DR. MICHAEL RILEY

POLLUTION CONTROL HEARINGS BOARD
FOR THE STATE OF WASHINGTON

AIRPORT COMMUNITIES COALITION, Appellant, v. STATE OF WASHINGTON DEPARTMENT OF ECOLOGY, and THE PORT OF SEATTLE, Respondents.	PCHB No. 01-160 **PREFILED TESTIMONY OF DR. MICHAEL RILEY** **AR 016606**

INDEX OF TESTIMONY

Page

ORIGINAL

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1191 SECOND AVE., SUITE 2200
SEATTLE, WA 98101
(206) 292-6300

1. I am a Civil Engineer with an undergraduate specialty in water resource engineering and graduate specialty in water quality hydrodynamics. I have worked as a consultant or in academia since 1980. I have assisted as an instructor for courses in urban hydrologic analysis, groundwater flow modeling and modeling of contaminant transport in groundwater. I have worked on numerous projects involving groundwater flow modeling and the transport of contaminants in groundwater, stormwater, lakes, rivers, and estuaries. A copy of my *curriculum vitae* is attached as Exhibit A.

SUMMARY OF TESTIMONY

2. I performed a modeling analysis of the fill criteria established in the 401 Certification to determine whether they are protective of water quality. I used conservative assumptions to run the model, including the assumption that all of the fill material used in the Third Runway embankment contained the maximum concentration of metals allowed by the numeric fill criteria in the 401 Certification. The model simulated how much of the soil constituents would leach out of the embankment over a span of 1,000 years. The model predicted that at no time in the 1,000 year period would discharges from the embankment exceed water quality criteria for neighboring creeks. Therefore, I conclude that the fill criteria in the 401 Certification are protective of water quality.

3. I also reviewed the low flow modeling performed by Pacific Groundwater Group. I concluded that both their approach and their results were reasonable. Dr. Patrick Lucia's criticisms of the low flow modeling work are either erroneous or irrelevant to the model outcome.

FILL CRITERIA

4. I am familiar with the Port of Seattle's plans to construct a Third Runway at Seattle-Tacoma International Airport, including the general design of the planned embankment. I am also familiar with Condition E of the 401 Certification issued to the Port for this project. Condition E includes numeric criteria for fill material that will be used to construct the embankment. These criteria apply to metals and to total petroleum hydrocarbons that could be present in potential fill sources.

5. If metals are in high concentration in soils and easily leached from the soils, then some metals could be transported to neighboring streams. Similarly, if petroleum mixtures are found in

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SEATTLE, WA 98101
(206) 292-6300

excessive amounts and consist of light, mobile compounds such as benzene, then some of these compounds could migrate to neighboring streams. If the metals or petroleum mixtures reach the surface water in high enough concentrations to adversely affect aquatic life, then the water quality would be affected. It is my understanding that the fill criteria in the 401 Certification were established to make sure that concentrations of these constituents in soil used for the Third Runway embankment were low enough so that water quality would not be affected.

6. The Port of Seattle asked S.S. Papadopulos & Associates to analyze whether the fill criteria in the 401 Certification could result in metals, petroleum compounds and other organic compounds reaching Miller or Walker Creeks in high enough concentrations to adversely affect water quality. I drafted a report describing the analysis undertaken and its results, entitled *Seattle-Tacoma International Airport Third Runway Embankment Fill Water Quality and Transport Analysis* (S.S. Papadopulos & Associates, Inc.) In our analysis, we focused on the concentration of metals and other compounds that could be expected in water discharging from the embankment. We considered this a conservative evaluation because we did not analyze how these concentrations would be reduced by mixing with shallow or regional groundwater, or how these concentrations would be attenuated as the groundwater migrated through soils between the embankment and the creeks.

Computer Model Used to Analyze Protectiveness of Fill Criteria.

7. Our analysis is based on a computer model of the embankment fill. The computer model considers infiltration of water through the embankment, leaching of compounds in the embankment by the infiltrating water and transport of those compounds through the embankment. For this analysis, we used the U.S. Geological Survey model code VS2DT. The code is specifically designed to simulate the movement of water and dissolved compounds through partially saturated soils such as in the embankment fill.

8. Many models are available to compute flow through saturated soils such as in aquifers. Soil is considered saturated only when the pore spaces are completely filled with water. That is, the soil is 100 percent saturated. If the soil moisture decreases by even one percent, the soil is considered unsaturated or partially saturated. That is, the saturation is at some level below 100 percent

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(206) 292-6300

saturation. A program code that can model changes in saturated conditions from near zero saturation to fully saturated conditions is known as a variably saturated flow model code.

9. VS2DT uses the standard equations for groundwater flow under either saturated or unsaturated conditions to predict the movement of water in soil. The movement of dissolved substances in the water is then simulated based on the movement of water and the interaction of the dissolved substance with the soil that the water is passing through.

10. We selected the VS2DT code for a number of reasons. First, VS2DT is a public domain code developed and supported by the U.S. Geological Survey (Survey). It has been through extensive review by the Survey and has been available for more than 10 years. Therefore, we have a high level of confidence that the code works properly. Second, we are familiar with the code and therefore could easily implement it. Third, the code includes all the aspects of groundwater flow that are significant to the embankment fill analysis we were performing. Specifically, the code simulates water movement through both saturated and unsaturated soils, the leaching of compounds from soils, and the movement of those compounds as dissolved substances in the water moving through the soil.

