The clean-up of the plant at Bracken Gold Mine

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Synopsis

Bracken Gold Mine ceased mining operations during February 1993. The clean-up of the gold plant, which had already commenced in September 1992, was completed in January 1994. The mine had been in production since early in 1962 but, because of a decreasing ore reserve, increasing working costs, and a relatively low gold price, closure had become inevitable.

The closure had been under consideration since August 1983, when the first estimate was made regarding the amount of gold that could be recovered from the clean-up operations. Until that stage, it had been accepted that Bracken would conform to the commonly accepted idea that 0.25% of the total gold produced by the plant would be recovered during the clean-up operation. This idea was dispelled when the initial estimates indicated that the gold recovery would vary between 0.049 and 0.095%. The actual figure realized was 0.036%, showing that there is no general formula for the calculation of the amount of gold to be recovered from such clean-up operations.

During the clean-up operation, Bracken became an unexpected contributor to the State's Reconstruction and Development Programme by having all the mine and plant buildings purchased and converted into a community development centre. This shortened the time available for the clean-up, and several of the buildings remained intact. However, the foundations and sub-soils had been sampled extensively, and it is considered that no recoverable gold was left behind.

Introduction

Bracken Gold Mine is situated near Evander, in the southeastern Transvaal. Bracken was the second gold mine to be brought into production in the Evander basin after Winkelhaak Gold Mine, and officially started production in February 1962. By the time production had ended in January 1994, 238.1 kg of gold had been produced from the 31.8 Mt of ore mined. These figures relate to Bracken Gold Mine only[1]. However, for a consideration of the total gold produced by the Bracken plant, the toll-milling of Winkelhaak low-grade ore and Kinross ore also needs to be taken into account. This information is given in Table I.

Bracken Gold Mine was planned as a relatively short-life, high-grade mine from the start. The plant was designed as a run-of-mine milling plant, which was a new and unproven concept at that stage. This design rejected the traditional crushing, screening, and multi-stage milling approach in favour of single-stage milling and classification. This change resulted in a plant of very compact design.

Table I

Total throughput and gold produced by the Bracken plant[2–4]

Mine	Material milled, t	Gold produced, kg
Bracken	31 832 569	238 134
Winkelhaak	66 348	44
Kinross	259 500	1 575
Total	32 158 417	239 753

By the early 1980s, it became apparent that the ore reserves were running out, and that closure was inevitable. Preliminary closure plans were initiated at that stage, involving the early calculations and investigations that are given in this paper, together with details of the eventual closure of the Bracken gold plant.

Records from the previous clean-up of gold-plants had given the gold-recovery figures reproduced in Table II. As shown, a significant amount of gold had been recovered from these pre-1985 clean-up operations, and the expectation of a high recovery from the clean-up in the case of the Bracken plant also prevailed. In fact, a gold-recovery figure of 0,25% of the total gold produced was assumed. Included in Table XIII is an estimate of the gold recovery based on the Harmony formula as given in a recent publication[8]. Calculations based on this formula indicated that the plant lock-up would be 0.30% of the total gold produced by the plant. Although the origin of this formula is not clear, the estimate is included to emphasize the high expectations that are generally held regarding the clean-up of a gold plant.

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Table II

Gold produced from plant clean-up operations[5–7]

Mine	Total gold produced kg	Clean-up gold produced kg	Clean-up gold %
Modderfontein Deep	187 000	528	0.282
East Geduld	524 434	1 857	0.354
St. Helena	615 689	2 719	0.442
Grootvlei (partial clean-up)	565 603	2 166	0.383
Marievale	272 400	394	0.145
WRCM—West Plant (estimate)	64 000	180	0.281

Clean-up administration

The administration relating to the clean-up of the Bracken plant was scheduled in such a way that a comprehensive record would be kept of all the data related to the following: the tonnages and grades of the material treated, the origin of the material, the treatment route, the scheduling of the treatment of materials from different sources, the final amount of gold recovered, the costs of treating the clean-up material, and the related excavation and restoration costs. This information was collected in order to provide data for the future clean-up of other gold plants in the GENCOR group, and specifically run-of-mine milling plants.

