

8 LIST OF REFERENCES

- ADAMSON, R.J. 1973. Gold metallurgy in South Africa. Johannesburg: Chamber of Mines of South Africa.
- ALLOWAY, B.J. 1995. Heavy metals in soils. London: Blackie Academic Professional Publisher.
- ALLOWAY, B.J. & AYRES, D.C. 1996. Chemical principles of environmental pollution. London: Blackie Academic Professional Publisher.
- AMERICAN PUBLIC HEALTH ASSOCIATION. 1995. Standard methods for the examination of water and waste water; nineteenth edition, Washington DC.
- AMERICAN SOCIETY FOR TESTING AND MATERIALS. 1990. Standard test method for pH of soils. Annual Book of ASTM Standards, 4, section 04.08: 1017-1019.
- ANTROBUS, E.S.A. & WHITESIDE, H.C.M. 1964. The geology of certain mines in the East Rand. (In: Haughton, S. H. ed. The geology of some ore deposits in Southern Africa. Vol. 1. Johannesburg: Geology Society of South Africa, pp. 126-160.)
- APPELO, C.A.J. & POSTMA, D. 1994. Geochemistry, groundwater and pollution. Rotterdam: Balkema.
- ASMAL, K. 1999. Groundwater map launch, Bisho, Eastern Cape on 1 February 1999. Speech by Prof. K. Asmal, Minister of Department of Water Affairs and Forestry.
- AUCAMP, P. 1997. Preliminary trace element soil pollution of soils affected by a tailings dam at Machavie Gold Mine, west of Potchefstroom. Council for Geoscience, (Rep. No. 1997-0159). Pretoria: Council for Geoscience.
- AUCAMP, P.J. & VIVIER, F.S. 1987. A novel approach to water quality criteria in South Africa. (In: Conference proceedings: Symposium Water 2000. Nice: IWSA.)
- BANKS, D., REIMANN, C., ROYSET, O., SKARPHAGEN, H. & SAETHER, O.M. 1995. Natural concentrations of major and trace elements in some Norwegian bedrock groundwaters. Appl. Geochem., 10: 1-16.
- BARTON, E.S. & HALLBAUER, D.K. 1996. Trace-element and U-Pb isotope compositions of pyrite types in the Proterozoic Black Reef, Transvaal Sequence, South Africa: Implications on genesis and age. Chem. Geol., 133: 173-199.
- BELLY, R.T. & BROCK, T.D. 1974. Ecology of iron-oxidizing bacteria in pyritic materials associated with coal. J. Bacteriol., 117: 726-732.

- BENNETT, H. & OLIVER, G. 1992. XRF analysis of ceramics, minerals and applied materials. New York: John Wiley & Sons.
- BIRKE, M. 1998. Geochemical investigations in urban areas – Megacities, mining districts, waste disposal and industrial zones. (In: Conference proceedings: Geocongress 1998, hosted by the Council for Geoscience, Pretoria, pp. 3-5.)
- BLAIR, R.D., CHERRY, J.A., LIM, T.P. & VIVYURKA, A. J. 1980. Groundwater monitoring and contaminant occurrence at an abandoned tailings area, Elliot Lake, Ontario. (In: Brawner, C. ed. Conference proceedings: First International Conference on Uranium Mine Waste Disposal, May 1980, pp. 19-21.)
- BLIGHT, G. & DU PREEZ, J. 1997. The escape of salt pollution from decommissioned gold residue deposits in South Africa. J. S. Afr. Inst. Min. Metall., Jul./Aug. 1997: 201-204.
- BLIGHT, G.E. & CALDWELL, J.A. 1984. The abatement of pollution from abandoned gold-residue dams. J. S. Afr. Inst. Min. Metall., 84(1): 1-9.
- BLOWES, D.W. 1995. Acid generation and contaminant transport in decommissioned sulfide-bearing mine-tailings impoundments. (In: Conference proceedings: Uranium Mining and Hydrogeology. Freiberg, Sachsen, pp. 43-53.)
- BLOWES, D.W. 1983. The influence of the capillary fringe on the quantity and quality of runoff in an inactive uranium mill tailings impoundment. Ontario: University of Waterloo (Ph.D. thesis).
- BLOWES, D.W., CHERRY, J.A. & REARDON, E.J. 1988. Geochemical evolution for four inactive sulphide-rich tailings impoundments in Canada. (In: Conference proceedings: International Conference on Control of Environmental Problems From Metal Mines, held on 20 - 24 June 1983, Roros, Norway.)
- BOWIE, S.H.U. & PLANT, J. 1983. Radioactivity in the environment. (In: Thornton, I. ed. Applied environmental geochemistry. New York: Academic Press, pp. 481-495.)
- BRINK, A.B.A. 1985. Engineering geology of South Africa, Vol. 4: Post-Gondwana Deposits. Pretoria: Building Publications.
- BROCK, T.D. & MADIGAN, M.T. 1991. Biology of microorganisms; sixth edition. Washington, New Jersey: Prentice Hall.
- BROOKS, R.R. 1987. Serpentine and its vegetation. London: Crom Helm.
- BRUSSEAU, M. & RAO, P. 1989. Sorption non-ideality during organic contaminant transport in porous media. Critical Review Environmental Control (CRC), 19: 22-99.

- BUNDESGESUNDHEITSAMT (BGA). 1993. Die neuen Trinkwasserleitwerte der WHO für chemische Stoffe und ihre praktische Bedeutung. Bundesgesundheitsblatt, 36. Jahrg., Mai 1993, 5 (Sonderdruck).
- CARUCCIO, F.T. 1968. An evaluation of factors affecting acid mine drainage production and the groundwater interactions in selected areas of Western Pennsylvania. (Second Symposium on Coal Mine Drainage Research, Bituminous Coal Research in Monroeville, Pennsylvania: 107-152.)
- CHERRY, J.A., BLACKPORT, R.J., DUBROSVSKY, N.M., GILHAM, R.W., LIM, T.P., MORIN, K.A., MURRAY, D., REARDON, E.J. & SMITH, D.J.A. 1980. Subsurface hydrology and geochemical evolution of inactive pyritic tailings in the Elliot Lake Uranium District. Canada. (In: Conference proceedings: Symposium on Uranium Mill Tailings Management. 24-25 Nov. 1980, Fort Collins, Colorado.)
- CLAUSEN, H.T. 1969. Dissolved solids load in the Vaal Barrage Water System with reference to mine effluents. (In: Paper presented at the Institute of Water Pollution Control Symposium.)
- COETZEE, H. & SZCZESNIAK, H. 1993. Detection and monitoring of pollution from mine tailings dams along rivers in the Witwatersrand gold fields, using airborne radiometric method. (In: Proceedings: Sixteenth International Colloquim on African Geology, pp. 94-96.)
- COETZEE, H. 1995. Radioactivity and the leakage of radioactive waste associated with Witwatersrand gold and uranium mining. (In: Conference proceedings: Uranium Mining and Hydrogeology, held in Freiberg, Sachsen, pp. 90-99.)
- COGHO, V.E., VAN NIEKERK, L.J., PRETORIUS, H.P.J. & HODGSON, F.D.I. 1992. The development of techniques for the evaluation and effective management of surface and groundwater-contamination in the Orange Free State Gold Fields (Rep. No. K5/224). Pretoria: Water Research Commission.
- COUNCIL FOR NUCLEAR SAFETY (CNS). 1996. Confidential report.
- COUNCIL FOR NUCLEAR SAFETY (CNS). 1997. Guideline to the assessment of radiation hazards to members of the public from mining and mineral processing facilities. Draft LG-1032, Pretoria, 50 p.
- CRAVOTTA, C.A., BRADY, K.B.C., SMITH, M.W. & BEAM, R.L. 1990. Effectiveness of the addition of alkaline materials at surface coal mines in preventing or abating acid mine drainage: Part 1. Geochemical considerations. (In: Conference proceedings:

- Conference on Mining, Reclamation and Exhibition in Charleston. West Virginia, 23-26 April 1990, pp. 226-225.)
- CREAMER, M. 1998. 12.3 t from poorest material. Mining Weekly, December 1998: 4-10.
- CROUNSE, R.G., PORIES, W.J., BRAY, J.T. & MAUGER, R.L. 1983. Geochemistry and man: health and disease. 1. Elements possibly essentials, those toxic and others. (In: Thornton, I. ed. Applied environmental geochemistry. New York: Academic Press, pp. 309-330.)
- DANIEL, D.E. ed. 1993. Geotechnical practice for waste disposal. London: Chapman & Hall.
- DAVIES, B.E. 1983. Heavy metal contamination from base metal mining and smelting: Implications for man and his environment. (In: Thornton, I. ed. Applied environment geochemistry. New York: Academic Press, pp. 452-462.)
- DE JESUS, A.S.M., MALAN, J J., ELLERBECK, V.T., VAN DER BANK, D.J. & MOOLMAN, E.W. 1987. An assessment of the Radium-226 concentration levels in tailings dams and environmental waters in the gold/uranium mining areas of the Witwatersrand. Pelindaba: Atomic Energy Corporation (Rep. PER-159).
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1995. Dolomitic groundwater resources of the Republic of South Africa (Rep. No. GH 3857), Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1996. Vaal River Barrage catchment: Impact of the mining industry on water quality. Report, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY. 1996a (DWAF). Volume 1: South African water quality guidelines - domestic water use. Report, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1996d. Volume 4: South African water quality guidelines – Agricultural water use: Irrigation. Report, Pretoria.
- DEPARTMENT OF WATER AFFAIRS AND FORESTRY (DWAF). 1998. Minimum requirements for water monitoring at waste management facilities. Documents 1-3, second edition. Pretoria.
- DORFLING, C. 1998. Mines agree on acid drainage. Mining Weekly, Nov. 1998: 13-19.
- DRIESSEN, P.M eds. 1991. The major soils of the world. Zutphen: Wöhrmann.
- DUBROSKY, N.M., MORIN, K.A., CHERRY, J.A. & SMYTH, D.J.A. 1984b. Uranium tailings acidification and subsurface contaminant migration in a sand aquifer. Canad. J. Water Poll. Res., 19(1): 55-89.

- DUBROSVSKY, N.M. 1986. Geochemical evolution of inactive pyritic tailings in the Elliot Lake Uranium District. University of Waterloo, Ontario: University of Waterloo (Ph. D. thesis).
- DUBROVSKY, N.M., CHERRY, J.A., REARDON, E.J. & VIVYURKA, A.J. 1984a. Geochemical evolution of inactive pyritic tailings in the Elliot Lake uranium district: 1. The groundwater zone. Canad. Geotech. J., 22(1): 110-128.
- DUNCAN, D.W. & BRUYNESTEYN, A. 1971. Enhancing bacterial activity in a uranium mine. Transactions of the Canadian Institute of Mining and Metallurgy and of the Society of Nova Scotia, 74: pp. 116.120.
- EALLES, K., FORSTER, S. & DU MANGO, L. 1997. Strain, water demand, and supply direction in the most stressed water systems of Lesotho, Namibia, South Africa, and Swaziland. (In: Rached, E., Rathgeber, E. & Brooks, D.B. eds. Water management in Africa and the Middle East. Ottawa: IDRC Publisher.)
- ELSENBROEK, J.H. & SZCZESNIAK, H.L. 1997. Regional geochemistry and statistics of the soils of the dolomites on a portion of the Ghaap Plateau Formation and a portion of the Malmani Subgroup, South Africa (Rep. No. 1997-0114). Pretoria: Council for Geoscience.
- ENGINEERING NEWS. 1997. An update of the South African waste scenario. Publication: 24–30 October 1997.
- EVANS, G.H. 1990. The geochemistry and environmental study of a reed-bed adjacent to a gold slimes dump, with aspects on acid mine water and heavy metal pollution. Johannesburg: University of Witwatersrand (B.Sc. thesis).
- EVERETT, L.G., WILSON, L.G. & HOYLMAN, E.W. 1984. Vadose zone monitoring for hazardous waste. Washington, New Jersey: Noyes Data Corporation.
- FAGERSTRÖM, T. & JERNELÖV, A. 1972. Aspects of the quantitative ecology of mercury. Water Resources, 6: 1193-1202.
- FEATHER, C.E. & KOEN, G.M. 1975. The mineralogy of the Witwatersrand reefs. Minerals Sci. Engng., 7(3): 189-224.
- FELL, R., MACGREGOR, P. & STAPLEDON, D. 1992. Geotechnical engineering of embankment dams. Rotterdam: Balkema.
- FENTON, G. 1997. Looking at liming ? How much do you need ? Agricultural Notes 5/115, electronic edition (www.agric.nsw.gov.au/arm/soil_pub/5115.htm).

- FERGUSON, K.D. & ERICKSON, P.M. 1988. Pre-mine prediction of acid mine drainage. (In: Salomons, W. & Förstner, U. eds. Environmental management of solid waste. Dredged material and mine tailings. Berlin: Springer, pp. 24-44.)
- FÖRSTNER, U. & KERSTEN, M. 1988. Assessment of metal mobility in dredged material and mine waste by pore water chemistry and solid speciation. (In: Salomons, W. & Förstner, U. eds. Chemistry and biology of solid waste. Berlin: Springer: pp. 214-238.)
- FÖRSTNER, U. & MÜLLER, G. 1974. Schwermetalle in Flüssen und Seen als Ausdruck der Umweltverschmutzung. Berlin: Springer.
- FÖRSTNER, U. & WITTMANN, G.T.W. 1976. Metal accumulations in acidic waters from gold mines in South Africa. *Geoforum*, 7: 44-49.
- FÖRSTNER, U. & WITTMANN, G.T.W. 1981. Metal pollution in the aquatic environment. Berlin: Springer.
- FÖRSTNER, U. 1982. Schadstoffe im Wasser, Metalle – Phenole und algenbürtige Stoffe. Bonn: Deutsche Forschungsgemeinschaft.
- FÖRSTNER, U. 1983. Metal pollution in rivers and estuaries. (In: Thornton, I. ed: Applied environmental geochemistry. New York: Academic Press, pp. 395-419.)
- FÖRSTNER, U. 1989. Contaminated sediments. (In: Lecture notes in earth sciences. Berlin: Springer.)
- FÖRSTNER, U. 1995. Non-linear release of metals from aquatic sediments. (In: Salomons, W. & Stigliani, W.M. eds. Biogeodynamics of pollutants in soils and sediments – Risk assessment of delayed and non-linear responses. Berlin: Springer, pp. 247-298.)
- FUGGLE, R.F. & RABIE, M.A. 1992. Environmental management in South Africa. Johannesburg: Juta.
- FUNKE, J.W. 1985. Contribution of mining wastes to the mineral pollution of the Vaal catchment area and of the Vaal Barrage. Pretoria: Water Research Commission.
- FUNKE, J.W. 1990. The water requirements and pollution potential of South African gold and uranium mines. Pretoria: Water Research Commission (Rep. No. KV9/90).
- GARRELS, R.M. & CHRIST, C.L. 1965. Solutions, minerals and equilibria. New York: Harper & Row.
- GOVERNMENT PRIINTER OF SOUTH AFRICA. 1986. Geological Map 2628 East Rand. Pretoria.
- GRIFFITHS, G. & SMITH, S. 1998. Risk assessment and management strategies. (In: Hester, R.E. & Harrison, R.M. eds. Contaminated land and its reclamation. London: Royal Society of Chemistry, pp. 103-123.)

