



Department of  
Industry and Resources

**RECORD  
2003/9**

# **INVENTORY OF ABANDONED MINE SITES PROGRESS 1999–2002**

**by W. R. Ormsby, H. M. Howard  
and N. W. Eaton**



**Geological Survey of Western Australia**





**GEOLOGICAL SURVEY OF WESTERN AUSTRALIA**

**Record 2003/9**

# **INVENTORY OF ABANDONED MINE SITES: PROGRESS 1999–2002**

**by**

**W. R. Ormsby, H. M. Howard, and N. W. Eaton**

**Perth 2003**

**MINISTER FOR STATE DEVELOPMENT**  
**Hon Clive Brown MLA**

**DIRECTOR GENERAL, DEPARTMENT OF INDUSTRY AND RESOURCES**  
**Jim Limerick**

**DIRECTOR, GEOLOGICAL SURVEY OF WESTERN AUSTRALIA**  
**Tim Griffin**

**WARNING: Abandoned mine sites are dangerous. Some of the dangers will not be obvious or visible. This publication has been produced to document attributes of abandoned mine sites, including their location and extent, surface features, and the more obvious sub-surface features. It is not intended to provide a complete assessment of risks. The Department of Industry and Resources does not encourage or recommend that you venture on or near abandoned mine sites.**

**REFERENCE**

**The recommended reference for this publication is:**

ORMSBY, W. R., HOWARD, H. M. and EATON, N. W., 2003, Inventory of abandoned mine sites: progress 1999–2002: Western Australia Geological Survey, Record 2003/9, 76p.

**National Library of Australia Card Number and ISBN 0 7307 8931 4**

**Grid references in this publication refer to the Geocentric Datum of Australia 1994 (GDA94). Locations mentioned in the text are referenced using Map Grid Australia (MGA) coordinates. All locations are quoted to at least the nearest 100 m.**

**Published 2003 by Geological Survey of Western Australia**

**Copies available from:**

Information Centre  
Department of Industry and Resources  
100 Plain Street  
EAST PERTH, WESTERN AUSTRALIA 6004  
Telephone: (08) 9222 3459 Facsimile: (08) 9222 3444

**This and other publications of the Geological Survey of Western Australia are available online through the Department's bookshop at [www.doir.wa.gov.au](http://www.doir.wa.gov.au)**

# Contents

Abstract .....	1
Introduction .....	1
National and international trends .....	2
Australia .....	2
Canada .....	2
United States of America .....	3
United Kingdom .....	3
Other countries .....	3
Western Australia .....	4
Methodology .....	4
Prioritization .....	4
MINEDEX .....	5
Prioritization of historic mine sites .....	5
Accidents .....	6
Other considerations .....	6
Spatial information .....	6
Historic maps .....	6
Aerial photographs .....	7
Orthophotographs .....	7
Company data .....	7
Tenements .....	7
Geological maps .....	8
Database attributes and development .....	8
Field data acquisition .....	9
Data validation and storage .....	11
Progress .....	12
Number of features collected .....	12
High-priority historic mine sites completed .....	13
Morphology of mining features .....	15
Underground features .....	15
Shafts with full bunds .....	16
Shafts with partial bunds .....	16
Shafts with no bund .....	19
Safety aspects of shafts .....	21
Environmental aspects of shafts .....	21
Preservation aspects of shafts .....	21
Geology and mineralization aspects of shafts .....	21
Open stopes .....	21
Safety aspects of open stopes .....	22
Environmental aspects of open stopes .....	24
Preservation aspects of open stopes .....	24
Geology and mineralization aspects of open stopes .....	24
Adits .....	24
Safety aspects of adits .....	25
Environmental aspects of adits .....	25
Preservation aspects of adits .....	25
Geology and mineralization aspects of adits .....	26
Subsidence .....	26
Safety aspects of subsidence .....	26
Environmental aspects of subsidence .....	26
Geology and mineralization aspects of subsidence .....	26
Collapsed drillholes .....	27
Safety aspects of collapsed drillholes .....	27
Environmental aspects of collapsed drillholes .....	27
Geology and mineralization aspects of collapsed drillholes .....	27
Collapsed shafts .....	28
Safety aspects of collapsed shafts .....	29
Environmental aspects of collapsed shafts .....	29
Preservation aspects of collapsed shafts .....	29
Geology and mineralization aspects of collapsed shafts .....	29
Opencuts .....	30
Deep pits/quarries (>10 m) .....	30
Shallow pits/quarries (<10 m) .....	31
Safety aspects of pits/quarries .....	33



Environmental aspects of pits/quarries .....	34
Preservation aspects of pits/quarries .....	34
Geology and mineralization aspects of pits/quarries .....	34
Mechanically excavated costeans/trenches .....	34
Hand-dug costeans/trenches .....	36
Undifferentiated costeans/trenches .....	37
Safety aspects of costeans/trenches .....	37
Environmental aspects of costeans/trenches .....	38
Preservation aspects of costeans/trenches .....	39
Geology and mineralization aspects of costeans/trenches .....	39
Shallow workings .....	39
Undifferentiated shallow workings .....	39
Mechanically excavated shallow workings .....	40
Safety aspects of shallow workings .....	41
Environmental aspects of shallow workings .....	42
Preservation aspects of shallow workings .....	42
Geology and mineralization aspects of shallow workings .....	42
Rehabilitated features .....	42
Safety aspects of rehabilitated features .....	43
Environmental aspects of rehabilitated features .....	43
Geology and mineralization aspects of rehabilitated features .....	43
Dumps .....	43
Waste, rock and soil, topsoil, rubbish, and ash dumps .....	43
Tailings dumps .....	46
Leach pads .....	48
Ramps/tramways .....	48
Safety aspects of dumps .....	49
Environmental aspects of dumps .....	49
Preservation aspects of dumps .....	50
Geology and mineralization aspects of dumps .....	50
Infrastructure .....	50
Infrastructure types .....	50
Safety aspects of infrastructure .....	54
Environmental aspects of infrastructure .....	54
Preservation aspects of infrastructure .....	54
Under infrastructure .....	54
Data applications .....	54
Feature hazard assessment .....	54
Additional hazard considerations .....	56
Proximity to access .....	56
Progressive shaft collapse .....	57
Fence and seal effectiveness .....	57
Backfilling of underground workings .....	59
Potential subsidence of underground workings .....	60
Environmental assessment .....	61
State of preservation assessment .....	63
Mineralization and geological mapping .....	63
References .....	69

## Appendices

1. Glossary of terms .....	70
2. List of acronyms and abbreviations .....	76

## Figures

1. Locations of MINEDEX MH sites and mineral fields in Western Australia .....	5
2. Sites page from the ArcPad application .....	8
3. Geologist using a Cassiopeia hand-held personal computer in left pocket connected by cable to the Omnistar DGPS unit in the backpack .....	10
4. Symbol hand-held personal computer with the attached Links Point GPS unit .....	10
5. Location of 88 705 sites in the WABMINES database as at 31 December 2002 .....	12
6. Number of abandoned mine site features recorded per year .....	13
7. Number of Priority 1 sites within a set buffer distance from a feature .....	13
8. Status of the Priority 1 MINEDEX MH sites as at 31 December 2002 .....	13
9. Number of Priority 1 sites completed per year .....	14
10. Number of features recorded per MINEDEX MH site per year .....	14

11.	Overall status of the inventory of abandoned mine sites as at 31 December 2002 .....	14
12.	Status of the inventory of abandoned mine sites with respect to MINEDEX MH sites completed as at 31 December 2002 .....	14
13.	Status of Priority 1 MINEDEX MH sites by mineral district as at 31 December 2002 .....	15
14.	Frequency distribution of feature groups .....	15
15.	Frequency distribution of underground features .....	16
16.	Typical shaft with a full bund, between 1 and 3 m high .....	16
17.	Timbered collar of the shaft shown in Figure 16 .....	16
18.	Frequency distribution of features for shafts with full bunds .....	17
19.	Typical shaft with a partial bund up to 1.1 m high .....	18
20.	Inclined shaft with a 30° dip .....	18
21.	Frequency distribution of features for shafts with partial bunds .....	18
22.	Shaft with no bund .....	19
23.	Frequency distribution of features for shafts with no bund .....	20
24.	Shaft with ladder access .....	20
25.	Open stope .....	22
26.	Frequency distribution of features for open stopes .....	22
27.	Circular histogram showing strike distribution of open stopes .....	23
28.	Adit of 1.5 m height and 1 m width .....	24
29.	Frequency distribution of depth for adits .....	25
30.	Subsidence caused by the collapse of underground workings .....	26
31.	Frequency distribution of depth for subsidence features .....	26
32.	Large collapsed drillhole .....	27
33.	Typical collapsed shaft with a partial bund to 1 m .....	28
34.	Frequency distribution of features for collapsed shafts .....	28
35.	Frequency distribution of opencut feature types .....	30
36.	Typical deep pit/quarry with a limited access ramp .....	30
37.	Frequency distribution of features for pits/quarries more than 10 m deep .....	31
38.	Typical shallow pit/quarry .....	32
39.	Frequency distribution of features for pits/quarries less than 10 m deep .....	33
40.	Typical mechanically (excavator or backhoe) excavated costean/trench with a partial bund to 2.5 m height .....	34
41.	Frequency distribution of features for mechanically excavated costeans/trenches .....	35
42.	Typical hand-dug costean/trench and adjacent shallow workings .....	36
43.	Frequency distribution of features for hand-dug costeans/trenches .....	36
44.	Frequency distribution of features for undifferentiated costeans/trenches .....	38
45.	Typical old shallow working, less than 0.5 m deep .....	39
46.	Frequency distribution of recorded features for undifferentiated shallow workings .....	40
47.	Mechanically excavated shallow working – alluvial pit .....	41
48.	Frequency distribution of features for mechanically excavated shallow workings .....	41
49.	Typical rehabilitated area showing ripped ground over workings .....	42
50.	Frequency distribution of rehabilitated features .....	43
51.	Frequency distribution of dump types .....	44
52.	Various types of dumps and their dimensions .....	44
53.	Frequency distribution of features for dump types .....	45
54.	Typical tailings dump .....	46
55.	Frequency distribution of features for tailings dumps .....	47
56.	Typical leach pad .....	48
57.	Ramp/tramway .....	48
58.	Frequency distribution of features for ramps/tramways .....	49
59.	Various types of infrastructure and their dimensions .....	51
60.	Frequency distribution of infrastructure features .....	53
61.	Nine-posted headframe and stand .....	53
62.	Example of possible hazard subcategories Underground 1 and Underground 2 in the Cue region .....	56
63.	Various types of shafts and their dimensions .....	58
64.	Various types of fences around shafts .....	59
65.	Various types of seals .....	60
66.	Examples of backfilled features .....	61
67.	Map showing abandoned workings close to the road in the Burbanks region, south of Coolgardie .....	62
68.	Subsidence of abandoned workings .....	62
69.	Map showing the locations of other mining-related features in the Coolgardie region .....	64
70.	Shaft on a sheared contact of a highly fractured and folded quartz vein .....	64
71.	Map showing the locations of abandoned shafts and shallow workings in the Coolgardie region .....	65
72.	Interpreted bedrock gold mineralization trends in the Coolgardie region with underlying orthophotograph .....	66
73.	Map showing the bedrock gold mineralization associations in the Coolgardie region .....	66
74.	Map showing the locations of alluvial and colluvial workings in the Coolgardie region .....	67
75.	Map showing the locations of black shales in the Coolgardie region, compared with the black shale units mapped by Hunter (1985) .....	67



## Tables

1. Summary of recent recorded abandoned mine accidents in Western Australia .....	6
2. Summary data for 5034 shafts with full bunds .....	17
3. Number of attributes for 5034 shafts with full bunds .....	17
4. Summary data for 7285 shafts with partial bunds .....	18
5. Number of attributes for 7285 shafts with partial bunds .....	19
6. Summary data for 922 shafts with no bund .....	20
7. Number of attributes for 922 shafts with no bund .....	20
8. Number of attributes for 1542 open stopes .....	23
9. Summary data for 1542 open stopes .....	23
10. Summary data for 133 adits .....	24
11. Number of attributes for 133 adits .....	25
12. Summary data for 189 subsidence features .....	26
13. Number of attributes for 189 subsidence features .....	27
14. Summary data for 53 collapsed drillholes .....	27
15. Number of attributes for 53 collapsed drillholes .....	28
16. Number of attributes for 1379 collapsed shafts .....	29
17. Summary data for 1379 collapsed shafts .....	29
18. Summary data for 61 pits/quarries more than 10 m deep .....	31
19. Number of attributes for 61 pits/quarries more than 10 m deep .....	32
20. Summary data for 463 pits/quarries less than 10 m deep .....	32
21. Number of attributes for 463 pits/quarries less than 10 m deep .....	33
22. Summary data for 429 mechanically excavated costeans .....	35
23. Number of attributes for 429 mechanically excavated costeans .....	35
24. Summary data for 122 hand-dug costeans .....	37
25. Number of attributes for 122 hand-dug costeans .....	37
26. Summary data for 5069 undifferentiated costeans .....	38
27. Number of attributes for 5069 undifferentiated costeans .....	38
28. Number of attributes for 44 844 undifferentiated shallow workings .....	40
29. Number of attributes for 2302 mechanically excavated shallow workings .....	42
30. Number of attributes for 12 052 rehabilitated features .....	43
31. Summary data for dump types .....	45
32. Number of attributes for dumps .....	46
33. Summary data for 534 tailings dumps .....	47
34. Number of attributes for 534 tailings dumps .....	47
35. Summary data for 36 leach pads .....	48
36. Number of attributes for 36 leach pads .....	48
37. Summary data for 102 ramp/tramways. ....	49
38. Number of attributes for 102 ramp/tramways. ....	50
39. Summary data for infrastructure types .....	52
40. Number of attributes for infrastructure types .....	52
41. Proposed key safety criteria for the main feature categories .....	55
42. Hierarchy of hazard subcategories showing different relative risk levels between the main hazard categories .....	56

# Inventory of abandoned mine sites: progress 1999–2002

by

W. R. Ormsby, H. M. Howard, and N. W. Eaton

## Abstract

This Record accompanies the first public release of the abandoned mine sites database. An inventory was recommended by the Minerals Environment Liaison Committee in 1994. Following a fatal accident at an abandoned mine site near Cue in 1997, the Western Australian Government initiated funding of an ongoing program within the then Department of Minerals and Energy to develop an inventory of abandoned mine sites in the State. The inventory currently contains records for 88 705 mining-related features, and includes about two-thirds of the highest priority historic mine sites in Western Australia.

This is a comprehensive digital database of abandoned mine sites that includes photographs of individual underground and surface excavations, dumps, and rehabilitation and infrastructure features. Mining-related features are illustrated and described by morphological criteria and key attributes.

The inventory provides baseline data on historical mining-related features in Western Australia, forming a solid foundation for future independent assessments of hazards, heritage value, and environmental impact. The database also provides a valuable contribution to the spatial distribution of mineralization in historical mining areas.

**KEYWORDS:** Western Australia, abandoned mines, underground mining, open cut mining, trenching, mine wastes, mine rehabilitation, infrastructure, mine safety, mine heritage, mineralization, mine geology.

## Introduction

Mining has occurred in Western Australia for more than 150 years, resulting in many thousands of workings that were abandoned after exploration or mining. Until recently, few of these workings and other associated mine site features were documented and many remain unrecorded.

The 1992 [Australian] National Strategy for Ecologically Sustainable Development set out a number of objectives to further develop the mining industry and efficiently manage the renewable and nonrenewable resources on which it depends (Ecological Sustainable Development Steering Committee, 1992). The first strategy objective (5.1) was 'To ensure sound environmental practices throughout the mining industry, governments will work through the Australian and New Zealand Minerals and Energy Council (ANZMEC, now the Ministerial Council of Mineral and Petroleum Resources) in conjunction with the Australian and New Zealand Environment and Conservation Council (ANZECC) to

develop guidelines for the rehabilitation of abandoned minesites' (Ecological Sustainable Development Steering Committee, 1992). The resulting inventory was intended to be a nationally consistent, computer-based, technical document outlining the safety and pollution hazards at each abandoned mine site. The inventories developed by each of the State governments may have a different focus according to the environmental and safety issues peculiar to that State.

In late 1992 the Minerals Environment Liaison Committee (MELC — an advisory group to the then Western Australian Department of Minerals and Energy, DME) decided to reassess the Western Australian gold industry's environmental performance and relevant administrative procedures. The Minister for Mines endorsed the decision in May 1993, and a subcommittee from MELC (consisting of industry representatives Dr Wolf Martinick and Doug Koontz, pastoral representative Ben Patrick, conservation representatives Andrew Corbyn and Robin Chapple, and senior departmental officers) then produced a report titled 'Conservation and rehabilitation



in the gold mining industry, 1994' (Minerals Environment Liaison Committee, 1994). One recommendation of the report was '...as a matter of urgency (the Western Australian) State government allocates financial resources to DME to compile its inventory of abandoned mines sites and that consideration be given to a five-year program to progressively rehabilitate priority sites identified because of public safety hazard or major environmental issues'.

The MELC recommendation was not implemented until after an abandoned mine-related fatality in Cue in 1997 and questions raised in the State Parliament in 1998. The Minister for Mines then confirmed that '...we will do the necessary audit on the rehabilitation of mine sites in the mining areas of Western Australia...' and '...that the money will be used to audit the disused shafts and other mining operations in Western Australia to see what should be done with them.' (Parliamentary Debates, 1998). The Minister further commented that '...once the audit is completed the issue will arise of how much we should spend to rehabilitate some of those sites.' (Parliamentary Debates, 1998). Funding was provided in the following year for work on 'a database for inventory of abandoned mine sites' (Parliamentary Debates, 1999). The Geological Survey of Western Australia (GSWA) began creating the inventory, which is now called the Western Australian abandoned mine site database (WABMINES), in July 1999.

The early planning for this inventory was undertaken by D. J. Flint in close collaboration with staff of the Western Australian Department of Industry and Resources' (DOIR's) Safety, Health, and Environmental Division (SHED), and in particular, A. Bradley and J. W. Biggs. The inventory's application and database were designed by D. B. Townsend, and updated by J. R. Gozzard. Field data were collected by N. G. Adamides, V. L. Cameron, R. W. Cooper, J. G. Downing, M. G. Doyle, H. M. Howard, R. L. Langford, T. Major, W. R. Ormsby, S. L. Risbey, C. D. Strickland, and M. Zengerer. Data and assistance were received from the various mining companies whose tenements are included in the areas covered.

This report discusses the context, methodology, status, and content of the inventory of abandoned mine sites in Western Australia, and is intended to accompany the first public release of the data, aiming to characterize and illustrate mine site features. The report also provides a comprehensive basis to discuss the application of the data to hazard, environmental, and state of preservation assessment, and mineralization and geological mapping.

## National and international trends

The following is a summary of the focus taken by national and international agencies in the development of inventories for abandoned mine sites.

### Australia

The State or Territorial governments of Australia are responsible for their own inventory of abandoned mine sites, many of which have been in progress for several years.

The inventory of abandoned mine sites for Queensland is an ongoing project that has focused on public safety, although environmental issues such as acid mine drainage are also of concern. As a result of the inventory, a program for the rehabilitation and capping of abandoned mine shafts has begun and many shafts at known sites have already been capped. As historic dangerous mine sites are reported, immediate action is taken to ensure public safety.

The Office of Minerals and Energy Resources of South Australia started a project to catalogue and monitor abandoned mine sites in the State and investigate any risk they pose. A MINE SUMMARIES database was created and is used in conjunction with the mine location plans to quickly identify the location and details of historic mines for landowners, local and State government, and the public. This database includes summary information on history, geology, mine workings, and historic records (Drew, 2002).

Victoria has numerous abandoned mine sites dating back to gold mining in the 19th Century. There are good records providing descriptions, interpretations, and an assessment of heritage status of about 2000 sites as a result of a long-term project to document historic mine sites. The emphasis has primarily been on heritage and conservation, therefore there is currently no coordinated program to prioritize or address rehabilitation of these sites.

New South Wales has undertaken a major survey of all abandoned mine sites. The priorities are to remove risks to public health and safety, stabilize sites and reduce the impact of erosion and mass movement, reduce contamination from sites, increase biological diversity of species in the area, and improve the visual amenity of sites. The focus of this program is on environmental concerns and public health issues, particularly in the Sydney drinking-water catchment area. The resulting inventory is intended to aid in prioritizing the rehabilitation of derelict mine sites. The State has also developed a program for rehabilitation of derelict mined lands, which is administered by the Department of Mineral Resources, in conjunction with the Environment Protection Authority, the Department of Land and Water Conservation, and the N.S.W. Minerals Council.

The Tasmanian Geological Survey has completed an abandoned mine sites inventory. The details included in the inventory are the land status, commodity, lease, years of operation, site elements (shafts, adits, dams etc.), and the safety and environmental issues at the site. The sites are prioritized on the basis of rehabilitation requirements, and a strategy for the rehabilitation of abandoned mining lands has been developed (Tasmanian Geological Survey, 1998). Many of the sites have already been rehabilitated.

The Northern Territory was due to commence an abandoned mine sites inventory in 2002 and the Australian Capital Territory does not yet have an abandoned mine sites inventory.

### Canada

In Canada the term 'abandoned mine' refers to those sites where advanced exploration, mining, or mine production

has ceased and rehabilitation is not complete. Inventories of abandoned mines exist in Newfoundland and Labrador, Nova Scotia, New Brunswick, Québec, Ontario, Manitoba, Saskatchewan, Alberta, British Columbia, Yukon, Nunavut, and Northwest Territories. These inventories range from comprehensive computer databases that are accessible to the public, to paper files and some that were compiled from a library search only. There are a total of 10 139 abandoned mine sites on file. More than 60% of the sites have had a field inspection, but most have not been tested for physical or chemical stability. Tens of millions of dollars have been spent on remedial work on abandoned mine sites, but much work still remains (Mackasey, 2000).

## United States of America

The United States of America have created abandoned mines inventories for many areas. This has been achieved largely by the Bureau of Land Management, the Forest Service, the National Park Service, and the Fish and Wildlife Service. These organizations have estimated 9200, 25 000, 4000, and 240 abandoned mine sites respectively, within the areas of land they manage (Mining Minerals and Sustainable Development, 2002). These data are not strictly comparable because the inventories were compiled using different definitions of 'abandoned mine site'. For example, some units within the National Park Service consider each feature of a mining operation such as a tunnel, shaft, road or historic building to be a site, therefore one operation would comprise many sites, whereas other units refer to all the features as a single site.

The purpose of the United States inventories is to determine the location of abandoned or inactive mines and to document the presence or absence of both environmental and physical hazards (United States Bureau of Mines, 1994). Environmental hazards include toxic substances, heavy metals, polychlorinated biphenyls, acids, petroleum products, asbestos, radioactive material, sedimentation, and dust. The physical hazards include abandoned explosives, unstable mining structures, mechanical equipment, scrap materials, underground workings, open pits, high walls, ditches, subsidence, waste piles and impoundments. The 16th annual meeting of the Association of Abandoned Mine Land Programs highlighted the main problems of toxic substances, subsidence, and mine drainage (Mesch and Malin, 1994).

The Bureau of Land Management (BLM) supports many of the U.S.A.'s abandoned mines inventories, many of which are focused on their impact on water quality, and public health and safety on public lands. Remediation programs have begun in many States to attend to those sites that have greatest impact on public safety and the region's water resources (Bureau of Land Management, 1997). Of the 65 000 abandoned sites under BLM's jurisdiction, the agency estimates that 5% may have Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or water quality problems and about 25% have physical safety hazards (Bureau of Land Management, 1997).

The Forest Service of the U.S. Department of Agriculture runs abandoned mine lands programs to

document the abandoned mines in the country's forests. The Minerals Availability System – Mineral Industry Location System database, compiled by the U.S. Department of the Interior, lists more than 13 500 past producing mines within the boundaries of the National Forest System (Shields et al., 1995). The primary concern of the inventories are the impacts on water, soil, and fisheries. For some inventories, such as in Ohio, hydrologists are required to determine the impact of a mine seep on the water quality of the watershed so that mines can be prioritized for treatment. The Forest Service estimates that about 1700 of its sites qualify for reclamation under CERCLA standards and about 4200 sites cause environmental harm under Clean Water Act (CWA) stipulations. Together these sites may represent about 17% of all the abandoned mine sites on National Forest System lands (Greeley, 1999).

The National Park Service established its Abandoned Mineral Land Program in 1983 and since then has completed an inventory, and set priorities for mitigation. Eighty-five abandoned mineral land sites have been rehabilitated, 766 openings have been closed, and 34 orphaned oil, and gas wells have been plugged (Abandoned Mineral Land Program, 1998). Environmental assessments of sites and reclamations in parks are yet to be conducted.

## United Kingdom

Since 1870 it has been a statutory requirement to record abandoned mines in England and Wales (National Rivers Authority, 1994). Before this date there were no records of abandoned mines. There is, nevertheless, no accurate inventory of abandoned mines because of the change of mine names when old leases are combined.

The British Coal Authority had a database of about 10 000 abandoned mine workings, although this is an estimate as some of these have been reopened for commercial, recreational and educational purposes. It is also estimated that there are 1700 abandoned metalliferous mine workings in southwest England (Mining Minerals and Sustainable Development, 2002).

The primary concern for abandoned mine sites in the United Kingdom is their effect on the many river systems and waterways. Pollution of rivers can seriously affect human health and have devastating biological impacts, leaving rivers fishless. The National Rivers Authority is involved in the monitoring of the problem and is working with the government departments to ameliorate the effects of abandoned mine sites.

## Other countries

Abandoned mine sites in South Africa are controlled under the Water Amendment Act 58, which was introduced in 1956. Prior to the Act many mines were abandoned without implementation of adequate pollution control measures. In 1976 an agreement, known as 'The Fanie Botha Accord', was made between the South African



Government and the mining industry for the provision of pollution control measures at abandoned collieries and the cost of their implementation.

The Environmental Protection Agency of Sweden has a list of more than 1000 abandoned mines, of which 70 have environmental significance (Mining Minerals and Sustainable Development, 2002).

In Ireland the Environmental Protection Agency has a list of 128 abandoned mines and most are very small or old and do not present an environmental problem (Mining Minerals and Sustainable Development, 2002).

The European Union also commissioned an inventory of abandoned mine waste sites in all the member States, which was completed in May 2000.

The National Survey of Japan located 5500 abandoned mines (United Nations Environment Programme, 2000).

## Western Australia

The Western Australian State government has given DoIR (formerly Department of mineral and Petroleum Resources — MPR, before that DME) the responsibility to compile an inventory of the abandoned mine sites for the State. The Geological Survey of Western Australia (GSWA) started the inventory in 1999, and during the first year of the program, a computer database and field assessment were designed and implemented. The project objectives were to accurately locate and document abandoned mine sites, to document factors relevant to the public safety and environmental hazards they pose, to assess their state of preservation, and to quantify the aggregate risk associated with each site. The inventory was intended to provide a sound basis for future planning of the necessary action and rehabilitation at high-risk abandoned mine sites.

Although the inventory was initiated from concerns for public safety and the environment, it has potential for assisting in studies of mineralization, and geological mapping. Data were collected for all mining-related features, which would allow consideration of the geology and mineralization aspects of each mine site feature where appropriate (in addition to public safety, environmental, and state of preservation issues).

The inventory principally consists of individual mining-related features such as shafts, dumps and buildings that are commonly found at sites of historic mine production. Most of these sites have been non-operational since 1990 and are therefore considered to be abandoned. Mines that have closed since 1990 are already well located and have environmental matters addressed within either Notices of Intent to commence mining operations (introduced in 1986) or by DoIR's environmental management system (introduced in 1990). The principal clients of the inventory of abandoned mine sites are the mining industry, DoIR (SHED), local governments, Department of Conservation and Land Management (CALM), land leaseholders, Heritage Council of Western Australia, and the public.

## Methodology

DoIR's mines and mineral deposits information (MINEDEX) database contains all pre-1985 historic mine (MH) production sites for Western Australia. Work for the inventory of abandoned mine sites project was prioritized mainly on the proximity of MH sites to populated towns and main roads, reflecting the major safety objective of the project. Other considerations included records of past accidents, and feedback from local governments.

A number of sources of data assisted in the identification of abandoned mines or target areas for fieldwork in any given area. The most widely used tool was aerial photography, but other sources of information included historical maps, geological maps, historic tenement boundaries and data provided by mining companies, and orthophotographs (aerial photographs that have been referenced to a coordinate system, and corrected to eliminate all variations in scale). Work programs were planned in the office with the assistance of these resources before each field trip.

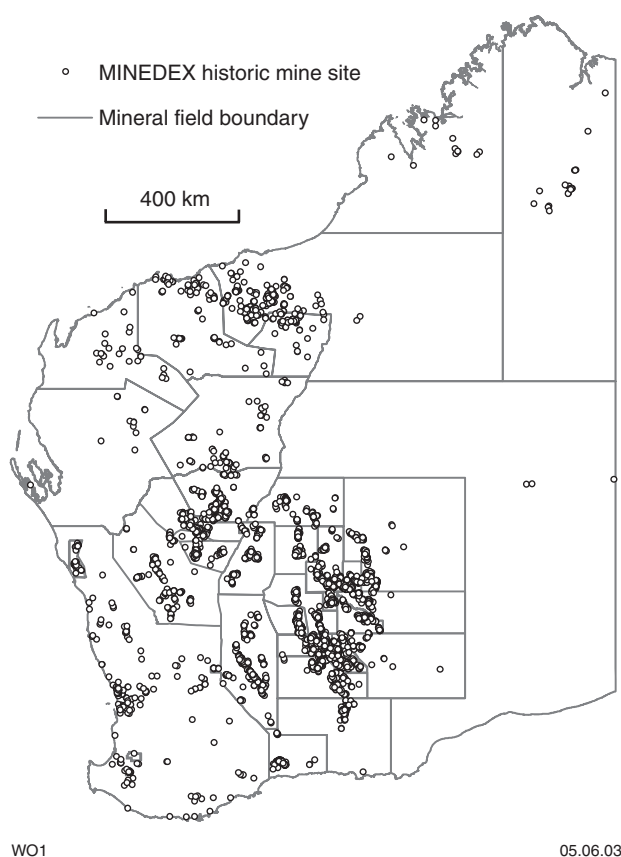
A purpose-made database was developed for the project, and an application was initially designed using Visual CE and MapPad software. Cassiopeia hand-held personal computers (PCs) were selected for data capture using the Differential Global Positioning System (DGPS) for accurate locations. Both the database and application improved with increased experience and improved technology. Major improvements were made in mid-2002 with the acquisition of Symbol hand-held PCs and a clip-on GPS. The application was simplified and changed to ArcPad software. These changes resulted in a several-fold improvement in the range of data collected and in increased data collection rates. The database structure was also simplified and expanded to incorporate extra useful information. The database itself was moved from a Microsoft Access (MS Access)-based system to the Oracle system, and was integrated with GSWA's Western Australian field observation database (WAROX).

Digital photographs of some feature types were collected from the outset. The use of photographs has subsequently expanded to provide more useful information. The photograph database is now fully integrated with WAROX.

Extensive database validation has been undertaken, and protocols have been established for the validation of new data and the extraction of data for clients.

## Prioritization

The overall distribution of abandoned mine sites in Western Australia is shown by the distribution of MH sites in MINEDEX. Although there are abandoned mine sites throughout the State, about 89% are in the 29 mineral fields in the southwestern quadrant of the State (Fig. 1), which represents only 34% of the total land area. About 80% of the rural and regional population of Western Australia, also reside in this area. Consequently, the mineral fields in the southwest have been the focus for the project.



**Figure 1. Locations of MINEDEX MH sites and mineral fields in Western Australia**

The highest priority was given to MH sites that were most accessible to the public, reflecting the emphasis on public safety, and precedence was given to those MH sites located within 10 km of populated towns and within 1 km of major roads. The areas inspected were further prioritized according to such factors as the history of abandoned mine site related accidents, and feedback from local governments.

## MINEDEX

The MINEDEX database was established in 1985, and contains records of the locations and estimated mineral resources and ore reserves of mines and mineral deposits in Western Australia (Cooper et al., 2002). Those records pertaining to reported gold production prior to 1985, or with the production of any commodity prior to 1989 are termed MH (historic mine) sites. These do not include some mines that may have been in production after those dates, which were regarded as 'current' in the database.

The pre-1985 gold production information is derived from the 'List of cancelled gold mining leases' (Department of Mines Western Australia, 1954) and gold production records of 1954–85 held by DoIR (Cooper et al., 2002). Gold production commencement and finish dates and cumulative production are provided in

MINEDEX for each site. Product type is also recorded as gold ore (most common), gold alluvial, gold dollied or gold tailings (for tailings retreatment).

The locations of some of the historic sites were taken as the centre of the tenement for which production was recorded and where no other information was available. Data on historic tenements are as documented on the production records, and hence do not provide an exhaustive list of historic tenements for that site (Cooper et al., 2002). The location accuracy is therefore quite variable, and only those deemed to be sufficiently accurate are labelled as 'Y' in the accuracy column and are displayed in DoIR's electronic tenement-graphics system (TENGRAPH).

An extract of MINEDEX showing MH sites was first released to the public in 2000 (Townsend et al., 2000), and a new public release has been made with 11 411 MH sites listed (Cooper et al., 2002).

The MINEDEX MH sites are the starting point for the prioritization and planning of abandoned mine site field inspections, and are useful for measuring overall progress. Fieldwork has shown that each site may represent anything from a single shaft through to tens of individual mine workings and associated mine features. Commonly, the workings are scattered along a semi-continuous line or zone, and it is difficult or impossible to delineate which are related to any specific site in MINEDEX. Furthermore, there are significant workings in areas well away from MINEDEX sites, either due to the limitations of point data as MH site locations, inaccuracies in the location data, or the absence of specific production records for those sites.

The digital MH site data are viewed using ArcView GIS (Geographic Information System) software on laptop computers in the office and in the field camp. They can also be loaded onto the hand-held computers carried in the field and used as a navigational aid to assist in locating areas of abandoned mine-related features.

## Prioritization of historic mine sites

The highest priority (Priority 1) MH sites are defined as those located within 10 km of populated towns and within 1 km of major roads. The greatest risk to public safety was assumed to be at sites closest to population centres. Population figures were only available from the Australian Bureau of Statistics for towns with populations in excess of 200. These were termed 'populated towns' for the purposes of this project.

A road dataset was acquired from the standard Western Australian Department of Land Administration (DOLA) 1:250 000 scale topographic sheets. The road data are divided into five levels: major roads comprise three levels — dual carriageway, principal road, and secondary road; and the other two levels are minor roads and tracks.

ArcView GIS software was used to select the MH sites that lie within buffer zones around towns and roads. A new dataset termed Priority 1 historic mine sites was then created from the buffer zones.



**Table 1. Summary of recent recorded abandoned mine accidents in Western Australia**

<i>Date</i>	<i>Injured</i>	<i>Location</i>	<i>Description</i>	<i>Injuries</i>
1987	Peter Allen Dale	Collie	Dived into water-filled pit	Broken neck
May 94	11-year-old boy	Kalgoorlie	Fell 15 m down 80 m shaft	Unknown
21 Oct 95	Shane Harvey	Widgiemooltha	Fell 15 m down shaft	Not seriously hurt
26 Jan 97	Mark Harman	Kalgoorlie	Fell 10 m with trail bike into shaft	Not seriously hurt
12 Feb 97	13-year-old boy	Cue	Fell 33 m into shaft	Fatal
08 Dec 97	Doug Tucker (14 yrs)	Kalgoorlie	Fell 30 m down shaft	Broken leg
31 Mar 00	Pet dog	Kalgoorlie	Fell down shaft under house	Survived

## Accidents

Table 1 lists some recent recorded historic mine site related accidents in Western Australia. The initial priorities for the project were strongly influenced by past accidents, incidents, and correspondence with local governments. Specifically, the fatalities listed in Table 1, and other accidents in Sandstone, Ravensthorpe, Widgiemooltha, Kalgoorlie and Collie, combined with advice from the Shire Councils in Yalgoo, Sandstone, Cue, and Ravensthorpe, led directly to work in most of those areas in the first two years of the project.

The majority of recorded accidents were in the Kalgoorlie region, as would be expected from a large population close to an area of extensive historical and current mining activity. Consequently, work began in the Kalgoorlie region in the second year and continued in the third and fourth years as the magnitude of the task became apparent.

## Other considerations

In addition to the main MH-site-based prioritization criteria of DoIR, the State battery sites and the explosives reserve areas have been integrated as additional parts of the project.

A reconnaissance survey of 73 State battery sites was carried out in the first year at the request of the W.A. Gold Corporation with the aim of assessing the potential risk posed to public safety and their impact on the environment (Adamides, 2000). Some of the sites were in high-priority areas such as Cue and Sandstone, and the methodology developed for the inventory of abandoned mine sites was ideal for completing the task quickly and efficiently.

The explosives reserve in Coolgardie was specifically surveyed with the dual purpose of completing a high-priority area for the abandoned mine sites project and conducting reconnaissance screening of old explosives reserves. As for the State batteries program, there is a requirement to document the existing infrastructure and potential hazards on all explosives reserves in Western Australia.

## Spatial information

A combination of spatial information was used for planning, navigation, and targeting purposes in the office

and in the field. Aerial photography was the main tool in combination with the MINEDEX MH sites throughout much of the project, and historic geological maps and spatial data provided by mining companies augmented this approach. TENGRAPH plots of topography, MH sites, current mines, and mineral tenements were used routinely in the first three years. In the field, MH site and road data were loaded into the Cassiopeia hand-held PC where appropriate. In year 4, orthophotographs, digital historic tenement data and digital geological maps were added as useful tools. The advent of the Symbol PC made in-field use of orthophotographs and other images possible. Furthermore, flexibility with display point symbols and colours facilitated the use of multiple targeting data in the field. For example, the MH sites could be shown in a different colour to targets selected from orthophotographs, and both could be different to the sites acquired in the previous day.

## Historic maps

GSWA Bulletins published between 1898 and 1920 contain historical maps, some of which locate individual mine sites or groups of mines. The maps are inaccurate by current standards, and do not correspond to any identified coordinate system (Kukuls, 2000). Kukuls (2000) documented the process used to scan and rectify these maps, as summarized below.

The maps were scanned on a flatbed scanner at a resolution of 300 dots per inch. The resultant TIF images were georeferenced to town and reserve boundaries, roads, railways, topographic features, and historic mining tenement boundaries extracted from TENGRAPH. The accuracy of the resultant image varies from map to map, and across the map, but the majority are accurate to within 15 m.

Currently, 64 historic maps have been scanned and georeferenced in this manner; however, the maps vary in the amount of detail they provide on mine workings. The 1898 Coolgardie geological map (Blatchford, 1899), for example, shows the location of 2079 workings whereas the adjoining 1912 map of the 'country between Tindalls and Londonderry' (Blatchford and Farquharson, 1913) showed only 64 workings.

The location of the workings on the detailed 1902 Kalgoorlie geological map (Maitland and Campbell, 1902)

were digitized using ArcView software. These digitized data were used in the field to locate historic workings.

The cumulative mapping, georeferencing, and GPS errors did at times cause problems in reconciling individual mapped features with ground observations. To assist in this process the rectification process was repeated in an iterative manner using more control points to help reduce the errors caused by mapping and georeferencing.

Ultimately, it is intended to add to the database the remaining points that are currently either under infrastructure or have been rehabilitated, using the most accurate rectified map available. These localities may be able to identify individual properties in a built-up area that are subject to abandoned workings.

## Aerial photographs

Interpretation of recent and older aerial photography has been the primary tool in identifying the location of mine and exploration workings before field checking. In many areas a series of 1:10 000-scale colour aerial photographs flown by DME in the early 1990s, were used to target areas for field inspection. Photographs from other sources, including DOLA and mining companies, have also been useful.