The Bracken closure

Early calculations and investigations

During August 1983, the management of the Bracken plant was asked to provide an estimate of the amount of gold that would be recovered from clean-up operations at the plant. This request referred to the fact that gold plants that had been cleaned up after mine closures in the past had produced at least 0.25% of their total gold production[9], as detailed in Table II. It was tacitly assumed that the Bracken plant would follow this trend and, on the basis of the gold produced by Bracken up until that time, it was expected that the clean-up would result in the recovery of at least 520 kg of gold[10]. However, detailed sampling of the identified clean-up areas at Bracken resulted in an estimate of only 110 kg of gold being recoverable[11].

In July 1988, the management was asked to submit a further estimate of the recoverable gold from the clean-up of the gold plant[12]. It was acknowledged that a run-of-mine milling plant generally produced less spillage than a conventional washing, screening, crushing, and multi-stage milling plant, thereby reducing the amount of gold available for clean-up. Since there was no precedent for the clean-up of a run-of-mine milling plant, it was regarded as reasonable that 0.10% of the total gold produced at a recovery of 95% be taken as the estimated gold production. Based on the gold produced by Bracken up to that date, this amounted to 217 kg of recoverable gold.

A survey to identify potential high-grade clean-up areas in the plant was subsequently requested[13]. The assay results for 25 samples taken from various sections of the plant varied from 0.7 to 3807 g/t of gold. Because of the limited value of this exercise, no further work was done[14].

Following on from the previous sampling exercise, an extensive sampling programme was undertaken during December 1989 and January 1990. Laboratory dissolution tests were also performed on selected samples[15]. The exercise started with the establishment of a sampling grid for the plant area, consisting of 107 sample points spaced at 20 m intervals. Figure 1 shows the plant area, while Table III indicates the location of the sample for each sampling point on the grid and gives the assay values for a surface sample, a sample taken at a depth of 0.5 m, and one taken at 1.0 m. The results of the dissolution tests are given in Table IV.