11. The first step in developing a model is to decide the physical setting that will be modeled. For our analysis, we took a cross section from design drawings as a representative slice through the embankment. Next, we overlaid a grid on the cross section. The grid is a series of rectangles that covers the cross section. Each square is assigned parameter values needed by the code to simulate the movement of water and transport of dissolved substances in the cross section.

12. In the following paragraphs, I describe the parameter values that we assigned to run the model, and how we selected them.

Flow Parameters Used in Model.

13. The water movement or flow parameters include hydraulic conductivity, soil moisture relationships for unsaturated flow, porosity and initial soil moisture. Hydraulic conductivity and the soil moisture relationships are the most important flow parameters. Hydraulic conductivity is a measure of the resistance of the soil to groundwater movement. A high value means groundwater moves relatively easily through the soil. The soil moisture relationships are used to describe how

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hydraulic conductivity changes if the soil becomes unsaturated. Typically, the hydraulic conductivity decreases dramatically as soil moisture decreases. This means there is more resistance to flow and the infiltrating water will move very slowly.

14. We estimated initial soil moisture based on the range of saturation expected in fill soils considering the soil moisture specifications issued by the Port and the exposure of the soils to precipitation during stockpiling, transport, and construction. The initial soil moisture is important in short-term simulations. In short-term simulations, if the soil moisture is too low, then all infiltrating water will simply increase the soil moisture content, with very little outflow predicted. Similarly, if the soil moisture is too high, infiltrating water will result in an immediate outflow. In effect, the results from the short-term simulation may be entirely determined by the initial conditions. In long-term simulations, the soil reaches an equilibrium soil moisture condition and then the outflow becomes less affected by the initial conditions. In our analysis, we predicted flow and transport over a period of a thousand years. Therefore, any error in the estimated initial soil moisture would only change outflow predictions by a year or two over a period of a thousand years. Consequently, the initial soil moisture is not a critical parameter for purposes of this model.

15. We developed flow parameters such as hydraulic conductivity and the soil moisture relationships from a review of the soil specifications for embankment fill material provided by the Port, and from literature values for different types of soils.

Transport Parameters Used in Model.

16. Transport parameters include dispersion coefficients, soil density, and the relationship between concentration of a substance in soil and the associated concentration in water. Of the transport parameters, the most significant is the relationship between the concentration of a substance in soil and the associated concentration in water. This is also called the partitioning relationship, or partitioning coefficient. Since the fill criteria specify the allowable concentrations of various constituents in the soil, the partitioning coefficient is used to predict the concentrations of those constituents that will disassociate from the soil and mix with the water infiltrating through the embankment fill material.

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(206) 292-6300

17. Basically, some of the metals in soil have to dissolve into the infiltrating water. For natural, uncontaminated soils, this means that a part of the soil must be dissolved by the infiltrating water in order to release the metals into solution. This disassociation and mixing is a naturally-occurring process that takes place whether constituents in soil are there naturally or as a result of human-caused contamination.

18. However, naturally occurring soils and soils with human-caused contamination may act quite differently. Contaminants are introduced to the soil, and therefore are on the outside of the soil particles or are trapped between soil particles. Consequently, infiltrating water is in direct contact with the contaminants. In naturally occurring soils, the metals are bound up as part of the soil. For instance, the soil may include some particles that include a mineral containing some arsenic. The infiltrating water may not be in direct contact with the arsenic, or even with the mineral that contains the arsenic. In order for the arsenic to be released into solution, the infiltrating water must be in direct contact with the mineral and must dissolve part of that mineral. Therefore, it is logical to expect that lower concentrations would be leached from naturally occurring soils than from soils contaminated by human activity.

19. We estimated dispersion parameters from literature values. Dispersion controls how fast a dissolved substance spreads out over time. Since long-term simulations were conducted, changes in dispersion values over reasonable ranges would not affect the model results. Consequently, this is not a significant parameter in this modeling analysis.

20. Soil density and the relationship between concentration of a substance in soil and the associated concentration in water were based on laboratory analysis of different soils used in the embankment fill. Initial concentration values were developed from a combination of laboratory analysis and the fill criteria specified in the 401 Certification.

21. The other important transport parameter used in the model is the initial concentration of the constituent being studied. We made very conservative assumptions concerning the concentration of metals and other compounds in soils in order to set the initial concentration in the model. For metals, we assumed that the fill material used in the embankment would be at the

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SEATTLE, WA 98101
(206) 292-6300

concentrations set in the 401 Certification. In other words, we assumed that all of this fill material would contain the maximum concentration of each constituent allowed by the numeric fill criteria in the 401 Certification. This is a conservative assumption because the actual concentrations of these constituents in much of the fill used in the embankment is lower than the maximum concentration allowed under the 401 Certification. For the drainage layer and the drainage layer cover, we used the results from soil testing of fill material the Port plans to use in these locations to set these initial concentrations.

22. After we selected the flow and transport parameters discussed above and assigned the grid values, we then specified the rate at which water would infiltrate through the top of the cross section. The infiltration rate was taken from the average infiltration rate predicted by Aqua Terra and Parametrix in their stormwater analysis. We used this average annual infiltration rate in the model because we were doing long-term predictions of one thousand years. Therefore, short-term precipitation and infiltration events over short periods such as daily, weekly, or monthly would not significantly affect the results over a period of a thousand years. Finally, we ran the model.

