Before the Hearing Panel
at Queenstown

under: the National Parks Act 1980 and Conservation Act 1987

and

in the matter submissions in relation to the Minister of Conservation's intention to grant a Concession Application by **Milford Dart Limited** to investigate, construct, operate and maintain a bus tunnel from the Routeburn Road in Mt Aspiring National Park to the Hollyford Road in Fiordland National Park

Statement of evidence in rebuttal of Ronald Fleming

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CHAPMAN TRIPP

STATEMENT OF EVIDENCE IN REBUTTAL OF RONALD W FLEMING

INTRODUCTION

1 My name is RONALD WILLIAM FLEMING. I am a Senior Principal with URS New Zealand Ltd (URS), (formerly Woodward-Clyde (NZ) Ltd), an environmental and engineering design company. I am authorised to give evidence on behalf of URS.

2 I graduated with a Bachelor of Engineering (Civil) in 1970. I am a Member of the Institution of Professional Engineers (MIPENZ), a Chartered Professional Engineer (CPEng) in the civil engineering field and I am on the International Register of Professional Engineers (IntPE). I am a Category A Recognised Engineer under the Building Act 2004.

3 Tunnel engineering is one of my specialist areas of expertise, having been involved in the design and/or construction of some 45 tunnels and underground structures of various types over a 30+ year period.

4 Through URS, I am a member of the Australasian Tunnelling Society (ATS) and I attend international tunnelling conferences to keep up to date on world best practice. The more recent tunnelling conferences attended are:

4.1 2006 – NoDig Trenchless Technology Conference, Brisbane, specifically covering micro-tunnelling.

4.2 2007 – Rapid Excavation and Tunnelling Conference, Toronto, at which I presented a paper on the Second Manapouri Tailrace Tunnel.

4.3 2008 – 13th Australasian Tunnelling Conference, Melbourne, at which I presented a paper on the CCC Ocean Outfall microtunnel.

4.4 2011 – 14th Australasian Tunnelling Conference, Auckland.

5 My consulting career with URS has been based in Christchurch from 1995 to 1999 and in Melbourne from June 1999 to April 2004, before returning to my current position in the Christchurch office of URS.

6 Prior to joining URS, I operated my own consulting practice, Fleming and Associates Ltd, from 1992 to 1995, and prior to 1992, I spent some 21 years with the Ministry of Works and Development, Power Division on hydro power projects design and construction.

7 During my 40+ years of work experience, the majority of my experience has been with tunnel based development schemes, some

18 years as a construction engineer, and approximately 13 years working in investigations or design teams.

8 I have the following specific experience relevant to the Milford Dart Project:

8.1 1971-73: Tongariro Power Development, Mangaio Tunnel. A 1 km long, 2.5 m diameter drill and blast tunnel. Position - Site Engineer during construction.

8.2 1977-82: Rangipo Underground Power House and associated tunnels, shafts, penstocks, surge chambers and civil construction works. Position - Construction Engineer.

8.3 1982-92: Clyde Power Project – Clyde Dam construction including dam foundation tunnels and shafts, and 15 km of 3.5 m dia drill and blast tunnels for the Cromwell Gorge Landslide Stabilisation project. Position - Construction Manager.

8.4 1993-95: Second Manapouri Tailrace Tunnel, Feasibility Stage – As an independent consultant to the Electricity Corporation (ECNZ), I provided engineering input into the Feasibility Study, in particular addressing tunnel design and constructability issues, assessment of environmental effects from construction works in the World Heritage listed Fiordland National Park, cost estimates, project delivery mechanisms and implementation of the design for this project.

8.5 1995-99: Second Manapouri Tailrace Tunnel, Design and Construction Stage – In 1995 I joined Woodward – Clyde, the design consultant appointed for this project, and I provided input into the civil and geotechnical design of the tunnel and other works, the cost estimate and program, the contract documentation, the environmental specification and the tender process. Following appointment of the construction contractor, I performed the role of Design Manager for the project. Note that this project won a number of awards of excellence including: the 2003 ACENZ Silver Award for Excellence and the 2003 IPENZ Supreme Award for Engineering Excellence (Energy Sector).

8.6 1995: Homer Tunnel Passing Bays: Design and construction of two passing bays inside the Homer Tunnel, in the Fiordland National Park.

8.7 1999-04: During this period I transferred to the URS Melbourne office, primarily working on irrigation dam remediation projects, but also carried out a technical due diligence for Snowy Hydro Ltd on their 12 tunnels and the maintenance design and construction monitoring on the

Eucumbene-Murray Tunnel and Tumut Powerhouse cable tunnels.

8.8 2004-12: From the URS Christchurch office, I have managed and provided engineering design input into a number of tunnel based hydro electric scheme pre-feasibility studies, as well as managing the study team and providing technical input into the Milford Dart feasibility study. I have also provided design and construction advice on a number of other tunnel projects including the Thomson – Yarra water supply tunnel in Victoria, the Johnson's Hill Motorway Tunnel in North Auckland and risk workshops for the Waterview Motorway Tunnel in Auckland.

8.9 Further recent relevant experience has included: Design Manager on the CCC Ocean Outfall Pipeline Project, which included 2.3 km of microtunnel; Homer Tunnel Options Study; North Bank Tunnel concept and pre-feasibility design; (a 35 km long tunnel project); Design Manager for the Amethyst hydro tunnel currently being constructed near Hari Hari and Project Director for the design of the Cleddau Village Flood Protection Project at Milford Sound. Note that the last mentioned has just been awarded the NZ Planning Institute's Rodney Davies Project Award, recognising "innovative and creative excellence in undertaking and completion of a project involving physical work or development".

