 1 *******************ROUGH DRAFT*********************

 2 *****************WILLIAM JOHNSON PhD*****************

 3   THE VIDEOGRAPHER: One moment please. We

 4 are going on the record. The time is 2:02. This is

 5 the videotaped deposition of William Johnson taken in

 6 the matter of PR Spring Tar Sand project groundwater

 7 discharge permit by rule before the Utah Water Quality

 8 Board.

 9   This deposition is being held at 175 South

10 Main, Salt Lake City, Utah on April 4, 201. My name

11 is Max Nelson from the firm of Tempest Reporting with

12 offices at 175 South Main Salt Lake City, Utah. I am

13 the video specialist. The reporter is Denise Kirk

14 from Tempest Reporting.

15   Counsel will now state their appearances

16 for the record and the witness will be sworn.

17   MR. DUBUC: Today's date is May 4th, 2012.

18 You said April.

19   MS. WALKER: This is Joro Walker and Rob

20 Dubuc on behalf of Living Rivers.

21   MR. McCONKIE: Paul McConkie on behalf of

22 the executive secretary.

23   MR. HOGLE: Chris Hogle and Benjamin

24 Machlis. And we have Barclay Cuthbart here who is a

25 representative of U.S. Oil Sands.

1   (Witness sworn.)

2 EXAMINATION

3 BY MS. WALKER:

4   Q.   Dr. Johnson, earlier in your testimony,

5 you were asked something about equation -- I don't

6 know the number of the equation but it's on page 11

7 and it has to do with retardation factor. I've handed

8 you just that page so you can refer to it. What's the

9 number of the equation?

10   A.   It's unnumbered.

11   Q.   Oh, okay, but line 19, it looks like?

12   A.   Uh-huh.

13   Q.   So you were asked is it true that you used

14 a value of 35 percent for moisture content in the

15 equation for calculating retardation factor and you

16 answered that that was correct, and I was wondering if

17 you wanted to clarify your response?

18   A.   Yeah. The 35 percent is correct. That's

19 what I used if that's volume per volume. But if it's

20 mass for mass which is usually how these per cents are

21 expressed then that's not what I used.

22   My answer was correct when I said I was

23 representing a saturated system. And it might be

24 useful for me to elaborate on that conversion and

25 maybe do it on the board. So here's a test.

1   So if we have I'm trying to remember what

2 the report said but I think somewhere between 15 and

3 20 percent by water content. So if we take an 20

4 percent water content, that 20 percent is 0.2 grams of

5 water per gram of sediment. Can you see that? So

6 that's mass for mass.

7   That doesn't speak to the issue of

8 transport. Because you need to understand how much of

9 the power value, how much of the pour space is

10 occupied by water.

11   So to do that you need to convert these to

12 volumes. So this -- I'm calling this water. It's not

13 really water, is it, it's residual organic material

14 that has some water, has did he d-limonene and has tar

15 but I'm calling it water just in this example, okay?

16   So I'm going to assume that it has an

17 density near water which is one. So water has one

18 milliliter of water per gram of water and then we need

19 an bulk density for sediment. That wasn't provided in

20 the report.

21   But a typical bulk density range is 1.5 to

22 two. So let's use something like just for easy math,

23 two, and it's two milliliters per gram. Since gram as

24 a sediment isn't a denominator we actually divide by

25 that. It's one gram of sediment. Sorry, I got it

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                                                   4

1 wrong -- yeah.

2   That's right.   One gram -- two grams of

3 sediment per one milliliter of sediment. Okay. So

4 when you do this conversion then, you end up with 0.4

5 milliliters of water per milliliter of sediment.

6 That's a volume for volume, okay? And this is

7 important because the porosity of most -- yeah,

8 reasonable porosity that would represent a sand that

9 would be .3. This exceeds that .3.

10   So that's why people have concluded that

11 this material will freely drain. Because there's more

12 volume of solution in the sediment than is represented

13 by the pour space in that sediment. So that explains

14 also this conversion issue.

15   Q.   Thanks for the explanation. Then I was

16 just -- you were present during Mr. Handl's testimony

17 and a good portion of that testimony discussed your

18 testimony. I was wondering, do you have a response to

19 that?

20   A.   Yeah. I'd like to clarify. Mr. Handl

21 brought up a number of concerns that he had that I

22 felt really didn't clearly explain the differences

23 between his approach and my approach.

24   He repeatedly stressed that his approach

25 was an equilibrium approach and that is true by my

                                                    5

1 approach is equilibrium proposal. When this is

2 equilibrium or not is not the primary issue but

3 they're both equilibrium approaches. There are

4 differences though and that's what I want to make

5 clear here.

6   Mr. Handl used Raoalt's (~ Raoalt's law,

7 and so this law governs the partitioning of compounds

8 from this organic mixture, this extract that has

9 d-limonene and tar compounds, bitumen compounds, into

10 water.

11   So that law is that the concentration in

12 the water of a compound coming from this picture is

13 equal to the mole fraction did he noted with an X.

14 Mole fraction of the bitumen compound and we were both

15 using benzo(a)pyrene, as the representative compound

16 for the car and I'm going tar, I'm to represent that

17 organic extract after adding d-limonene to the system.

18   MR. HOGLE: Can I interpose something. It

19 looks like he's refreshing his recollection or looking

20 at something and that's okay but I'm entitled to a

21 copy of it.

22   MS. WALKER: Okay, I have a copy for you.

23   A.   Can I keep going?

24   Q.   Well, let me -- hang on.

25   Q.   I made sure that's exactly what he's going

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6

1 off there.

2   A.   So that represents the mole fraction of

3 benzo(a)pyrene in the extract, this mixture of

4 d-limonene and tar compounds and water. And so that

5 is multiplied by the normal solubility that one is

6 looking at, any this case benzo(a)pyrene, in water.

7 And specifically you need to specify what phase this

8 is.