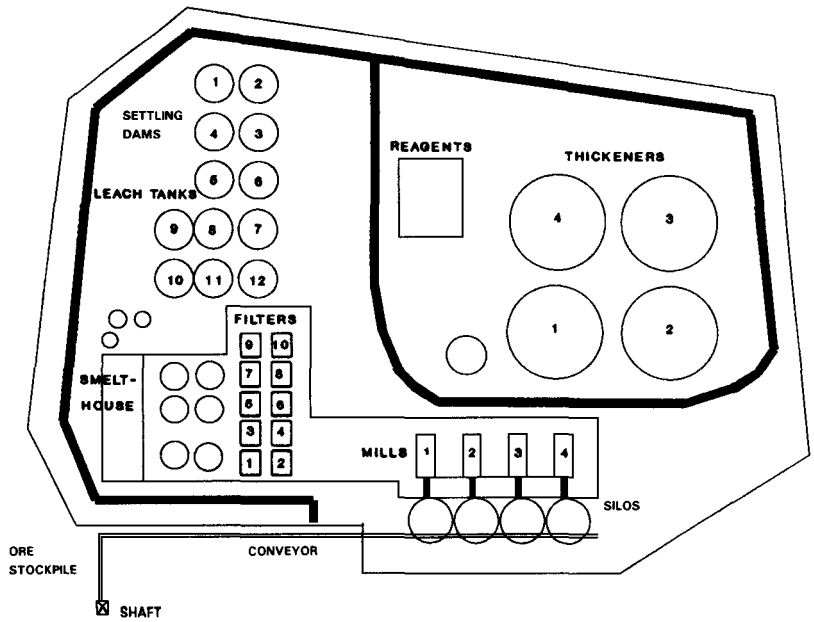

Figure 1—Layout of the Bracken metallurgical plant

Table III

Assay value for the grid samples

Plant area	Sample number	A Surface Au g/t	B Au at 0.5 m g/t	C Au at 1.0 m g/t	Average Au value g/t
Thickeners	4	4.79	0.72	2.27	2.59
	6	0.56	0.32	0.51	0.46
	8	0.11	<0.01	<0.01	0.04
	11	6.09	1.57	0.65	2.77
Mills	13	1.71	0.29	1.37	1.12
	14	3.49	0.13	0.22	1.28
	15	0.85	0.43	0.18	0.49
	18	17.43	2.57	1.13	7.04
Thickeners	20	1.37	0.21	<0.01	0.53
	23	0.65	<0.01	<0.01	0.22
	25	0.43	1.83	0.22	0.83
Mills	33	63.90	3.53	3.24	23.56
	34	143.30	0.89	0.76	48.32
	36	17.38	0.17	0.44	6.00
	37	1.57	0.28	0.34	0.73
	38	164.00	0.21	0.13	54.78
	42	0.30	0.62	<0.01	0.31
	44	3.02	0.41	0.07	1.17
	46	11.42	1.69	0.37	4.49
	48	1.22	0.36	0.20	0.59
	49	2.62	2.87	6.71	4.07
	50	4.72	0.55	0.62	1.96
	55	0.50	0.81	0.55	0.62
	56	221.80	1.75	1.83	75.13
	61	1.44	0.18	0.05	0.56
	62	30.00	0.93	3.99	11.64
Reagents	65	0.25	<0.01	<0.01	0.08
	67	2.45	<0.01	<0.01	0.82
	69	0.02	<0.01	<0.01	0.01
	72	0.47	2.08	1.64	1.40
	73	0.46	1.18	1.21	0.95
	74	0.94	1.18	1.21	1.11
	75	0.94	1.18	0.73	0.95
Leach	77	0.92	0.72	0.53	0.72
	78	3.15	0.41	1.13	1.56
	79	0.98	0.49	0.19	0.55
	80	0.82	2.85	0.27	1.31
	81	11.42	1.31	2.85	5.19
	82	24.12	1.45	1.32	8.96
Filter	88	0.97	0.17	0.39	0.51
Smelthouse	91	2.10	2.02	5.91	3.35
	92	9.83	0.53	0.62	3.66
	93	4.52	0.33	0.32	1.72
	94	5.47	4.49	2.95	4.30
	95	55.53	3.07	0.95	19.85
	96	1.81	4.01	0.73	2.18
	97	0.93	1.16	0.57	0.89
	98	1.51	0.69	1.07	1.09
	99	1.73	1.53	0.55	1.27
	100	2.51	1.41	0.33	1.42
	101	1.13	2.23	0.18	1.18
	103	2.45	0.33	0.23	1.00
Conveyor section	106	1.53	4.40	1.39	2.44
	107	0.35	0.49	<0.01	0.28
Waste-rock dump	108				1.79
Toe dam	109				6.01

It should be noted that certain samples could not be taken for reasons of inaccessibility. The assay results given in Table III show that the mill and filter buildings, the smelthouse, and the surrounding areas constituted the higher-grade areas of the plant. Furthermore, the grades decreased with depth. The dissolution tests indicated that generally more than 86% of the gold could be recovered by cyanidation. Based on these results, 229.8 kg of gold was calculated to be locked-up within the plant area contained in 84 kt of total material available for treatment. At a recovery of 86%, this equates to 197.6 kg of clean-up gold being recoverable, or 0.087% of the total gold produced by the plant over its operating lifetime.

Table IV

Results of laboratory dissolution tests

Sample	Type of material	Head value Au g/t	Solution value Au g/t	Washed residue Au g/t	Dissolution %
20–A	Rock	1.37	0.83	0.11	91.97
23–A	Soil	0.65	0.01	0.33	49.23
42–A	Rock & concrete	0.30	0.89	0.13	56.67
42–B	Rock & soil	0.62	0.51	0.08	87.10
46–A/B/C	Soil	4.49	2.98	0.28	93.76
50–A/B/C	Soil	1.96	1.71	0.24	87.76
56–A	Concrete	221.80	115,20	10.16	95.42
56–B/C	Soil	1.79	1.62	0.37	79.33
91–A/B	Rock & concrete	2.06	1.01	0.39	81.07
91–C	Rock & concrete	5.91	3.98	2.14	63.79
106–A/B/C	Rock & concrete	2.44	2.11	0.19	92.21
108	Rock & concrete	1.79	3.23	0.17	90.50
109	Rock	6.01	2.11	0.32	94.68

Notes

(1) **Head Value**
The head value given for all the leaching tests is that obtained during the sampling exercise (Table III). It is the average value for samples A, B, and C unless otherwise stated.

