NOISE REDUCTION STRATEGIES EXPERT REVIEW PANEL

Final Report

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Executive Summary

As our everyday lives become increasingly complex, we look for reprieve however possible. Ideally, many of us seek solitude by isolating ourselves from the byproducts of modern society. Societal noise is one such byproduct with noise generated by traffic representing a large portion. Thus, it is logical that, whenever reasonable, measures should be taken to reduce traffic noise.

In the coming years, the Washington State Department of Transportation (WSDOT) will be undertaking a monumental project involving the reconstruction of a major urban corridor: State Route (SR) 520. In order to determine the most viable solutions for reducing noise along this corridor, an Expert Review Panel (ERP) was convened. By way of a meeting of the ERP conducted September 15-17, 2008, as documented herein, recommendations were developed that focus on noise reduction strategies that could be considered by WSDOT for the SR 520 Corridor Program.

During this process, dozens of strategies and their components were identified and discussed. At first, the ERP did not allow traditional barriers – engineering, institutional, or societal – to limit their thinking. Strategies discussed included both conventional and innovative means to reduce noise. Without caveats, the team was able to develop alternative solutions that might not otherwise have come to light.

As the process continued, however, consideration of strategies that are realistic were once again introduced. With this “filter” applied, viable strategies were identified and further sorted into their likely use at various places along the corridor. Some of the key components of these strategies include:

- **Quieter pavements –** with alternatives that accommodate periodic renewal of the pavement surface for maintaining quieter pavement over time.
- **Roadway design –** with alternatives that seek to shield sensitive receptors from and/or reduce noise.
- **Noise barriers –** with alternatives that balance the need for noise abatement with potentially competing demands for aesthetics. Some alternatives departed from the more conventional use of noise barriers, and included sound absorption applied to other design features.
- **Modeling –** recognizing the complexity of this issue, and thus the need for a more sophisticated assessment in order to quantify the costs and benefits of the various strategies.
- **Perception –** looking at how the public will perceive the noise generated along the project corridor, and what means can be taken to improve this perception.
- **Operation and finance –** using economic incentives and disincentives as a means to improve noise via traffic management.
- **Studded tires affecting acoustical (and other measures of) durability of pavements –** specific issues related to a paramount factor in the overall noise issue: the use of studded tires. Limiting or eliminating the use of studded tires is a recommendation of the ERP.

- **Vehicle sources** – identifying means to reduce vehicle noise beyond tire-pavement noise sources.
- **Structures –** issues specific to the structures along the project, like those related to expansion joints.
- **Arterials** – issues specific to the arterial streets that are part or immediately adjacent to this project. For example, heavy trucks on arterials drowning out potential noise improvements on SR 520.
- **Lids and tunnels –** issues specific to the proposed lids and tunnels found in various alternatives for this project. For example, muting the noise that is directed out of the lids on either end.

It should be noted that the strategies that were recommended did not go through a detailed safety evaluation or a life cycle cost analysis. These issues where discussed on a general basis, but will need to be reviewed in more detail to determine the feasibility of these strategies in the preliminary and final engineering phases. The safety of SR 520 is the utmost importance to WSDOT, and any strategy that jeopardizes the safety of the facility will be eliminated.

In the end, a list of site-specific strategies was developed and accompanied with recommendations for additional information that could be collected to assist WSDOT with identifying the best “mix of fixes” for reducing noise along the SR 520 corridor. It was clear that no one noise-reducing component would work by itself. The best solution will be a system of components that are designed to work together. Only then will the collective needs of the majority of the stakeholders be met. This holistic approach should complement the current SR 520 team approach, which appears to be very responsive to the concerns of the public with respect to the noise issue, particularly how it might affect local residents, drivers, and those that use the parks, schools, and other private and public facilities located along this corridor.

Corridor Background

The SR 520 Bridge Replacement and High Occupancy Vehicle (HOV) Corridor Project is a six-mile highway improvement undertaking on SR 520 that begins at Interstate 5 in Seattle and extends to 108th Avenue Northeast in Bellevue (just west of Interstate 405). The project will replace all existing bridges including the Portage Bay Bridge, Union Bay Bridge, and Evergreen Point Bridge with new, safer bridges designed to withstand earthquakes and windstorms. The HOV lane will be moved to the inside lane and be expanded along the six-mile corridor, all the way to SR 202 in Redmond. The project will also improve the existing roadway between Interstate 5 in Seattle and Bellevue Way or 108th Avenue Northeast on the Eastside by widening shoulders to help reduce congestion by improving roadway operations and driver safety. The project includes a new regional bicycle/pedestrian path across Lake Washington. Appendix A includes a schematic of the proposed project.

The existing Portage Bay Bridge, Union Bay Bridge, and approaches to the Evergreen Point Bridge are vulnerable to earthquake damage because of their hollow columns. The floating portion of the Evergreen Point Bridge is susceptible to damage by high winds and has required many bridge closures over the past several years. One of the reasons for this is that the bridge elevation is a foot lower in the water than when it first opened. Both structure types have been determined to be at high risk of failure and need to be replaced. As one of only two main east-west routes across Lake Washington, SR 520 is vital to keeping the region moving and, as a result, to the health of the regional economy.

Expert Review Panel for Noise Reduction Strategies

In July 2008, the SR 520 team issued invitations for the convening of an Expert Review Panel (ERP) with the specific task of identifying Noise Reduction Strategies for the corridor. Eleven individuals with noise, pavement, and economics backgrounds were selected. Included were both public and private sector representatives. The ERP was well balanced to include experienced national and international recognized professionals from a complementary array of fields. Appendix B includes details about each person.

The Noise Reduction Strategy ERP was charged with two objectives:

1. *Develop recommendations regarding which strategy, or combination of strategies, could be incorporated into the SR 520 Corridor Program.*
2. *Develop strategies that are suitable for each segment of the project.*

A three-day workshop was conducted during September 15-17, 2008 at the SR 520 project offices in downtown Seattle. The final agenda for the workshop was as follows:

<u>Monday, September 15, 2008</u>

- ♦ Welcome, introductions, and overview presentation
- ♦ Presentations of key issues by mediation participants
- ♦ Presentations of project components by WSDOT staff
- ♦ Site tour (by land)

- ♦ Unrestricted identification of candidate strategy components
- ♦ Unrestricted identification of data gathering needs

Tuesday, September 16, 2008

- ♦ Categorization of components into strategy types
- ♦ Preliminary identification of corridor-specific strategies
- ♦ Interim presentation to mediation participants and others (by Mr. Rob Greene and Dr. Paul Donavan, representing the ERP)
- ♦ Site tour (by water)

Wednesday, September 17, 2008

- ♦ Finalize corridor-specific strategy selection
- ♦ Develop preliminary prioritization of strategy components
- ♦ Finalize recommendations for additional data gathering
- ♦ Final presentation to mediation participants and others

During the workshop, the SR 520 team gave the panel full license to examine all potential solutions and combinations of potential solutions for reducing traffic noise. A venue was provided where free and open dialogue between the panel members was encouraged, thus enabling the panel to conduct a thorough and critical review of the noise issues, and ultimately develop noise reduction strategies that would be suitable for the SR 520 project.

The workshop was well resourced, and the panel was well supported at all times. To assist the ERP, the SR 520 team provided complete access to project experts and information, including engineering reports, noise studies, and technical drawings. Of greatest importance to the ERP were the extensive and thorough traffic noise surveys that had been conducted earlier by the SR 520 team.

It was evident to the ERP that WSDOT and the SR 520 team are determined to address the traffic noise concerns of the residents immediately adjacent to the SR 520 corridor, as well as those residents living further away who could be potentially affected by traffic noise from the project. At the onset of the workshop, neighborhood representatives from the mediation group made presentations about their noise concerns directly to the ERP. After each presentation, the ERP had the opportunity to ask questions of the neighborhood representatives, and at the conclusion of the presentations, the ERP was able to personally meet the neighborhood representatives and discuss their concerns further.

At the conclusion of the workshop, a presentation was conducted along with the ERP, providing another opportunity to freely exchange the preliminary findings of the ERP with members of the public.

During the workshop, the SR 520 team also arranged for the ERP to inspect the corridor, both by land and by water. The experts gained firsthand knowledge about the natural settings of the highway, the existing highway structures, and the location of residential neighborhoods and public and private recreational facilities. WSDOT made sure that the panel was exposed to rush hour traffic flows and visited problematic noise generating features of the existing highway.

Furthermore, during the highway inspections, the panel was shown individual residential and recreational properties for which the SR 520 team identified as potentially being adversely impacted by the new highway. This enabled the ERP to focus its attention on potential site-specific solutions to traffic noise at those particular locations, so they could be incorporated into larger noise reduction strategies.

This document is a report of the project review by the ERP including the specific recommendations generated during the workshop. As is described herein, a systems approach to this problem is recommended, which should complement the current SR 520 team approach of being responsive to the concerns of the public with respect to the noise issue. This is particularly true given the attention being given to how noise might affect local residents, drivers, and those that use the parks, schools, and other private and public facilities located along this corridor.

Objectives and Assumptions

The great complexity of this project was abundantly clear to the ERP. As a result, it was acknowledged that optimized site-specific recommendations for noise reducing strategies could not be a product of this workshop. However, the objectives of the workshop could still be satisfied with the development of a list of viable strategies that could subsequently be analyzed in terms of their benefits and costs.

A number of key considerations were made in developing the final recommendations. Among these are:

- **Public sensitivity –** this began with the definition of "public" because abutting property users, drivers, recreational users, and even commercial interests are all affected by this corridor in different ways. The feedback from the mediation group was particularly helpful to the ERP in this regard.
- **Environmental and cultural considerations –** during the review of project details, it was clear that WSDOT had considered environmental and cultural impacts as part of the project. The ERP further considered this in the noise reduction strategies that were recommended. Most of the recommendations will affect WSDOT's environmental considerations, often in a positive sense.
- **Cost –** with what appear to be reasonable budgetary constraints, the ERP further considered viability in terms of likely cost implications of the various noise reducing strategies. In a much more implicit sense, the benefits of the noise reduction in terms of their monetized value were also considered by some panelists. It was recognized by the ERP, however, that a detailed cost analysis of the recommendations would be conducted subsequent to this effort as part of the prioritization process.

