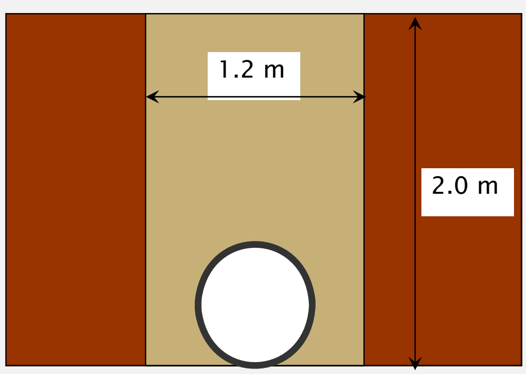
Examples of Easement Valuations



Value Consensus

- No international consensus exists
- Some countries assign only a nominal value to underground space taken for public purposes at depth
- Japan has made space below 40 m depth in urban areas into public space

Space Taken by Buried Utility



Easement Value

30%

Land Value

$200 / m^2

Construction Cost

$100 / lineal m

Space value

$72 / lineal m

Relative Cost for Underground Space

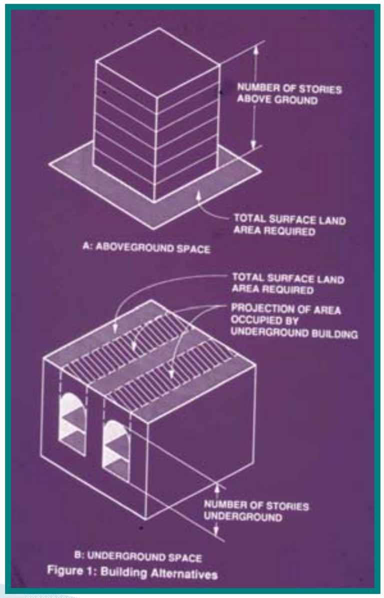
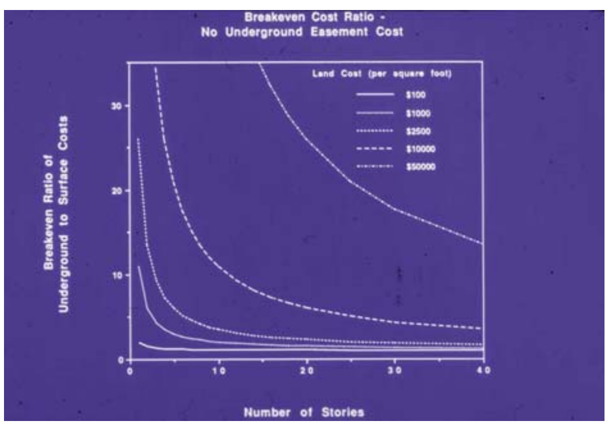
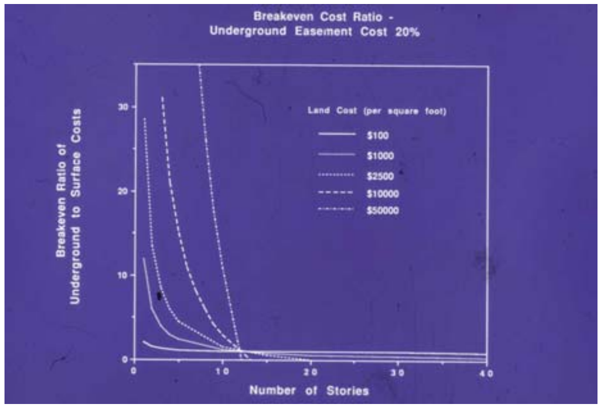