9   So for a liquid compound, we can denote

10 this as a liquid. That's Raoalt's. The concentration

11 you'll end up in the water is an function or a product

12 of the mole fraction of that compound in the organic

13 extract as appear pure substance.

14   Okay, so you can take a pure drop of

15 liquid benzo(a)pyrene, and you can put that into an

16 beaker of water, and let it equilibrate.

17   At first there will be no benzo(a)pyrene

18 in the water. It will all be in the liquid, pure

19 liquid droplet of benzo(a)pyrene. It will start

20 moving into the water. You'll start dissolving some

21 benzo(a)pyrene.

22   And as it accumulates to the water, some

23 of it will come back to the liquid droplets. So after

24 a certain amount of time the amount coming back to the

25 liquid drop let is equal to that leaving it and that

                                                    7

 1 calls equilibrium.

 2   At that point you reach a solubility of

 3 that compound in the water. And that's measured in

 4 the laboratory and so that's readily available for a

 5 lot of compounds.

 6   So figure out what the concentration would

 7 be coming from this organic mixture you'd multiple

 8 these two parameters. Now this wasn't given to us.

 9 But we can estimate it based on a number of

10 assumptions. And what Mr. Handl did was to oh to

11 represent benzo(a)pyrene coming from crude petroleum.

12   What he said is the mole fraction from

13 crude petroleum. So this is a representation of what

14 might be in the extract. From crude petroleum he said

15 that that mole fraction is 1.5 and N to the minus

16 four. 0.00015. Okay? That's the moles of

17 benzo(a)pyrene per mole of the organic phase.

18   So that would be the value he used and

19 then he multiplied that by a solubility in water for

20 benzo(a)pyrene and used a value of 3.8 micrograms per

21 liter.

22   Now this is a mass concentration. So this

23 this isn't quite right because this is emotional

24 fraction and this is an this should be moles per liter

25 so the calculation you did isn't quite right but what

                                                         8

 1 it does do is show you that the normal water

 2 solubility is delighted a large amount by the fact

 3 that that benzo(a)pyrene is only one small fraction of

 4 the crude petroleum. So what you end up with in the

 5 water as it calculated was 5.7 plus ten to the minus

 6 fourth.

 7   Ten to the minus fourth micrograms per

 8 liter. And so he's showing this is very negligible

 9 and indeed it is, but it is because he's using a very

10 simple form of an partitioning law.

11   He's using Raoalt's law under very

12 specific assumptions. And that's what I want to make

13 clear here is what those assumptions are and how they

14 relate to this.

15   There's two points I want to make here.

16 One is that this represents only one of hundreds to

17 thousands of compounds that make up the crude

18 petroleum and that likewise make um the tar.

19   And so if you are trying to understand a

20 risk of this material, looking at one compound doesn't

21 tell you much because you need to do the same process

22 for the other hundred to thousand compounds. And add

23 them up and then you have some idea of how much

24 material is coming into the water.

25   So by demonstrating it's a small amount

9

 1 for one compound doesn't answer the question of the

 2 effect of this tar on the water. Okay?

 3 So that's one important point I wanted to make about

 4 his testimony.

 5   Now, you can actually do an analysis of

 6 this material, whether it's the crude petroleum or the

 7 extract with d-limonene and tar compounds. And figure

 8 out the mole fraction of every last compound in there

 9 and then do this operation for each of the

10 solubilities, if you can find the solubilities for all

11 those compounds and come up with an accurate estimate.

12   What I did and what he did was to look at

13 what would be a representative compound that would

14 kind of represent the whole mixture, okay? So I chose

15 something that I felt to be in the middle in terms of

16 solubilities so I chose benzo(a)pyrene and I chose a

17 value from the literature for benzo(a)pyrene of 1.5

18 micrograms per liter.

19   Now, if all the compounds of that

20 characteristic, then the whole mixture is made up of

21 those compounds and the mole fraction is one. And so

22 then the solubility you get is 1.5 -- woops -- that's

23 pretty bad, hopefully you can kind of see that,

24 micrograms per liter.

25   So that's what I was doing by representing

                                                    10

 1 the ** mixture with benzo(a)pyrene. I didn't go

 2 through all the trouble of tallying all the compounds.

 3 Neither did Mr. Handl. That's a big task.

 4   What he did is he took four representative

 5 compounds and said that the overall solubility should

 6 be around five micrograms per liter. That's more than

 7 mine.

 8   So in terms of saying how much is coming

 9 out of this material, I'm actually being more

10 conservative than Mr. Handl. Okay? At least in terms

11 of the pure water solubility.

12   So he is saying somewhere around five

13 micrograms per liter. This is a factor of three

14 different. It's pretty inconsequential in the grand

15 scheme of things because if you include only one

16 compound you are 10,000 times lower.

17   The point is we're both recognizing

18 there's a whole bunch of different compounds in the

19 mixture your and trying to find a way to represent

20 that. So that's another point I wanted to make.

21 We've really chosen similar representative compounds.

22 And treated it similarly so that's not really an issue

23 either. So the major issue is that Raoalt's by itself

24 assumes two things: This is worth writing down too.

25 /-FRBLGS.

11

 1   A.   It assumes am I still in the frame I guess

 2 so because I'm in there -- assumes, one, ideal

 3 solution and I'll try to explain what that is. And

 4 then it assumes no phase change. The know phase

 5 change is the easier one to deal with so I'm going to

 6 start with that. And what it means or the

 7 significance of this is that solids dissolve less than

 8 liquids.

 9   So if the tar is there as a solid to begin

10 with, it doesn't dissolve much. If it becomes a

11 liquid, it dissolves to an much greater extent, okay?

12   And Mr. Handl and I have both mentioned

13 the fact that there are seeps, flowing seeps on the

14 site so there is liquid tar on the site.