(2) **Conditions for the Leaching Tests**
(a) Grading 83% – 75 µm
(b) Water-to-solids ratio 1
(c) Lime addition (as 100% CaO): minimum 1875 ppm CaO, or conditioning to pH 11,5
(d) Cyanide addition (as 100% NaCN), ppm
Rock samples 200
Soil samples 400
Concrete samples 1000
(e) Bottle-rolling period 24 h
(f) All tests in duplicate

During 1991, a financial exercise based on the costs of excavating and treating the clean-up material established that the payable gold grade[16] was 1.69 g/t. The lower-grade areas were therefore excluded from the cleaning-up exercise. Based on an excavation depth of 1 m, the higher-grade areas amounted to 33.36 kt of material at an average gold grade of 4.0 g/t. At a recovery of 86%, 114.8 kg of gold would be recovered, representing 0.049% of the total gold production up to that time. The main area targeted for the clean-up included the mill buildings, the filter building, the smelthouse, and their surrounding areas.

Actual plant clean-up

The clean-up of the Bracken gold plant started during September 1992. At that stage, underground ore was still being treated, albeit at ever-reducing tonnages. The last

underground ore was treated at Bracken on 15th February, 1993, and the Bracken plant was stopped on 28th April, 1993. The clean-up material remaining at that time and about 7 kt of underground ore was then transported to the Leslie plant. The treatment of Bracken clean-up material ceased during January 1994, and the rehabilitation of the Bracken plant and its environs was completed during October 1994.

A complete record was kept of all the sampling procedures and sample values in the various sections of the plant[17]. Tables V to XI give the assay values of the special clean-up samples taken in the different sections. The range of values obtained shows the highly variable nature of the clean-up material. This information was used by the plant staff in deciding whether the material would be treated or dumped.

Table XII gives a summary of the gold recovered during the various months that the clean-up was in operation based on the assay values obtained for each section as given in Tables V to XI. Representative samples of all the materials treated were leached in the laboratory to provide the respective recovery values.

Shaft bins, conveyors, and ore stockpile

The waste-rock conveyor section was cleaned first and the equipment removed. The shaft bins and ramp area were subsequently sampled and treated, followed by the dismantling of the ore conveyors to the mill silos. The ore stockpile was sampled, and excavated to a depth of 0.5 to 1 m to ensure that no gold-bearing material was left behind. All this material was treated at the Bracken plant. The assay ranges of the special samples taken in specific areas are given in Table V.

Mill section and silos

The dead loads in the silos were removed, and each silo was washed out. All the mill liners were removed, and the concentrate was tabled. The insides of the mill shells were de-scaled with needle de-scalers to remove all traces of concentrate, and were then scoured with concrete. The mill feed and discharge hoppers, and the cyclone underflow and overflow boxes, were cleaned, while the feed belts, gantries, and cyclones were removed and cleaned. All this material, except that from the last mill, was treated at Bracken, while the material from the last mill was treated at Leslie. The particularly high values from the scale material should be noted. Great care was taken to remove all this material from the mill buildings and trenches, but the tonnages were very low. Table VI gives the range of assay values for all the special samples taken in the mill silo section and mill buildings.