9 For the Milford Dart Project, I have lead a team of multi-disciplined URS professionals, with the team covering the various aspects of scheme layout concepts, planning, environmental impacts, engineering geology, geotechnical design, hydrology and hydraulics, civil structures design, tunnel design, mechanical and electrical design including fire-life safety design, constructability and temporary works issues, cost estimates and program. My experience and that of the URS team in working on several challenging major projects in the Fiordland National Park has provided a significant yardstick in our approach to mitigating the environmental effects from the construction of the Milford Dart project to an acceptable level.

10 My primary areas of expertise relevant to this Project have been: concept design and constructability input into the tunnel and above ground structures, assessment and mitigation of environmental impacts from construction, cost estimating and programming, and management of and engineering input into the design team. In presenting this evidence I have for completeness had to describe aspects of the project that are outside my specialist field of expertise. Other specialist team members have addressed such areas in the study and my evidence is based on the outcomes from this work.

SCOPE OF EVIDENCE

11 I have been asked by Milford Dart Ltd to prepare evidence in relation to matters raised by submitters concerning tunnelling related issues and the management of impacts that the tunnel construction might have on the National Park, as well as the safe operation of the tunnel and the long term management of any leachate risk from the spoil stockpile.

12 The specific submitters evidence that I have read and will address are:

12.1 Mr Alan Christopher Reid Bremner for Mr Geoff Thompson and Southern Lakes Helicopters,

12.2 Mr Jason Law, and

12.3 Venture Southland (excerpts).

13 I will cover the submitters' concerns in my evidence under the following headings:

13.1 The Design Stages of Major Projects

13.2 Time & Cost Estimate

13.3 Bus Tunnel Design Compared with Traditional Road Tunnel Design

13.4 Safe Construction, Maintenance & Operation of the Tunnel

13.5 Seismic Risk

13.6 Environmental Management During Construction

13.7 Spoil Management

13.8 Conclusions

THE DESIGN STAGES OF MAJOR PROJECTS

14 There have been a number of comments regarding perceived design deficiencies of the tunnel, which imply a lack of understanding of the stage this project is at in the design process. I will briefly describe the typical design process that major civil engineering projects go through before the technical feasibility (including environmental feasibility) and economic viability of a project is finally proven to the extent that the project may proceed.

15 Major civil engineering projects, including tunnels, typically progress through at least 4 stages of design development before being committed to construction. These stages are:

15.1 Concept Design stage: Initial scoping and development of the proposal to determine possible layout, project constraints, engineering and environmental issues and preliminary costing.

15.2 Pre-feasibility Design stage: Options study to "fine tune" the concept design to a point where one or two viable options have been determined; environmental and engineering constraints have been identified and sufficient studies carried out to confirm the concept. For a project in a National Park this would include specific environmental studies to address areas of potential concern, followed by a Concession application if the studies prove positive. Landowner consultation may take place at this stage. More detailed constructability assessment, project cost estimate and programme.

15.3 Feasibility Design stage: Design reduced to a preferred option. Geotechnical site investigations undertaken to prove engineering feasibility. Accurate survey and any remaining environmental studies carried out. Design firmed up and more accurately defined. Stakeholder consultation takes place. Resource Consent application lodged.

15.4 Detailed Design stage: Detailed design of the final project elements. Contract documents including specifications and management plans produced. Project tendered to contractors for pricing.

16 Each of these stages represents a decision "gate" for the developer, where a Go/No Go decision is made based on the technical and environmental feasibility and commercial viability. Typically a large number of projects do not advance past stages 1 or 2 for technical or commercial reasons.

17 The Milford Dart Project is currently at the Pre-feasibility Design stage, where the technical feasibility and economics have been proven to the extent required for that stage and subject to a Concession being awarded by DoC, Milford Dart will consider whether to advance into Feasibility Design. The concerns raised by submitters on design details therefore need to be kept in context in relation to this staged design process.

TIME AND COST ESTIMATE FOR THE PROPOSED TUNNEL

18 I understand that some submitters have questioned the estimated time and cost to construct the proposed tunnel. I consider the best way to address this issue is to put current New Zealand hard rock tunnelling experience in historical context.

19 Tunnel design and construction methodology in general has undergone some major changes in the last 30 – 40 years, driven by

the growing need for tunnels worldwide, for infrastructure developments for highway, rail, water supply and hydropower. The improvements in technology have resulted in the more rapid excavation of both soft ground and hard rock tunnels, with a significant reduction in tunnel cost and construction time. I will concentrate on the more relevant hard rock technology in this evidence.

20 Some of the significant changes that have occurred in hard rock tunnelling worldwide are:

20.1 The now widespread use of Tunnel Boring Machines (TBM) instead of slower and more costly drill and blast techniques. This has increased excavation progress from typically 6 to 8 metres per day for drill and blast, to 15 to 25 metres per day for a hard rock TBM from a single heading. As a direct result of this, the cost per metre of a long TBM tunnel is now typically less than half that of a drill and blast excavated tunnel.

20.2 The improved practicality and economics of excavating long tunnels from a single heading, using a TBM, has been a significant breakthrough. Previously for a long tunnel, multiple access points were needed to make drill and blast techniques viable in terms of cost and construction time, and if these multiple headings were not practicable, for example in a National Park location such as for the Manapouri Tunnel or this Milford Dart tunnel, then the scheme was unlikely to be economic.

20.3 The improved technology of TBMs, resulting, inter alia: in greater power, larger diameter, better reliability, more flexibility in coping with changing ground conditions and the ability to withstand very wet conditions.

20.4 Development of an extensive "toolbox" of rock condition risk management provisions that are now able to be incorporated into the TBM design to mitigate against changing or unforeseen ground conditions, including the negotiation of faults. These include provisions for steel set erection, rockbolting, probe drilling ahead, drainage drilling ahead, shotcrete (sprayed concrete), geophysical prediction of rock conditions ahead and others.

20.5 The evolution of the continuous tunnel conveyor for removing tunnel spoil from the TBM directly to the spoil disposal area outside the tunnel portal. The Manapouri Tailrace muck conveyor ran the full length of the tunnel.