Aerial photographs were studied stereoscopically in the office, and target areas were marked on transparent overlays for checking. Until the advent of good quality orthophotographs, and the Symbol hardware, the photographs were extensively used for field navigation purposes, and progress was marked on the overlays as numbered points. Aerial photograph details were also recorded in the earlier versions of the WABMINES database, reflecting this usage. Although it is still a useful navigation and targeting aid, the importance of the aerial photographs has reduced with the introduction of the new technology.

Another use of aerial photographs, especially older ones, has been the identification of mine workings that are under infrastructure, or rehabilitated. These workings were marked on an overlay along with a number of distinctive control points such as other (remaining) feature sites, and road junctions. Early aerial photographs were simply georeferenced, and additional points digitized. Later in the project, the photographs were scanned to create TIF images that were georeferenced using ER Mapper software.

## Orthophotographs

Orthophotographs came into regular use in the fourth year of the project with the introduction of the Symbol hand-held PC and the acquisition of additional photographs.

The orthophotographs were acquired in ER Mapper image format and cropped into smaller JPEG tiles using a purpose-made extension in ArcView. Experimentation determined that JPEG tiles covering a 2 × 2 km area with a JPEG quality value of 80 achieved a good compromise between file size and detail. The appropriate JPEG images

were then loaded into the Symbol PC and taken into the field. The Symbol PC with the GPS continuously activated enabled the direct viewing of the operator location with an orthophotograph background. This functionality proved useful in the field for locating workings, but most importantly for directly entering the location of features that were not easily or safely assessable such as the centre of a high waste dump or a large rubbish dump. The dimensions of some larger features could be determined directly from the orthophotograph, whereas other parameters such as edge condition could be observed and entered into the database at the same time.

In some cases a print made of the orthophotograph was carried in the field as a navigation aid. The advantage of this type of hardcopy over a conventional aerial photograph was the ability to customize the image by adding, for example, grid lines, topographic contours, tenement boundaries, or any other useful digital information.

Another use of the orthophotographs was for targeting features, particularly in areas where they were sparse, but still significant. An extract of the image was viewed on the laptop computer and targets were saved in a shapefile using ArcView. For example, a number of targets were identified, mainly by colour contrast, from the orthophotograph of an area west and south of Coolgardie, where there were no records of historic mine sites in either MINEDEX or on the historical geological map. The targets were loaded onto the Symbol PC and visited in the field. Even though many targets were rabbit warrens and other irrelevant features, a number of isolated but significant workings were found.

## Company data

Some mining companies provided digital survey data that located features such as open pits, dumps, costeans, and, in some cases, abandoned workings. Where applicable, data were converted into point shapefiles, loaded into the Symbol PC or laptop computer, and used as a targeting tool in the field. Some of the data were also used for locating features that are now under infrastructure or rehabilitated.

## Tenements

The boundaries of expired tenements in TENGRAPH are available as a single file. Although the attributes for the tenement boundary polygons only include the tenement name, expired gold mining leases (GMLs) in particular are identifiable and were useful for locating target areas. This was especially the case where other sources of information such as aerial photographs were either not available at the appropriate scale, or where vegetation had obscured workings. The locations of historic tenements are a more comprehensive guide to areas of previous mining or exploration activity than the MH site database, as many abandoned workings were either of an exploratory nature or did not have reported production. In some cases the tenement outline also more accurately represents the area

from which the production came rather than the MH site point-location data.

## Geological maps

Geological maps assisted in focusing the search for abandoned workings by highlighting areas of outcrop and prospective rock types. For example, many gold workings are along specific surfaces such as black shale contacts or faults. Most field time was therefore devoted to looking in areas with a higher probability of abandoned workings as indicated by the geological maps, in combination with the historic tenement and MH site data. Lower probability areas such as granites were examined from aerial photographs or orthophotographs with fewer, but targeted, site inspections.

Digital versions of geological maps were a useful underlay for other map data in ArcView.

## Database attributes and development

The database attributes were decided after consultation with representatives from the main stakeholder groups, including the Mining Operations Division of DoIR (now SHED), CALM, the Department of Environmental Protection (now the Environmental Protection Authority), the Heritage Council of Western Australia, and the Amalgamated Prospectors and Leaseholders Association of Western Australia (APLA).

The glossary in Appendix 1 defines the current attributes or parameters, and lists the abbreviations and attribute names in the same order as the database extract, and each value name or parameter in alphabetical order. Examples of each feature group are presented in **Morphology of mining features**. Some background on the evolution of the database attributes is given below so that the user can more fully understand and appropriately utilize the database.

The database was initially grouped into the main, underground, opencut, infrastructure, and dump sections, mainly for data entry purposes. For the first three years, both the Cassiopeia PC MapPad/Visual CE application and WABMINES were structured around these five sections. The main section carried all of the site identification information, date, feature group selection, location information from the GPS, photograph numbers, and a number of assessment fields relating to hazards, and environmental and heritage issues.

The application automatically assigned a field identification number to each site, which commenced from the number 0001 each day (or after each data download). Upon downloading each day, every record was assigned an MS Access database-generated AutoNumber. The records collected by the Cassiopeia PC can now be identified in the 'SITEID' column by the originator's prefix followed by a number reflecting the AutoNumber sequence for that originator then a dash and the original field identification number (e.g. RWC20\_0042).

For the feature groups 'shallow working' and 'rehabilitated', only the remainder of the main section was completed, therefore no dimensions or other attributes apart from the assessment fields were completed. For the 'underground', 'opencut', 'dump', and 'infrastructure' feature groups, separate pages were entered in the Cassiopeia PC application to record more details. Each of these pages contained feature group specific attributes such as 'U/G\_Length' or 'Infra\_Depth' or 'O/P\_Fences', and every attribute corresponded with a specific column in the MS Access database.

A new feature group called 'collapsed shaft' was introduced in late May 2002 to include shafts that are currently less than 2 m deep, but show evidence of a greater original depth. A collapsed shaft was recorded before this either as 'shaft' in the 'UG\_Type' field with a depth range of 0–2 m or as 'rehabilitated', meaning naturally rehabilitated.

When the Symbol hand-held PC was introduced in late July 2002, the opportunity was taken to fully review the database structure and the new ArcPad application, and many changes have since been made. Common attributes were combined wherever possible, e.g. 'U/G\_Length', 'O/P\_Length', 'Infra\_Length', and 'Dump\_Length' were rationalized into a single attribute called 'LENGTH'. This considerably simplified the database structure and the application. Five separate pages were created for the purposes of data entry: Sites (Fig. 2), Attribs, U/G, O/P, Infra/dump, and Fieldnotes. The Attribs page included all dimensions, orientation measurements, photograph numbers, and other common attributes such as bund height. The 'SITEID' values were also simplified to the initials of the originator and a sequential number (e.g. CDS10000).

The screenshot shows a data entry form titled 'AbMines Entry Form Ver2 Rel1'. It has five tabs: 'Sites', 'Attribs', 'U/G', 'O/P', and 'Infra/dump'. The 'Sites' tab is active. The form contains the following fields and values:

Field	Value
Obsdate	12/05/2003
SiteID	JRG
Easting	
Northing	
Feature Gp	
Safety	
Visibility	
Visual Impact	Low
Condition	Poor

At the bottom of the form are 'OK' and 'Cancel' buttons. Below the form, the text 'WO131' and '13.05.03' is visible.

Figure 2. Sites page from the ArcPad application



Separate fields in the database for 'U/G\_Type', 'O/P\_Type', 'Infra\_Type', and 'Dump\_Type' were combined into a single 'TYPE' column, although they remained separated in the new application for ease of data entry. Changes were also made for the 'TYPE' values where some infrequently used categories such as 'multiple shafts' and 'well' were omitted from the new application. In this case, all shafts are now entered individually and a well is recorded as a shaft if appropriate. All discontinued 'TYPE' values in the database are listed in the data dictionary. New 'TYPE' categories 'ash dump' and 'other infrastructure' were introduced to cater for ash dumps and infrastructure types not listed respectively, and 'DUMP\_OTHER' values for 'cars' and 'old bottles/cans' were also added.

Comments in the older version of the database were prefixed by 'GEOL', 'VEG', or 'HAZARD' to denote the nature of the comment and have now been replaced by two fields termed 'MINE\_NOTE' and 'NOTES'. In the new application the comments field has been replaced by 'Mine Notes' and 'Geology'. Data were migrated to the appropriate fields in the new database depending upon their prefix. Prefixes are therefore no longer required.

Some of the changes to the database allowed for recording of more information where relevant. Previously only the bund maximum height was recorded for partial bunds and the bund minimum height for full bunds into database fields labelled 'O/P\_Bund\_Height' or 'U/G\_Bund\_Height'. 'BUND\_MAX' and 'BUND\_MIN' replaced these fields and are used for any feature type with a bund. Data entry was considerably faster with the Symbol PC and the revised ArcView application. Consequently, from 14 August 2002, dimensions were routinely recorded for all features (previously they were not recorded for shallow and rehabilitated workings).

The fields 'EXCAV\_METH' and 'SIGNS' were also added to the database. The excavation method was included to cover all workings that were definitely made by machinery by recording the value 'mechanical'. The purpose of this was to differentiate older workings from workings that are more recent. Wherever reference was made in the 'MINE\_NOTE' section of the database to a mechanical excavation such as 'bulldozer pit', the value 'mechanical' was added retrospectively to the 'EXCAV\_METH' field. No entries have been placed in the 'SIGNS' field, but the field is intended for future recording of the presence of feature-specific warning signs. Both 'EXCAV\_METH' and 'SIGNS' will be included in the latest version of the application for use in the 2003 field season.

The range of values was expanded for the 'DEPTH' field with the new application, resulting in better definition of the features. The 'shallow' depth range of 0–2 m was replaced by 'extremely shallow' for 0–0.5 m, 'very shallow' for 0.5–1 m, and 'moderately shallow' for 1–2 m. Depth ranges were previously different for opencut and underground features. The new range of values allowed the use of 'extremely deep' for underground workings more than 20 m deep, whereas 10 m was previously the maximum allowable depth field.

Shallow costeans and trenches were frequently recorded as shallow workings in both the Cassiopeia and

Symbol PC-based applications, with a comment entered in the 'Comments' or 'Hazard' sections of the applications (now the 'MINE\_NOTE' column of the database). When the Cassiopeia PC application was used, other attributes such as depth, length, and width were recorded in the comments for some trenches if they were considered major features. All shallow working records with a comment indicating that they were actually costeans or trenches are now recorded as 'costean/trench' types in the 'opencut' feature group to ensure consistency in terminology.

## Field data acquisition

Data were collected during the first three years of the project using a Cassiopeia PA-2400W hand-held PC linked to a DGPS with the Microsoft Windows CE operating system software. During most of that time, an Omnistar Geomatic Locator DGPS was used, which provided a real-time location with a positional accuracy of within 3 m. The DGPS was connected by cable to the Cassiopeia PC and was carried in a backpack (Fig. 3). After the removal of selective availability of the positioning system by the U.S. Government, the standalone positional accuracy of the GPS improved to within 5 m. Consequently, after considerable field-testing, the DGPS was found to be unnecessary, and the more compact Garmin II or Garmin 12 hand-held GPS units, were connected by cable to the Cassiopeia PC from 17 September 2001.

From 1 August 2002, the data collection system was upgraded to a Symbol PPT 2800 series pocket PC with a clip-on Links Point GPS 17-27 (Fig. 4). The positional accuracy remained the same as with the Garmin hand-held GPS, but there were no longer any connecting cables.

The initial database was created as a table in MS Access 97 and copied to the Cassiopeia PC, and the database application forms were designed using Visual CE. The GIS software for the Cassiopeia PC was MapPad, which linked the GPS with the Visual CE application forms. All data were output into a single table in the Cassiopeia PC.

The Symbol PC uses the Microsoft Pocket PC Software 2002 operating system, whereas the application and GIS for the Symbol PC used ArcPad software. The ArcPad application was designed using ArcPad Studio software (Gozzard, 2002a). Data were output as a DBF file and four ArcView shapefiles.

Field procedures were similar for both the Cassiopeia and Symbol PC systems. Because the GPS was located in a backpack for the Cassiopeia PC system, the user stood as close as safely possible to the feature, and waited for the GPS coordinates to stabilize. For essentially point data such as shafts, the user stood to the side of the feature. Linear surface features such as costeans were usually recorded from either end, with the trend recorded as a strike, or in comments. Centroids were normally used for smaller linear features or small area-based features such as footings and small dumps. Larger features such as waste dumps and tailings dams were normally recorded from one





WO132

13.05.03

**Figure 3. Geologist using a Cassiopeia hand-held personal computer in left pocket connected by cable to the Omnistar Differential Global Positioning System (DGPS) unit in the backpack**

corner or edge, and the location was described in the comments. The coordinates of other corners were also frequently recorded in the comments. Wherever possible, the location of the feature was also marked on an aerial photograph and labelled with the field site number (which recommenced at 0001 each day).

The application form was displayed once the point was acquired using MapPad, and the user then recorded the various attributes of the feature. There was a significant time delay between acquiring the point and the display of the application form. This time delay increased as the number of records increased, and ultimately became a limiting factor to the number of sites that could be recorded in a day. All dimensions were estimated, or measured off aerial photographs for larger features, and the appropriate attributes recorded by stylus on the touch-screen keypad. Orientation measurements were made with a compass where required. Comments were hand written into a field notebook and were periodically transcribed into the laptop MS Access database either by hand or with the assistance of voice recognition software.

A problem with the Cassiopeia PC application arose from the retention (or carry over) of successive records on the underground, opencut, infrastructure, and dump pages. To avoid this problem, a 'blank' record was made



WO133

26.05.03

**Figure 4. Symbol hand-held personal computer with the attached Links Point GPS unit**

following every entry of data on these pages. If this procedure was overlooked, false duplicate records were created in the database. Only careful data validation could then correct this problem.

Digital photographs were taken initially with a Kodak DC240 zoom digital camera (1.31 Megapixels). During 2001 two Kodak DC3400 zoom digital cameras (2.1 Megapixels) were also used. Until the 2002 field season, one photograph was normally taken for all features more than 2 m deep, and most of these photographs were of shaft collars. In 2002 a new standard of two photographs per shaft was adopted. One photograph was taken at a moderate distance away from the feature to highlight its visibility, and the other was a close up of the shaft collar as previously recorded. No limits were placed on the number of photographs, and they were taken to illustrate any aspect of any feature. The unique sequential photograph number was entered for each camera in the application and stored as 'FIELDID' in the database.

The Symbol PC was held at arms length facing the feature to be located until the GPS reading stabilized. As a guide, a Position Dilution of Precision (PDOP) value of less than five normally indicated a good location fix. The positioning of the GPS was similar to that for the Cassiopeia PC, except that the operator could safely hold

the GPS closer to the feature. In contrast to the Cassiopeia PC, the application form was displayed almost immediately after the point was acquired, irrespective of how many records were stored. It was necessary to enter a new site identification number for each feature recorded. This consisted of the user's initials (which were automatically set by the application) followed by a sequential number that was entered on the touch-screen keypad using a stylus. To assist with this the previous 'SITEID' number was displayed as soon as the application form opened (Gozzard and Langford, 2003). The attributes were recorded with a stylus on the touch-screen keypad. The word recognition software enabled comments to be added relatively quickly, so this was done in the field rather than transcribed later.

To eliminate record duplication, no data were carried over or retained from one site record to the next in the Symbol PC application.

The Symbol PC enabled more flexibility in the display of data points using the colour screen. Targeting points could, for example, be displayed in a different colour. The display could be set at a fixed scale, and zoomed in or out with the use of toggle switches. Nevertheless, the greater power demands of the colour screen did require changing the small lithium ion batteries up to three times a day (compared with several times a week for dry cell alkaline batteries in the Cassiopeia PC), and there were time delays involved with re-establishing the GPS position. Power management thus became important, and the vehicle 12-volt charger was used wherever possible to top up the battery charge. Connection to the vehicle-mounted aerial was found to quickly re-establish the GPS position after a battery change.

Each team member operated autonomously, but normally in the same general region as the others for safety purposes. In addition, an EPIRB emergency satellite locator beacon was always carried, and, in the fourth year, a Globalstar dual mode GSM/satellite phone was carried to supplement normal GSWA safety precautions.

Data were downloaded daily from both the Cassiopeia and the Symbol PC systems to a field-based laptop computer. The Cassiopeia PC data downloading was a comparatively slow process that involved using the Visual CE software to synchronize the table in the Cassiopeia PC with a blank MS Access table on the laptop computer. The table was then edited to remove blank records, validated, and appended to the master MS Access table on the laptop computer. A copy of the master table was then exported as a DBF file, and loaded into ArcView as a new table. The table was loaded into ArcView as an event theme so that the data could be viewed. In some cases, a shapefile was created in ArcView to mark the extent of recorded data to avoid duplication of field sites. This file was then copied back into the Cassiopeia PC using ActiveSync and MS Explorer for future reference. Visual CE was used to synchronize a blank MS Access table in the laptop computer with the Cassiopeia PC in readiness for data collection the next day.

The Symbol PC daily data download was much faster. The DBF file and shapefiles were copied to the laptop

computer using ActiveSync and MS Explorer. The shapefiles could be loaded directly into ArcView and the DBF file edited using the same program. Daily shapefiles could be renamed and then copied back into the Symbol PC using ActiveSync and MS Explorer for future reference. Alternatively, a copy of the DBF file was imported into MS Access and then either retained as a daily file or appended to an individual master file. Any editing of the data in MS Access would require exporting as a DBF file then loading it as a new table in ArcView, before viewing the data as an event theme, as for the Cassiopeia PC procedure. ActiveSync and MS Explorer were used to copy a blank application table back into the Symbol PC.

Any office-based data entry was either through the Symbol PC application, directly into an MS Access table, or preferably into a purpose-made form called WABMINES\_FIELD in the forms part of the wabmines.mdb (i.e. the MS Access database).

Field data backups were carried out daily, mainly onto a Superdisc high-capacity floppy disk. A complete master copy of the MS Access database was maintained on one central laptop computer throughout the use of the Cassiopeia PC system, and a copy of the database was stored on the Perth office network whenever possible. Each user became responsible for their own copy of their current field data when the Symbol PC system was introduced. This allowed more flexibility in the use of several field laptop computers, and geographically separated teams. Each user submitted a single validated copy of an MS Access database table to the database administrator upon return to the Perth office.

Digital photographs were backed up daily, onto either a laptop computer or a compact disk. In the fourth year, digital photographs were mostly rotated in the field to a vertical format before backup.

## Data validation and storage

Data validation was carried out at a number of different stages during the project. Site identification numbers were checked daily, and records were validated for each field (especially the date, location, and feature group fields). Field photograph numbers were also validated daily.

Each user made a thorough check of their own dataset before submitting it to the database administrator once the Symbol PC system was introduced. These were similar to the daily checks, but also include a spelling check of the 'MINE\_NOTE' and 'NOTES' fields.

The database administrator conducted another automated series of data validation checks as part of the process for importation of each user's MS Access database into WAROX.

The regular submission of digital photographs to WAROX commenced after the introduction of the Symbol PC system. This required the matching of a system-generated 'PICNO' with the 'FIELDNO' and the relabelling of the file name to match the 'PICNO'. The user was

responsible for this process. Any errors in the photograph field numbering became apparent in this process, and needed to be resolved before submission of the photographs to the database administrator for loading into WAROX. A thumbnail photograph was also generated for each full-sized digital photograph, including those taken before the introduction of the new database. Where necessary, photographs were rotated to vertical format before the creation of thumbnails. Random checks were made on the photograph database by examining specific photographs selected by 'PICNO' alone, ensuring that they matched the attributes for that record, and were in the correct format (landscape or portrait).

A one-off thorough database validation was completed, and particular attention was given to the correct transfer of data from the original MS Access-based Cassiopeia database into WAROX. A significant source of error was due to 'carry overs' in the original data where repetitions were found in some data fields, and were rectified with systematic checking. Other errors were related to the changes made to the database structure, the coding of the data, and the units of the numerical fields. The authority table was checked, and all unique values in the database were cross-checked with the authority table. All data fields were checked to ensure that data were within valid ranges for each feature group and type. Data were also checked for logical inconsistencies, and consistency in the use of dimensions and classifications. Photographs were also checked to test the photograph database integrity.

WABMINES was incorporated into WAROX (Gozzard, 2002b) in the first half of year four. Previously, a master copy of the MS Access-based WABMINES database was stored on the Perth office network.

The WABMINES data are stored in four tables in the Oracle database: WAROX\_SITES, WAROX\_WABMINES, WAROX\_FIELDNOTES, and WAROX\_PHOTOS. Only the WAROX\_WABMINES table is unique to the abandoned mine sites project and contains most of the project specific data. Other GSWA users share the other tables, and all tables are linked by a common 'SITENO'. The WAROX\_SITES table contains all the location data, the WAROX\_FIELDNOTES contains geological- and vegetation-related notes, and the WAROX\_PHOTOS table lists all the digital photographs.

Data can be accessed from the database in a number of ways, including a WAROX browser-based application on the intranet, and an Oracle\_Prod.mdb that links an MS Access database to the Oracle tables. All data validation and editing was carried out in MS Access via the Oracle\_Prod.mdb. The various tables can be linked by queries in MS Access using the 'SITENO'.

## Progress

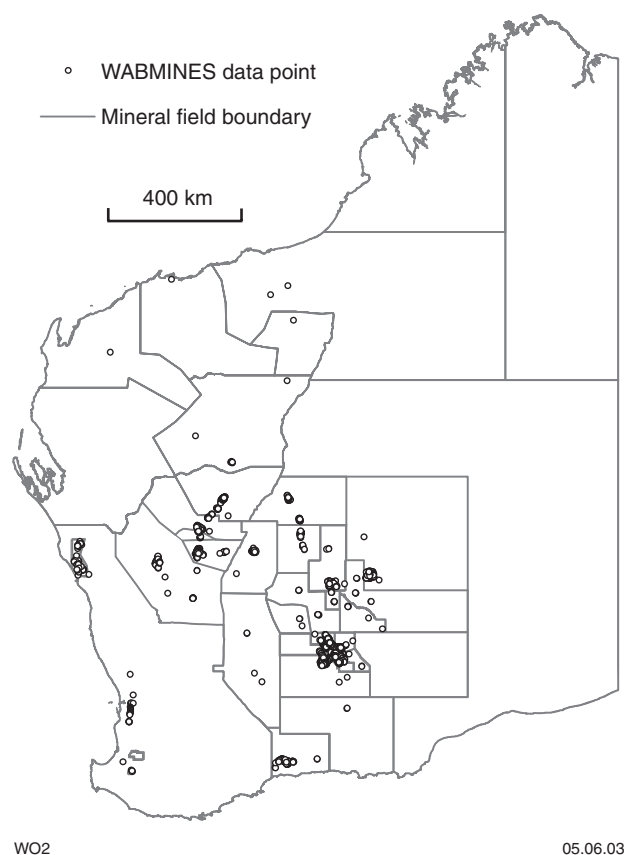
Despite the limitations of the MH site listing from MINEDEX (see **Methodology**), this remains the best benchmark for estimating progress of the abandoned mine sites project. The percentage of the Priority 1 MH sites and the total number of MH sites completed indicate the degree of completion of the project.

The spatial distribution of MH sites is uneven because they cluster around historic mining centres. Consequently, it is difficult to give a clear spatial indication of progress by simply plotting completed MH sites on a map of Western Australia, particularly since multiple overlying sites are not discernible. Progress is better portrayed spatially by mapping the degree of completion by areas such as mineral fields.

## Number of features collected

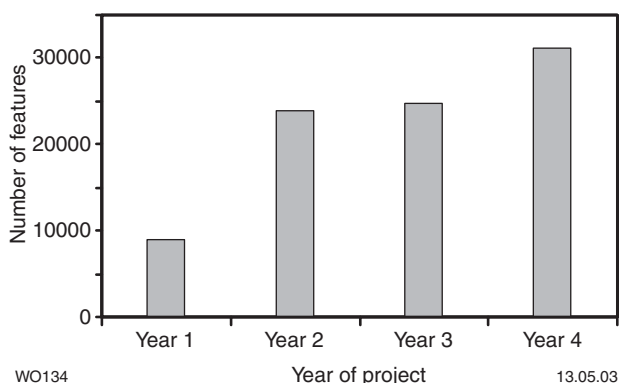
Figure 5 shows the location of 88 705 features included in the inventory as at 31 December 2002, and Figure 6 shows the number of features recorded in each year of the project.

After an initial ramping up in year one, the number of records stabilized around 24 000/year in years 2 and 3. In the first half of year 4, the number of records exceeded 31 000, reflecting in part the productivity gains from hardware and software enhancements. There is usually a trade-off between quantity and quality of data collected, nevertheless, the hardware and software enhancements increased the number of features recorded without compromising quality.



**Figure 5.** Location of 88 705 sites in the WABMINES database as at 31 December 2002





**Figure 6. Number of abandoned mine site features recorded per year**

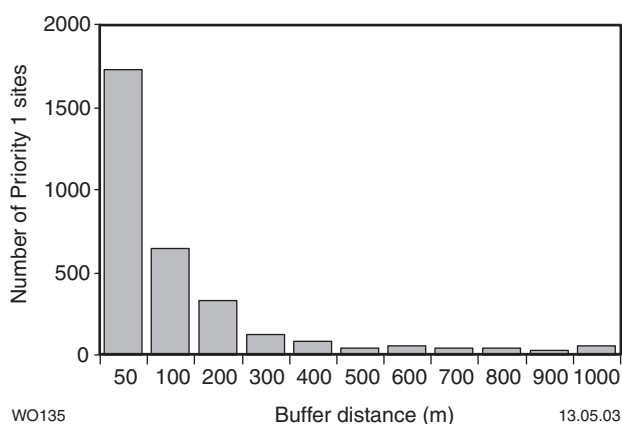
## High-priority historic mine sites completed

The following factors complicate the determination of the number of MH sites completed:

- error in the location of MH sites;
- the difficulties in assigning boundaries to MH sites that are represented by a point, many of which are better represented by a polygon (but the size and shape of this polygon varies from site to site, and is not normally known);
- accounting for all MH sites under infrastructure.

Assigning a buffer distance around each MH site rectifies the first two factors above, and a mine site is deemed to be assessed if a feature is found within the buffer.

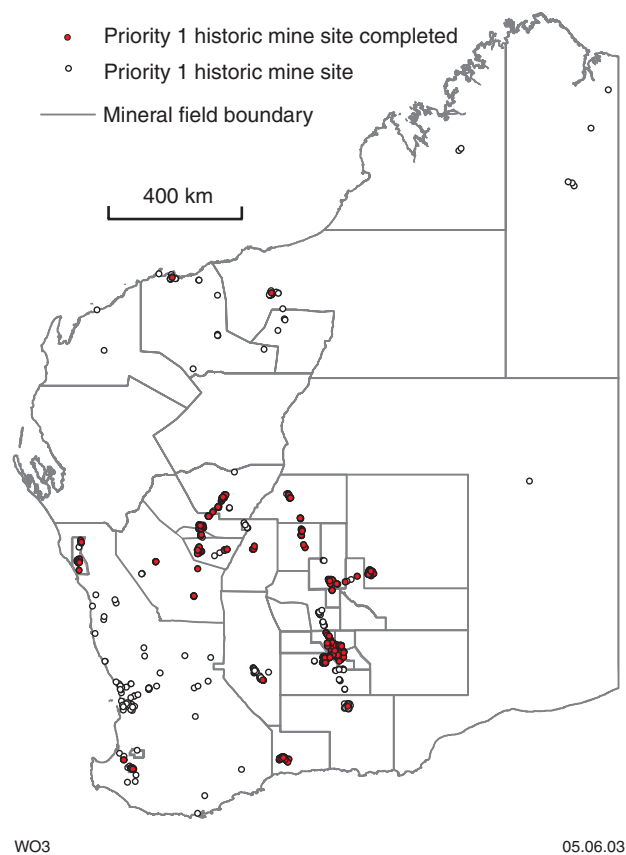
The buffer distance was determined by examining the number of Priority 1 MH sites within different distances from each mining feature (WABMINES data point) in the database (Fig. 7).



**Figure 7. Number of Priority 1 sites within a set buffer distance from a feature**

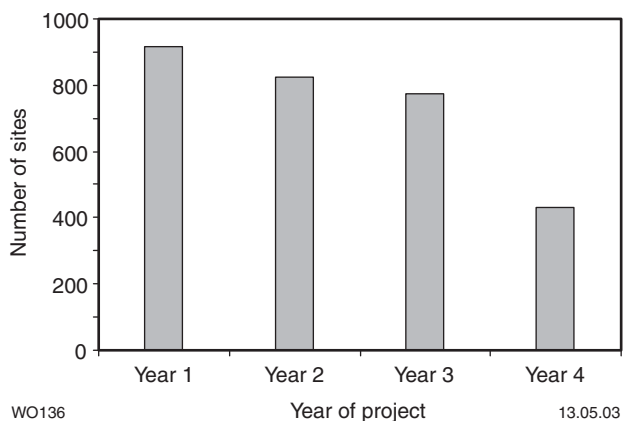
As can be seen from the data presented in Figure 7, there is a distinct break in the data at 200 m, suggesting that this is an appropriate buffer distance. Examining the resultant selected Priority 1 MH sites, non-selected sites, and WABMINES points in ArcView tested this suggestion, and the 200-m buffer distance was found to closely correspond with manual selections, with the exception of some areas now under infrastructure. Priority 1 MH sites in areas under infrastructure were manually deemed as being completed if fieldwork was finished in the surrounding area.

Both Priority 1 and all MH sites were assigned completed using the above methodology. As of 31 December 2002, 2945 out of a total of 4247 Priority 1 MH sites were completed (Fig. 8). The number of Priority 1 sites completed has been constant, averaging around 845 per year (Fig. 9), taking into account that year 4 is still current. In contrast, the number of features collected per MH site has progressively increased each year, doubling in year 4 compared with year 3 (Fig. 10). The large increase is due to a number of factors, including the increased density of features in the areas surveyed, and an increased emphasis on collecting all relevant features, even well away from the MH site, but still broadly within the Priority 1 guidelines.

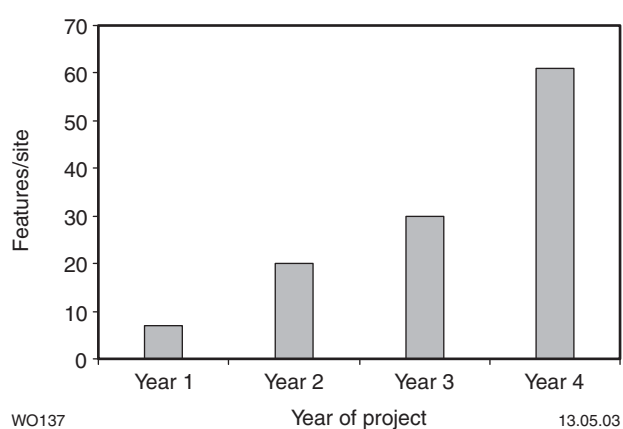


**Figure 8. Status of the Priority 1 MINEDEX MH sites as at 31 December 2002**

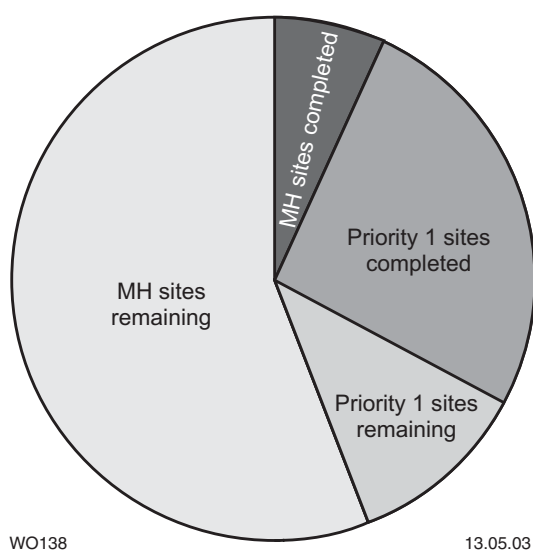




**Figure 9. Number of Priority 1 sites completed per year**



**Figure 10. Number of features recorded per MINEDEX MH site per year**



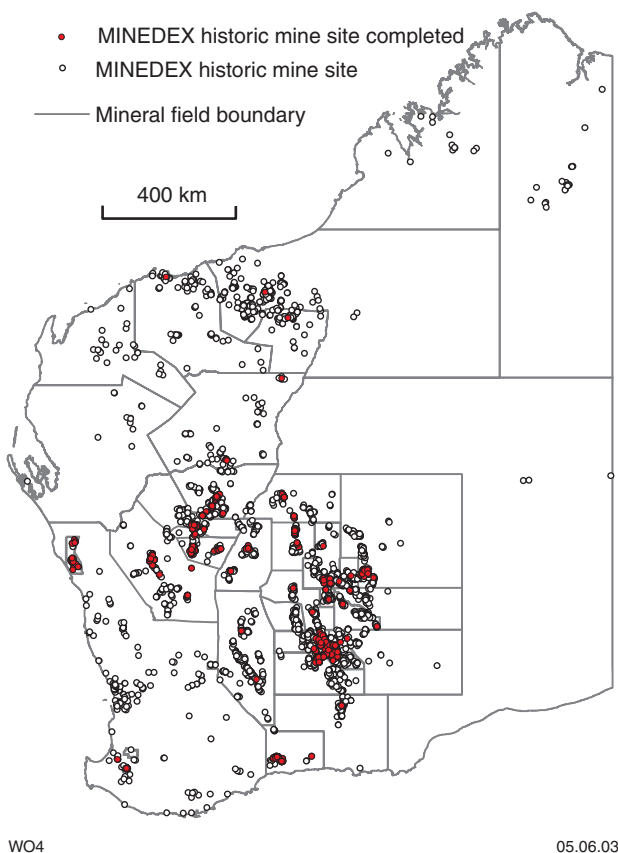
**Figure 11. Overall status of the inventory of abandoned mine sites as at 31 December 2002**

Other MH sites were completed where they were close to the Priority 1 sites, or were readily accessible even though they did not lie along a major road as defined in the database. This was particularly the case near townships and along tracks frequented by visitors. A total of 3725 out of 11 411 MH sites, including the Priority 1 sites, were completed by the end of 2002.

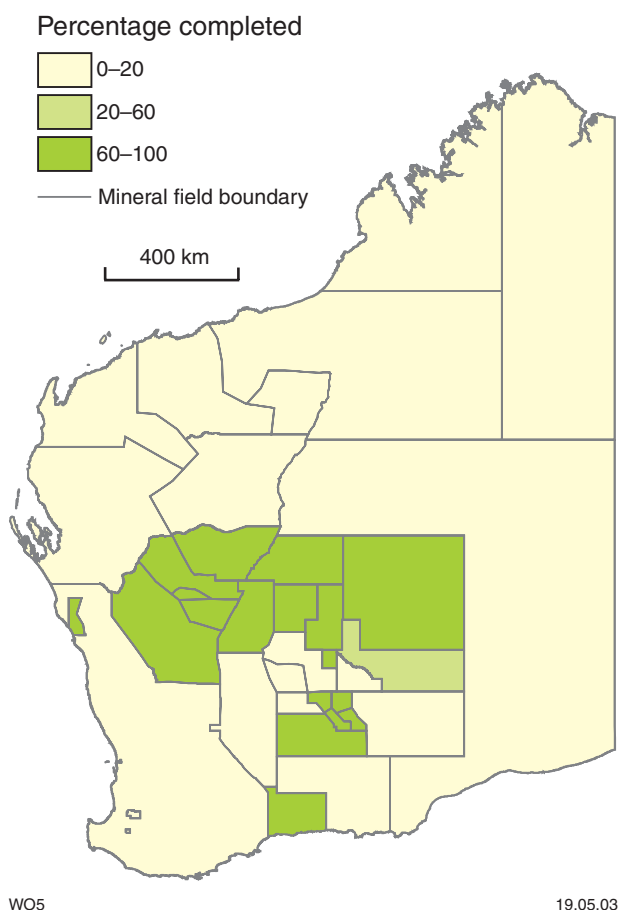
Figures 11 and 12 show the overall status of the project with respect to MH sites.

Figure 13 shows the degree of completion of Priority 1 MH sites for each mineral district. The inventory of the highest priority sites is more than 80% completed in 16 mineral districts or mineral fields, covering the Northampton, Murchison, East Murchison, Mount Margaret, Broad Arrow, North Coolgardie, Northeast Coolgardie, East Coolgardie, Coolgardie, and Phillips River mineral fields.

By comparison, when all of the MH sites are considered, the inventory is more than 80% complete in only the Northampton and Phillips River mineral fields, and the Mount Magnet mineral district in the Murchison mineral field.



**Figure 12. Status of the inventory of abandoned mine sites with respect to MINEDEX MH sites completed as at 31 December 2002**



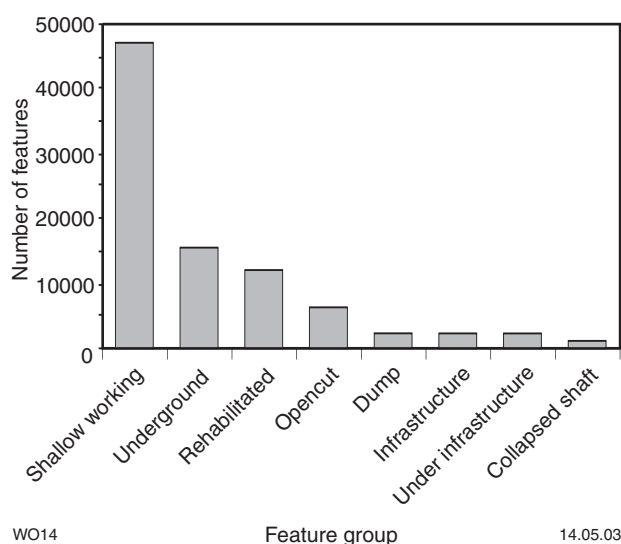
**Figure 13. Status of Priority 1 MINEDEX MH sites by mineral district as at 31 December 2002**

## Morphology of mining features

Mining-related features are classified into the following feature groups (see Appendix 1 for definitions):

- underground
- collapsed shaft
- opencut
- shallow working
- rehabilitated
- dump
- infrastructure
- under infrastructure.

Of the 88 705 features in the database, about 95% are related to workings or excavations, more than half of which (>47 000) are shallow workings (Fig. 14). Underground features are the next largest feature group with more than 15 000 workings, followed closely by more than 12 000 rehabilitated features, most of which were originally workings. There are also more than 6000 opencut features and less than 2500 features in each of the remaining dump, infrastructure, under infrastructure, and collapsed shaft categories.



**Figure 14. Frequency distribution of feature groups**

The following section describes and illustrates the range of features within each of the eight feature groups, and discusses aspects of the four main areas of application of the data: safety, environment, state of preservation, and geology and mineralization.

## Underground features

Underground features in the WABMINES database are divided into five types:

- shaft
- open stope
- adit
- subsidence
- collapsed drillhole.

By far the largest category is shaft, with more than 13 000 features or 86% of the underground features in the database (Fig. 15). A significant number (1542) of underground features are open stopes. Adits are less common (133), due in part to the relatively flat topography of much of the area examined to date, and the fact that many declines are still in operation. The subsidence and collapsed drillhole categories contain relatively small numbers of features (189 and 53 respectively).

A shaft is currently defined as an excavation of limited area compared with its depth, with the depth more than 2 m. Before the introduction of the collapsed shaft feature group, some shafts were recorded with depths of less than 2 m. Three subtypes of shaft are described for this analysis, determined by the presence and completeness of a surrounding pile of rock or bund.

From a distance the bund is usually the most visible morphological characteristic of a shaft. Shafts most commonly have partial or full bunds (7285 and 5034 features respectively) although there are a substantial number of shafts with no bund at all (922).