15   But the vast majority of the tar is a

16 solid or a semi-solid. It's not flowing. It's not

17 behaving as a liquid and has an much lower effective

18 solubility. That's certainly the case because if it

19 weren't they wouldn't need to use d-limonene to

20 extract it, they could just pump it out. So the

21 d-limonene allows them to extract tar.

22   So the very critical difference between

23 what one of the two critical difference

24 echocardiograms between what Mr. Handl is doing and

25 what I am doing is I'm recognizing that the majority

                                          12

 1 of the tar on the site is a semi-solid and, therefore

 2 has an much lower effective solubility and that when

 3 you add the d-limonene to that tar, you've turned that

 4 tar into a liquid and the compounds will now dissolve

 5 according to their sub cooled liquid solubilities. So

 6 that's a much higher solubility than the solid state.

 7   I can quantify that for you and I will

 8 real quickly but I wanted to bring it up conceptually

 9 first. So the important thing here is that liquid

10 solubility is much much greater than solid solubility.

11   And that's very important because of

12 course the higher the solubility the more that will go

13 into water and if it comes into contact with water and

14 then therefore the higher the potential risk S so

15 that's number two in these issues.

16   Number one is ideal solution. I'm come

17 back to this in a bit but I want to cover conceptually

18 ideal solution before I go into the nitty-gritty of

19 this. Ideal solution is a hard concept to get across

20 and the best way that I can put it is that in the

21 raffinate phase, the water phase that results from

22 equilibration of this d-limonene, tar extract with

23 water, in that raffinate phase, if it's an ideal

24 solution that means that the benzo(a)pyrene and the

25 d-limonene, I shouldn't say benzo(a)pyrene, the

1 bitumen compounds, benzo(a)pyrene being a

2 representative, and the d-limonene is low enough that

3 they don't affect one another. They act as molecules

4 just bouncing off one foot they even find one another

5 as so-called hard spheres. They don't change on e

6 another's properties in water, okay? That's an

7 so-called ideal solution.

8   Mr. Handl assumed that to be the case and

9 he assumed it to be the case because the solution is

10 dilute, okay? The problem is dilute is a vague term.

11 And handle admits that it's a vague term in his

12 testimony -- is that the term for it last week -- he

13 admitted that there's a continuum of diluteness. And

14 that the transition from ideal to non-ideal solution

15 is along this continuum without a clearly defined

16 threshold.

17   So that's the problem is he has assumed

18 that it's ideal and there is a lot of well there's

19 empirical data and there are other reasons to believe

20 it's not ideal. And non-ideality is important and I

21 want to explain that a little bit more.

22   But before I do that, this relates to my

23 previous testimony, my previous recorded testimony on

24 video where it was brought up that the text

25 Schwarzenbach Gschwend and Imboden states that the

1 threshold for non-ideal solution, okay, for a

2 co-solute effect is another way to put a nonideal

3 solution, and the molecules are affecting one another,

4 that that threshold should be .001 volumes for

5 volumes, that is volume of molecules and interest in

6 the solution per volume of water.

7   I made the point that this is an

8 overgeneralization, okay? Mr. Handl has made the

9 point that it's not an overgeneralization, okay? But

10 it is. And there's two reasons I can give you right

11 now that it is.

12   First of all, there is a significant

13 number of publications in the literature in peer

14 reviewed journals that show that for agents not

15 exactly d-limonene but acting the same way as

16 d-limonene in water increase the solubility of

17 compounds such as bitumen compounds in water

18 significantly, even when they're at concentrations far

19 lows below the zero.

20   One specific paper is the one by Mackay

21 and Gschwend, and Gschwend is the second author on the

22 textbook that states that, but he published an paper

23 showing that in fact natural organic matter, which can

24 act as a co-solute just like d-limonene can, increases

25 the solubility of tar compounds by factors of between

1 I think it was ten to 50. Something in that range.

2   And this is published in environmental

3 science and technology. That is the top scientific

4 particular journal for this field.   So that author

5 who made that statement, he was responsible for that

6 portion of the text, actually published results that

7 show that that .001 is isn't over generally saying and

8 when you talk about highly like the. Polycyclic

9 aromatic hydrocarbons, that you can have a cosolute

10 effect well below that threshold and in fact what they

11 saw for natural organic matter which is actually going

12 to have less cosolvency power or cosolute power than

13 d-limonene because they are more compatible with water

14 and obviously I'd have to lecture on this a while to

15 make that clearer.

16   But the natural organic matter would not

17 be as effective as d-limonene and yet they saw the

18 solubility enhancement in only four milligrams per

19 liter in solution. Far lower than the 13 point 18 of

20 d-limonene that's expected in the water, okay? So

21 there's lots of empirical evidence for this effect.

22   The other thing I'd like to do is clarify

23 how in my testimony I showed to show from first

24 principles from very basic equation is how ideal

25 solution in phase change are accounted for. Before

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1 I'd written that the concentration in water -- can I

2 go out to here? Concentration in water is equal to the

3 mole fraction of the you compound in the ex extract

4 and I'm not going to label it because this can be

 5 benzo(a)pyrene or any number of bitumen compounds.

 6 Right? We know there's a hundred to a thousand of

 7 those kind. Times the normal solubility in water as a

 8 liquid. Okay? That's the most basic statement in

 9 Raoalt's law. This is exactly how Mr. Handl used it.

10 Okay?

11   This is incomplete. In my testimony

12 starting with equations 13 and 14 in my supplemental

13 testimony, which are basic equations found in

14 Schwarzenbach Gschwend and Imboden they describe the

15 very fundamental property called activity that is the

16 fundamental (~ word ~) amount of properties that

17 governs contaminate partitioning in the environment.

18   And so starting with those equation is I

19 developed this equation which is more complete because

20 you end I with these two terms. I simply did some

21 algebra to rearrange them and ended up with Raoalt's

22 law but with two additional terms tacked on, which is

23 the activity coefficient for the compound in pure

24 water over the activity coefficient of the compound --

25 actually -- I didn't mean to put that on there -- in

 1 the raffinate. In that water phase that's in

 2 equilibrium with the extract. The organic mixture

 3 ever d-limonene and tar compounds.