Figure 1: Building Alternatives

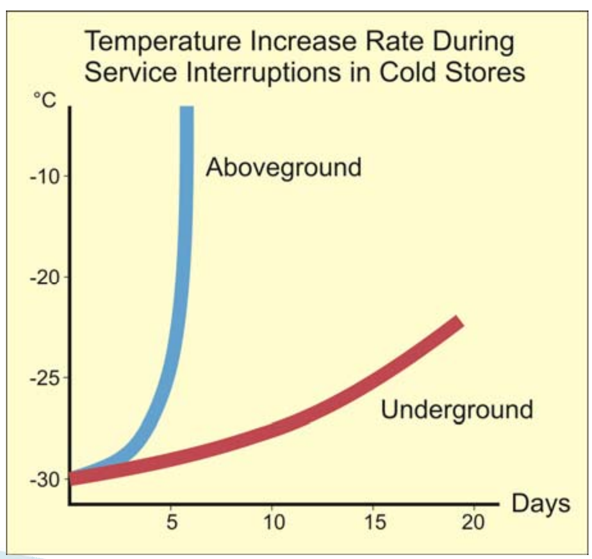
Breakeven ratio – no underground easement cost



Breakeven ratio – underground easement cost at 20%

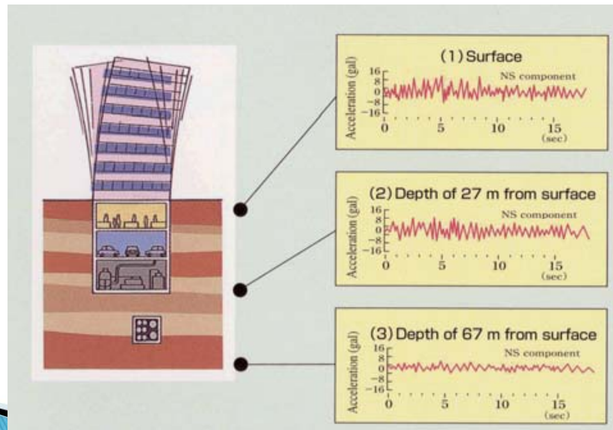


Thermal Stability in Cold Stores



Redrawn from Scandinavian Data

Smaller impact of earthquakes on the facilities and objects under the ground
--- The deeper, the safer ---



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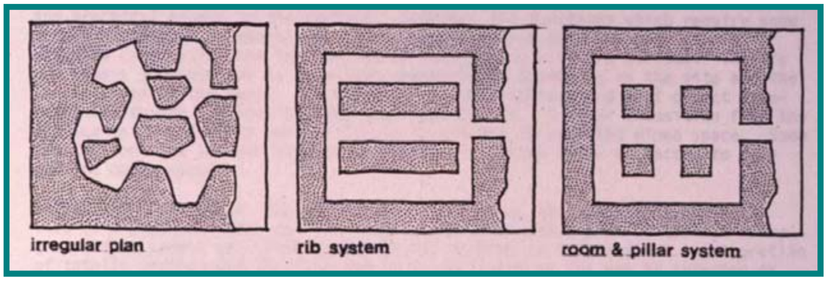
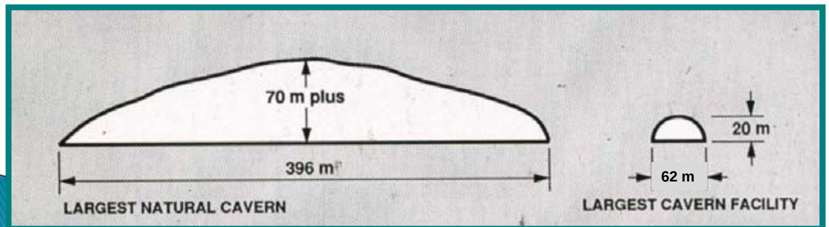
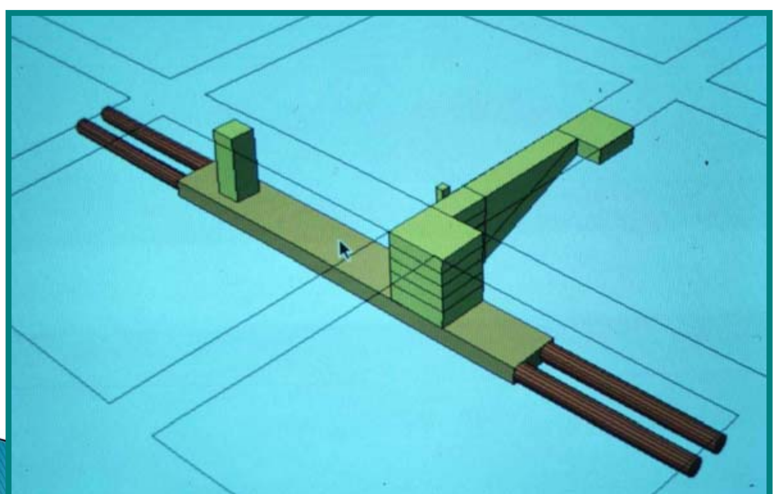
Layout Issues and Costs