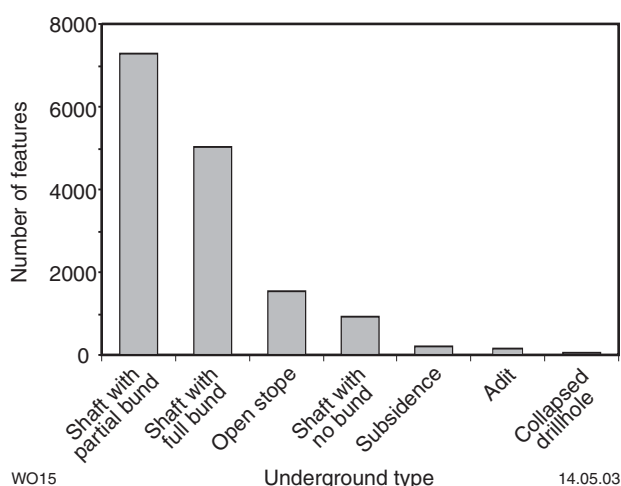


Figure 15. Frequency distribution of underground features

## Shafts with full bunds

A shaft with a full bund is surrounded by a wall of built-up waste rock (Figs 16 and 17). Shafts with full bunds comprise 38% of the underground shafts. The majority are more than 5 m deep, and more than a third (34%) are more than 10 m deep (Fig. 18a). A further 405 shafts with full bunds are less than 2 m deep. The frequency distribution of minimum bund heights is left-skewed, the majority being less than 1.1 m (Fig. 18b). Data on the maximum bund height are more limited (476 records), but they range from 0.3 to 6 m, averaging 1.6 m. Although 98% of the shafts with full bunds are vertical, some are inclined, most commonly at an angle of between 66° and 75° (Fig. 18c).

The majority of shaft collars for this subtype were originally rectangular, with mean dimensions of 1.9 m length and 1.1 m width (Table 2). About a third of shaft collars have been enlarged by subsidence, with 6% resulting in the extreme case of a conical collar (Table 3). Although most shafts with full bunds originally had supporting timber collars extending above ground level to retain the bund material, most have no collar timbers or the timbers are in poor condition. Preserved headframes and other forms of hole access are rare.

Nearly 92% of shafts with full bunds are not fenced and more than 95% have no form of seal. Nonetheless, shafts with full bunds are the most visible of all types, with nearly 94% being visible from a moderate distance.

## Shafts with partial bunds

A shaft with a partial bund is partly surrounded by a wall of built-up waste rock. The waste rock is normally spread around about three-quarters of the shaft, allowing an opening on one side for entry (Figs 19 and 20). Shafts with partial bunds form the largest subtype (55%) of the underground shafts. Although almost half are less than 5 m deep (Fig. 21a), and most are less than 10 m deep, more than 1000 (12%) have a depth more than 10 m. A further 1388 shafts with partial bunds have recorded depths of less than 2 m. The distribution of maximum bund heights is

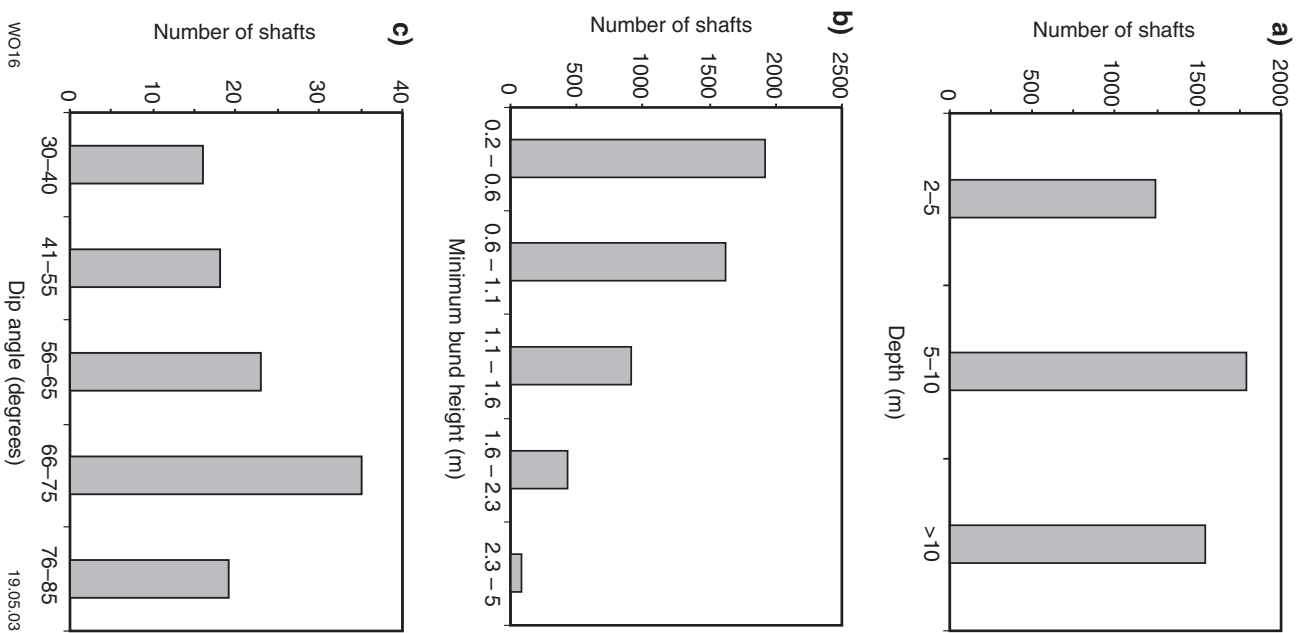


Figure 16. Typical shaft with a full bund, between 1 and 3 m high (13.5 km east of Boulder; Zone 51, MGA 369080E 6592470N)



Figure 17. Timbered collar of the shaft shown in Figure 16. Shaft is 2.2 m long, 1 m wide, and 5–10 m deep

very similar to the minimum bund heights of shafts with full bunds, with most being less than 1.1 m (Fig. 21b). The reduced volume of bund material for shafts with partial bunds compared with full bunds is consistent with their overall shallower depth. Although the majority of shafts with partial bunds are vertical, 5% are inclined (Fig. 20), the most common angles of inclination between 36° and 53° (Fig. 21c). In contrast, about 2% of shafts with full bunds are inclined. Shafts with partial bunds are generally inclined at shallower angles than those with full bunds.



**Figure 18. Frequency distribution of features for shafts with full bunds: a) depth; b) minimum bund height; c) shaft dip**

**Table 2. Summary data for 5034 shafts with full bunds**

	Length (m)	Width (m)
Mean	1.9	1.1
Minimum	0.5	0.3
Maximum	10	7

**Table 3. Number of attributes for 5034 shafts with full bunds**

Visibility		Fences		Edge stability		Base condition		Underground seal type		Underground seal condition		Underground timber condition		Underground access		Underground headframe condition	
Visible	4 722	None	4 614	Firm	2 750	Empty	2 319	None	4 819	None	4 819	None	2 610	None	4 933	None	4 986
Partially hidden	259	Fenced	301	Slight subsidence	898	Rock	2 252	Timber	82	Poor	171	Poor	2 045	Ladder	81	Good	26
Hidden	18	Open	100	Severe subsidence	461	Water	197	Tin	56	Good	44	Good	379	Side ramp	9	Poor	22
No surface expression	13	Locked gate	19	Undercut	342	Rubbish	154	Partial	31					Rope	6		
Null	22			Conical collar	305	Tailings	8	Mesh	17					Other	5		
				Cracked	203	Water and rubbish	4	Rubbish	14								
				Unknown	32	Null	100	Steel plate	7								
				Null	43			Other	7								
								Concrete	1								





WO52

10.04.03

**Figure 19.** Typical shaft with a partial bund up to 1.1 m high. The shaft is 1.4 m long, 1 m wide, and 5–10 m deep (9 km northwest of Bardoc; Zone 51, MGA 330813E 6649318N)



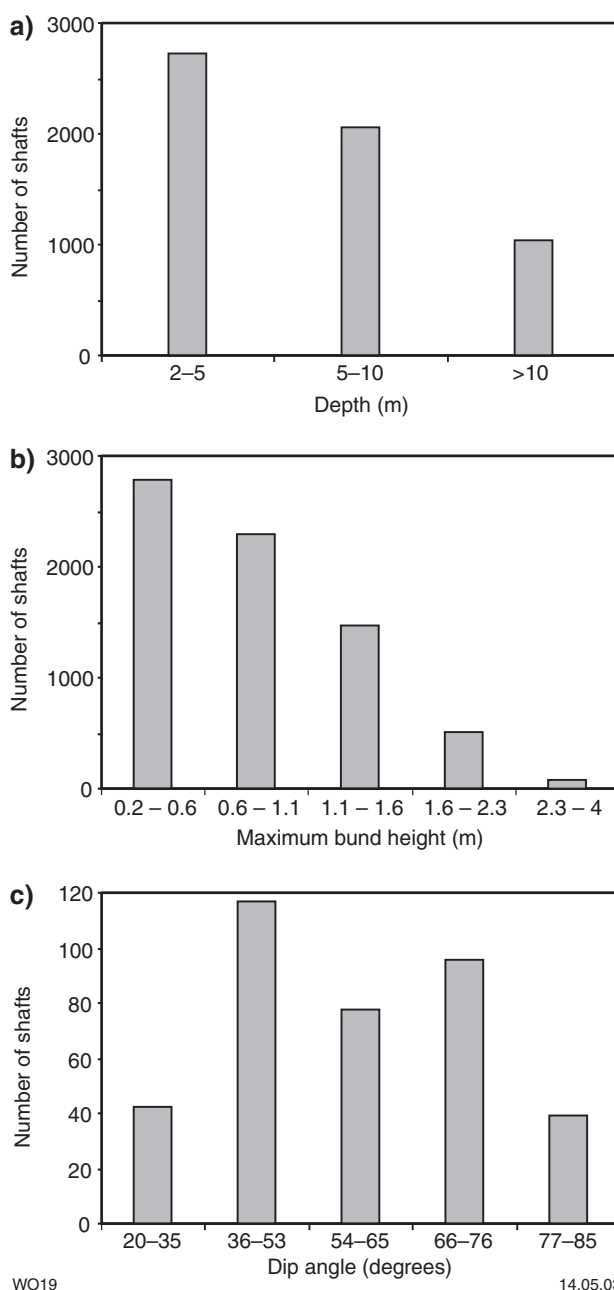
WO53

10.04.03

**Figure 20.** Inclined shaft with a 30° dip (3 km northeast of Kundip; Zone 51, MGA 240394E 6270597N)

The majority of shaft collars, for this subtype, were originally rectangular with mean dimensions of 2 m length and 1.2 m width (Table 4). More than a quarter of shaft collars have been enlarged by subsidence, with 3% resulting in the extreme case of a conical collar (Table 5). Collar timbers are significantly less common than for shafts with full bunds (18% compared to 48%), and proportionally fewer are in good condition (1.4% compared to 7.5%). Preserved headframes and other forms of hole access are also rare.

Similar proportions of shafts with a partial bund are not fenced and have no form of seal compared to those with a full bund. Although less visible than shafts with a full bund, more than 80% of partially banded shafts are still visible from a moderate distance.



**Figure 21.** Frequency distribution of features for shafts with partial bunds: a) depth; b) maximum bund height; c) shaft dip

**Table 4.** Summary data for 7285 shafts with partial bunds

	Length (m)	Width (m)
Mean	2	1.2
Minimum	0.3	0.1
Maximum	25	25

Table 5. Number of attributes for 7285 shafts with partial bunds

Visibility	Fences	Edge stability	Base condition	Underground seal type		Underground seal condition		Underground timber condition		Underground access		Underground headframe condition
				None	7 039	None	7 039	None	5 974	None	7 152	
Visible	5 873	Firm	Rock	None	7 039	None	7 039	None	5 974	None	7 152	None
Partially hidden	1 238	Slight subsidence	Empty	Timber	87	Timber	87	Poor	1238	Ladder	78	Poor
Hidden	74	Undercut	Rubbish	Tin	55	Tin	55	Good	73	Side ramp	41	Good
No surface expression	70	Severe subsidence	Water	Partial	46	Partial	46	Good	73	Steps	7	Good
Null	30	Cracked	Tailings	Rubbish	28	Rubbish	28	Good	73	Other	4	Good
		Conical collar	Water and rubbish	Mesh	16	Mesh	16	Good	73	Rope	3	Good
		Unknown	Null	Other	11	Other	11	Good	73			
		Null		Steel plate	3	Steel plate	3	Good	73			
				Concrete	1	Concrete	1	Good	73			

## Shafts with no bund

Shafts with no bund (Fig. 22) comprise only 7% of the underground shafts. Their depth distribution is relatively uniform (Fig. 23a). There are 296 of these shafts with depths between 2 and 5 m, 224 with depths from 5 to 10 m, and 209 with depths greater than 10 m. A further 154 shafts have depths of less than 2 m, many of which are actually rehabilitated shafts that have subsequently undergone further subsidence. Although the majority of the shafts with no bund are vertical, 6% are inclined, with the most common angle of inclination being 61° to 77° (Fig. 23b).

The shaft collars have mean length of 2.3 m and mean width of 1.5 m (Table 6), slightly larger dimensions than shafts with full or partial bunds. Nearly a quarter of the shaft collars are enlarged as a result of subsidence, but the greater mean dimensions appear to be related to greater depth and overall scale of the mine. Some of these shafts have no bund because they are very deep, and consequently there was too much waste rock to store around the shaft collar as a bund. Although collar timbers are less than half as common than for shafts with full bunds (21% compared to 48%, Table 7), the condition of the timbers is much better (33% in good condition compared to 16%). Shafts with no bund have a low, but significantly higher incidence of headframes (5%) and forms of hole access (7.4%) compared with those with a bund. Ladders are by far the most common type of hole access (81%; Fig. 24).

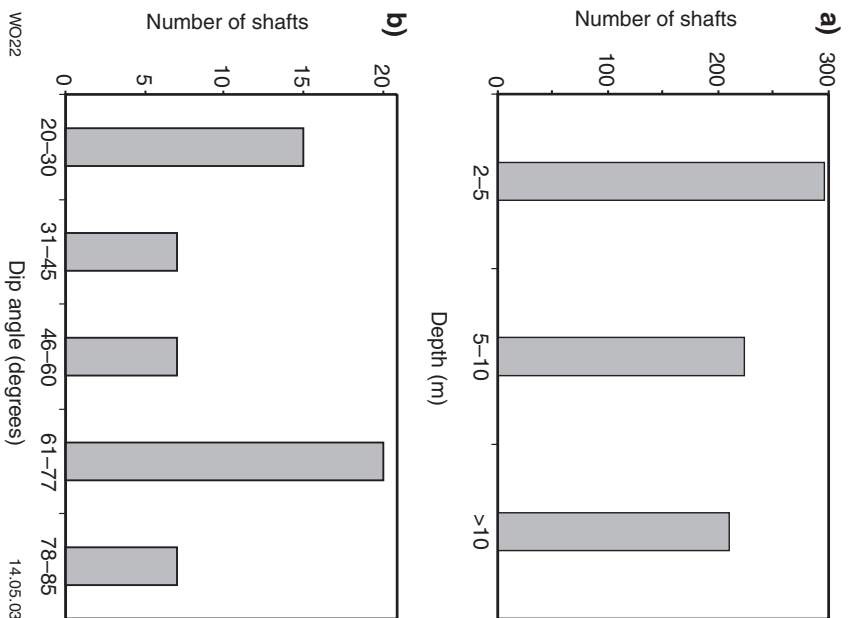
About 42% of shafts with no bund have no surface expression compared with 1% or less for shafts with bunds. Conversely, only about 38% are visible from a moderate distance. This is partly compensated for by the higher incidence of fencing (about 16% compared to 8%), and seals (about 16% compared to 3–4%). Shafts with no bund also have a significantly higher proportion of seals in good condition (4.6%), compared with those with bunds (0.9% for full bunds, and 0.4% for partial bunds).



WO54

10.04.03

Figure 22. Shaft with no bund. The shaft is 3 m long, 1.5 m wide, and more than 10 m deep (1.5 km southeast of Broad Arrow; Zone 51, MGA 348497E 6624626N)



**Figure 23.** Frequency distribution of features for shafts with no bund: a) depth; b) shaft dip



**Figure 24.** Shaft with ladder access (2 km northeast of Kundip; Zone 51, MGA 240126E 6269731N)

**Table 6.** Summary data for 922 shafts with no bund

	Length (m)	Width (m)
Mean	2.3	1.5
Minimum	0.5	0.3
Maximum	50	40

**Table 7.** Number of attributes for 922 shafts with no bund

Visibility		Fences		Edge stability		Base condition		Underground seal type		Underground seal condition		Underground timber condition		Underground access		Underground headframe condition	
No surface expression	386	None	772	Firm	530	Rock	364	None	772	None	774	None	728	None	854	None	876
Visible	348	Fenced	108	Slight subsidence	136	Empty	337	Timber	40	Poor	106	Poor	131	Ladder	55	Good	30
Partially hidden	144	Locked gate	18	Undercut	91	Water	99	Mesh	32	Good	42	Good	63	Side ramp	6	Poor	16
Hidden	35	Open	24	Cracked	54	Rubbish	65	Partial	29					Other	5		
Null	9			Severe subsidence	44	Tailings	7	Tin	23					Rope	1		
				Conical collar	30	Oversize	1	Steel plate	10					Steps	1		
				Unknown	13	Water and rubbish	1	Other	7								
				Null	24	Null	48	Concrete	6								
								Rubbish	3								



### **Safety aspects of shafts**

Any bund normally greatly increases the visibility of a shaft from a moderate distance. Shafts with full bunds are typically more visible than those with partial bunds, and both are much more frequently visible than shafts with no bund. The visual effectiveness of a bund is mostly related to how well it stands out from the surrounding landscape, and how clearly it is associated with the feature. Vegetation may hide or partly hide a bund. A shaft is more likely to be hidden from view if the bund is low and higher bunds are normally more visible than lower bunds. The colour contrast between the bund material and the surrounding landscape can also influence the visibility of the bund.

Bunds can provide a physical barrier to accidental entry to a shaft. Full bunds provide a better barrier than partial bunds, which by definition have an opening. Normally, when a bund is present, the higher the bund, the better the barrier, but the deeper the shaft. Shafts with full bunds tend to be deeper than those with partial bunds. Nevertheless, some of the deepest shafts have no bund at all. This, combined with the high proportion of shafts with no bund and no surface expression, makes them potentially the most hazardous of all shaft types.

Shaft collars in poor condition can present a hazard due to potential edge collapse. Twenty nine percent of shafts have significant collar subsidence recorded (see **Progressive shaft collapse**). A further 5% have cracked collars indicating that future subsidence is likely, and another 8% have visibly undercut collars. Undercut collars are potentially hazardous as they may fail under the weight of a vehicle or even a person. Collar timbers in good condition are normally indicative of good, stable shaft collars, but they only represent 4% of all shafts. The poor condition or absence of collar timbers are not necessarily indicators of collar stability.

Fences and seals can provide a barrier to accidental entry to a shaft, but they are not common and their effectiveness varies greatly (see **Fence and seal effectiveness**). Overall, only 0.9% of shafts have seals in good condition that are most likely to prevent entry.

Headframes are rare (less than 1% of all shafts), but can provide a visual cue of the presence of a shaft, sometimes when no other is apparent. Even where present, headframes may be in poor condition and therefore potentially hazardous in their own right.

Base condition may have an influence on the outcome of an accidental fall down a shaft. Most shafts have an empty or rock base condition (89%), meaning that in most cases there is no water or rubbish recorded at the bottom of the shaft. The base of a shaft could not normally be observed if it is more than 10 m deep, therefore the base condition in these instances is difficult to confirm. Water was recorded in the base of only 4% of all shafts, although it is notably more prevalent in shafts with no bund (10.7%), compared to those with bunds (3.7 to 3.9%). Rubbish was recorded in 4.6% of all shafts.

Most shafts (about 98%) have no means of access, hence no means of exit, if entered accidentally. For the minority of shafts that do have some means of access,

ladders are by far the most common. The condition of the ladder is normally difficult to ascertain, and therefore is not routinely recorded.

### **Environmental aspects of shafts**

A full bund and to a lesser extent a partial bund tend to act as deterrents to wildlife, reducing the possibility of accidental entry. Conversely, disused shafts can provide habitat to some fauna (as occasionally recorded in the 'MINE\_NOTE' column of the database). A full or partial bund may also block the inflow of surface water and therefore may help to prevent erosion of the shaft collar and surrounding area.

A full bund normally indicates that no attempt has been made to backfill these features. In a minority of instances, a partial bund or no bund may indicate that some attempt has been made to backfill a shaft by pushing the bund material into the opening. Tailings are occasionally dumped or washed into shafts (0.3% of shafts), giving rise to the potential contamination of groundwater by heavy metals or acid.

More commonly, rubbish is dumped into shafts (4.3% of shafts), and rarely both water and rubbish have been recorded (0.1% of shafts), again introducing the possibility of groundwater contamination.

### **Preservation aspects of shafts**

Most shafts in the database are not modern, and only 109 have been given the field assessment of fair or good condition. This reflects the relatively small number of shafts with good collar timber condition, headframes in good condition, and other original associated items such as ladders. Some shafts that were not given a field assessment of fair or good condition may nevertheless have historical significance, which is not apparent from a field inspection or may help to complete a picture of historical mining activity in an area.

### **Geology and mineralization aspects of shafts**

Full and partial bunds normally give a good indication of the base of shaft rock type and the degree of weathering. The depth of weathering can then be inferred from the shaft depth. In some shafts, potentially mineralized material (normally quartz) is segregated on part of the bund wall, or strong shearing or foliation is observed in the bund material. Direct observation of mineralization controls is sometimes possible, and features within the shaft walls such as veins or structure type, width, and orientation can be measured. The azimuth and dip of the shaft collar can also give an indication of the orientation of the mineralization.

### **Open stopes**

Open stopes comprise 10% of the underground features in the WABMINES database.

An open stope is a vertical or inclined underground excavation that follows the orebody, is open to the surface,



and appears to have been formed primarily by the removal of ore from beneath (Fig. 25). Most open stopes (43%) have depths of between 2 and 5 m (Fig. 26a), although many (31%) have depths of between 5 and 10 m.

Many open stopes have some form of bund, normally indicating some disposal of waste rock on the surface or, less commonly, a later attempt at reducing the hazard of the feature. Bunds are commonly partial (72%), some are full (5%), and 23% of open stopes have no bund at all (Table 8). The frequency distribution of maximum bund heights for open stopes with partial bunds is strongly left-skewed with 78% being less than 1.1 m (Fig. 26b).

The majority of openings to stopes are elongate, with average dimensions of  $7.6 \times 1.9$  m (Table 9). Almost half the open stopes have edges that are either, subsided, cracked, or undercut (Table 8) due to the instability caused by stoping out elongate dipping veins and structures. This instability in the surface may account for the enlarged widths of openings in some cases. Many of the open stopes in the database dip to the west at between  $61^\circ$  and  $76^\circ$  (Fig. 26c) and strike north-northwesterly (Fig. 27).

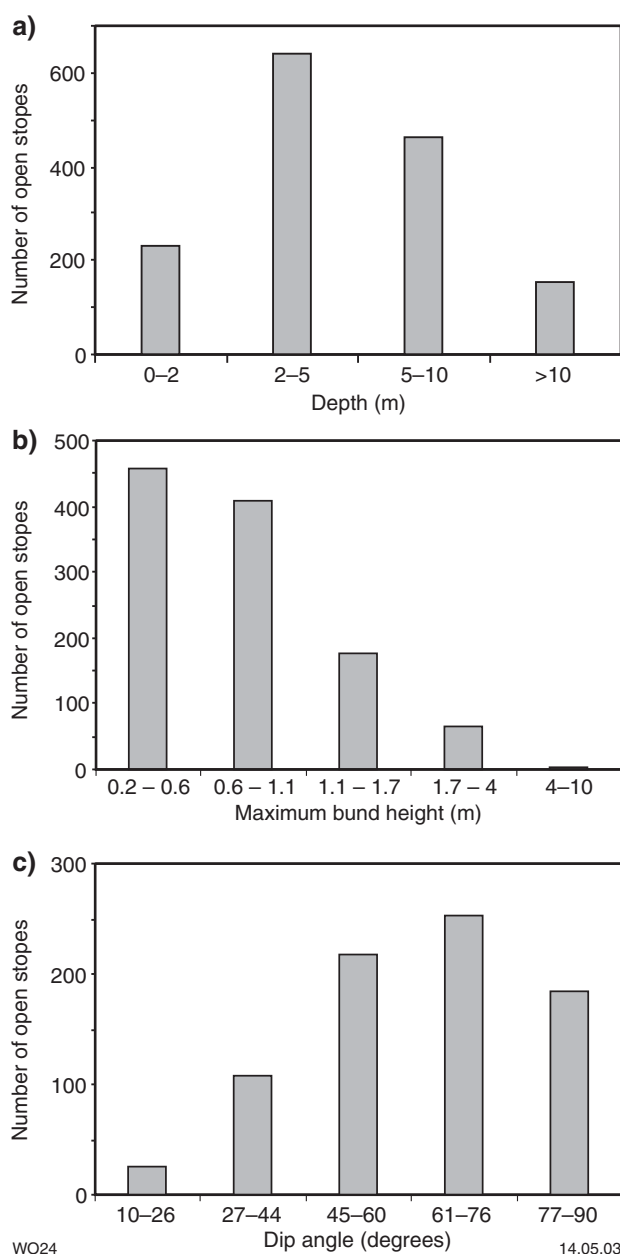
Timbers are occasionally present, normally as hangingwall or backfill supports (7.2% of stopes), but they are also mainly in poor condition (6.7% of stopes). As would be expected, hole access from the surface is uncommon (3%), but where it is present, side ramp is the main form of access (59%), followed by ladder (27%).

Most stopes have either an empty or rock base condition (87%). The base of a stope cannot normally be observed if it is more than 10 m deep, therefore the base condition in these instances is difficult to confirm. Water was recorded in the base of only 6% of all stopes, and rubbish in 3.8%.

About 10% of open stopes have a fence of some kind, and about 2% have some form of seal, although only 0.3% have a seal in good condition.



**Figure 25.** Open stope, 3 m long, 3 m wide, and 5–10 m deep, with a  $40^\circ$  dip (7 km north of Coolgardie; Zone 51, MGA 323408E 6580870N)



**Figure 26.** Frequency distribution of features for open stopes: a) depth; b) maximum bund height; c) dip angle

### Safety aspects of open stopes

Similar safety considerations apply to open stopes as for shafts. A considerably higher proportion of open stopes have no bund compared with shafts (23% compared to 7%), and this is reflected in their lower overall visibility (68% compared to 83%). Because open stopes are excavated from beneath and worked upward to the surface, the excavated material might be placed in a dump away from the surface opening of the stope. The size of a bund therefore is not always a reflection of the size of the hole.

Table 8. Number of attributes for 1542 open stopes

Bund	Visibility	Fences	Edge stability	Base condition	Underground seal type	Underground seal condition	Underground timber condition	Underground access
Partial	Visible	None	Firm	Rock	None	None	None	None
1 108	325	1 388	820	752	1 513	1507	1 430	1 491
351	Partially hidden	Fenced	Slight subsidence	Empty	Timber	Poor	Poor	Side ramp
83	No surface expression	Open subsidence	Severe	Water	Partial	Good	Good	Ladder
	Hidden	Locked gate	Undercut	Rubbish	Mesh	5	8	Other
	Null		Cracked	Water and rubbish	Rubbish	3	3	Rope
			Null	Tailings	Tin	3	3	Steps
				Null	Other	1		
				41				

Table 9. Summary data for 1542 open stopes

	Length (m)	Width (m)	Minimum bund height (m)
Mean	7.6	1.9	0.5
Minimum	0.4	0.2	0.2
Maximum	135	20	2.7

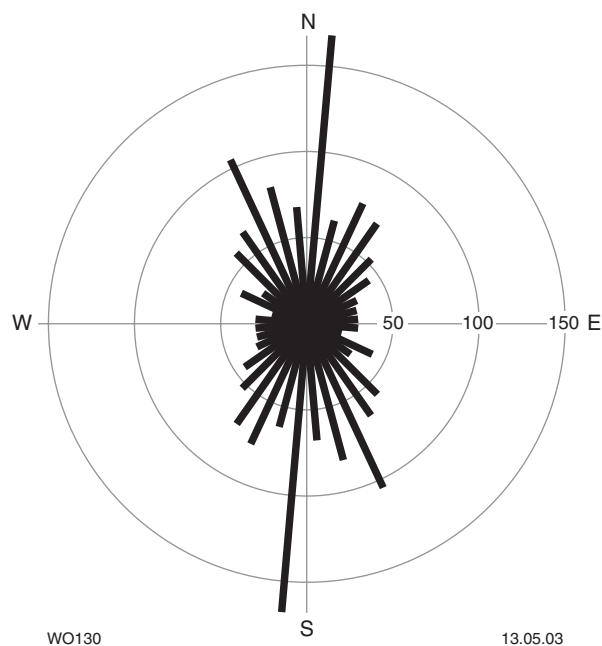


Figure 27. Circular histogram showing strike distribution of open stopes

Unlike shafts with no bunds, only 8.6% of open stopes have no surface expression (cf. 42%). This is probably due to the larger and particularly more elongate dimensions of most open stopes, which make them more obvious from a moderate distance.

The elongate dimensions and dipping nature of many open stopes may induce instability in the ground and make them more prone to collapse and subsidence than shafts. Open stopes can be irregular in shape and may extend into larger underground cavities. False bottoms can form where waste rock has been used for backfill, and in some places backfill is supported by timber that may give way over time. Timbers are considerably less commonly observed than for shafts (7.2% compared to 30%), but this mainly reflects their primary use as hangingwall support rather than collar support.

Overall, open stopes are fenced about as commonly as shafts (10%), although not as commonly as shafts with no bund (16%), despite a greater proportion of them having no bund. Seals are less common for open stopes than for shafts (2% compared to 5%), probably due to their

larger size, more elongate shape, and different primary purpose (i.e. mining of ore rather than access).

Recorded base conditions are similar for shafts and open stopes. Although stopes are not primarily designed for access from the surface, their overall provision for access is similar to shafts. The relatively high proportion of side ramp access suggests that a minority of stopes (2%) can conceivably be walked in to and out of from the surface. Although this may assist exit if someone falls in, it may also encourage access into these potentially dangerous features.

### **Environmental aspects of open stopes**

The environmental issues are similar for open stopes as for shafts. Bunds, particularly full bunds are less common (5% compared to 38%), so there are fewer deterrents to wildlife, increasing the possibility of accidental entry.

Tailings are rarely dumped or washed into open stopes (0.1% of open stopes), giving rise to the potential contamination of groundwater by heavy metals or acid.

More commonly, rubbish is dumped into open stopes (3.8% of open stopes), and rarely both water and rubbish has been recorded (0.2% of open stopes), again introducing the possibility of groundwater contamination.

### **Preservation aspects of open stopes**

Most open stopes in the database are old, and none have been given the field assessment of fair or good condition. This reflects the relatively small number of stopes with good collar timber condition (0.5%), the absence of headframes for this type of feature, and general lack of associated items such as ladders (0.9%). Some open stopes may nevertheless have historical significance that is not apparent from a field inspection, or may help to complete a picture of historical mining activity in an area.

### **Geology and mineralization aspects of open stopes**

Bunds can give a good indication of the rock type and the degree of weathering, although they are not as common for open stopes as for shafts, and their provenance is not as clear. Direct observation of mineralization controls is sometimes possible, and features within the stope walls such as veins or structure type, width, and orientation can be measured.

The strike and dip of the open stope can also give a good indication of the orientation of the mineralization. Figure 27 demonstrates the dominant northwest to north orientation of open stopes, and hence mineralization in the areas covered by the inventory to date (mainly the Yilgarn Craton).

## **Adits**

Adits comprise 0.9% of the underground features in the WABMINES database. An adit is a horizontal or nearly



**Figure 28. Adit of 1.5 m height and 1 m width (9 km east of Ravensthorpe; Zone 51, MGA 235048E 6277910N)**

horizontal passage driven from the surface (Fig. 28) for the working or dewatering of a mine (American Geological Institute, 1997). In the WABMINES database, the dip of an adit can be up to 20°.

The majority of portals to adits are rectangular, with average dimensions of 2 × 1.1 m (Table 10). Length refers to the longer dimension of the portal, whereas depth refers to the maximum distance excavated.

The low angle of dip of an adit dictates that full bunds around the opening are rare. Most adits have partial bunds above the portal or around a declining entry slot, or have no bund at all (Table 11). For adits with partial bunds, the mean maximum bund height is 0.9 m. The majority of adits are less than 5 m deep (58%, Fig. 29), although a significant proportion (26%) are deeper than 10 m.

Most adits do not have timbers (90%) for support, and recorded edge conditions, although less meaningful, are similar to those for shafts, as they may refer to the condition of the entry cut to the portal or the portal itself. The base condition is usually empty or rock (93%), with few instances of rubbish or water.

Very few adits are fenced (2%), and only about 6% have any form of seal, with only one example in good condition.

**Table 10. Summary data for 133 adits**

	<i>Length</i>	<i>Width</i>	<i>Minimum bund height</i>	<i>Maximum bund height</i>
	(m)	(m)	(m)	(m)
Mean	2.0	1.1	0.7	0.9
Minimum	0.5	0.1	0.3	0.2
Maximum	10	4.5	1.5	2



Table 11. Number of attributes for 133 adits

Bund	Visibility	Fences	Edge stability	Base condition	Underground seal type	Underground seal condition	Underground timber condition	Underground access
Partial	72	87	84	78	125	125	120	110
None	55	41	20	46	None	None	None	None
Full	6	4	10	3	Partial	Poor	Poor	Other
		Locked gate	Severe subsidence	Water	Other	Good	Good	Side ramp
		Open	Undercut	Rubbish	Mesh			Steps
			Cracked	Tailings				
			Null	Null				
	Visible	None	Firm	Rock	None	None		
	Partially hidden	Fenced	Slight subsidence	Empty	Partial	Poor		
	No surface expression	Locked gate	Severe subsidence	Water	Other	Good		
	Hidden	Open	Undercut	Rubbish	Mesh			
	Null		Cracked	Tailings				
			Null	Null				

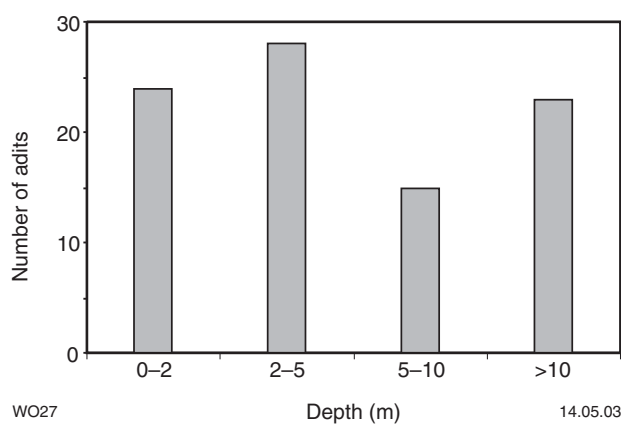


Figure 29. Frequency distribution of depth for adits

### Safety aspects of adits

The vertical depths of adits (the portal length plus depth below the surface of the portal) tend to be relatively shallow (<4 m), unless they originate from within an opencut (which is described as a separate feature). There is some risk of falling around the portal area if approached from further up the hillside, although many have partial bunds to provide a visual cue and barrier. Adits do tend to be less visible than shafts (65% compared to 83%), and have similar visibility to open stopes (68%), although only 3% have no surface expression (cf. 8.6% for open stopes).

Most adits may be entered deliberately, since fences with locked gates and good seals are extremely rare. Persons deliberately entering an adit may be at risk from rock falls, access to other hazardous underground features such as stopes, winzes or rises, or even exposure to toxic gases.

### Environmental aspects of adits

Accidental entry to adits by wildlife is possible, but the consequences are less likely to be serious due to the relatively shallow depth of the portal, and easy egress. Adits are commonly used as habitat for fauna, providing good shelter.

Adits can have a significant impact on the surrounding area due to associated down-slope waste dumps on steeper hills, and the area sometimes occupied by lead-in cuts or declines on gently sloping or flat surfaces. These workings can promote erosion. Adits could also potentially access groundwater that may be acidic or contaminated with heavy metals, but water was only recorded in three out of the 133 adits in WABMINES.

### Preservation aspects of adits

Only six adits were assessed in the field as having fair condition. As for open stopes, most adits do not have the additional attributes such as timbers in good condition (2.3%) or headframes. Some adits may nevertheless have historical significance that is not apparent from a field inspection, or may help to complete a picture of historical mining activity in an area.

### Geology and mineralization aspects of adits

Adits can provide access for geological mapping and sampling, although they were not entered for compiling this inventory. Adits commonly cut across stratigraphy or mineralization, so their orientation is not normally of direct relevance for deducing mineralization orientations. A possible exception is the observation that some adits were driven beneath a hard ferricrete or calcrete capping, apparently to extract subhorizontal supergene mineralization.

Bund and associated waste dump material can provide information on rock type and degree of weathering, but the source of this material is not always clear.

### Subsidence

A depression at the surface due to the apparent internal collapse of an underground feature is classified as a subsidence feature in WABMINES (Fig. 30). Subsidence features comprise 1.2% of the underground features in the database.

Because these surface depressions are not the result of excavation from the surface, bunds are rarely present. Where recorded as present, full bunds have recently been emplaced, and partial bunds tend to be associated with an adjacent feature. Only 7% of subsidence features are fenced.

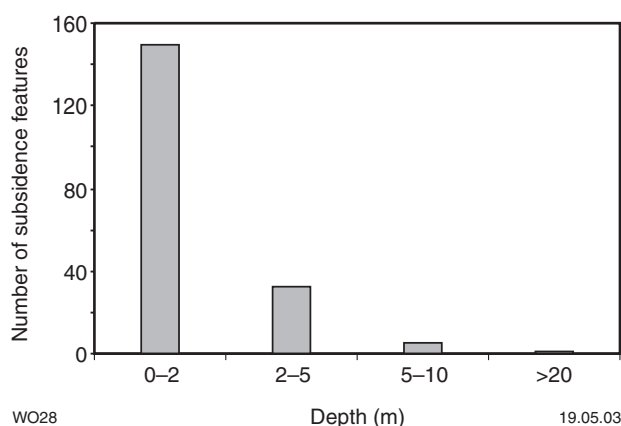
The majority (80%) of subsidence features have depths of less than 2 m (Fig. 31), 17% have depths of between 2 and 5 m, and the remaining 3% are deeper than 5 m. The mean dimensions of the subsidence features are 5.8 m length and 3.3 m width, but they can vary greatly from very small openings to large depressions (Table 12). Most subsidence features have extremely subsided or slightly subsided edges (about 72%, Table 13) and, significantly, nearly 13% of subsidence features have undercut edges.



WO58

10.04.03

**Figure 30.** Subsidence caused by the collapse of underground workings. Feature is 3.5 m long, 2.5 m wide, and 1–2 m deep (10 km north of Coolgardie; Zone 51, MGA 323625E 6584400N)



**Figure 31.** Frequency distribution of depth for subsidence features

**Table 12.** Summary data for 189 subsidence features

	Length (m)	Width (m)
Mean	5.8	3.3
Minimum	0.2	0.2
Maximum	50	50

The base condition for most subsidence features is rock or not recorded.