 4   So that's one term and then the other term

 5 I came up with was the vapor pressure of pure liquid

 6 d-limonene over the vapor pressure -- I'm sorry --

 7 vapor pressure of pure liquid tar compound, bitumen

 8 compound whether it's benzo(a)pyrene or what have you,

 9 over the vapor pressure of the solid form of that

10 compound.

11   What these two terms representative is

12 nonideal solution and phase change. In other words,

13 the two concerns that I had that weren't being

14 accounted for in fact come out of the fundamental

15 equation is just by some rearrangement algebraically.

16 They have to exist, okay?

17   And this term here, again is the activity

18 coefficient of the tar compound, the bitumen, in pure

19 water, versus the raffinate.

20   Now, an activity coefficient is one is

21 ideal solution. Now you can use the solubilities of

22 these compounds as I did in my testimony, to figure

23 out what these activity coefficients are in these two

24 phases and do that in my supplemental testimony.

25   What I find is this ratio ends up being

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 1 much much greater than one. What that means is it's

 2 going to push more of the compound into the water.

 3 The other term here ends up being much much greater

 4 than one. Just like solubilities, the vapor pressures

 5 of compounds are higher for the liquid than the solid.

 6 So this term is also much much greater than one.

 7   So both of these terms work to push more

 8 of the bitumen compounds into the raffinate. These

 9 were not accounted for in Mr. Handl's testimony and

10 his calculations.

11   So I've used representative compounds to

12 show that this is the case in my supplemental

13 testimony. Strong indication that there's going to be

14 an much larger concentration in the water than is

15 predicted by Raoalt's. I predicted somewhere in the

16 range of a thousand. Okay? It can be proven quite

17 easily.

18   All that needs to be done is to have U.S.

19 Oil Sands equilibrate the d-limonene tar mixture with

20 water and find out how much comes into the water after

21 a period of equilibration. That's the best way to do

22 it. Okay? There's plenty of ammunition here to say it

23 needs to be done.

24   Some other things I'd like to clarify. In

25 Mr. Handl's testimony he made the point that my

                                                   19

 1 ternary diagram, point wasn't scaled. It wasn't

 2 scaled because I was using a conceptual diagram as he

 3 did in one of us appendices of his testimony. So I

 4 was simply following his lead on that.

 5   The ternary diagram, what it does is it

 6 takes each of the three components about we're

 7 concerned with in this mixture. Let me see if I -- I

 8 got this right. We have bitumen at one apex of this

 9 triangle. We have d-limonene at the other apex of

10 this triangle and we have water at the other pay

11 appendix of this triangle.

12   These are the three things that are kind

13 of being mixed together. Bitumen and d-limonene are

14 both hydrophobic compounds. The fundamental tenet in

15 comparative partitioning is that like dissolves like.

16 These guys are a lot like one another and so they mix.

17 So you can get any mixture of these things to exist.

18   It can be all bitumen with a little bit of

19 d-limonene, all d-limonene with a little bit of

20 bitumen in it, okay?

21   And so you have a phase over here that's

22 the organic phase that exists along this line. Mr.

23 Handl made this point in his video testimony last

24 week.

25   He also made the point that you get an

                                                    20

 1 raffinate phase separate from the organic phase or

 2 extract. You get an raffinate phase and then I'm just

 3 plot go this conceptually, not quantitatively. If it

 4 was quantitative you wouldn't even see it. That was

 5 the point he made is that the solubility in bitumen is

 6 very very low. In fact, it is according to him, five

 7 micrograms per liter, okay? Five micrograms per liter

 8 plotted on this diagram is five micrograms per

 9 kilogram or in fraction it's five times ten to the

10 minus 9th meaning that the amount of bitumen in this

11 water is five times ten to the minus ninth, the

12 distance across this line. So you wouldn't even see

13 it being distinct from this apex. Okay?

14   So this point here that represents that

15 point is exaggerated. The solubility of d-limonene in

16 water so this is benzo(a)pyrene -- well this is

17 bitumen. This is Mr. Handl's value for bitumen

18 solubility in water.

19   And then the solubility of d-limonene in

20 water is 13.8 milligrams -- milligrams per liter.

21 Okay? 13.8 milligrams per liter equals 13.8

22 milligrams per kilogram equals 1.3 times ten -- I know

23 Joro hates when I write like this so let's fix it.

24 That's scientific notation five times ten to the minus

25 ninth. And this is 1.3 times ten to the minus --

1 let's see, that would be sixth --fifth. Okay? So

2 that -- it would stick out more so to put this

3 proportionately even though they're both exaggerated,

4 it would be more than that of bitumen in water.

5   So two points I want to top make here.

6 The raffinate here if I plotted these you wouldn't see

7 them. It's not visible if it's to scale. That's why

8 I didn't make the flat scale.

9   The other point is that he says it's a

10 tiny raffinate phase. And I don't know if he means to

11 do this but it seems to imply that therefore what's

12 the problem, okay?

13   The problem is that if we increase the

14 concentration of bitumen compounds in the water by a

15 thousand, now they become five times ten to the minus

16 sixth. Still invisible, still a tiny raffinate even

17 though they're a thousand times more concentrated. So

18 the fact it's a tiny raffinate doesn't mean it's not a

19 big problem.

20   So I just don't want that to cloud this

21 issue, okay? It is a tiny raffinate. That doesn't

22 mean it's not a big problem. Same thing with

23 compounds in general. They're all sparingly soluble.

24 But, of course, we don't want to drink water with

25 polycyclic aromatic hydrocarbons in it because they're

                                                    22

 1 highly carcinogenic and they're, you know, the maximum

 2 contaminate levels associated with those are down in

 3 the micrograms per liter range.