- **Maintenance** – there are maintenance considerations – sometimes significant – associated with the various noise reducing strategies. This too was a factor given related issues such as cost, safety, effectiveness, and possibly environmental impacts of maintenance activities.
- **Constructability –** most of the noise reducing strategies will introduce features on the project that would not necessarily be compatible with the currently anticipated construction process. Therefore, considerations were made in this regard.
- **Durability and longevity –** the life cycles of several of the strategy components were discussed, especially the use of quieter pavements. This discussion was framed with respect to the punishing effects of studded tire use. The concept of "acoustical durability" (how tire-pavement noise changes over time) was also used as opposed to broader and more familiar concepts of functional, structural, and material durability.
- **Corridor (physical) restrictions –** the limits of the project are reasonably confined, and the strategies discussed considered this focus.
- **Local, state, and federal laws, ordinances, regulations, and standards –** while institutional boundaries and potentially diverse policies were at first "ignored", they eventually became a consideration in the discussion.

For any given recommendation, it is not possible to achieve the ideal result for each of the considerations presented above. In fact, quantifying and comparing recommendations in a rational way will be a difficult task considering the inherent subjectivity of some of these considerations. The recommendations developed by the ERP have therefore simply been presented along with additional information (data needs) that may assist in the process of prioritization and selection. It was the understanding of the ERP that this process will be subsequently conducted by WSDOT or others.

Noise Reduction Strategy Components

Discussions during the three-day ERP meeting culminated in a long list of what can be termed components of noise reduction strategies. Most of these components were conceived during an open-ended brainstorming session conducted at the end of the first day. The second day focused on the organization and categorization of these components, with a preliminary prioritization on the third day. The preliminary prioritization was developed through an informal balloting process that included three levels of desirability:

1. **Option A (Recommended):** Acceptable as a recommendation without further discussion;
2. **Option B (Contingent Recommendation):** Recommendation is possible, but additional information should be collected and assessed first; and
3. **Option C (Not Recommended):** Given checks for realism and likelihood of success as a noise-reducing feature/action, the component should not be recommended for further consideration.

Coinciding with the informal balloting of each item, two questions were asked of the ERP:

1. What information is still needed before a given component should be recommended?
2. What fundamental objections exist with respect to recommending against further consideration of a given component?

During the course of the balloting process, each panel member was given the opportunity to clarify or elaborate the reason for his or her vote. On several occasions, this process resulted in further, more comprehensive panel discussions, after which panel members were allowed to change their vote if their opinion on the subject being balloted had changed. Furthermore, during the balloting process, whenever a panel member believed that they were unqualified to provide an expert opinion on the subject being examined, they were allowed to exempt themselves from the balloting on that subject.

The following sections include a list of the various noise-reducing components that were discussed. They have been categorized into 11 topics that have not been prioritized herein. Instead, the categories allowed the ERP to easily work with the various components during the course of the workshop.

Quieter Pavements

Given the expertise that had been assembled as part of the ERP, there was substantial discussion about quieter pavement alternatives as part of an overall noise reduction strategy for the corridor. The concept of using quieter pavements for noise mitigation is not new. It is routine practice in various parts of the world. Under special programs, it has been used in the United States. The ERP acknowledges that pavement choices and effectiveness vary from state to state depending on their unique conditions. Recognizing this, WSDOT is in the midst of evaluating a number of potential quieter pavement options. As mentioned previously, institutional or engineering barriers were not a consideration at first, so a number of innovative alternatives were discussed along with more conventional options.

Later, with respect to the selection of viable options, the considerations listed previously were applied. Three additional considerations were also made due to the recognized importance of quieter pavements by the public. They are as follows:

First, there is recognition that pavement wear due to the use of studded tires is an overriding issue. From what data had been collected to date, it is clear that this poses the most significant challenge to the success of any quieter pavement option in terms of its ability to provide good acoustical durability. In Washington State, all pavements will experience accelerated wear because of studded tire usage, however, some quieter pavement options may be particularly vulnerable, leading to an accelerated preservation/replacement schedule that, in turn, requires higher budgets for these activities.

The second additional consideration is the definition of "failure" with respect to the pavement life cycle and the associated costs. Conventional life cycles for paving materials are derived based on their ability to maintain functional and/or structural performance. The former is often in terms of the ability to maintain a smooth and safe riding surface. The latter is material-specific but includes things like rutting, cracking, and faulting of the pavement. In terms of noise, an additional consideration for acoustical durability might be made, where an otherwise "good" pavement could require resurfacing prior to achieving the end of its life in other respects.

The definition of acoustical "failure" must not be arbitrary, as it has both technical and policy implications. For example, if quieter pavement is being considered for noise mitigation, then the noise would presumably be maintained at or below a level that was assumed in the noise impact analysis, traffic noise prediction model, or an adopted environmental document. An example of this is the Arizona experience, where a noise level 4 dBA below the "average" pavement used in the FHWA Traffic Noise Model (TNM®) must be maintained in perpetuity, or else additional abatement must be retrofitted. A target level for noise reduction can be established through a balance of acoustical and more conventional modes of pavement failure given reasonable expectations of pavement longevity under the operating conditions. In the case of SR 520, this would be significantly influenced by the continued use of studded tires.

A third additional consideration is safety. With a variety of pavement options comes an accompanying variety of safety implications. For a pavement surface to be safe, it must provide an adequate degree of skid resistance for stopping (braking) capacity. It should also disperse or drain off excess water that may otherwise pool on the surface during heavy rain.

The various strategy components that were discussed include the following:

1. **Open-Graded Friction Course (with or without Asphalt Rubber)**

Open-graded friction courses (OGFC) are a type of hot-mix asphalt (HMA) that may or may not possess significant porosity[1]. The surface is usually applied as a wearing course atop a thicker pavement layer that provides the structural capacity (either dense-graded asphalt or concrete pavement). Being placed as a relatively thin overlay, the OGFC becomes sacrificial in the sense that once the noise-reducing properties have reached a threshold value, it can be removed and replaced (sometimes referred to as a "mill and fill" operation). OGFC with the greatest noise-reducing capability is typically constructed with a small nominal maximum aggregate size (typically 9.5 mm or less). Furthermore, the binder should be modified with a polymer or rubber. In the case of the former, SBS modifiers (a type of synthetic rubber) have been successfully used in some locations. When rubber is used, it is sometimes termed an Asphalt Rubber Friction Course (ARFC). ARFC is the pavement surfacing used as part of the Quiet Pavement

[1] http://www.trb.org/news/blurb_detail.asp?id=3275

Pilot Program in the State of Arizona[2]. Numerous states have had success with OGFC overlays. One notable trial on Interstate 80 in Davis, California has been tracked for its noise reducing properties for over 10 years[3]. Another frequently cited application is on California State Route (LA) 138[4]. Also worth noting is the two (soon to be three) trials of ARFC and OGFC that are being evaluated by WSDOT[5]. The use of ARFC in a continuous renewal (remove and replace) cycle was identified as a separate topic given the limited information that is currently available.

Balloting: *OGFC – A:7, B:3, C:0*
ARFC – A:3, B:7, C:0
ARFC renewal – A:0; B:8; C:1

Data Needs: *Durability data until "failure" should be known for conditions found on the SR 520 corridor. Existing test sections will be good source. Constructability concerns and constraints should be investigated, especially paving temperature. Some of this guidance could possibly be identified through formation of an unbiased task group with broad but specialized expertise on these topics. Quality of materials, especially aggregates, should be examined with respect to resisting studded tire damage. Applicable to structures due to additional weight?*

Objections: *Difficult to repeatedly overlay. Possible stripping issues should be investigated.*

2. Stone Matrix Asphalt

Stone matrix asphalt (SMA) is a common type of HMA used in various states and countries[6]. It differs from other asphalt mixtures in that it relies on "stone-on-stone contact" to distribute the loads imparted by traffic. It is recognized that for the same nominal maximum aggregate size, SMA is typically no quieter than dense-graded asphalt[7,8]. However, a smaller nominal maximum aggregate size is possible with SMA, while still maintaining good drainage, resistance to rutting, and – with proper materials selection – additional resistance to studded tire damage. In Denmark, SMA mixtures with 4 to 6 mm aggregates are currently being evaluated as lower-noise surfaces[9]. In the UK, some of the so-called "thin surfacings" are similar to SMA mixtures, and are pre-certified by Highways Authority Product Approval Scheme (HAPAS) based on various performance measures[10].

Balloting: *A:3, B:6, C:0*

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[2] http://www.quietroads.com/
[3] http://www.dot.ca.gov/hq/env/noise/pub/IH80_davis_ogacpvmntwtudy_7yrrpt.pdf
[4] http://www.dot.ca.gov/hq/env/noise/index.htm
[5] http://www.wsdot.wa.gov/Projects/QuieterPavement/
[6] http://books.trbbookstore.org/nr425.aspx
[7] http://www.eng.auburn.edu/center/ncat/reports/rep04-02.pdf
[8] http://epubl.luth.se/1402-1617/2006/122/LTU-EX-06122-SE.pdf
[9] http://www.vejdirektoratet.dk/publikationer/VInot066/index.htm
[10] http://www.bbacerts.co.uk/hapas.html

Data Needs: Needs to be tested in Washington State to assess durability. Durability data until "failure" should be known for conditions found on SR 520 corridor. Quality of materials, especially aggregates, should be examined with respect to resisting studded tire damage, particularly if smaller aggregates are used.