### Safety aspects of subsidence

Subsidence features have the lowest visibility of all underground features (56%), and are comparable to open stopes in having 8.5% with no surface expression. This is largely due to the absence of bunds (83% have no record of a bund). Nevertheless, the majority of subsidence features are shallow, and can be easily accessed. Unfortunately, one serious potential hazard for these types of features is the possibility of sudden further subsidence into an underground void, especially under the weight of a person, or with the assistance of surface water runoff. Smaller voids with very little or no surface expression may open at depth to large cavities such as stopes.

### Environmental aspects of subsidence

Wildlife is not prevented from entering subsidence features that do not have a bund or fence. Surface water may cause serious erosion of the surrounding area, and can facilitate further subsidence.

### Geology and mineralization aspects of subsidence

Occasionally, geological or mineralization observations can be made in the walls of a subsidence feature. The

Table 13. Number of attributes for 189 subsidence features

<i>Bund</i>		<i>Visibility</i>		<i>Fences</i>		<i>Edge stability</i>		<i>Base condition</i>	
None	157	Visible	105	None	176	Severe subsidence	115	Rock	101
Partial	21	Partially hidden	66	Fenced	10	Undercut	24	Empty	9
Full	11	No surface expression	16	Open subsidence	3	Slight	22	Rubbish	3
		Hidden	1			Cracked	8	Oversize	1
		Null	1			Firm	5	Null	75
						Unknown	1		
						Null	14		

strike of subsidence may follow that of an underlying stope, and hence reflect that of the mineralization, but in many cases the origin of the subsidence is uncertain.

### Collapsed drillholes

There are 53 collapsed drillholes recorded in the database, and these represent significant collapse or subsidence of a drillhole collar (Fig. 32). The extent of subsidence or collapse caused by a collapsed drillhole is small compared with most other underground features, with mean dimensions at the surface of 0.9 m length and 0.6 m width (Table 14).

The depth measures the current extent of subsidence, and although this is most commonly less than 2 m depth (Table 15), some are between 2 and 5 m deep.

Since the area around the drillhole opening has collapsed, it is not surprising that the edge condition of many of the drillholes is severely (38%) or slightly (21%) subsided. Significantly, this feature has the highest recorded incidence of undercut edges (21%) in the underground feature group.

Only one of the 53 collapsed drillholes is fenced and one is partially sealed. The majority (72%) are visible, and the remainder are partially hidden, hidden or have no surface expression.

### Safety aspects of collapsed drillholes

Collapsed drillholes are potentially hazardous to unwary people and animals for obvious reasons. The relatively high incidence of undercutting increases the probability of injury due to sudden edge collapse under the weight of a person or animal. Although most drillholes extend well beyond the collapsed collar depth, the diameter of the hole is usually small, so the depth to which larger animals can fall is limited.

### Environmental aspects of collapsed drillholes

Collapsed drillholes, as for any uncapped drillholes, may pose a risk to small wildlife that may enter and fall down the drillhole, and are unable to escape. This risk may be enhanced by the funnelling effect of the collapsed collar.

Some drillhole collars collapse with the assistance of surface water runoff, which can severely erode and enlarge the collar.

### Geology and mineralization aspects of collapsed drillholes

As for many drillholes, geological and mineralization information can be gained from observing the cuttings or samples that surround drillhole collars.



Figure 32. Large collapsed drillhole (0.5 km north of Kunanulling; Zone 51, MGA 314880E 6604500N). Stick is 1 m long

Table 14. Summary data for 53 collapsed drillholes

	<i>Length (m)</i>	<i>Width (m)</i>
Mean	0.9	0.6
Minimum	0.2	0.2
Maximum	4	2

Table 15. Number of attributes for 53 collapsed drillholes

Depth (m)		Visibility		Fences		Edge stability		Base condition		Underground seal type		Underground seal condition	
0–2	47	Visible	38	None	52	Severe subsidence	20	Rock	30	None	52	None	52
2–5	5	No surface expression	8	Fenced	1	Slight subsidence	11	Empty	2	Partial	1	Poor	1
Null	1	Partially hidden	6			Undercut	11	Null	21				
		Hidden	1			Firm	3						
						Cracked	1						
						Null	7						

## Collapsed shafts

The category of collapsed shaft has 1379 features recorded since its introduction in late May 2002. A collapsed shaft is less than 2 m deep, but shows evidence of greater original depth (Fig. 33). This evidence may include a substantial volume of bund material, or remnant collar material. Collapsed shafts are now most commonly between 1 and 2 m deep (Fig. 34a).

Almost half (49%) the collapsed shafts in the database have partial bunds, whereas 15% have full bunds (Table 16). Bunds around collapsed shafts were not recorded before the introduction of the Symbol PC in August 2002, and this accounts for the large proportion of collapsed shafts with null entries. The proportion of partial bunds to full bunds (77%) is substantially higher than the overall proportion of these types of bunds for deeper shafts (59%). The maximum bund height for partial bunds is predominantly less than 1.2 m (Fig. 34b), similar to the 1.1 m recorded for shafts with partial bunds. The minimum bund height for full bunds is most commonly less than 0.6 m (Fig. 34c), compared with 1.1 m for intact



Figure 33. Typical collapsed shaft, 3 m long, 2 m wide, and 1 m deep, with a partial bund to 1 m height (5.5 km northeast of Coolgardie; Zone 51, MGA 327554E 6578720N)

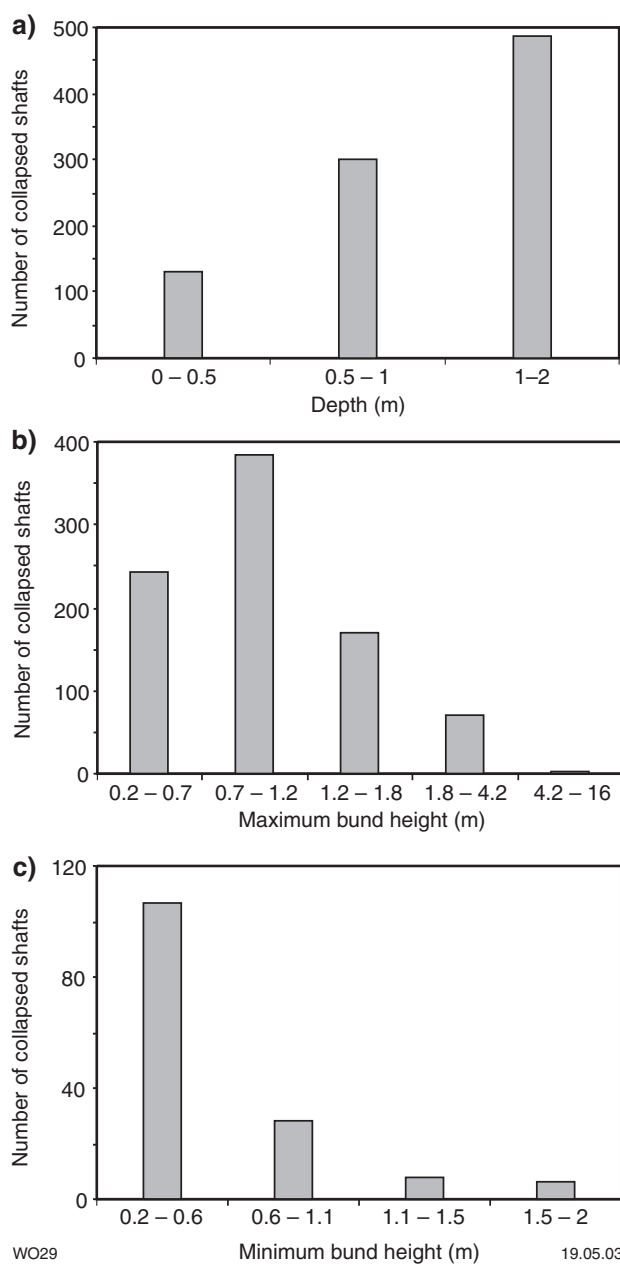


Figure 34. Frequency distribution of features for collapsed shafts: a) depth; b) maximum bund height; c) minimum bund height



Table 16. Number of attributes for 1379 collapsed shafts

Bund	Visibility	Fences	Edge stability	Base condition	Underground seal type	Underground seal condition	Underground timber condition	Underground access
Partial	677	724	752	Rock	Other	Poor	Poor	Ladder
Full	200	207	89	Rubbish	Partial	Null	82	1
Null	502	7	30	Empty	Timber	1	1 297	1 378
		2	15	Null	Null	1 375		
	No surface expression	439	13					
	Null		Firm					
			Cracked					
			Unknown					
			Null					
			475					

Table 17. Summary data for 1379 collapsed shafts

	Length (m)	Width (m)
Mean	3.9	3
Minimum	0.6	0.4
Maximum	25	15

shafts with full bunds. These observations suggest that collapsed shafts show a bias towards shallower original depths (2–10 m) that is more characteristic of intact shafts with partial bunds or comparatively shallow shafts with full bunds.

The majority of shaft collars for this feature group were originally rectangular but are now enlarged and more equidimensional, with average dimensions of  $3.9 \times 3$  m (Table 17). As would be expected, severely subsided edges are most common, resulting in more oval shapes.

A minority of collapsed shafts have visible timbers that are all in poor condition, and any form of access or seal is rare. Only 5% have fences recorded, but most are visible (77% of the features with a recorded visibility).

### Safety aspects of collapsed shafts

The comparatively high visibility of collapsed shafts is due to the common presence of a significant bund. Most collapsed shafts can be walked into and out of due to their shallow depth and normally rounded edges. The main hazard for collapsed shafts is the undefined potential for further subsidence. Some collapsed shafts may not be completely filled at depth, or the fill material may migrate into adjacent underground openings, resulting in further collapse. Sometimes the base or edges of collapsed shafts are cracked or have small openings, suggesting that subsidence is still occurring.

### Environmental aspects of collapsed shafts

Accidental entry into a collapsed shaft by wildlife is unlikely to cause problems, in most cases. Some collapsed shafts have formed by the assistance of surface water runoff, and there may be associated erosion.

### Preservation aspects of collapsed shafts

Most collapsed shafts do not possess any additional attributes, such as headframes, and were therefore classified as being in poor condition.

### Geology and mineralization aspects of collapsed shafts

Full and partial bunds normally give a good indication of the base of shaft rock type and the degree of weathering. Sometimes, potentially mineralized material (normally quartz) is segregated on part of the bund wall, or strong shearing or foliation is observed in the bund material.

Direct observation of mineralization controls within the shaft walls is not normally possible because of the severe subsidence and collapse of the shaft edges.

## Opencuts

An opencut is defined as a surface working in which the working area is kept open to the sky (American Geological Institute, 1997). Opencut workings are classified as either a costean/trench or a pit/quarry in the abandoned mine sites inventory. A trench is defined as a narrow shallow ditch cut across a mineral deposit to obtain samples or to observe character (American Geological Institute, 1997). A costean is more specifically defined as a trench cut across the conjectured line of outcrop of a seam or orebody to expose the full width.

Costean/trench has here been divided into three subtypes depending on the excavation method. The majority of costeans/trenches (more than 5000) have no recorded excavation method, and are classified as undifferentiated costeans (Fig. 35). Although mechanically excavated costeans/trenches are more numerous in the database (429 features) than those dug by hand (122 features), this may not reflect their overall abundance in the undifferentiated costeans. The excavation method was recorded during the 2002 field season, and even then, most of the obviously nonmechanically excavated costeans were not explicitly recorded as such.

A pit is defined as a mine, quarry or excavation worked by the opencut method to obtain material of value (American Geological Institute, 1997), whereas a quarry is usually a term reserved for the extraction of building stone as slate, limestone, and so on. A quarry is distinguished from a mine because it is open at the top and front (American Geological Institute, 1997). The pit/quarry feature type has been divided into 61 deep and 463 shallow pits/quarries.

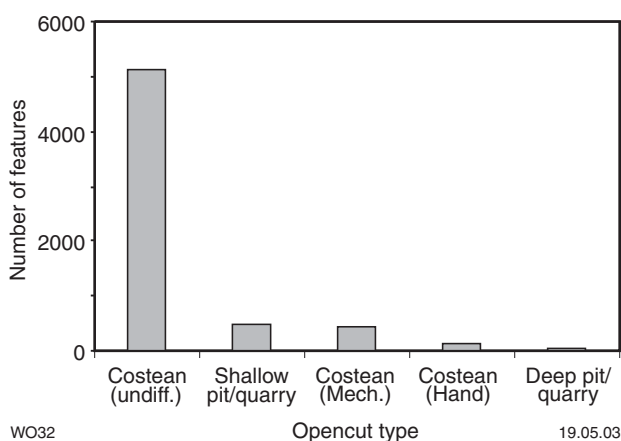


Figure 35. Frequency distribution of opencut feature types

## Deep pits/quarries (>10 m)

Pits/quarries comprise 16% of the opencut features in the WABMINES database. Of these, only 12% are more than 10 m deep. Deep pits/quarries are the largest of all surface mine workings (Fig. 36). Their lengths are most commonly between 100 and 400 m (Fig. 37a), with a mean length of 230 m (Table 18). Their widths are more evenly distributed over a wide range from 4 to 300 m (Fig. 37b), with a mean width of 110 m. The majority (61%) of deep pits/quarries have depths of more than 20 m (Fig. 37c).

Many deep pits/quarries have full bunds around the opening (Table 19), with a minimum bund height most commonly between 1.5 and 2 m (Fig. 37d). This type of bund is usually constructed for safety purposes. Some pits/quarries have partial bunds, which may consist of an adjacent waste rock dump, or have no bund at all. Not surprisingly, deep pits/quarries are amongst the most visible of all working types (93% are visible).

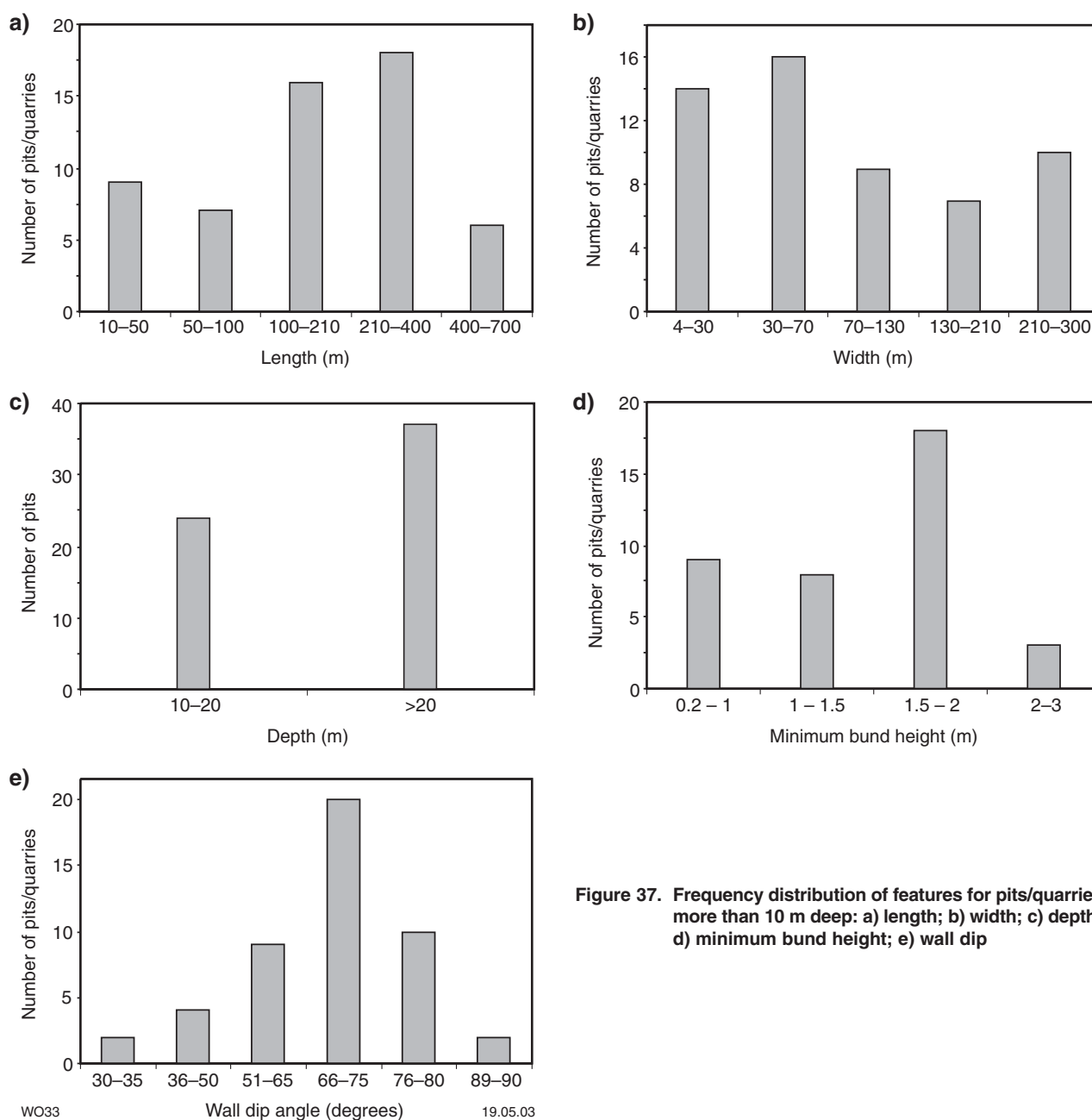
The majority of the deep pits/quarries have firm edges and wall dips of between 66° and 75° (Fig. 37e), consistent with their relatively recently mechanically excavated origin. About 43% of deep pits/quarries have access ramps. Most of the ramps (83%) have only limited access, suggesting that attempts have been made to block access by bunds, trenches or fences. About 13% of deep pits/quarries are fully fenced, including 3% by locked gate.

Although more than half of the deep pits/quarries have empty or rock base condition (52%), 44% had water in the base. The water was typically clear, and either rainwater or groundwater.

Underground openings in 30% of deep pits/quarries may be either exposed older workings (shafts, drives or stopes), or more recent declines.



Figure 36. Typical deep pit/quarry, 300 m long, 180 m wide, and more than 20 m deep, with a limited access ramp (1.5 km south of Broad Arrow; Zone 51, MGA 339482E 6629793N)



**Figure 37. Frequency distribution of features for pits/quarries more than 10 m deep: a) length; b) width; c) depth; d) minimum bund height; e) wall dip**

**Table 18. Summary data for 61 pits/quarries more than 10 m deep**

	Length (m)	Width (m)
Mean	230	110
Minimum	10	4
Maximum	700	300

### Shallow pits/quarries (<10 m)

Of the pits/quarries in the WABMINES database, 88% are less than 10 m deep. The mean length of shallow pits/quarries (Fig. 38) is about 35 m, and the mean width is 15 m (Table 20), indicating that shallow pits/quarries are significantly smaller than deep pits/quarries. The majority of shallow pits/quarries (43%) have depths of between 2 and 5 m (Fig. 39a). In contrast to deep pits/quarries, 60% of shallow pits/quarries have partial bunds around the opening, 35% have no recorded bund, and only 5% have a full bund (Table 21). The maximum bund height for partial bunds of shallow pits/quarries is most commonly between 0.7 and 1.2 m (Fig. 39b), although there is a broad range of heights between 0.2 and 2.5 m. The smaller size and less substantial bunds of shallower pits/quarries

**Table 19. Number of attributes for 61 pits/quarries more than 10 m deep**

Bund	Visibility	Fences	Edge stability	Base condition	Opencut opening	Ramp condition	Water condition						
Full	38	57	51	Firm	34	Water	27	None	43	Limited access	19	Clear	19
None	13	2	6	Slight subsidence	10	Empty	16	Yes	18	Good	4	Brown	4
Partial	10	2	2	Cracked	9	Rock	16			Poor	3	Green	4
			2	Undercut	4	Water and rubbish	1			Null	35	Null	34
				Severe subsidence	4	Null	1						



**Figure 38. Typical shallow pit/quarry, 40 m long, 10 m wide, and 2.6 m deep (6.5 km northeast of Coolgardie; Zone 51, MGA 329220E 6579005N)**

**Table 20. Summary data for 463 pits/quarries less than 10 m deep**

	<i>Length</i> ( <i>m</i> )	<i>Width</i> ( <i>m</i> )
Mean	35	15
Minimum	2.3	1
Maximum	700	300

compared with deeper pits/quarries have resulted in a lower overall visibility of 84%, and a significant number of examples with no surface expression (12).

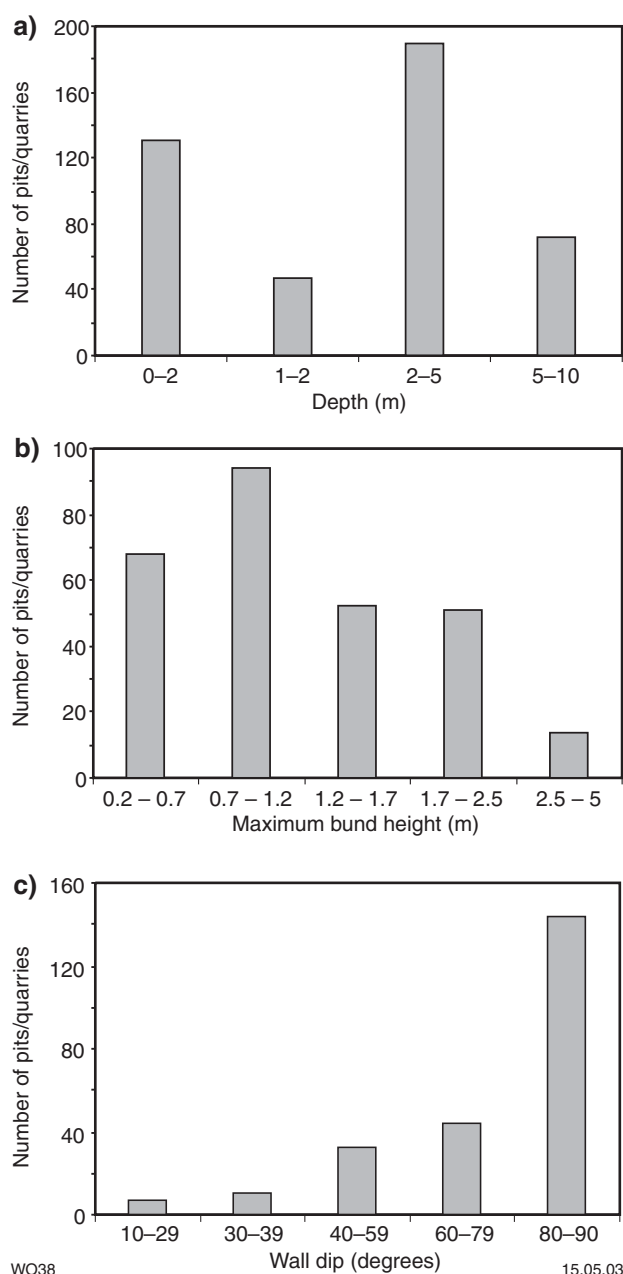
The overwhelming majority of the shallow pits/quarries for which wall dips are recorded have very steep dips of between 80° and 90° (Fig. 39c), reflecting less emphasis on wall stability than for the shallower dipping deeper pits/quarries. This appears to be supported by a lower proportion of shallow pits/quarries with firm edges (35% compared to 56%). Severely and slightly subsided edges account for 41% of these features, and undercutting was relatively common (11%).

Ramps are comparatively uncommon (5%) for the shallow pits/quarries, probably due to an increased proportion that have either not been excavated mechanically, or have not needed access for machinery.

Most shallow pits/quarries have a rock or empty base condition (79%), with about 8% containing water and 6% rubbish. Underground openings are less than half as common than for deeper pits/quarries (14% compared to 30%).

Only about 6% of shallow pits/quarries are fenced, of which about half are fully fenced.





**Figure 39.** Frequency distribution of features for pits/quarries less than 10 m deep: a) depth; b) maximum bund height; c) wall dip

### ***Safety aspects of pits/quarries***

The comparatively high visibility of deep pits/quarries makes them less likely to be accidentally entered than most other working types. Nevertheless, they do present a number of potentially serious hazards. The relatively steep sides of a deep pit/quarry can be subject to sudden wall failure, potentially endangering people near the pit edge or beneath the failure in the pit. About 15% of deeper pits/quarries have cracked edges recorded, indicating the potential for this type of failure. Although vehicular ramp access is limited to many deep pits/quarries, most could be accessed on foot. In the deeper pits, even a single loose

**Table 21. Number of attributes for 463 pits/quarries less than 10 m deep**

Bund	Visibility	Fences	Edge stability	Base condition	Opencut opening	Ramp condition	Water condition							
Partial	277	387	434	Firm	163	Rock	274	Yes	64	None	438	None	422	
	164	61	14	Slight subsidence	145	Empty	93	Null	399	Limited access	10	Brown	15	
	22	No surface expression	14	Undercut	52	Water	39			Good	8	Clear	13	
		3	Locked gate	1	Cracked	47	Rubbish	29			Poor	7	Green	10
				Severe subsidence	47	Water and rubbish	2						Black	3
			Null	9	Null	26								

stone falling from a pit wall has the potential to cause serious injuries.

Shallower pits/quarries tend to be less visible than deeper pits/quarries, increasing the likelihood of accidental entry. Wall failure is even more likely for some shallower pits, which tend to have steeper sides, and a relatively high proportion of undercut edges.

Fences are more common for deep, rather than shallow pits/quarries, but are still only found in a minority of cases. Only three fences are of the most effective locked-gate type.

The presence of underground openings in a significant number of pits/quarries introduces all of the hazards of underground features, but usually without the protection of bunds or individual fencing.

The presence of water in the base of many pits/quarries introduces the possibility of drowning by either swimming or diving into the water. The depth of the water and the nature of the underlying base are not normally known. Furthermore, water can conceal large rocks, underground workings, and rubbish, and some water can be potentially toxic or acidic due to the breakdown of sulfide minerals.

### ***Environmental aspects of pits/quarries***

Deep pits/quarries have the highest visual impact assessment of all the subcategories, with 70% having a high visual impact. Nevertheless, as a group, only 4% of opencut features have either a high or a moderate visual impact.

There is some risk to wildlife associated with accidental entry or wall collapse of pits/quarries. Wildlife may be attracted to accessible pits by the presence of water or shelter. The water quality may have an impact on the fauna. As for shafts, some animals may use a pit/quarry for habitat.

In deep pits or quarries, particularly where the water table is intersected, the weathering of exposed mineralization may cause groundwater contamination. Surface drainage can remove topsoil and deeply erode pit walls and ramps. Furthermore, compacted soil around the pit/quarry edges can hinder revegetation.

### ***Preservation aspects of pits/quarries***

Many of the large, pits/quarries are mechanically excavated modern features in relatively good condition. Some of the smaller shallow pits/quarries may have been hand dug, but are generally more poorly preserved.

### ***Geology and mineralization aspects of pits/quarries***

Both shallow and deep pits/quarries reveal a vertical section of the geology and can provide an opportunity to observe rock types, weathering, structures, and mineralization. Mineralization controls can be observed and measured in pit walls. Most pits/quarries were not entered, but large scale observations were made where possible.

The overall strike of the pit/quarry can give an indication of the general trend of the mineralization. Older workings exposed in pit walls and deeper final excavations in the base of pits can give an indication of the orientation of the higher grade mineralization.

Bund material can give a good indication of the rock type, although the provenance of this material is not always clear.

## **Mechanically excavated costeans/trenches**

Costeans and trenches are not distinguished from one another in the database and are referred to as costeans in the text. Costeans comprise 6.3% of the features in the database and, of these, 0.5% (7.6% of costeans) are recorded as having been mechanically excavated (Fig. 40).

The majority of mechanically excavated costeans are elongate shallow features with lengths most commonly between 2 and 35 m (Fig. 41a), with a mean of 21 m (Table 22). Widths are most commonly between 0.5 and 4 m (Fig. 41b), with a mean of 2.8 m. The majority of the costeans are less than 2 m deep, and mechanically excavated costeans more than 5 m deep are rare (<1%, Fig. 41c).

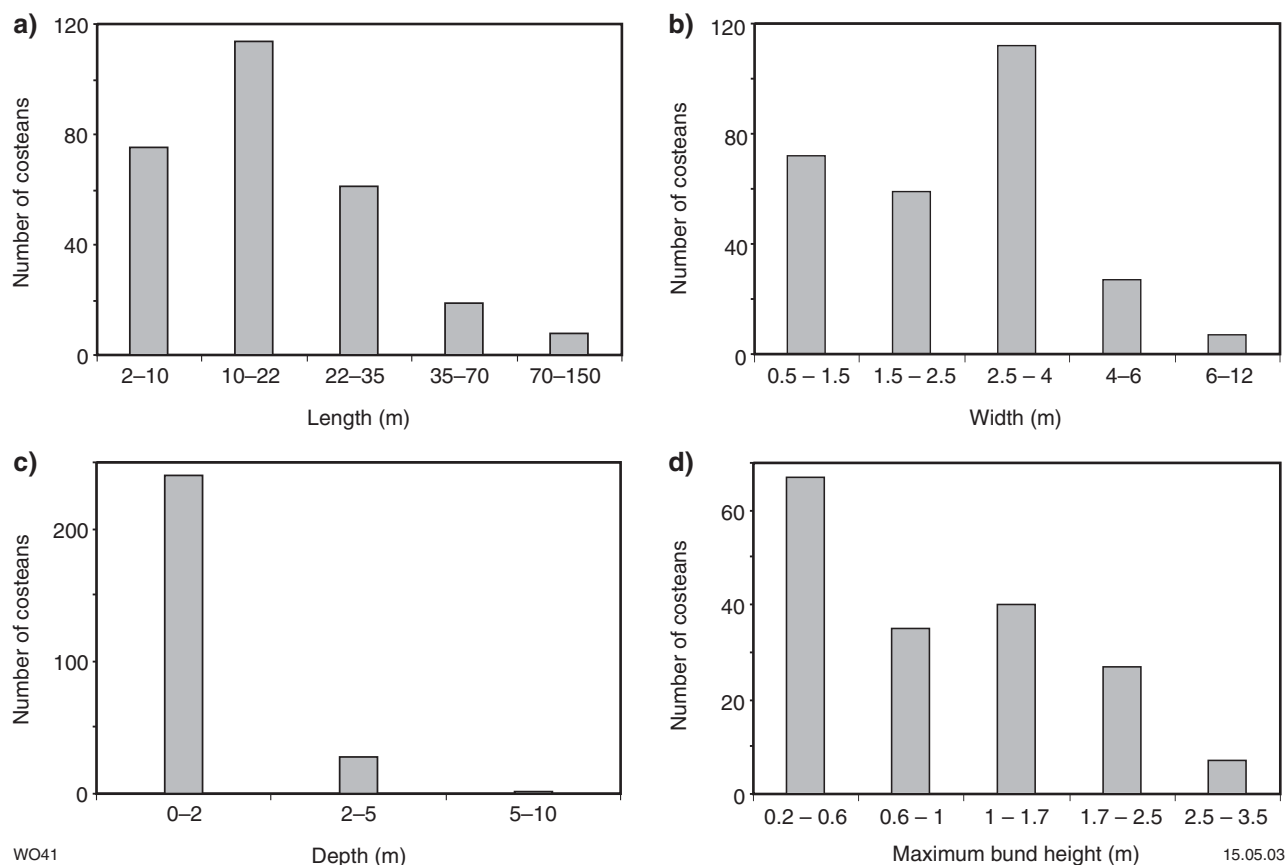
Three main excavation methods can be inferred from the working dimensions and the location of the dump of waste rock. Excavator or backhoe costeans are comparatively narrow and deep, and normally have a pile of discarded waste rock to one side of the working, effectively forming a partial bund. Bulldozer costeans are wider, but tend to be shallower. They normally have an entry ramp at one end and a pile of waste rock at the other end, which can also be regarded as a partial bund. Loader costeans have a similar form to a bulldozer costean, but



W063

10.04.03

**Figure 40.** Typical mechanically (excavator or backhoe) excavated costean/trench, 30 m long, 2 m wide, and 0–5 m deep, with a partial bund to 2.5 m height (35 km south-southwest of Meekatharra; Zone 50, MGA 633436E 7025882N)



**Figure 41. Frequency distribution of features for mechanically excavated costeans/trenches: a) length; b) width; c) depth; d) maximum bund height**

are distinguished by having a separate waste dump that could be placed some distance away from the excavation. These dumps are normally considered to be separate features, rather than constituting a bund.

Unfortunately, it is difficult to accurately determine the presence of a bund from the statistics given in Table 23 due to the large number of null values that are due to no record of this attribute. Any significant bund associated with a costean was recorded after the introduction of the Symbol PC. Statistics from these data show 69% of the 205 mechanically excavated costeans have partial bunds, and the remainder have no significant bunds. Where bund

**Table 22. Summary data for 429 mechanically excavated costeans**

	<i>Length (m)</i>	<i>Width (m)</i>	<i>Maximum bund height (m)</i>
Mean	21	2.8	1.1
Minimum	2	0.5	0.1
Maximum	150	12	3.5

**Table 23. Number of attributes for 429 mechanically excavated costeans**

<i>Bund</i>		<i>Visibility</i>		<i>Fences</i>		<i>Edge stability</i>		<i>Base condition</i>	
Partial	186	Visible	213	None	427	Slight subsidence	143	Rock	193
Full	6	Partially hidden	64	Locked gate	1	Severe subsidence	76	Empty	24
Null	237	No surface expression	2	Open	1	Firm	41	Water	11
		Null	150			Undercut	8	Rubbish	7
						Cracked	5	Tailings	2
						Null	156	Null	192

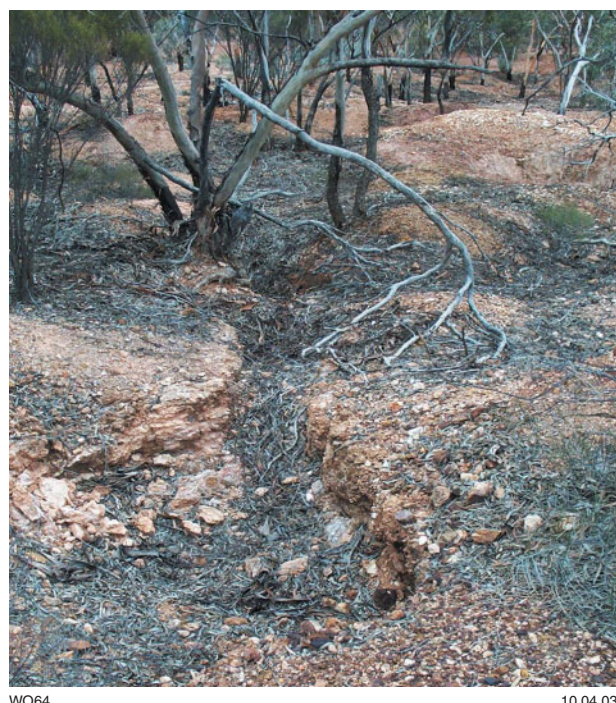
type is known, 97% have partial bunds and 3% have full bunds. The maximum bund height for costeans with a partial bund is broadly distributed, mainly between 0.2 and 2.5 m, with the most common range from 0.2 to 0.6 m (Fig. 41d), and a mean of 1.1 m (Table 22). Just over three-quarters of the mechanically excavated costeans are visible from a moderate distance when only the non-null records are taken into account. This is slightly less than for the shallow pits/quarries, as would be expected due to their smaller size.

Eighty percent of all mechanically excavated costeans with a non-null record for edge condition have either slightly or severely subsided edges, and 15% have firm edges. Most costeans of this type with a non-null record for edge condition have rock or empty as the recorded base condition (92%). Only a relatively small proportion has water (4.6%) or rubbish (3%) in the base.

### Hand-dug costeans/trenches

About 2% of the costeans in the database were recorded as hand-dug, however, a much higher proportion exists, although this attribute was not routinely recorded.

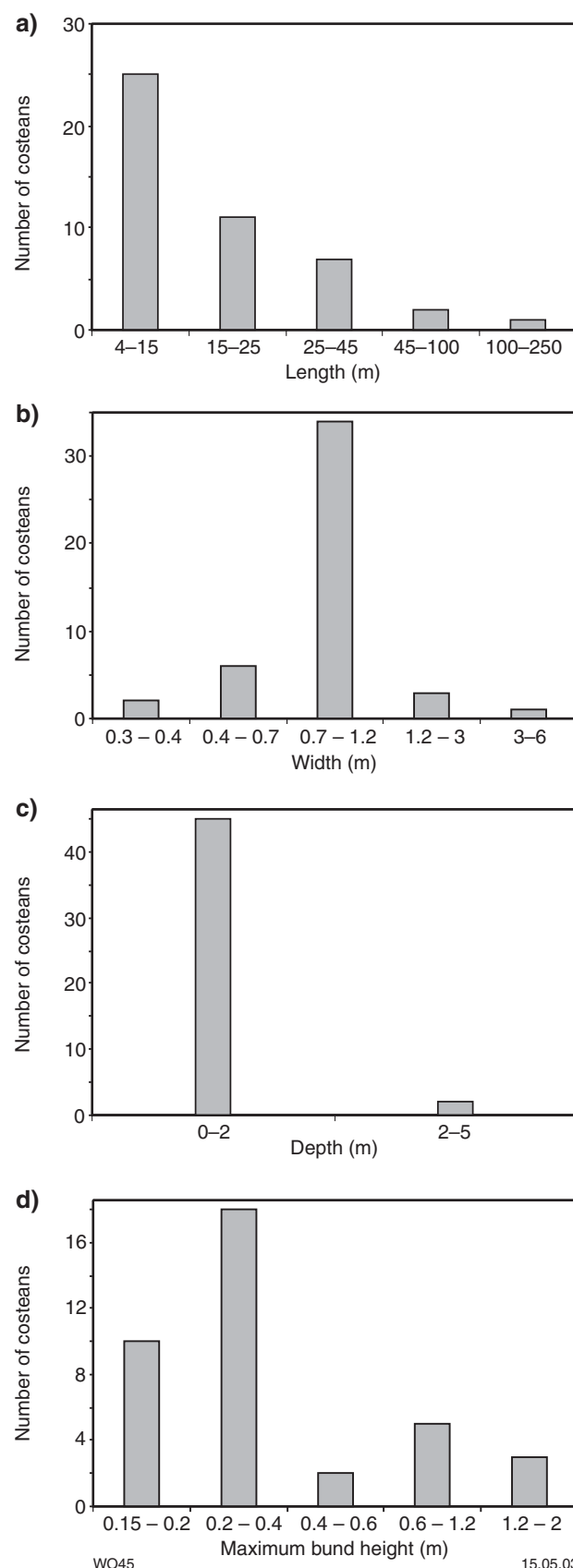
Hand-dug costeans are typically much narrower, shorter and shallower features than mechanically excavated costeans (Fig. 42). The majority of hand-dug costeans have lengths of less than 15 m (Fig. 43a), and widths of between 0.7 and 1.2 m (Fig. 43b). Mean length and width are 25 and 1.2 m respectively (Table 24). Most



WO64

10.04.03

**Figure 42.** Typical hand-dug costean/trench and adjacent shallow workings (largely filled with leaves), 10 m long, less than 1 m wide, and 0–2 m deep (1 km west of Bardoc; Zone 51, MGA 335507E 6641995N)



**Figure 43.** Frequency distribution of features for hand-dug costeans/trenches: a) length; b) width; c) depth; d) maximum bund height



**Table 24. Summary data for 122 hand-dug costeans**

	<i>Length (m)</i>	<i>Width (m)</i>	<i>Maximum bund height (m)</i>
Mean	25	1.2	0.5
Minimum	4	0.3	0.1
Maximum	250	6	2

hand-dug costeans are less than 2 m deep (Fig. 43c), and many are less than 1 m deep (not shown due to insufficient data).