- HAHNE, H.C.H.; HUTSON, J.L. & DU PLESSIS, M. 1976. Pilot investigation on mine dump materials: Mineralogical, chemical and textural properties. Pretoria: Department of Agricultural Technical Services (Rep. No. 841/55/76).
- HALLBAUER, D.K. 1986. The mineralogy and geochemistry of Witwatersrand pyrite, gold, uranium, and carbonaceous matter. (In: Anhaeusser, C.R. & Maske, S. eds. Mineral Deposits of Southern Africa, I. Johannesburg: Geological Society of South Africa, pp. 731-752.)
- HAWLEY, J.R. 1977. The problem of acid mine drainage in the province of Ontario. Ontario: Ministry of the Environment.
- HEINRICHS, H. & HERRMANN, A.G. 1990. Praktikum der analytischen Geochemie. Berlin: Springer.
- HEROLD, C. 1981. A model to simulate daily river flows and associated diffuse-source conservative pollutants (Rep. No.3/81). University of the Witwatersrand, Johannesburg: Hydrological Research Unit.
- HÖLTING, B.H. 1996. Hydrogeologie. Stuttgart: Enke.
- HOLTZ, R.D. & KOVACS, W.D. 1981. An introduction to geotechnical engineering. Washington, New Jersey: Prentice Hall.
- HORTON, J.H. & HAWKINS, R.H. 1965. Flow path from the soil surface to the water table. Soil Science, 100(6): 377-383.
- HUTCHINSON, T.C. 1981. Effects of heavy metal pollution on plants. London: Applied Science Publishers.
- HUTCHINSON, I.P.G. & ELLISON, R.D. 1992. Mine waste management. Boca Raton: Lewis Publishers.
- JENNINGS, J.E.B., BRINK, A B.A. & WILLIAMS, A.A.B. 1973. Revised guide to soil profiling for civil engineering purposes in South Africa. Transactions of the South African Institute of Civil Engineers (SAICE), 15.
- JOHNSON, M. S., COOKE, J. A. & STEVENSON, J. K. W. 1998. Revegetation of metalliferous wastes and land after metal mining. (In: Hester, R. E. & Harrison, R. M. eds. Mining and its environmental impact, pp. 31-47. Cambridge: Royal Society of Chemistry.)
- JOUBERT, R. 1998. The agricultural viability of two reclaimed tailings dams near Springs, East Rand. Pretoria: University of Pretoria (B.Sc. thesis).
- KABATA-PENDIAS, A. & PENDIAS, H. 1992. Trace elements in soils and plants. Boca Raton, Florida: CRC Press.

- KABATA-PENDIAS, A. 1992. Behavioural properties of trace metals in soils. Appl. Geochem., 2: 3-9.
- KABATA-PENDIAS, A. 1994. Agricultural problems related to excessive trace element contents of soils. (In: Salomons, W., Mader, P. & Förstner, U. eds: Pathways, impact and engineering aspects of metal polluted sites. Berlin: Springer.)
- KAFRI, U., FOSTER, M., DETREMMERIE, F. SIMONIS, J. & WIEGMANS, F.E. 1986. The hydrogeology of the dolomite aquifer in the Kliprivier-Natalspruit basin (Report GH 3408). Pretoria: Department of Water Affairs and Forestry.
- KAVANAUGH, M. 1996. Resolving the conflict between policy and practicality. Water Quality International (WQI), Dec.1996: 13-14.
- KLEINMANN, R.L.P., CRERAR, D.A. & PACELLI, R.R. 1981. Biogeochemistry of acid mine drainage and a method to control acid formation. Mining Engineering, 33.
- KLIPPEL, R.W. & HAGARMAN, J.A. 1983. Landfilling air pollution dust from specialty steel production on a Solvay Process waterbed. (In: Conference proceedings: Fifteenthth Mid-Atlantic Industrial Waste Conference, held in Lewisburg, PA.)
- KÖLLING, M. 1990. Modellierung geochemischer Prozesse in Sickerwasser und Grundwasser. –Beispiel. Die Pyritverwitterung und das Problem saurer Grubenwässer. Bremen: Geowissenschaften Universität Bremen (Rep. 8).
- LABUSCHAGNE, L.S., HOLDSWORTH, R. & STONE, T.P. 1993. Regional stream sediment geochemical survey of South Africa. J. Geo. Explor., 47(1-3): 283-296.
- LAEGERWERFF, J.V. & BROWER, D.L. 1974. Trace substances in environmental health. Missouri, Columbia: University of Missouri.
- LAHERMO, P., MANNIO, J. & TARAVALINEN, T. 1995. The hydrogeochemical comparison of streams and lakes in Finland. Appl. Geochem., 10: 205-210.
- LAMPKIN, A.J. & SOMMERFELD, M.R. 1981. Impact of reclamation on drainage from the Sheldon mine complex, Yavapai County, Arizona. Journal of Arizona-Nevada Academic Science, 16: 65-68.
- LIDE, D. R. ed. 1999. Handbook of Chemistry and Physics; 78th edition. Boca Raton, Florida: CRC Publisher.
- LIEBENBERG, W.R. 1973. Mineralogical features of gold ores in South Africa. (In: Adamson, R.J.: Gold metallurgy in South Africa. Johannesburg: Chamber of Mines of South Africa, pp. 352-426.)
- LLOYD, J.W. & HEATHCOTE, J.A. 1985. Natural inorganic hydrogeochemistry in relation to groundwater. Oxford: Clarendon Press.

- LLOYD, P.J.D. 1981. The flotation of gold, uranium and pyrite from Witwatersrand areas. J. S. Afr. Inst. Min. Metall., 81(2): 41-47.
- LLOYD, P.J.D. 1997. Comment on paper: The escape of salt pollution from decommissioned gold residue deposits. J. S. Afr. Inst. Min. Metall., Nov./Dec. 1997: 325-327.
- LOGAN, T.J. 1992. Reclamation of chemically degraded soils. (In: Lal, R. & Stewart, B.A. eds: Advances in soil science - soil restoration. New York: Springer, pp. 13-31.)
- LUNDGREN, D.G., VESTAL, J.R. & TABITA, F.R. 1972. The microbiology of mine drainage pollution. (In: Mitchell, R. ed. Water pollution microbiology. New York: Wiley, pp. 69-88.)
- MACKAY, D. & CHERRY, J. 1989. Groundwater contamination: pump-and-treat remediation. Environ. Sci. Technol., 23(6): 630-636.
- MARSAL, D. 1987. Statistics for geoscientists. New York: Pergamon Press.
- MARSDEN, D.D. 1986. The current limited impact of Witwatersrand gold-mine residues on water pollution in the Vaal River system. J. S. Afr. Inst. Min. Metall., 86(12): 481-504.
- MARTIN, J.P. & KOERNER, R.M. 1984a: The influence of vadose zone conditions on groundwater pollution - Part 1: Basic principles and static conditions. J. Hazard. Mat., 8: 349-366.
- MARTIN, J.P. & KOERNER, R.M. 1984b. The influence of vadose zone conditions on groundwater pollution - Part 2: Fluid movement. J. Hazard. Mat., 9: 181-207.
- MATHEWSON, C.C. 1981. Engineering geology. Ohio: Merrill.
- MECER, J. & COHEN, R. 1990. A review of immiscible fluids in the subsurface; properties, models, characterization and remediation. Journal of Contaminant Hydrology, 6: 107-163.
- MENDE, A. & MOCKER, D. 1995. Mobilisierung von konventionellen und radioaktiven Schadstoffen des Altbergbaus durch sauren Regen. (In: Conference proceedings: Uranium Mining and Hydrogeology, held in Freiberg, Sachsen, pp. 345-354.)
- MERRINGTON, G. & ALLOWAY, B.J. 1993. Das Verhalten von Schwermetallen in Abraum und Böden im Bereich alter eisenmetallischer Minen. (In: Arendt, F., Annokée, G.J., Bosman, R. & Van den Brink, W.J. eds. Altlastensanierung 1993 - Fourth international KfK/TNO congress for remediation. Berlin (Mai 1993), Deutschland, pp. 225-233.)
- MEYER, M., SAAGER, R. & VÖLKEL, V. 1986. Uranium distribution and redistribution in a suite of fresh and weathered pre-Witwatersrand and Witwatersrand conglomerates

- from South Africa. Johannesburg: Economic Research Unit of the University of Witwatersrand (Information Circular No. 174).
- MILLS, P.C. 1993. Water movement and water chemistry in the unsaturated zone beneath a low level waste disposal site in Sheffield/Illinois. Series of the USGS Water Supply Paper. Washington DC (Rep. No. 2398).
- MINING JOURNAL RESEARCH SERVICES. 1996. Tailings dams incidents: 1980-1996 – a study for the United Nations Environmental Programme (UNEP). Mining Environmentl Management, 9: 15-19.
- MITCHELL, R. 1978. Water pollution microbiology. New York: Wiley.
- MOORE, J.W. & RAMAMOORTHY, S. 1984. Heavy metals in natural waters – Applied monitoring and impact assessment. Berlin: Springer.
- MOREL, F.M.M. & HERING, J.G. 1993. Principles and applications of aquatic chemistry. New York: Wiley.
- MORIN, K.A. 1983. Prediction of subsurface contaminant transport in acidic seepage from uranium tailings impoundments. Ontario: University of Waterloo (Ph.D. thesis).
- MORIN, K.A., CHERRY, J.A., DAVE, N.D., LIM, T.P. & VIVYURKA, A.J. 1988a. Migration of acidic groundwater seepage from uranium-tailings impoundments, 1. Field study and conceptual hydrogeochemical model. Journal of Contaminant Hydrology, 2(4): 271-303.
- MORIN, K.A., CHERRY, J.A., NAND, K.D., LIM, T.P. & VIVYURKA, A.J. 1988b). Migration of acidic groundwater seepage from uranium-tailings impoundments, 2. Geochemical behaviour of radionuclides in groundwater. Journal of Contaminant Hydrology, 2(4): 304-322.
- MORTH, A.H., SMITH, E.E. & SHUMATE, K.S. 1972. Pyritic systems: a mathematical model. United States Environmental Protection Agency (Rep. R-2-72-002).
- MORTIMER, C. E. 1987. Chemistry. Belmont, California: Wadsworth.
- MÜLLER, G. 1979. Schwermetalle in den Sedimenten des Rheins – Veränderungen seit 1971. Umschau, 79: 778-783.
- MULVEY, P. 1998. Groundwater monitoring. Mining Environment Management, Jul. 1998: 13-20.
- NATIONAL RESEARCH COUNCIL. 1994. Alternatives for groundwater cleanup. Washington DC: National Academy Press.
- NATIONAL WATER ACT. 1998. National Water Act. Government Gazette of the Republic of South Africa, 398(19182) from 26 August 1998, Cape Town.

- NÉMETH, T., MOLNÁR, E., CSILLAG, J., BUTJÁS, K., LUKÁCS, A., PÁRTAY, G., FÉHER, J. & VAN GENUCHTEN, M.Th. 1993. Mobility of some heavy metals in soil-plant systems studied on soil monoliths. Wat. Sci. Tech., 28(3-5): 389-398.
- NEST VAN DER, L.J. & DEVENTER VAN, P.W. (1996): PRINCIPLES OF SUCCESSFUL REHABILITATION. (In: Conference proceedings: Second International Conference on Mining and Industrial Waste Management, held at Johannesburg on 2-4 June 1996.)
- NETHERLANDS MINISTRY OF HOUSING, PHYSICAL PLANNING AND ENVIRONMENT. 1997. Environmental quality standards for soil and water – *The Dutch List*. Leidschendam.
- OLSON, B.H. 1983. Microbial mediation and biogeochemical cycling of metals. (In: Thornton, I. ed. Applied Environmental Geochemistry. New York: Academic Press, pp. 210-226.)
- PALMER, M.C. 1992. Principles of contaminant hydrogeology. London: Lewis Publishers.
- PARSONS, R. & JOLLY, J. 1994. The development of a systematic method for evaluating site suitability for waste disposal based on geohydrological criteria. Pretoria: Water Research Commission (Rep. No. 485/1/94).
- PIERZYNSKI, G.M., SIMS, J.T. & VANCE, G.F. 1994. Soils and environmental quality. Boca Raton, Florida : Lewis Publishers.
- PRÜEB, A., TURIAN, G. & SCHWEIKLE, V. 1991. Ableitung kritischer Gehalte and NH_3NO_3 extrahierbaren ökotoxikologisch relevanten Spurenelementen in Böden SW-Deutschlands. Mitt. Dt. Bodenkundl. Ges., 66(1): 385-388.
- PULLES, W., HEATH, R. & HOWARD, M. 1996. A manual to assess and manage the impact of gold mining operations on the surface water environment. Pretoria: Water Research Commission (Rep. No. TT/79/96).
- PULLES, W., HOWIE, D., OTTO, D. & EASTON, J. 1995. A manual on mine water treatment and management - Practices in South Africa. Pretoria: Water Research Commission (Rep. No. TT 80/96).
- RICHTER, C. 1993. Rehabilitation and the Minerals Act 1991. SA Mining, Coal, Gold and Base Minerals, Feb. 1993, 25-26.
- ROBB, L.J. & MEYER, F.M. 1995. The Witwatersrand Basin, South Africa: Geological framework and mineralization processes. Economic Research Unit of the University of Witwatersrand, Johannesburg.
- ROSE, C. W. 1966. Agricultural physics. London: Pergamon Press.