Table V

Special clean-up samples: shaft bins, conveyor area, and ore stockpile

Sample	Range of assay values, Au g/t	No. of samples
Ramp	0.48 to 0.97	6
Reef box	5.17 to 50.93	4
Shaft-bin area	0.57 to 4.16	6
Ore stockpile	0.51 to 3.89	6

Table VI

Special clean-up samples: mill section and silos

Sample	Range of assay values, Au g/t	No. of samples
Pedestal and foundation concrete	0.31 to 2.14	3
Mill silo dead load	5.03	1
Mill silo liner scaling	4.18 to 41.18	3
Mill floor scaling:		
General	0.65 to 125.14	7
Top 2 mm only	541 to 13 360	4
Mill Floor:		
0 to 0.1 m depth	3.60	1
0.1 to 0.3 m depth	1.40	1
0.3 to 0.7 m depth	1.04	1
0.7 to 1.0 m depth	0.15	1
Trench spillage	234 to 5 317	12
Trench scaling	610	1
Mill feed hopper	140 to 15 960	3
Mill load	380 to 1 004	2
Mill shell scaling	117 to 2 920	5
Cyclone boxes load	15 to 1 930	5
Cyclone overflow launder scaling	13 to 743	7
Mill return dam scaling	0.31 to 19.0	4

Thickener Section

A hydraulic breaker was used to break the concrete thickeners after the solids had been washed out. The separation of the steel reinforcing from the concrete was very time-consuming and, because of the low gold assays reported for the concrete, this material was dumped and only the scale was treated at Bracken. The area around the thickeners was also extensively sampled to a depth of 2 m, but the assay values were low. The ranges of assay values for the special samples taken in the thickener section are given in Table VII.

Leaching section and settling dams

The number of leaching tanks used was reduced progressively in accordance with the tonnage treated, and the tanks were washed out and de-commissioned. Previous sampling had shown that the area was of relatively low grade. The additional samples taken from this section gave the range of assay values shown in Table VIII, which confirmed the low values obtained on all but the scale material. This material was treated at Bracken during the clean-up operation as it became available. Spillage from the leaching section had accumulated in settling dams adjoining the section over the years. These dams were also cleaned, and the material was treated at Bracken.

Table VII

Special clean-up samples: thickener section

Sample	Range of assay values, Au g/t	No. of samples
Thickener foundation	0.01 to 1.00	4
Thickener:		
Wall	0.29 to 0.87	8
Floor	0.11 to 1.83	16
Bed	14 to 426	3
Thickener area soil:		
Surface	0.10 to 2.19	9
0 to 1 m depth	0.13 to 0.5	8
1 to 2 m depth	0.09 to 0.95	6
Thickener feed pipe scaling	33.48 to 133.13	4
Thickener scaling	1.60 to 6.07	11
Thickener rake scaling	15.78 to 450.76	4
Dorrco launder scaling	16.93 to 17.53	3

Table VIII

Special clean-up samples: leaching section and settling dams

Sample	Range of assay values, Au g/t	No. of samples
Leach tanks scaling	3.11 to 72.33	11
Leach tanks spillage	8.96	1
Pipes scaling	1.79 to 66.69	3
Leach tanks grit	2.83 to 5.15	3
Settling dams	1.37 to 4.79	8

Filter section

The filter area was originally considered to be a high-grade area but, apart from scale and some slime found below the drainage floor, the material in the area was of low grade. All the scale was removed with hammers and treated. The spillage was removed and treated at Bracken. The ashed timber material of the filter drum was treated at Leslie. Table IX gives the range of assay values for the special samples taken from this section.

Precipitation section and smelthouse

The smelthouse, in particular, was thoroughly cleaned since, in addition to gold smelting, mill gold had been treated in this area for the recovery of osmiridium since 1967. The building structures were thoroughly hosed down, and all the material collected was treated at Bracken, except for the concrete below the arc furnace, which was treated at Leslie. Table X gives the range of assays for the special samples taken in this area. Again, the tonnages were low.

Waste-rock dump

The remnants of the waste-rock dump were also sampled to ensure that any profitably recoverable material would be treated before the closure of the Bracken plant and the rehabilitation of the area. This material contained significant amounts of boiler ash and general rubbish, and its grade was too low for economic recovery. The rehabilitation of the dump area was therefore given the go-ahead, and the remaining waste rock was used as land-fill. Table XI gives the results for the special samples taken.

Summary of clean-up operations

A summary of the material treated during the months that the clean- up was under way is given in Table XII. A total of 85.959 kg of gold was recovered from the clean-up operations at the Bracken gold plant over a period of 17 months. A record was kept of all the costs incurred during the clean-up period from September 1992 to January 1994, including salaries, treatment costs, transportation costs, excavation costs, and other related costs. It was shown that a profit was made from the clean-up operations during this time, and this was used for further rehabilitation of the Bracken property (Table XII).