As with the mechanically excavated costeans, no record was routinely made for bunds for many of the hand-dug costeans. Commonly, hand-dug costeans are old, with substantially dispersed partial bunds. The limited available data shows maximum partial bund heights of mostly between 0.15 and 0.4 m (Fig. 43d), with a mean of 0.5 m. Sixty percent of costeans recorded as hand dug were visible from a moderate distance and only one partial fence was recorded. Eighty-six percent of all hand-dug costeans with a non-null record for edge condition have either slightly or severely subsided edges, and 11% have firm edges (Table 25).

## Undifferentiated costeans/trenches

Undifferentiated costeans/trenches are those for which the method of excavation has not been recorded. Only the development and improvement of the WABMINES database and application led to the recording of the detailed information used for differentiating the hand-dug and mechanically excavated costean subgroups. There are 5115 undifferentiated costeans in the database, constituting 90% of all costeans.

The majority of undifferentiated costeans have lengths of less than 18 m (Fig. 44a) and widths between 0.75 and 1.4 m (Fig. 44b). Lengths range up to 550 m and average 29 m (Table 26), whereas widths average 1.6 m. These dimensions, especially the widths, can be used to infer that most of the undifferentiated costeans are in fact hand dug. More than 90% of the costeans are shallow (<2 m); only a small proportion (9%) have depths of between 2 and 5 m, and costeans more than 5 m deep are very rare (Fig. 44c).

Most (53%) undifferentiated costeans have no associated bund recorded (Table 27), but this is related to the lack of routine recording of this information for much of the project. About 46% have partial bunds and the remaining 1% have full bunds. The maximum bund height for costeans with partial bunds is commonly between 0.35 and 1.3 m, with a broad spread between 0.2 and 2.2 m (Fig. 44d). Seventy-one percent of undifferentiated costeans were recorded as visible from a moderate distance when only the non-null records are taken into account.

Sixty-nine percent of the undifferentiated costeans with a non-null record for edge condition have either slightly or severely subsided edges, and 23% have firm edges. Most costeans of this type with a non-null record for edge condition have rock or empty base condition (95%). Only a relatively small proportion has water (3.8%) or rubbish (1.4%) in the base. Fences are rare, with only 21 records of any fence at all, of which six are fully fenced and one has a locked gate.

## Safety aspects of costeans/trenches

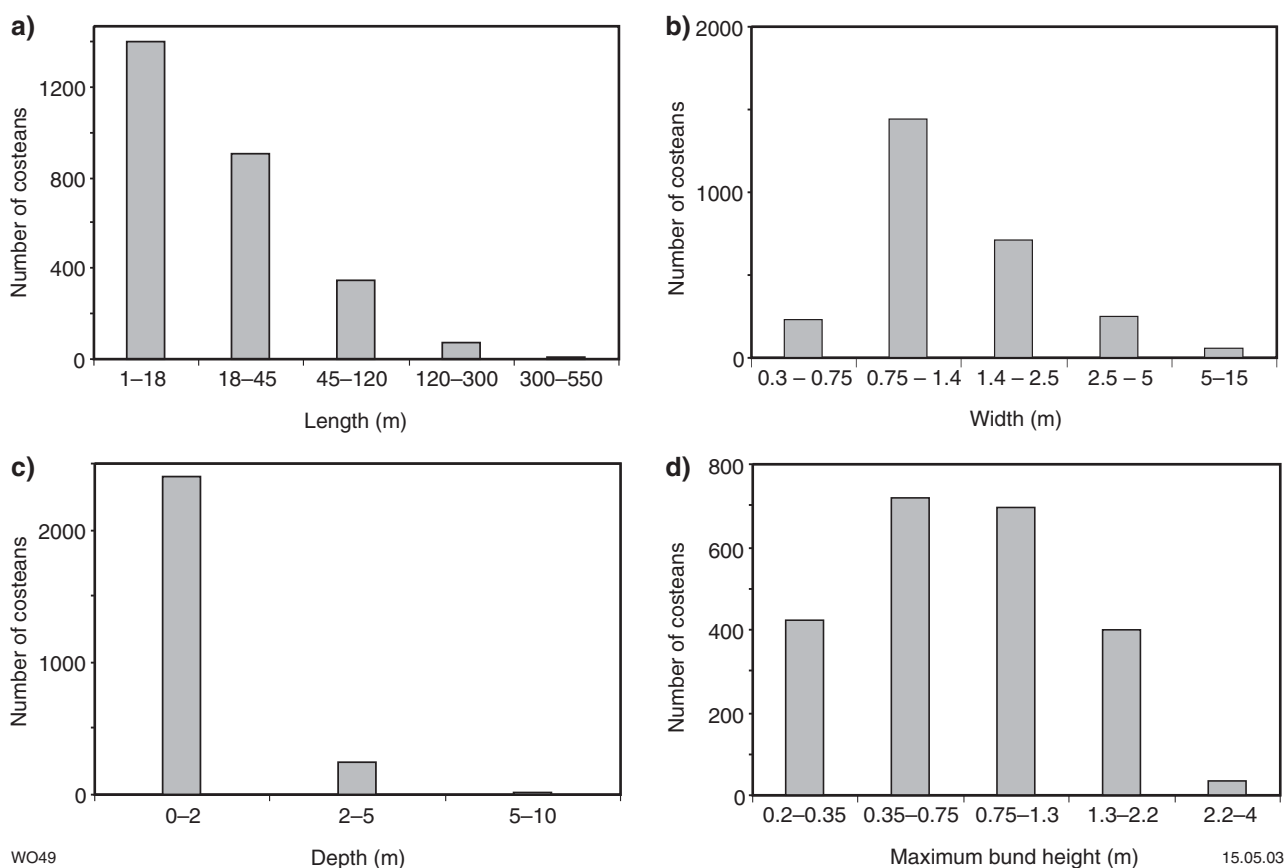
Costeans of all types have a moderately high visibility (71%), but are considerably less visible than pits and quarries. The most significant visual cue from a distance can be the partial bund of excavated material, which is normally to one side or end of the costean and this can only be a partial barrier to accidental entry. Mechanically excavated costeans with the waste material physically removed from the working are difficult to see.

Costeans are mostly less than 2 m deep, reducing the potential for serious injury caused by accidental entry. Furthermore, many costeans can be walked into and out of without difficulty. Most costeans have either slightly or severely subsided edges. Generally, more edge subsidence occurs over time, reducing the wall slope and depth of the costean, and hence the risk of injury. Old, hand-dug costeans are therefore normally less potentially hazardous than the most recent, mechanically excavated costeans. Cracked and undercut edges can present a hazard for edge collapse, although they are relatively uncommon (7.4%). Due to the shallow depth of most costeans, the consequences of edge collapse are not likely to be as serious as for many deeper pits and quarries.

The most potentially hazardous costeans are the minority that are mechanically excavated and more than 2 m in depth with firm, cracked or undercut edges. These

**Table 25. Number of attributes for 122 hand-dug costeans**

<i>Bund</i>		<i>Visibility</i>		<i>Fences</i>		<i>Edge stability</i>		<i>Base condition</i>	
Partial	41	Visible	27	None	120	Severe subsidence	30	Rock	34
Null	80	Partially hidden	17	Open	1	Slight subsidence	8	Rubbish	1
		Null	77			Firm	4	Null	86
						Undercut	1		
						Null	78		



**Figure 44. Frequency distribution of features for undifferentiated costeans/trenches: a) length; b) width; c) depth; d) maximum bund height**

**Table 26. Summary data for 5069 undifferentiated costeans**

	Length (m)	Width (m)
Mean	29	1.6
Minimum	1	0.3
Maximum	550	15

can present the same dangers as shallow pits/quarries, but may be less visible, especially if they have no bund, and only a few are fenced. The most common method of rehabilitation for costeans is backfilling.

### **Environmental aspects of costeans/trenches**

There is some risk to wildlife and livestock falling in and becoming injured and trapped in some of the deeper costeans.

**Table 27. Number of attributes for 5069 undifferentiated costeans**

Bund	Visibility	Fences	Edge stability	Base condition	Revegetation
Partial 2 315	Visible 1 920	None 5 049	Slight subsidence 1 055	Rock 1 851	Full 6
Full 54	Partially hidden 776	Open 13	Severe subsidence 769	Empty 193	Partial 3
Null 2 700	No surface expression 8	Fenced 6	Firm 609	Water 83	Null 5 060
	Hidden 4	Locked gate 1	Cracked 92	Rubbish 30	
	Null 2 361		Undercut 114	Oversize 1	
			Null 2 430	Tailings 1	
				Water and rubbish 1	
				Null 2 909	

Depending on their location, costeans may become the focus for surface-water runoff, and erosion. This may lead to natural rehabilitation by gradually filling-in the excavation, but remove topsoil from the surrounding area in the process. The combination of vegetation regrowth, and nearly complete natural filling-in of some old costeans can make them almost indistinguishable from the surrounding area. This is in stark contrast to many of the relatively recent mechanically excavated costeans that form prominent features on the landscape.

### **Preservation aspects of costeans/trenches**

No costeans were given the field assessment of fair or good condition.

### **Geology and mineralization aspects of costeans/trenches**

Many costeans or trenches reveal something of the geology, unless they are substantially filled in by edge collapse. Costeans typically aim to crosscut structures, rock types or mineralization controls and therefore can provide an opportunity to examine and measure these features.

The depths of some mechanically excavated costeans may give an indication of the depth of weathering or cover over bedrock, as they may be dug to the hard rock interface. Bund material can also provide information on rock type, possible mineralization controls and the degree of weathering.

## **Shallow workings**

Shallow workings constitute about 53% of the WABMINES database, and include pits, cavities, holes, or other uncovered excavations, that are less than 2 m deep (Fig. 45). Shallow workings have been subdivided into two types to highlight the different morphologies resulting



WO65

10.04.03

**Figure 45. Typical old shallow working, less than 0.5 m deep (6 km south of Coolgardie; Zone 51, MGA 324062E 6568392N)**

from different methods of excavation: undifferentiated and mechanically excavated. The data have limitations because excavation method, dimensions, depth, and other attributes have only been routinely recorded since the introduction of the Symbol PC.

Some shallow workings can be positively identified as being mechanically excavated. These comprise only 6% of all shallow workings recorded since the introduction of the Symbol PC. The remainder appear to be mainly old and hand dug, but only a small number of workings have specifically been recorded as such. Consequently, all nonmechanically excavated shallow workings are grouped as undifferentiated.

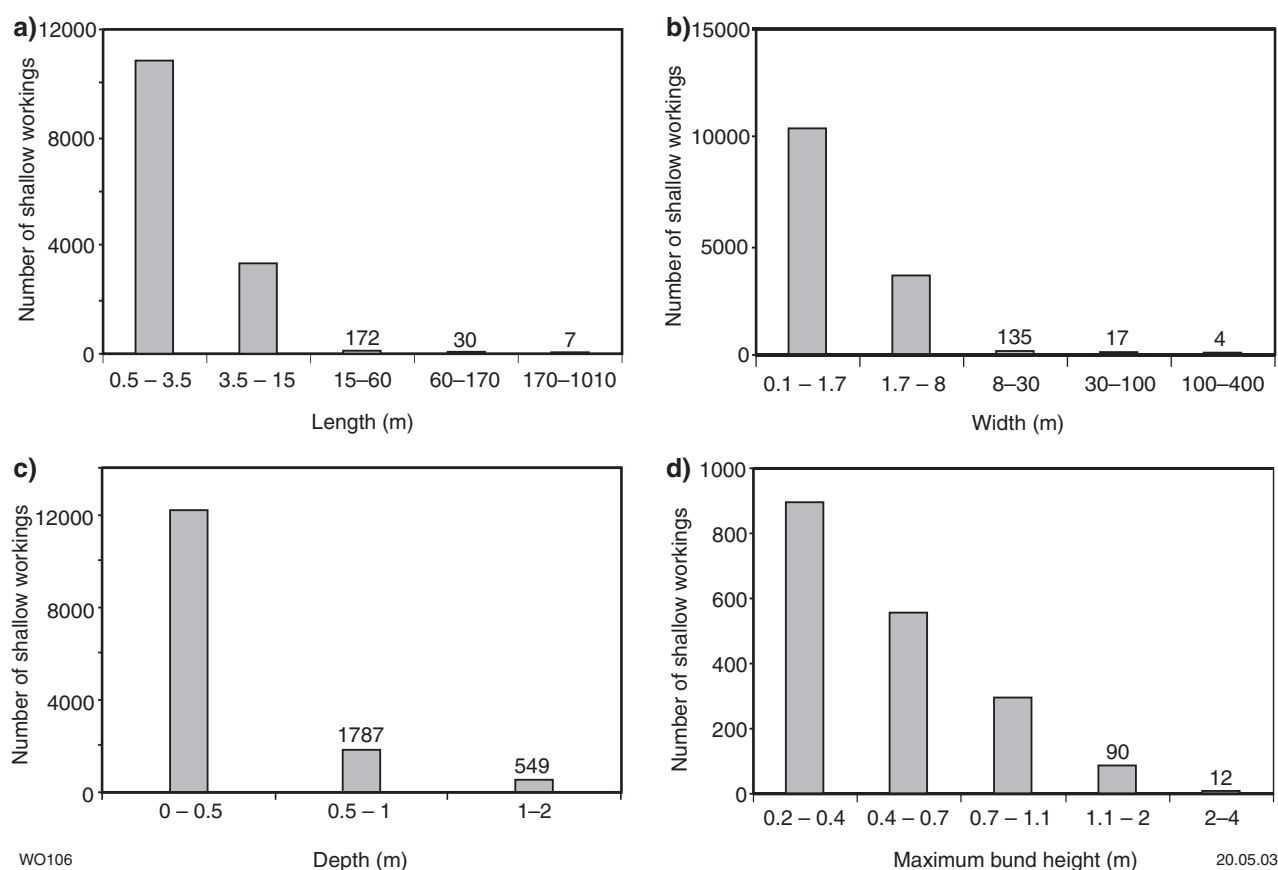
There are more than 44 000 undifferentiated shallow workings, and only 2300 mechanically excavated shallow workings. The following section describes and illustrates the characteristics of the undifferentiated and mechanically excavated shallow workings.

## **Undifferentiated shallow workings**

About 95% of the shallow workings in the WABMINES database are undifferentiated in terms of their method of excavation, although most are probably old and hand dug. Undifferentiated shallow workings are commonly less than 3.5 m long (Fig. 46a) and 1.7 m wide (Fig. 46b). The largest dimensions of 1010 m length and 400 m width represent large areas that include shallow workings too numerous to capture individually. More than three-quarters (84%) of undifferentiated shallow workings are less than 0.5 m deep (Fig. 46c). A significant 12% are between 0.5 and 1 m deep, and only 4% have depths of between 1 and 2 m.

About a third of the records for undifferentiated shallow workings have information on bunds, and other attributes where appropriate. These indicate that about 13% of undifferentiated workings have bunds. This is substantially more than shown in Table 28, in which most of the null values can be attributed to an absence of data. Nevertheless, bunds are comparatively uncommon for undifferentiated shallow workings. In this context they refer to the pile of waste rock adjacent to the working. Although almost all shallow workings originally had an adjacent waste rock pile, most are old, dispersed, and very low. A bund is only recorded if it is significant and effective in providing a visual cue or physical barrier. Of those shallow workings for which bund type is known, 96% have partial bunds and 4% have full bunds. Full bunds are unusual for shallow workings because of the normally small volume of material extracted. The maximum bund height for undifferentiated shallow workings with partial bunds is most commonly between 0.2 and 0.4 m (Fig. 46d). Excluding the null records, 80% of undifferentiated shallow workings are visible.

Almost all undifferentiated shallow workings have either extremely subsided (68%) or slightly subsided edges (24%), after excluding the large number of records with no data. Only 7% of the edges are firm. Base condition was mainly rock (89%) with about 10% containing significant rubbish.



**Figure 46. Frequency distribution of recorded features for undifferentiated shallow workings: a) length; b) width; c) depth; d) maximum bund height**

**Table 28. Number of attributes for 44 844 undifferentiated shallow workings**

Bund		Visibility		Edge stability		Base condition	
Partial	1 792	Visible	13 088	Severe subsidence	5 818	Rock	1 585
Full	73	Partially hidden	3 151	Slight subsidence	2 100	Rubbish	186
Null	42 969	Hidden	98	Firm	597	Empty	6
		No surface expression	4	Undercut	81	Water	5
		Null	28 493	Conical collar	7	Tailings	3
				Cracked	2	Null	43 049
				Null	36 229		

## Mechanically excavated shallow workings

About 5% of the shallow workings in the WABMINES database have been recorded as mechanically excavated (Fig. 47). Mechanically excavated shallow workings are commonly longer and wider than undifferentiated shallow workings, with most common lengths of less than 7 m (Fig. 48a) and widths of less than 3.5 m (Fig. 48b). The largest dimensions of 300 m in length and 100 m in width reflect large, shallow alluvial workings. Almost three-quarters (73%) of mechanically excavated shallow

workings are less than 0.5 m deep (Fig. 48c), and most of the remainder (21%) are between 0.5 and 1 m deep. Only a small proportion (6.6%) has depths of between 1 and 2 m. The data shows a slight tendency for mechanically excavated shallow workings to be deeper than the undifferentiated workings.

About half of the records for mechanically excavated shallow workings have information on bunds, and other attributes where appropriate. These show that 21% of mechanically excavated shallow workings have bunds. This is double the value shown in Table 29, in which most



of the null values are due to no data being collected. Bunds are therefore still in the minority, but are more common than for undifferentiated shallow workings. Some mechanically excavated shallow workings such as borrow pits and some alluvial workings have no adjacent waste rock because all the material has been removed. Other workings of this type, such as bulldozer scrapes, may not have significant adjacent heaps of waste rock. Of those shallow workings for which bund type is known, 99% have partial bunds and only 1% have full bunds. The most common maximum bund height for shallow workings with partial bunds is distributed over a broad range from 0.2 to 1.2 m (Fig. 48d). Excluding the null records, 93% of mechanically excavated shallow workings are visible.

Almost all undifferentiated shallow workings have either extremely subsided (60%) or slightly subsided edges (37%), after excluding the large number of records with no data. Only 2% of the edges are firm. Base condition was mainly rock (92.5%) with 7.5% containing significant rubbish for the comparatively small amount of data on this attribute.

### Safety aspects of shallow workings

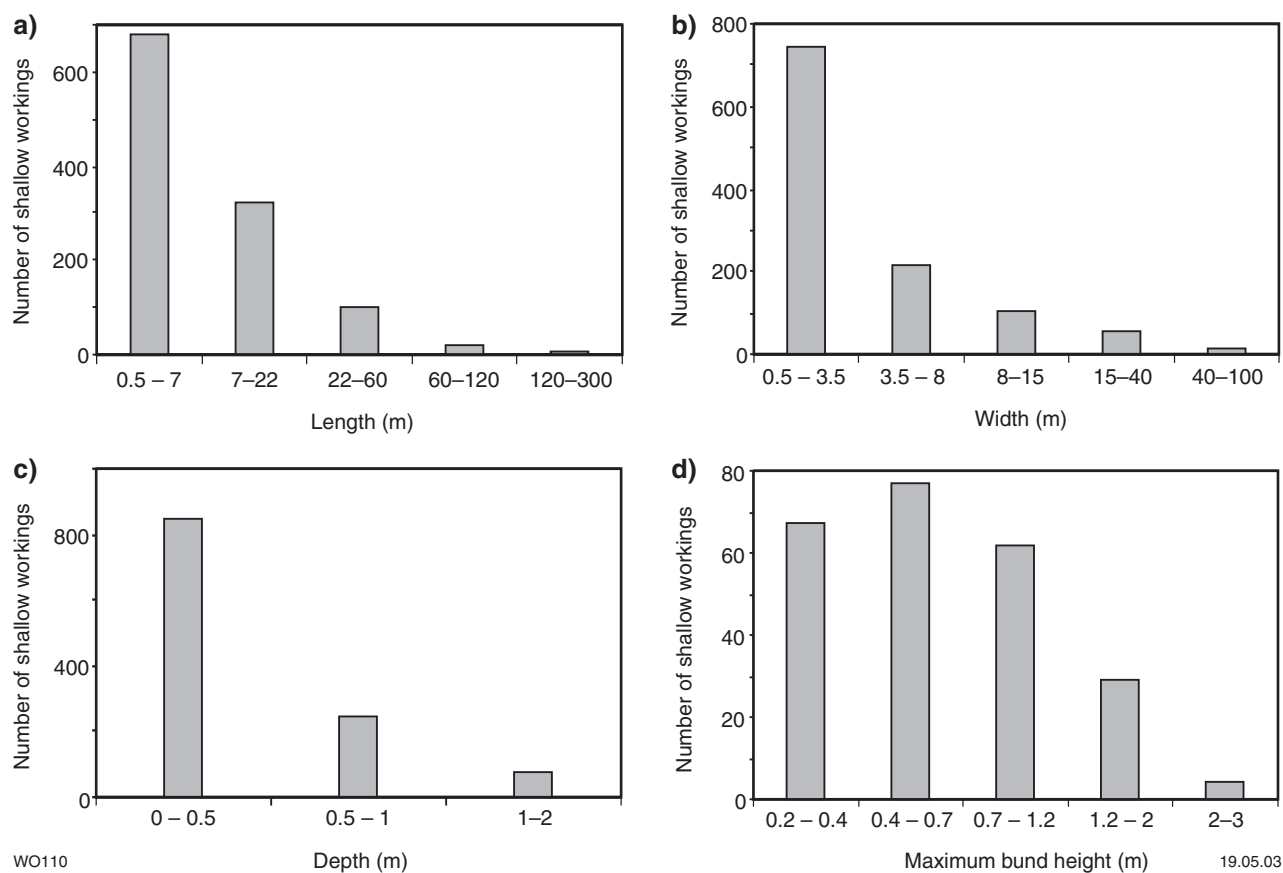
Shallow workings are less than 2 m deep by definition, and most are less than 0.5 m deep, consequently, the



WO66

10.04.03

**Figure 47. Mechanically excavated shallow working – alluvial pit, 100 m long, 20 m wide, and 1–2 m deep (3.5 km northeast of Coolgardie; Zone 51, MGA 326780E 6577270N)**



WO110

19.05.03

**Figure 48. Frequency distribution of features for mechanically excavated shallow workings: a) length; b) width; c) depth; d) maximum bund height**

**Table 29. Number of attributes for 2302 mechanically excavated shallow workings**

<i>Bund</i>		<i>Visibility</i>		<i>Edge stability</i>		<i>Base condition</i>	
Partial	238	Visible	1 085	Severe subsidence	587	Rock	259
Full	2	Partially hidden	84	Slight subsidence	360	Rubbish	21
Null	2 062	Null	1 133	Firm	21	Null	2 022
				Undercut	3		
				Conical collar	1		
				Null	1 330		

potential for serious injury is low. Furthermore, almost all shallow workings can be walked into and out of without difficulty. Most shallow workings have either slightly or severely subsided edges. As for costeans, edge subsidence occurs over time, reducing the wall slope and depth of the working, and hence the risk of injury. Old, hand-dug shallow workings are therefore normally less potentially hazardous than the most recent, mechanically excavated shallow workings. The significant exceptions are those shallow workings more than about 1 m deep with firm only slightly subsided or undercut edges.

All types of shallow workings have an overall high visibility (81%), particularly for mechanically excavated types. The visibility is high even though significant bunds are uncommon compared with other workings. This is probably due to a combination of subtle colour, depth, and textural contrasts between not only the waste material, but also the base of shallow workings and the surrounding area. Bunds do not play a significant role in providing a physical barrier to accidental entry in most shallow workings.

### ***Environmental aspects of shallow workings***

The main environmental problem created by shallow workings is the disturbance of the natural condition of large areas of ground by the pits and cavities and their associated extracted material. Many undifferentiated shallow workings are old, small, revegetated, and significantly naturally rehabilitated by edge subsidence. In contrast, some of the more recent mechanically excavated shallow workings can form prominent features on the landscape, with only partial or no revegetation. Overall, shallow workings were assessed to have a low visual impact, with only 0.1% of features given a field rating of moderate visual impact.

### ***Preservation aspects of shallow workings***

Most of the undifferentiated shallow workings are old, and their condition is poor.

### ***Geology and mineralization aspects of shallow workings***

Shallow workings expose rock types, and provide the opportunity to study the degree of weathering and mineralization either directly or from observations of the waste material. Measurements of structural or vein orientations can be made in places.

Many undifferentiated shallow workings are clearly old, and focused on quartz veins or some other obvious form of mineralization. In contrast, mechanically excavated (hence more recent) shallow workings tend to have more diverse purposes, which may not be directly related to bedrock mineralization, such as for gravel extraction or systematic geochemical sampling.

Both undifferentiated and mechanically excavated types of shallow workings may be primarily for alluvial or colluvial mining purposes. The predominance of alluvial or colluvial material in the waste material, and the mode of occurrence of these types of workings can indicate their purpose. Many abandoned alluvial or colluvial workings cluster together, and some cover a considerable area of intensive excavations.

## **Rehabilitated features**

Features that have been restored to a previous condition, mainly by bulldozing and ripping are referred to as rehabilitated (Fig. 49). Prior to the introduction of the collapsed shaft feature group, some collapsed shafts were considered to be ‘naturally rehabilitated’ and therefore were included in this group (about 2% of the total). There are 12 052 rehabilitated features, comprising 13.6% of the



**Figure 49. Typical rehabilitated area showing ripped ground over workings (34 km north of Leinster; Zone 51, MGA 259148E 6940971N)**

WABMINES database. Where possible, the type of feature that has been rehabilitated has been recorded. Most rehabilitated features were individual costeans and shafts, but a minority refer to other features or to areas that originally contained multiple individual features.

Dimensions are only examined for features recorded since the introduction of the Symbol PC, and represent about 5% of all rehabilitated features. They range in length from 0.2 to 550 m, but are commonly less than 20 m long (Fig. 50a). Widths range from 0.2 to 400 m, and are commonly less than 8 m (Fig. 50b).

As for dimensions, visibility was recorded for about 5% of all rehabilitated features. When only the non-null values in Table 30 are considered, about 60% of the rehabilitated features are visible from a moderate distance.

### Safety aspects of rehabilitated features

Most rehabilitated features are backfilled workings. Backfilling can dramatically reduce the hazard of the original feature, with some uncommon (<5%), but significant, exceptions (see **Backfilling of underground workings**) related to either incomplete backfilling or subsidence after backfilling.

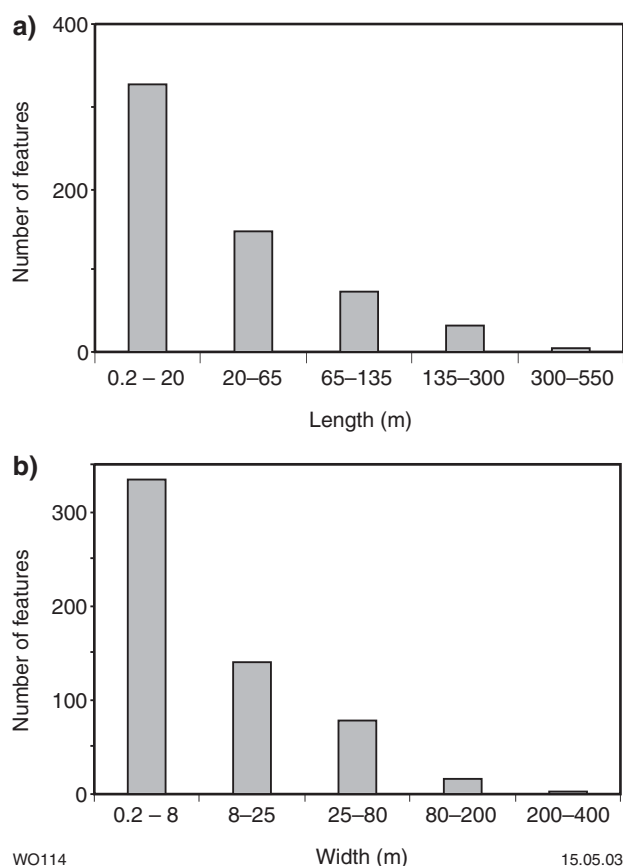


Figure 50. Frequency distribution of rehabilitated features: a) length; b) width

Table 30. Number of attributes for 12 052 rehabilitated features

Type		Visibility	
Shaft	372	Visible	644
Costean/trench	236	No surface expression	282
Pit/quarry	17	Partially hidden	151
Open stope	3	Hidden	5
Other infrastructure	3	Null	10 970
Subsidence	2		
Adit	1		
Building	1		
Machinery	1		
Topsoil dump	1		
Null	11 415		

Some rehabilitated features recorded before the introduction of the collapsed shaft feature group are collapsed shafts (see **Collapsed shafts**).

A minority of shafts are backfilled with rubbish, which may be potentially hazardous, especially if voids remain.

### Environmental aspects of rehabilitated features

Most rehabilitated features pose no environmental problems. Over time they commonly revegetate and become almost indistinguishable from the surrounding area. The exceptions are those that undergo further subsidence, which may be assisted by surface water runoff, and therefore accompanied by erosion.

### Geology and mineralization aspects of rehabilitated features

Rock type observations and styles of mineralization can be accessed from backfill, which is normally derived from bund material. However, in some cases, backfill may be derived from elsewhere and therefore not be representative of the feature locality.

## Dumps

Dumps comprise 2.6% of the WABMINES database, and are divided into seven different types according to their morphology, purpose and composition. The largest categories of dumps are waste, tailings, rubbish, and rock and soil dumps comprising 38%, 23%, 16% and 14% of dumps respectively (Fig. 51). The smaller dump categories include ramp/tramway, topsoil, leach pad, and ash dumps.

### Waste, rock and soil, topsoil, rubbish, and ash dumps

Waste, rock and soil, topsoil, rubbish, and ash dumps are characterized by their compositions, which are largely self-explanatory, although some types have rather specific characteristics. For example, waste dumps consist specifically of mine waste or spoil materials (Fig. 52a),



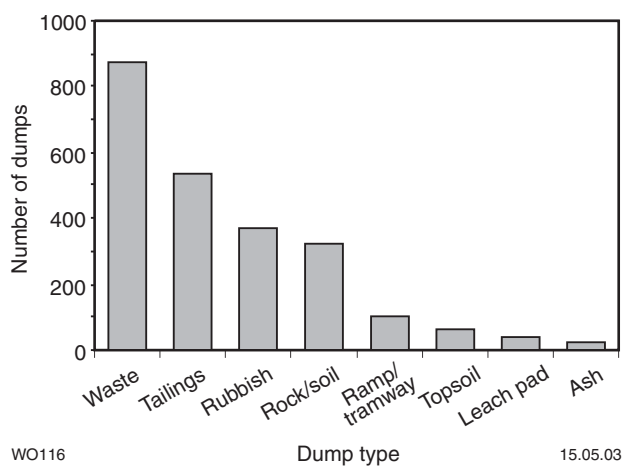


Figure 51. Frequency distribution of dump types



WO68

15.05.03

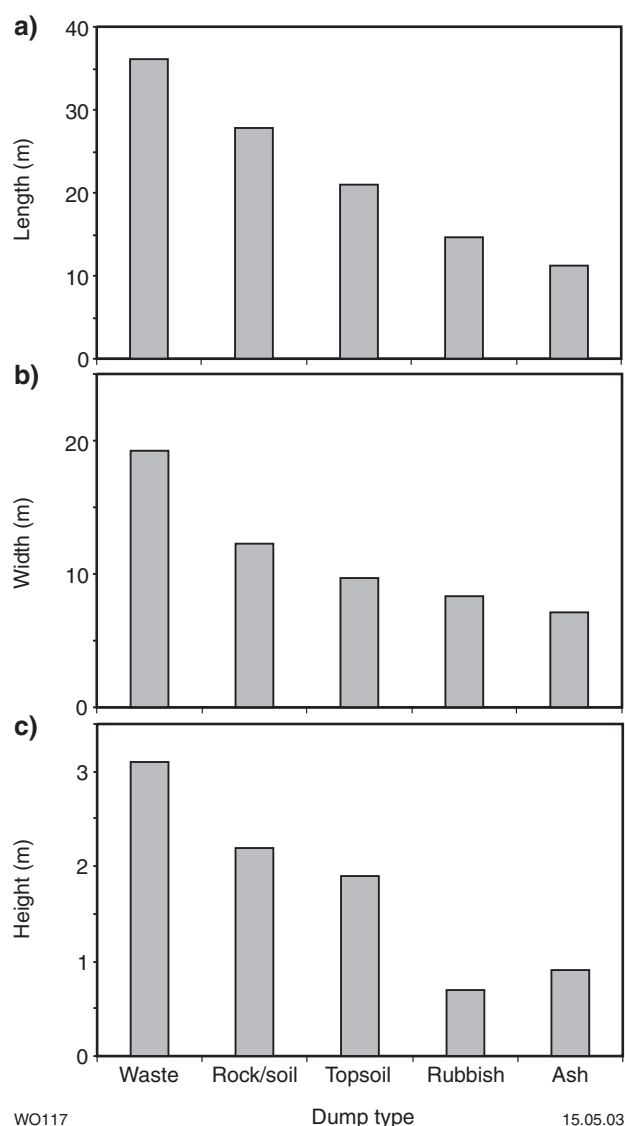
Figure 52. Various types of dumps and their dimensions (length  $\times$  width  $\times$  height) :

- a) waste dump, 60  $\times$  40  $\times$  3 m (3 km northeast of Kundip; Zone 51, MGA 240464E 6270638N);
- b) rubbish dump, 8  $\times$  5  $\times$  1 m (2 km northeast of Kundip; Zone 51, MGA 240665E 6269221N);
- c) topsoil dump, 40  $\times$  20  $\times$  3 m (9 km north of Mount Magnet; Zone 50, MGA 581586E 6904059N);
- d) rock and soil dump, 60  $\times$  30  $\times$  3 m (12 km northwest of Cue; Zone 50, MGA 578554 6972059);
- e) ash dump, 20  $\times$  3  $\times$  1 m (80 km south of Laverton; Zone 51, MGA 444552E 6753379N)



and rubbish dumps do not include material extracted from the ground during mining or exploration (Fig. 52b). Topsoil dumps are composed primarily of soil and are normally set aside from the waste rock for rehabilitation purposes (Fig. 52c). Rock and soil dumps consist of a mixture of waste rock and soil (Fig. 52d), and ash dumps were usually produced during steam production and therefore indicate the former position of a boiler (Fig. 52e).

Although all dump types vary significantly in size, some generalizations can be made for the waste, rock and soil, topsoil, rubbish, and ash dump types. Overall, waste dumps are the largest (Fig. 53), followed by rock and soil dumps, topsoil dumps, rubbish dumps, and ash dumps. Mean lengths, widths, and heights are 36, 19, and 3 m respectively for waste dumps, and 11, 7, and 0.9 m respectively for ash dumps (Table 31). The mean height for rubbish dumps is significantly reduced by the small percentage (<2%) that occupy depressions in the ground.



**Figure 53. Frequency distribution of features for dump types:**  
a) length; b) width; c) height

**Table 31. Summary data for dump types**

	Waste dump			Rock and soil dump			Topsoil dump			Rubbish dump			Ash dump		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Length (m)	36	3	650	27.7	1	520	20.9	3	200	14.7	1	200	11.2	3	30
Width (m)	19.3	1	580	12.3	1	400	9.7	2	100	8.3	0.5	150	7.1	2	20
Height (m)	3.1	0.3	50	2.2	0.1	20	1.9	0.6	4	0.7	0.01	4	0.9	0.1	2
Edge dip (°)	39	10	90	47	10	80	36	30	60	55	45	75	30	15	45

Height appears to influence visibility, with the largest features (waste, rock and soil, and topsoil dumps) all having a very high visibility (between 94% and 97%). The smaller, and lower, rubbish and ash dumps have much lower visibilities of 80% and 68% respectively.

Average edge or side dip angles have been recorded for about half of these features and are shown in Table 31. These five dump types generally have low to moderate mean wall dip angles of between 30° and 55°.

The main dump material varies according to the dump type and mainly reflects the size of the dominant components (Table 32). Scrap metal is a common but minor component of topsoil, and rock and soil dumps, and is less common in waste dumps. Smaller amounts of general rubbish are in all of these dump types. The main component of rubbish dumps is scrap metal, followed by old bottles and cans, and general rubbish.

Waste, topsoil, rock and soil, and rubbish dumps are most commonly rectangular in shape, although oval and other (irregular) shapes are also well represented, especially for rock and soil dumps. Conical shapes are also fairly common for waste dumps, and rock and soil dumps.

Between 57% and 68% of waste, rock and soil, topsoil, and ash dumps are partially revegetated, and between 12% and 15% are fully revegetated. The dumps labelled as with no revegetation show the largest variation, ranging from 5% for ash dumps to 25% for waste dumps. After the exclusion of the high number of null records for rubbish dumps, the figures fall into the same ranges as above (partially 62%, fully 14%, and none 25%).

A minority of waste dumps have access ramps, most of which are in good condition. Fences are rare for all dump types, although some may have been included in a much larger boundary fence that encircled the entire abandoned mining site.