- RÖSNER, T. 1996. Einfluß von Goldhalden auf die Grundwasserqualität in der East Rand Region/Witwatersrand – Zwischenbericht. Bonn: DAAD (unpubl.)
- RÖSNER, T., BOER, R.H., REYNEKE, R., AUCAMP, P. & VERMAAK, J.J.G. 1998. A preliminary assessment of pollution contained in the unsaturated and saturated zone beneath reclaimed gold-mine residue deposits. Pretoria: Water Research Commission (Rep. No. K5/797/0/1).
- RULKENS, W.H., GROTENHUIS, J.T.C. & TICHY, R. 1995. Methods for cleaning contaminated soils and sediments. (In: Förstner, U. ed. Heavy metals. Berlin: Springer, pp. 164-186.)
- RUNNELS, D.D., SHEPHERD, T.A. & ANGINO, E.E. 1992. Metals in water. Envir. Sci. and Technol., 26(12): 2316-2322.
- RUST, E., VAN DEN BERG, J.P. & JACOBSZ, S.W. 1995. Seepage analysis from piezocone dissipation tests. (In: Conference proceedings: International Symposium on Cone Penetration Testing, held at the Swedish Geotechnical Institute, Linköping, Sweden.)
- SALOMONS, W. & STIGLIANI, W.M. 1995. Biogeodynamics of pollutants in soils and sediments – Risk assessment of delayed and non-linear responses. Berlin: Springer.
- SCHEFFER-SCHACHTSCHABEL, P. 1984. Lehrbuch der Bodenkunde. Stuttgart: Enke.
- SCHLOEMANN, H. 1994. The geochemistry of some Western Cape soils (South Africa) with emphasis on toxic and essential elements. Cape Town: University of Cape Town (Ph.D. thesis).
- SCOTT, R. 1995. Flooding of Central and East Rand gold mines – An investigation into controls over the inflow rate, water quality and the predicted impacts of flooded mines. Pretoria: Water Research Commission (Rep. No. 486/1/95), Pretoria.
- SILVER, M. 1987. Distribution of iron-oxidizing bacteria in the Nordic uranium tailings deposit, Elliot Lake, Ontario, Canada. Applied and Environmental Microbiology, 53 (4): 846-852.
- SINGER, P.C. & STUMM, W. 1970. Acid mine drainage: The determining step. Science, 20. Feb.1970: 1121-1123.
- SKIVINGTON, P. 1997. Risk assessment for water quality management. Pretoria: Water Research Commission (Rep. No. TT90/97).
- SMITH, E.E. & SHUMATE, K.S. 1970. The sulfide to sulfate reaction mechanism. United States Environmental Protection Agency (Rep. No. 14016).

- SOIL CLASSIFICATION WORKING GROUP. 1991. Soil classification: A taxonomic system for South Africa. Memoirs on the Agricultural Natural Resource of South Africa, 15.
- SOUTH AFRICAN BUREAU OF STANDARDS. 1984. Specification for water for domestic supplies (Rep. 24101984), Pretoria.
- SOUTH AFRICAN BUREAU OF STANDARDS. 1997. Proposed code of practice for mine residue deposits, Pretoria.
- STEFFEN, O. ROBERTSON, A. & KIRSTEN, H. 1988. Research on the contribution of mine dumps to the mineral pollution load in the Vaal barrage. Pretoria: Water Research Commission (Rep. No. PT. 3632/10).
- SUTTON, P. & DICK, W.A. 1984. Reclamation of acid mined lands in humid areas. Advances in Agronomy, 41: 377-405.
- TAVENAS, F., JEAN, P., LEBLOND, P. & LEROUEIL, S. 1983. The permeability of natural soft clays. Part II: Permeability characteristics. Canadian Geotechnical Journal, 20: 645-660.
- THORNTON, I. ed. 1983. Applied Environmental Geochemistry. New York: Academic Press.
- TRAVIS, C. & DOTY, C. 1990. Can contaminated aquifers at Superfund sites be remediated? Environ. Sci. Techn., 24(10): 1464-1466.
- TUREKIAN, K.K. & WEDEPOHL, K.H. 1961. Distribution of the elements in some units of the earth crust. Bull. Soc. Am., 72: 175-192.
- UMWELTBUNDESAMT. 1996. Methods in soil protection used in Poland, Slovakia, the Czech Republic and Hungary (Rep. Texte 77/96, ISSN 0722-186X), Berlin.
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). 1976. Erosion and sediment control, surface mining in the eastern U.S. Washington D.C.: U.S. Government Printing Office (Rep. EPA-625/33-76-006).
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). 1985. Wastes from the extraction and beneficiation of metallic ores, phosphate rock, asbestos, overburden from uranium mining and oil shale. Washington D.C. Report to Congress (EPA-530/SW-85-033).
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). 1987a. Underground storage tank corrective technologies. Hazardous Waste Engineering Research Laboratory. U.S. Government Printing Office (Rep. EPA-600/2-89-035), Washington D.C.

- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). 1989. Evaluation of ground water extraction remedies. U.S. Government Printing Office (Vols. 1 and 2), Washington DC: U.S. Government Printing Office.
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY (EPA). 1996a. Groundwater clean-up at Superfund sites (brochure of Superfund & EPCRA).
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY. 1997a (EPA). EPA Superfund today - focus on risk assessment (rep. EPA 540-K-96-003), Washington DC.
- UNITED STATES ENVIRONMENTAL PROTECTION AGENCY. 1997b (EPA). Rules of thumb for Superfund remedy selection (rep. EPA 540-R-97-013), Washington DC.
- UTERMANN, J., GÄBLER, H.E., HINDEL, R., KUES, J., MEDERER, J. & PLUQUET, E. 1998. Schwermetallgehalte im Bodenwasser – ein Vergleich von drei Extraktionsverfahren. Z. angew. Geol. 44: 204-209.
- VAN DEN BERG, J.P. 1995. Monitoring of phreatic surface of a tailings dam and the subsequent stability implications. Pretoria: University of Pretoria (M.Sc. dissertation).
- VAN DER NEST, L.J. & DEVENTER VAN, P.W. 1996. Principles of successful rehabilitation. (In: Conference proceedings: Second International Conference on Mining and Industrial Waste Management, held at Johannesburg on 2-4 June 1996.)
- VAUGHAN, D.J. & CRAIG, J.R. 1978. Mineral chemistry of metal sulfides. (In: Harland, W. Agrell, B.S.O., Cook, A.H. & Hughes, N.F. eds. Cambridge Earth Science Series. Cambridge: Cambridge University Press.)
- VEGTER, J.R. 1984. The role of groundwater in South Africa's water supply. (In: Conference proceedings: Groundwater Technology, Johannesburg, pp. 3-14.)
- VON RAHDEN, H.V.R. 1970. Mineralogical and geochemical studies of some Witwatersrand gold ores with special reference to the nature of phyllosilicates. Johannesburg: University of Witwatersrand (Ph. D. thesis).
- WAGENER, F.M., VAN DEN BERG, J. P. & JACOBSZ, S.W. 1997. Monitoring seepage regime in tailings dams in practice. (In: Conference proceedings: Second International Conference on Mining and Industrial Waste Management, held on 2-4 June 1997 at the South African Institute of Civil Engineers (SAICE), Johannesburg.)
- WAGNER, J.C. & VAN NIEKERK, A.M. 1987. Quality and treatment of effluents originating from mine and municipality solid waste sites. (In: Conference proceedings: Mining and Industrial Waste Management, held in Johannesburg, pp. 283-288.)

- WALTON, D.G. & LEVIN, M. 1993. The identification and verification of polluted areas in the dolomitic aquifers of the PWV area. Atomic Energy Corporation, Pretoria, GEA-1045.
- WARD, R.C. & ROBINSON, M. 1990. Principles of hydrology. London: McGraw-Hill.
- WATES, J.A., STRAYTON, G. & BROWN, S.A.P. 1997. Environmental aspects relating to the design and construction of tailings dams in South Africa. (In: Conference proceedings: Second International Conference on Mining and Industrial Waste Management, held on 2-4 June at the South African Institute of Civil Engineers (SAICE), Johannesburg.)
- WEATHER BUREAU. 1999. Weather data from 1961-1990. Pretoria: Directorate of Climatology, electronic edition (www.sawb.gov.za/www/climate).
- WHITE, R.E. 1989. Introduction to the principles and practices of soil science. London: Blackwell Scientific Publications.
- WHITNEY, D.A. & LAMOND, R.E. 1999. Liming acid soils. Kansas State University Notes on Soil Fertility, electronic edition (www.oznet.ksu.edu/library/crpsl2/MF1065.pdf).
- WHITTEN, D.G.A. & BROOKS, J.R.V. 1972. Dictionary of geology. New York: Penguin Books.
- WILD, A. ed. 1988. Soil conditions and plant growth. London: Longman.
- WILLIAMS, D.A. & ABADJIEV, C.B. 1997. Horizontal and vertical drains in tailings dams ? (In: Conference proceedings: Second International Conference on Mining and Industrial Waste Management, held on 2-4 June 1997 at the SAICE, Johannesburg.)
- WILLIAMS, E.G., ROSE, A.W., PARIZEK, R.R. & WATERS, S.A. 1982. Factors controlling the generation of acid mine drainage. U.S. Bureau of Mines (rep. res. Grant G105086).
- WOOD, P.A. 1998. Remediation methods for contaminated sites. (In: Hester, R.E. & Harrison, R. M. eds. Contaminated land and its reclamation. London: Royal Society of Chemistry, pp. 47-72.)
- YOUNG, P.J., POLLARD, S. & CROWCROFT, P. 1998. Overview: Context, calculating risk and using consultants. (In: Hester, R.E. & Harrison, R.M. eds. Contaminated land and its reclamation. London: Royal Society of Chemistry, pp. 1-24.)
- ZNATOWICZ, K.P.S. 1993. Radioactive and heavy metal pollution associated with a gold tailings dam on the East Rand. Johannesburg: University of Witwatersrand (M.Sc. dissertation).

APPENDIX A

Soil parameters and test pit logs

Table A.1 - Summary of soil parameters of study sites A-G.

SAMPLE DESCRIPTION			PARTICLE SIZE				ATTERBERG LIMITS					IN-SITU PROPERTIES				PERMEABILITY
TEST PIT and Sample No.	DEPTH (m)	UNIFIED SOIL CLASSIFICATION SYSTEM (U.S.C.S.)	% Clay	% Silt	% Sand	% Gravel	LL	LS	PI	PI ws	Exp	pH	Bulk density (kg/m ³)	SG	e %	K (cm/s)
Study Site A																
A/1/1	0.20	SC-SM	13.15	23.50	62.50	0.50	18.75	2.06	5.98	4.80	low	3.06	1752.88	2.72	0.55	1 x 10 ⁻⁷
A/1/2	0.40	SC	15.82	20.38	54.60	9.20	20.98	3.77	9.81	6.90	low	4.22	1816.08	2.72	0.50	1 x 10 ⁻⁷
A/1/3	1.00	SC-SM	7.51	25.49	53.00	14.00	21.01	2.79	5.94	3.85	low	6.11	-	-	-	-
A/2/2	0.35	SC	10.62	15.48	51.20	22.70	23.05	5.27	9.30	4.03	low	4.33	-	-	-	-
A/2/4	0.90	SC	8.54	21.96	57.30	12.20	26.23	5.21	8.26	3.55	low	4.36	1551.43	2.81	0.81	1 x 10 ⁻⁷
A/3/2	0.30	SC	8.45	8.45	52.20	30.90	28.70	7.22	12.25	2.89	low	6.45	-	-	-	-
A/3/3	0.70	SC	11.31	28.39	56.00	4.30	25.69	5.58	9.34	5.11	low	6.90	-	-	-	-
A/3/4	1.00	SC	12.10	31.40	45.80	10.70	25.24	5.49	8.99	5.65	low	6.87	-	-	-	-
Study Site B																
B/1/1	0.10	CL	29.80	24.60	45.60	0.00	28.00	7.28	13.07	11.79	low	3.64	1695.54	2.48	0.46	1 x 10 ⁻⁸
B/1/2	0.50	CL	34.68	21.82	43.50	0.00	29.32	8.18	13.01	11.73	low	3.53	1619.22	2.45	0.51	1 x 10 ⁻⁸
B/2/1	0.30	ML	50.92	26.18	22.90	0.00	48.40	10.91	19.17	16.54	low	4.19	-	-	-	-
B/2/2	0.50	MH	63.66	23.54	12.40	0.40	50.31	11.13	20.64	19.63	low	5.09	-	-	-	-
B/2/4	2.00	MH	50.24	43.46	6.30	0.00	57.83	11.82	26.00	25.67	med	5.74	-	-	-	-
B/3/1	0.40	CL	31.71	29.59	38.50	0.20	28.78	7.42	12.74	11.28	low	6.19	-	-	-	-
B/3/3	1.00	CL	41.80	28.00	30.10	0.10	33.41	8.97	14.82	13.65	low	6.63	1665.46	-	-	-
B/3/4	1.60	SC	19.02	21.68	50.30	9.00	34.84	8.36	15.61	8.21	low	6.66	-	-	-	-
Study Site C																
C/1/2	0.80	CL	46.78	28.42	24.80	0.00	32.72	8.93	15.10	14.26	low	3.95	1602.09	2.61	0.63	8 x 10 ⁻⁸
C/1/3	1.40	CL	28.90	32.40	38.60	0.10	38.33	8.89	18.61	14.06	low	3.82	1520.08	2.80	0.84	9.5 x 10 ⁻⁶
C/1/4	2.20	CL	34.33	32.77	30.70	2.20	35.52	9.03	17.43	14.09	low	5.01	-	-	-	-
C/2/1	0.15	CL	35.37	30.53	43.70	0.40	45.01	7.73	25.13	21.10	med	6.09	-	-	-	-
C/2/2	0.40	CL	35.75	21.15	42.60	0.50	48.06	10.38	28.01	23.52	med	5.05	-	-	-	-
C/2/4	2.30	SC	19.51	13.09	50.80	16.60	44.86	10.93	26.68	13.46	med	7.44	-	-	-	-
C/3/1	0.30	CL	24.58	36.62	38.80	0.00	29.89	6.97	13.03	11.95	low	3.52	-	-	-	-
C/3/2	0.60	CL	38.41	27.79	33.60	0.20	34.53	9.14	16.50	15.20	low	4.85	1700.96	2.40	0.41	1 x 10 ⁻⁸
C/3/3	1.65	CH	48.66	26.64	23.70	1.00	52.85	8.93	31.38	28.47	med	7.69	1738.90	2.57	0.48	1 x 10 ⁻⁹
Study Site D																
D/1/1	0.10	CL	27.77	27.33	44.90	0.00	28.18	7.84	13.39	11.75	low	3.65	1684.51	2.61	0.55	9 x 10 ⁻⁷
D/1/2	0.30	CL	41.64	25.46	32.90	0.00	31.92	8.69	14.70	13.49	low	6.00	1566.60	2.64	0.69	9 x 10 ⁻⁷
D/1/4	1.30	SC	20.93	23.57	48.30	7.20	32.38	8.04	15.72	9.36	low	6.78	1644.29	2.69	0.64	7 x 10 ⁻⁷
D/2/1	0.40	CL	31.33	24.67	44.00	0.00	34.09	9.88	16.48	14.55	low	3.76	-	-	-	-

Table A.1 continued.