 4   So the other thing I want to say about

 5 this is that and I think I'm skipping ahead but that's

 6 okay. Notice the difference in solubility. So the

 7 question is is this an ideal solution? Will the

 8 bitumen and d-limonene affect one another? Well, Mr.

 9 Handl makes the argument that are they're similar,

10 therefore there's this sniff test, right? If it

11 doesn't smell right it's bad. Seems like a non

12 sequitur to me but the point that he was making and

13 they do have some similarities. But they are not

14 equivalent. D-limonene is 10,000 times, four orders

15 of magnitude more soluble in water than d-limonene.

16 That's a factor of 10,000.

17   If something is 10,000 times more soluble

18 in water, it provides -- it has the ability to act as

19 a carrier for the less soluble compounds. And that's

20 why you see in these empirical results the fact that

21 you do have solubility enhancement of these less

22 soluble compounds in the presence of these more

23 soluble compounds.

24   Okay. Some more points I want to make. A

25 lot of these I've covered. I'm trying to make sure I

                                                23

 1 don't miss something.

 2   Okay. So some criticisms Mr. Handl had of

 3 my testimony. That I didn't identify in equation 12 a

 4 solid, that the compound was a solid in equation 12.

 5 But in the equation is that led to equation 12 it was

 6 very clear to the compound was an solid.

 7   I used the vapor pressure of the solid.

 8 Perhaps he's misunderstanding my testimony, I'm not

 9 sure. But this is an critical point. I'm accounting

10 for the fact that there's a transition from solid to

11 liquid in this process. And Mr. Handl is not doing

12 that. Okay?

13   I think I made that clear in the previous

14 equation. On page 25 Mr. Handl pointed out that my

15 equation 27 has an error or that I made an error. And

16 he's correct there was an math error. So I want to

17 clarify this.

18   He had criticized that the entropy of

19 melting which is just so he's easier to recognize than

20 the testimony, the entropy of melting is Delta S melt.

21   And in the equation I wanted to know the

22 entropy of felt he melting at the melting temperature.

23 He said I should have used a different value than I

24 used. Well that's not true. The value that I used to

25 represent benzo(a)pyrene was 56 point five juice per

                                                    24

1 mole degree kelvin. That's an J for July. That's an

2 accepted value for compounds that don't have flexible

3 chains on their structure. Okay?

4   So that's a representative value that

5 nobody would have any problem with. I've used that

6 value. He also said I used the wrong temperature and

7 in fact I had used the correct temperature.

8 Temperature of melting of 177 degrees C and but in my

9 testimony somehow I typed in a different number. So I

10 apologize for that. But I did in fact in my

11 calculation use 177 C.

12   Now there was an math error when I did the

13 calculation and so it came out to be 54. I had said

14 that the ratio, this calculation was for the ratio of

15 vapor pressure of the liquid relative to the solid

16 accounting for that phase change. And I had said in

17 my testimony 200, math error, I apologize. It's 54.

18 Okay?

19   Now, remember this is one of two factors

20 that contribute to the enhanced solubility in the

21 presents of d-limonene. The other one was the

22 activity coefficient ratio. That was something like a

23 factor of ten. So that times this is a factor of 540.

24 That's still a formidable increase.

25   Independently I had calculated a factor of

1 1440 in my original testimony. They're a factor of

2 three apart. A little less than that. That's

3 reasonable agreement for two completely independent

4 methods. They're both saying that you have around a

5 factor of a thousand increase. So anyway I just I

6 want to give him credit for recognizing that error

7 there. But it's not a major problem.

8   So Mr. Handl makes the point that on page

9 67, line six through nine of in I transcript that I

10 stated that the vapor pressure of d-limonene was two

11 meters. I stated two millimeters. And that was an

12 uncorrected transcript. So that was apparently an

13 error on the part of the court reporter and I hadn't

14 had the chance to correct that yet.

15   He goes to know say that I missed the

16 chance to correct the error on subsequent pages but

17 actually that same error two meters is in Chris

18 Hogle's statements too. So that's apparently on the

19 part of the court reporter.

20   He indicates Mr. Handl indicates that on

21 page eight of my direct testimony I may be double

22 counting solubility. I am not double counting

23 solubility I'm using an expression that keys on the

24 solubility of a compound, and this is established in

25 many many publications note I believe those by Dr.

 1 Kerry Chu of the U.S. Geological Survey well renown

 2 chemical engineering professional and who works on or

 3 who paid the way for much of the research on

 4 contaminate partitioning.

 5   I already covered the issue of the sniff

 6 test. And so the final thing I want to address is

 7 that Mr. Handl provided a calculation in his video

 8 testimony last week in which he writes that he's

 9 calculating the concentration of bitumen compounds in

10 water and so he says CIW equals mole fraction of I and

11 d-limonene times the activity coefficient of I in

12 d-limonene times the concentration of the compound I

13 in water as a liquid.

14   As you can see this is almost his same

15 Raoalt's Law as before but what he's done is he's

16 added an activity coefficient. And by doing though he

17 says he's taking care of the issue of nonideality.

18   This is the activity coefficient of the

19 compound whether it's benzo(a)pyrene or polycyclic

20 aromatic hydrocarbon you love best in d-limonene. And

21 and he said and is correct that they're similar to one

22 another, therefore they're perfectly compatible.

23   And if they're perfectly compatible that

24 activity coefficient is one. So he has made no change

25 in his calculation.

1   What's missing here is the activity

2 coefficient of the compound in water. That's where

3 all the nonideality at resides. And that value is

4 somewhere in the range of one billion, 230 million to

5 be more precise. It's big. Meaning it's wildly

6 incompatible and that's what drives all the issues

7 that we're talking about. Okay?

8   So he has made for substantive change. If

9 he's claiming and he seems to be claiming that this is

10 accounting for non ideality, he's absolutely

11 incorrect. He's got only half a story here and the

12 equation I showed you takes care, it incorporates both

13 activity coefficients of the benzo(a)pyrene in the

14 water as well as the d-limonene and so tells the whole

15 story.