In accordance with the legal requirements of plant closure, a radiometric survey was conducted during the clean-up operations. The only areas that showed relatively high levels of radiation were the foundations of the shaking tables in the smelthouse. However, after this material had been excavated and treated for gold recovery, the radiation levels dropped to within the legal limits. This was not unexpected since the Kimberley Reef mined in the Evander area contains very low concentrations of radioactive minerals.

Table IX

Special clean-up samples: filter section

Sample	Range of assay values, Au g/t	No. of samples
Filter plant feed pipe scaling	108 to 784	3
Foundation concrete	0.91	1
Filter floor spillage	1.37 to 2.07	3
Filter pan scaling	1.65 to 7.62	4
Filter drum scaling	8.18 to 26.51	7
Filter plant pipe scaling	0.18 to 6.68	6
Filter drum timber	16.58	1
Ashed filter drum timber	29.23 to 391.33	3
Slime under drainage floor	2.29 to 2.42	4

Table X

Special clean-up samples: precipitation section and smelthouse

Sample	Range of assay values, Au g/t	No. of samples
Gold sump scaling	6.07 to 9.21	6
Zinc sulphate tank scaling	4 080 to 6 153	3
Barren solution tank scaling	0.27	1
Shaking table concrete	85 to 1 140	4
Shaking table floor concrete	29 to 332	6
Shaking table sump	37 796	1
Shaking table scaling	20 to 1 100	5
Arc furnace:		
Scrubber sump	85.32	1
Scrubber sump scaling	112 to 744	4
Arc furnace fan dust	920	1
Smelthouse trenches	243 to 1 918	7
Slag mill floor concrete	16 to 316	4

Table XI

Special clean-up samples: waste-rock dump

Sample	Range of assay values, Au g/t	No. of samples
Waste rock dump	0.46 to 0.64	3

Concluding remarks

The clean-up of the Bracken gold plant led to a recovery of 85.959 kg of gold, which equates to 0.036% of the gold produced by the plant over its total lifetime. This figure is significantly lower than that obtained from the clean-up operations in other gold plants. It is also lower than expected when compared with the calculations made during the various investigations prior to the clean-up. Table XIII summarizes the results of the various estimates.

The clean-up procedure followed at Bracken gold plant was carried out in accordance with a comprehensive recovery plan, which aimed at the recording and documentation of all the information from the clean-up. The data accumulated and the experience gained will be of great benefit in the future clean-up operations of run-of-mine gold plants.

It is clear that there is no universal formula for the prediction of the amount of gold that will be recovered from a gold plant at the end of its useful life. The gold recovered depends entirely on the design of the plant and the type of spillage management exercised during its production life. It is apparent that the compact nature of the Bracken plant was the main reason for the small amount of clean-up gold recovered.

Table XII

Summary of clean-up material treated[18]

Month	Origin of material	Estimated mass t	Gold recovered kg	Total cost of demolition R
September 1992	Mill: silos, launders, conveyors, cyclone boxes, settling dams	415.4	3.930	74 568
	Settling dams	715.0	1.869	
October 1992	Stockpile	1 860.0	6.512	52 614
November 1992	Filters: drainage floor slime, scaling	200.0	0.409	93 587
December 1992	—	—	—	61 213
January 1993	Thickeners	160.0	0.510	55 019
February 1993	Mills: foundations, concrete	243.0	1.100	36 094
March 1993	Mills: scaling, foundations	215.9	2.048	37 438
April 1993	Mills: scaling, mill load, cyclone boxes	16.0	15.472	49.739
May 1993	—	—	—	60 329
June 1993	Mills: launders, pipes, spillage, floor	1 603.0	17.040	118 343
	Filters: scaling	746.0	11.444	
July 1993	Mills: launders, floor scaling	157.0	3.704	72 385
August 1993	Mills: launders, scaling, concrete	120.00	6.355	173 706
September 1993	—	—	—	65 471
October 1993	Mills: launders, scaling, concrete	102.0	5.750	205 703
November 1993	—	—	—	246 055
December 1993	Smelthouse: shaking table, floor, concrete, scaling	3.0	4.900	232 155
January 1994	Smelthouse: floor, sumps, scrubber, furnace	40.0	4.916	64 763
Total		6 586.3	85.959	1 699 182
Income: average gold price received R36 000 per kg				3 094 524