Modeling of Historic Fill Sources.

23. Because ACC has raised concerns that some of the fill material accepted for use in the embankment prior to issuance of the 401 Certification might contain elevated levels of TPH and other compounds, we decided to run two other simulations to determine whether these historic fill sources could pose a threat to water quality. We worked with the Port and its fill contractor to identify the volume of material accepted from each historic fill source, the location where the fill material has been placed in the embankment, and the results of laboratory analyses on the fill material. We then used the VS2DT model to perform separate simulations including those fill materials, given their location in the embankment, their thickness, and the concentration of compounds of concern in the fill material. We conservatively set the constituent concentration used in the model at the highest concentration observed from soil testing of those fill materials.

24. These two additional simulations looked at fill materials obtained from the First Avenue Bridge construction project and the Black River Quarry, and from the Hamm Creek habitat

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restoration project. The First Avenue Bridge and Black River Quarry materials were suspected of containing petroleum hydrocarbons. Petroleum hydrocarbons were not detected in First Avenue Bridge fill material actually used in the Third Runway embankment, but some detected levels were found in fill material that the Port rejected. The Black River Quarry material had some detectable levels of heavy oil petroleum hydrocarbons (TPH-O), but not detectable levels of the more mobile lighter compounds found in gasoline.

25. For purposes of this simulation, we assumed that all of the fill material accepted from these sites contained TPH-O at the highest concentration detected in any single sample from these sites. In actuality, many samples taken from these fill sources showed no detectable levels of petroleum hydrocarbons. Consequently, this was a very conservative assumption.

26. Some of the samples of the Hamm Creek fill material had detectable levels of organic compounds, including PCBs and DDT. To simulate the transport of these constituents through the embankment, we used the same assumption as for petroleum compounds. That is, we assumed that all of the fill accepted from Hamm Creek contained the highest concentration of organic compounds detected in any single sample from that source, even though other sampling results showed lower or non-detectable levels of the same compounds. Again, this is a very conservative assumption. We then obtained information about the volume of this material used in the embankment, its location and thickness, and used that to perform the simulation.

Results of Modeling.

27. The model predicted that very low concentrations of metals would infiltrate through the embankment. We compared the maximum concentration of metals expected to occur in discharge from the embankment over the 1000-year period modeled to applicable surface water criteria in WAC 173-201A. No criteria are available for some of the metals studied. For those metals, we compared the model results to concentrations considered protective of aquatic receptors. All of the metal concentrations modeled were well below the surface water criteria and the concentrations that are protective of aquatic receptors. The net result is that the concentration of metals from the embankment can reasonably be expected not to harm water quality in Miller or Walker Creeks.

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28. The simulation of the Hamm Creek fill material did not indicate any migration of PCBs or DDT (or related compounds) from the fill material. This is not surprising, as PCBs and DDT do not readily dissolve in water and are not easily transported by groundwater.

29. In the simulation of First Avenue Bridge and Black River Quarry fill, lighter petroleum compounds showed some tendency to migrate through the embankment. However, the model predicted that petroleum hydrocarbons would not discharge from the embankment in concentrations above levels that are protective of aquatic organisms. Heavier petroleum compounds showed little potential for migration to surface water.

Conservatism of Model Results.

30. Model results can be affected by the choice of parameters used in the model and by the way models are designed. In our analysis, we based the model parameters on either reasonable values for the embankment or data from fill material to be used in the embankment. The model was intentionally designed to be conservative. For example, the model only considered transport within the embankment and assumed that all of the infiltrating water would discharge at the toe of the fill. In actuality, it is expected that most infiltrating groundwater will seep into shallow, perched groundwater and the regional aquifer before reaching surface water. The mixing of infiltrating groundwater with shallow and regional groundwater, which would further reduce the concentration of metals, was not considered in our modeling analysis.

31. Our model also did not consider attenuation processes that will occur after metals discharge from the embankment. As the metals are transported though the shallow and regional groundwater, the concentration of metals will be further reduced by interaction between the metals and the soils in the shallow and regional aquifers. Organic compounds, such as petroleum compounds, decay from microbiological and chemical processes. The decay of organic compounds reduces their concentration with time. Decay processes were not considered in our modeling analysis, even though the model simulations were carried out for a long time period of 1000 years, during which time considerable decay would be expected.

AR 016614

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32. We also performed a sensitivity analysis to test how the model results would change if different input parameters were used. We did this by running a simulation after changing two of the most important input parameters: the soil-water partitioning coefficient, and the concentration of a constituent in fill material. To be conservative, we selected the constituent with the greatest potential to migrate, which is arsenic. We then assumed that the fill material in the embankment contained ten times the concentration of arsenic allowed by the 401 Certification. Finally, we substituted the lowest soil-water partitioning coefficient we found in any of the source data. Even with this greatly accentuated potential for migration, the simulation showed that arsenic concentrations would not exceed surface water criteria.

33. The results of the sensitivity analysis are not unexpected considering the results of laboratory analyses conducted by the Port. The drainage layer soils in particular showed a high capacity to adsorb metals and therefore buffer the effect of the artificially high concentrations of arsenic simulated in the fill material.