20.6 The less environmentally intrusive and safer working environment of TBM tunnelling compared with drill and blast.

TBM tunnelling is quieter and requires about a quarter the workforce required for drill and blast tunnelling.

21 These changes have resulted in a reduction in the construction cost of tunnels, and importantly, a reduction in the risk of the cost overruns that have traditionally plagued the industry.

22 In New Zealand, the industry had been slow to move forward, partly as a result of the lack of suitable projects, and partly due to an apparent reluctance to repeat the Kaimai experience or to undertake long tunnels. The first TBM introduced into New Zealand was the Kaimai Tunnel hard rock TBM in the early 1970s. While the TBM was subsequently judged a success, it was unable to cope with the hard, blocky andesite rock in the western side and had to be withdrawn from the tunnel and used on the eastern end. It then performed well by the standards of the day, excavating about 55% or 4 km of tunnel, but in much softer ignimbrite rock. However the average excavation rate of 115 metres per month achieved falls well below a typical rate of 500 metres+ per month which could reasonably be expected using a modern TBM.

23 Two long tunnels were excavated in New Zealand in the 1960s and 1970s using drill and blast techniques. The 10 km long first Manapouri Tailrace Tunnel was excavated from one heading and the 20 km long Moawhango-Tongariro tunnel was excavated from each end.

24 Apart from the above tunnels, there were a number of other shorter drill and blast tunnels constructed during this period, particularly on the Tongariro Scheme, where some 50 km of tunnelling was undertaken, a number of road tunnels and many rail tunnels. New Zealand does have a significant history of tunnelling.

25 In 1992, the feasibility of the Second Manapouri Tailrace Tunnel (2MTT) was investigated and I was part of that study team, which included a tunnel design and construction expert from the Channel Tunnel Project and other international experts.

26 The Second Manapouri Tailrace Tunnel was successfully constructed between 1996 and 2001, albeit excavation taking longer than planned due to a number of factors, many of which such as the isolation factor and very hard rock are not relevant to the Milford Dart tunnel.

27 A key factor in that project was the hardness of the rock and whether the contractor had adequately provided for it in selecting and operating the TBM. That particular rock was amongst the hardest bored by a large TBM at the time. It was often in excess of 200 MPa, and in some instances around 300 MPa (concrete is typically 30 MPa). This was the main reason why the tunnel ran over time. In comparison, the rock through which the Milford Dart tunnel

is proposed is expected to be in the order of 150 Mpa which is well within recent TBM capability.

28 The Milford Dart Tunnel has a stated construction period of 3-4 years, which includes 12-15 months TBM procurement period. The TBM tunnel excavation is expected to take about 2 to 2.5 years which is an average excavation rate of 12-15 metres/day. This is well within the capabilities of a modern TBM.

29 Mr Bremner goes to great length to attempt to compare tunnel costs with other tunnels on a $\$/m^3$ basis. In many years of tunnel estimating I have found this approach is not valid as there are so many variables that are site specific including: rock type and hardness; rock support design; final lining design; groundwater volumes; isolation of site (eg: Manapouri had no road access); staging area available (city tunnels usually have very constrained site access); TBM type and cost; type of tunnel (road tunnels require expensive fire life safety provisions); and many others.

30 I consider that the cost estimate for the Milford Dart Tunnel is realistic for the stage of design the tunnel is at. Revised estimates will be developed at each subsequent stage of the project as the design is refined and a commercial decision will be made at each stage whether to advance to the next stage.

31 I understand submitters have noted the number of faults that were encountered in the Manapouri Tairace Tunnel. These caused major problems during the initial tailrace tunnel excavation, using drill and blast techniques, and were anticipated when planning the second tunnel. The TBM negotiated these faults with relative ease, in fact at a greater advance rate than in the rock. Faults arise in virtually all tunnelling, particularly in New Zealand and are able to be provided for as part of the construction planning. Preliminary geological assessment and fly overs have indicated that no known significant faults are present in the Milford Dart tunnel although this will be confirmed by the geological mapping required during detail design. Any faults that are present in the Milford Dart tunnel are expected to be of much lesser extent than encountered on the Manapouri tunnels and suitable contingency planning will be undertaken during design and construction to ensure that these can be safely negotiated.

32 I also understand that submitters have raised concerns that far less is known about the geology of the Milford Dart Tunnel alignment than was known about the 2MTT alignment and as a result they expect a lot of drilling will be required along its alignment. In response to this, I note that URS is satisfied with the information it has to date including a detailed PhD thesis on the geology of this specific area and the investigations of our own specialists. Investigations drilling of deep tunnels such as this is often impractical and provided sound base data can be obtained from portal investigations, regional geology and from surface mapping,

any additional information provided by drilling is of minor value. I am therefore confident that there will be no need for any drilling other than the portal investigation drilling described in the concession application.

BUS TUNNEL DESIGN

33 Submitters have raised concerns over a number of design aspects including the diameter of the tunnel and the fire-life safety and emergency egress provisions of this tunnel design when compared with a traditional road tunnel.

34 For the avoidance of any misunderstanding, the proposed Milford Dart Tunnel is a bus tunnel, not a road tunnel and as such NZTA standards have no relevance inside the tunnel. The tunnel is based more on typical underground railway tube tunnels that are common worldwide. The tunnel will be a single lane bus transport tunnel which will only accept diesel buses that comply with minimum standards of fitness for purpose and mechanical condition. Access will be strictly controlled and limited to buses complying with a set of conditions.

35 The diameter has been set nominally at 5 m excavated diameter, based on the largest commercial bus dimensions currently permitted on the road. This geometry provides sufficient space for a running surface and side kerbs for bus guidance and passenger egress in an emergency.

36 In any transport tunnel, life and fire safety provisions are major issues requiring certain standards of design to be complied with. With a number of major tunnel fires occurring overseas in recent years, standards are becoming more stringent.