3. Composite Pavement

The definition of a composite pavement used here is an underlying new concrete pavement that is overlaid with a sacrificial asphalt layer that is periodically replaced to restore function[11] – in this case, reduce noise level. This includes both the OGFC/ARFC and small-stone SMA mixtures previously described. Reflection of joint movement through the asphalt layer (leading to cracks on the pavement surface) is sometimes cited as a contributing factor in defining failure of these pavement types. To mitigate this, continuously reinforced concrete pavement (CRCP) is most often used as the structural layer. However, with relatively small changes in temperature in the Seattle area, rapid development of reflective cracking has not been a major concern, especially if proper joint design is used (possibly a shorter joint spacing, for example).

Balloting: A:4, B:5, C:1
Data Needs: Need to determine if this option will work on this project – possibly based on test sections reportedly planned for 2009. Need to determine if lack of local experience with CRCP construction will affect quality of final product.
Objections: New concrete as a structural support system is not justified in terms of cost.

4. Quieter Concrete Pavement

The level of tire-pavement noise generated on concrete pavements ranges widely. Work underway at the National Concrete Pavement Technology Center at Iowa State University has revealed that tire-pavement noise levels for concrete pavements measured nationwide have a range that is in excess of 10 dBA.[12] The surface texture of the concrete is one of the most important considerations. Among the various options that are available, diamond grinding appears to be one of the best. Some drag surfaces – possibly combined with diamond grooving – could also be used for new construction. In order to help resist and accommodate the inevitable wear of the pavement due to studded tire use, the concrete should be constructed with a hard, durable mortar and aggregate. In an extreme example of this, high-performance concrete (HPC) could be used that typically has very low water/cementitious material (w/cm) ratios and uses various supplementary cementitious materials[13]. Concrete pavements should be constructed thicker than what is necessary for structural performance. This will allow for periodic diamond grinding for

[11] http://www.cproadmap.org/research/project.cfm?projectID=-1115188206
[12] http://www.cptechcenter.org/projects/detail.cfm?projectID=-1317576198
[13] http://www.tfhrc.gov/structur/hpc/hpc.htm

functional (acoustical) restoration. It is the understanding of the ERP that this is common practice in the State today.

Balloting:	*Diamond Grinding – A:1, B:6, C:2* *Drag and Grooving – A:2, B:4, C:3* *High Performance Concrete – A:1, B:6, C:2*
Data Needs:	*Determination of how quieter concrete pavement can be consistently constructed. Determine how well concrete surfaces can resist studded tire wear. Look at WSDOT quieter concrete pavement experiments: both underway and those planned for summer 2009. If used, benefit of HPC should be quantified with respect to additional cost. WSDOT test sections of HPC can be referenced.*
Objections:	*Not going to find noise reduction; too expensive; studded tires will compromise drag texture.*

5. Porous Asphalt

With a composition similar to OGFC, porous asphalt is a pavement system that includes a thicker layer (or layers) of a high-porosity material. The thickness is generally 1.5 to 5 inches, compared to 1 inch or less that is typical of OGFC. Porous asphalts are used in Europe and Japan where the structural capacity is reportedly similar to dense-graded HMA. To date, there has been very limited use of Porous Asphalt in the United States. In Japan, there is a variant of double-layer porous asphalt that has a higher porosity than is typically seen elsewhere[14]. In Europe, several countries have also used double-layer porous asphalt. One example is a proprietary product developed by Skanska in Sweden that consists of an advanced binder, high quality stone (with a maximum size of 11 mm, and designed for studded tire wear), and very high porosity[15]. The top lift is designed to be resurfaced for purposes of restoring the noise reduction. At present, this is every three years, but improvements in the design suggest that this period may be increased. It should be noted that in Sweden, there is heavy studded tire usage (typically 70%), so this renewal cycle should be longer on the SR 520 project since the percentage of studded tires is less. More on this option is available from Dr. Ulf Sandberg.

Balloting:	*Porous Asphalt – A:0, B:10, C:0* *Japanese Porous Asphalt – A:0, B:3, C:5* *Swedish Porous Asphalt – A:0, B:4, C:6*
Data Needs:	*Durability data until "failure" should be known for conditions found on the SR 520 corridor. Quality of materials, especially aggregates, should be examined with respect to resisting studded tire damage. Applicable to structures due to additional weight? Need and expense of mitigating clogging of porous system. Should be tried on inclines, as trials to date have been on relatively flat sections.*

[14] http://www.vejdirektoratet.dk/publikationer/VInot031/html/chapter07.htm
[15] http://www.norskasfaltforening.no/Artikler/1294/11_-_Tyst_asfalt_Henrik_Sjoholm.pdf

Objections: *With a number of viable options already available with current US practice, higher risk options like this may not be necessary. The life cycle is too short.*

6. Innovative Pavement Surfaces

A number of additional, more innovative, approaches to pavement design were discussed. Among these is the use of an asphalt modifier consisting of Trinidad lake asphalt. WSDOT reported that this has been used on the Tacoma Narrows Bridge[16]. The benefit of the modifier is a possible weight reduction and increased resilience (flexibility). High friction surfaces (HFS) were also discussed. These are similar to a "chip seal" process, but use a much smaller high-quality stone (commonly calcined bauxite) and an epoxy resin type binder[17]. Steel slag aggregates in HMA have also been reportedly used for noise reduction in the past[18]. Finally, poroelastic pavements (PERS) are a newer pavement concept that continues to be evaluated in Sweden, Japan, the Netherlands, and now under a new European study termed PERSUADE[19]. PERS is probably the quietest pavement surface ever measured, is resilient to studded tire damage, but is also very expensive and the durability under high traffic requires further study.

Balloting: *Trinidad Asphalt Modifier – A:0, B:6, C:3*
High Friction Surfacing – A:0, B:4, C:5
Steel Slag Aggregate for Asphalt – A:0, B:3, C:6
Poroelastic Pavement – A:0, B:3, C:6

Data Needs: *Little if any durability data exists for these surfaces, especially with respect to their resistance of studded tire damage.*

Objections: *Most of these surfaces have little if any exposure in the US, making their design, construction, and performance questionable. Considering the risks of potential failure, it is not recommended on this project except in possibly isolated cases such as ramps or test sections. Significant sources of steel slag are not readily available.*

Roadway Design

7. Minimize Up-grades

Acceleration noise (engine, transmission, exhaust) from traffic tends to be increased on uphill grades (up-grades). Design measures should be taken to minimize up-grades that are present on the project. This includes the grades on the approaches to the high rise on structures, where long gradual grades are preferred over short, steeper grades. For on-ramps, acceleration noise is inevitable, but can be minimized if efforts are made to minimize any up-grades, or instead promote down-grades wherever possible.

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[16] http://www.wsdot.wa.gov/biz/mats/Pavement/TrinidadLakeAsphaltOverlay.pdf
[17] http://www.highfrictionroads.com
[18] http://www.euroslag.com/media/downloads/Dunster.pdf
[19] http://nr2c.fehrl.org/?m=23&mode=download&id_file=5532

Balloting: *Minimize Grades – A:9, B:0, C:0*
Encourage Down-grades on all On-ramps – A:9, B:0, C:0

8. Higher Alignment with Shorter Noise Barrier

Along the corridor, improvements can possibly be made in reducing noise by increasing the height of the roadway. At the same time, shorter noise barriers could be used. By increasing the elevation of the roadway, the noise path is above the receptors at the lower elevations. By using a shorter noise barrier, wind loads on the structure are reduced. This recommendation should be balanced with the stated desires of the mediation panel to maintain a generally low bridge profile.

Balloting: *A:3, B:5, C:2*
Data Needs: *Modeling should be used to determine if this option is effective. The overall cost effectiveness must also be known considering the impact to structural design.*
Objections: *To recommend this may conflict with view issues (at least, for opaque barriers). Cost implications may likely be prohibitive.*

9. Manage Pump House and Ventilation Noise

Noise that is generated at the pump houses (used for drainage management) and at ventilation sites should be managed through use of appropriate noise control methods.

Balloting: *A:10, B:0, C:0*

10. Quieter Rumble Strips

Noise generated by vehicles that stray onto rumble strips is a common complaint. While important for safety, newer designs are available that maintain the necessary noise and vibration level for the vehicle occupants, while reducing the noise that is generated outside the vehicle[20]. These newer designs could be optimized for the vehicles and speeds expected on the SR 520 project.

Balloting: *A:4, B:5, C:0*
Data Needs: *Before recommendation is made, specific methods should to be tested to determine what works. Cost effectiveness and maintenance issues should also be considered.*

Noise Barriers

11. Noise Barriers

Noise barriers are commonplace on highway projects throughout the world as one of the most effective ways to mitigate noise. Over the years, numerous types of barriers have

[20] http://www.trl.co.uk/store/report_detail.asp?srid=5396&pid=174

emerged that are able to accommodate site-specific requirements including the need for sound absorption and in some cases, the minimization of visual impacts using transparent materials. The ERP believes that no single type of barrier is appropriate for the whole length of the corridor. Instead, it is recommended that all currently available options be considered, with the final selection based on the local conditions. For example, if parallel barriers are spaced such that absorptive barriers would reduce overall levels (commonly a 10:1 ratio or less of spacing-to-height), then these should be considered. Furthermore, transparent barriers could be considered for use where view preservation is believed to be an issue from an aesthetic or safety standpoint. The ERP recognizes the various concerns of the public with the use of noise barriers, however, barriers should be considered for noise reduction as they are a proven solution.