34. Based on this analysis, it is my opinion that the fill criteria in the 401 Certification are fully protective of water quality in Miller and Walker Creeks. In addition, the fill criteria are highly conservative considering that metals are not easily dissolved from the soils being used in the embankment. Even if the metals in these soils are above background concentrations, it is unlikely that the metals will dissolve into water infiltrating the embankment at concentrations above water quality criteria and even less likely that concentrations above water quality criteria will reach Miller or Walker Creeks.

LOW FLOW ANALYSIS

35. I also reviewed the embankment low flow analysis performed by Pacific Groundwater Group. Pacific Groundwater Group (PGG) conducted a modeling analysis to predict how quickly water infiltrating at the ground surface would reach groundwater. These results were then applied to the low flow analysis conducted by Aqua Terra and Parametrix. PGG and Aqua Terra/Parametrix analyses indicated that the embankment fill will dampen and lag groundwater flows, hold water in storage, and will contribute more water during low-flow periods than under present conditions. This

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is partly because more water will infiltrate the embankment, rather than running off during storm events. Infiltrating water will move slowly through the embankment and will either discharge from the embankment to groundwater or seep from the toe of the embankment. In either case, the water will reach area creeks more slowly and over a longer period of time than would occur under present rainfall-runoff processes.

36. PGG used two methodologies in their analysis. The first method considered vertical movement of water infiltrating from the surface of the embankment to the bottom of the embankment. The second method considered movement of infiltrating water in the soils and drainage layer beneath the embankment. The decision to separate analyses of vertical groundwater flow and horizontal groundwater flow is not unusual. This two-step process is especially appropriate when one process requires more computer time or more complex analysis than another process.

37. In PGG's analysis, the vertical movement of groundwater is very complicated since rainfall is intermittent, resulting in variable saturation levels in the embankment. The analysis of variably saturated flow requires considerable computer time and is typically simplified as a flow that moves only vertically downward. This saves computer time with little effect on model results since infiltrating rainwater moves principally downward. I therefore agree that PGG's decision to model flows through the embankment using a one-dimensional version of the groundwater model Hydrus was appropriate.

38. The second method used by PGG is a simpler process of saturated groundwater flow, such as in a groundwater aquifer. In this case, they used a spreadsheet model (Slice) to predict the amount of infiltrating water that reaches shallow groundwater or regional groundwater, or that discharges from the drainage layer to the ground surface. Although the spreadsheet PGG used was developed specifically for this project, in my opinion the results were reasonable.

RESPONSE TO DIRECT TESTIMONY OF DR. PATRICK LUCIA

39. I have read Dr. Patrick Lucia's prefiled direct testimony. His objections to the PGG modeling can be summarized as:

AR 016616

- use of the Hydrus and Slice models oversimplifies the effect of the embankment on the timing of groundwater flow to the creeks. Specifically, if a more complex modeling approach had been used, longer lag times would have been computed;
- the modeling did not account for an initial lag from the time when construction is completed until water first starts to discharge from the embankment;
- selection of parameters was not based on laboratory analysis of the fill material. Dr. Lucia specifically refers to the value for hydraulic conductivity, which was based on a grain-size analysis; and
- lack of a sensitivity analysis to show how results may change with a different set of parameters used in the model.

40. For the most part, Dr. Lucia's criticisms are either erroneous or irrelevant. For instance, the more complex analysis discussed by Dr. Lucia would result in longer lag times from the time of precipitation events until the infiltrating water discharges from the embankment. However, a longer lag time would probably result in a more regular or even flow of groundwater from the embankment. That is, the longer time would be more beneficial to base flow in the creek rather than detrimental. In this respect, the PGG analysis is more conservative than the approach recommended by Dr. Lucia.

41. Second, laboratory analyses are rarely used to compute hydraulic conductivity values in a modeling analysis. Even if such data are available, it is doubtful that the data would be meaningful considering the high fraction of gravel in the fill, which would interfere with normal laboratory methods. The hydraulic conductivity value used by PGG is relatively low and is more representative of a silty sand than a sand and gravel mixture. Therefore, the value used is reasonable because the hydraulic conductivity will be most strongly determined by the finest particles present in the soil.

42. Even though PGG did not conduct a sensitivity analysis, their selection of parameters is reasonable. A sensitivity analysis is sometimes a useful tool to show how model results may change if different parameter values are used. However, in the final analysis, the design of a

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1191 SECOND AVE., SUITE 2200
SEATTLE, WA 98101
(206) 292-6300

stormwater facility should be based on reasonable parameters and not on some sensitivity analysis or worst-case analysis, which would probably result in a grossly over-designed system.

43. The concern that PGG did not account for a lag time from the end of construction until groundwater begins to discharge from the embankment seems to be completely erroneous. Such a lag time would only be expected if dry fill material was used and was protected from any exposure to rainfall while being stockpiled or being placed in the embankment. In actuality, construction of the embankment will span a period of years. Fill material will not be dried prior to placement, and in fact is required to have some water content in order to be compacted in place. Therefore, water will infiltrate the fill throughout the construction process, and no significant lag after completion can reasonably be expected.