37 In a road tunnel, the nature of vehicles using the tunnel is typically uncontrolled, both in terms of the mode of fuel system and in the goods they carry. Vehicles typically vary from private cars, trailers, trucks of all types, including petrol tankers. The vehicles may be fuelled by petrol, diesel or LPG. Cargos are uncontrolled and could include explosives or highly inflammable goods, such as the margarine that caused the major fire in the Mt Blanc Tunnel in Europe. Tunnel are often two way, increasing the risk of vehicle to vehicle accidents.

38 Designing a tunnel to cope with these hazards and provide adequate escape for people in the event of a fire or explosion is complex and the systems typically incorporated in road tunnel design represent a high proportion of the capital cost of a tunnel. To provide adequate safety features, road tunnels require extensive ventilation systems to remove smoke and provide fresh air, safe refuges for people every few hundred metres, an alternative escape tunnel, fire suppression provisions and fire proof control, detection and deluge systems.

39 The design approach for the Milford Dart tunnel is typical for a dedicated rail tunnel such as an underground tube and is based on the following premises:

39.1 There will be no public access except on the buses. Automatic, solid security gates at each portal will prevent people and animal access into the tunnel.

39.2 There will be no uncontrolled vehicle access. Only approved diesel buses will operate in the tunnel. The only inflammable material carried will be the diesel fuel in each bus, i.e.: no cargo will be permitted.

39.3 Buses will be designed with two hour fire rated engine compartments separately isolating the engine, the diesel tank and passengers, and the compartments will contain fire detection and suppression equipment.

39.4 Each bus will be in radio contact with the tunnel controller, who will also be able to track the position of the bus inside the tunnel.

39.5 Buses will be staggered in the tunnel by at least 1 km to mitigate the risk of bus to bus accidents.

39.6 As for an underground tube, there will be no forced ventilation. The "piston effect" of the buses moving through the tunnel will provide adequate changes of air in the tunnel. An emergency forced ventilation system will be installed in the Hollyford portal structure which will start automatically in the event of a fire.

39.7 Safety and emergency egress procedures will be developed and communicated to passengers via on board TV monitors to ensure safe egress from the tunnel in the event of an emergency.

39.8 Emergency rescue vehicles will be stationed at the Hollyford portal with tunnel operations personnel trained in all aspects of handling emergencies.

40 URS has undertaken this concept design for fire, life safety design in consultation with a number of industry experts. A conclusion that has come out of the process is that there is a wide diversity of fire, life safety practices around the world and in New Zealand, which are mainly aimed at road tunnels. The system design needs to consider the specific tunnel situation, the type of tunnel, its use, the type of transport, the frequency of vehicles, the risk of fire and the ability to evacuate people in the event of an emergency. This risk based concept will be developed further during the feasibility stage of the project.

41 The use of the approved diesel buses in a totally controlled manner is a key factor in the tunnel design and hence in the commercial viability of the project.

42 The use of a tunnel of this size to take tourists through in a diesel powered carriage is not unique in New Zealand. It happens every day as trains pass through various tunnels in New Zealand and overseas. A good example is the Otira Rail Tunnel that allows TranzAlpine Railway to pass from Canterbury to the West Coast under Arthurs Pass has many similar features and has been operating successfully since 1923. The key similarities include:

42.1 Similar diameter and length - 5m high, 4.5m wide and 8.6 km long

42.2 Single lane/ track - one way operation at a time

42.3 Use of Diesel engines to pull carriages through tunnel

42.4 Transports over 200,000 tourists a year on the TranzAlpine as well a very significant volume of hard coal

42.5 Passes through rather than near a major fault

43 Concerns have been expressed by submitters over the practicality of constructing an 11 km long tunnel. With the advanced technology of TBMs as described previously, long tunnels are becoming very common throughout the world. I have attached at **Appendix 1** Table 1 "Examples of Notable International and NZ Tunnels" to my evidence, courtesy of Laurie Richards, a New Zealand rock mechanics and tunnel expert who compiled the table for his evidence in support of the Milford Dart tunnel. Laurie has also advised me that he is currently working on the Luhri Project in Himachal Pradesh (India) on twin 9 m diameter, 35 km long tunnels, eventually to extend to 80 km of tunnelling on that project.

44 Consequently, in my view this tunnel is well within current industry capabilities.

45 A submitter drew a comparison of this tunnel with the Pike River Coal situation. I need to emphasise strongly that civil engineering tunnels should not be compared to mine access tunnels because the ground conditions, the risks, construction and operational issues are completely different. Mine access tunnels and operating mines are exposed to rock that is loosely termed "coal measures"; usually a sandstone/siltstone formation containing seams of coal which trap methane gas and are prone to Acid Mine Drainage (AMD) due to this coal. The Milford Dart tunnel will be through schist rock which is not a coal bearing formation.

SAFE CONSTRUCTION, MAINTENANCE & OPERATION OF THE TUNNEL

46 The safe construction and operation of the tunnel is managed by the Health and Safety in Employment Act 1992. The object of the Act is to promote the prevention of harm to all people at work, and others in, or in the vicinity of, places of work.

47 The Act applies to all New Zealand workplaces and places duties on employers, the self-employed, employees, principals and others who are in a position to manage or control hazards. The emphasis of the law is on the systematic management of health and safety at work. It requires employers and others to maintain safe working environments, and implement sound practice. It recognises that successful health and safety management is best achieved through good faith co-operation in the place of work and, in particular, through the input of those doing the work.

48 The Department of Labour administers and enforces the HSE Act in land based activities including the construction of tunnels

49 The HSE Act allows for the development and approval of statements of preferred work practice, known as "approved codes of practice".

50 The has been no relevant New Zealand code of practice for tunnelling since the Tunnel Safety Regulations were rescinded when the HSE Act came in. Consequently, current tunnel design and construction experience is to utilise relevant codes from other countries that represent world's best practices, such as the revised British Standard BS 6164 'Code of practice for health and safety in tunnelling in the construction industry'.