Layout Freedom and Limitation

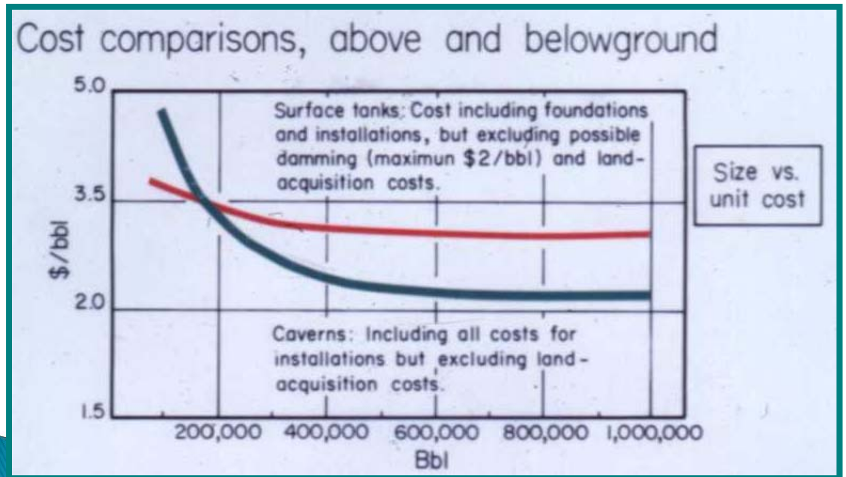




Adapting Designs to Geology and Urban Design

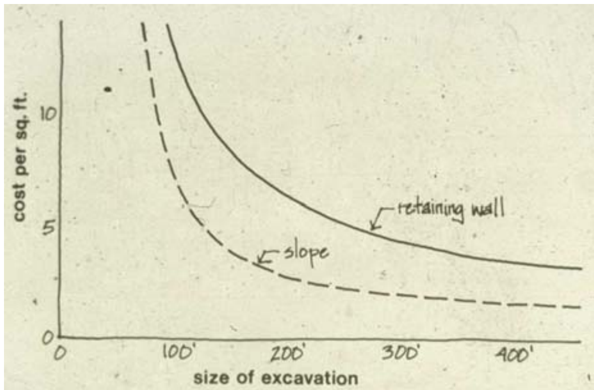


Cost versus Size for Oil Storage Caverns



Cost of Cut-and-Cover Space

Unit Cost of Open Cut Excavation versus Size of Excavation

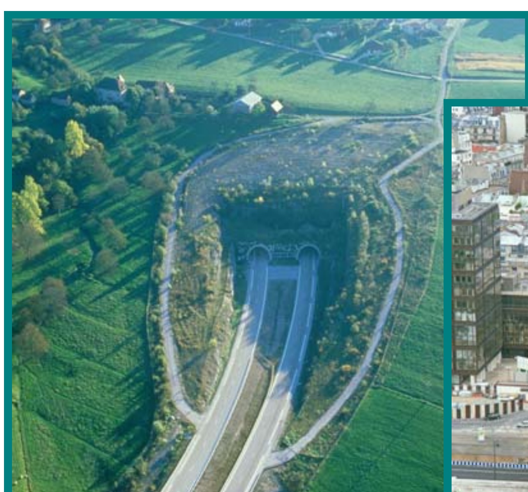


Studying Potential Compatibility for Infill Sites

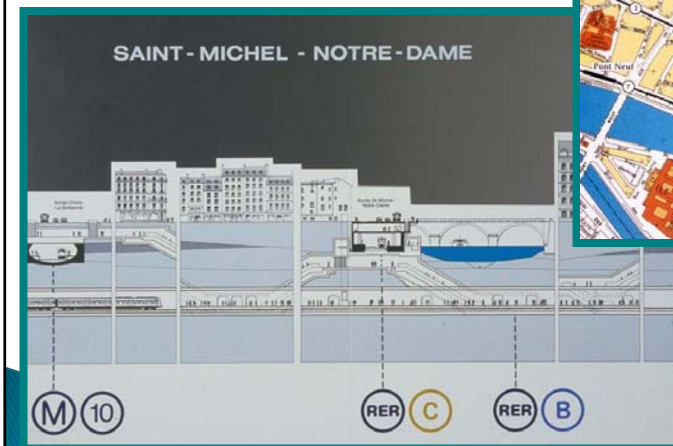
- Depth of adjacent foundations
- Soil/rock conditions
- Access
  - Excavation
  - Building servicing
  - Pedestrian
  - Safety
- Connections to existing building
  - Physical compatibility
  - Usage compatibility
- Building utilities
  - Ventilation

Ventilation Structures