16   A.   I think that's all.

17   Q.   I just -- if I may, since we had a lot of

18 discussion about admissibility and partial miss

19 ability, if you could just tie what you just were

20 explaining to us to those terms as well, maybe it will

21 help us understand that issue.

22   A.   Yeah, okay. That's important because

23 these different terms. Miscibility, immiscibility,

24 ideal, nonideal. Those are terms that are expressing

25 similar things, okay?

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1   So if we go back to my simple definition

2 of an ideal solution as being one in which the bitumen

3 compounds and the d-limonene in this raffinate water

4 rich phase don't affect one another, okay that's an

5 so-called ideal solution, okay?

6   So it becomes a nonideal solution when

7 they start to affect one another and hopefully I've

8 made clear why it is they affect one another and how

9 to quantify that

10   Now, minute and immiscibility play a role

11 in this right because if something is completely I am

12 might be, then for instance if water and the organic

13 extract are completely I am might be then the water

14 remains pure, and the organic extract materials, the

15 d-limonene and the benzo(a)pyrene don't enter into the

16 water because there's complete immiscibility and so

17 there's no mixing at all and there's no issue.

18   But of course that doesn't occur. So

19 immiscibility is a hypothetical animal, okay?   You

20 always have some degree of miscibility.

21   So immiscibility versus miscibility is

22 subjective and it is operational. In other words, as

23 a chemical engineer you are wondering whether or not

24 you'll be able to separately collect this organic

25 phase because if it's I am might be with the water you

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1 won't. It will become part of the water phase.

2 That's why the d-limonene is useful. You can remove

3 it from this water sediment slur I and process it.

4 Okay?

5   So it's clearly partially miscible, okay?

6 It dissolves to some extent. That's why we have an

7 issue. But it doesn't dissolve completely. So it's

8 partially I am miscible. Mr. Handl was unwilling to

9 use that term last time because it states in his own

10 reference per ease handbook which he calls the bible

11 for chemical engineers, it states there that an

12 partially miscible solution with suffer nonidealities,

13 okay? Which goes against his assumption of an ideal

14 solution, okay? They're clearly partially miscible.

15 Partial miscibility can lead to nonideality.

16   It says that in Perry's Handbook. There's

17 this continuum then from completely immiscible which

18 doesn't actually exist to partially immiscible to

19 completely immiscible and there's this transition from

20 ideal to nonideal.

21   So that's how the two terms relate to one

22 another. Does that clarify that well enough?

23   Q.   Yes, thank you. I just had another

24 clarifying point. So when you were showing us those

25 two factors that the one that accounts for northern

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1 ideality and the one that accounts for phase change,

2 were you assuming then in that situation that the

3 solutions were nonideal?

4   A.   No, there's no -- I don't have to assume

5 anything to develop that. That equation is diagnostic

6 to (anthropomorphite) right? It's got no (word)

7 assumptions built in.

 8   What those terms do is if the activity

 9 coefficient ratio ends up larger than one, that means

10 there's nonideality that drives the compound into

11 solution which is indeed what I found to be the case

12 when I did the calculations for a representative

13 compound. But there's no assumption (ipari) that's

14 that the case.

15   Q.   Okay. Then finally, was there any

16 evidence that you saw, so hard evidence, that supports

17 your calculations?

18   A.   Yes. The U. S. Oil sands own results with

19 I forget the place where they did the pilot study but

20 they had material from there that they had monitored.

21 So they were looking at the residual extract, the

22 extract that's in the processed sand.

23   They quantified that, they quantified the

24 petroleum hydrocarbons that are present in the

25 processed water, which apparently gets returned back

 1 into the process.

 2   And so I think that's probably the most

 3 illuminating in terms of what ends up in the water.

 4 And the numbers that they gave showed that the amount

 5 of petroleum hydrocarbons which you'd expect to be

 6 dominated by is polycyclic aromatic hydrocarbons in

 7 the asphaltines and the other components of the tar,

 8 those concentrations were a factor of something like

 9 10,000, much higher than what I had predicted. And so

10 they are strong indicator that the processes that

11 we're concerned about are occurring.

12   So again, that is in a way a leach test,

13 okay? They have their own data that demonstrates that

14 there is a large amount of these compounds that will

15 go into the water once you add d-limonene to the

16 system.

17   Now, I believe what's needed is a more

18 controlled leach test, you know, done by a reputable

19 group, consultant or academic group or what have you,

20 but somebody who can do these leach tests and it's not

21 difficult to do to get to the truth of how much is

22 going to be in the water.

23   Q.   Okay. Thank you.

24   A.   You bet.

25   MR. HOGLE: Let's take a break, okay.

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                                                    32

 1   THE VIDEOGRAPHER: We're going off the

 2 record, the time is 2:54.

 3   (Brief recess.)

 4   THE VIDEOGRAPHER: One moment please.

 5 We're going back on the record. The time is 319.

 6 EXAMINATION

 7 BY MR. HOGLE:

 8   Q.   Dr. Johnson, we've met before. I'm Chris

 9 Hogle. Just a few questions. Nowhere near like last

10 time.

11   There was some discussion about bitumen,

12 whether it's a solid or a liquid or both. If it's in

13 its natural state, bitumen is more like a liquid then

14 the factor by which it becomes more water soluble in

15 the d-limonene water bitumen phase, that factor is

16 reduced, right?

17   A.   That's correct.

18   Q.   Okay. In its natural state, what

19 percentage of bitumen is a solid?

20   A.   It depends on the setting. It depends on

21 the setting.

22   Q.   Okay. Have you seen the bitumen in the

23 area in which the PR Spring will happen?

24   A.   I have not been there.

25   Q.   What have you seen in terms of bitumen and

                                                     33

1 the percentage of how much of it is a solid versus a

2 liquid?