51 The British Tunnelling Society & Association of British Insurers have issued a joint code of practice on risk management for tunnel projects, which provides guidelines on industry best practice for design, construction and operation of tunnels of all types.

52 Milford Dart tunnel will be designed, constructed and operated in accordance with recognised industry best standards. Over the last ten years there have been significant advances in tunnel technology in Europe, UK, USA, Asia and Australia and each country has developed standards that apply to their situations. During the design phase, the various standards will be researched to ensure the most appropriate approach to design, construction and operation is used, to ensure compliance with the HSE Act.

SEISMIC RISK

53 I understand that submitters have raised concerns about the risk of earthquakes to customer travelling in buses through the tunnel.

54 Tunnels are recognised in civil engineering as arguably the least vulnerable structure in a seismic event and in fact the majority of tunnels until recently were not designed for seismic loading. In layman's terms, under a seismic event a tunnel moves as one with the ground, in sharp contrast with an above-ground structure which will move and deflect according to its shape. Unlike a tall above ground building, a tunnel is unlikely to deflect sufficiently to cause damage, unless fractured by a fault, which is uncommon.

55 A paper "Seismic Design of Tunnels" by Jaw-Nan Wang, Ph.D, P.E of Parsons Brinckerhoff (1993) describes the seismic performance of tunnels succinctly as per the following excerpts:

> "While the general public is often sceptical about the performance of underground structures, tunnel designers know that underground structures are among the safest shelters during earthquakes, based primarily on damage data reported in the past.
>
> One of the significant aspects of the 1989 Loma Prieta earthquake in the San Francisco area was its severe impact on the above ground transportation system:
>
> - The collapse of the I-880 viaduct claimed more than 40 lives.
> - The direct damage costs to the transportation facilities alone totalled nearly $2 billion (Werner and Taylor, 1990).
> - The indirect losses were several times greater as a result of major disruptions of transportation, particularly on the San Francisco-Oakland Bay Bridge and several major segments of the Bay area highway system.
>
> The San Francisco Bay Area Rapid Transit (BART) subway system was found to be one of the safest places during the event, and it became the only direct public transportation link between Oakland and San Francisco after the earthquake. Had BART been damaged and rendered inoperative, the consequences and impact on the Bay area would have been unthinkable.
>
> The 60-mile BART system was unscathed by the earthquake because engineers had the foresight 30 years ago to incorporate state-of-the-art seismic design criteria in their plans for the subway tunnels (SFBARTD, 1960; Kuesel, 1969; and Douglas and Warshaw, 1971). The Loma Prieta earthquake proved the worth of their pioneering efforts."

56 While I have not been involved in any assessment, I am aware that during the Christchurch earthquakes the Lyttelton Road and Rail tunnels which were very close to the epicentre of the earthquakes, were undamaged internally. The only damage was to the external buildings.

57 Notwithstanding this, the Milford Dart tunnel and associated portal structures will be designed in accordance with the latest seismic codes and international best practice.

ENVIRONMENTAL MANAGEMENT DURING CONSTRUCTION

58 The Second Manapouri Tailrace Tunnel set a benchmark for environmental management of a tunnel construction project in a pristine National Park setting. That project won awards in recognition of the overall engineering and environmental achievements during the project. These awards included the IPENZ Supreme Award for Engineering Excellence for 2003 and the ACENZ Silver Award of Merit in Recognition of an Outstanding Project for 2003.

59 This recognition was the culmination of a number of management actions that were implemented from the initial planning stage, through construction and final restoration. Specific actions were as follows:

59.1 Client and consultant recognition of the immense value and sensitivity of the site environment and from the earliest planning stage treating the project as a "model environmental project".

59.2 Following stakeholder consultation, establishing the environmental issues and what additional work needed to be carried out to determine the effects construction might have on these and what mitigation measures would be necessary to alleviate the concern. (This project did not come under the Resource Management Act).

59.3 Including a comprehensive Environmental Protection specification in the contract documents which covered all areas of environmental impacts, mitigation requirements, minimum standards, environmental construction management plans and monitoring during construction.

59.4 Including the requirement for the contractor to employ a full time Environmental Officer on site to monitor environmental compliance. In addition, the Engineer and client's site representatives were empowered to strictly monitor the contractor's environmental performance on a daily basis, with monthly reviews.

59.5 Working in close consultation with DoC and other stakeholders prior to and throughout the project.

59.6 Placing a high value on environmental track record when selecting the contractor.

59.7 Ensuring that the environmental construction management plans produced by the contractor were appropriate and complete, requiring these to be maintained as "living documents" and monitoring compliance with the plans.

59.8 Management reviews of environmental performance and issues at monthly meetings.

60 I have personally been involved in several projects in the Fiordland National Park with the Manapouri Tunnel project, several smaller projects for Meridian Energy and its predecessors on the Manapouri Power Station, the Homer Tunnel Passing Bay Project, this Milford Dart Project and more recently the Cleddau Village Flood Protection Project. I have a very good understanding and appreciation of the very special nature and values of the pristine environment in the National Park.

61 The Cleddau Village Flood Protection works in Milford Sound were designed to both protect the existing Village in the National Park and allow for its future expansion by upgrading and extending the existing stop banks and raising the Village site by 4m in height. A concession was granted by the Department of Conservation and resource consents from both the Southland District and Southland Regional Councils.

62 These works have recently been completed and involved;

62.1 the upgrading and repair of approximately 1,100 metres of existing river protection structures, and the construction of approximately 800 metres of new protection measures, in total providing approximately 1.9 kilometres of river protection structures, along the true right bank of the Cleddau River. These works have been designed to withstand a 100 year ARI (Average Recurrence Interval) flood event in the Cleddau River;

62.2 the establishment of a local source of rock and fill material for the river protection works project. We were given permission to clear 6.9 hectares of native forest but only needed to ultimately clear less that 2 hectares;

62.3 the establishment of a materials processing, handling and storage area in conjunction with the borrow site; and

62.4 the diversion of flows in the Glow Worm Creek catchment to avoid ponding behind the flood protection works, possibly resulting in flooding at the Milford Sound Lodge.