Balloting: *Opaque, Reflective Barriers – A:9, B:0, C:1*
Opaque, Absorptive Barriers – A:10, B:0, C:0
Transparent Barrier – A:9, B:1, C:0
Data Needs: *Before transparent barriers are selected, vendors should be queried about cleaning/maintenance options as they fit within WSDOT practice; information on the resistance to various foreign substances should also be sought.*
Objections: *If only opaque barriers are used, the vehicle occupants will lose the views from the structure, and abutting residences may lose views of lakes, mountains, etc.*

12. Absorptive Material on Safety Barriers and Retaining Walls

The ERP believes that additional benefit in noise reduction can likely result from the application of acoustically absorptive material on the traffic-facing surfaces of both the 42-inch-high safety barrier and the retaining walls on the project. Application of a sprayable cementitious[21] (such as a minimum of 1 inch of Acoustement 40) or a poroelastic[22] (preformed resin/polyurethane-bound rubber) material could possibly be used for this purpose.

Balloting: *Application to Safety Barriers – A:7, B:2, C:0*
Application to Retaining Walls – A:10, B:0, C:0
Data Needs: *Before a recommendation is made, the effectiveness of candidate materials should be determined, along with its availability.*

13. Transparent Barrier Options

If transparent barriers are used, there are additional options that can be incorporated into a noise reduction strategy. For example, the barriers can be developed in such a way that the transparent panels are placed atop a foundation consisting of absorptive barrier. This combination barrier could reduce issues with graffiti, and possibly assist with adverse parallel barrier effects. Measures to minimize the number of bird strikes on transparent

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[21] http://www.pyrok.com/a40_data.html
[22] http://www.qcity.org/downloads/SP4/D4-01_ACL_12M.pdf

barrier can also be included in the design[23]. Various options have been used previously, and the benefits and costs of these should be considered. Finally, designs of transparent barrier with curved tops or even transparent "tunnels" have been used elsewhere, and could be considered for this project[24].

Balloting: *Combination Transparent/Absorptive Barrier – A:7, B:2, C:0*
Bird Strike Prevention Measures – A:6, B:4, C:0
Curved/Tunneled Barriers – A:1, B:4, C:5

Data Needs: *Effectiveness of the combination barrier should be determined, along with the benefit that is gained with having the clear barrier at a higher level in terms of its effectiveness in graffiti prevention and aesthetic appeal. Effectiveness and cost of various bird strike prevention options should be investigated. The benefit of curved barrier should be determined through modeling.*

Objections: *Curved or "tunnel" barrier could lead to maintenance (especially cleaning) and potential ventilation issues.*

14. Alternative and Innovative Noise Barriers

Various options for alternative and innovative noise barriers were advanced. It was the consensus of the ERP that as more maintenance-friendly solutions for barrier technology are brought into practice, these should be considered for segments of the barrier that will inevitably be replaced during the life of the barrier. With respect to the original design, consideration should be given to using local or "famous" artists to assist with the barrier aesthetic designs. This could improve public perception and may deter graffiti to some degree. Living or "green" barriers are another consideration where vegetation is incorporated into the barrier design. Lightweight barriers can also be used, particularly on structures where dead loading is an additional consideration.

Balloting: *Panel Replacements with Improved Technology as it becomes available – A:8, B:1, C:0*
Barrier Design involving Local or Famous Artists – A:6, B:3, C:0
Living Barriers – A:2, B:7, C:1
Lightweight Barriers – A:3, B:4, C:3

Data Needs: *Recommendation for using improved technology is too vague – will depend on specific technology. Effectiveness of living barriers should be determined, particularly with maintenance, public perception, and irrigation requirements. Lightweight barriers should be used only when appropriate (e.g., when reducing dead loads are important).*

Objections: *The objections outweighed the benefit for living barriers. With respect to lightweight barriers, the best barrier for the application should be selected, and the design of the structure fit to accommodate it.*

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[23] http:// www.adc40.org/summer2008/BinetteTRB08.pdf

[24] http://www.cyro.com/methacrylates/MCMSbase/Pages/ProvideResource.aspx?respath=/NR/rdonlyres/06E8EAF2-324E-4C6B-AB44-C63F49A1BF73/0/4126PLEXIGLASSOUNDSTOPFlier_en.pdf

15. Barrier Operation and Maintenance

With respect to operation and maintenance of barriers, the ERP identified two components. First, where the barrier separates the multi-use pathway and the roadway, doors should be installed for access and safety reasons. Second, with the recognition that graffiti is a long-standing problem with respect to barriers worldwide, WSDOT could consider establishing a graffiti resistance program that can include innovative methods to cover barriers (such as vegetation) or other targeted maintenance activities.

Balloting: *Doors along Barriers that separate Multi-Use Path – A:10, B:0, C:0*
Targeted Graffiti Resistance Program – A:8, B:2, C:0

Data Needs: *Graffiti resistance program effectiveness should be determined. Too many unknowns.*

Modeling

16. Advanced Acoustical Modeling

To adhere to federal regulations for the EIS, traffic noise modeling must be conducted with the FHWA TNM® version 2.5. While the model has been extensively validated, there remain limitations in the ability of the model to account for a number of the complex features inherent in this project. The ERP identified a need for supplemental modeling for acoustics using Cadna[25], Soundplan[26], or another ISO 9613-2 compliant product[27]. Such a tool cannot be used for the EIS, but can be used for final design. Meanwhile, the TNM® software is currently undergoing revision that will result in version 3.0 in the future[28]. It has been recommended that these developments be closely monitored by WSDOT.

Balloting: *Supplemental Modeling – A:9, B:0, C:0*
Track Development of Next Generation of TNM® – A:10, B:0, C:0

17. Advanced Climatic Characterization

The ERP recognizes that TNM and federal noise policy require the use of "average" climatological conditions in project modeling. However, more advanced models provide for inputs for microclimatological conditions allow for improved predictive capability. One condition is the presence of temperature gradients, or more specifically an inverted lapse condition (where the air near the ground is cooler than that directly above). A range of potential conditions could be analyzed to determine the impact to the overall predictions. Prevailing winds could also be considered in the analysis based on measurements in the vicinity of the project for microscale conditions that differ from the modeled average.

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[25] http://www.acu-vib.com.au/cadna.htm
[26] http://www.soundplan.com/
[27] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=20649
[28] http://www.pooledfund.org/projectdetails.asp?id=384&status=4

Balloting:	*Modeling of Atmospheric Lapse Condition – A:5, B:2, C:1* *Modeling of Prevailing Winds – A:8, B:1, C:0*
Data Needs:	*Determine if inverted lapse condition occurs prior to consideration in modeling. Determine if prevailing winds might be significant enough to affect prediction.*
Objections:	*Temperature inversions are rare for the project area and special modeling is not needed.*

Perception

18. Avoid Repeating Features and Impulses on Pavement Surface

While overall noise levels are affected by the pavement surface, additional perception issues can be introduced (or avoided) due to repeating features on the pavement. This could introduce tonality, or by transient events that lead to impulsive noise. Both should be avoided by minimizing them in design. For example, as a repeating feature, transverse tining should be avoided. Widened or improperly maintained contraction joints should also be avoided.

Balloting: *A:10, B:0, C:0*

19. Construction Noise Plan

A construction noise plan should be developed that involves substantial and targeted public input. Case studies have shown that a proactive plan can help to significantly improve the experience for the public. The FHWA's Construction Noise Handbook[29], its Roadway Construction Noise Model (RCNM), and multiple case studies are available to serve as a guide.

Balloting: *A:10, B:0, C:0*

20. Accelerated Schedule for Installation of Noise Mitigation and Vegetation

The various noise mitigation measures that are included in the project's final design may be accelerated in terms of their scheduled installation. This includes the installation of barriers as well as replacing vegetation that is disturbed or removed. For the latter, vegetation that is particularly fast growing could be selected for visual screening (e.g., Boston ivy for retaining walls). A mix of vegetation with fast-growing and long-term concealing characteristics might be advantageous.

Balloting: *Accelerated Schedule – A:10, B:0, C:0*
Accelerated Vegetation – A:9, B:0, C:0

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[29] http://www.fhwa.dot.gov/ENVIRonment/noise/handbook/index.htm

Operation and Finance

21. Construction Noise Penalties and Incentives

Noise that is generated as part of highway construction should be controlled. Controls may include different aspects like time of day, materials to be used, location of staging areas, types of back-up alarms, location of temporary noise shielding, and methods of conducting activities. Establishing a plan to do this is important and was identified as a separate recommendation. For this component, noise levels would be monitored during construction and penalties (and possibly incentives) used to control both noise levels and the time-of-day of noise-generating activities.

Balloting: *A:8, B:1, C:1*
Data Needs: *Specifications would need to be identified and/or developed. Methods to check noise in the field need to be identified.*
Objections: *Will be difficult to determine proper levels of incentive or penalty. At what point would operations be shut down? What about pile driving? Municipal codes seem to cover some of this already – at least day-night ordinances.*

22. Real-Time Speed Advisory or Enforcement

Permanent radar speed detectors can be installed at strategic locations along the corridor as a means of advising drivers of their speed. This is relevant given that the traffic noise is a function of speed. A more invasive alternative to this would involve enforcement of speeds through cameras and/or special enforcement actions.

Balloting: *Speed Advisory – A:7, B:1, C:2*
Speed Enforcement – A:3, B:1, C:6
Data Needs: *Before installation, it should be determined how prevalent speeding is, and its impact to noise levels. Applicability of these units within the community should also be determined.*
Objections: *Speed is likely not an issue. As an advisory device, the effect "wears off" over time. As enforcement, it is not well received by the community.*

23. Construction Payment Adjustments for Pavement Noise

Currently, pavements are constructed with disincentives for poor quality. Quite often, pay reductions will result from pavements that are constructed too rough or of low strength or density. It is becoming increasingly common in Europe to also include pay adjustments for as-constructed quality with respect to tire-pavement noise[30]. For pavements constructed with high levels of noise, a penalty is applied.