3   A.   Oh, I've seen examples of tar sands and

4 oil shales that people of from in archives, okay?

5   Q.   Uh-huh and what's the split between solid

6 versus liquid?

7   A.   Oh, they were all solid.

8   Q.   Okay. Have you seen anywhere -- so when

9 you say all solid, a hundred percent?

10   A.   Yeah, I would say a hundred percent solid.

11 I mean, I don't want to say I'm not going to hold this

12 to a quantitative -- you know technically glass is a

13 liquid. All right? So there's plenty of, you know --

14 there's a spectrum here, okay? The point is they were

15 in the state where they would have reduced solubility

16 because the molecules aren't free to move into the

17 April I couldn't say base.

18   Q.   But in terms of the bitumen that you've

19 seen, have you seen anywhere it's less than a hundred

20 percent solid?

21   A.   Yeah. Yeah.

22   Q.   Okay. Have you seen any where it's 50

23 percent solid and 50 percent liquid?

24   A.   Well, to answer honestly no but I imagine

25 they exist, yeah. Maybe to clarify, whether it's in a

 1 solid versus a liquid form depends on how many

 2 compounds, how much of the mixture is made up by

 3 compounds that have melting temperatures that are

 4 below -- that are, I have to get this straight -- that

 5 are below the temperature of interest, okay?

 6   Now, those compounds also have to be the

 7 ones that most readily vaporize, move into the

 8 atmosphere. As they sit out in the environment for

 9 thousands, Millenia, you know, those compounds

10 vaporize off and what remains are the compounds that

11 do not vaporize and those also happen to have melting

12 temperatures that are higher than the temperature of

13 the environment.

14   So that's why they end up in solid form.

15 So a fresh bitumen taken from the subsurface may be

16 liquid but it won't stay that way for, you know, after

17 those compounds vaporize off.

18   Q.   Would you characterize as light distillate

19 as a liquid or solid?

20   A.   Light distillate?

21   Q.   Yes.

22   A.   Those would be liquid.

23   Q.   Heavy distillate?

24   A.   It depends on the mixture of the compounds

25 it's comprised of.

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1   Q.   Gas oil?

2   A.   Gas oil?

3   Q.   Yes, sir.

4   A.   Gas oil. Well gasoline is liquid. Gas

5 oil I'm not sure precisely what you mean.

6   Q.   Heating oil?

7   A.   Oh heating oil is liquid.

8   Q.   All right. So changing topics a little

9 bit, you recognized an mathematical error that you had

10 in your supplemental testimony?

11   A.   That's right.

12   Q.   And when you corrected it there was a

13 factor of three difference, I think you said 540

14 versus 1440?

15   A.   Yeah, less than a factor of three but more

16 than a factor of two.

17   Q.   And that was a single mathematical error

18 in your calculation that resulted in that, right?

19   A.   Yeah.

20   Q.   Okay. You said if I wrote down in my notes

21 correctly, you said that you'll start to see non ideal

22 interactions when your solution is at at ten to the

23 negative three in volume concentrations, did I get

24 that right?

25   A.   Did I say that?

 1   Q.   I thought -- yeah I wrote that down?

 2   A.   Well I was referring to the statement by

 3 -- in Gschwend and Imboden which you brought up during

 4 any previous testimony, yeah.

 5   Q.   So basically did I paraphrase that right?

 6   A.   Uh-huh yeah.

 7   Q.   Could you calculate for us on the board

 8 there the volume fraction of saturated d-limonene in

 9 water solution?

10   A.   Sure, yeah. So the solubility of

11 d-limonene was?

12   Q.   13.8 milligrams better liter or kilogram?

13   A.   13.8 milligrams per liter, okay? And

14 that's milligrams of d-limonene per liter of water.

15 So to figure out the volume fraction we need to

16 understand the volume associated with that mass of

17 d-limonene, right? So we need density for

18 d-limonene. Mark has got that.

19   MR. MACHLIS: Page 31 of his January

20 testimony.

21   Q.   I'm just going to hand you your January 20

22 testimony and it's open to page 31.

23   A.   So specifically gravity is how it's listed

24 here is .84. So that's one milliliter of d-limonene

25 per zero .84 grams of d-limonene. Right?

                                                    37

 1   Q.   Right.

 2   A.   So -- okay. So now we have millimeters of

 3 d-limonene per liter of water, right so we want to get

 4 those in equivalent units so we simply need to

 5 recognize that one liter of water is one thousand

 6 milliliters of water and that will of milliliters of

 7 d-limonene per milliliter of water. Which gives us

 8 our fraction.

 9   MR. CUTHBART: You need your conversion

10 between milligrams, if I might add that.

11   A.   That wouldn't have been a good number for

12 you anyway. Grams down there. So one gram of

13 d-limonene per ten to the third milligrams. Of

14 d-limonene. Right?

15   So there's ten to the sixth as the

16 denominator just to make this easy let's call that

17 one, okay? So it's 13 -- woops -- 13.8 -- well

18 milliliters of d-limonene -- 13.8 times ten to the

19 minus sixth milliliters of d-limonene per milliliter

20 of water.

21   Q.   Okay. Thanks.

22   A.   Okay.

23   Q.   So that's a very small fraction. Okay?

24 That concentration of d-limonene is much larger than

25 the four milligrams per liter that resulted in
                      Page 34

 1 significant solubilization of polycyclic aromatic

 2 hydrocarbons by natural organic matter. That was the

 3 agent here.

 4   My point being that, yes, it's below that

 5 .001 threshold, but even the author of that textbook

 6 that in fact would be responsible for that statement,

 7 for that threshold has published papers showing

 8 there's a significant effect of low concentrations for

 9 hydrophobic compounds.

10   Q.   Move to strike as nonresponsive the

11 testimony after he answered my question with the 13.8

12 times ten to the sixth.