63 The works complied with the Environmental and Safety Management Plans in place and I have just been advised that URS and DoC have been awarded the NZ Planning Institute's Rodney Davies Project Award, recognising "innovative and creative excellence in

undertaking and completion of a project involving physical work or development".

64 As a result of the Manapouri experience and the other projects carried out in the Fiordland National Park I have no doubt that the Milford Dart tunnel project can be undertaken in a safe and environmentally sensitive manner.

65 To achieve this objective for Milford Dart and subject to final DoC and Resource Consent conditions, the overall Environmental Construction Management Plan required for the project construction and operation will cover all potential environmental impacts. It will also specifically include the following supplementary plans:

65.1 Bush Clearance Plan

65.2 Dust Management Plan

65.3 Traffic Management Plan

65.4 Noise Management Plan

65.5 Water Treatment and Discharge Management Plan

65.6 Stormwater Management Plan

65.7 Tunnel Spoil Disposal Management Plan

65.8 Hazardous Substances Spill Contingency Plan

65.9 Weed Control Plan

65.10 Restoration Plan

65.11 And any other plans required by DoC or by the Resource Consents.

66 A full time environmental manager will be required on site during construction and site management will be required to monitor and regularly audit the contractor's environmental performance.

SPOIL MANAGEMENT

67 Tunnel spoil from the TBM is to be disposed of on the airstrip area at the Lower Hollyford area. I understand concerns have been raised over the capacity of the proposed area to accommodate the spoil volume and about how any leachate from the spoil disposal site will be managed with the risk from the large floods down the Hollyford River.

68 With regard to the risk of leachate from the tunnel spoil, I have attached as **Appendix 2** to my evidence a memorandum from URS

Senior Principal Engineering Geologist, Don Macfarlane dated 1 December 2006 that addressed this issue.

69 Mr Macfarlane concluded that the geological formation at this location is most unlikely to be prone to Acid Mine Drainage (AMD), and if it was to occur, it would only be in very small quantities. Water discharges from Milford Dart tunnel will be monitored during construction and in the unlikely event that any such spoil or AMD is found, it will be encapsulated and stored on part of the disposal site above the 100 year flood (1% AEP) level. Treatment before burial will also be considered.

70 Concerns have been expressed over bulking of tunnel spoil, raising the question of whether there will be sufficient capacity in the proposed spoil disposal area. Tunnel spoil of the expected grading from a TBM will bulk between 40% and 60% of its solid volume, however, on re-compacting on the spoil disposal area, this volume will reduce to about 10% to 15% of its original solid volume. We have assumed 20% as a conservative bulking percentage for volume calculations.

CONCLUSIONS

71 The pre-feasibility design studies carried out to date have demonstrated that an 11.6 km long hard rock tunnel, excavated by a Tunnel Boring Machine is a viable engineering project.

72 The studies have identified the environmental impacts on the National Park both during construction and during the operation of the Milford Dart Tunnel. By drawing on equivalent environmental mitigation experience from the Second Manapouri Tailrace Tunnel, the recent Cleddau Village Flood protection works, and other projects that I have been involved with in the Fiordland National Park, I am confident that satisfactory measures can be put in place for the Milford Dart Tunnel to protect the environment during both construction and operation.

73 I am also confident that the tunnel can be built, maintained and operated in a safe manner.

74 In conclusion, I am satisfied that the engineering and environmental work carried out to date by URS, which has been under my control, is consistent with the available information and has been completed to an appropriate level for a concession application. Subject to this limitation of the stage of the project, I believe that this project is technically viable and will able to be constructed and operated within the environmental and safety constraints documented.

Dated: 4 May 2012

RW Fleming

APPENDIX 1

TABLE 1: EXAMPLES OF NOTABLE INTERNATIONAL AND NZ TUNNELS			
Name	Location	km	Opened
Longest continuous rock tunnels			
Päijänne Water Tunnel	Southern Finland, Finland	120	1982
Bolmen Water Tunnel	Kronoberg/Scania, Sweden	82	1987
Railroad tunnels (excluding subways) over 10 kms long			
Seikan Tunnel	Tsugaru Strait, Japan	53.9	1988
Channel Tunnel	English Channel, England - France	50.0	1994
Hakkoda Tunnel	Hakkoda Mountains, Japan	26.5	2010
Iwate-Ichinohe Tunnel	Japan	25.8	2002
Daishimizu Tunnel	Mikuni Mountain Range, Japan	22.2	1982
Wushaoling Tunnel	Wuwei, China	20.1	2006
Simplon I	Alps, Switzerland - Italy	19.8	1906
Simplon II	Alps, Switzerland - Italy	19.8	1922
Vereina	Klosters - Sagliains, Switzerland	19.1	1999
Shin Kanmon	Kanmon Straits, Japan	18.7	1975
Apennine	Bologna - Florence, Italy	18.5	1934
Qinling I-II	Qinling Mountains, China	18.5	2002
Rokkô	Rokkô Mountain, Japan	16.3	1972
Furka Base	Andermatt - Brig, Switzerland	15.4	1982
Haruna	Gunma Prefecture, Japan	15.4	1982
Severomuyskiy	Baikal Amur Mainline, Russia	15.3	2001
Gorigamine	Takasaki - Nagano, Japan	15.2	1997
Monte Santomarco	Paola - Cosenza, Italy	15.0	1987
St. Gotthard	Alps, Switzerland	15.0	1882
Nakayama	Nakayama Pass, Honshu, Japan	14.9	1982
Lötschberg	Alps, Switzerland	14.6	1913
Mount Macdonald Tunnel	Rogers Pass, Glacier National Park, Canada	14.6	1989
Romeriksporten	Oslo - Gardermoen airport, Norway	14.6	1999