Balloting: *A:4, B:4, C:1*
Data Needs: *How should the noise be measured, what are the pay schedules. Can the construction be controlled well enough to effectively limit noise given the*

[30] http://www.trl.co.uk/silvia/Silvia/pages/index.html

	controls available to the contractor? Would this performance specification conflict with other methods-based specifications that the contractor is working under?
Objections:	*This would not be like paying for smoothness. There are too many conflicts since the mixture or texture is specified. There is not enough data to establish appropriate penalty levels at this time.*

24. Heavy Truck Tolls with Noise Considerations

Noise emissions from heavy trucks are significantly greater than from other vehicles (except possibly some motorcycles). It is possible that the toll structure that is developed for this project could be modified to account for this. Additional toll could be levied at times of day that additional noise is not desired (night).

Balloting:	*A:1, B:5, C:3*
Data Needs:	*Acceptance by the community should be determined. Determination should be made of the additional toll. Coupling with additional pavement damage from heavy trucks should be made. Impacts of joints by heavy trucks is another consideration that needs more information. Need to determine how this will affect diversion of trucks not wanting to pay higher toll.*
Objections:	*Size and weight issues already regulate trucks. Since both I-90 and SR 520 might be tolled, there might be little impact from additional toll on SR 520.*

Studded Tires affecting Acoustical Durability of Pavements

25. Tax Studded Tires

Studded tires have been previously identified as one of the most significant challenges to providing long-term noise mitigation via quieter pavements. In general, there are serious impacts to both the functional and structural performance of pavements because of studded tire use. To help offset the additional cost that is incurred by their use, a tax levied on studded tires is proposed.

Balloting:	*A:8, B:2, C:0*
Data Needs:	*More information is needed about how this would work, and how the funding would be applied to maintaining roadways including SR 520. It is also important to study how prolific the use of studded tires is today, and what the trends are for their use in the future.*

26. Prohibit Studded Tires

As an alternative to taxation, the option that is preferred by the majority of the ERP is the prohibition of studded tires. Ideally, this would be statewide, but at the very least, the prohibition of studded tires along SR 520 should be considered. Due to the significant costs associated with studded tire damage to pavements, numerous states with significant winter climates have prohibited their use[31]. Among these are Minnesota, Wisconsin, Michigan, and Illinois.

Balloting: *Prohibit Studded Tires Statewide – A:7, B:3, C:0*
Prohibit Studded Tires on SR 520 – A:7, B:2, C:1
Data Needs: *Need to evaluate the safety and legal implications of this. Should look at various other States' experiences from previous years.*
Objections: *Outlawing studded tires on only SR 520 is not enforceable or practical. Vehicles with studded tires will likely take alternate routes.*

27. Limit Studded Tire Use to One Lane

Studded tire use can be limited to a single lane, which would then be resurfaced more frequently, while the remaining lanes would have longer lives. High fines could be used to assist in enforcement.

Balloting: *A:5, B:3, C:2*
Data Needs: *Safety implications should be studied along with the cost-benefit.*
Objections: *Not practical, not enforceable.*

28. Require Retractable Studs

It appears that tires with retractable studs might be available in the near future[32]. Assuming safety is not compromised, the use of these tires in lieu of other options could be possible, although not highly recommended.

Balloting: *A:0, B:3, C:7*
Data Needs: *Determine how practical this is to implement. Are there other adverse effects? Is this providing an unfair competitive advantage to one company?*
Objections: *Something else about the tire is likely being compromised, safety concerns, potential commercial interests being promoted.*

Vehicle Sources

29. Prohibit Compression Braking

Signs should be posted that prohibit the use of compression brakes along SR 520. While enforcement is difficult, such signs may limit the use of these systems that are often a source of noise complaints. Before adopting as a strategy component, WSDOT should consult with the traffic engineering division about their experience with current regulations and enforcement.

Balloting: *A:10, B:0, C:0*

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[31] http://www.wsdot.wa.gov/biz/mats/pavement/PavementsStuddedTiresFinalv2.pdf
[32] http://www.qtires.com/

30. Restrict Truck Lane for Increased Barrier Effectiveness

Lane restrictions for heavy trucks could be used – either to the outside or inside lane. If designed as a system, this can potentially make more effective use of noise barriers, including the proposed absorptive safety barrier.

Balloting: *A:8, B:1, C:1*
Data Needs: *There are only 2 lanes, so is this practical?*
Objections: *This does not appear to be practical.*

31. Reduced Speed Limits at Night

With speed being an important variable in noise generation, lower speed limits at night could be used to reduce noise at the time when the public is most sensitive to noise.

Balloting: *A:4, B:4, C:2*
Data Needs: *Effectiveness should be evaluated considering the percentage of truck traffic at night, among other factors.*
Objections: *This may reduce the capacity of the roadway. Enforcement will be difficult and there is likely minimal benefit to overall noise from this reduction. This is particularly true with vehicles with loud engine or exhaust sources (e.g., motorcycles).*

Structures

32. Quieter Bridge Joints

Bridge joints are known to be a noise source of concern – from both an overall level and annoyance perspective. Implementing quieter bridge joint designs is recommended. This should begin with an inventory of current bridge joints (for noise), both inside and out of Washington. Examples include steel ramps, finger joints, and special German joints optimized for low noise[33].

Balloting: *A:10, B:0, C:0*

33. Local Absorptive Material near Joint

In a fashion similar to what is under consideration for the Tacoma Narrows Bridge, the liberal application of sound absorbing material on reflective surfaces near bridge joints may reduce joint noise propagation.

Balloting: *A:0, B:10, C:0*
Data Needs: *The effectiveness including frequency attenuation should be determined, and final design concepts investigated that are compatible with the SR 520 project.*

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[33] http://en.structurae.de/refs/items/index.cfm?id=r0029498

34. Under Deck Covers

Encapsulation of the underside of bridge decks could potentially reduce noise, particularly in the vicinity of grating or joints[34].

Balloting:	*A:4, B:5, C:1*
Data Needs:	*Effectiveness of this should be determined. Specific application locations should be identified. Probably not needed in pontoon area.*
Objections:	*Likely a costly option. Tire noise would not likely be reduced appreciably.*

Arterials

35. Traffic Management and Calming

On the arterials immediately adjacent to and crossing SR 520, improvements to traffic management and calming can assist in the overall noise generation for those abutting these arterials. Roundabouts could be used, for example, to reduce or eliminate stop and go traffic. Air quality and fuel consumption are also improved. If signals are to be used, timing and synchronization of the signals with other signals along the arterials can be introduced. Finally, speed bumps along the arterials could be eliminated to avoid impulse noise, rattles, and accelerating noise associated with vehicles as they pass over them.

Balloting:	*Roundabouts – A:9, B:1, C:0* *Signal Timing – A:9, B:0, C:1* *Eliminate Speed Bumps – A:10, B:0, C:0*
Data Needs:	*The effectiveness should be determined.*
Objections:	*Signal timing is good for other reasons, but it is not clear how it will be a benefit for noise since it does not entirely eliminate stop & go.*

36. Quieter Pavement on Arterials

Quieter pavement could be used on the arterial streets, which may provide some benefit, particularly for speeds in excess of 20-30 mph[35]. Some caution should be exercised given that adjoining pavements may be louder, which could mask the benefits of the quieter pavement on the arterial.

Balloting:	*A:6, B:1, C:3*
Data Needs:	*Speeds of the arterials should be examined to determine the effectiveness of this option.*
Objections:	*There are limited areas to use this alternative. Speeds are likely too low.*

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[34] http://international.fhwa.dot.gov/superiormaterials/chap3.cfm#innovation
[35] http://www.tcpsc.com/LittleBookQuieterPavements.pdf

37. Recommend Truck Restrictions

To further reduce noise, truck movements could be restricted on arterial streets as appropriate to reduce engine, braking, exhaust, and mechanical noise.

Balloting: *A:2, B:2, C:3*
Data Needs: *Determine if local communities would agree, and determine the specific location and times for the restrictions to make them most effective.*
Objections: *Trucks are already restricted as much as possible. This is a local jurisdiction issue.*

Lids and Tunnel

38. Absorptive Material inside Lids and Tunnel

Absorptive material can be used as a lining inside tunnels and lids, especially near the exit from these structures[36]. There are maintenance considerations including cleaning, but the noise reduction benefits could offset this. Additional absorption (including the possibility of absorptive pavements) could also be used in the vicinity of transit stations to make the rider experience less stressful.

Balloting: *Inside of Lids and Tunnel – A:9, B:1, C:0*
Additional Treatment at Transit Stations – A:6, B:4, C:0
Data Needs: *The effectiveness of these treatments should be determined.*

39. Portal Treatments

In addition to the placement of acoustically absorptive material on the sides and ceiling surfaces near the exits from the lids and tunnels, the portals to both the lids and the tunnels can be treated in different ways to minimize the noise impacts adjacent to these features. For example, a "portal lip" design could assist in directing the acoustical energy away from users of the public open spaces above. Barriers that are adjacent to the portals could also be designed to seamlessly integrate with the portal. Finally, vegetation could be placed directly adjacent to the portal that would serve to deter pedestrian activity at these locations while "softening" their appearance.

Balloting: *Portal Lip – A:2, B:7, C:1*
Integrate Barriers with Portal – A:10, B:0, C:0
Vegetation near Portal – A:8, B:2, C:0
Data Needs: *Portal lip design is needed including engineering considerations, effectiveness. The effectiveness, maintenance, and irrigation issues for vegetation should also be investigated.*
Objections: *Portal lip will not be effective or may be redundant since the safety barrier will be there. There will likely be additional maintenance issues.*

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[36] Woehner, Helmut, "Sound Propagation at Tunnel Openings," Noise Control Engineering Journal, Vol. 39, No. 2, Sep-Oct 1992, pp. 47-56.