44. Dr. Lucia also raises a concern that the drainage layer is a significant pathway for the transport of hazardous substances. There appears to be a complete lack of understanding on Dr. Lucia's part as to how the drainage layer will function and affect water quality. Material being used in the drainage layer shows a very high capacity to adsorb metals that may be released from the embankment above. Because of the drainage layer cover overlying the drainage layer, fill material with higher numeric fill criteria (but still far below levels that would be considered "hazardous") are only in direct contact with the drainage layer hundreds of feet from the toe of the embankment slope. Therefore, the infiltrating water will have a long pathway to reach the toe of the embankment and discharge from the drainage layer. Metals in the water will be adsorbed by the drainage layer material resulting in lower concentrations discharging from the slope.

45. Dr. Lucia also has the impression that the drainage layer will carry a large volume of flow. The work conducted by PGG, which I verified, indicates that most of the water that infiltrates through the embankment (approximately 93%) will continue to percolate through the drainage layer into the natural soils under the drain. Only about seven percent of the infiltrating water is predicted to reach the toe of the embankment slope. Consequently, the drainage layer is neither a significant pathway nor a conduit for the transport of large amounts of water or metals from the embankment. Of the small amount of water that is expected to seep from the drainage layer, some of it will flow

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(206) 292-6300

overland and seep back into soils downslope from the embankment, some will be collected by the stormwater system and discharged under the Port's NPDES permitted stormwater discharge, and some portion will seep into adjacent wetlands. Considering the small amount of water expected to discharge from the drainage layer and low concentrations expected in water infiltrating through the drainage layer, it is unreasonable to assume that there will be significant water quality impacts from the drainage layer discharge.

46. Finally, Dr. Lucia raises a number of concerns about the protectiveness of the numeric fill criteria. He suggests that some of the criteria were not set at a sufficiently low PQL, that some of the criteria exceed natural background levels, and that the Port is not clearly required to meet more stringent criteria for certain portions of the embankment. However, Dr. Lucia has not presented any analysis to show that the numeric fill criteria will harm water quality, while the model I describe above shows that the criteria are very protective. His concerns about the fill criteria have no merit.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct.

DATED this 6th day of March, 2002 at Olympia, Washington.

Michael Riley

Michael Riley

BROWN REAVIS & MANNING PLLC
1191 Second Ave., Suite 2200
Seattle, WA 98101
(206) 292-6300

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S. S. PAPADOPULOS & ASSOCIATES, INC.
ENVIRONMENTAL & WATER-RESOURCE CONSULTANTS

MICHAEL RILEY

Water Resource Engineer

Education

PhD in Civil Engineering, 1988, University of Minnesota, Minneapolis.
BS in Civil Engineering, 1980, University of Minnesota, Minneapolis.
BA in History, 1977, Marquette University, Milwaukee, Wisconsin.
Specialized Training:

- Course work in hydrology, 1981-82, University of Maryland, College Park.
- EPA Training, 1991(Use of WASP4 water- and sediment-quality fate-and-transport model).
- Short Courses in Groundwater Modeling, 1991, 1994, 1996

Professional History

S.S. Papadopulos & Associates, Inc., Olympia Washington: Vice President, 1997 to present; Boulder, Colorado: Senior Water Resource Engineer/Hydrologist, 1994-1997.

Converse Consultants NW, Seattle, Washington: Associate Scientist/Engineer, 1993-1994.

S.S. Papadopulos & Associates, Bethesda, Maryland: Senior Water Resources Engineer/Hydrologist, 1992-1993.

Parametrix, Inc., Environmental Consulting and Engineering, Kirkland, Washington: Water Resources Engineer and Director of Water Resource Division, 1988-1992.

St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis, Minnesota, 1983-1988.

University of Maryland, Water Resources Research Assistant, College Park, Maryland, 1981-1983.

Greenhorne & O'Mara, Engineering and Environmental Consulting, Riverdale, Maryland. Water Resource Engineer, 1980-1981.

Summary of Qualifications

Dr. Riley has over 15 years of experience in investigating contaminant transport in groundwater, surface water, and sediments. His special interests are risk assessments and analysis of exposure pathways, identification of effective innovative technologies for remediation of groundwater, hydrology of coastal environments, groundwater/surface-water interactions, and remediation of contaminated sediments. He has applied numerical models related to groundwater hydrology (*MODFLOW*), surface-water hydrology *(HEC-1, SWMM, TR-20, HSPF*), hydraulics *(HEC-2, DYNFLOW)*, and contaminant transport in groundwater and surface water *(SUTRA, MT3D, WASP4)* for numerous site investigations located throughout the United States. In addition, Dr. Riley has developed computer programs to address lake and reservoir dynamics, density stratified flow, sedimentation, and oil-spill impacts to coastal environs. Dr. Riley is Office Manager of the Olympia, Washington office

Awards & Honors

Sommerfeld Fellowship, University of Minnesota

Representative Project Experience

S.S. Papadopulos & Associates, Inc., Environmental & Water-Resource Consultants, Olympia, Washington.