SAMPLE DESCRIPTION			GRADING ANALYSES				ATTERBERG LIMITS					IN-SITU PROPERTIES				PERMEABILITY
TEST PIT and Sample No.	DEPTH (m)	UNIFIED SOIL CLASSIFICATION SYSTEM U.S.C.S.	% Clay	% Silt	% Sand	% Gravel	LL	LS	PI	PI ws	Exp	pH	Bulk density (kg/m ³)	SG	e %	K (cm/s)
Study Site D																
D/2/2	0.70	CL	42.23	25.67	32.10	0.00	37.13	10.73	15.73	14.38	low	3.89	-	-	-	-
D/2/4	0.60	CL	35.00	35.70	29.30	1.00	40.93	9.97	19.20	16.90	low	6.29	-	-	-	-
D/3/1	0.10	SC	14.37	28.83	55.80	0.00	20.48	3.52	7.20	6.09	low	3.47	-	-	-	-
D/3/2	0.50	CL	34.73	22.67	39.50	3.10	32.68	9.14	15.53	13.07	low	6.75	-	-	-	-
D/3/4	1.90	CH	51.44	25.96	22.50	0.10	55.87	11.09	32.28	30.32	med	-	1553.81	2.68	0.72	7.5 x 10 ⁻⁸
Study Site E																
E/1/2	0.70	CL	33.29	23.21	42.70	0.80	45.57	7.83	27.43	23.05	med	6.72	1775.29	2.55	0.44	1 x 10 ⁻⁸
E/1/3	1.50	CL	40.06	22.34	37.50	0.10	46.19	7.28	26.31	21.28	med	6.97	1535.78	2.70	0.76	9.5 x 10 ⁻⁷
E/2/1	0.45	CH	37.39	23.61	37.40	1.60	56.54	11.67	32.58	28.91	high	7.74	1484.87	2.68	0.80	9 x 10 ⁻⁷
E/2/2	0.75	CH	35.02	20.38	36.20	8.40	52.32	11.32	27.65	22.27	med	7.79	-	-	-	-
E/2/3	1.15	CH	46.55	24.65	28.30	0.50	64.10	11.15	37.23	34.27	v high	8.31	1535.06	2.68	0.75	8 x 10 ⁻⁸
E/3/1	0.30	CH	38.38	30.02	31.00	0.60	56.02	9.84	32.59	38.38	high	5.12	-	-	-	-
E/3/2	0.70	CL	39.19	29.61	31.00	0.00	48.69	7.30	28.31	26.88	high	6.75	-	-	-	-
Study Site F																
F/1/1	0.60	CL	40.16	28.54	31.30	0.00	30.12	8.81	13.60	12.73	low	6.69	1709.29	2.51	0.47	1 x 10 ⁻⁸
F/1/2	1.00	CL	28.23	28.07	43.70	0.00	24.79	7.04	11.11	9.90	low	3.66	1711.02	2.71	0.58	6 x 10 ⁻⁷
F/1/3	1.60	CL	40.82	28.28	30.60	0.30	29.52	8.30	13.01	12.09	low	6.62	-	-	-	-
F/2/1	0.20	CL	30.05	24.80	44.70	0.00	26.10	6.92	11.32	10.09	low	4.37	-	-	-	-
F/2/2	0.50	CL	40.34	21.46	38.20	0.00	30.69	7.98	12.94	11.82	low	6.67	-	-	-	-
F/2/3	1.50	CL	44.22	26.78	29.00	0.00	33.32	8.55	15.22	14.33	low	6.29	-	-	-	-
F/3/1	0.10	CL	25.56	28.74	45.70	0.00	23.72	6.12	10.66	9.41	low	4.53	-	-	-	-
F/3/2	0.50	CL	30.96	24.94	44.10	0.00	25.99	7.67	10.98	9.78	low	5.17	1661.44	2.78	0.67	6 x 10 ⁻⁷
F/3/4	1.60	CL	19.72	16.48	43.30	20.50	29.67	7.81	12.91	6.21	low	4.70	-	-	-	-
F/4/1	0.30	CL	13.70	37.00	49.30	0.00	21.32	4.32	7.45	6.64	low	3.70	-	-	-	-
F/4/2	0.60	CL	29.24	23.56	47.20	0.00	25.48	7.85	11.23	10.04	low	4.71	-	-	-	-
F/4/4	2.20	CL	39.56	26.84	33.20	0.40	31.55	8.83	17.23	15.89	low	4.65	1739.57	2.72	0.56	6 x 10 ⁻⁸
Study Site G																
G/1/1	0.30	SC	14.10	26.80	58.10	0.30	19.39	4.36	7.54	5.78	low	3.99	1786.21	2.64	0.48	1 x 10 ⁻⁷
G/1/3	1.00	SC	23.61	23.99	35.60	16.80	29.26	7.79	14.76	9.48	low	6.89	-	-	-	-
G/2/2	1.00	SC	22.63	25.37	43.50	8.50	24.21	6.23	10.75	7.60	low	6.31	1782.53	2.68	0.50	1 x 10 ⁻⁷
G/3/1	0.20	SC	18.74	28.06	53.20	0.00	22.90	6.42	10.37	8.27	low	4.03	-	-	-	-
G/3/2	0.50	SC	24.69	32.61	41.30	1.40	23.18	6.98	10.03	7.90	low	4.83	-	-	-	-
G/3/3	1.20	CL	31.45	21.15	34.60	12.80	30.85	8.60	11.54	8.23	low	6.74	-	-	-	-

Note: LL: Liquid limit. LS: Linear shrinkage. PI: Plasticity Index. PI ws: Plasticity index of whole sample. Exp: Expansiveness SG: Specific gravity e: void ratio. K: Estimated saturated hydraulic conductivity. U.S. soil symbols are explained in Table 3.11.

Test Pit Log

Test pit number: B/1

Depth (m)	Profile description	Sample number	Geotechnical parameters						Geochemical parameters (elements in mg/kg)															
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe %	Mn %	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn
0	Slightly moist, dark red brown, dense, open structured, silty sand with abundant fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium.	B/1/1	29,80	12	1695,54	2,48	0,46	1×10^{-8}	3,64	9,8	0,06	17	281	27	232	87	19	173	13	0	16	0	156	135
0,30		B/1/2	34,68	12	1619,22	2,45	0,51	1×10^{-8}	3,53	9,6	0,06	17	259	18	226	89	20	153	14	0	17	0	158	102
1	Moist, red brown, firm, intact, sandy clay with occasional fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium.	B/1/3	-	-	-	-	-	-	10,1	0,06	17	231	8	230	79	20	115	13	0	18	0	165	91	
1,90		B/1/4	-	-	-	-	-	-	10,4	0,07	19	236	7	246	87	21	106	10	0	19	0	172	72	
2	Moist, red brown, firm, intact, sandy clay with numerous coarse-, medium- and fine-grained subrounded ferricrete gravel; Ferruginised colluvium.																							
2,10																								
3	Notes 1. No refusal. 2. No water table encountered.																							

meter

Date: 21/4/1998 Locality: Case Study Site B

Elevation: 1609 m

Profiled by: P Aucamp & T Rösner

Test Pit Log

Test pit number: B/3

Depth (m)	Profile description	Sample number	Geotechnical parameters					Geochemical parameters (elements in mg/kg)																			
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe %	Mn %	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn			
0	Slightly moist, light grey banded yellow brown, very soft, layered sandy silt, Tailings.																										
0,30	Moist, dark grey, dense, open structured sandy clay with abundant fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium.	B/3/1	31,71	11	-	-	-	-	6,19	6,0	0,04	43	230	19	211	48	12	85	0	0	12	0	89	53			
0,50		B/3/2	-	-	-	-	-	-	6,2	0,03	22	204	13	163	46	20	78	9	0	21	0	96	40				
0,90	Moist, dark olive mottled dark grey, firm, intact sandy clay with scattered fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium.	B/3/3	41,8	14	-	-	-	-	6,63	7,2	0,04	19	197	9	230	51	19	85	13	0	23	0	113	44			
1,40		B/3/4	19,02	8,21	-	-	-	-	6,66	8,7	0,47	6	1018	124	204	67	4	126	83	0	8	0	163	39			
2	Abundant medium- and fine-grained subrounded to subangular ferricrete gravel in very moist, light olive mottled black, dark red brown and dark yellow brown sandy clay; Ferruginised colluvium. The overall consistency is stiff.																										
2,10																											
3	Notes 1. No refusal. 2. No water table encountered.																										

meter

Date: 21/4/1998 Locality: Case Study Site B

Elevation: 1613 m

Profiled by: P Aucamp & T Rösner

Test Pit Log

Test pit number: C/1

	Profile description	Sample number	Geotechnical parameters						Geochemical parameters (elements in mg/kg)															
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe %	Mn %	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn
0	Slightly moist, pale yellow, firm, intact sandy silt with occasional fine-grained gypsum crystals (up to 5 mm in diameter); Tailings.	C/1/1	-	-	-	-	-	-	-	7,1	0,03	68	205	13	170	44	8	77	0	0	7	0	112	49
0,60			Slightly moist, dark brown stained dark grey, firm, intact sandy clay with scattered fine-grained gypsum crystals (up to 5 mm in diameter) and zones of moist, dark grey soft, intact, sandy clay; Colluvium.	C/1/2	46,78	14	1602,09	2,61	0,63	8×10^{-8}	3,92	8,5	0,04	25	212	14	191	50	18	79	8	0	21	0
1	Slightly moist, red brown mottled and speckled dark red brown and black, firm intact sandy clay with abundant coarse-, medium- and fine-grained, subrounded ferricrete gravel and with scattered fine-grained gypsum crystals (up to 5 mm in diameter); Ferruginised colluvium.	C/1/3			28,90	14	1520,08	2,80	0,84	$9,5 \times 10^{-8}$	3,82	14,2	0,06	7	526	33	369	67	0	76	118	0	0	0
1,20			Slightly moist, red brown mottled and stained light grey, yellow brown and brown stiff, intact sandy clay with occasional coarse-, medium- and fine-grained, subrounded ferricrete gravel; Ferruginised colluvium.	C/1/4	34,33	14	-	-	-	-	5,01	10,6	0,11	22	511	25	220	54	16	65	10	0	17	0
1,90	Notes 1. No refusal. 2. No water table encountered.																							
2																								
2,30																								
3																								

meter

Date: 04.06.98 Locality: Case Study Site C

Elevation: 1605 m

Profiled by: P Aucamp & T Rösner

Test Pit Log

Test pit number: C/2

Depth (m)	Profile description	Sample number	Geotechnical parameters						Geochemical parameters (elements in mg/kg)																	
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe %	Mn %	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn		
0																										
0,10	Slightly moist, pale yellow brown, very soft intact sandy silt with occasional fine-grained gypsum crystals (up to 5 mm in diameter); Tailings.	C/2/1	35,37	21	-	-	-	-	6,09	6,91	0,05	13	370	20	223	32	16	51	14	0	17	0	99	34		
0,25		C/2/2	35,75	24	-	-	-	-	5,05	7,1	0,07	15	383	28	230	32	15	72	15	0	17	0	107	41		
1	Slightly moist, dark grey occasionally mottled and striped dark yellow brown, stiff shattered sandy clay with scattered fine-grained gypsum crystals (up to 5 mm in diameter); Alluvium.																									
1,10																										
	Moist, dark grey occasionally mottled dark yellow brown, soft, intact sandy clay with scattered fine-grained gypsum crystals (up to 5 mm in diameter); Alluvium.	C/2/3	-	-	-	-	-	-	-	7,1	0,03	21	406	16	270	27	14	56	17	0	19	0	166	33		
2	Moist, grey mottled and speckled dark yellow brown, soft, intact sandy clay with sporadic coarse-grained, subangular quartz gravel; Alluvium.																									
2,40	Abundant coarse-, medium- and fine-grained subangular ferricrete and quartz gravel in wet orange brown speckled and mottled black and dark yellow brown, clayey sand. Ferruginised alluvium. The overall consistency is soft.	C/2/4	19,51	27	-	-	-	-	7,44	23,9	0,17	38	428	188	622	89	0	282	8	0	0	0	937	28		
3	Notes 1. No refusal. 2. Perched water table at 2,00 m.																									