Transitional Structures



Access Points



Construction Techniques

- Surface disruption
- Damage to adjacent structures
- Cost and duration of work relative to aboveground construction
- Increasing mechanization
- Cut-and-cover methods versus bored tunneling or trenchless methods

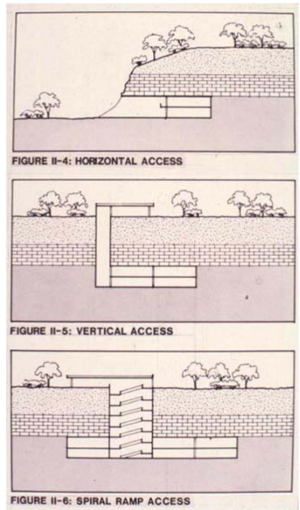
Construction Disruption

Underground Utilities

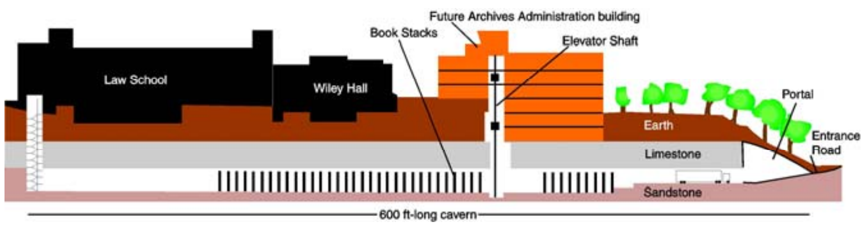
Wall Street, New York 1917

Access to Mined Space

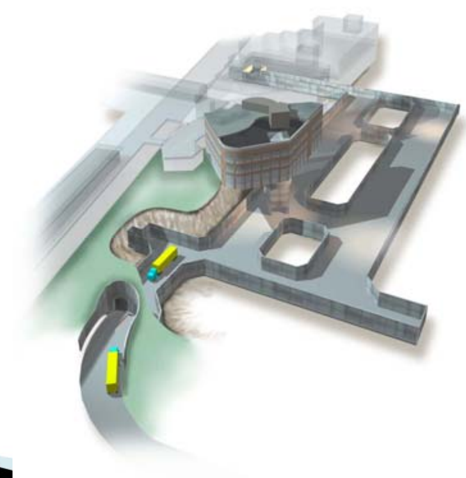
- Depends on topography
- Important for cost and operations
- Portal arrangements can be a significant cost and difficulty for rock cavern developments
- Need to preserve good opportunities