## Tailings dumps

The tailings dump type consists of the gangue and other refuse material resulting from the washing, concentration, or treatment of ground ore (American Geological Institute, 1997). Tailings are normally transported as slurry, and contained in a dam (Fig. 54). Tailings are the largest of all dump types, with a mean length of 95 m (Table 33), although many are towards the lower end of their size range at less than 40 m (Fig. 55a). Their large size is also reflected in their mean width of 58 m, but their most common width is less than 30 m (Fig. 55b). The mean height of 2.2 m for tailings dumps is not particularly large compared with other dump types, and the most common height range is between 1.6 and 4 m (Fig. 55c). Tailings dumps have a highly variable wall dip ranging from 3° to 90°, probably reflecting the various processes of no containment, dam containment, subsequent excavation, and dispersion. Some tailings dumps have near-vertical walls due to later partial removal for reprocessing purposes. Dispersion was recorded for about 20% of tailings dumps, with a mean dispersion distance of 106 m, and a maximum of 2000 m. Due to their size and

**Table 32. Number of attributes for dumps**

Dump type	Waste	Rock and soil	Topsoil	Rubbish	Ash
<b>Dump material</b>					
Oversize	3	2	–	–	–
Rock	611	187	1	5	–
Gravel	211	114	16	1	–
Sand	22	4	14	5	2
Tailings	4	1	–	3	–
Other	14	6	18	75	1
Null	8	9	11	280	19
<b>Visibility</b>					
Visible	825	302	58	296	15
Partially hidden	43	20	1	68	7
Null	5	1	1	5	–
<b>Fences</b>					
None	864	311	–	368	21
Open	7	9	–	1	1
Fenced	2	–	–	–	–
Locked gate	–	3	–	–	–
<b>Revegetation</b>					
None	157	82	8	38	1
Partial	585	184	41	95	15
Full	110	40	9	21	3
Null	21	17	2	215	3
<b>Ramp condition</b>					
None	854	–	–	–	–
Good	11	–	–	–	–
Limited access	6	–	–	–	–
Poor	2	–	–	–	–
<b>Other dump waste</b>					
Scrap metal	26	43	10	144	–
Old bottles/cans	–	–	–	99	–
General rubbish	11	11	2	60	2
Plastic lining	3	1	–	12	–
Cars	–	–	–	12	–
Null	833	268	48	54	20
<b>Shape</b>					
Rectangular	375	91	33	74	4
Oval	128	69	8	23	8
Cone	195	34	5	4	–
Slab	14	11	–	–	1
Other	124	88	3	50	2
Null	37	30	11	218	7



W073

10.04.03

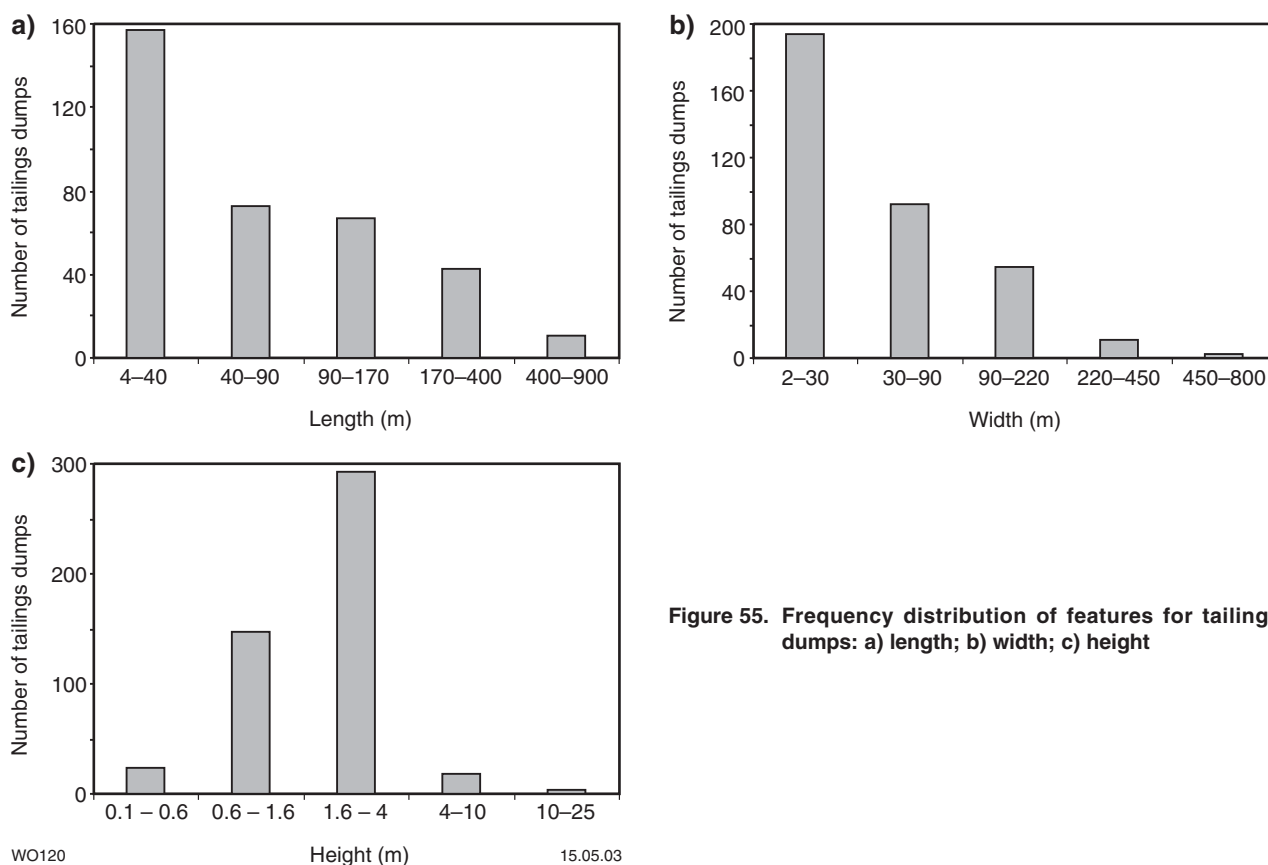
**Figure 54. Typical tailings dump, 160 m long, 75 m wide, and 3 m high (6 km southeast of Boulder; Zone 51, MGA 360054E 6589865N)**

dispersion characteristics, tailings dumps are highly visible (90%, Table 34). Although tailings dumps most often contain no other significant material than tailings, plastic lining was recorded for 32% of tailings features, with minor amounts of scrap metal and general rubbish (Table 34).

Half of all tailings dumps are rectangular, with most of the remainder being irregular (21%) and slab shaped (18%). Nearly half of all tailings dumps are partially revegetated, a third are fully revegetated, and the remainder show no revegetation (Table 34). Only 4% of tailings dumps have any type of fencing.

**Table 33. Summary data for 534 tailings dumps**

	<i>Length (m)</i>	<i>Width (m)</i>	<i>Height (m)</i>	<i>Wall dip (°)</i>	<i>Dispersion distance (m)</i>
Mean	95	58	2.2	44	106
Minimum	4	2	0.1	3	1
Maximum	900	800	25	90	2 000



**Figure 55. Frequency distribution of features for tailings dumps: a) length; b) width; c) height**

**Table 34. Number of attributes for 534 tailings dumps**

<i>Visibility</i>		<i>Fences</i>		<i>Revegetation</i>		<i>Other dump waste</i>		<i>Shape</i>	
Visible	481	None	513	Partial	263	Plastic lining	173	Rectangular	268
Partially hidden	51	Open	15	Full	178	Scrap metal	39	Other	110
Null	2	Locked gate	4	None	88	General rubbish	9	Slab	97
		Fenced	2	Null	5	Null	313	Oval	21
								Cone	4
								Null	34

## Leach pads

A leach pad is composed of mineralized materials stacked to permit wanted minerals to be effectively and selectively dissolved by application of a suitable solute (American Geological Institute, 1997). Abandoned leach pads are not common, with only 36 records in WABMINES (Fig. 56). They have mean dimensions of 73 m length, 45 m width, and 2 m height (Table 35). Wall-dip angles vary less than for tailings dams, ranging from 30° to 80°. Dispersion was recorded for seven leach pads for a distance of up to 800 m. Almost all leach pads (97%) were visible from a moderate distance (Table 36).

Most leach pads contain visible plastic lining (83%), and occasionally scrap metal or general rubbish is present. The majority of leach pads are rectangular (83%) and partially revegetated (75%). Only one pad was fenced.



WO74

10.04.03

**Figure 56.** Typical leach pad, 75 m long, 40 m wide, and 2 m high; note the plastic lining (1.5 km south of Sandstone; Zone 50, 725744E 6900721N)

## Ramps/tramways

Ramps/tramways include a diverse range of features from more-recent vehicle-loading ramps to tramway bases adjacent to abandoned shafts, batteries, or dumps. They are included in the dump feature group because they are commonly made of waste rock, but they can be identified by their shape, associated features such as railway irons or wooden pylons, and mode of occurrence (Fig. 57). The WABMINES database has 102 records for ramps/tramways. Their dimensions are highly variable (Table 37). They range in length from 5 to 1000 m, but are most commonly less than 25 m long (Fig. 58a). Most are less than 12 m wide, although the largest are up to 50 m wide (Fig. 58b). Their heights range from 0.1 to 8 m, but are commonly between 1.3 and 2.5 m (Fig. 58c). Ramp/tramway sides have dips of between 20° and 90°, and visibility is moderate at 77.5%.



WO75

10.04.03

**Figure 57.** Ramp/tramway, 30 m long, 15 m wide, and 4 m high (35 km south-southwest of Meekatharra; Zone 50, MGA 633774E 7025299N)

**Table 35.** Summary data for 36 leach pads

	<i>Length (m)</i>	<i>Width (m)</i>	<i>Height (m)</i>	<i>Depth (m)</i>	<i>Wall dip (°)</i>	<i>Dispersion distance (m)</i>
Mean	73	45	2	1–2	51	576
Minimum	12	8	1	1	30	5
Maximum	200	160	5	5	80	800

**Table 36.** Number of attributes for 36 leach pads

<i>Visibility</i>		<i>Fences</i>		<i>Revegetation</i>		<i>Other dump waste</i>		<i>Shape</i>	
Visible	35	None	35	Partial	27	Plastic lining	30	Rectangular	30
Partially hidden	1	Locked gate	1	None	7	Scrap metal	2	Slab	6
				Full	2	General rubbish	1		
						Null	3		



**Table 37. Summary data for 102 ramps/tramways**

	Length (m)	Width (m)	Height (m)	Wall dip (°)
Mean	83	7	2.2	51
Minimum	5	0.5	0.1	20
Maximum	1 000	50	8	90

The main dump material is rock, and less commonly they are composed of gravel (Table 38). Scrap metal is present in 16% of ramps/tramways. A typical ramp/tramway is rectangular (60%), and is partially (66%) or fully revegetated (30%). Only 4% of ramps/tramways are fenced.

### Safety aspects of dumps

The main attributes of dumps that could influence safety are their height, wall dip, and composition. Edge collapse is a possibility for high dumps with a steep wall or edge dip. This is likely to happen where material has been later extracted, resulting in a steep and potentially unstable dump face, as has been observed locally for waste and tailings dumps. Erosion of fine-grained material such as soil may also lead to dump instability, or may form deep, steep-sided crevasses, which is common in tailings dumps.

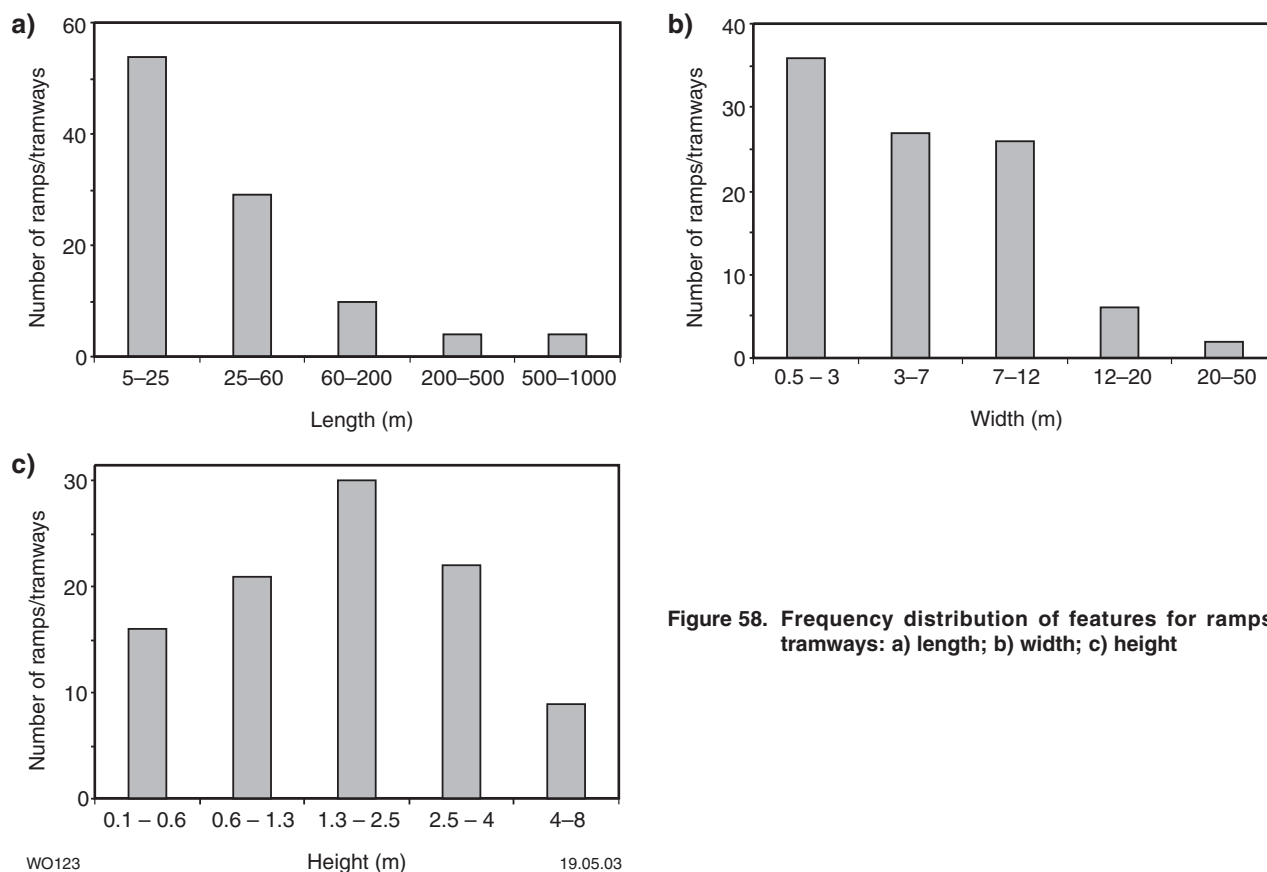
The combination of steep sides, height, and particularly loose material can also increase the risk of accidental falls.

Most rubbish dumps are potentially hazardous due to the possibility of injury on sharp edges of scrap metal, broken glass, splintered timber, nails, and other discarded items. They may also contain remnants of toxic chemicals or other potentially harmful materials such as asbestos. Consequently, rubbish can also potentially increase the risk of harm if it forms a component of other dump types. For example, scrap metal is most commonly found in rubbish dumps (39% of records), but also commonly found in ramps/tramways (16% of records), topsoil dumps (16% of records), and rock and soil dumps (13% of records).

Few dumps are fenced (45 or <2%), and only seven fences are of the most secure locked-gate type. Accidental entry is unlikely for most dumps because visibility is comparatively high overall (90%), although rubbish dumps, ash dumps, and ramps/tramways are all significantly less visible from a moderate distance.

### Environmental aspects of dumps

The main impact of mine dumps on the environment is through the area of land they cover, and their potentially high visual profile. The dump feature group has the highest overall occurrence (14%) of a moderate or high visual impact rating. About 2% of both waste and tailings dumps were assigned a field visual impact rating of high.



**Figure 58. Frequency distribution of features for ramps/tramways: a) length; b) width; c) height**

**Table 38. Number of attributes for 102 ramps/tramways**

Visibility		Fences		Revegetation		Dump material		Other dump waste		Shape	
Visible	79	None	98	Partial	57	Rock	75	Scrap metal	16	Rectangular	61
Partially hidden	23	Open	3	Full	31	Gravel	20	Null	86	Other	34
		Locked gate	1	None	9	Other	2			Null	7
				Null	5	Tailings	2				
						Null	3				

Moderate visual impact ratings were also applied to rubbish dumps, rock and soil dumps, ramps/tramways, and leach pads. The impact of some tailings dumps and leach pads has been increased by dispersion.

Regrowth of vegetation can be a slow process, and the ground may appear disturbed for many years after mining ceased. Overall, 62% of dump features are partially revegetated, 19% are fully revegetated, and 19% are not revegetated at all. The incidence of no revegetation ranges from 5% for ash dumps to 27% for rock and soil dumps, and 25% for rubbish dumps.

Dumps that contain sulfide-rich waste rock, in particular tailings dumps, and some waste dumps may cause acid mine drainage. Relatively insoluble sulfide when exposed to air and water is converted to soluble sulfuric acid and iron compounds by oxidation. The sulfuric acid dissolves metals such as aluminium, copper, and zinc. Traces of these elements are naturally present in water, however, hydrologic and weathering processes can substantially increase their concentrations (Mining Minerals and Sustainable Development, 2002). Sulfides in waste rock are, nevertheless, rare.

Contamination of the surrounding environment is also possible for rubbish dumps that may contain toxic waste materials, and for tailings dams, which may contain anomalous levels of metals and other elements.

### **Preservation aspects of dumps**

Some of the dumps in the database are fully revegetated, suggesting that they may be old. The significance of many of these dumps is most likely related to their historical or spatial context (or both) in association with other features. In particular, tramways used to transport ore from mine workings to processing mills may have heritage value when considered in context with other local features of a mining process. Two ramp/tramway features have been given a field assessment of fair condition.

### **Geology and mineralization aspects of dumps**

Dump types that contain a high proportion of rock, such as waste dumps, rock and soil dumps, and ramps/tramways can provide information on host-rock type and degree of weathering, and an indication of mineralization style. This is most useful if the source of the material is clear.

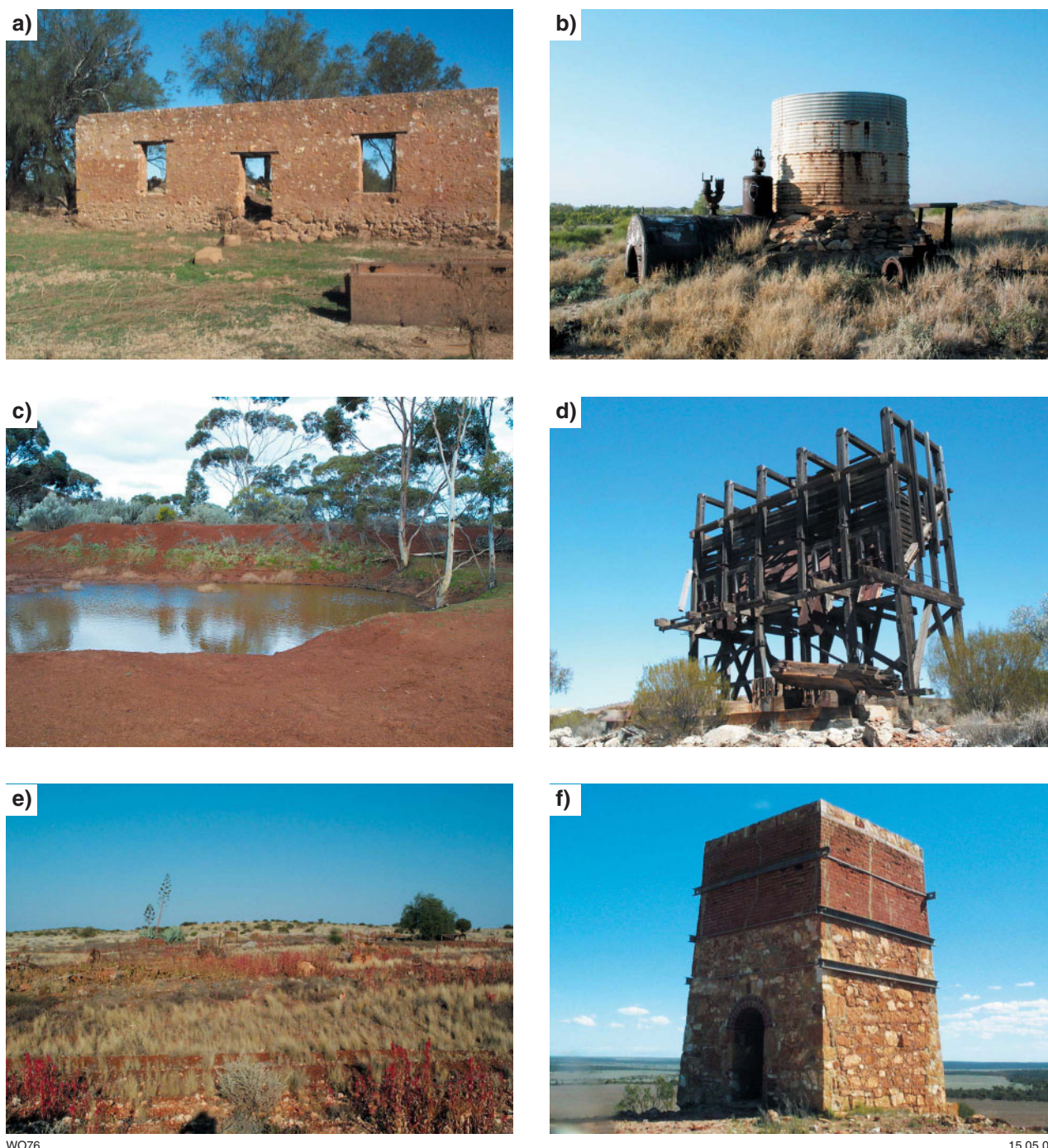
## **Infrastructure**

Infrastructure features comprise 2.5% of the WABMINES database, and include battery/mill, building, chimney, headframe/winder, machinery, town remnant, shaft footing, dam/sump, and other categories (Fig. 59). The largest infrastructure category is building, which comprises 49% of infrastructures (Fig. 60a). Machinery and dam/sump contain moderate numbers of features, comprising 19% and 15% of infrastructure features, respectively. All other categories each comprise about 5% or less of the infrastructure features. They are discussed below in order of decreasing abundance. The main morphological attributes for this feature group are dimensions. Mean dimensions for all infrastructure types are shown in Figure 60b,c,d and listed in Table 39, and the number of attributes are listed in Table 40.

### **Infrastructure types**

Buildings comprise the single largest infrastructure group category, with 1088 records. Seventy percent of buildings have only footings remaining, normally consisting of a concrete slab or foundation. Some of the older footings are only a level earth pad with border stones outlining the area where a timber and canvas shelter may have once stood. Many of the remaining buildings are in some state of disrepair, and show a large variation in construction, from timber and galvanized iron through to stone or brick (Fig. 59a). Some buildings were dwellings, others were directly associated with mine offices, workshops, stores, and so on, and for some, the original purpose is unclear. Buildings have a wide range of dimensions, but average 11 m in length, 6.5 m in width, and 1.3 m in height (Table 39). These figures are partly distorted by a number of large areas containing multiple buildings. Most buildings (>90%) are less than 25 m long, 12 m wide, and 3 m high. A minority of buildings (18) also had a depth of up to 2 m (Table 40). Because buildings have predominantly low footings, they have the lowest overall visibility of all infrastructure types (70%).

Machinery accounts for 429 of the infrastructure records. As for buildings, the majority of machinery has only footings remaining (69%), as most machinery has been removed offsite. The most common type of footing is a concrete block, normally with remnants of attachment bolts. Machinery left in place includes mostly items such as incomplete boilers, engines, disused mining vehicles, and miscellaneous parts (Fig. 59b). The machinery have



WO76

15.05.03

**Figure 59. Various types of infrastructure and their dimensions (length × width × height):**

- a) remnants of a stone building, 8 × 8 × 3 m (56 km north of Northampton; Zone 50, MGA 267268E 6917667N);
- b) remains of machinery, 5 × 3 × 3 m (27 km east of Nullagine; Zone 51, MGA 227527E 7580761N);
- c) typical dam/sump – water dam, 30 × 25 × 1–2 m (2.5 km east-northeast of Coolgardie; Zone 51, MGA 327195E 6575380N);
- d) battery/mill – battery feeder, 10 × 7 × 12 m (2 km northeast of Coolgardie; Zone 51, MGA 326270E 6575265N);
- e) typical town remnant, the Kathleen townsite. Few features remain in the 100 m long by 50 m wide area (47 km north of Leinster; Zone 51, MGA 259537E 6954644N);
- f) stone chimney, 3 × 3 × 5 m (52 km north of Northampton; Zone 50, MGA 266968E 6913410N)



**Table 39. Summary data for infrastructure types**

	<i>Building</i>	<i>Machinery</i>	<i>Dam/ sump</i>	<i>Other</i>	<i>Battery/ mill</i>	<i>Town remnant</i>	<i>Headframe/ winder</i>	<i>Shaft footing</i>	<i>Chimney</i>
Mean length (m)	11.2	11.8	30.8	19.6	29.7	112.8	10.1	3.5	4.2
Minimum length (m)	0.5	0.5	1	0.5	1	1.2	1	0.5	1
Maximum length (m)	750	200	700	400	750	1 200	50	13	10
Mean width (m)	6.5	5.2	17	3.4	14.2	66	4.7	2.4	1.9
Minimum width (m)	0.3	0.2	1	0.4	1	0.5	0.5	0.5	1
Maximum width (m)	250	50	200	30	300	600	20	8	3
Mean height (m)	1.3	1.8	1.4	1	3.7	1.3	4.8	1.5	2.6
Minimum height (m)	0.01	0.1	0.1	0.01	0.1	0.2	0.2	0.1	0.3
Maximum height (m)	25	10	6	3	45	4	30	20	8

**Table 40. Number of attributes for infrastructure types**

	<i>Building</i>	<i>Machinery</i>	<i>Dam/ sump</i>	<i>Battery/ mill</i>	<i>Town remnant</i>	<i>Headframe/ winder</i>	<i>Shaft footing</i>	<i>Chimney</i>	<i>Other</i>
<b>Visibility</b>									
Visible	757	363	281	97	50	49	33	9	94
Partially hidden	218	65	52	13	7	1	4	–	16
Hidden	2	2	–	–	–	–	–	–	1
Null	111	–	1	–	1	–	–	–	2
<b>Depth (m)</b>									
0 – 0.5	1	2	24	3	–	4	–	–	–
0.5 – 1	12	19	106	9	–	–	–	–	7
1–2	5	9	91	6	–	–	–	–	–
2–5	–	2	25	3	–	–	–	–	–
5–10	–	–	3	1	–	–	–	–	–
Null	1 070	398	85	88	–	–	–	–	102
<b>Fences</b>									
Fenced	12	7	6	4	3	5	–	–	2
Locked gate	4	7	–	5	1	2	–	–	–
Open	16	9	2	1	–	4	–	–	1
Null	1 056	407	326	100	54	39	–	–	110

average dimensions of 12 m length, 5 m width, and 1.8 m height (Table 39). As for buildings, these figures are partly distorted by a number of large areas containing multiple machinery and associated infrastructure rather than individual machines. Most machinery (>90%) are less than 25 m long, 13 m wide, and 4 m high. A significant number of machinery footings (32) also have depths of between 2 and 5 m (Table 40), representing wells or cavities that allowed for large objects such as flywheels. Machinery has a comparatively high visibility of 84%.

Dam/sump is the last major category of infrastructure type, with 334 records. It includes a variety of infrastructure-related features ranging from water dams (Fig. 59c) to drilling sumps, settling ponds, and other fluid-storage functions including water tanks. In contrast to most other infrastructure types, dams/sumps are normally in-ground features with only about 10% recorded as ‘footings only’. Dams/sumps have average

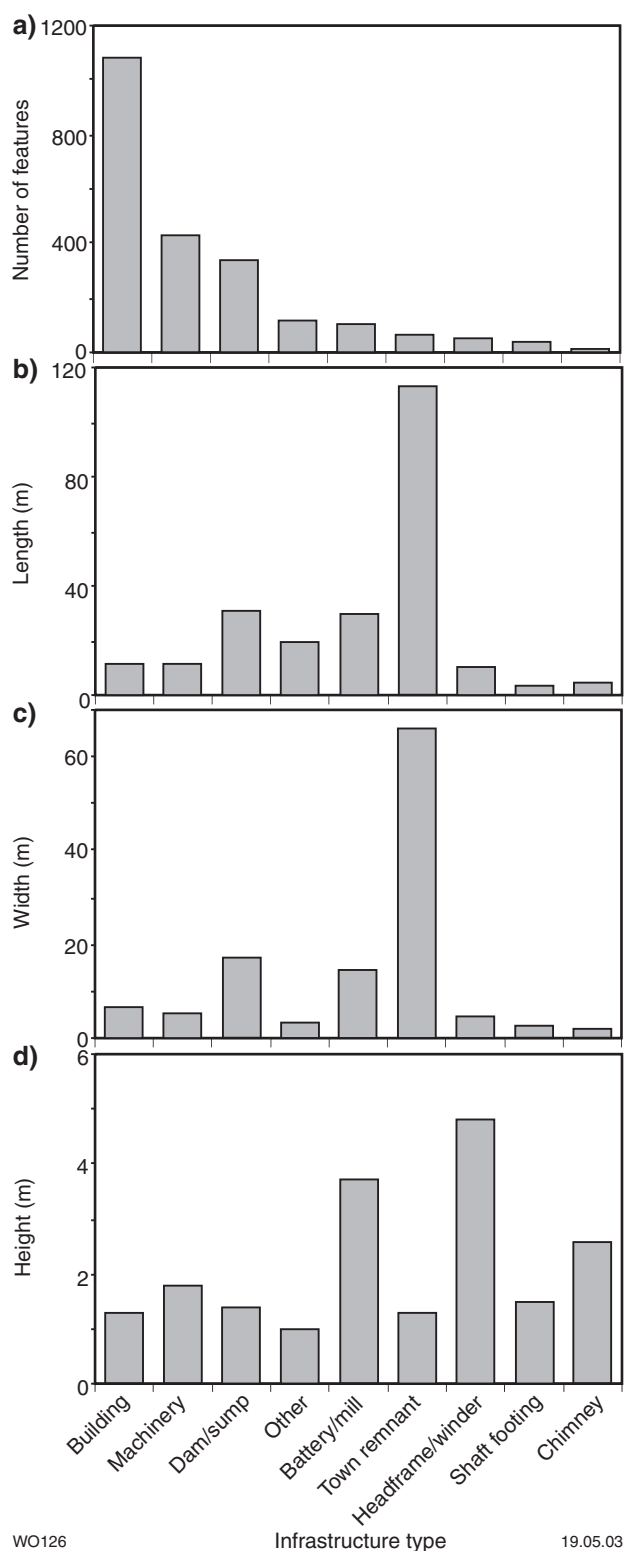
dimensions of 31 m length, 17 m width, and 1.4 m height (Table 39), and depths of mostly less than 2 m (Table 40). Dams/sumps have the same degree of visibility as machinery (84%).

The battery/mill infrastructure type includes the batteries, crushers, and mills used for the treatment of ore and the buildings they are housed in, and can also include their associated equipment such as feeders and the powerhouse (Fig. 59d). There are 110 records for batteries/mills in the database, nearly half (46%) of which are ‘footings only’.

Mean dimensions are 30 m length, 14 m width, and 3.7 m height. A significant number of batteries/mills (22) also have depths of less than 2 m (Table 40).

There are 59 records of town remnants in the database. Town remnants are the remains of a town site that either do not specifically fit into any other infrastructure types





**Figure 60. Frequency distribution of infrastructure features:**  
a) infrastructure types; b) mean lengths; c) mean widths; d) mean heights



WO81

10.04.03

**Figure 61. Nine-posted headframe and stand, 3 m long, 3 m wide, and 8 m high (3 km southeast of Boulder; Zone 51, MGA 357738E 6591584N)**

or are too numerous to warrant individual description (Fig. 59e). Consequently, they can be either individual features or large areas of multiple features. They have the largest mean dimensions of all infrastructure types, with mean length, width and height of 113, 66, and 1.3 m respectively (Table 39). About 36% of town remnants are 'footings only'.

Only nine chimneys are recorded in the WABMINES database (Fig. 59f), as they are normally associated with a building or building footing. The 'other' infrastructure type may include any type of infrastructure that is not listed, or for which the purpose is unclear. Examples include gravesites, mine camps, forges, and explosives magazines, and the largest features include railway lines.

The headframe/winder infrastructure type has 50 records, and refers specifically to shaft headframes and their associated winding equipment used for shaft haulage (Fig. 61). Forty-four percent are 'footings only', normally concrete winder or headframe mountings. Mean dimensions are 10 m length, 5 m width, and 5 m height.

Shaft footings are closely related to headframe/winder footings. Shaft footings are close to shafts and normally made of concrete, but are not necessarily headframe or winder footings. Thirty-seven shaft footings are listed in the database.

Battery/mill, town remnant, headframe/winder, shaft footings, chimney and 'other' infrastructure types all have comparatively high visibilities, ranging from 86% for town remnant up to 100% for chimney (Table 40).

Fences are uncommon for all types of infrastructure, varying between 3% and 9% for all feature types with the notable exception of headframe/winder 22% of which are fenced, most likely because of their close proximity to a shaft. The more secure locked-gate fence is most common around battery/mill and headframe/winder types.

### ***Safety aspects of infrastructure***

The main overriding safety consideration for buildings, town remnants, batteries/mills, headframes/winders, and chimneys is the structural integrity of the feature. In general, the older and less maintained the feature is, the greater the potential hazard. The height of a feature can also influence safety. For example, a building in very poor condition, but collapsed, is potentially less hazardous than one that is partially standing, unstable, and 2 m high. Features that are classed as 'footings only' may present an even lower hazard, although rubbish such as scrap iron, timber, and nails can still present significant potential for injury.

Some buildings and footings have a depth, such as cellars, or sumps for machinery flywheels. The sides to these cavities may be vertical and the depth significant, resulting in hazards similar to those for shallow opencuts or deeper shallow workings.

Similar depth-related hazards may be associated with the dam/sump features, with the added increased possibility of water in the base, although many dam/sump features did not have water recorded in the base. Nevertheless, base condition was only recorded routinely after the introduction of the Symbol PC in 2002. Furthermore, most of the data collection occurred during a period of below-average rainfall. The potential for water-related hazards must be taken into account when assessing dam/sump features.

Machinery can present hazards related to moving parts and structural integrity. Scrap metal is also commonly found close to abandoned machinery, increasing the likelihood of injury on sharp edges.

Most infrastructure is not fenced, enabling relatively easy access.

### ***Environmental aspects of infrastructure***

Although infrastructure features do not cause many of the environmental problems commonly associated with mining, the ground that they occupy is not returned to its original state and therefore some features may be considered an environmental problem. The size and untidiness of some infrastructure sites increases their visual impact. A total of 235, or nearly 11%, of all infrastructure sites were given a field visual impact rating of moderate or high.

### ***Preservation aspects of infrastructure***

Well-preserved machinery and batteries/mills could provide an insight to historical mineral-processing techniques. Buildings, dams, headframes/winders, shaft footings, chimneys, and other infrastructure features may

also be of significance in the context of locally related features. A total of 161 features have been given a field assessment of fair or good condition. The majority of these features are machinery (55), followed by buildings (51), and batteries/mills (30). Other features that have been given a fair or good condition field assessment are headframe/winder (13), town remnant (6), chimney (3), dam/sump (2), and other (1).

## **Under infrastructure**

The under infrastructure category refers to historic underground, opencut or infrastructure features that are now either beneath, or have been removed in the development of, more-recent features. Many of these features have been located from aerial photographs, and historical and company maps. There are 2054 features classed as under infrastructure, comprising 2.3% of the WABMINES database. The 1902 Geological Map of Kalgoorlie (Maitland and Campbell, 1902) is the source for 2.8% of these features. The Hallberg (2000) 1:25 000-scale compilation aerial photographs were used to identify 4.1% of these features, and company data from Normandy Mining for the Wiluna area were used to locate positions of 14.1% of the features. MINEDEX points comprise 13.1% and the remaining features (65.9%) have been digitized from controlled or rectified aerial photographs and GSWA Bulletin maps.

Because the features no longer exist on the ground, there are no safety, environmental, or heritage issues relating to them. These features are most useful in their spatial context to help map mineralization trends (see **Mineralization and geological mapping**).

## **Data applications**

The inventory of abandoned mine sites can be used to assess hazard, environmental, heritage, and geological issues. This section is intended to illustrate the main potential applications of the data and a number of pertinent observations, rather than to provide a comprehensive analysis of the data.

### **Feature hazard assessment**

A hazard assessment could be carried out in a number of ways. Adamides (2000) proposed a method of assigning risk ratings to underground, opencut, and shallow workings in the abandoned mine site inventory in the Cue region. This method involved allocating a subjective rating factor to the attributes of depth, edge condition, seal safety, fence condition, and presence and height of a bund. For example, a full protective bund around a shaft was given a factor of 1, partial bund 1.5, and no bund was allocated a factor of 2. The factors were combined in a formula to give a risk rating number. The ratings were then summed for each 50 × 50 m grid square for the entire CUE 1:250 000 sheet area. The resultant values were then colour coded to identify high-risk areas. The results of this approach were highly dependent upon the values of the

risk factors and how they were combined in the formula. No risk factors were applied to dump, infrastructure or rehabilitated features, assuming that only questionable or relatively minimal risks were associated with these.

An alternative approach is to define two or three key safety criteria for each feature group (or type if appropriate), with ranges of values for each. The key safety criteria were chosen to:

- represent the major parameters that influence the perception of safety of a feature in the field;
- be applicable across all of the WABMINES data irrespective of collection date;
- indicate a practical way to reduce the hazard of a feature;
- represent the minimum number of parameters necessary for 'first pass' screening.

An example of this approach is shown in Table 41. The database is then queried to find all records that match each possible combination (or permutation) of the key safety criteria. Each permutation is documented with statistics and photographs into summary sheets in a similar manner

to the morphology section of this report. The permutations can then be grouped and ranked into hazard subcategories according to perceived risk such as Underground 1 for the highest risk group in the 'underground' hazard category. Any number of permutations could be attributed to the same hazard subcategory if deemed to be of equivalent risk. If an important subcategory such as Underground 1 is too broad, it could be further subdivided (e.g. Underground 1a or 1b) using a similar approach with other lower-order safety criteria such as visibility, seal type, and edge condition. This process is repeated for all of the main hazard category types, of underground, opencut, shallow working, dump, infrastructure, and rehabilitated. Note that the hazard category types do not necessarily need to be the same as the feature group types. A hierarchy of hazard subcategories such as the one shown in Table 42 could then be constructed to reflect the relative risks of all the features in WABMINES. Maps can then be made showing the distribution of features within each subcategory. For example, Figure 62 shows the locations of features that match the requirements of two possible hazard subcategories, Underground 1 and Underground 2 in the Cue region.

**Table 41. Proposed key safety criteria for the main feature categories**

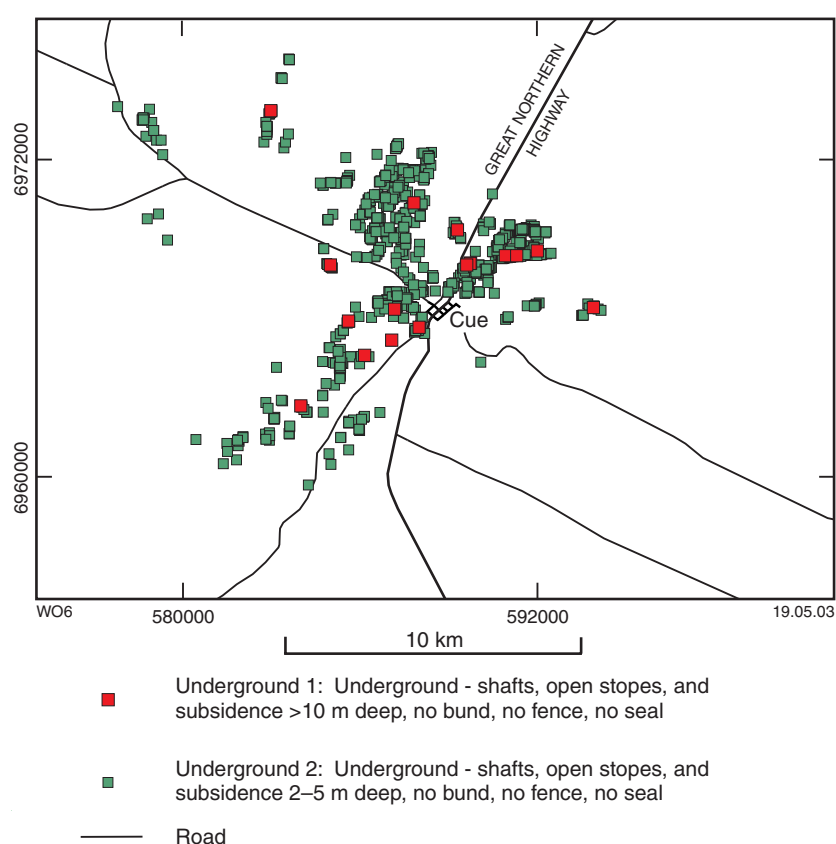
<i>Feature group</i> <i>Feature types</i>	<i>Key safety criteria</i>
<b>Collapsed shaft/Underground</b>	
Collapsed shaft, shaft, open stope, and subsidence	Depth: 0–2 m; 2–10 m; >10 m Bund: Full; partial; none Fences: Locked gate or good seal; fence; none
Adit, portal	Fences/bund/seal: Good seal or locked gate; bund or fence; no fence, seal or bund
Collapsed drillhole	None
<b>Opencut</b>	
Pit/quarry	Depth: <10 m; >10 m Fences/bund: Fully fenced or full bund; open (partial) fence or partial bund; no bund or fence
<b>Shallow working</b>	
Costean/trench	Depth: 0–2 m; 2–5 m; >5m Condition: Safe; partially safe; unsafe
<b>Dump</b>	
Waste, rock and soil, topsoil, ramp/tramway, ash	Mine note: Mention of steep face; no mention of steep face Dip: <60° or null; >60° Dump other: Cars, general rubbish, scrap metal, or old bottles/cans; null
Tailings dump, leach pad	Mine note: Mention of deep crevasses or erosion; no mention of deep crevasses or erosion Dip: <60° or null; >60°
Rubbish dump	None
<b>Infrastructure</b>	
Building, headframe/winder, machinery, battery/mill, shaft footing, chimney, town remnant, and other	Heritage value: Footings only; good, fair or poor Depth: <2 m or null; >2 m Mine note: Mention of potentially hazardous factors; no mention of potentially hazardous factors
Dam/sump	Dip: <35° or null; >35° Base condition: Water or rubbish; null, empty, oversize, rock or tailings
<b>Rehabilitated</b>	
Rehabilitated	Depth: <0.5 m or null; >0.5 m Mine note: Mention of continued subsidence; no mention of continued subsidence

**Table 42. Hierarchy of hazard subcategories showing different relative risk levels between the main hazard categories**

	<i>Underground</i>	<i>Opencut</i>	<i>Shallow working</i>	<i>Dump</i>	<i>Infrastructure</i>	<i>Rehabilitated</i>
Highest risk	Underground 1a	—	—	—	—	—
	Underground 1b	—	—	—	—	—
	Underground 2	Opencut 1a	—	—	—	—
	Underground 3	Opencut 1b	—	—	—	—
	Underground 4	Opencut 2	Shallow working 1	—	—	—
	Underground 5	Opencut 3	Shallow working 2	—	—	—
	Underground 6	Opencut 4	Shallow working 3	Dump 1	—	—
	Underground 7	—	Shallow working 4	Dump 2	Infrastructure 1	Rehabilitated 1
Lowest risk	Underground 8	—	Shallow working 5	Dump 3	Infrastructure 2	Rehabilitated 2

**NOTES:**

- (a) The above example is for illustrative purposes only, and is not the result of the proposed analysis
- (b) Each hazard subcategory (e.g. Underground 2) is defined by a combination of the key safety criteria in Table 41
- (c) Lower order safety criteria may define further subdivisions such as Opencut 1a

**Figure 62. Example of possible hazard subcategories Underground 1 and Underground 2 in the Cue region**

The above approach has the advantage that all features are included in the ranking, but they are not all compared on the same basis. The approach recognizes different levels of risk between each hazard category. The use of summary sheets enables an informed assessment of the relative ranking of combinations of key safety criteria based on all data in the database.