meter

Date: 04.06.98 Locality: Case Study Site C

Elevation: 1612 m

Profiled by: P Aucamp & T Rösner

Test Pit Log

Test pit number: F/1

0	Profile description	Sample number	Geotechnical parameters					Geochemical parameters (elements in mg/kg)																				
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe	Mn	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn				
0	Slightly moist, pale yellow brown, very soft, layered sandy silt, Tailings																											
0,50	Slightly moist, dark red brown, soft, open textured sandy clay with abundant fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium	F/1/1	40,16	13	1709,29	2,51	0,47	1×10^{-8}	6,69	8,6	0,16	20	188	5	178	53	22	76	11	0	21	0	139	43				
0,70																												
1	Slightly moist, red brown, soft, open textured sandy clay with abundant fine-grained gypsum crystals (up to 5 mm in diameter) Colluvium.	F/1/2	28,23	10	1711,02	2,71	0,58	6×10^{-7}	3,66	7,3	0,19	31	222	30	170	90	22	143	10	0	18	57	127	80				
1,10																												
1,40	Moist, dark red brown, stiff, intact sandy clay with abundant fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium.	F/1/3	40,82	12,01	-	-	-	-	6,62	8,3	0,12	21	182	4	169	49	23	68	11	0	20	0	134	40				
2	Very moist, dark red brown, stiff, intact sandy clay with abundant fine-grained gypsum crystals (up to 5 mm in diameter); Colluvium																											
2,40			F/1/4	-	-	-	-	-	-	-	8,2	0,09	21	178	3	200	43	24	62	9	0	21	0	133	36			
3	Very moist, dark red brown, stiff, intact sandy clay with abundant coarse-, medium- and fine-grained subangular ferricrete gravel Ferruginised colluvium.																											
	Notes 1. No refusal 2. No water table encountered																											

meter

Date: 21/4/1998 Locality: Case Study Site F

Elevation: 1583 m

Profiled by: P Aucamp & T Rösner

Test Pit Log

Test pit number: G/2

Depth (m)	Profile description	Sample number	Geotechnical parameters					Geochemical parameters (elements in mg/kg)																		
			% Clay	PI ws	Dry density	SG	e	K cm/s	pH	Fe %	Mn %	As	Ba	Co	Cr	Cu	Mo	Ni	Pb	Sn	Th	U	V	Zn		
0	Slightly moist, pale yellow banded and mottled yellow brown and orange, very soft layered sandy silt, Tailings.																									
0,45																										
0,80	Moist, olive stained pale yellow brown, loose intact clayey sand; Colluvium.	G/2/1	-	-	-	-	-	-	-	-	4,1	0,02	21	190	14	125	39	26	56	0	2	17	0	54	35	
0,95																										
1	Moist, light olive occasionally mottled dark olive and brown, loose, intact clayey sand with occasional coarse-, medium- and fine-grained, subrounded ferricrete gravel; Ferruginised colluvium.	G/2/2	22,63	8	1728,53	2,68	0,50	1×10^{-7}	6,31	5,4	0,05	22	192	18	159	47	24	73	3	0	19	0	74	56		
1,10																										
2	Very wet, light olive occasionally mottled dark olive and brown, soft, intact clayey sand with abundant coarse-, medium- and fine-grained, subrounded ferricrete gravel; Ferruginised colluvium.																									
3	Notes 1. Gradual refusal at 1,10 m on hardpan ferricrete. 2. Perched water table at 0,95 m.																									

meter

Date: 04.06.98

Locality: Case Study Site G

Elevation: 1607 m

Profiled by:

P Aucamp & T Rösner

APPENDIX B

Geochemical results

Table B.1 - Summary of geochemical soil analyses (technique: XRF, all trace elements in mg/kg).

Site	Sample- No.	TiO ₂ %	MnO %	Fe ₂ O ₃ %	Sc	V	Cr	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	W	Pb	Th	U
A	1/1	0.94	0.02	3.64	11	62	197	10	55	43	41	102	68	16	14	519	13	3	0	0	188	7	0	0	0
A	1/2	0.98	0.02	4.26	14	70	202	11	62	43	66	77	78	19	21	509	16	9	6	0	194	10	0	1	0
A	1/3	0.57	0.02	7.95	16	143	341	17	37	48	282	14	95	41	18	273	16	9	0	0	408	6	7	12	0
A	2/1	0.89	0.02	4.08	11	76	246	12	60	54	58	70	62	21	9	522	15	10	0	0	175	5	0	2	0
A	2/2	1.02	0.03	7.61	20	117	310	14	85	94	108	30	78	23	17	485	21	19	9	0	263	6	0	14	12
A	2/3	0.81	0.02	9.08	21	180	360	5	62	93	40	17	78	23	15	414	19	18	0	0	314	7	2	15	7
A	2/4	0.86	0.05	18.05	31	327	494	4	78	106	84	8	49	15	6	346	15	4	0	19	362	4	60	2	0
A	3/1	0.99	0.02	3.9	13	59	152	11	58	39	45	37	70	22	24	612	22	26	0	0	144	8	0	14	0
A	3/2	1.04	0.02	7.52	19	132	266	16	94	55	58	24	90	26	27	432	23	20	0	0	200	7	2	19	0
A	3/3	1.06	0.04	12.15	25	279	351	7	67	57	31	20	58	25	18	439	22	17	0	0	204	6	9	17	0
A	3/4	1.11	0.07	15.09	28	332	341	22	65	70	31	16	47	24	15	432	21	12	0	0	302	4	28	12	0
B	1/1	1.21	0.06	9.75	25	156	232	27	173	87	135	17	85	23	35	429	22	19	0	0	281	7	13	16	0
B	1/2	1.2	0.06	9.61	24	158	226	18	153	89	102	17	85	22	33	428	23	20	0	0	259	7	14	17	0
B	1/3	1.22	0.06	10.11	24	165	230	8	115	79	91	17	82	22	28	431	23	20	0	0	231	6	13	18	0
B	1/4	1.3	0.07	10.44	26	172	246	7	106	87	72	19	77	21	23	444	25	21	0	0	236	8	10	19	0
B	2/1	0.92	0.1	13.18	32	207	372	76	241	135	126	18	79	22	29	200	17	9	0	0	286	4	15	15	0
B	2/2	0.92	0.1	12.87	30	202	344	51	190	143	78	23	76	23	22	200	18	10	0	0	247	5	6	14	0
B	2/3	1.05	0.06	13.61	35	197	374	10	139	130	57	17	64	26	26	251	19	14	0	0	293	6	4	16	0
B	2/4	0.95	0.06	15.14	41	203	485	16	140	170	51	3	72	35	35	186	17	12	0	0	400	5	6	15	0
B	3/1	1.05	0.04	5.97	16	89	211	19	85	48	53	43	90	35	31	421	21	12	0	0	230	8	0	12	0
B	3/2	1.12	0.03	6.22	18	96	163	13	78	46	40	22	96	35	33	437	25	20	0	0	204	7	9	21	0
B	3/3	1.18	0.04	7.2	19	113	230	9	85	51	44	19	101	31	29	418	26	19	0	0	197	6	13	23	0
B	3/4	1.22	0.47	8.65	21	163	204	124	126	67	39	6	89	42	26	409	19	4	0	0	1018	5	83	8	0
C	1/1	1.03	0.03	7.14	18	112	170	13	77	44	49	68	96	16	17	405	18	8	0	0	205	6	0	7	0
C	1/2	1.1	0.04	8.54	21	126	191	14	79	50	47	25	107	20	30	388	24	18	0	0	212	7	8	21	0
C	1/3	1.06	0.06	14.23	27	254	369	33	76	67	36	7	74	19	9	361	12	0	0	0	526	3	118	0	0
C	1/4	1.05	0.11	10.55	21	167	220	25	65	54	38	22	93	30	21	397	22	16	0	0	511	5	10	17	0
C	2/1	0.99	0.05	6.91	15	99	223	20	51	32	34	13	70	57	31	405	22	16	0	0	370	5	14	17	0
C	2/2	0.96	0.07	7.07	16	107	230	28	72	32	41	15	71	53	33	378	22	15	0	0	383	6	15	17	0
C	2/3	1.03	0.03	7.05	17	166	270	16	56	27	33	21	57	57	24	359	23	14	0	0	406	6	17	19	0
C	2/4	0.84	0.17	23.86	36	937	622	188	282	89	28	38	43	30	115	246	10	0	0	64	428	10	8	0	0
C	3/1	1.31	0.03	4.09	14	98	166	22	53	46	29	30	67	26	28	537	27	23	0	0	193	8	5	20	8
C	3/2	1.18	0.1	6.85	17	146	201	40	76	39	34	23	78	28	32	444	24	18	0	0	237	6	19	18	0

Table B.1 continued.

Site	Sample- No.	TiO ₂ %	MnO %	Fe ₂ O ₃ %	Sc	V	Cr	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	W	Pb	Th	U
C	3/3	1.02	0.15	10.44	23	220	247	44	75	47	36	16	72	35	24	303	21	8	0	0	539	5	29	16	0
C	3/4	1.01	0.1	7.32	19	178	213	42	65	42	36	24	64	35	30	378	23	14	0	0	292	7	7	18	0
D	1/1	1.11	0.04	6.15	17	100	155	21	82	51	54	50	97	20	26	465	20	14	0	0	207	7	0	8	0
D	1/2	1.03	0.02	7.1	19	112	159	15	77	62	49	21	105	26	30	396	22	19	0	0	188	6	6	18	0
D	1/3	1.11	0.03	7.44	19	120	161	23	79	51	40	18	96	24	27	443	23	21	0	0	196	6	4	19	0
D	1/4	1.13	0.37	10.21	21	199	195	90	99	78	38	9	89	47	25	433	18	10	0	0	1252	4	46	8	0
D	2/1	1.24	0.06	8.86	22	150	189	23	109	93	55	64	95	22	27	434	16	6	0	0	342	5	0	1	0
D	2/2	1.1	0.08	9.44	23	164	192	40	142	97	61	16	104	25	34	356	21	15	0	0	312	5	10	15	0
D	2/3	1.21	0.46	10.53	23	213	181	295	157	96	40	9	85	89	23	377	16	7	0	0	1696	5	62	5	0
D	2/4	1.43	0.41	11.73	28	199	246	99	120	116	53	8	92	42	33	419	22	18	0	0	716	5	21	15	0
D	3/1	1.14	0.04	3.43	10	61	113	25	48	33	37	35	75	33	21	571	22	22	0	0	195	7	0	14	0
D	3/2	1.05	0.05	6.67	19	90	175	23	70	42	48	17	129	43	29	403	22	17	0	0	305	6	6	18	0
D	3/3	1.14	0.1	9.04	19	108	146	30	59	35	28	8	87	55	24	482	23	20	0	0	707	7	9	16	0
D	3/4	1.02	0.03	6.79	19	85	196	10	75	50	49	20	101	46	26	380	23	17	0	0	228	6	1	19	0
E	1/1	1.06	0.14	5.89	16	111	279	36	106	26	58	21	68	32	36	448	22	16	0	0	248	6	14	15	0
E	1/2	1.09	0.27	6.11	17	134	294	47	70	31	37	17	61	33	32	438	23	15	0	0	533	7	21	16	0
E	1/3	1.11	0.07	12.15	24	261	403	20	88	38	24	7	62	22	31	359	22	10	0	0	194	4	25	15	0
E	1/4	0.93	0.07	18.76	31	581	498	47	135	57	22	24	50	18	29	255	11	0	0	85	271	5	41	0	0
E	2/1	0.9	0.08	6.62	17	99	258	24	69	52	43	36	60	52	18	351	17	9	0	0	191	5	0	8	0
E	2/2	0.95	0.07	6.89	20	113	285	17	66	54	47	22	60	54	16	349	19	14	0	0	274	3	2	12	0
E	2/3	0.99	0.1	7.84	20	161	305	25	78	58	41	10	49	39	32	332	20	14	0	0	266	5	11	15	0
E	3/1	0.96	0.02	4.49	13	102	235	23	65	31	57	19	66	39	44	393	23	15	0	0	138	6	15	18	0
E	3/2	1.08	0.02	4.71	15	147	297	18	68	33	68	19	58	31	39	420	24	16	0	0	118	8	12	19	0
E	3/3	1.07	0.02	3.62	13	118	287	14	61	27	83	23	58	29	30	480	24	19	0	0	109	8	10	17	0

Table B.1 continued.

Site	Sample- No.	TiO ₂ %	MnO %	Fe ₂ O ₃ %	Sc	V	Cr	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	W	Pb	Th	U
F	1/1	1.16	0.16	8.59	22	139	178	5	76	53	43	20	89	25	24	462	25	22	0	0	188	6	11	21	0
F	1/2	1.12	0.19	7.33	20	127	170	30	143	90	80	31	88	21	37	484	24	22	0	0	222	8	10	18	57
F	1/3	1.18	0.12	8.28	21	134	169	4	68	49	40	21	81	23	18	498	25	23	0	0	182	6	11	20	0
F	1/4	1.18	0.09	8.16	20	133	200	3	62	43	36	21	77	24	17	506	25	24	0	0	178	8	9	21	0
F	2/1	1.07	0.44	8.46	21	135	202	9	83	68	46	20	82	27	28	462	22	22	0	0	235	6	11	18	0
F	2/2	1.04	0.18	9.34	24	152	208	5	88	68	46	17	87	24	24	422	22	20	0	0	214	7	12	18	0
F	2/3	1.13	0.11	9.6	24	154	199	4	78	63	39	20	77	22	21	439	23	21	0	0	196	6	10	20	0
F	2/4	1.11	0.11	9.04	22	144	209	4	66	54	37	18	70	23	19	469	23	23	0	0	186	5	7	20	0
F	3/1	1.06	0.04	5.44	18	125	179	60	312	55	205	200	79	13	35	479	35	24	0	0	194	12	0	0	1175
F	3/2	1.07	0.04	6.61	20	131	178	51	301	56	281	72	91	21	46	474	36	36	0	0	183	9	3	13	704
F	3/3	0.87	0.06	7.22	18	129	291	14	83	47	40	24	68	28	16	379	20	15	0	0	179	7	10	16	9
F	3/4	0.87	0.06	7.58	18	142	292	15	96	52	51	28	68	28	17	355	21	14	0	0	170	6	4	15	50
F	4/1	1.05	0.03	5.17	18	118	267	32	187	74	147	92	77	24	23	518	41	43	0	0	188	9	0	50	932
F	4/2	1.06	0.05	8.07	21	132	174	12	92	53	41	21	83	22	23	462	23	21	0	0	179	7	9	19	0
F	4/3	1.05	0.04	7.23	19	135	181	25	147	58	98	27	84	24	35	462	24	23	0	0	201	8	8	17	100
F	4/4	1.16	0.06	8.51	22	138	199	5	78	53	49	19	77	22	21	482	24	21	0	0	191	7	7	19	0
G	1/1	1.06	0.02	3.08	13	47	122	47	103	41	39	52	84	19	28	545	19	19	0	0	176	8	0	9	0
G	1/2	0.98	0.01	5.27	16	58	141	8	70	43	44	23	113	21	25	405	21	18	0	0	185	7	4	17	0
G	1/3	1.12	0.03	4.18	16	41	126	12	66	39	40	22	104	20	26	479	24	22	0	0	178	7	2	20	0
G	2/1	1.03	0.02	4.06	14	54	125	14	56	39	35	21	86	22	21	549	22	26	2	0	190	7	0	17	0
G	2/2	1.13	0.05	5.44	16	74	159	18	73	47	56	22	93	20	34	516	23	24	0	0	192	8	3	19	0
G	3/1	1.16	0.03	2.93	14	31	97	21	67	33	40	56	91	21	31	497	20	14	0	0	209	9	0	8	0
G	3/2	1.15	0.02	3.31	14	34	104	12	55	34	38	36	106	23	32	488	22	19	0	0	224	6	0	15	0
G	3/3	1.12	0.03	3.89	14	41	121	22	73	42	44	22	119	23	27	414	24	19	0	0	206	6	7	20	0

Table B.2 - Main statistical parameters from Table B.1.