Dayaoshan	Nanling Mountains, China	14.3	1987
Hokuriku	Sea of Japan coast, Japan	13.9	1962
Fréjus Mont Cenis	Alps, France	13.5	1871
Shin Shimizu	Mikuni Mountains, Japan	13.5	1967
Savio Rail Tunnel	Helsinki - Kerava, Finland	13.5	2008
Sciliar	Verona - Brennero, Italy	13.2	1993
Subways Metro/Underground railway tunnels longer than 10 kms			
Serpukhovsko-Timiryazevskaya Line	Moscow, Russia	41.5	2002
U7	Spandau-Rudow, Berlin, Germany	31.8	1984
Northen Line	Morden-Bank-East Finchley, London, UK	27.8	1940
Blue Line	Kungsträdgården-Hjulsta, Stockholm, Sweden	14.3	1977
Vehicular tunnels longer than 10 kms			
Lærdal	Laerdal - Aurland, Norway	24.5	2000
St. Gotthard	Alps, Switzerland	16.4	1980
Arlberg	Alps, Austria	14.0	1979
Fréjus	Alps, France	12.9	1980
Hsuehshan	Taipei - Yilan, Taiwan	12.9	2006
Mt. Blanc	Alps, France - Italy	11.3	1965
Gudvanga	Bergen - Oslo, Norway	11.4	1991
Folgefonn	Odda - Gjerde, Norway	11.2	2001
Kanetsu Expressway southbound	Tokyo - Niigata, Japan	11.0	1991
Kanetsu Expressway northbound	Tokyo - Niigata, Japan	10.9	1985
Gran Sasso d'Italia East	Abruzzo, Italy	10.2	1984
Gran Sasso d'Italia West	Abruzzo, Italy	10.2	1995
NOTABLE NZ TUNNELS	Start of construction		
Rail			
Kaimai	Bay of Plenty, NZ	8.9	1978
Rimutaka	Wellington, NZ	8.8	1955

Otira	West Coast, NZ	8.6	1923
Hydro			
Moawhango - Tongariro	Tongariro National Park	20	
Manapouri Tailrace Tunnel – 1	Fiordland National Park	9.8	1968
Manapouri Tailrace Tunnel – 2	Fiordland National Park	9.8	2001
Road			
Lyttelton	Christchurch	1.9	1964
Homer	Fiordland National Park	1.2	1953

APPENDIX 2: DON MACFARLANE MEMORANDUM

URS

Memorandum

Date: 1 December 2006

To: Ron Fleming, Tim Allan

From: Don Macfarlane

Subject: **Milford-Dart tunnel - acid leachate risk**

Summary

There is no documented evidence to indicate that there is significant metallic mineralisation in any of the rock types that will be encountered in the Milford-Dart tunnel.

Consequently, it is difficult to envisage a situation in which acid leachates from the tunnel spoil would become a problem either during construction or in the long term.

Normal construction practices, such as tunnel logging and routine rock sampling from the TBM conveyor, will identify any concentrations of sulphide minerals at an early stage, should they be present. These can then be separately treated (eg. by encapsulating them in the spoil dump to prevent oxidation) if present in sufficient quantity to warrant such treatment.

Such a requirement can be readily imposed as a condition on any concession / consent that is granted.

1. Introduction

External review of the pre-feasibility assessment for the Milford-Dart tunnel raised a concern that tunnel spoil could generate acid leachate that would discharge to the environment.

To evaluate the potential for this to occur I have reviewed the general geology of the proposed tunnel route, reviewed the mineralogy of the rocks based on published chemical and mineralogical analyses, and researched the conditions under which acid leachates may form. This memo summarises the results of my research.

2. What is Acid Leachate?

Acid mine drainage (AMD), or acid rock drainage (ARD) are terms commonly used to refer to the outflow of acidic water leachate from (usually abandoned) metal mines or coal mines. However, other areas where the earth has been disturbed (eg. construction sites) may also contribute acid rock drainage to the environment. Acid rock drainage also occurs naturally within some geological conditions as part of the rock weathering process but is exacerbated by large-scale earth disturbances characteristic of mining and other large construction activities, usually within rocks containing an abundance of sulphide minerals.

The sulphide ore minerals (sphalerite, galena, pentlandite and chalcopyrite) are the main sources of the base metals zinc, lead, nickel and copper. Pyrite (iron sulphide) is common in all sulphide ore deposits. These minerals can also occur as minor constituents of other rocks.

The sulphide minerals are known to be a significant source of acid leachates when present in sufficient concentration, and exposed to air and water. Acid leachates can cause significant environmental damage in streams affected by such discharges.

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2.1 Formation of acid leachate

Acid mine drainage results from the oxidation of sulphide-bearing rocks (e.g. rocks with the common sulphide minerals pyrite and pyrrhotite). Mining operations can expose large quantities of sulphidic rocks, and produce mine waste rock and tailings rich in sulphide minerals. The percolation of oxygenated water through the workings and waste rock dumps generates an acidic fluid, rich in metals leached from the minerals in the rocks. Both the low pH and metals in this liquid can cause ecological damage when it enters streams and groundwater. Abandoned metalliferous mines with large amounts of pyrite in their waste rock dumps are the greatest source of acid drainage and associated environmental damage.

The formation of AMD is primarily a function of the geology, hydrology and mining technology employed for the site. AMD is formed by a series of complex geo-chemical and microbial reactions that occur when water comes into contact with sulphide bearing rocks. The resulting water is usually high in acidity and dissolved metals. The metals stay dissolved in solution until the pH rises to a level where precipitation occurs.

The acid producing potential in a rock is tied directly to the amount of sulphides bound up in the rock in various forms. Sulphides are crystalline substances that contain sulphur combined with a metal or semi-metal, but no oxygen. The most common forms are pyrite and marcasite (FeS_2).