40. Masking Features

Features could be introduced atop the lids including water features, such as linear waterfalls with turbulent flow. There would be associated maintenance considerations with this feature. In some cases, acoustic sculptures have also been built into projects that allow the public to view the noise that is generated under the lid from a different perspective. Artist Bruce Odland is well known for such sculptures[37].

Balloting:	*Water Features – A:3, B:3, C:2* *Acoustic Sculptures – A:2, B:5, C:3*
Data Needs:	*For water features, input is needed from maintenance as well as from the community. For sculptures, more details are needed including specific artists.*
Objections:	*For water features, these might be aesthetically pleasing, but you are adding noise even if it is masking. There are water features in the vicinity of the bridge now, but are not turned on because of driver distractions and sustainability. For acoustic sculptures, there may be a conflict with noise reduction. Results are listener dependent, and some have been taken down.*

Corridor Zone-Specific Noise Reduction Strategies

With various noise reduction strategy components identified and balloted, the ERP identified strategies for noise reduction that could be specifically assigned to the various zones within the corridor. These zones were defined based on characteristics that are common and relevant with respect to noise reduction. Appendix A illustrates the boundaries of the zones that were used by the ERP.

The following sections summarize potential strategy recommendations. In some cases, these recommendations are left more "generic" such as the use of "quieter pavements". In this case, the strategy component alternatives listed previously should be reviewed with respect to benefits and costs before a final selection is made.

For each of the zones, characteristics and features are first listed that are relevant to the selection of appropriate noise mitigation measured. The potential noise control strategy is then outlined.

It should be stressed that the items listed below as "potential strategy components for consideration" are not prioritized. If desired, the ERP ballot results identified previously can be used for preliminary prioritization. However, final prioritization cannot be achieved until the benefits and costs of each component are determined. The scope of this task is beyond the duties of the Noise ERP.

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[37] http://www.bruceodland.net/

West Side, Zone 1

Interstate 5 to East side of Portage Bay

Characteristics

- Same for Alternatives A, K, and L
- Bowl section
- I-5 interchange
- Large retaining walls
- 2 lids – one on I-5, and one on SR 520
- Arterials – heavy traffic and modifications will be made
- Elevation change (grade)
- Ramps
- Structure across Portage Bay
- Section 4(f) issue – park impacts, constructive use
- House boats

Potential Strategy Components for Consideration

- Quieter pavement
- Gentle grades
- Absorptive material on all safety barriers
- Parallel transparent barriers on structure (with absorptive bases) for best noise reduction – between traffic and pedestrian/bicycle area
- As an option with less noise reduction, shorter opaque absorptive barriers designed to protect views
- Absorptive treatment on retaining walls
- Quieter expansion joints
- Under deck covering
- Traffic calming of arterials
- Quieter pavements on arterial roads
- Absorptive material inside of lidded area
- Integrate sound walls and retaining walls with portals
- Dense vegetation on lid top adjacent to portal for buffer for pedestrian deterrence

West Side, Zone 2 (Alternative A)

East side of Portage Bay to West side of Arboretum

Characteristics

- Depressed section
- Large retaining walls
- 1 lid
- 1 wide overpass
- Arterials including Montlake Blvd. and Lake Washington Blvd. with heavy traffic
- Ramps including loop ramp (on down-grade)

- Second parallel bascule bridge
- Front line receiver removal at some locations on Montlake
- Optional flyover access ramps

Potential Strategy Components for Consideration

- Quieter pavement
- Absorptive material on all safety barriers
- Conventional barriers
- Absorptive treatment on retaining walls
- Quieter bridge joints
- Traffic calming of arterials
- Quieter pavements on arterial roads
- Absorptive material on inside of lidded area
- Integrate sound walls and retaining walls with portals
- Dense vegetation on lid top adjacent to portal for buffer for pedestrian deterrence
- Consider HFS on tight horizontal curve on-ramp
- If constructed, flyover access ramps should use transparent barrier on south side (may not be necessary if noise absorptive safety barriers are effective)

West Side, Zone 2 (Alternative K)

East side of Portage Bay to West side of Arboretum

Characteristics

- Depressed section
- Large retaining walls
- 1 larger lid
- 2 lids over Lake Washington Bypass
- Arterials including modified traffic patterns on Montlake Blvd. and Lake Washington Blvd.
- Ramps
- New Pacific Interchange traffic tunnel
- Optional off-ramp from eastbound SR 520 to Montlake

Potential Strategy Components for Consideration

- Quieter pavement
- Absorptive material on all safety barriers
- Conventional barriers
- Absorptive treatment on retaining walls
- Traffic calming of arterials
- Quieter pavements on arterial roads
- Absorptive material inside of lidded areas
- Absorptive material for cut and cover sections of tunnel
- Integrate sound walls and retaining walls with portals (of lids and tunnel) as applicable

- Dense vegetation on lid top adjacent to portal for buffer for pedestrian deterrence
- If constructed, flyover access ramps should use transparent barrier on south side (may not be necessary if noise absorptive safety barriers are effective)

West Side, Zone 2 (Alternative L)

East side of Portage Bay to West side of Arboretum

Characteristics

- Depressed section
- Large retaining walls
- 2 lids – above 520 and at Montlake/Pacific
- SPUI located on top of 520 with start/stop
- New bascule bridge
- Arterials including modified traffic patterns on Montlake Blvd. and Lake Washington Blvd.
- Numerous ramps

Potential Strategy Components for Consideration

- Quieter pavement
- Absorptive material on all safety barriers
- Conventional barriers
- Absorptive treatment on retaining walls
- Quieter bridge joints
- Traffic calming of arterials
- Quieter pavements on arterial roads
- Absorptive material inside of lidded area
- Integrate sound walls and retaining walls with portals
- Dense vegetation on lid top adjacent to portal for buffer for pedestrian deterrence
- If constructed, access ramps and Pacific Interchange should use transparent noise barrier (may not be necessary if noise absorptive treatment of safety barriers is used)

West Side, Zone 3

Arboretum, East side of Portage Bay to West side of Arboretum

Characteristics

- For Alternative A, without the Foster Island Land Bridge, the grade is gradual to the west high rise
- For Alternative K (with the Land Bridge), the grade is not significant until just before the high rise where it becomes steep
- For Alternative L (with the Land Bridge), the grade to the high rise is gradual past the Land Bridge
- All viaduct
- Foster Island Land Bridge for Alternatives K and L including retaining walls

Potential Strategy Components for Consideration

- Quieter pavement
- Gentle grades and higher profile
- Absorptive material on all safety barriers
- Parallel transparent barriers on structure (with absorptive bases) for best noise reduction – between traffic and pedestrian/bicycle area
- As an option with less noise reduction, shorter opaque absorptive barriers designed to protect views
- Quieter expansion joints
- Under deck covering
- Absorptive material inside land bridge
- Integrate sound walls and retaining walls with portals
- Dense vegetation on land bridge top adjacent to portal for buffer for pedestrian deterrence

West Side, Zone 4

East of the Arboretum into Lake Washington and terminating at the pontoon sections

Characteristics

- For Alternative A, without the Foster Island Land Bridge, the grade is gradual to the west high rise
- For Alternative K (with the Land Bridge), the grade is not significant until just before the high rise where it becomes steep
- For Alternative L (with the Land Bridge), the grade to the high rise is gradual past the Land Bridge
- Bridge (west approach)
- Includes high rise

Potential Strategy Components for Consideration

- Quieter pavement
- Gentle grades and higher profile
- Absorptive material on all safety barriers
- Transparent barriers on south side of structure (with absorptive bases) for best noise reduction – between traffic and pedestrian/bicycle area
- As an option with less noise reduction, shorter opaque absorptive barriers designed to protect views
- Quieter expansion joints
- Under deck covering

Floating Bridge (Zone 5)

Pontoon sections only

Characteristics

- Structure deck supported on approx. 20-ft. columns separated from pontoon platforms
- No nearby residents
- Considerations for drivers perception and pedestrians, bicyclists

Potential Strategy Components for Consideration

- Quieter pavement
- Absorptive material on all safety barriers
- As needed (especially closer to high rises on east and west), parallel transparent barriers on structure (with absorptive bases) for best noise reduction – between traffic and pedestrian/bicycle area
- Quieter expansion joints
- Under deck covering (may be desired for aesthetic continuity)

East Side High Rise (Zone 6)

Beginning at the end of the pontoon sections, ending landside

Characteristics

- High rise
- Grade change (5%)

Potential Strategy Components for Consideration

- Gentle grades and higher profile
- Quieter pavement
- Absorptive material on all safety barriers
- Parallel transparent barriers on structure (with absorptive bases) for best noise reduction – between traffic and pedestrian/bicycle area
- Quieter bridge joints
- Under deck covering

East Side (Zone 7)

All landside East of Lake Washington

Characteristics

- Depressed and elevated sections
- Numerous grade changes – up to 5% in some places
- Large retaining walls
- Lids
- Arterials including modified traffic patterns

- Numerous ramps
- Significant vegetation (existing)

Potential Strategy Components for Consideration

- Minimize grades, consider line of sight issues for residences
- Quieter pavement
- Absorptive material on all safety barriers
- Absorptive barriers, or transparent barriers may be considered for aesthetic continuity and shadow issues and recreation (trail) impacts
- Absorptive treatment of retaining walls
- Traffic calming of arterials
- Quieter pavements on arterial roads
- Absorptive material inside of lidded area (with additional considerations for those with transit use)
- Integrate sound walls and retaining walls with portals
- Dense vegetation on lid top adjacent to portal for buffer (pedestrian deterrence)
- Rapid re-vegetation of all areas affected by clearing during construction

Corridor-wide and Statewide Strategies

In addition to the recommendations for noise reducing strategies that have been provided previously for the various zones, some strategy components are recommended for adoption throughout the corridor. These include:

- Installation of doors along the barriers that separate the multi-use path from the highway for safety concerns
- Initiation of a targeted graffiti resistance program for noise walls
- Advanced modeling of the various noise reduction methods identified herein
- Construction noise plan including penalties and incentives
- Accelerated schedule for the installation of noise mitigation
- Speed advisories along the corridors to deter drivers from speeding
- Taxation of studded tires to help recover pavement maintenance costs
- Prohibition of studded tires on the SR 520 corridor
- Prohibition of compression braking (especially un-muffled) of trucks
- Restriction of the truck lane for increased barrier effectiveness
- Traffic control and calming features for arterials

Furthermore, it is the consensus of the ERP that the State of Washington should strongly consider the prohibition of studded tires statewide.

