Costs and Benefits of Geological Mapping
Contributions of Subhash Bhagwat
Illinois, Kentucky, Spain, and Nevada
Geology-for-Planning Boone and Winnebago Counties

“Seasoned” Mapping and Derived Benefits for 31 Years

Funded by County Boards and State
Winnebago-Boone Counties Benefit:Cost Study

- **1984** – 3-D geologic mapping completed.
- **1989** – Illinois Senate Resolution 881 required documenting benefits and costs of geologic mapping.
- Most detailed mapping in Illinois to date had been here.
- **1990** – Mapping program chosen for a case study economic analysis of geologic mapping (first ever) – 10 years after map distribution.
- **1991** – Published as ISGS Circular 549 by Bhagwat and Berg.
Data Collection

Questionnaire sent to 80 Winnebago-Boone map users: 55 were interviewed.

– County planning and health departments
– City planning departments
– Mineral extraction companies
– Real estate developers
– Well drillers
– Illinois EPA
– Managers of waste water and sewer treatment facilities
– Agricultural extension offices
– County highway departments
– Geological and engineering consultants
Questions to Users

• For what purpose are geologic maps used and for what purpose?
• Can you quantify the amount of money saved due to availability of geologic maps?
• If you can not identify dollar savings, can you describe how much time was saved in terms of manpower on an annual basis?
• Do you know of instances where availability of geologic maps would have improved planning and saved money? If yes, in what form and how much?
• How are these savings documented?
• How accurate were the maps that you used? Give the approximate percentage of time that the maps proved accurate.
• What additional map features would you like to see in geologic maps to make them more useful to you?
Cost and Benefits

• 1980 cost of $174,372 recalculated in 1990 $$s to $289,500.

• Basic economic premise - geologic maps are a “public good”.

• Benefit assessment based on the rationale that a future cost could be avoided because of knowledge gained through a geologic mapping program is equivalent to benefits attributable to the program.

• Only quantifiable benefit data – costs of cleaning up contaminated sites from waste disposal and industrial activity.
  – ***Very conservative approach looking at just 1 potential benefit of geologic maps.
Benefit Reductions Based on Environmental Regulatory Effectiveness

• Benefits (avoidable costs) reduced 50%, 75%, and 90% to account for future effectiveness of environmental regulations (regulatory efficiency).
  – Scenario 1 – benefits reduced 50% assuming no dramatic change from past practices will occur in siting facilities or waste disposal.
  – Scenario 2 – benefits reduced 75% to account for progress in regulating and designing safer waste disposal facilities.
  – Scenario 3 – benefits reduced 90% assuming that environmental protection regulations will be highly effective.

***Assumes great confidence in environmental protection strategies.

***Assumes “what lies beneath” (geology) is nearly “completely” understood; however, it is vastly unknown.
Growth in Federal Environmental Regulations (Title 40 CFR)
## Summary Benefits and Costs

<table>
<thead>
<tr>
<th>Cost ($M)</th>
<th>Scenario</th>
<th>B/C ratio</th>
<th>Total benefits ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boone-Winnebago</td>
<td>$0.3</td>
<td>1 (50%)</td>
<td>23.5 - 54.5</td>
</tr>
<tr>
<td>Counties</td>
<td>2 (75%)</td>
<td>11.7 - 27.2</td>
<td>3.5 – 8.1</td>
</tr>
<tr>
<td>3 (90%)</td>
<td>4.7 – 10.9</td>
<td>1.4 – 3.3</td>
<td></td>
</tr>
<tr>
<td><strong>Maximum regulatory efficiency</strong></td>
<td><strong>Quantifiable benefit data</strong></td>
<td>costs of cleaning up contaminated sites from waste disposal/industrial activity.</td>
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</table>

**Statewide projection 21.0**

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<th>Scenario</th>
<th>B/C ratio</th>
<th>Total benefits ($M)</th>
</tr>
</thead>
<tbody>
<tr>
<td>from B-W Counties</td>
<td>2</td>
<td>3.0 – 7.0</td>
<td>63.0 – 147.0</td>
</tr>
<tr>
<td>3</td>
<td>1.2 – 2.8</td>
<td>25.0 – 59.0</td>
<td></td>
</tr>
<tr>
<td><strong>Statewide projection 55.0</strong></td>
<td><strong>from ISGS cost</strong></td>
<td>Cost estimates</td>
<td></td>
</tr>
<tr>
<td>Cost ($M)</td>
<td>Scenario</td>
<td>B/C ratio</td>
<td>Total benefits ($M)</td>
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<tr>
<td>-----------</td>
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<tr>
<td>2</td>
<td>1.2 – 2.7</td>
<td>63.0 – 147.0</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.5 – 1.1</td>
<td>25.0 – 59.0</td>
<td></td>
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</tbody>
</table>
Economic benefits of detailed geologic mapping to Kentucky