13   I wanted to ask you where you got the

14 information that you provided in your testimony -- in

15 your testimony from before, you indicated that you

16 relied on some U.S. Oil Sands information or that you

17 said some U.S. Oil Sands information supported your

18 conclusion?

19   A.   Right.

20   Q.   Could you identify that for us?

21   A.   Well, I can tell you that it was

22 information provided to counsel that they apparently

23 were able to view it for a short time. They had notes

24 on that. They showed me their notes.

25   So I used the information they had on

1 their notes to make the calculation.

2   Q.   Okay.

3   A.   What the note showed is petroleum

4 hydrocarbon concentration in the process water.

5   Q.   Okay.

6   A.   I think it might have been called return

7 water. I can't remember off the top of my head.

8   Q.   I would make a request to see the notes

9 that he utilized and relied on and, you know, you

10 don't have to tell me now whether you'll let me see

11 that. I think I'm entitled to see that because he used

12 it. Any other information that you received that was

13 company information?

14   A.   I don't believe so.

15   Q.   Okay. All right. One final question:

16 Solubility is different than mobility, true?

17   A.   They're related but they're different.

18   Q.   Okay. And mobility being the propensity

19 of something to transport, right depends in part at

20 least on the -- what it has to transport through,

21 correct?

22   A.   Correct.

23   Q.   So a factor in determining the mobility in

24 this case is the permanent I can't built of the

25 subsurface material at the project sight, wouldn't you

1 say that that's accurate?

2   A.   Yeah. My testimony doesn't go there but

3 that's true.

4   Q.   Okay, that's all I have.

5   A.   But one thing issued mention is that

6 permeability is a tricky matter. Hydrologists know

7 that when water moves through the subsurface it's not

8 moving through that matrix porosity, it's moving

9 through fractures and things that transport things

10 much much fast other.

11   Q.   Move to strike as nonresponsive. No

12 further questions.

13   MR. McCONKIE: I have no questions.

14   MS. WALKER: I have a few questions.

15   MS. WALKER: I have a few questions.

16 FURTHER EXAMINATION

17 BY MS. WALKER:

18   Q.   So Chris was asking -- I'm sorry Mr. Hogle

19 was asking you about this 13.8 to the minus sixth and

20 you were relating it to four milligrams per liter.

21 Could you just explain that because he moved to strike

22 it so I'd like you to explain it to me?

23   A.   The point made here is that 1.38 times ten

24 to the minus fifth is a volume/volume fraction and

25 much lower, almost two orders of magnitude lower than

                                                    41

1 that .001 threshold, okay?

2   By the way, in that same text, in that

3 same section they show that for volume volume fraction

4 is lower than that .001 there's significant solubility

5 enhancement so even the remainder of that paragraph

6 recognition that that's a rough threshold. Okay?

7   Now, there's empirical evidence that shows

8 that the zero .001 doesn't apply for hide phone I can

9 compounds. One nice piece of empirical evidence is

10 this publication by Allison Mackay and Phil Gschwend.

11 Phil is an environmental engineer at MIT, he's well

12 known in the field of contaminate transport especially

13 related to hydrophobic organic compounds being

14 solubilized, being carried into the water by

15 cosolutes, okay?

16   And what they saw, this is empirical, it

17 was at a coal tar site, where they saw that natural

18 organic matter at an concentration of other only four

19 milligrams per liter caused factors of ten to 50

20 increases in the solubility. You can't see that can

21 you?

22   THE VIDEOGRAPHER: Yes.

23   A.   In the solubility of polycyclic aromatic

24 hydrocarbons. Now, that's really important because

25 this is well well below and we don't have, for natural

1 organic matter we don't have an molecular weight and I

2 don't have a density. I'd have to guesstimate an

3 density.

4   But the point is comparing them only a

5 mass basis, these are -- this is much lower, okay?

6 And it's having a large effect. And so Gschwend who

7 is the second author on that textbook that states the

8 zero .001 rule of thumb recognition that it's only an

9 rule of thumb. It's not hard and fast. Okay?

10   Q.   And then what were you saying about rocks

11 and mobility?

12   A.   Well, when you talk about permeability of

13 rocks, it's not the permeability of the rock itself

14 that matters, okay? So I do know that a significant

15 component of the lithology at the site is limestone,

16 for example. Limestone related rocks. Okay?

17   Well, when you've got surface and you are

18 concerned about some kind of source of water at the

19 surface, let's say rainfall, going down to the

20 subsurface to the water table, how it gets there is

21 not by flowing through the pour spaces in the rocks

22 unless it's something like a sand.

23   But when you are talking about hard rock

24 lithology like lime stones where it's flowing in

25 fractures, okay, and the transport can be very rapid

43

1 in fractures.

2   And so the question of the permeability of

3 the limestones is really immaterial to the potential

4 for transport. Okay? The question is fracture

5 density, the site has springs nearby so there's

6 clearly places where the groundwater, at least from

7 what I've read in U.S. Oil Sands NOI, it appears

8 there's places where groundwater is close to the

9 surface. So it's it highly variable.

10   So, anyway, the major issue is that

11 permeability of this rock doesn't tell you about the

12 rate of transport in the system. It's more

13 complicated.

14   Q.   Okay. And did you see anything in your

15 review of the I know and the permit by rule anything

16 talking about how much bitumen was solid versus how

17 much of it -- well I'm sorry.

18   Let me be more clear. How much of the

19 bitumen that we're dealing with in the PR Spring case

20 was liquid versus solid?

21   A.   No, I don't remember any information in

22 that regard.

23   Q.   Okay. And then just to be clear, so when

24 you were looking at counsel's notes about the

25 documents, were those marked confidential?

1   A.   Yes. Those were marked confidential.

2 Yes.

3   MS. WALKER: All right, thank you, no

4 further questions.

5   MR. HOGLE: No questions.

6   MR. McCONKIE: No questions.

7   THE VIDEOGRAPHER: We are going off the

8 record. The time is 3:37.

9   (Proceedings concluded.)

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