Dr. Riley conducts data analysis; identifies remedial alternatives and feasibility studies for groundwater, soil and sediment contamination, and applies and develops numerical models and computer programs for these investigations. Examples of project work include:

- **Kalama Chemical, Kalama, Washington.** Served as project manager for remediation of this chemical manufacturing facility. Assisted in negotiations for termination of a RCRA order under EPA and implementation of a MTCA order under the Washington Department of Ecology. Provided oversight to other contractors including: development of the MTCA RI Work Plan and implementation of the plan, development of revised monitoring program for the site, implementation and interpretation of studies of the effect of tides and river stage on groundwater flow dynamics, and preparation of annual reports for Interim Corrective Measures in operation on the site.
- **Seattle-Tacoma International Airport Groundwater Model Study, Seattle, Washington:** Prepared a groundwater model of the airport and surrounding areas to predict the potential for contaminants in selected areas of the airport to migrate to off-site water users. A model area of approximately 60 sq. mi. includes five aquifers and two surface water basins. HSPF modeling of the basins provided estimates of recharge to the groundwater system and groundwater discharge to creeks, springs, and seeps was used as base flow additions in the surface water models. Based on model results, a groundwater monitoring network will be developed to verify model results and to measure concentrations in groundwater along the migration pathways.
- **McCormick & Baxter Site, Portland, Oregon**: Assisted the Oregon Department of Ecology in evaluating groundwater flow, dissolved-phase contaminant transport, and non-aqueous-phase contaminant transport from upland areas to the Willamette River. The long-term study objectives are to evaluate upland remedial actions that would be protective of surface water and sediments.
- **East Multnomah Groundwater and Database Project, Portland, Oregon:** Served as Project Manager for this model study that included a regional-scale model and a smaller detail model of the area of a TCE groundwater plume. The detail model, which was the main focus of the study, was used initially to identify parties potentially responsible for the TCE contamination. The model was later used to develop remedial action plans for two sites and to address questions of potential migration of contaminants to a down-gradient municipal well field.
- **Hytek Site, Kent, Washington:** Conducted an annual review of the performance of a groundwater containment system at this RCRA site. A MODFLOW groundwater model was developed by SSP&A for the site. The model is applied annually to existing water level data and meteorological conditions. The model is used to evaluate the effectiveness of the containment system in capturing contaminated groundwater and to set pumping rates for the coming year. The model was also used with the MT3D transport model to simulate concentrations at selected wells and concentrations from the extraction wells as a means of further evaluating the actual and expected response of the system.

Representative Project Experience
– continued

- **Tarpits Superfund Site, Tacoma, Washington:** Provided technical assistance in support of litigation at this former manufactured gas plant site. Technical support included data review of groundwater chemistry and water levels, analysis of surface-water flows, and evaluation of the hydrogeology of the site.
- **Harbor Avenue Pump Station, Seattle, Washington:** Provided senior overview for this groundwater model study of a construction site located across Harbor Avenue from a landfill. The model was used to simulate groundwater flow and to design a slurry wall between the landfill and the construction site that would prevent the migration of landfill leachate to the construction site.
- **Pasco Bulk Fuel Terminal, Pasco, Washington:** Provided oversight and technical direction on this investigation of a bulk fuel terminal on the Columbia River. The investigation included groundwater and surface-water monitoring at a down-gradient drainage channel and pond, and sediment sampling in the Columbia River. Provided an extensive review of the Phase I report and development of the Phase II scope of work. Negotiated changes in the long-term monitoring plan that allowed for reduced sampling over time.
- **Pacific Sound Resources Superfund Site, Seattle, Washington:** Provided technical oversight and data analysis on this near-shore former wood treatment site. Assisted with design and data analysis of two tidal studies to determine changes in groundwater flow patterns over the tidal cycle and the net gradients and flow directions from the site. Assisted in the design of a slurry containment wall between the main process areas and the shoreline. Analyzed tidal effects on the slurry wall and the effect of the slurry wall in reducing tidally-induced groundwater level fluctuations behind the slurry wall.
- **Heleva Superfund Site, Whitehall Township, Pennsylvania:** Conducted groundwater model studies to support the design of remedial actions at the site. The MODFLOW model was used to design a groundwater containment system and allowed optimization of the extraction system from a network of five wells operating at a total rate of 900 gpm to three wells operating at a total rate of 450 gpm. The model was calibrated to steady-state flow rates and to three large-scale, multi-day pump tests. The model was used in conjunction with the MT3D transport code to estimate the contaminant concentration in the pump effluent for design of a groundwater treatment system.
- **ReSolve Chemicals Superfund Site, North Dartmouth, Massachusetts**: Assisted in the evaluation of alternative extraction well placement in response to EPA comments on a 35% design report. A groundwater model was developed for the design process to test alternate locations of extraction wells requested by EPA and to test location changes necessitated by easements and utilities. The model allowed optimization of well locations and capture of contaminated groundwater while holding pumping rates to a minimum design level.
- **American Barrel Yard Site, Salt Lake City, Utah:** For this site of previous creosote and manufactured gas plant operations, provided litigation support on the extent of contamination, the type of contamination associated with different operations, the history of different operations, and the fate of contaminants generated at different times and under different operations on the site.

Representative Project Experience
– continued

- **Jordan East Site, Salt Lake City, Utah:** For this former coal tar manufacturing facility where roofing pitch, creosote, and coal tar products were produced, provided litigation support on the potential migration of complex organics from coal tar wastes to groundwater and timing of waste disposal relative to the magnitude and extent of contaminant migration in groundwater.