Subhash B. Bhagwat
Senior Mineral Economist
Illinois State Geological Survey

Viju C. Ipe
Assistant Mineral Economist
Illinois State Geological Survey

Special Report 3

Department of Natural Resources
George H. Ryan, Governor
Illinois State Geological Survey
Kentucky Mapping Program – 1961-78

• Only state to be mapped at 24K-scale

• Done for mineral resource exploration. Direct impact - $50M in benefits to coal industry by 1979.

• 1999 evaluation on Economic Benefits of Detailed Geologic Mapping to Kentucky by the ISGS – based on 100s of questionnaires sent to map users.

• Provides insights for mapping needs and standards.

NOTE – This was traditional 2-D geological mapping, NOT 3-D.
Uses of Kentucky GQ Maps

Map use for exploration and development

- Coal: 30%
- Oil & Gas: 30%
- Industry: 30%
- Groundwater: 70%

Map use in environmental consulting

- Pollution prevention: 70%
- Industrial: 50%
- Site clean-up: 80%

Map use in hazard prevention and protection

- Landslides: 40%
- Earthquakes: 10%
- Karst problems: 50%
- Subsidence: 40%

Map use in engineering applications

- Buildings & foundations: 50%
- Roads & highways: 30%
- Railroads: 15%
- Pipelines: 25%
- Utilities: 20%
- Dams, dikes, locks: 30%
CONCLUSION:

Using very conservative assumptions, there was return of $25-39 for each federal and state dollar invested in mapping.
Geological Mapping in Spain
Cost/benefit analysis

Manuel Regueiro & Roberto Rodríguez
ICOG
History of the Geological Map of Spain. First period 1849-1926

Ezquerra del Bayo (1850)

Geognostic Squetch of Spain

E: 1: 5.000.000

Commission for the Geological Chart of Madrid and General of the Kingdom

Royal Decree 12 July 1849
1996-2003
realizado 100%
Total investment: 121,27 M€

MAGNA Plan: investment
ECONOMIC ASSESSMENT OF THE MAGNA PLAN
What savings has the MAGNA plan meant for the national economy?

Is it worth to maintain geological mapping programs?

If this is so: with what intensity and scope?
20 consulting companies 11 universities 2 regional geological surveys
638 geologists/engineers and 400 specialists
METODOLOGY

1. Selection of 1,200 users of geological maps between companies and institutions
2. Drafting of questionnaire: 12 detailed questions, 50 numeric replies or yes/no 9 descriptive replies
3. Enquires sent to 1,200 users
4. Telephonic follow up
5. Reception of 311 replies (26% of total enquires), 118 completed, 193 partially filled
6. Analysis of replies (8,400 alphanumeric data and 1,200 descriptive replies)
ACTIVITIES DEVELOPED BY THE ORGANISATIONS THAT REQUIRE GEOLOGICAL MAPS

REPLIES RECEIVED (%)

- Natural Resources: 80%
- Environment: 80%
- Engineering: 60%
- Land Use Planning: 50%
- Natural Hazards: 40%
- Research Education: 30%
- Expert Reports: 20%
ECONOMIC EVALUATION
In a typical project of your organization, when there are no geological maps available, what % of the budget should be invested in substitutive geological research by own work or subcontractors?
For a particular project carried out in the last 5 years by your organisation:

Which is your best estimation of the savings generated by the existence of geological maps?

In your case how much will you be ready to pay for the map?