Table XIII

Gold estimates for the Bracken clean-up

Number	Date	Clean-up gold recovered kg	Clean-up gold %
1	Historical formula	520.0	0.250
2	Harmony formula	719.3	0.300
3	August 1983	110.0	0.053
4	July 1988	217.0	0.095
5	December 1989	197.6	0.087
6	1991	114.8	0.049
7	January 1994	85.959 – Actual	0.036

It is to be noted that the complete clean-up of the Bracken plant as originally planned was not realized. Although the equipment, floors, sumps, and trenches were thoroughly cleaned and de-scaled, and the expansion joints in the buildings were checked and sampled for gold spillage, the clean-up of the plant was conducted in a much shorter period of time than had been planned. This was because the buildings were purchased early in 1994 by SASOL Limited for use, in accordance with the State's Reconstruction and Development Programme, as a community development centre. It is possible that complete demolition of all the buildings and foundations may have resulted in the recovery of additional gold. However, it is considered unlikely that this would have significantly affected the overall outcome of the clean-up.

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References

1. MOSELEY, R. Bracken Mines Limited, memorandum, Feb. 1994.
2. REYSENBACH, J. Effect of the treatment of Winkelhaak dump rock on Bracken plant results. Union Corporation Limited, 18th Jul., 1980.
3. KRUGER, S.F., and DE RUIJTER, M.A. Effect of the treatment of Winkelhaak dump rock on Bracken plant results. Union Corporation Limited, Dec. 1980.
4. DE RUIJTER, M.A. The toll-milling of Kinross ore at Bracken Mines Limited—a summary of the metallurgical aspects. General Mining—Union Corporation Limited, 26th Apr., 1983.
5. FUTCHER, G.W., and MORRIS, A.N. *Association of Mine Managers' Circular* no. 2/87. Aug. 1987.
6. VAN WALSEM, H.J., and DE RUIJTER, M.A. West Rand Consolidated Mines Limited, draft plan for the clean-up of the West Plant. Metallurgical Services Department, report no. MS/W/1989/001/01. 1st Feb., 1989.
7. COOKE, D.A. Private communication, Dec. 1994.
8. MCLOUGHLIN, G.K. The mini plant—Harmony clean-up operation. *Association of Mine Metallurgical Managers' Association Circular,* no. 2/94. Nov. 1994.
9. FREER, J.S. Private communication, Aug. 1983.
10. DE RUIJTER, M.A., HOLMES, T.J., and HODGES, C.G. Bracken Mines Limited, memorandum, Aug. 1982.
11. DE RUIJTER, M.A. Bracken Mines Limited, memorandum, Sep. 1983.
12. FREER, J.S. GENCOR memorandum, 3rd Aug., 1988.
13. FREER, J.S. GENCOR memorandum, 16th Sep., 1988.
14. OLIVIER, G.E., and CARTER, A.J. Bracken and Leslie Gold Mines—clean-up potential. Metallurgical Services Department, report no. MS/G/NFR/1989/014/01. 3rd May, 1989.
15. HOLMES, P.R., and DE RUIJTER, M.A. Clean-up potential and closure plan of the Bracken metallurgical plant. Metallurgical Services Department, report no. MS/BM/1990/015/01. 1st Feb., 1990.
16. GREYLING, F.E., and MOSELEY, R. Preliminary clean-up for Bracken gold plant. Metallurgical Services Department, report no. MS/BM/1991/001/01. 13th Nov., 1991.
17. MOSELEY, R. Special clean-up samples. Bracken Mines Limited, memorandum, Jun. 1994.
18. MOSELEY, R. Bracken Mines Limited, memorandum, Mar. 1994. ◆