## Additional hazard considerations

### Proximity to access

The hazard assessment methodologies discussed above rank each feature or group of features on their own characteristics or inherent risk, irrespective of their



proximity to access. Most features in the database were, nevertheless, recorded because of their proximity to main roads and populated towns following the historic mine site prioritization process.

A further refinement could be made to the hazard assessment by assigning higher risk to features that are easily accessible to the public. The difficulty lies in defining accessibility, applying it with GIS data, and in making an appropriate modification to the risk rating.

Areas closest to populated towns can be accessed by walking, and those further away by bicycle, horse, or motorbike. In principle, accessibility could be modelled as a function of distance from a population centre, reflecting decreasing accessibility with increased distance. A similar function could be defined for proximity to roads, parking bays, and tourist stops. Alternatively, set buffer distances could be assigned around towns and roads, with an accessibility rating for each buffer distance. In practice, natural or man-made features such as vegetation, fences, and walking tracks will markedly influence accessibility. These features are not normally recorded on digital datasets in sufficient detail to make an accurate prediction of accessibility.

Another problem with defining accessibility lies in the inaccuracy of DOLA's current GIS roads dataset. Some of the roads are inaccurately mapped, and modifications have been made since the dataset was released in 1994. These modifications are not only to the realignment of some roads, but also include new roads, road closures, and the upgrading or downgrading of the road classification. Although adequate in most cases for defining Priority 1 historic mine sites, the current road dataset is not so useful in defining detailed buffers or accessibility functions over distances of less than 1 km. Furthermore, any track, including station tracks and exploration access tracks, can increase accessibility to the general public, especially four-wheel drive vehicles. Many of these tracks are not included in the roads dataset.

Finally, it is not clear how the risk rating should be modified even if accessibility could be well defined. Increased accessibility results in a higher probability of visitation by the public, but this is also influenced by other factors, such as the demographics of a town and the composition and frequency of traffic on a road. Consequently, it is recommended that accessibility be used as a tool to help prioritize remedial action after the hazard assessment has been completed, rather than as an integral part of the hazard assessment.

## Progressive shaft collapse

Shaft collar collapse is common in abandoned mines. The purpose of a shaft collar is to retain any unconsolidated material near the top of the shaft, including discarded waste material. Most abandoned shaft collars in the inventory consist of timber, sometimes in combination with iron sheeting. More-recent collars may include a steel-pipe or iron framework and iron sheeting, or concrete.

Collar collapse is caused primarily by the deterioration of the collar materials. Figure 63a illustrates a timbered

collar in good condition. If the material surrounding the upper part of the collar is not very competent, it begins to slump into the shaft as the collar timbers decay (Fig. 63b). This process can be accelerated with the assistance of termites in the timbers, and water runoff. Continued subsidence can result in considerable enlarging of the collar (Fig. 63c). In smaller shafts, the surrounding bund material can collapse into, and effectively infill, the shaft, whereas in larger shafts the subsidence may form a large conical-shaped depression (Fig. 63d). Any fences built too close to a shaft may eventually collapse into the subsidence cone.

In areas where the near-surface rock is more competent, shaft collars may remain essentially intact even if timbers are absent (Fig. 63e). The competency of the collar material is dependent upon both rock type and depth and degree of weathering. Fresh rock, or thick surface ferricrete or calcrete can all form competent shaft collars. Any secondary capping can nevertheless result in undercutting in the softer underlying clay, creating a potentially unstable collar (Fig. 63f).

## Fence and seal effectiveness

Fences and seals can indicate that a hazard is present, and prevent access to hazards. Fence and seal effectiveness ranges from poor (Fig. 64a) to very good (Fig. 64b).

A minimum of a single strand of wire between star pickets does not provide a barrier to entry, but can indicate that a hazard is nearby, even in the dark. However, these types of fences can be easily broken or damaged and may not even prevent accidental access. In Figure 64a the fence was placed too close to the shaft collar, and one star picket has fallen into the expanding area of collar subsidence. Two or three strands of plain or barbed wire are better than one, but still barely hinder access.

A more effective and quite common fence type consists of wide-spaced wire mesh or ringlock netting, normally with one or two strands of barbed wire at the top, and star pickets (Fig. 64c). These fences can prevent accidental access for people and livestock, and can deter wildlife. They are not normally intended to bear much load, and therefore tend to slacken with time. Occasionally this type of fence is constructed with sturdy, stained wooden or steel posts in a similar manner to agricultural fencing, and can be quite durable.

A 2 m-high chain-mesh fence supported with steel posts can be very effective in preventing entry by livestock, wildlife, and most people, especially if one or more strands of barbed wire are added to the top (Fig. 64b). However, determined people can either push underneath, or cut through this type of fence as shown in Figure 64d. Any type of fence can be vandalized, or have parts stolen for materials. For example, the upper steel supporting poles are missing in some fences of this type, resulting in a weakened structure that is prone to failure.

Seals can vary greatly in effectiveness, from dangerously concealing a working, to preventing accidental entry, to deterring efforts to enter. The most rudimentary type of seal consists of loose wood or steel, dead trees, or even rubbish laid across a working. These

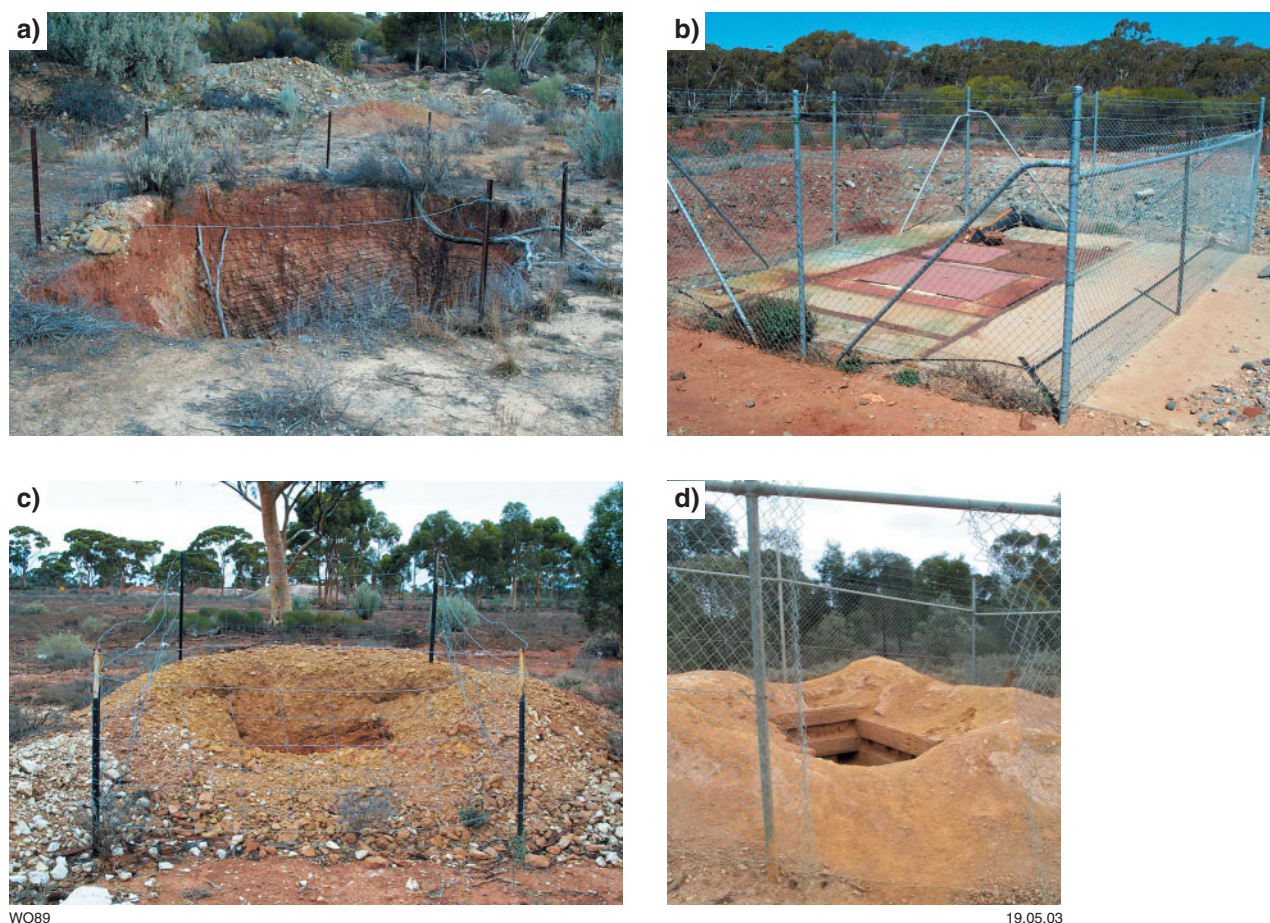


WO83

15.05.03

**Figure 63.** Various types of shafts and their dimensions (length  $\times$  width, and depth): a) three-chambered shaft (3.5  $\times$  1.2 m, >10 m deep) with collar timbers in good condition (1 km northwest of Bardoc; Zone 51, MGA 335217E 6642975N); b) two-chambered shaft (2.6  $\times$  1.5 m, >10 m deep) with collar timbers in poor condition, resulting in collapse of the upper shaft collar (5.5 km north of Coolgardie; Zone 51, MGA 323893E 6579364N); c) three-chambered shaft (4  $\times$  1.2 m, >10 m deep) with severe subsidence of the upper shaft collar caused by shaft collar collapse in unstable near-surface conditions (2.5 km north of Kanowna; Zone 51, MGA 365864E 6615065N); d) 10 to 20 m-deep shaft with severe collar collapse, and a subsidence cone that is encroaching on the surrounding, three-strand wire fence in poor condition (1 km northeast of Coolgardie; Zone 51, MGA 325280E 6574870N); e) competent shaft collar (1.8  $\times$  0.7 m) in firm saprolite after porphyry (10 km southwest of Coolgardie; Zone 51, MGA 319335E 666110N); f) shaft collar (1.2  $\times$  0.7 m) showing undercutting beneath hard caprock and remnant collar timbers in poor condition (6 km northwest of Bardoc; Zone 51, MGA 331892E 6646764N)





**Figure 64.** Various types of fences around shafts (with length  $\times$  width): a) poor-quality, collapsing, single-strand barbed wire and star picket fence, partial mesh seal and shaft (2  $\times$  1 m, >10 m deep) with no bund (4.5 km south of Coolgardie; Zone 51, MGA 325374E 6569731N); b) good-quality 2.5 m-high, three-strand barbed wire and close-spaced wire fence, and welded steel plate seal over a shaft (3  $\times$  2 m) and surrounding full bund (10 km southeast of Kunanulling; Zone 51, MGA 320385E 6595400N); c) typical fence, 1.2 m high, consisting of one strand of barbed wire and wide-spaced wire mesh with star picket posts, surrounding a shaft (1.5  $\times$  1.2 m, 5–10 m deep) with a full bund (6 km south of Bardoc; Zone 51, MGA 337874E 6636968N); d) damaged, three-strand barbed wire and close-spaced wire-mesh fence, with steel posts and cross beams, surrounding a shaft (2  $\times$  1.2 m, >10 m deep) with a full bund (in Kalgoorlie–Boulder; Zone 51, MGA 355788E 6594860N)

objects may not even prevent accidental entry. Although they can provide a visual cue that a hazard is present (Fig. 65a), they can equally serve to disguise a working (Fig. 65b,c). Steel mesh laid over or across a working can provide a good barrier to accidental entry (Fig. 63a), but can become ineffective with severe collar collapse, as illustrated in Figure 64a. If not large or heavy enough, or not securely fixed to the ground, the steel mesh can also be displaced, allowing entry. Iron sheeting sometimes covers workings, but again can be dislodged, especially by strong winds. It can also serve to disguise a working, and especially if rusted, may not support the weight of an animal or person.

A concrete cap may appear to be a permanent safe seal for a working, but in several examples collar collapse has resulted in openings around the edges of the concrete. An extreme example is shown in Figure 65d where a circular concrete seal has collapsed into a working, and appears to be upside down. A padlocked or welded steel plate with

surrounding concrete collar as in Figure 64b can prevent accidental, and all but the most determined forced, entry, but is most practical for more-recent workings with collars in good condition and no bund.

## Backfilling of underground workings

Underground workings are sometimes backfilled using the bund material as fill. This procedure can be detrimental to the safety of the feature, leaving it with no bund, and giving the appearance of being made safe. In some cases there is insufficient material to completely fill the working, leaving a depression with no protective bund. Alternatively, the incomplete filling of a working can leave small, but deep openings that are difficult to see (Fig. 66).

Bund material is commonly relatively fine and oxidized, and consequently is prone to subsidence, especially if assisted by either surface or ground water.





**Figure 65.** Various types of seals: a) partial seal of loose timber and steel rails has improved the visibility of this shaft ( $1.3 \times 1.3$  m, >10 m deep), but may not prevent accidental entry (6 km northeast of Coolgardie; Zone 51, MGA 328239E 6579062N); b) partial seal of loose timber partially conceals this shaft ( $1.5 \times 1$  m, 5–10 m deep; 10 km southwest of Coolgardie; Zone 51, MGA 319700E 6565450N); c) car disguises a shaft ( $3 \times 3$  m, 5–10 m deep), but may not protect from accidental entry (3.5 km northeast of Coolgardie; Zone 51, MGA 327140E 6576810N); d) apparently inverted concrete seal in a collapsed underground working, now  $5 \times 5$  m, and 2–5 m deep (8 km south of Coolgardie; Zone 51, MGA 322709E 6566601N)

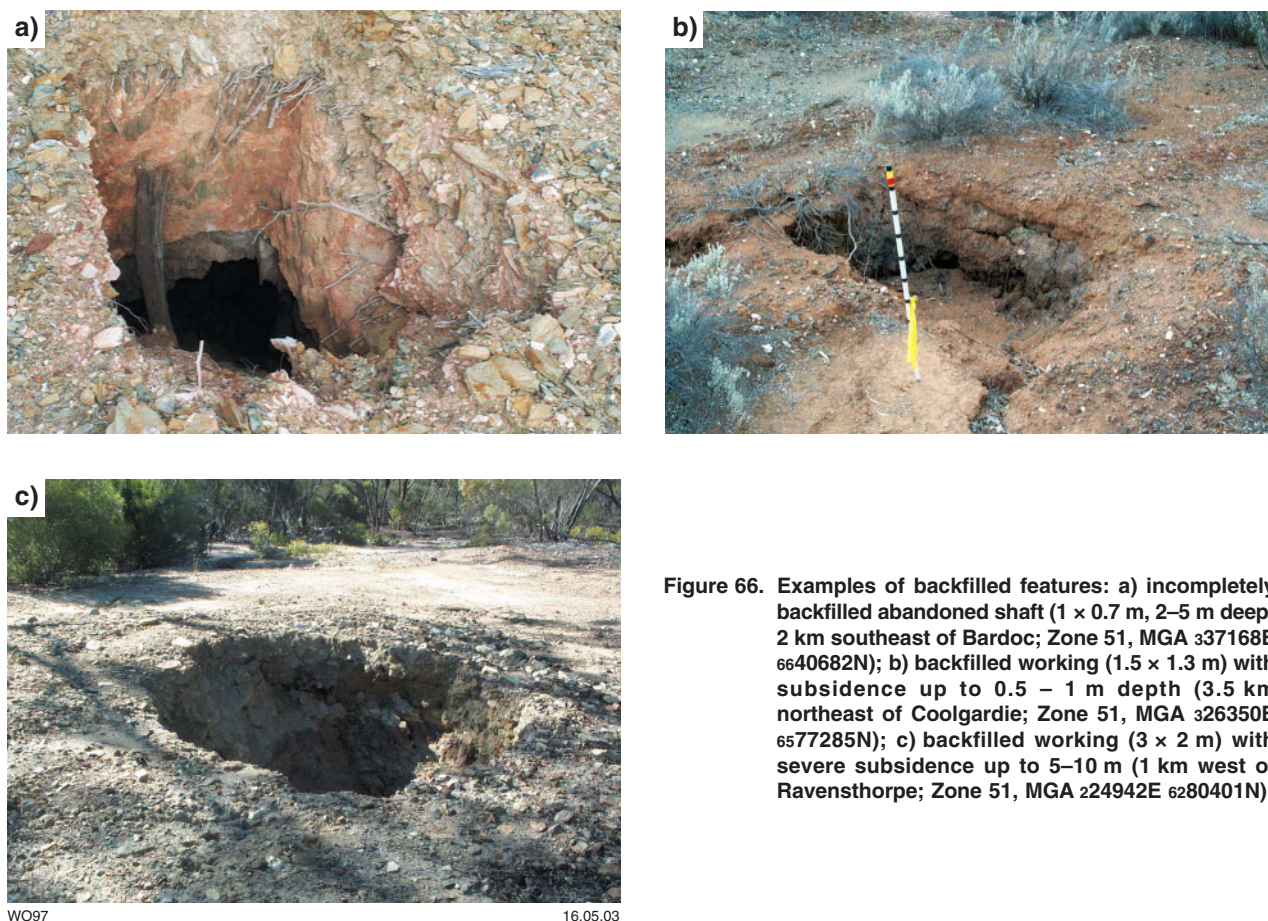
The material may not only compact, but can also migrate into adjacent stopes and drives in the subsurface and hence begin to subside over time (Fig. 66b), until a substantial hazard can develop (Fig. 66c).

### Potential subsidence of underground workings

The abandoned mine site data can be used to help predict areas with an increased probability of subsidence related to abandoned mine workings. This is of particular interest for infrastructure such as roads, but is also of relevance

for land use planning in historic mining areas. In general, abandoned workings tend to form distinct trends, which are governed by the underlying geology (see **Mineralization and geological mapping**). Depending on the nature and scale of historic mining in the region, extensive subsurface workings may have been developed along the same trend, sometimes linking up the shafts and other workings visible on the surface. Consequently, there is an increased probability of subsidence of abandoned workings anywhere along these historic mine trends. The subsidence may result over a previously rehabilitated feature such as a filled-in shaft, or may result from the collapse of a concealed near-surface drive or stope.





**Figure 66. Examples of backfilled features:** a) incompletely backfilled abandoned shaft (1 × 0.7 m, 2–5 m deep; 2 km southeast of Bardoc; Zone 51, MGA 337168E 6640682N); b) backfilled working (1.5 × 1.3 m) with subsidence up to 0.5 – 1 m depth (3.5 km northeast of Coolgardie; Zone 51, MGA 326350E 6577285N); c) backfilled working (3 × 2 m) with severe subsidence up to 5–10 m (1 km west of Ravensthorpe; Zone 51, MGA 224942E 6280401N)

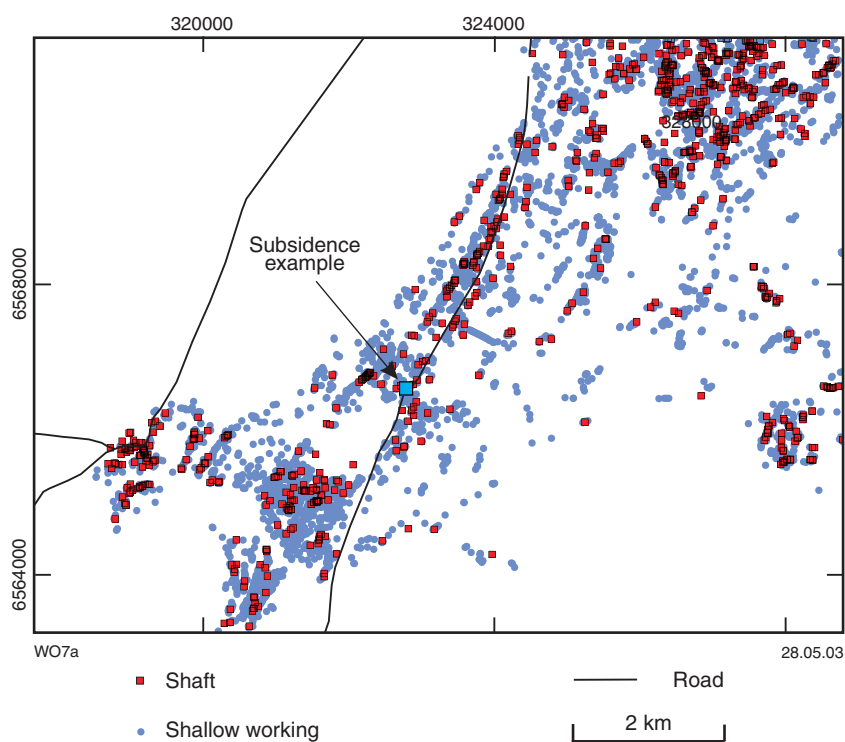
One example of direct relevance to public safety is where the trend of abandoned mine workings crosses roads. This is of particular concern where the abandoned workings are closely aligned to the road, as in the Burbanks region (Fig. 67) where a significant hazard was located close to the road during the course of fieldwork. An abandoned working had subsided to depths of between 5 and 10 m as shown in Figure 68. This feature was particularly hazardous as it was difficult to see, even from the nearby road, before remedial action was taken.

Although further studies are not currently within the scope of the project, more work could be carried out in key areas where abandoned mine workings traverse current or planned infrastructure. For example, historic mine records could be examined to establish the size and extent of some of the larger mines. This information could be combined with the geological information obtained from DoIR's WABMINES and possibly WAMEX (Western Australian mineral exploration) and WAMIN (Western Australian mineral occurrence) databases to define specific areas of higher risk of subsidence, such as along the surface projection of a line of stopes. Such areas could then be subjected to closer scrutiny prior to construction or to closer monitoring if under existing infrastructure.

## Environmental assessment

WABMINES can be used as a tool to identify features that have resulted from recent exploration that may require rehabilitation under the Mining Act (1978). The main features of concern are costeans, drill sumps, collapsed drillholes, shallow pits, and waste and rubbish dumps. Many of these features will be identifiable in the 'EXCAV\_METH' column of the dataset as 'MEC'. They are commented on in the 'MINE\_NOTE' column as 'bulldozer costean' or 'loader costean' or similar. The dimensions and other recorded parameters, particularly edge condition, and in some cases photographs, could assist in the assessment of these features. Some of these features will predate the Mining Act (1978), but may still be of concern for safety and environmental reasons.

Rehabilitated features are also recorded in WABMINES wherever they are readily identifiable. The most common mechanically rehabilitated features are mechanically excavated costeans and abandoned shafts. Ineffective or incomplete rehabilitation may be commented on in the 'MINE\_NOTE' section and may be accompanied by photographs. The 'REVEG' field in the database was only used for the dump feature group prior to 1 August 2002 on the Cassiopeia PC. Revegetation has been recorded for rehabilitated features since the Symbol



**Figure 67.** Map showing abandoned workings close to the road in the Burbanks region, south of Coolgardie, and the location of the subsidence example in Figure 68



**Figure 68.** a) Subsidence of an abandoned working (4 × 3 m, 5–10 m deep) adjacent to the road as shown in Figure 67 (8 km south of Coolgardie; Zone 51, MGA 322782E 6566561N); b) downhole view of the subsidence shown in (a)



PC was introduced. Unlike most data fields, the revegetation column has the option of 'none' to distinguish instances where no revegetation was observed from those where the status was not recorded.

Dispersion direction and distance from tailings dumps are recorded to aid in the assessment of the impact of the dump on the surrounding environment. Photographs are taken of significant dumps if they are not still in use, and the average side dip is recorded. Instances of significant erosion are recorded in 'MINE\_NOTE'. For waste dumps the oxidation state of the dump material may be recorded in 'MINE\_NOTE', and particular attention is paid to abandoned dumps of sulfide material that have the potential for acid formation.

The condition of any water observed in the base of opencuts is recorded as a colour in the 'WATER' column of the database. Any entry in this field indicates that significant water was present at the time of observation. Although no water samples have been collected, the colour, accompanying photograph and comments in 'MINE\_NOTE' may allude to any potential in situ acid formation or contamination.

Finally, the visual impact rating may give an indication of the overall environmental impact of a feature. Those features with a moderate to high visual impact rating may simply be large or prominent, but this can be checked with the dimensions. Any notable rubbish or plant debris will be recorded in 'MINE\_NOTE' and may be photographed.

## State of preservation assessment

The WABMINES data are useful for identifying the locations of potentially significant historical features, and for analysing patterns of early occupation.

MacGill (1998) proposed a number of criteria and guidelines for the assessment of the cultural heritage significance of historic minesites in Western Australia. These criteria included aesthetic, historic, scientific, and social values, rarity, and representativeness. A number of these values could only be assigned after significant research that is outside the scope of the inventory of abandoned mine sites. Nevertheless, the 'CONDITION' definitions in WABMINES (Appendix 1) are based upon the 'Specific site type and condition integrity' section of the 'Historic mining places report form' provided by MacGill (1998). This information deals with the degree of preservation, and when complemented with photographs and other attributes in WABMINES, could assist in heritage assessment.

Most features that may be of relevance to heritage issues are recorded in the infrastructure feature group as building, chimney, battery/mill, headframe/winder, shaft footing, town remnant, machinery and other feature types. These features are frequently incomplete and in poor condition, and in many cases only the footings remain.

Mine workings were also assessed for their condition. Only a relatively small number of shafts have intact extra features such as collar timbers, ladders, and headframes.

All headframes can be identified by an entry in the 'UG\_HEADFRM' column of the database irrespective of age, size, type or significance. As all shafts have at least one photograph, these factors can normally be ascertained from viewing the appropriate photograph or any comments in the 'MINE\_NOTE' section (or both). Some headframes may have been relocated from a shaft, or have been deemed to be of such significance that they warranted a separate entry as infrastructure under the headframe/winder or shaft footing type categories.

Some dump types are also potentially useful for recording the presence of early mining-related activity. A new type category called ash has been created to record significant ash heaps that mark the former locations of boilers for steam-powered machinery. All dump records with mention of ash in the 'MINE\_NOTE' section have been retrospectively labelled ash in the 'TYPE' column. A new rubbish dump subcategory of old bottles/cans has been added to the 'DUMP\_OTHER' column to include these distinctive types of rubbish. As many of the early mining camps were of wood and hessian or canvas construction, commonly the only obvious sign of previous occupation are these dumps. Figure 69 shows a number of features that may be of relevance for mapping early mining-related activity.

Groupings of some mine-related features that were individually assessed as having poor to fair condition could possess historic value as a group. Features may also have a historical significance that is not apparent from a field inspection. The correlation of historic mine sites from MINEDEX or historic tenement data (or both) with the WABMINES data may assist in identifying the former names of some localities where they are not currently known.

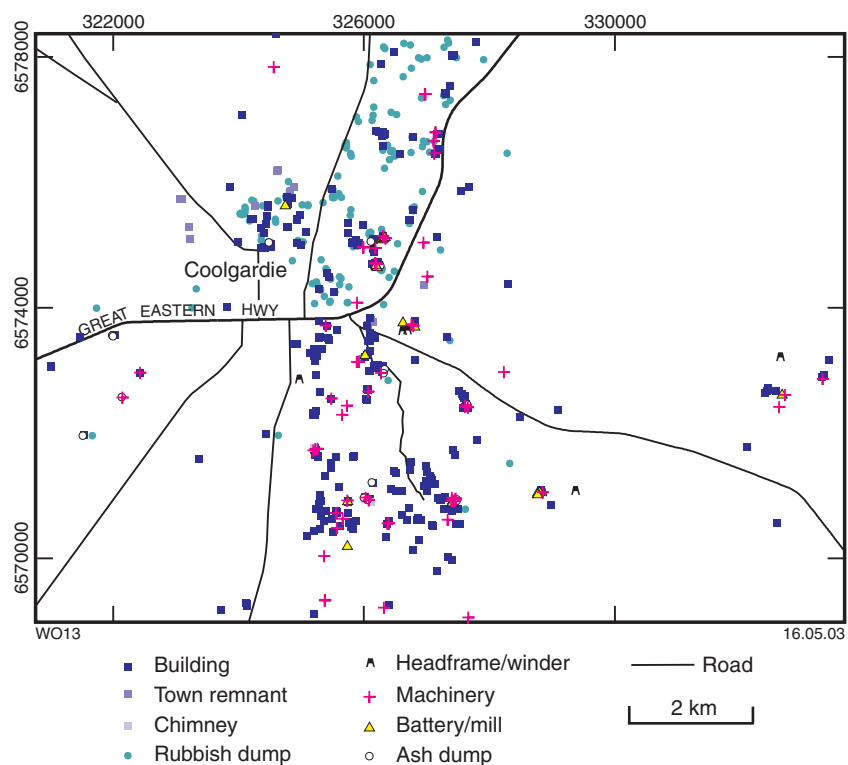
Historical photographs could be scanned into the database and correlated with WABMINES sites. The WABMINES database could ultimately record the historical names for all known sites along with historical and current photographs, and could be linked to the appropriate MINEDEX production records. This would provide a valuable resource for historical research and the production of information literature for the general public.

## Mineralization and geological mapping

Data stored in WABMINES can assist in the mapping of mineralization and geology by providing spatial distribution, lithological, and structural information. Abandoned shallow gold workings and shafts commonly follow mineralized features such as quartz veins (Fig. 70). They once formed the equivalent of the drillhole for exploration purposes with one notable difference — they were commonly excavated directly on the surface outcrop of the features and followed both the dip and strike of the mineralization. In contrast, modern exploration drilling commonly attempts to cut across the strike and dip of mineralized zones to give an indication of true width.

The recent WABMINES data are most useful for analytical purposes due to the completeness of the data





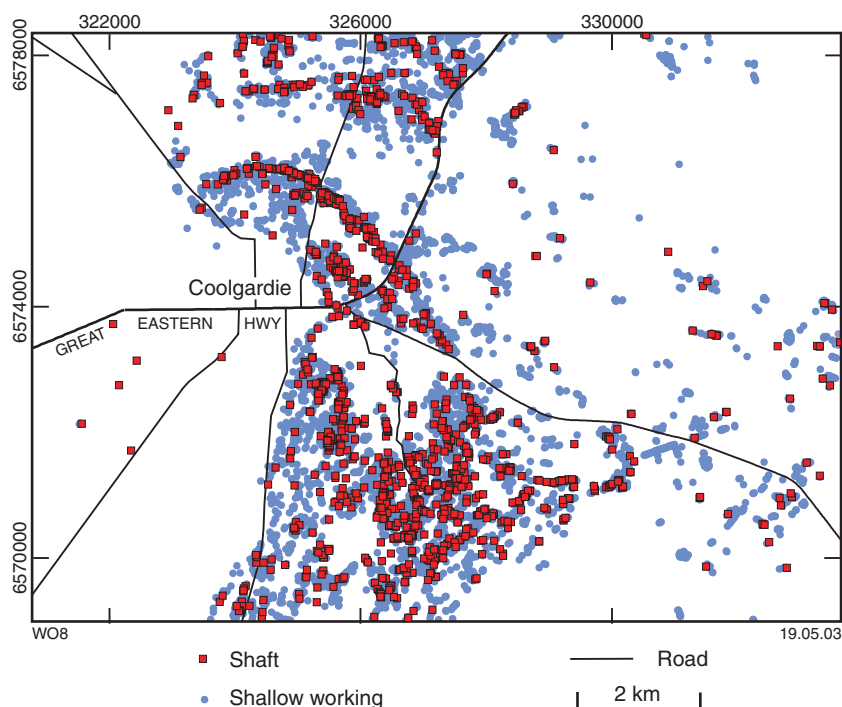
**Figure 69. Map showing the locations of other mining-related features in the Coolgardie region**



**Figure 70. Shaft (2 × 1.5 m, 10–20 m deep) on a sheared contact (290° strike and 80°N dip) of a highly fractured and folded quartz vein (2 km northeast of Coolgardie; Zone 51, MGA 326060E 6575260N)**

for shallow workings, and notes that were made specifically to distinguish more recent excavations that may have been dug on a grid pattern, or for other purposes. Recent ‘mechanical excavations’ can often be distinguished in the field by the dimensions and shape of the excavation or the location and shape of the extracted material, or both. Comments in the ‘MINE\_NOTE’ section of the database identify mechanical excavations either directly or by reference to the machinery type such as ‘dozer scrape’, ‘loader pit’ or ‘excavator pit’. Old shallow workings are typically small and less than 1 m deep due to severe edge subsidence and infilling by soil. The following example from the Coolgardie region illustrates a potential use of the data.

A selection was made of only the shallow workings and shafts (including open stopes and collapsed shafts) because they are best represented by point data and are most likely to lie along mineralization. Conversely, recorded points for costeans, trenches, adits, and even opencuts may lie significant distances from the mineralized structures. The shallow working data was then filtered (by searching the ‘MINE\_NOTE’ field) to remove alluvial/colluvial features, any reference to costeans/trenches, or more-recent mechanical excavations, or excavations made for other purposes. Figure 71 shows the resultant shallow workings, and shafts (including open stopes and collapsed shafts). Some major bedrock mineralization trends are immediately apparent, and further processing of the data such as gridding and contouring combined with imaging of counts of feature



**Figure 71. Map showing the locations of abandoned shafts and shallow workings in the Coolgardie region**

points per grid cell could produce a clearer picture of the major bedrock mineralization trends. The interpretation can then be made using underlays of orthophotographs and geological maps (Fig. 72).

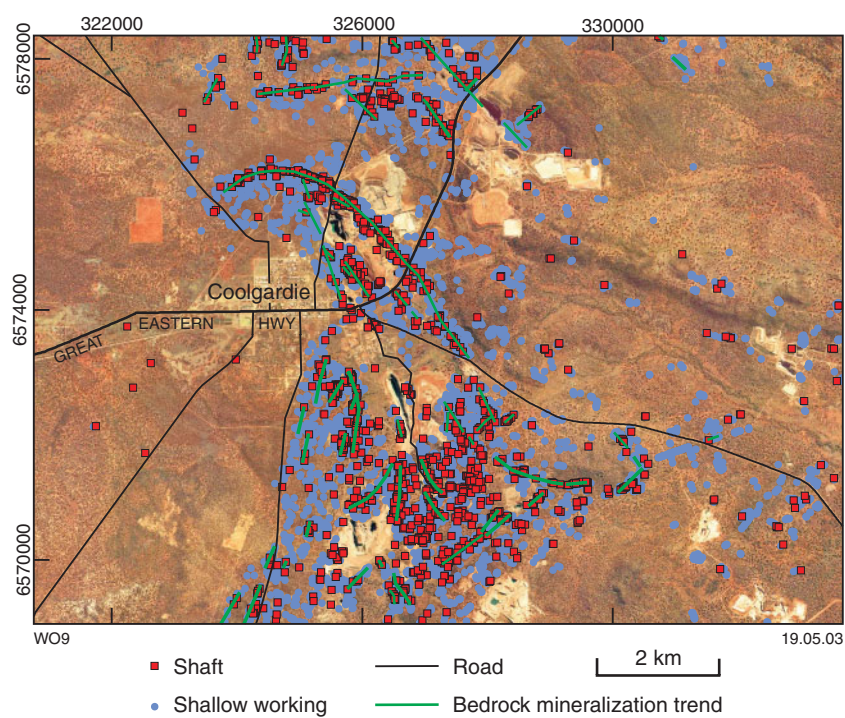
The 'NOTES' section of the WABMINES data was searched for comments on mineralization associated features such as black shale, porphyry, quartz veins, and shearing. Plotting of the distribution of these features can then assist the characterization of mineralization trends (Fig. 73).

The data can also be used on a more-local scale for understanding the dimensions and orientation of the mineralization. These can be inferred from the trend of the workings, and even the dimensions and orientations of individual shafts and open stopes. Furthermore, wherever possible, measurements are made and photographs are taken of potentially mineralized features such as quartz veins and shears (Fig. 70). Any measurements or comments on the mineralization are recorded in the 'NOTES' section of WABMINES. In some localities, the 'NOTES' and plots of shallow working and shaft trends can be used to identify or infer the intersection of crosscutting mineralized trends that may potentially localize high-grade mineralization.

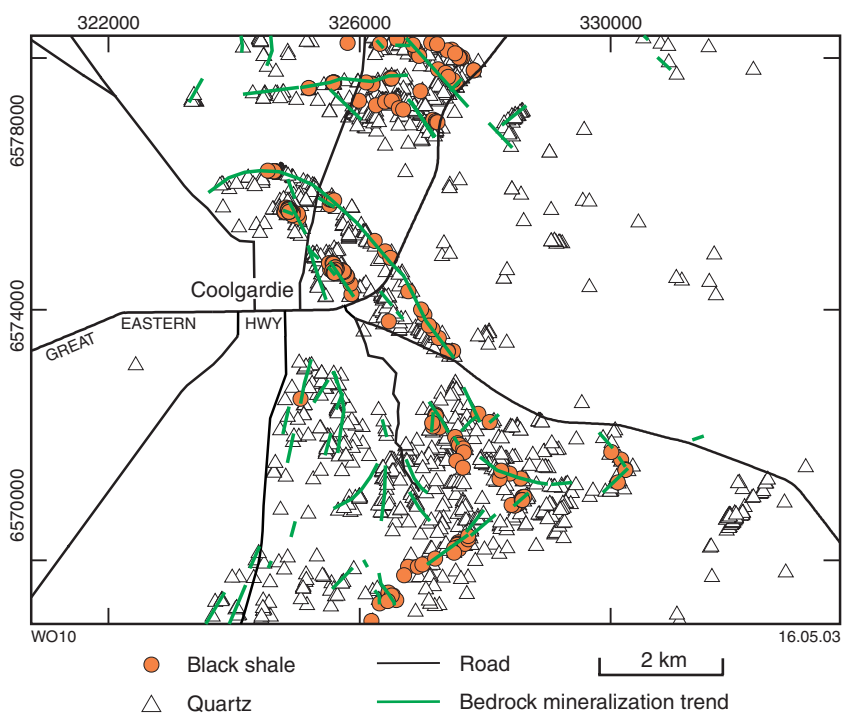
In the Coolgardie region, alluvial or colluvial deposits (or both) were mapped from the distribution of shallow workings and opencut features associated with alluvial and colluvial mining. These data were obtained by searching the 'MINE\_NOTE' section of shallow working and opencut feature records for any reference to 'alluvial' or 'colluvial' comments. Mechanical excavations were not

excluded because they commonly represent valid data points for this type of deposit. Mapping of alluvial deposits tends to be less precise because they may have a large areal extent that can be difficult to capture with point data (a polygon would be more appropriate). In some cases each individual working is captured, but in other cases where there are a very large number of workings or individual workings are difficult to identify, alluvial workings can be represented by a single point (with area recorded in 'MINE\_NOTE') or a series of bounding points. Figure 74 shows the distribution of alluvial and colluvial workings in the Coolgardie region with the interpreted bedrock gold-mineralization trends. The mapping of alluvial deposits is best done using the point data in conjunction with comments in the 'MINE\_NOTE' section, and underlays of historical geological maps, orthophotographs, and a digital elevation model or topographic map. Polygons could then be made outlining interpreted mineralized areas.