Sediment/Groundwater/Surface-water Investigations

- **Thea Foss/Tacoma Coal Gas Site Groundwater Model, Tacoma, Washington:** Conducted a groundwater model study of a former manufactured gas facility located on the shore of Thea Foss Waterway. The project objectives were to quantify contaminant loading to the waterway and, following remedial actions, to predict the potential for re-contamination of sediments from continuing sources of contaminants. The groundwater model incorporated the effect of tides, aquifer compression, and saline boundary conditions on groundwater flow.
- **Southwest Harbor Project Soil Remediation Analysis, Seattle, Washington:** Assisted in the development of a strategy to determine site-specific soil concentrations suitable for on-site disposal. The study involved designation of site groundwater as non-potable, analysis of tides to identify groundwater flow pathways and exposure routes, chemical sampling of surface water and groundwater, and development of a conceptual model of groundwater/surface-water interaction. From the conceptual model, a multi-step partitioning and mixing model was developed to identify soil concentrations suitable for on-site disposal. The modeling effort involved surface water criteria, allowable changes up the groundwater flow path taking into account a surface-water mixing zone, tidal mixing in a discharge line, infiltration under different post-development caps, mixing of infiltrate with ambient groundwater flow, and soil/groundwater partitioning of contaminants. This modeling analysis resulted in over 90% of contaminated soils remaining onsite.
- **Port Quendall Terminal, Renton, Washington:** Performed a model analysis of groundwater flow and contaminant transport from a former wood treatment site on Lake Washington. The purpose was to predict allowable concentrations in groundwater that would be protective of surface water, estimate the potential for groundwater flux to re-contaminate near-shore remediated sediments, and evaluate remedial actions for protecting surface water and near-shore sediments.
- **Salmon-Rearing Netpen Studies, Puget Sound, Washington:** Conducted model studies on a series of proposed salmon netpens. One of the issues involved possible nutrient enrichment of sediments due to settlement of feces and uningested food. A discrete particle settling model was developed to simulate the movement of suspended particles representing feces and fish food. The model operated with tidal current measurements to predict an area of impact from the salmon net pen based on mass loading to the sediments.

Representative Project Experience *– continued*

- **Southwest Harbor Project, Lockheed Site, Seattle, Washington:** Part of a team investigating contaminant movement from proposed contaminated sediment disposal sites to Elliott Bay. Investigation included installation of upland and offshore wells, groundwater sampling, tidal studies, and sediment pore-water flux studies. Primarily responsible for implementation of a contaminant transport model that used the results of the field investigations. This model was used to evaluate the potential for migration of contaminants from the proposed disposal alternatives, estimate the concentrations of selected compounds in groundwater reaching Elliott Bay (for use in a risk assessment of different alternatives), and make recommendations on design of the contaminated fill and containment cap to minimize contaminant migration.
- **Lake Union Capping Feasibility Study, Seattle, Washington:** Conducted sediment investigation and groundwater model analysis to evaluate the feasibility of sediment remediation along Gas Works Park on Lake Union. Samples of sediment core were analyzed for chemistry and sediment pore-water to develop sediment-to-groundwater exchange rates. The purpose of this groundwater model study of upland groundwater and contaminant transport was to estimate the potential for sediment contamination due to movement of contaminated groundwater through off-shore sediments.
- **University Regulator CSO Control Project, Seattle, Washington**: Served as Project Manager to evaluate the sediment and water-quality impacts of a stormwater diversion and combined sewer overflow. Near-field and far-field models were developed. The near-field model was used to design the outfall structure and evaluate the mixing zone close to the outfall. The far-field model was used to predict concentrations in the effluent plume away from the outfall. The models were used to compare differences in concentration of conservative and non-conservative constituents. The non-conservative constituents, represented by particles with a decay rate related to the settling velocity, allowed a prediction of settling areas for different size particles and identification of areas of potential sediment contamination from the CSO effluent.

Previous Experience

Converse Consultants NW, Seattle, Washington.

Worked on projects related to site cleanup under CERCLA and the Washington State Model Toxics Control Act. Site investigations focused on groundwater contamination and soil and surface-water contamination for development of consistent cleanup levels for each media. Actively involved in negotiations with EPA and the Washington Department of Ecology on cleanup levels for soils and groundwater. Worked on developing cleanup criteria, risk assessments, and remedies consistent with redevelopment of sites. Assisted in development of presumptive remedies, early actions, and Engineering Evaluation/Cost Analysis (EECA) under the Superfund Accelerated Cleanup Model.

Parametrix, Inc., Environmental Consulting and Engineering, Kirkland, Washington.

Worked on numerous projects including: (1) environmental impact studies involving water-quality assessments of oil-spill impacts from U.S. Navy base operations, dispersions and tidal flushing analysis of outfalls from wastewater treatment plants, and circulation impacts from shoreline development; (2) remedial investigations and feasibility studies at pulp and paper plants, mining and smelter

Previous Experience
– continued

operations, and municipal outfalls; (3) NPDES permitting investigations for both outfall and stormwater that included hydrologic analysis, identification of runoff paths, and evaluation of the water quality of the storm runoff; and (4) sediment cleanup in the Pacific Northwest.

St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis.

Provided support on research projects that included development of dynamic flow-nutrient-biological interaction models for prediction of lake eutrophication and the effect of treatment strategies on density stratified plumes in lakes and rivers, and the effect of barge traffic on mixing dynamics in rivers.

Greenhorne & O'Mara, Engineering and Environmental Consulting, Riverdale, Maryland.

Performed and reviewed flood studies for the FEMA flood insurance program. Project experience included review and implementation of hydrology programs (SWMM, HEC-1, TR-20) and hydraulic programs (HEC-2) to identify and delineate floodplain boundaries.