2.2 Requirements for AMD and factors affecting the rate of acid generation

The primary requirements for acid generation from a tunnel waste rock stack are:

1. sulphide minerals must be present in the tunnelled rock
2. these minerals must be exposed to water or a humid atmosphere
3. there must be an oxidant present (usually oxygen in the form of O_2)

If these conditions are present, other factors will determine the rate of acid generation These include the pH (acidity) of the water, temperature, and the surface area of exposed metal sulphide.

In nature, exposed sulphide minerals react with oxygen and water to produce sulphuric acid. Mine (or other construction) waste material may also contain buffering capabilities in the form of calcium carbonates which will act to neutralise the acid producing potential of the sulphide minerals.

Acid production and neutralisation may be occurring at the same time in the waste rock stack and, in the mining environment, the rate of acid production often exceeds the rate of acid neutralisation. A common treatment for acid producing mine overburden is to amend it with lime (calcium carbonate). It is necessary to know the acid producing potential of the overburden pile to determine how much calcium carbonate to add to the tailings pile.

To prevent acid leachate, water and air contact with the acidic material must be eliminated. One method for preventing acid leachate is to prevent the material from oxidizing. Burying waste rock, or covering the waste with an impermeable liner, reduces the potential for pyrite to oxidise and sulphuric acid to form.

3. Milford Dart tunnel leachate risk

3.1 General geology

As has been described elsewhere, the tunnel route is mapped as weakly metamorphosed sedimentary rocks belonging to the Caples Group of rocks. The sequence of rocks from west to east (Hollyford to Routeburn) is:

Harris Saddle Formation - low grade semi-schists derived mainly from andesitic flow rocks, pillow lavas and breccias

Momus Sandstone – mapped and described as massive sandstone, dominantly relatively quartzose, with rare mudstone and conglomerate. Aerial inspection suggests that these rocks might also be low grade semi-schists.

Kays Creek Formation - a distinctive geological unit consisting of red and green volcaniclastic sandstone, mudstone and breccias

Upper Peak Formation - thin-bedded graded sandstone and black mudstone. These relatively fine grained sandstones and siltstones with 'abundant' sedimentary structures will form roughly the last 670 m of tunnel approaching the Routeburn portal.

Greenstone Melange – this unit forms an extensive fault-bounded unit 1 to 5 km wide that includes blocks of gabbro, dolerite, greenschist and sandstone in a sheared mudstone or serpentinite matrix.

3.2 Mineralisation in the Milford-Dart Tunnel Rocks

Of the 29 rock samples analysed by Kawachi (1970)[1], 12 are from close to (within about 2km) of the tunnel route (Figure 1) and all of the geological units expected in the tunnel are represented in the analyses.

Table 1 presents the results for the 12 rock samples closest to the tunnel route, plus 2 samples from the Kays Creek Formation which were taken from further away. Pyrite is not mentioned in the mineral assemblages of any of the rock samples described by Kawachi (1970), and his whole-rock chemical analyses for the same rocks do not report any sulphide minerals.

This does not necessarily preclude the presence of pyrite or other sulphides in the rocks along the tunnel, but it does indicate that if they are present then they are only likely to be present in very small quantities.

The rocks of the Milford-Dart project area have not been mined. As historical data show, and exploration by mining companies has also concluded, there are insufficient quantities of metallic minerals in these rocks to warrant mining. Williams (1974)[2] indicates that gold and scheelite were

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1 Kawachi, Y. (1970). Geology and metamorphism near the head of Lake Wakatipu. PhD Thesis submitted to the University of Otago.

2 Williams, G.J. (1974). *Economic geology of New Zealand.* Australasian Institute of Mining and Metallurgy, Monograph Series No.4.

mined in the Haast Schist rocks that occur to the east and southeast of the tunnel location, but comments (p48) that "the appearance of the Chl 2 [textural] subzone seems to effectively limit both gold and scheelite mineralisation westwards". The tunnel rocks are mapped as textural zones 2 and 3a (II and IIIa) by Kawachi (1970), confirming that gold and scheelite mineralisation is unlikely to be present.

Based on maps and text in Williams (1974), there is no known mineralisation of economic significance within the tunnel area. The only rocks that might have the potential to contain metallic mineralisation are the serpentinites in the Greenstone Melange but Williams (Figures 10.1, 10.3) indicates that the associated ultramafic rocks that might contain ore-grade chromium or nickel mineralisation are absent through the tunnel area. Williams (p145) also quotes Mutch (in press as at 1974) as reporting in relation to mineralisation in NW Otago that "native minerals and primary metallic ores are confined to unaltered or serpentinised dunite and peridotite, and sulphides to crushed serpentinite with rodingite inclusions". These rock types have not been reported from the tunnel area.

Turnbull (2000)[3] (p58-60) discusses the distribution of metallic minerals over a wide area of NW Otago, but makes no mention of significant mineralisation in the Caples Group rocks other than scheelite in schistose rocks at Glenorchy, with which minor amounts of other minerals (including pyrite, arsenopyrite and sphalerite) are found. Again, this mineralisation is well away from the tunnel route.

4. Conclusions

There is no documented evidence to indicate that there is significant metallic mineralisation in any of the rock types that will be encountered in the Milford-Dart tunnel. Consequently, it is difficult to envisage a situation in which acid leachates from the tunnel spoil would become a problem either during construction or in the long term.

Normal construction practices, such as tunnel logging and routine rock sampling from the TBM conveyor, will identify any concentrations of sulphide minerals at an early stage, should they be present. These can then be separately treated (eg. by encapsulating them in the spoil dump to prevent oxidation) if present in sufficient quantity to warrant such treatment. Such a requirement can be readily imposed as a condition on any concession / consent that is granted.

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3 Turnbull, I.M. (2000). Compiler. *Geology of the Wakatipu Area.* Institute of Geological & Nuclear Sciences 1:250,000 geological map 18.