In addition to mineralization mapping, the WABMINES data can assist in geological mapping. Rock types and structural measurements (normally bedding or foliation) have been recorded in 'NOTES' for some features where appropriate. Because no petrological samples are taken, the rock type is only a quick field identification. The WABMINES data can provide further data points for mapping distinctive marker lithologies such as black shale and banded iron formation. Figure 75 shows the black shale localities recorded for the Coolgardie region, with a regional map underlay. This type of data can therefore be used to refine regional mapping interpretations.

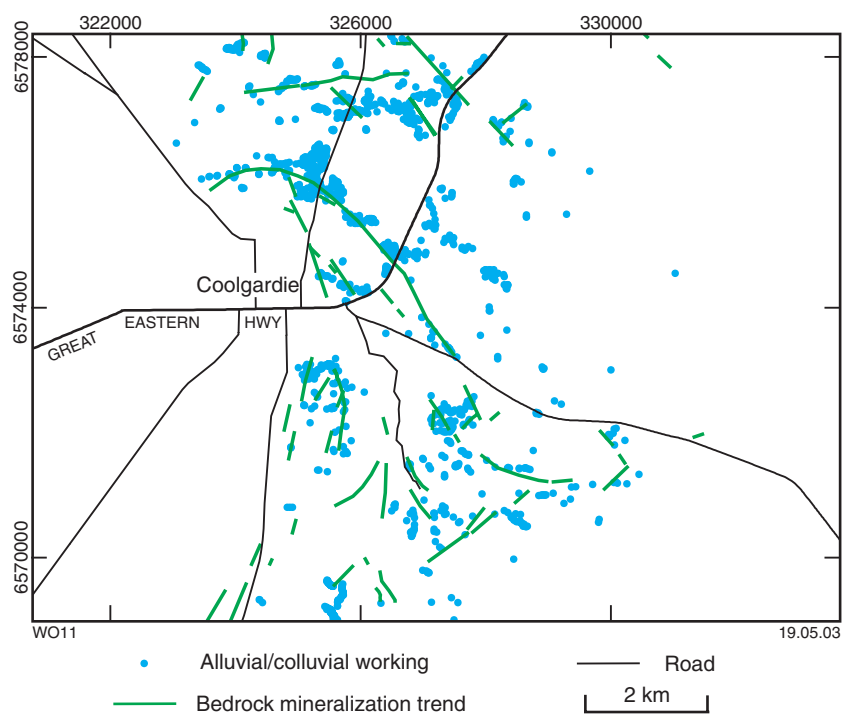


**Figure 72. Interpreted bedrock gold mineralization trends in the Coolgardie region with underlying orthophotograph**

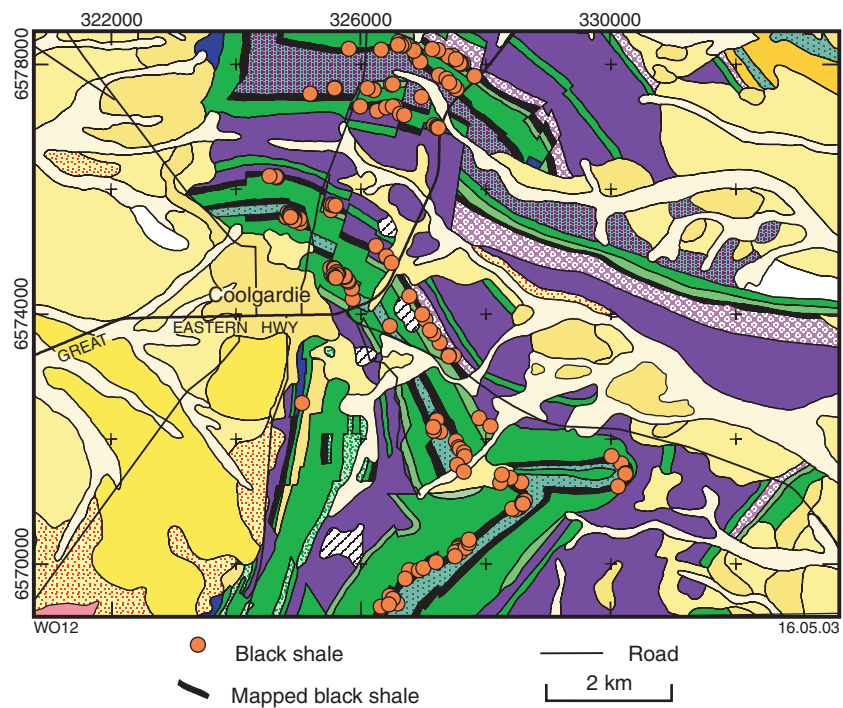


**Figure 73. Map showing the bedrock gold mineralization associations in the Coolgardie region**





**Figure 74. Map showing the locations of alluvial and colluvial workings in the Coolgardie region**



**Figure 75. Map showing the locations of black shales in the Coolgardie region, compared with the black shale units mapped by Hunter (1985)**

As for mapping hard-rock mineralization trends, the best data for geological mapping are derived from shallow workings, collapsed shafts, and shafts (because these features can be easily represented as point data). The exact location of a particular measurement or rock type may not be as clear for long linear features such as costeans and trenches or large opencuts. Rock types are sometimes recorded for waste dumps, however, they may be located a significant distance from their source, particularly for opencuts and large underground workings, and therefore should not be used for detailed mapping purposes unless the source of the material was clearly identified. The excavation method is not relevant for geological mapping purposes.

To assist in mapping mineralization trends, and also more recent features for rehabilitation monitoring, an extra data field has been created termed 'excavation method'. This field has been retrospectively populated based upon comments in the 'MINE\_NOTE' section, and will be used from the commencement of fieldwork in 2003 to record all excavations that were clearly mechanical. This data will facilitate the filtering of older sites from more-recent sites.

Other WABMINES data fields are being considered for recording alluvial and colluvial workings, structural orientations, rock, vein, and commodity types, foliation intensity, and the degree of weathering. The degree of

weathering would be recorded for the base of the working (the top of the associated bund or waste pile) and in conjunction with feature depth could provide an indication of the depth of oxidation. Wherever possible these data could be integrated with DoIR's WAROX, WAMIN, and MINEDEX databases.

Currently, no attempt has been made to reconcile the historic mine site locations from MINEDEX with the WABMINES data. This exercise is complicated by the inaccuracy of some of the historic mine site locations, and the fact that recorded production may have been achieved from multiple workings in an area. Occasionally, site-identifying information is obtained from the field inspections and is recorded in 'MINE\_NOTE'. In some cases other information held by DoIR may assist in this type of reconciliation.

WABMINES has been used by the Resource Access group of GSWA to assist in assessing the mineralization potential of areas with proposed future development. The WABMINES data, and interpretations of mineralization trends based on them, can provide an invaluable tool for future land use planning purposes.

## References

- ABANDONED MINERAL LAND PROGRAM, 1998, National Park Service, United States Department of the Interior, viewed 28 January 2003, <<http://www.aqd.nps.gov/grd/distland/amlprog.htm>>.
- ADAMIDES, N. G., 2000, Inventory of State batteries sites of Western Australia: Western Australia Geological Survey (unpublished).
- AMERICAN GEOLOGICAL INSTITUTE, (compiler), 1997, Dictionary of Mining, Mineral and Related Terms, (2nd edition): Virginia, U.S.A., American Geological Institute, 646p.
- BLATCHFORD, T., 1899, The geology of the Coolgardie Goldfield: Western Australia Geological Survey, Bulletin 3, 100p.
- BLATCHFORD, T., and FARQUHARSON, R. A., 1913, Geological investigations in the area embracing the Burbanks and Londonderry mining centres, with special reference to the ore deposits and their future prospects: Western Australia Geological Survey, Bulletin 53.
- BUREAU OF LAND MANAGEMENT, 1997, United States Department of the Interior, viewed 28 January 2003, <<http://www.blm.gov/nhp/efoia/wo/fy97/im97-75.html>>.
- COOPER, R. W., FLINT D. J., and SEARSTON, S. M., 2002, Mines and mineral deposits of Western Australia: digital extract from MINEDEX — an explanatory note, 2002 update: Western Australia Geological Survey, Record 2002/19, 25p.
- DEPARTMENT OF MINES WESTERN AUSTRALIA, 1954, List of cancelled gold mining leases which have produced gold: Western Australia Department of Mines, 271p.
- DREW, G., 2002, Abandoned mines in South Australia: MESA Journal, v. 24, p. 27–29.
- ECOLOGICAL SUSTAINABLE DEVELOPMENT STEERING COMMITTEE, 1992, National Strategy for Ecologically Sustainable Development, Environment Australia, viewed 23 May 2003, <<http://www.ea.gov.au/esd/national/nsesd/strategy/mining.html>>.
- GOZZARD, J. R., 2002a, Documentation for the abandoned mine sites ArcPad application: Western Australia Geological Survey (unpublished).
- GOZZARD, J. R., 2002b, Database procedures for GSWA's abandoned mine sites database: Western Australia Geological Survey (unpublished).
- GOZZARD, J. R., and LANGFORD, R. L., 2003, A user's guide to the abandoned mine sites ArcPad application, Version 2.: Western Australia Geological Survey (unpublished).
- GREELEY, M., 1999, Forest Service, United States Department of the Interior, viewed 28 January 2003, <<http://www.fs.fed.us/geology/amlpaper.htm>>.
- HALLBERG, J. A., 2000, Hallberg Murchison 1:25 000 geology dataset: Western Australia Geological Survey, Record 2000/20.
- HUNTER, W. M., 1985, Kalgoorlie, W.A. Sheet 3136: Western Australia Geological Survey, 1:100 000 Geological Series.
- KUKULS, L., 2000, 1899–1999 and beyond: History meets technology to locate abandoned mine sites: Mapping Sciences Institute Australia Conference, Sydney, N.S.W., 2000, Proceedings, p. 189–194.
- MACGILL, G., 1998, A policy and strategy for the conservation of mining heritage in Western Australia: Perth, Western Australia, Ministry for Planning (unpublished).
- MACKASEY, W. O., 2000, Abandoned Mines in Canada: Mining Watch, viewed 18 November 2002, <[http://www.miningwatch.ca/publications/Mackasey\\_abandoned\\_mines.html](http://www.miningwatch.ca/publications/Mackasey_abandoned_mines.html)>.
- MAITLAND, A. G., and CAMPBELL, W. D., 1902, Geological map of Kalgoorlie: Western Australia Geological Survey.
- MESCH, M. R., and MALIN, L., 1994, The Utah Division of Oil, Gas and Mining Abandoned Mine Reclamation Program: The Association of Abandoned Mine Land Programs, 16th Annual Conference, Park City, Utah, U.S.A., Proceedings, 590p.
- MINERALS ENVIRONMENT LIAISON COMMITTEE, 1994, Conservation and rehabilitation in the gold mining industry, 1994: Perth, W.A., A report to the Hon. Minister for Mines, MGC70497 (unpublished).
- MINING MINERALS AND SUSTAINABLE DEVELOPMENT, 2002, Mining for the future, Appendix C: Abandoned Mines Working Paper, International Institute for Environment and Development, viewed 18 November 2002, <[http://www.iied.org.mmsd/activities/mine\\_closure\\_policy.html](http://www.iied.org.mmsd/activities/mine_closure_policy.html)>.
- NATIONAL RIVERS AUTHORITY, 1994, Abandoned mines and the water environment: London, U.K., Water Quality Series, v. 14, 46p.
- OWENS, B. B., 1981, Locations of past and present State batteries: Perth, W.A., Department of Minerals and Energy, internal report (unpublished).
- PARLIAMENTARY DEBATES (HANSARD), 1998, Mining Amendment Regulations (No. 4) 1997, Motion for disallowance: Parliament of Western Australia, p. 1479–1509.
- PARLIAMENTARY DEBATES (HANSARD), 1999, Legislative Assembly Estimates Committee A, Division 33: Minerals and Energy: Parliament of Western Australia, p. E393.
- SHIELDS, D. J., BROWN, D. D., and BROWN, T. C., 1995, Distribution of abandoned and inactive mines on National Forest System lands: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-260, 195p.
- TASMANIAN GEOLOGICAL SURVEY, 1998, Strategy — the rehabilitation of abandoned mining lands: Tasmanian Geological Survey, Record 1998/07, 11p.
- TOWNSEND, D. B., GAO, M., and MORGAN, W. R., 2000, Mines and mineral deposits of Western Australia; digital extract from MINEDEX — an explanatory note: Western Australia Geological Survey, Record 2000/13, 28p.
- UNITED NATIONS ENVIRONMENT PROGRAMME, 2000, Abandoned mine sites: problems, issues and options, industry and environment: Special Issue on Mining and Sustainable Development II, v. 23, p. 36–38.
- UNITED STATES BUREAU OF MINES, 1994, Abandoned mine land inventory and hazard evaluation Handbook: United States Department of the Interior, Bureau of Mines, 162p.
- WESTERN AUSTRALIAN GOVERNMENT, 1978, Mining Act, 1978: Perth, Western Australia, Government Printer, Part 1, p. 8.



## Appendix 1

## Glossary of terms

<i>Attribute/ Value</i>	<i>Attribute name/ Value name</i>	<i>Description</i>
<b>AZIMUTH</b>	<b>Azimuth</b>	Dip direction of feature in degrees Grid. Used only for underground features, especially linear ones such as shafts and adits. Use 0° for north
<b>BASE_COND</b>	<b>Base condition</b>	
EM	Empty	For underground features, a large empty void (probable stoping or extensive underground workings) indicated by a distinctive hollow echo sound heard from an object hitting the bottom of the excavation (usually a shaft). Also has previously been used to indicate no material remaining, or rubbish or water in the base of an opencut
OVBC	Oversize	Extraordinarily large rocks obtained from blasting, at the base of an excavation
ROBC	Rock	Rock or soil or sediment forming the base of an excavation (i.e. no significant rubbish and/or water and/or oversize material)
RUBC	Rubbish	Significant rubbish in the base of an excavation
TABC	Tailings	Tailings can be observed in the base of an excavation. See tailings dump for definition of tailings
WA	Water	Water in the base of an excavation
WR	Water and rubbish	Water and significant rubbish in the base of an excavation
<b>BUND</b>	<b>Bund</b>	An embankment of earth or a wall constructed of brick, stone, concrete or other approved material to form the perimeter or part of the perimeter of a compound (W.A. Government, 1992). In WABMINES, a bund usually consists of the waste rock excavated from the working. For pits and quarries the bund is normally purposely constructed around the feature to minimise inadvertent public access.
FUBU	Full bund	A full bund is a complete rock barrier at the surface around the feature
PABU	Partial bund	Portions of a rock barrier are present at the surface around the feature. For underground features a partial bund usually consists of the waste rock excavated from the working with a gap left for easy access. For costeans and trenches, the adjacent pile(s) of waste rock are considered to be bunds
<b>BUND_MAX</b>	<b>Maximum bund height</b>	Maximum height of a bund around a feature in metres to one decimal place
<b>BUND_MIN</b>	<b>Minimum bund height</b>	Minimum height of bund around a feature in metres to one decimal place
<b>CONDITION</b>	<b>Condition</b>	
GO	Good	For infrastructure features: remains that are structurally sound that may have some equipment in place, and the former functions of which are recognizable or capable of being interpreted. For mine workings: only applies to recently used and working shafts with everything still in place
FA	Fair	For infrastructure features: remains that are in a state of collapse or decay, but the former functions of which are likely to be capable of being interpreted with a reasonable degree of certainty For mine workings: extra features such as timbers, ladders, headframes, and well-built bund walls that are relatively well preserved and with no apparent subsidence
PO	Poor	For infrastructure features: remains that are in a state of collapse or dispersal such that interpreting their former functions is likely to be difficult or highly speculative. For mine workings: no extra features such as timbers, ladders, headframes, well-built bund walls etc. or where such extra features are present, they are not well preserved. Dump, opencut, and rehabilitated features are all assigned poor condition. Ramps and tramways (dump category features) are assessed as for infrastructure
FO	Footings only	Footings: a relatively shallow foundation by which concentrated loads of a structure are distributed directly to the supporting soil or rock through an enlargement of the base of a column or wall (AGI, 1997). For infrastructure features: any form of foundations with or without bolts where walls of buildings, or machinery are completely removed
<b>DEPTH</b>	<b>Depth</b>	Normally maximum depth except for features with a high length to width ratio, such as costeans where an average depth is given. For an adit, depth refers to the maximum distance excavated (beyond the portal or opening) as though it were a near-horizontal shaft
XS	Extremely shallow	0 to 0.5 m deep
VS	Very shallow	0.5 to 1 m deep
MS	Moderately shallow	1 to 2 m deep
MD	Moderately deep	2 to 5 m deep
DE	Deep	5 to 10 m deep
VD	Very deep	10 to 20 m deep
XD	Extremely deep	>20 m deep

## Appendix 1 (continued)

<i>Attribute/ Value</i>	<i>Attribute name/ Value name</i>	<i>Description</i>
SO	Shallow	Discontinued use after 28/2/00; 0 to 5 m deep
DD	Deep	Discontinued use after 31/7/02; >10 m deep
SH	Shallow	Discontinued use after 31/8/02; 0 to 2 m deep
<b>DIP</b>	<b>Dip</b>	Angle at which a feature is inclined from the horizontal. Assumed to be 90° for collapsed shafts, shafts, and open stopes unless stated otherwise. Used in conjunction with azimuth or strike, or for the average wall dip for opencuts and dumps
<b>DISP_DIR</b>	<b>Dump dispersion direction</b>	
N	North	Main dispersion direction of dump material is to the north
NE	Northeast	Main dispersion direction of dump material is to the northeast
E	East	Main dispersion direction of dump material is to the east
SE	Southeast	Main dispersion direction of dump material is to the southeast
S	South	Main dispersion direction of dump material is to the south
SW	Southwest	Main dispersion direction of dump material is to the southwest
W	West	Main dispersion direction of dump material is to the west
NW	Northwest	Main dispersion direction of dump material is to the northwest
<b>DISP_DIST</b>	<b>Dump dispersion distance</b>	Estimated dispersion distance of dump materials in metres
<b>DLAT</b>	<b>Degrees latitude</b>	Latitude reference in decimal degrees. Datum is GDA94
<b>DLONG</b>	<b>Degrees longitude</b>	Longitude reference in decimal degrees. Datum is GDA94
<b>DUMP MATER</b>	<b>Dump material</b>	
Gvl	Gravel	Main dump material is gravel size (2 to 20 mm). Commonly, this material has been screened or crushed to meet this size range
OVDm	Oversize	Main dump material consists of extraordinarily large rocks obtained from blasting
RODM	Rock	Main dump material is larger than gravel, but may be highly variable in size. This is the most common size for material obtained from opencut and underground mining
Sd	Sand	Main dump material is sand size (1/16 to 2 mm), but does not include tailings
TADM	Tailings	Main dump material is tailings. See tailings dump for definition of tailings
OTDM	Other	Main dump material is not sand, gravel, rock, oversize, tailings or rubbish. The material type should be recorded in MINE_NOTE
<b>DUMP_OTHER</b>	<b>Other dump waste</b>	
CA	Cars	Dump either consists mainly of, or incorporates, old car bodies
GR	General rubbish	Dump either consists mainly of, or incorporates, general rubbish
OB	Old bottles/cans	Dump either consists mainly of, or incorporates, old bottles and/or cans
PL	Plastic lining	Dump either consists mainly of, or incorporates, plastic lining
SM	Scrap metal	Dump either consists mainly of, or incorporates, scrap metal
<b>EASTING</b>	<b>Easting</b>	Map Grid Australia easting reference in metres, using Geocentric Datum of Australia 1994 (GDA94)
<b>EDGES</b>	<b>Edge stability</b>	
FI	Firm	Stable edge in original condition
CR	Cracked	An otherwise stable edge weakening due to visible cracks
SS	Slight subsidence	Original edge slightly collapsed usually resulting in a reduced edge dip
UC	Undercut	Original edge weakened due to being undercut, resulting in an overhang
XSB	Severe subsidence	Original edge severely collapsed usually resulting in a considerably reduced edge dip and/or a considerable increase in the surface area of the feature at ground level
CC	Conical collar	Normally only applies to underground features or collapsed shafts where the edges collapse to form a conical-shaped depression. An extreme special case of edge collapse
UK	Unknown	Edge stability unknown as cannot be observed
<b>EXCAV_METH</b>	<b>Excavation method</b>	
MEC	Mechanical	Excavation has definitely been made by machinery (e.g. bulldozer, excavator or loader). Commonly indicated by the dimensions and shape of the excavation and the location and shape of the extracted material
HND	Hand dug	Excavation has definitely been made by hand

## Appendix 1 (continued)

<i>Attribute/ Value</i>	<i>Attribute name/ Value name</i>	<i>Description</i>
<b>FEAT_GROUP</b>	<b>Feature group</b>	
CS	Collapsed shaft	Shaft currently <2 m deep, but showing evidence of greater original depth. Evidence may include substantial bunds and remnant collar materials
CUT	Opencut	Surface working in which the working area is kept open to the sky (American Geological Institute, 1997, henceforth referred to as AGI). In WABMINES, opencut features are pits/quarries >2 m deep and costeans/trenches of any depth
DU	Dump	Pile or heap of ore, coal, or waste at a mine (AGI, 1997). In WABMINES, dump types are: waste dump, rock and soil, topsoil, rubbish dump, ash dump, tailings, leach pad, and ramp/tramway, not necessarily at a mine
IN	Infrastructure	Basic facilities, equipment, roads, and installations needed for the functioning of a system (AGI, 1987). In WABMINES, infrastructure types are: buildings, headframe/winder, machinery, battery/mill, shaft footing, dam/sump, town remnant, chimney, and other
RH	Rehabilitated	Restored to a previous condition (Little et al., 1973). In WABMINES this mainly refers to remedial bulldozing and ripping. Where possible, the type of feature that has been rehabilitated is also listed under TYPE (e.g. shaft or costean)
SHW	Shallow working	Pit, cavity, hole, or other uncovered cutting produced by excavation and <2 m deep. Areas of multiple similar features can be recorded by a centroid location and the dimensions recorded in the MINE_NOTE section
UI	Under infrastructure	In WABMINES this refers to historic underground, opencut or infrastructure features that are now either beneath, or have been removed in the development of, more recent features. Usually located from aerial photographs, and historical and company maps
UG	Underground	Below the surface of the ground (Little et al., 1973). In WABMINES this refers to the following types of mining features: shaft, well, multiple shafts, open stope, adit, decline, subsidence, and collapsed drillhole
<b>FENCES</b>	<b>Fences</b>	
OP	Open	Feature is partly surrounded by a fence of any type or condition. Type and condition should be described in MINE NOTES and be evident in photographs
FE	Fenced	Feature is completely surrounded by a fence of any type or condition except a locked gate. Type and condition should be described in MINE_NOTE and be evident in photographs
LG	Locked gate	Access to the feature cannot be easily gained through the fence. The only entrance is a locked gate. This type of fence is commonly high, of small-mesh construction and may have barbed wire around the top
<b>HEIGHT</b>	<b>Height</b>	Estimated maximum height from ground level to top of feature in metres
<b>HMAPID</b>	<b>1:100 000 map index number</b>	1:100 000 map reference
<b>LENGTH</b>	<b>Length</b>	Estimated maximum length of a feature at ground level in metres. Refers to the longer dimension of an adit opening (portal) as though it were a near horizontal shaft
<b>MINE_NOTE</b>	<b>Mine notes</b>	Comments relating to any non-geological aspects of the feature
<b>NORTHING</b>	<b>Northing</b>	Map Grid Australia northing reference in metres. Datum is Geocentric Datum of Australia 1994 (GDA94)
<b>NOTES</b>	<b>Field notes</b>	Geological comments including rock types, degree of weathering, structural measurements, and types, dimensions and orientation of mineralization. Some records also contain observations on vegetation types
<b>OBSDATE</b>	<b>Observation date</b>	Date on which the data were recorded
<b>OP_OPENING</b>	<b>Opencut opening</b>	
YOU	Yes	One or more underground openings are visible within an opencut feature. The opening may be a shaft, stope or adit. If possible, these features are also described as separate sites
<b>PRECISION</b>	<b>Precision</b>	Precision of the Global Positioning System (GPS) location in metres
<b>QMAPID</b>	<b>1:250 000 map index number</b>	1:250 000 map reference
<b>RAMP</b>	<b>Ramp condition</b>	
GORA	Good	Ramp appears as though it can be safely accessed. Used mainly for opencut features and dumps
PORA	Poor	Ramp access to a feature is possible, but the ramp appears to be potentially hazardous due to either severe erosion or actual or potential side wall collapse. Mainly used for opencuts and dumps
LA	Limited access	Vehicular ramp access to a feature is difficult or impossible due to an obstruction such as a trench, bund or fence. Mainly used for opencuts and dumps



## Appendix 1 (continued)

<i>Attribute/ Value</i>	<i>Attribute name/ Value name</i>	<i>Description</i>
<b>REVEG</b>	<b>Revegetation</b>	
FURE	Full	Feature is vegetated in a similar manner to the surrounding undisturbed area
PARE	Partial	Some vegetation is established on the feature, but less than on the surrounding undisturbed area
NO	None	No vegetation at all is associated with the feature
<b>SHAPE</b>	<b>Shape</b>	
CN	Cone	Three dimensional, cone shaped. Used exclusively for dumps
OVL	Oval	Oval shaped in plan view. Mainly used for dumps or pits and quarries
RE	Rectangular	Rectangular shaped in plan view. Mainly used for dumps and assumed for excavations
SB	Slab	Three-dimensional shape with rectangular plan view and relatively low flat and level upper surface. Mainly used for tailings dumps and leach pads
OTSH	Other	Shape other than cone, oval, rectangular or slab, commonly meaning irregular. Used mainly for dumps. May be more fully described in MINE_NOTE
<b>SIGNS</b>	<b>Signs</b>	
YSI	Yes	Warning sign is visible, clearly relating specifically to the recorded feature
<b>SITENO</b>	<b>Site number</b>	Unique database generated number for each site. Used to link records between tables
<b>SITEID</b>	<b>Site identification</b>	Unique name recorded by the user for each site, comprising the user's initials and a sequential number
<b>STRIKE</b>	<b>Strike</b>	Direction or trend of a feature in degrees Grid. Used for trends of linear surface features such as costeans and the long axes of opencuts and dumps. Also can be used for planar underground features such as open stopes in conjunction with dip using the right hand rule (when facing the direction of the strike bearing, the dip is to the right). Use 0° for north
<b>TYPE</b>	<b>Type</b>	
AD	Adit	Horizontal or nearly horizontal passage driven from the surface for the working or dewatering of a mine (AGI, 1997). In WABMINES, the dip of the feature can be up to 20°
ASH	Ash dump	Inorganic residue after burning (Jackson, 1997). Commonly indicates the former presence of a boiler used for steam production
BM	Battery/mill	Battery: a series of stamps, commonly five, operated in one box or mortar, for crushing ores; also the box in which they are operated (AGI, 1997). Mill: a mineral treatment plant in which crushing, wet grinding, and further treatment of ore is conducted (AGI, 1997). In WABMINES, it may also include a power station or pump house
BU	Building	Office, workshop, house or shed not included under battery/mill
CD	Collapsed drillhole	Surface subsidence around a drillhole collar
CH	Chimney	The passage or flue by which the smoke from a fire, etc., ascends (Little et al. 1973). In WABMINES, it refers to a chimney, smokestack or funnel
CO	Costean/trench	Costean: a trench cut across the conjectured line of outcrop of a seam or orebody to expose the full width (Nelson, 1995). Trench: in geological exploration, a narrow shallow ditch cut across a mineral deposit to obtain samples or to observe character (AGI, 1997)
DC	Decline	A development opening driven from the surface to any level or between any two levels in a mine at gradients permitting the use of trackless equipment (W.A. Government, 1994)
DM	Dam/sump	Dam: any accumulation or storage of water, whether natural or artificial (W.A. Government, 1978). Sump: a pit or basin in which the returns from a borehole are collected and stored and in which the cuttings settle before recirculating the cuttings-free fluid (AGI, 1997). For WABMINES, includes tank
HW	Headframe/winder	Headframe: the steel or timber frame at the top of a shaft that carries the sheave or pulley for the hoisting rope and serves various other purposes (AGI, 1997) Winding apparatus: the machinery and equipment used to lower and raise loads through a shaft (AGI, 1997)
LP	Leach pad	Leach pile: mineralized materials stacked so as to permit wanted minerals to be effectively and selectively dissolved by application of a suitable solute (AGI, 1997)
MA	Machinery	Includes all mechanical appliances of whatever kind used or intended to be used for any mining purpose (W.A. Government, 1978). In WABMINES this can include a boiler, pump or winder engine
MSH	Multiple shafts	Discontinued use. Referred to a group of shafts. From 1/1/02, all shafts are recorded as separate features
OS	Open stope	An underground working place either unsupported or supported by timbers or pillars of rock (Pryor, 1963). In WABMINES this refers to either a vertical or inclined underground excavation that follows the orebody, is open to the surface, and appears to have been formed primarily by the removal of ore from beneath
OTIN	Other infrastructure	Includes any infrastructure not covered by the types: battery/mill, buildings, chimney, dam/sump, headframe/winder, machinery, shaft footings or town remnant. Details should be included in the MINE_NOTE section

## Appendix 1 (continued)

Attribute/ Value	Attribute name/ Value name	Description
PI	Pit/quarry	Pit: a mine, quarry or excavation worked by the opencut method to obtain material of value (AGI, 1997). Quarry: an open or surface mineral working, usually for the extraction of building stone (slate, limestone, etc.). It is distinguished from a mine because a quarry usually is open at the top and front (AGI, 1997)
RD	Rubbish dump	Dump consisting of rubbish
RS	Rock and soil dump	Dump that consists of a mixture of rock and soil and hence is neither a waste dump nor a top soil dump
RT	Ramp/tramway	Ramp: an inclined approach; used loosely when applied to a loading ramp (AGI, 1997). Tramway: a roadway having plates or rails on which wheeled vehicles may run (AGI, 1997). In WABMINES, ramp applies to a loading ramp. Tramways are usually made of waste rock and adjacent to shafts
SF	Shaft footing	Footing associated with a shaft and/or headframe
SFT	Shaft	An excavation of limited area compared with its depth; made for finding or mining ore or coal, raising water, ore, rock, or coal, hoisting and lowering workers and material or ventilating underground workings (AGI, 1997). In WABMINES, current usage only includes workings >2 m deep. Prior to June 2002, did include shallower collapsed and rehabilitated shafts
SUUG	Subsidence	The sudden sinking or gradual downward settling of the earth's surface with little or no horizontal motion (AGI, 1997). In WABMINES, refers to surface subsidence due to apparent internal collapse of underground feature
TADU	Tailings dump	Tailings: the gangue and other refuse material resulting from the washing, concentration, or treatment of ground ore (AGI, 1997). Tailings are normally held within a tailings dam. Tailings dam: one to which slurry is transported, the solids settling while the liquid may be withdrawn (AGI, 1997)
TR	Town remnant	Remains of a town site that either do not specifically fit into any of the following categories: buildings, chimney, dam/sump or rubbish dump, or are too numerous to warrant individual description
TS	Topsoil dump	Topsoil: the dark-coloured upper portion of a soil varying in depth according to soil type (Jackson, 1997). In WABMINES refers to a dump made primarily of soil. These dumps are normally set aside from the waste rock for rehabilitation purposes
WD	Waste dump	The area where mine waste or spoil materials are disposed of or piled (AGI, 1997)
WE	Well	Discontinued use. From 1/1/02, all wells are recorded as shafts or dams/sumps. Well: a borehole or shaft sunk into the ground for the following purposes: obtaining water, oil, gas or mineral solutions from an underground source (AGI, 1997)
<b>UG_ACCESS</b>	<b>Underground access</b>	
LD	Ladder	Timber or metal ladder used for access in an underground feature is visible. Ladder is not necessarily safe to use
RP	Rope	Rope or steel cable used for access in an underground feature is visible. Rope is not necessarily safe to use
SR	Side ramp	Ramp used for accessing an underground feature
ST	Steps	Steps used for accessing an underground feature
OTUA	Other	An alternative form of access to an underground feature is visible, other than a ladder, side ramp, steps or rope. The form of access should be recorded in MINE_NOTE
<b>UG_HEADFRM</b>	<b>Underground headframe condition</b>	
GOUH	Good	Headframe for an underground feature is intact, secure, and is not likely to cause harm or injury
POUH	Poor	Headframe for an underground feature is either incomplete, insecure or collapsed
<b>UG_SEAL_CO</b>	<b>Underground seal condition</b>	
GOUH	Good	Entrance to an underground excavation has been blocked to the extent that the feature is inaccessible
POUE	Poor	Entrance to an underground feature has not been blocked to the extent, or in such a way as to prevent entry
<b>UG_SEAL_TY</b>	<b>Underground seal type</b>	
CT	Concrete	Entrance to an underground excavation has been blocked largely by concrete. Concrete is usually in the form of a slab or block
ME	Mesh	Entrance to an underground excavation has been blocked largely by steel mesh
PAUS	Partial	Entrance to an underground excavation that is only partially blocked, irrespective of the material used
RUUS	Rubbish	Discontinued use after 31/7/02
SP	Steel plate	Entrance to an underground excavation has been blocked largely by steel plating
TM	Timber	Entrance to an underground excavation has been blocked largely by timber
TN	Tin	Entrance to an underground excavation has been blocked largely by tin
OTUS	Other	Entrance to an underground excavation has been blocked largely by something other than concrete, mesh, timber, tin or steel plate. The material should be described in MINE_NOTE

## Appendix 1 (continued)

<i>Attribute/ Value</i>	<i>Attribute name/ Value name</i>	<i>Description</i>
<b>UG_TIMBERS</b>	<b>Underground timber condition</b>	Condition of the material (usually timber) used to support the collar of an underground feature
GOUT	Good	The material appears to be able to provide effective support for the collar. Collar: The term applied to the timbering or concrete around the mouth or top of a shaft (AGI, 1997)
POUT	Poor	The material is unable to provide effective support for the collar. Poor-condition timbers may include only minor remnants of the former collar
<b>VISIBILITY</b>	<b>Visibility</b>	
VI	Visible	Capable of being seen (Little et al., 1973). In WABMINES a feature is visible when it can be viewed from a moderate distance
PH	Partially hidden	Feature partially concealed from view from a moderate distance
HD	Hidden	Concealed (Little et al., 1973). In WABMINES a feature is hidden commonly by vegetation when concealed from view from a moderate distance
NX	No surface expression	Feature is not visible from a moderate distance because it does not project above ground level
<b>VISUAL_IMP</b>	<b>Visual impact</b>	
HI	High	Any large feature and some moderately sized features that are disturbed by recent activity, untidy, with rubbish, and in poor condition
MO	Moderate	Medium-sized feature that is either disturbed by recent activity or untidy with some rubbish and plant debris or in fair condition
LO	Low	Any small feature and some moderately sized features that are undisturbed by recent activity, tidy, without rubbish and in good condition
<b>WATER</b>	<b>Water condition</b>	
BK	Black	Water at the base of the feature is black in colour. Used mainly for opencut features
BR	Brown	Water at the base of the feature is brown in colour. Used mainly for opencut features
CL	Clear	Water at the base of the feature is colourless. Used mainly for opencut features
GN	Green	Water at the base of the feature is green in colour. Used mainly for opencut features
<b>WIDTH</b>	<b>Width</b>	Estimated maximum width of feature at ground level in metres. For features with a high length to width ratio such as costeans, an average width is given

**NOTES:** WABMINES: Western Australian abandoned mine sites database  
An empty field means either 'none' or 'null' (i.e. not recorded)

## References

- AMERICAN GEOLOGICAL INSTITUTE, 1997, Dictionary of mining, mineral and related terms: Virginia, USA, American Geological Institute, 646p.
- JACKSON, J. A., (editor), 1997, Glossary of Geology (4th edition): Virginia, USA, American Geological Institute, 788p.
- LITTLE, W., FOWLER, H. W., and COULSON, J., 1973, The Shorter Oxford English Dictionary; on historical principles (3rd edition) *edited by* C. T. ONIONS *revised by* G. W. S. FRIEDRICHSEN: Oxford, U.K., Clarendon Press.
- WESTERN AUSTRALIAN GOVERNMENT, 1978, Mining Act, 1978: Perth, Western Australia, Government Printer, Part 1, p. 8.
- WESTERN AUSTRALIAN GOVERNMENT, 1992, W.A. Explosives and Dangerous Goods (Dangerous Goods Handling and Storage) Regulations: Perth, Western Australia, Government Printer, Part 1, Preliminary, r. 1.3., p. 2.
- WESTERN AUSTRALIAN GOVERNMENT, 1994, Mines Safety and Inspection Act, 1994: Perth, Western Australia, Government Printer, Part 1, Preliminary, s. 4, p. 3.



## Appendix 2

## List of acronyms and abbreviations

---

AGI	American Geological Institute
ANZECC	Australian and New Zealand Environment and Conservation Council
ANZMEC	Australian and New Zealand Minerals and Energy Council
APLA	Amalgamated Prospectors and Leaseholders Association of Western Australia
BLM	Bureau of Land Management (U.S.A)
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act (U.S.A)
CWA	Clean Water Act (U.S.A)
CALM	Western Australian Department of Conservation and Land Management
DGPS	Differential Global Positioning System
DoIR	Western Australian Department of Industry and Resources
DOLA	Western Australian Department of Land Administration
DME	Western Australian Department of Minerals and Energy (now DoIR)
DBF	Database format
EPIRB	Emergency Position Indicating Radiobeacon
GeoVIEW.WA <sup>†</sup>	GSWA's integrated geoscience information system
GIS	Geographic Information System
GML	Gold mining lease
GPS	Global Positioning System
GSM	Global system for mobiles
GSWA	Geological Survey of Western Australia
IIED	International Institute for Environment and Development
MELC	Minerals Environment Liaison Committee
MGA	Map Grid Australia
MH	MINEDEX historic mine site
MINEDEX	DoIR's mines and mineral deposits information database
MPR	Western Australian Department of Mineral and Petroleum Resources (formerly DME, now DoIR)
PC	Personal computer
PDOP	Position Dilution of Precision
SHED	Safety, Health and Environment Division (DoIR)
TENGRAPH*	DoIR's electronic tenement-graphics system
TIF	Tagged image file format
UNEP	United Nations Environment Programme
WABMINES	Western Australian abandoned mine sites database
WAMEX	Western Australian mineral exploration database
WAMIN	Western Australian mineral occurrence database
WAROX	Western Australian field observation database

---

**NOTE:** \* TENGRAPH is a registered Trade Mark for DoIR;

<sup>†</sup> pending