	TiO ₂ %	MnO %	Fe ₂ O ₃ %	Sc	V	Cr	Co	Ni	Cu	Zn	As	Rb	Sr	Y	Zr	Nb	Mo	Sn	Sb	Ba	W	Pb	Th	U
MIN	0.57	0.01	2.93	10	31	97	3	37	26	22	3	43	13	6	186	10	0	0	0	109	3	0	0	0
MAX	1.43	0.47	23.86	41	937	622	295	312	170	282	200	129	89	115	612	41	43	9	85	1696	12	118	50	1175
STDEV	0.12	0.10	3.74	5.8	117.5	96.6	41.0	54.1	28.1	46.1	27.1	17.0	12.4	12.4	82.9	4.6	7.2	1.2	11.9	239.5	1.6	18.7	7.2	181.9
AVG	1.06	0.09	8.17	20.2	151.7	237.5	29.5	96.6	60.1	59.5	28.6	80.0	29.1	27.0	420.6	21.6	16.4	0.2	2.1	299.6	6.4	12.3	14.7	37.7

Table B.3 - Background values for the Vryheid Formation (all trace elements in mg/kg, n=21).

Sample- No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	AVG	STDEV
TiO ₂ %	1.06	1.08	1.01	0.96	0.95	0.92	0.99	0.95	0.96	1.01	0.91	0.89	0.95	0.97	1	0.91	1	0.84	0.91	0.89	0.99	0.96	0.06
MnO %	0.14	0.05	0.1	0.04	0.11	0.08	0.06	0.08	0.1	0.12	0.13	0.08	0.07	0.07	0.06	0.05	0.08	0.06	0.08	0.06	0.09	0.08	0.03
Fe ₂ O ₃ %	6.44	3.3	4.99	4.48	4.6	2.58	2.63	4.31	5.05	4.59	5.85	4.8	4.37	4.44	4.87	3.77	4.96	3.13	5.62	2.51	5.1	4.40	1.07
As	26	18	25	24	17	18	14	19	22	15	20	22	27	25	20	28	24	23	31	21	26	22.14	4.41
Ba	246	266	270	257	267	183	177	196	277	279	341	192	161	169	171	153	174	145	251	85	214	213.05	60.72
Co	18	12	18	10	18	12	10	15	15	18	21	13	13	14	13	12	15	10	15	11	15	14.19	3.08
Cr	157	93	123	130	117	83	107	115	139	145	175	132	134	132	149	136	130	96	223	80	131	129.86	31.89
Cu	43	28	46	24	33	26	24	33	46	34	37	41	36	37	37	35	39	29	39	21	38	34.57	7.09
Mo	20	30	18	19	19	25	28	25	21	22	22	17	28	24	23	20	23	27	21	39	22	23.48	4.99
Nb	21	24	20	21	18	20	21	20	18	20	18	17	21	21	21	19	21	20	19	20	20	20.00	1.52
Ni	61	33	51	38	42	29	26	44	53	41	46	50	50	51	55	48	56	38	59	32	54	45.57	9.99
Pb	12	5	15	5	33	17	14	20	25	15	16	30	10	8	10	20	14	3	11	4	17	14.48	8.04
Rb	89	84	89	97	78	72	73	76	72	80	70	83	79	81	83	68	79	69	82	50	80	77.81	9.63
Sb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0	0	0.76	3.49
Sc	18	12	13	13	12	8	10	12	15	12	15	14	13	14	13	12	15	10	16	9	14	12.86	2.37
Sn	0	2	0	0	0	0	2	0	7	1	0	0	0	1	2	1	0	6	0	0	0	1.05	1.96
Sr	36	33	37	45	25	36	32	29	102	29	27	29	27	26	25	26	23	24	35	22	34	33.43	16.72
Th	15	18	12	18	8	12	14	12	12	12	10	8	15	16	15	12	14	15	14	15	13	13.33	2.69
U	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.00	0.00
V	99	41	69	55	68	36	34	61	75	67	97	67	66	67	73	59	79	44	106	37	74	65.43	20.11
W	8	8	8	6	6	10	9	6	7	8	8	7	8	9	7	7	7	8	7	8	14	7.90	1.73
Y	31	29	29	31	22	23	23	26	28	27	26	25	28	28	27	24	25	24	22	21	30	26.14	3.02
Zn	68	48	125	41	136	205	230	142	199	80	74	145	93	87	79	60	67	49	78	56	108	103.33	54.74
Zr	492	623	494	443	553	609	656	616	591	579	579	502	603	555	542	520	528	560	532	793	549	567.57	72.56

Table B.4 - Extraction test results of the gold mine tailings (all element concentrations in mg/l).

Sample- No.	1	2	3	4	5	6	7	8	9	10	11	12	13
As	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00
Ca	1574.50	660.00	202.50	860.00	1082.50	500.00	1362.50	1770.00	1342.50	2185.00	2182.50	1750.00	3020.00
Co	0.50	1.00	0.00	0.00	10.00	17.50	25.00	30.00	2.50	15.00	15.00	10.00	25.00
Cr	0.00	0.00	0.00	0.00	1.75	1.25	1.75	2.25	1.00	0.50	5.00	2.50	5.00
Cu	2.50	2.50	0.00	0.25	12.52	17.50	22.50	22.50	1.50	2.50	7.50	5.00	10.00
Fe	0.75	2.50	0.50	0.00	50.00	87.50	105.00	60.00	25.00	7.50	55.00	37.50	5.00
Mg	7.50	72.50	17.50	10.00	460.00	687.50	802.50	927.50	290.00	312.50	955.00	650.00	1487.50
Mn	1.25	2.50	0.50	0.50	15.00	22.50	25.00	27.50	10.00	42.50	35.00	25.00	45.00
Ni	1.25	2.50	0.00	0.00	32.50	57.50	77.50	105.00	10.00	45.00	47.50	35.00	80.00
Pb	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.75	0.25	0.50	0.50	0.50	0.75
S	1257.50	697.50	60.00	650.00	3090.00	3712.50	5097.00	6132.50	2510.00	4837.50	4820.00	4827.50	11262.50
U	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Zn	0.25	1.50	0.25	0.00	7.50	10.00	12.50	15.00	10.00	80.00	40.00	27.50	60.00

Note: 0 means below detection limit.

Table B.5 - Threshold excess ratios for the extractable trace element concentrations in soils of study site F.

Sample- No.	F/1/1	F/1/2	F/1/3	F/1/4	F/2/1	F/2/2	F/2/3	F/2/4	F/3/1	F/3/2	F/3/3	F/3/4	F/4/1	F/4/2	F/4/3	F/4/4
As	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	-	40	-	-	-	-	-	1.5	30	10	4	5	30	5	2	1.5
Cr	-	-	-	-	-	-	-	-	-	-	-	-	12.5	-	-	-
Cu	-	3.75	-	-	-	-	-	-	0.13	-	-	0.25	1.25	0.13	-	0.38
Ni	-	72.5	-	-	2.5	-	-	0.25	77.5	15	2.5	10	40	10	2	5
Pb	-	0.38	-	-	-	-	-	-	-	-	-	0.25	0.5	-	-	-
U	-	-	-	-	-	-	-	-	118.75	62.5	-	-	1500	-	-	-
Zn	-	2.75	-	-	0.2	0.05	-	0.15	6.25	2.75	0.2	1	5.75	1	-	0.5

Note: - indicates where no excess occurred.

Table B.6 - Trace element mobility in soil. Extractable trace element concentrations are expressed as a percentage of the total concentration.

Sample	F/1/1	F/1/2	F/1/3	F/1/4	F/2/1	F/2/2	F/2/3	F/2/4	F/3/1	F/3/2	F/3/3	F/3/4	F/4/1	F/4/2	F/4/3	F/4/4
Soil pH	6.69	3.66	6.62	-	4.37	6.67	6.29	-	4.53	5.17	-	4.7	3.7	4.71	-	4.65
As	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Co	-	66.67	-	-	-	-	-	18.75	25	9.8	14.29	16.67	46.88	20.83	4	15
Cr	-	-	-	-	-	-	-	-	-	-	-	-	0.47	-	-	-
Cu	-	8.33	-	-	-	-	-	-	0.45	-	-	0.96	3.38	0.47	-	1.42
Fe	-	-	-	-	-	-	-	-	-	-	-	-	19.34	-	-	8.81
Ni	-	50.7	-	-	3.01	-	-	0.38	24.84	4.98	3.01	10.42	21.39	10.87	1.36	6.41
Pb	-	7.5	-	-	-	-	-	-	-	-	<0.01	12.5	-	-	-	-
U	-	-	-	-	-	-	-	-	0.4	0.36	-	-	6.44	-	-	-
Zn	-	34.38	-	-	4.35	1.09	-	4.05	30.49	9.79	5	19.61	39.12	24.39	-	10.2

Table B-7: Correlation matrix (Pearson coefficient) for selected major and trace elements in solid tailings samples from five different tailings dams situated in the East Rand area (source data from Rösner, 1996; n=36).

	SiO ₂	TiO ₂	Al ₂ O ₃	Fe ₂ O ₃	MnO	MgO	CaO	Na ₂ O	K ₂ O	P ₂ O ₅	As	Co	Cu	Cr	Ni	Pb	Zn	Th	U
SiO ₂	1	0.55	0.86	0.67	0.26	0.40	0.11	0.03	0.81	0.30	0.14	0.3	0.26	0.44	0.36	0.12	0.10	0.07	0.08
TiO ₂		1	0.74	0.03	0.33	0.58	0.28	0.10	0.82	0.26	0.16	0.45	0.30	0.66	0.57	0.01	0.14	0.15	0.16
Al ₂ O ₃			1	0.41	0.22	0.47	0.40	0.02	0.96	0.31	0.10	0.42	0.30	0.60	0.45	0.08	0.15	0.11	0.14
Fe ₂ O ₃				1	0.33	0.20	0.08	0.26	0.27	0.52	0.06	0	0.02	0.07	0.03	0.09	0.01	0.05	0.01
MnO					1	0.22	0.51	0.18	0.12	0.49	0.16	0.01	0.07	0.02	0.09	0.10	0.17	0.04	0.06
MgO						1	0.15	0.17	0.39	0.30	0.02	0.22	0.24	0.32	0.38	0.01	0.19	0.17	0.07
CaO							1	0.14	0.46	0.02	0.19	0.49	0.35	0.48	0.36	0.46	0.48	0.17	0.54
Na ₂ O								1	0.07	0.08	0.10	0.07	0.02	0.03	0.12	0.27	0.08	0.26	0.05
K ₂ O									1	0.27	0.18	0.47	0.32	0.70	0.51	0.07	0.13	0.15	0.16
P ₂ O ₅										1	0.12	0.10	0.19	0.11	0.09	0.26	0.55	0.07	0.38
As											1	0.30	0.45	0.32	0.24	0.32	0.06	0.17	0.24
Co												1	0.72	0.48	0.90	0.36	0.56	0.38	0.66
Cu													1	0.45	0.76	0.12	0.24	0.19	0.30
Cr														1	0.62	0.12	0.60	0.27	0.19
Ni															1	0.15	0.43	0.33	0.50
Pb																1	0.72	0.15	0.84
Zn																	1	0.18	0.92
Th																		1	0.28
U																			1

r = 1 maximum positive correlation between two variables;
r = 0 no correlation between two variables;
r = -1 maximum negative correlation between two variables.

Table B-8: Correlation matrix (Pearson coefficient) for selected trace elements in soils of the sites A-G (n = 81).

Element	As	Ba	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Th	U	Zn
As	1	0.23	0	0.13	0.08	0.24	0.25	0.08	0.41	0.34	0.25	0.74	0.26
Ba		1	0.78	0.14	0.30	0.34	0.73	0.40	0.17	0.58	0.25	0.08	0.13
Co			1	0.23	0.31	0.37	0.63	0.35	0.51	0.40	0.29	0.10	0.05
Cr				1	0.56	0.83	0.04	0.59	0.41	0.24	0.17	0.01	0.13
Cu					1	0.68	0.25	0.33	0.59	0.13	0.07	0.05	0
Fe						1	0.26	0.56	0.49	0.38	0.20	0.08	0.20
Mn							1	0.19	0.16	0.48	0.12	0.09	0.12
Mo								1	0.11	0.42	0.63	0.37	0.32
Ni									1	0.02	0.09	0.60	0.25
Pb										1	0.33	0.13	0.03
Th											1	0.15	0.06
U												1	0.46
Zn													1

Table B-9: Correlation (Pearson coefficient) of selected trace elements with the clay content in the soil (n=59).

	As	Ba	Co	Cr	Cu	Fe	Mn	Mo	Ni	Pb	Th	U	Zn
Clay	0.3	0.02	0.03	0.10	0.24	0.12	0.12	0.01	0.10	0.03	0.23	0.15	0.18

r = 1 maximum positive correlation between two variables;

r = 0 no correlation between two variables;

r = -1 maximum negative correlation between two variables.



APPENDIX C

Geochemical properties of selected elements and compounds

Table C.1 - Main geochemical properties of elements of concern.