Conclusions and Next Steps

In the identification of the various strategy components, data needs have also been identified. For those recommendations that will be considered by WSDOT, these data needs should be fulfilled to the greatest extent feasible.

With respect to the benefits that will be received in terms of noise mitigation, these must be confirmed through modeling, including the use of the more advanced models that are available today. Examples include Cadna, Soundplan, or other ISO 9613-2 compliant products.

The life cycle costs for the various strategy components must also be determined prior to their adoption. This includes both capital and recurring costs. Maintenance costs should be linked to the various strategy components identified herein. For example, graffiti and vandalism can be particularly problematic, and therefore WSDOT maintenance staff should be included during the final decision making process.

Close monitoring of both current and planned quieter pavement test sections should also help identify the life cycles of some of the various quieter pavement solutions under conditions that will likely be present on SR 520. Rapid pavement wear under studded tire use is a paramount concern of the ERP, and recommendations for limiting or eliminating their use should be considered a high priority. That said, exploring pavement options that can better resist the additional damage from studded tires should continue. Future pavement test sections could explore some of the more innovative quieter pavement options that have been identified herein, but only after an assessment is made of the benefits and costs that might result from their use.

Finally, safety implications should be determined for each strategy component. These should consider all those potentially impacted including both the public and the WSDOT maintenance staff.

Appendix A – Project Zone Map


ZONE 6
ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 5
ZONE 7
N
5
520
Lake Washington

Appendix B – Panel Member Resumes

Robert Otto Rasmussen, PhD, PE (TX) (panel facilitator)

The Transtec Group, Inc.

Dr. Rasmussen is recognized internationally for his exceptional technical abilities in all aspects of pavements from materials to design to construction. He holds a B.S. in Civil Engineering from the University of Arizona, and a M.S.E. and Ph.D. from the University of Texas at Austin. With previous employment by the Arizona Department of Transportation and Western Technologies Laboratories, he currently serves as Vice President and Chief Engineer of The Transtec Group, Inc., a pavement and materials engineering firm headquartered in Austin, Texas. Dr. Rasmussen has served as a Principal Investigator and Program Manager on numerous national level research projects, and has overseen over $20 million of research, largely funded by the FHWA and various State DOTs. The most notable include the FHWA HIPERPAV system, FHWA ProVAL Profile Analyzer software, the FHWA Pavement Surface Characteristics IDIQ program, the ISU-FHWA Concrete Pavements Surface Characteristics Program, and various elements of Quiet Pavement Research in the States of Colorado, Missouri, Kansas, and Virginia. Dr. Rasmussen is a registered professional engineer in the State of Texas.

Dr. Rasmussen is currently supervising the development and delivery of what will be over 40 tire-pavement noise workshops for the FHWA, as well as having recently overseen the delivery of pavement smoothness workshops for the FHWA in New York, Iowa, and New Jersey. He is a primary author of “Characterizing the Splash and Spray Potential of Pavements”, and has co-authored an “Innovative Texture Methods” white paper for the FHWA. Dr. Rasmussen also recently co-authored the FHWA “Little Book of Quieter Pavements”.

Dr. Rasmussen has conducted hundreds of presentations, workshops, and instructional courses worldwide. He is frequently invited to speak at industry conferences because of his energetic delivery style, as well as his ability to communicate complex engineering concepts in a simple and entertaining manner. Recognizing this, he recently received an international award from the World Road Congress. Furthermore, Dr. Rasmussen has authored dozens of peer-reviewed papers, and is an active member on numerous editorial boards, expert task groups, and industry groups including TRB, AAPT, ASCE, ACPA, RILEM, SAE, ASA, and INCE.

Dr. Paul Donavan

Illingworth & Rodkin, Inc.

An acoustician by training, Dr. Donavan has concentrated his career on various aspects of noise and vibration measurement, analysis, and control. He is nationally and internationally recognized for his expertise in tire/pavement noise and general motor vehicle noise. Dr. Donavan has contributed significantly to quiet pavement research efforts for the States of California and Arizona. He pioneered the use of on-board sound intensity for tire/pavement noise measurement for application within state transportation agencies and recently completed a research project (NCHRP 1-44) on this topic for the National Cooperative Highway Research Program. Some of his recent major projects for

Caltrans have included the assessment quieter pavement options for at-grade, bridge deck, and elevated structure surfaces, localization of truck noise sources using acoustic beam forming, and the experimental evaluation of quieter pavements in Europe. He has been extensively involved in the ADOT Quiet Pavement Pilot Program as well as other pavement noise evaluation projects for the State of Arizona. Dr. Donavan also has considerable background in environmental acoustics, aerodynamic noise generation, sound propagation, structure-borne noise analysis, instrumentation development as well as vehicle interior and exterior noise control.

While at General Motors, Dr. Donavan developed the application of sound intensity to tire noise measurement and experimentally investigated tire noise mechanisms. He also demonstrated the relationship between exterior tire sound intensity and vehicle interior and passby noise, developed methods of noise specification for tire suppliers to GM, and isolated the effects of quiet ISO test pavements from tire noise generation. Prior to this, Dr. Donavan worked on noise projects for the US National Bureau of Standards and at Wyle Laboratories under contracts with the US Environmental Protection Agency.

Dr. Donavan has written and given more than 40 papers at national and international noise conferences, contributed to five ANSI, AASHTO, and SAE standards, and twice co-authored chapters in the Handbook of Noise and Vibration Control. He is currently a co-instructor of the FHWA sponsored Tire/Pavement Noise 101 course and has also given short courses/seminars on a variety of other noise and vibration topics.

Gary Fromm, PE (AZ,CA)

Jacobs

After graduating from the University of Arizona, Mr. Fromm moved to California and worked for Caltrans in the Stockton District office. He gained experience in a broad range of disciplines including planning, design, construction services, survey, and materials testing. His experience ranged from rural mountainous highways to urban freeways. Mr. Fromm served as project manger on several projects in addition to being the corridor manager on three highways. After 11 years with Caltrans, he moved back to Arizona and joined Carter & Burgess. He started as the operations manger for the Transportation Group and has worked for several municipalities as well as counties and the Arizona Department of Transportation (ADOT). Carter & Burgess was recently acquired by Jacobs Engineering and Mr. Fromm is a Manager of Projects and supervises staff that ranges in discipline from Highway Design, Land Development, Transit, and Federal Programs.

While working with ADOT, Mr. Fromm was involved with the Quiet Pavement Program, a Federal Pilot Program to evaluate rubberize asphalt as noise mitigation. He worked closely with ADOT to develop design standards and specifications for the placement of AR-ACFC on the regional freeway system. Mr. Fromm was the Design Manager for 3 out of the 5 original projects ADOT programmed to place AR-ACFC on the regional freeway system. This program had such an overwhelming positive response with the public that ADOT decided to pave the remaining segments of the freeway system. He worked closely with ADOT to develop the Quiet Pavement Phase II Program and was the

Design Manager for another three segments. Mr. Fromm is currently managing the noise monitoring contract that has taken noise measurements before the improvements and additional measurements after the improvements. These readings will be used to evaluate the sustainability of noise reduction on an AR-ACFC surface. If the noise reduction is sustainable FHWA may consider this a viable noise mitigation measure.

Rob Greene, INCE Bd. Cert.

Parsons Brinckerhoff

Mr. Greene is Vice President, and Manager of PB's Acoustics-Vibration and Air Quality Practices. Previously, he served as Principal Scientist and Technical Lead of the URS Corporation Acoustics and Vibration Group. Mr. Greene is the responsible professional for managing noise/vibration and air quality investigations and impact assessments for major public and private sector projects. He is a Board Certified Noise Control Engineer (#84004, exp. 2012) with 30 years of experience in acoustics/vibration, environmental noise analysis, and instrumentation/measurement systems. Mr. Greene holds a Bachelor of Science degree in Environmental Science, is certified by the National Transit Institute (at Rutgers University) in Transit Noise and Vibration Impact Assessment and by Caltrans in traffic noise assessment. He is a licensed Acoustical Consultant by the County of Orange (200516, exp. 2010). Mr. Greene is a Member of the National Academy of Science Transportation Research Board's Transportation Related Noise and Vibration Committee ADC40.

Dr. Steve Muench, P.E. (WA)

University of Washington, Civil & Environmental Engineering

Dr. Muench has been involved with roadway design and construction both professionally and academically for over 10 years. He has professional experience in roadway design, academic experience in transportation infrastructure and both professional and academic experience in web-based learning delivery systems.

Before becoming a professor, Dr. Muench served as a design engineer for two years at Perteet, Inc. (a transportation engineering consultant based in Everett, WA), where he designed a number of roadway improvement projects. Dr. Muench is a registered professional engineer in the State of Washington based on this experience. Academically, Dr. Muench has built on this expertise by leading a number of studies chiefly concentrating on pavement design, construction, rehabilitation, and management. Dr. Muench's recent work considers sustainability as a key decision component. Dr. Muench teaches six different classes in the construction and transportation engineering fields and has been integral to the development seven different online learning tools, the latest of which, Pavement Interactive, is an online wiki for the pavement community (http://pavementinteractive.org). Dr. Muench is also co-founder of an online training company specializing in training for the hot mix asphalt industry. The company, Pavia Systems (www.paviasystems.com) is based largely on his research along with that of Professor Joe Mahoney and Research Engineer George White. Pavia Systems has produced online training and other products for clients such as the Washington State Department of Transportation (WSDOT), the California Department of Transportation (Caltrans), Lakeside Industries (pavement contractor), Roadtec (equipment manufacturer) and American Infrastructure (infrastructure contractor). Dr. Muench routinely serves as the transportation and construction subject-matter expert for training development.