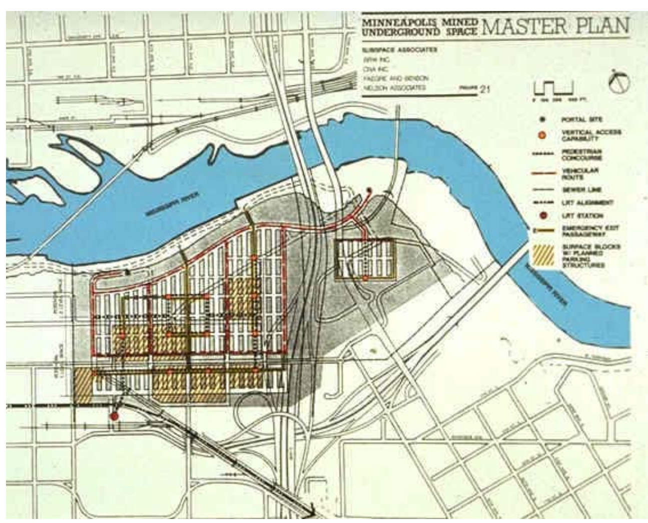
U of MN Archives - Section



University of Minnesota Archives



Minneapolis Mined Space Master Plan



An example of good landscape formation and its benefits

Matsumoto Ryuhei Ministry of Land, Infrastructure and Transport , JAPAN

[Before] Ise city in 1990

Electric wires
Disorderly outdoor advertising

Buildings without uniformity

[After] in 1993

Electric wires go to underground
Restrictions on disorderly outdoor advertising

Induction(誘導) to unify colors and exteriors of buildings

Number of tourists:
350,000 persons in 1992 → 3 million persons in 2002

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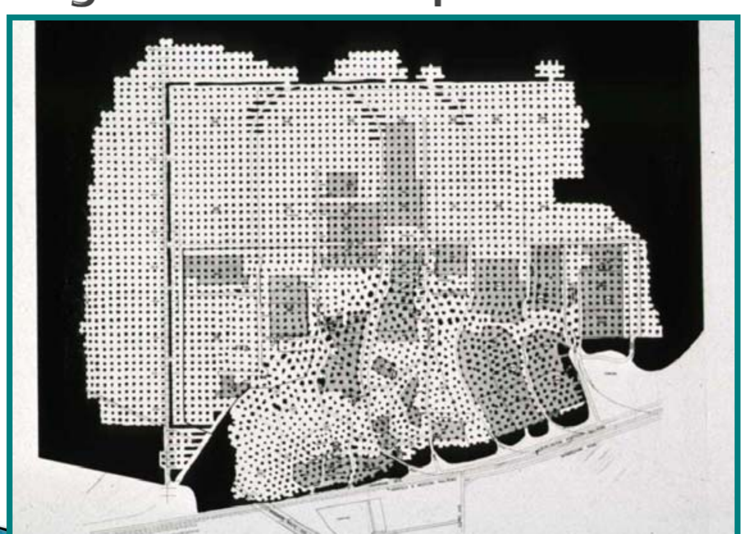
Create Multiple Value Benefits

- Combine mining of aggregate with space generation
- Benefits
  - Cheaper provision of concrete, asphalt and aggregate to city construction
  - Less traffic congestion, pollution, road damage
  - Full or partial payment for space created
- Difficulties
  - Concentrated heavy goods traffic
  - Vibration from blasting or crushing operations, etc.