Element	Occurrence in the gold-bearing conglomerates	Geochemical properties In soil and waters	Environmental and health effects	Permissible contents in water and soil
Sulphate (SO ₄)	Predominantly from the oxidation of sulphide-bearing minerals such as pyrite [FeS ₂].	Readily soluble in water, excess Ca ²⁺ e.g. in dolomitic aquifers results in the precipitation of CaSO ₄ .	Contents of 200-400 mg/l cause a salt and bitter taste in drinking water. Higher contents (> 600 mg/l) can cause diarrhoea (DWAF, 1996a).	Target water quality ranges from 0-200 mg/l in waters for domestic use (DWAF, 1996a).
Arsenic (As)	Arsenopyrite [FeSAs]. Further sources are realgar [As ₂ S ₂] and orpiment [As ₂ S ₃].	Arsenic is rarely encountered in natural waters (Lide, 1999). However, As dissolves under acid conditions such as in the presence of AMD.	A toxic, non-essential element that causes chronic (cancer) and acute poisoning (nerve damage). As (III) shows phytotoxic effects at contents between 1-4 mg/kg in plant leaves (Alloway, 1995). Long-term exposure of 200-300 µg/l can cause skin cancer, contents above 1000 µg/l are considered to be lethal to man (DWAF, 1996a).	Target water quality for domestic use is ≤ 10 µg/l and < 200 µg/l (only for short-term exposure) for potable water (DWAF, 1996a). For comparison, the limit of the European Union for drinking water is given as 50 µg/l (EU 98/83/EG). The target soil quality is given as < 29 mg/kg and intervention value with > 55 mg/kg dry weight (Dutch List, 1997).
Cobalt (Co)	Cobaltite [CoAsS] and other sulphide minerals such as pyrite. In pyrite, Co can be camouflaged by Fe.	Properties are similar to Fe and Ni, where the pH is the main parameter for the solubility. During the weathering process, Co may dissolve more readily than Ni. Co is usually found in soils in Co (II) species. At low pH it is oxidised to Co (III) and often found associated with Fe (Lide, 1999).	Only a few plant species accumulate Co under acidic soil conditions above 100 mg/kg which causes severe phytotoxicity. Contents of 0.1-5 mg/l when added to nutrients have been found to be toxic in a variety of food crops. However, the occurrence of Co is not common under field conditions (DWAF, 1996d).	No target water quality for domestic use is available, but a concentration of ≤ 50 µg/kg is recommended in soils (DWAF, 1996d). The target soil quality is given as < 20 mg/kg and the intervention value with > 240 mg/kg dry weight (Dutch List, 1997).

Table C.1 continued.

Chromium (Cr)	Cr is widely distributed in soils and rocks where it occurs in minerals such as chromite [(Fe, Mg) (Cr, Al) ₂ O ₄].	Occurs as Cr (III) and Cr (VI) in waters, where Cr (III) is most stable. Cr is transported primarily in the solid phase in streams, and therefore is not bio-available (Moore & Ramamoorthy, 1984).	Although Cr is present in all soils and plants, it is considered agriculturally as a deleterious element, where Cr (VI) is more phytotoxic than the Cr (III). Phytotoxic effects occur between 5-30 mg/kg in plant leaves (Alloway, 1995). However, Cr is essential to animals and man and is often found in high contents in combination with nucleic acids. The normal human adult body contains about 6 mg (Crouse et al., 1983).	Target quality in waters for domestic use is 50 µg/l (BGA, 1993). Drinking water generally contains the same Cr levels as surface and groundwaters. The target soil quality is given as < 100 mg/kg and the intervention value with > 380 mg/kg dry weight (Dutch List, 1997).
Copper (Cu)	Widely distributed in sulphides, arsenites, chlorides, and carbonates.	At neutral to alkaline pH, the content in surface waters is usually low, whereas in acidic waters, Cu readily dissolves and significantly higher contents might occur (Lide, 1999).	Cu is an essential element for almost all living organisms and the normal average human adult contains about 100-150 mg (Crouse et al., 1983). Contents above 30 mg/l can cause acute poisoning for man with nausea and vomiting (DWAf, 1996a).	Target water quality for domestic use water is < 1 mg/l and for potable water should not exceed 30 mg/l (1996a). The target soil quality is given as < 36 mg/kg and the intervention value with > 190 mg/kg dry weight (Dutch List, 1997).
Iron (Fe)	Magnetite [Fe ₃ O ₄], pyrite [FeS ₂] and weathering products such as goethite [FeO(OH)].	Important factor controlling the migration of Fe is the contents of other metals such as Mn (DWAf, 1996a). AMD can cause a very low pH in waters resulting in dissolved contents of Fe to the order of several hundred mg/l (DWAf, 1996a).	Is an essential element for all living organisms and an average human adult contains about 4-5 g (Crouse et al., 1983). Poisoning is rare, since very high contents of dissolved Fe in natural waters hardly ever occur. Chronic poisoning can be expected at 10-20 mg/l (Lide, 1999).	Target water quality for domestic use is ≤ 0.1 mg/l. No target soil quality is given since Fe is a major constituent of soils.
Nickel (Ni)	Pyrrhothite [Fe _{1-x} S], which can contain up to 5 % Ni and pentlandite [(Fe, Ni) ₉ S ₈]. Further mineral sources are chalcopyrite [CuFeS ₂] and gersdorffite [NiAsS]. In addition, Ni can be camouflaged by Fe in pyrite.	Is strongly retained by soils, preferably in the fine particle size fraction (Moore & Ramamoorthy, 1984). During weathering Ni is readily remobilized, whereas precipitation occurs mainly in the presence of Fe and Mn oxides (Alloway, 1995) or possibly as As oxides. Ni, Fe and Co arsenates are insoluble, except at low pH.	Ni is is phytotoxic under acid soil conditions (Németh, Molnár, Csillag, Butjás, Lukács, Pártay, Féher & Van Genuchten, 1993) and toxic to man, causing liver and heart damage, cancer and dermatitis at high concentrations.	Target water quality for domestic use is not available. The limit for agricultural use such as irrigation is given as ≤ 0.2 mg/l (DWAf, 1996d). The target soil quality is given as < 35 mg/kg and the intervention value with > 210 mg/kg dry weight (Dutch List, 1997).

Table C.1 continued.

Manganese (Mn)	Spahlerite [(Zn, Fe)S], which often contains some Mn.	Similar to Fe, where both elements tend to dissolve under aerobic conditions and co-precipitate under anaerobic conditions. Once Mn is dissolved, it is difficult to remove from solution except at high pH, where it precipitates as the hydroxide (DWAF, 1996a).	Mn is essential to a wide variety of animals (Crouse et al., 1983). Although it is less toxic than other metals, chronic effects occur at contents above 20 mg/l (DWAF, 1996a).	Target water quality for domestic use is given as ≤ 0.05 mg/l (DWAF, 1996a). No target soil quality is given since Mn is a major constituent of soils.
Lead (Pb)	Galena [PbS].	Contents of Pb in soil solution reach a minimum below a pH of 5-6 and increase below pH 4 - 5 and above 6-7, because metal-organic complexes are formed in this pH range (Lide, 1999). Chemical properties are similar to those of Cd, Co, Ni and Zn (DWAF, 1996d). In connection with AMD, Pb forms insoluble $PbCO_3$ (cerussite), $PbSO_4$ (anglesite) compounds or Fe-hydroxides. Much of the Pb transported in streams is in the form of suspended matter, and thus not bio-available (Lide, 1999).	Pb is non-essential and above normal blood and tissue levels toxic to humans and animals. Pb is neither as toxic as many other heavy metals nor as bio-available, however, it is generally more ubiquitous in the environment and is a cumulative toxin in the mammalian body, thus toxic concentrations can accumulate in the bone marrow (Alloway & Ayres, 1996). Significant health effects such as limitation of neurological functions can be expected from contents above 50 μ g/l. Very high levels of Pb are lethal to man (Lide, 1999).	Target water quality for domestic use is given as ≤ 10 μ g/l (DWAF, 1996a). The target soil quality is given as < 85 mg/kg and the intervention value with > 230 mg/kg (Dutch List, 1997).
Zinc (Zn)	Sphalerite [ZnS], which is often associated with galena.	Zn is dissolved under acidic conditions, whereas at pH > 8 it precipitates as the relatively stable hydroxide $Zn(OH)_2$ (Moore & Ramamoorthy, 1984). Zn strongly interacts with Cd, which shows similar geochemical properties (Lide, 1999).	Zn is an essential element is a variety of animals (Olson, 1983). Zn is phytotoxic and less toxic to man than other heavy metals (Alloway & Ayres, 1996); acute toxic effects can be expected at contents above 700 mg/l (DWAF, 1996a). Zn is mainly a cause of	Target water quality for domestic use is given as ≤ 3 mg/l. The target soil quality is given as < 140 mg/kg and the intervention value with > 720 mg/kg dry weight (Dutch List, 1997).

Table C-1 continued.

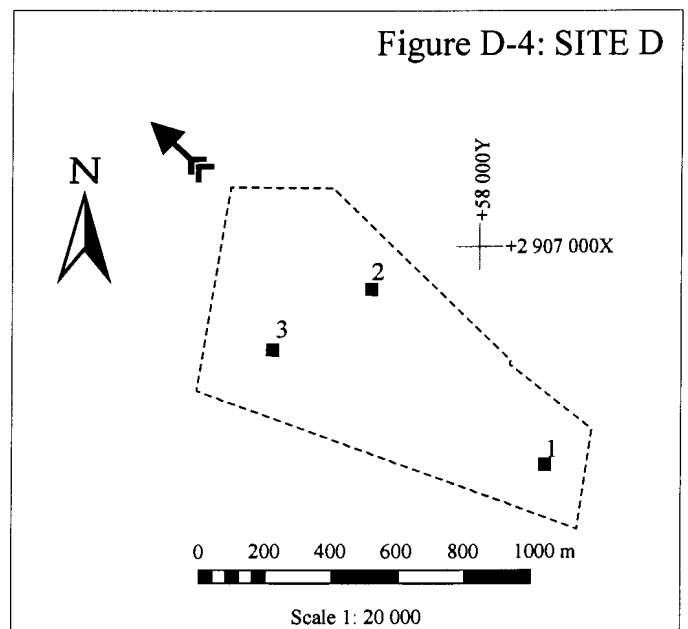
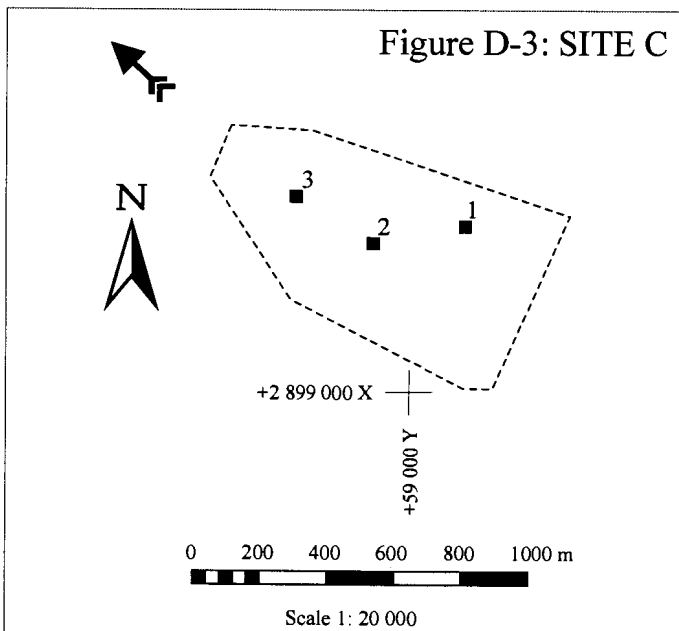
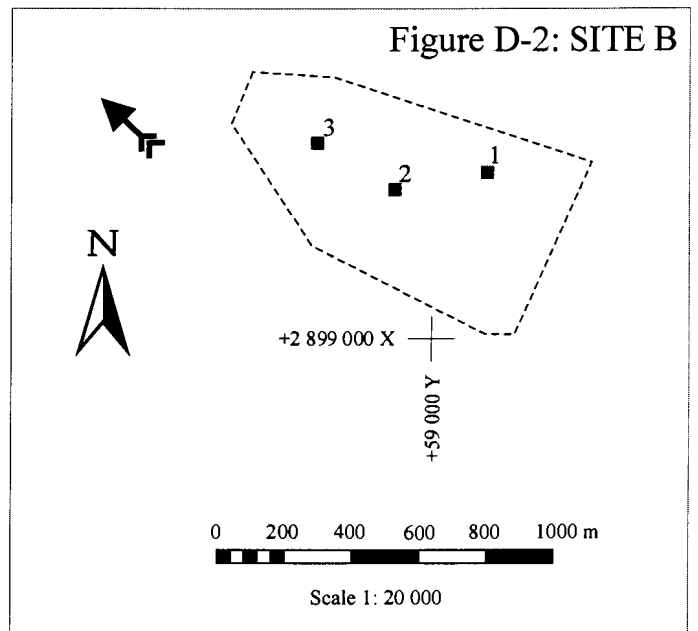
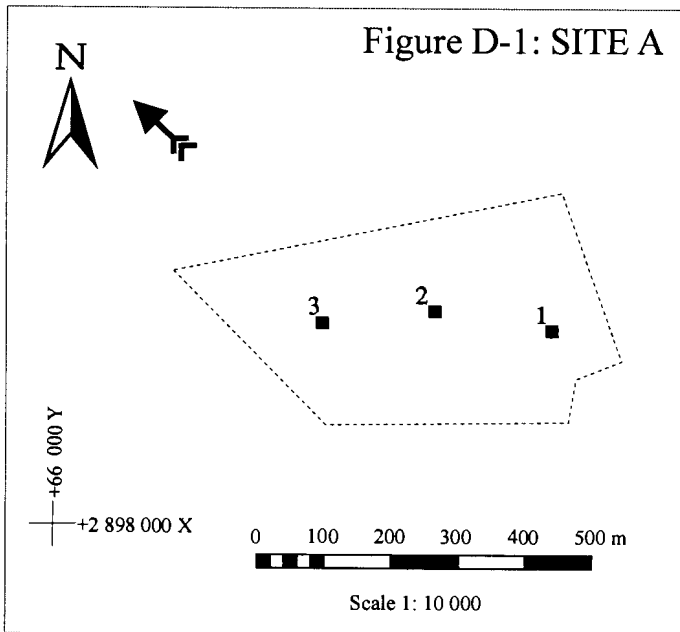
Uranium (U)	Uraninite [UO ₂], which alters to limonite and hematite. Further sources are zircon and monazite (Meyer, Saager & Kölpel, 1986). Note, that the Wits ore is low in Th (CNS, 1997).	U has a complex decay chain resulting in emissions of different radiations and the generation of different radioactive daughter products. U can accumulate in waters and migrate over long distances even at pH > 7.5, because of its ability to form complexes such as with carbonates in dolomitic waters (Bowie & Plant, 1983).	U and its compounds are highly toxic, both under chemical and radiological aspects. However, U contents in human bodies vary due to geographic differences of U in the environment averaging 0.02 mg per 70 kg (Lide, 1999).	A U content of 0.07 mg/l should not be exceeded in water for domestic use. Contents above 0.284 mg/l indicate a cancer risk < 1 : 200 000 and above 1.42 mg/l an increased cancer risk for humans in the long-term or renal damage in the short-time (DWAF, 1996a). Target water quality for irrigation waters is given as > 0.1 mg/l only over the short-term and on a site-specific base (DWAF, 1996).
Cyanide (CN)	CN is typically not contained in the Wits ore, but added [NaCN] during the gold recovery process.	Most of the aqueous cyanide is in the hydrocyanic form and is largely undissociated at pH values < 8 (DWAF, 1996f). In addition, the cyanide ion (CN ⁻) decomposes in aqueous solutions to cyanate (OCN ⁻), which is not stable and further decomposes to CO ₂ and NH ₃ (Mortimer, 1987).	Toxicity depends on various factors such as pH, temperature, dissolved oxygen content, salinity and the presence of other ions in solution. Chronic effects are expected at concentrations of about 4 µg/l and acute effects at concentrations > 11 µg/l free cyanide (DWAF, 1996 f). The lethal dose for humans is 1-3 mg/kg body weight (Lide, 1999).	The target water quality for free cyanide in aquatic ecosystems is given as ≤ 1 µg/l (DWAF, 1996 f). For comparison, the limit of the European Union for drinking water is given as 50 µg/l for total CN (EU 98/83/EG). The target soil quality is given as < 5 mg/kg (pH < 5) and the intervention value with > 50 mg/kg dry weight (pH < 5) would require remedial actions (Dutch List, 1997).