Dr. Muench has won three national awards in relation to his work at the University of Washington. First, The WSDOT Pavement Guide Interactive (http://training.ce.washington.edu/wsdot) was one of only two nationwide recipients of the National Engineering Education Delivery System (NEEDS) 2003 Premier Award. This award recognizes high-quality, non-commercial courseware designed to enhance engineering education (more information at: http://www.needs.org). Second, Dr. Muench, along with co-instructor Joe Mahoney won the 2003 R1edu award for online education. Third Dr. Muench (along with co-author Joe Mahoney) won the 2004 K.B. Woods Award given by the Transportation Research Board for the best paper in the area of design and construction for his paper, A Computer-Based Multimedia Pavement Training Tool for Self-Directed Learning., Dr. Muench is also a member of TRB committee AFH60 (Flexible Pavement Construction and Rehabilitation) and has organized invited sessions on sustainable roadway practices and materials in each of the last two years.

Mike Oliver, P.Eng

British Columbia Ministry of Transportation & Infrastructure

Mr. Oliver graduated from the University of British Columbia with a degree in Geotechnical Engineering in 1973. After working in mining and exploration in British Columbia and overseas for two years, and after working in small towns and villages all over the world, he joined the Provincial agency of the British Columbia Ministry of Transportation.

From 1975 to 1990, Mr. Oliver held several jobs within the Ministry including gravel prospecting, gravel management, materials selection, geological hazards identification, and mapping for property development and materials quality management. He became a Regional Geotechnical Engineer in 1990 and was responsible for the geotechnical engineering of many projects including slope stability, foundation engineering for walls, bridges, and pavements. In 1995, Mr. Oliver became Chief, Geotechnical, Materials, and Pavement Engineer for the Ministry. In this time, he brought forward technical improvements in business practices including the use of end product specifications, enhanced bonus penalties, open graded friction course, Superpave, and asphalt rubber. Mr. Oliver has also been involved in the implementation of design build, design build finance operate, alliance, and other methods of project procurement for the Ministry. The British Columbia paving rehabilitation program, during his tenure as Chief, has had budgets of 200 million CAD per year and I have set technical direction for paving of over 20,000 lane-kilometers of inventory. Mr. Oliver has authored many papers including the use of open graded friction course pavements in BC. He is on the OECD committee for long-life pavements, and chairs the C-LTPP committee the BC Roadbuilders/Agency paving committee.

Dr. Judy Rochat

U.S. Department of Transportation / Volpe Center

Dr. Rochat is a physical scientist in the Acoustics Facility at the U.S. Department of Transportation / Research and Innovative Technology Administration / John A. Volpe National Transportation Systems Center (Volpe Center). She is the project leader for all highway noise projects at the Volpe Center, where projects involve developing prediction models, designing and executing noise measurement programs and related data analysis, and providing technical guidance to members of the highway noise community. For FHWA, her work supports the Traffic Noise Model (TNM), including software development, field measurements and analysis for software validation, and TNM technical support. Also for FHWA, she produced an instructional video on acoustics and highway noise, managed the development of a new highway construction noise manual and model (Roadway Construction Noise Model, RCNM), and provides technical guidance for policy changes.

Dr. Rochat is involved in numerous tire/pavement noise studies, addressing measurement, prediction, and policy issues; examples include projects for Arizona DOT and Caltrans, where both involve measurements and analysis to evaluate quieter pavement as a noise abatement tool. In addition, she serves as a panel member for NCHRP projects and for the US Tire/Pavement Noise Expert Task Group. She received a B.A. in Applied Mathematics from the University of California, San Diego in 1990; an M.S in Acoustics from the Pennsylvania State University in 1994; and a Ph.D. in Acoustics from the Pennsylvania State University in 1998. She is a member of the Institute of Noise Control Engineering – USA, where she serves on the technical advisory board; the Acoustical Society of America; the American Institute of Aeronautics and Astronautics; and the Transportation-Related Noise and Vibration Committee (ADC40) of the Transportation Research Board, where she serves as the chair. Dr. Rochat has published in several technical journals and conference proceedings, and she authored the Transportation Noise Issues chapter of the 2004 McGraw-Hill Handbook of Transportation Engineering.

Dr. Ulf Sandberg, INCE Bd. Cert.

Swedish National Road and Transport Research Institute

Dr. Sandberg is a Senior Research Scientist at the Swedish National Road and Transport Research Institute (VTI) and 2002-2008 an Adjunct Professor in Tire/Road Noise at Chalmers University of Technology. His main subject of experience and research is the tire/pavement interaction (noise, rolling resistance, skid resistance) but he has also worked with other aspects of traffic noise since 1974 when he was enrolled by VTI. Dr Sandberg has worked with quiet pavements since 1976; in recent years mostly in international projects. A special problem addressed in Sweden, and common to Seattle, is the durability of quiet pavements under the wear of studded tires. Regarding publications, for example, Dr Sandberg is the first author of the 640-page Tyre/Road Noise Reference Book which is used extensively worldwide in courses and as a reference. He is currently finishing a very comprehensive international review of quiet pavement technology in urban areas for the Hong Kong Department of Environment.

Leonard Sielecki, M.Sc, MCIP, R.P.Bio

British Columbia Ministry of Transportation & Infrastructure

Mr. Sielecki is a registered professional biologist and a registered professional land use planner employed by the Engineering Branch of the British Columbia Ministry of Transportation and Infrastructure in Canada. Since 1996, he has been the Ministry's environmental issues expert. Leonard is also an external expert on the Highway 61 Project for the Ontario Ministry of Transportation in Canada and an external expert for the Chilla-Motichur Corridor Project in Rajaji National Park in the State of Uttarakhand in India. In 2005, the United States National Academies of Science appointed Leonard to the Transportation Research Board expert panel overseeing the ongoing National Cooperative Highway Research Program study on animal collisions in North America. Currently, he is completing a Ph.D. on transportation hazard risk assessment and mitigation at the University of Victoria. Leonard is a member of the American Planning Association, the American Association of Geographers, the Canadian Institute of Planners, and the Canadian Association of Road Safety Professionals.

John Stout, M.A.Econ

HDR Decision Economics

Mr. Stout is a Senior Economist with HDR|Decision Economics and possesses more than 12 years of experience in applied economics focusing on innovative economic modeling and analysis to support decision making for private and public-sector clients for major construction projects. His project experience has included cost-benefit and risk analysis, and economic feasibility studies for major highways, toll roads, passenger and freight rail, tunnels, bridge replacements, and transit implementation alternatives. Mr. Stout has led these studies for various clients such as several State Departments of Transportation and Transportation Authorities, California Metropolitan Water District, New York City Department of Environmental Protection, Federal Transit Administration and US Customs and Border Protection.

Clair Wakefield, M.A.Sc, P.Eng

Wakefield Acoustics, Ltd.

Since receiving his M.A.Sc. degree in Mechanical Engineering (Acoustics) from the University of British Columbia in 1973, Mr. Wakefield has gained 35 years of experience in acoustics and noise control engineering, both as a private sector consultant and as a government specialist. From 1973 to 1980, as an employee, and subsequently partner, of the Vancouver B.C. acoustical consulting firm of Harford Kennedy Wakefield Ltd., and its predecessor firm, Acoustical Engineering Ltd., he participated in and directed a wide range of projects in community/environmental noise impact assessment and control, industrial/occupational noise control, architectural acoustics and building noise and vibration control. From 1980 to 1988, Mr. Wakefield served as the B.C. Ministry of Transportation and Highways' first Sound Control Studies Engineer. There, as an in-house consultant/specialist, he developed highway noise impact assessment and mitigation policy and procedures and conducted many studies of the impacts of highway noise on adjacent sensitive land uses. In 1988, Mr. Wakefield formed Wakefield Acoustics Ltd. in Victoria, B.C. to provide a full range of consulting engineering services in acoustical design and noise and vibration impact assessment and control. The firm's primary focus has been the assessment and control of noise from highway and other major transportation/infrastructure projects. Recently such projects have included the Sea to Sky Highway Project connecting Vancouver to Whistler B.C (site of the 2010 Olympic Winter Games) as well as the Port Mann/Highway 1 and South Fraser Perimeter Road components of the B.C. Ministry of Transportation & Infrastructure's "Gateway Program."

Mr. Wakefield has been a Member of the Acoustical Society of America (ASA) since 1974 and is currently on the Board of Director's of the Canadian Acoustical Association (CAA).

Appendix C – Non Panel Participant List

Non-Expert Review Panel Participants

Julie Meredith, PE	*Program Director*
Larry Kyle, PE, SE	*Program Engineering Manager*
Erin Fletcher, PE	*Design Team*
Janet Buoy	*Design Team*
Dave Warner, PE	*West Side Design*
George Fies, PE	*East Side Design*
Michael Minor	*DEIS Noise Specialist*
Elizabeth Faulkner	*Communications*
John Chaney	*Communications*
Jeff Uhlmeyer, PE	*Materials*
Mia Waters	*Air Quality, Acoustics, and Energy*
Tim Sexton	*Air Quality, Acoustics, and Energy*
Archie Allen	*NWR Maintenance*
Penny Mabie	*Facilitator*
Robert Whirledge	*ERP Secretary*
Dan Rozycki	*ERP Report Editor*

The panel would like to acknowledge the SR 520 Program Delivery Expert Review Panel, and specifically Mr. Brent Felker, PE of HDR, who served as the facilitator. Components of that ERP report have been included herein.