Professional Societies

American Geophysical Union
National Ground Water Association
Geological Society of America

PUBLICATIONS

Riley, M. and C.J. Neville, 2001, **Natural Attenuation in Tidal Zones.** National Ground Water Association Northwest Focus Conference, February 2001. (Accepted)

Ford, B. and M. Riley, 1998, **A Practical Application of MODFLOW and UCODE (Universal Inverse Code) for Design of a Recovery Well System and Evaluation Well System Performance.** *Proceedings of the MODFLOW >98 Conference*, October 1998, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado.

Neville, C.J., M. Riley, and C. Zheng, 1998, **Implicit Modeling of Low-Permeability Features: An Appraisal for Solute Transport.** *Proceedings of the MODFLOW >98 Conference*, October 1998, International Ground Water Modeling Center, Colorado School of Mines, Golden, Colorado

Pascoe, G.A., M.J. Riley, T.A. Floyd, C.L. Gould, 1998, **Use of a Risk-Based Hydrogeologic Model to Set Remedial Goals for PCBs, PAHs, and TPH in Soils during Redevelopment of an Industrial Site.** *Environmental Science and Toxicology*, v. 32, no. 6, pp. 813-820.

Riley, M., G. Biswas, C. Boatman, M. Utting, R. Brockhaus, and D. Hotchkiss, 1994, **Groundwater Model Simulation of Chemical Transport from a Nearshore Confined Sediment Disposal Facility.** *In:* Dredging '94, Prodeedings of the Second International Conference on Dredging and Dredge Material Placement, 1994. E.C. McNair, Jr., (ed.). American Society of Civil Engineers, New York, New York.

Riley, M.J., and H.G. Stefan, 1988, **Development of the Minnesota Lake Water Quality Management Model. MINLAKE.** *Lake and Reservoir Management*, North American Lake Management Society, v. 4, no. 2, pp. 73-83.

Riley, M.J., and H.G. Stefan, 1988, **MINLAKE: A Lake Water Quality Simulation Model.** *Ecological Modeling*, v. 43, no. 3/4, pp. 155-182.

Hanson, M., M. Riley, and H. Stefan, 1987, **An Introduction to Mathematical Modeling of Lake Processes for Management Decisions.** Project Report 249, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis.

Riley, M.J., and H.G. Stefan, 1987, **Dynamic Lake Water Quality Simulation Model MINLAKE.** Project Report 263, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis.

Stefan, H.G., and M.J. Riley, 1985, **Mixing of a Stratified River by Barge Tows.** *Water Resources Research*, v. 21, no. 8.

Stefan, H., G. Farrell, M. Riley, K. Lindquist, and G. Horsch, 1984, **Mixing of the Seneca and Blue Lake Waste Water Treatment Plant Effluents with the Minnesota River.** Project Report 277, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis.

Stefan, H., M. Riley, G. Farrell, and Y. Chen, 1984, **Near-field Water Quality of the Metro WWTP Effluent Mixing Zone in the Mississippi River Under Summer Conditions.** Project Report 231, St. Anthony Falls Hydraulic Laboratory, University of Minnesota, Minneapolis.

PRESENTATIONS

Riley, M., G. Bennett, and W.Guo, 1998, **Comparison of MODFLOW/SEAWAT to Other Model Applications in Coastal Areas.** Presented at the MODFLOW '98 Conference, International Ground Water Modeling Center and Colorado School of Mines, Golden, Colorado, October 4-7, 1998.

Pascoe, G., L. Gould, J. Martin, M. Riley, and T. Floyd, 1995, **Use of a Hydrogeologic Model to set Remedial Goals for Subsurface Soils in a Puget Sound Basin Watershed.** Presented at the Society of Environmental Toxicology and Chemistry annual meeting, Vancouver, British Columbia, Canada, November 6, 1995.

Hathaway, D.L. and M.J. Riley, 1995, **Evaluating the Performance of Hydraulic Containment Systems.** Presented at the American Institute of Hydrology Annual Meeting, Denver, Colorado, May 14-18, 1995.

Riley, M.J., R. Matsuda, et al., 1991, **A Risk Approach to Classifying Contaminated Sediments in Elliott Bay.** Presented at the Puget Sound Research Conference, Seattle, Washington.

Hinckley, D., B. Maier, R. Cardwell, M. Riley, R. Matsuda, et al., 1991, **Rapid Methods for Quantitatively Assessing Ecological and Human Health Risks in Contaminated Sediments.** Presented at the Puget Sound Research Conference, 1991, Seattle, Washington.

Lindquist, K., M. Riley, and H. Stefan, 1987, **Sinking Flow into a Shallow Cross Current.** Presented at the Third International Symposium of Density Stratified Flows, February 1987, **IAHF**, American Geophysical Union, and the American Society of Civil Engineers.

Hanson, M., H. Stefan, and M. Riley, 1986, **Dynamic (Mathematical) Modeling of Lake Processes for Management Decisions.** Presented at the International Symposium on Lake and Watershed Management, November 13-16, 1985, North American Lake Management Society.

Stefan, H.G., and M.J. Riley, 1986, **Dynamic Lake Water Quality Modeling.** Presented at the Eastern Simulation Conference, March 10-12, 1986, Norfolk, Virginia, Society of Computer Simulation.