Note: Abbreviations DWAF = Department of Water Affairs and Forestry. BGA = Bundesgesundheitsamt, Germany. Dutch List, 1997 refers to the Netherlands Ministry of Housing, Physical Planning and Environment, 1997



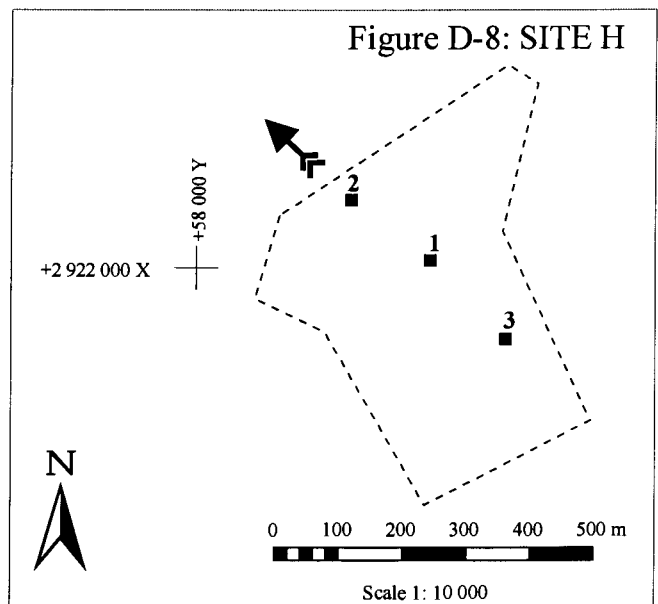
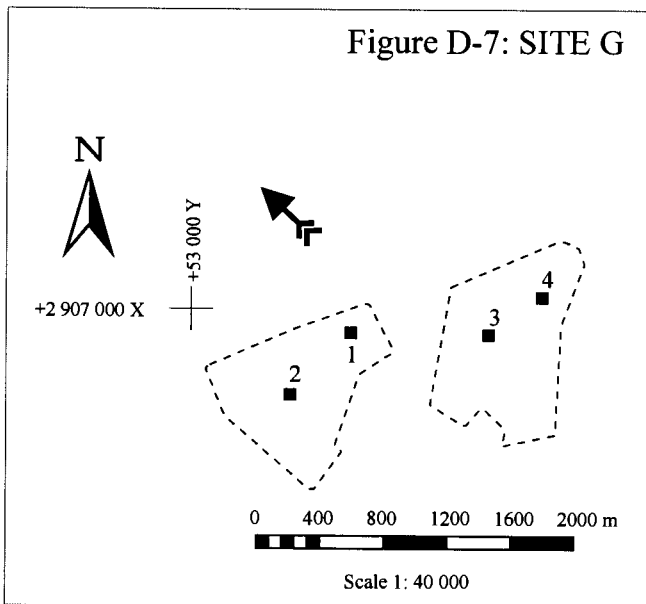
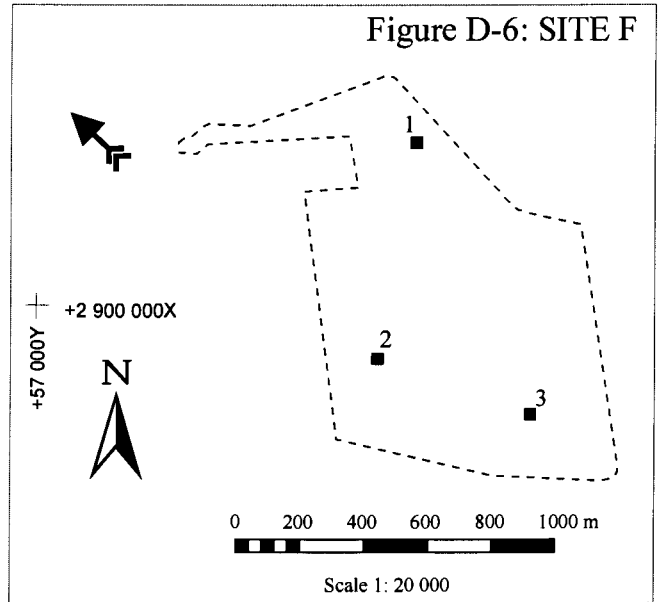
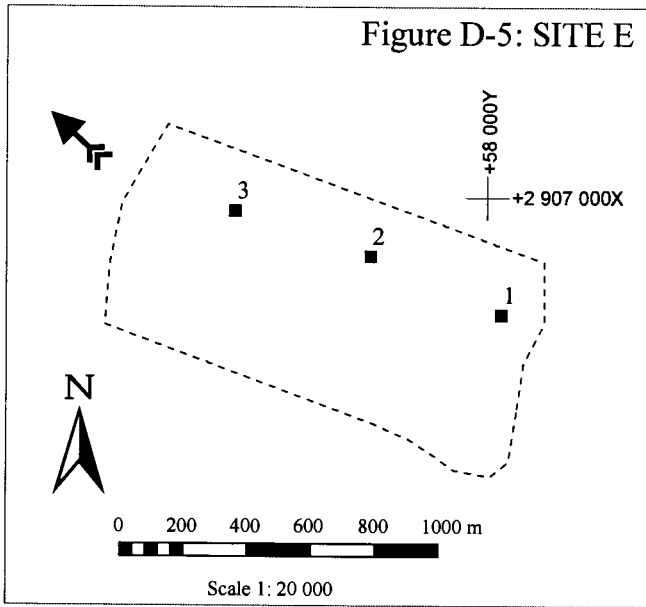
APPENDIX D

Study site maps



LEGEND

- Test pit (TP)
- ↖ Prevailing wind direction
- ⬭ Site boundary



LEGEND

- Test pit (TP)
- ↖ Prevailing wind direction
- ⋮ Site boundary



APPENDIX E

Photographs



Fig. E.1 - Study site A. Partially reclaimed. Dam height approximately 15-20 metres.

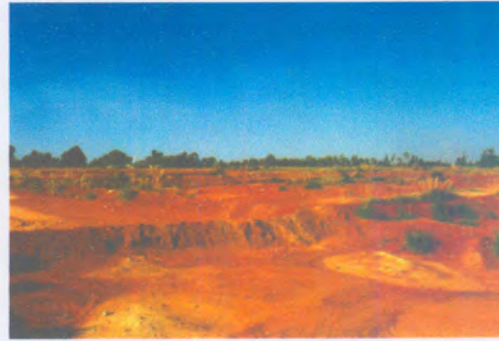


FIG. E.2 - Study site B. Some portions of tailings remaining on the surface. Paddocks were established to prevent storm water run-off.

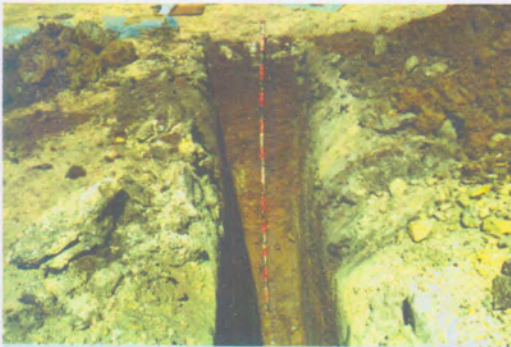


FIG. E.3 - Study site B. One of the test pits, maximum depth 2.40 m.



FIG. E.4 - Study site D. Some portions of tailings remaining on the surface. Grass cover is poorly developed.



FIG. E.5 - Study site E. Some portions of tailings remaining on the surface. Paddocks were established to prevent storm water run-off.



FIG. E.6 - Study site F. Some portions of tailings remaining on the surface. Grass cover is poorly developed



FIG. E.7 - Study site I. Rehabilitation of the slope wall to prevent wind erosion and dust generation.



FIG. E.8 - Track-mounted backactor on a Mercedes Unimog in action at one of the investigated sites.



FIG. E.9 - Seepage sampling next to an operating tailings dam site near Duduza. The water is highly acidic.



FIG. E.10 - Seepage in test pit C/2. A sample was taken for chemical analysis.

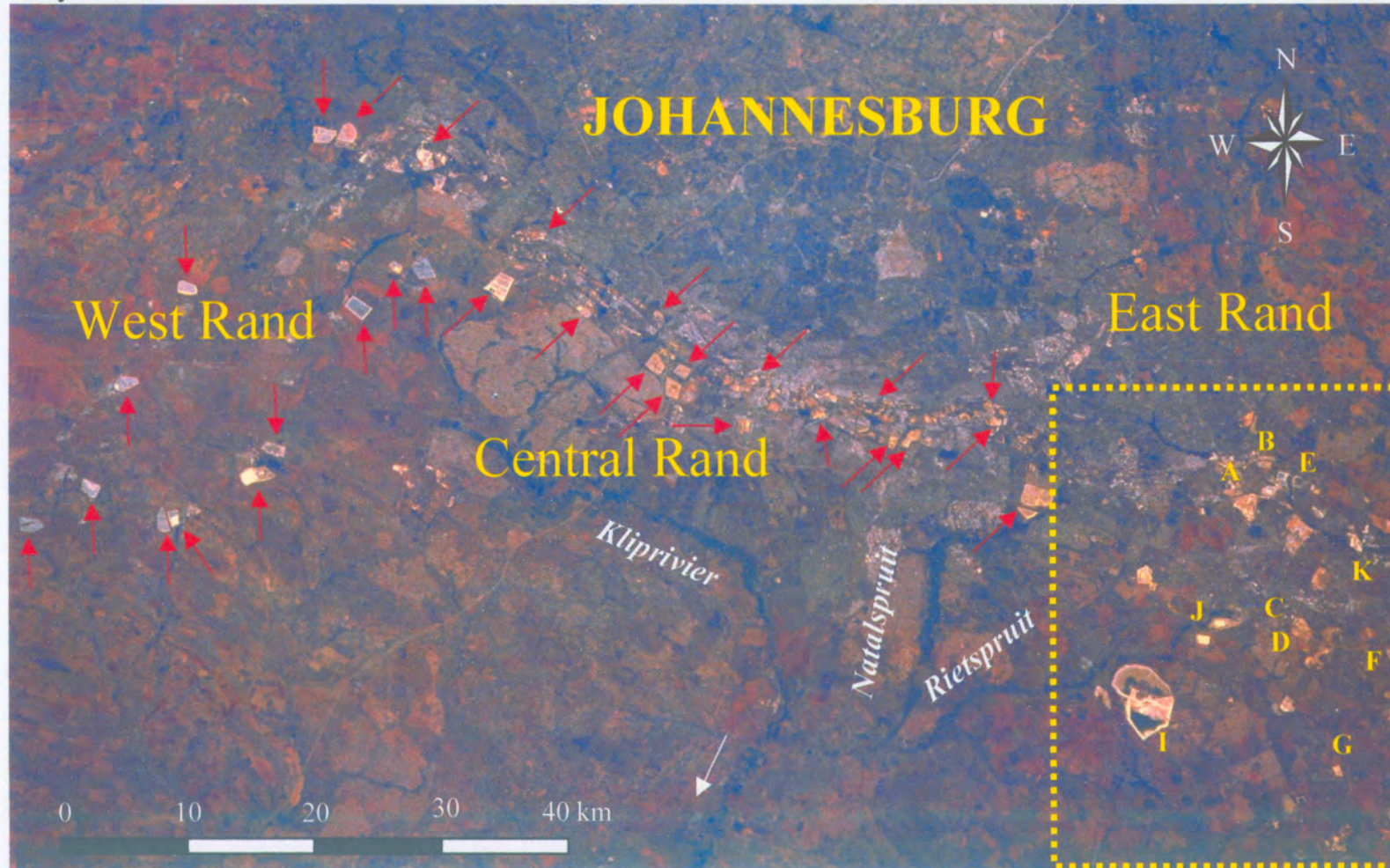


FIG. E.11 - Ferricrete block consisting of iron concretions.



FIG. E.12 - Precipitation of secondary minerals such as gypsum. Photograph taken at study site G.

Fig. E.13 - Satellite image of the Johannesburg area, depicting the location of tailings dams, drainage systems and the study area



→ Location of tailings dams

NASA: STO53-080-032/1 (1994)



I declare that this thesis which I am submitting to the University of Pretoria for the Ph.D. degree, represents my own work and has never been submitted by me to any other tertiary institution for any degree.

Thorsten Rösner
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Thorsten Rösner