Reuse of Mine Voids

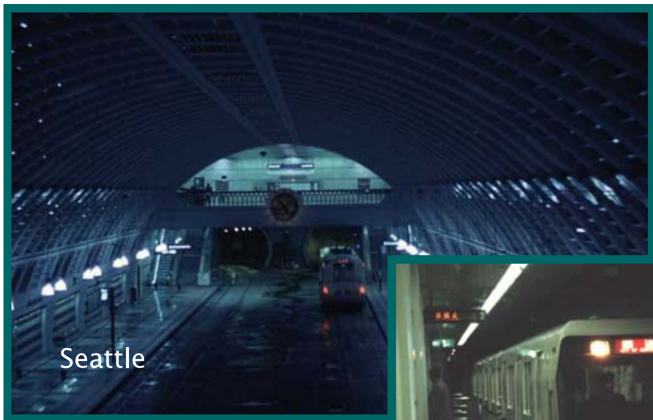
Kansas City

Mining for Future Space Use



Kansas City, USA

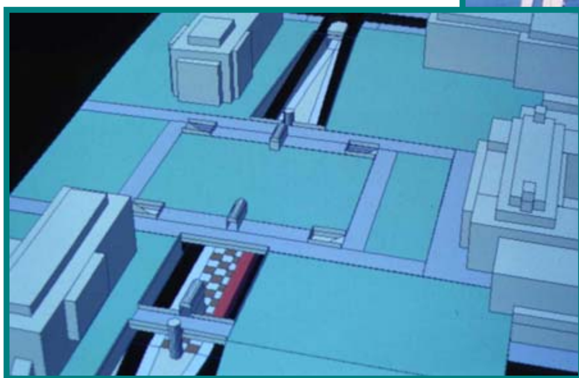
Large Scale versus Small Scale

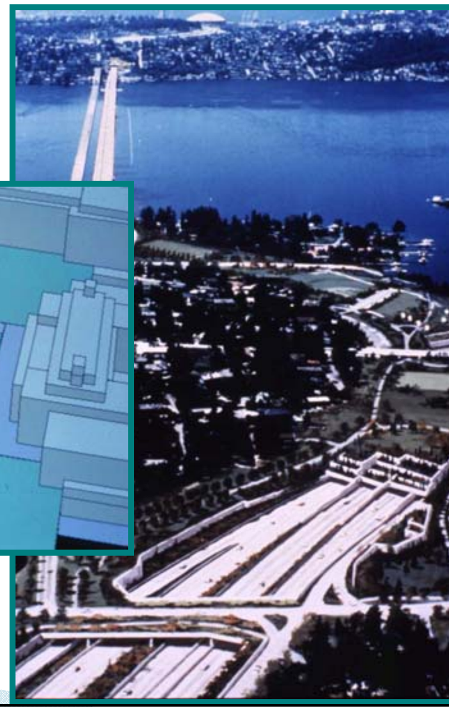

Seattle

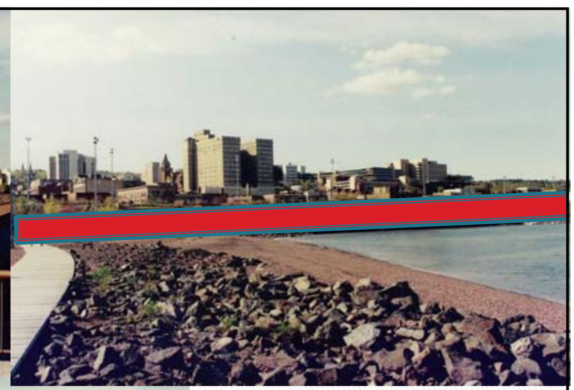

Osaka

Partial Underground Solutions

Land Bridges







Duluth, USA

Covered freeway sections

Four short tunnels (longest 1500 ft)

Eventual compromise

Artificial Ground Level

Tsukuba Science City
Japan

Questions?

Also, for email follow up:
sterling@Latech.edu