Which is your best estimation of the needed investment to obtain the geological information contained in the MAGNA sheets, in case those did not exist?
<table>
<thead>
<tr>
<th></th>
<th>BY SHEET (€)</th>
<th>TOTAL (€ MM)</th>
<th>ADDED VALUE (€ MM)</th>
<th>MULTIPLE INVESTMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAXIMUM VALUE</td>
<td>20 170</td>
<td>3 339.67</td>
<td>3 218.40</td>
<td>27.54</td>
</tr>
<tr>
<td>MINIMUM VALUE</td>
<td>7 579</td>
<td>1 254.90</td>
<td>1 133.63</td>
<td>10.35</td>
</tr>
<tr>
<td>HOW MUCH WOULD YOU PAY</td>
<td>1 549</td>
<td>256.48</td>
<td>135.21</td>
<td>2.11</td>
</tr>
<tr>
<td>SUBSTITUTIVE GEOLOGICAL INVESTMENT</td>
<td>13 443</td>
<td>2 225.84</td>
<td>2 104.57</td>
<td>18.35</td>
</tr>
</tbody>
</table>
The Magna plan has a ratio of cost / benefit of 18.

That is, an investment of 122 M€ has produced savings to the Spanish economy of 2 200 M€ until 2004.
The Nevada Bureau of Mines and Geology: Current and Future Benefits to the University, the State, and the Region

2014

Subhash B. Bhagwat
Contents

Executive summary 3
1. Introduction 5
2. Objectives 7
3. Previous studies on benefits of geologic information 7
4. Methodology for the present study 8
5. The NBMG program and its impacts 9
  5.1 Minerals 9
  5.2 Energy 12
  5.3 Water 16
  5.4 Natural hazards 16
    5.4.1 Earthquakes 16
    5.4.2 Floods 18
    5.4.3 Radon 18
    5.4.4 Environmental concerns 19
  5.5 Science education 20
  5.6 Geologic research 21
6. Results of the Nevada user survey on geologic information 26
7. Assessing the benefits 42
8. A look to the future of NBMG at UNR 44
9. Conclusions 48

Appendix A. User survey and assessment 50
Appendix B. Cost of power plants by source of energy 54
Appendix C-1. Sage-Grouse habitat categorization map 55
Appendix C-2. Sage-Grouse habitats and active mines and mineral deposits 56
Appendix C-3. Sage-Grouse habitats and recent exploration projects and mining claims 57
Appendix D. Public vs. private goods 58
Appendix E. Statistics on visitors to GBSSRL 61
Figure 3: Existing natural resource activity in Nevada.
Figure 4: Cumulative production potential as function of price per ounce of gold for the Tonopah quadrangle

Figure 5: Cumulative production potential as function of price per ounce of silver for the Tonopah quadrangle

Growth in Nevada Mining GDP
Figure 15: Areas of detailed mapping (1:24,000 scale) in Nevada, as of 2012, shown in dark blue. This work has been carried out primarily by NBMG and the USGS.
Economic Cost and Benefit Assessment

Figure 17: Type and number of organizations responding

- Min.Res.Ind.(Large)
- Min.Res.Ind.(Junior)
- Energy Res.Ind.(Large)
- Energy Res.Ind.(Small)
- Water Res.Ind.
- Construct.Ind.
- Transp.Ind.
- Tourism Ind.
- Real Estate
- Geotechn. Firm
- Indep. Consultant
- Publ.Util.(power,water)
- Fed. Govt.
- State Govt.
- County Govt.
- City Govt.
- Educat. Instit.
- General Public
- Other
Figure 31: Expected willingness to pay per geologic map

Figure 32: Preferred mapping scale
Table 5: Values of geologic information as reported by all respondents.

<table>
<thead>
<tr>
<th></th>
<th>Highest</th>
<th>Lowest</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum reported</td>
<td>$1,000,000</td>
<td>$25</td>
<td>$43,742</td>
</tr>
<tr>
<td>Minimum reported</td>
<td>$50,000</td>
<td>$20</td>
<td>$6,970</td>
</tr>
<tr>
<td>Best estimate reported</td>
<td>$200,000</td>
<td>$25</td>
<td>$20,957</td>
</tr>
</tbody>
</table>
Cost and Benefit Conclusions

- Willingness to pay per map - $6,414
- Total value of maps sold over 40 mos. - $13M
- Cost of mapping - $90,000 per 24K quad.
  - Note - some faculty said 200K was cost for some maps.
- Cost:benefit ratio – 1:147.

Reasons for differences with IL and KY
- IL limited by 2 counties that are non mining and benefits were reduced considerably (regulatory efficiency).
- KY produces coal-a low value mineral.
- NV is earthquake prone and produces higher value minerals.