STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 BROADWAY
ALBANY, NEW YORK 12233-1010

In the Matter

- of -

the Application for Permits To Construct and Operate a Solid Waste Management Facility in Ava, Oneida County, Pursuant to Articles 15, 19, 24, and 27 of the Environmental Conservation Law, and Parts 201, et seq., 301, et seq., 364, 608, and 663 of Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York

- by -

Oneida-Herkimer Solid Waste Management Authority,

Applicant.

DEC Project No. 6-3024-00009/00007

DECISION OF THE COMMISSIONER

March 19, 2004

DECISION OF THE COMMISSIONER

The Oneida-Herkimer Solid Waste Management Authority (the "Authority") proposes to construct and operate a full-service sanitary landfill in the Town of Ava, Oneida County. The Authority seeks a variety of permits and variances from the Department of Environmental Conservation ("Department") in order to construct and operate the landfill.

In his hearing report (attached), Administrative Law Judge ("ALJ") Edward Buhrmaster concluded that the Authority met its burden of proof on all the issues identified for adjudication. Accordingly, he recommends that the permits requested by the Authority be granted, consistent with the drafts prepared by Department Staff.

After reviewing the record in this case, including the parties' comments on the hearing report, I hereby adopt the ALJ's hearing report. The report, together with my comments herein, constitute my decision in this matter. Accordingly, I hereby grant the Authority's permit application.

Permit Application Proceedings

The ALJ's hearing report contains a complete recital of all proceedings leading up to the issuance of that report, which will not be repeated here. In sum, in an interim decision dated

April 2, 2002, the following issues were certified for adjudication:

Hydrogeology

- Whether the landfill would be constructed over a principal aquifer in violation of 6 NYCRR 360-2.12(c)(1)(i);

- Whether the Authority correctly characterized the critical stratigraphic section and groundwater flows under the landfill;

- Whether the groundwater suppression system would have the unintended effect of facilitating leachate migration off site;

Wetland Impacts

- Whether the groundwater suppression system would substantially lower the water table at the site and, thereby, adversely impact wetlands and other surface water resources;

- Whether the leachate collection system would substantially alter the hydrology of the site and surrounding wetlands by diverting precipitation;

- Whether the landfill would have an adverse impact on area flood controls;

Threatened Bird Species Habitat Impacts

- Whether the construction or operation of the proposed landfill would cause or contribute to the adverse modification of the critical habitat of several threatened bird species;

Air Quality Impacts

- Whether concentrations of PM10 resulting from the operation of the landfill would exceed National Ambient Air Quality Standards; and

- Whether emissions of the hazardous air pollutants vinyl chloride and acrylonitrile would exceed State guidelines during the life of the landfill.

After extensive hearings on the matter, the ALJ issued a hearing report concluding that the Authority met its burden of proof on all certified issues, and recommending that the permits requested by the Authority be granted. On June 26, 2003, the hearing report was released, pursuant to 6 NYCRR 624.13(a)(2)(ii), as a recommended decision for comment by the parties to the proceedings. The Authority, Department Staff, and project objectors ("Objectors") all filed comments and replies.

Related Proceedings

Previously, on June 17, 2003, Objectors requested that a determination on the Authority's permit application be held in abeyance pending a decision on a related wetlands reclassification request filed with the Department by the Adirondack Communities Advisory League ("ACAL"), one of the Objectors in this proceeding. That request, originally filed in 2002, sought reclassification of State regulated wetland WL-2, which occupies portions of the project site, from Class II to Class I.

By letter dated June 26, 2003, the parties were informed that the Commissioner was reserving decision on the abeyance request until the comment period on the recommended decision expired. In their comments on the recommended decision, Objectors renewed their abeyance request.

By letter determination dated March 19, 2004, I denied ACAL's request to reclassify WL-2 from Class II to Class I. Accordingly, Objectors' request in these proceedings that a determination on the Authority's permit application be held in abeyance has been rendered academic.

Discussion

ALJ Buhrmaster's hearing report contains a complete analysis of the hearing record and the arguments of the parties presented in their closing briefs. For the reasons stated in the hearing report, I affirm and adopt the ALJ's analyses, conclusions, and recommendations concerning the issues adjudicated and the points raised by the parties in their briefs.

One issue raised in the parties' comments on the hearing report, however, requires further discussion. Objectors argue that, prior to permit issuance, the Authority should be required to conduct a full-scale pump test to determine whether a principal aquifer exists under the landfill site. Objectors contend that uncertainties exist concerning the hydrologic productivity of the deep sand/till unit, referred to herein as the "buried valley aquifer," and its confinement or vulnerability to activities at the surface. Objectors assert that a full-scale pump test will confirm, one way or the other, the productivity of the buried valley aquifer and, thus, its status as a principal aquifer. They also claim that such a test would not cause any significant delay, and its cost would be insignificant compared to the overall cost of developing the landfill project.

The Authority argues, as an initial matter, that once the hearing record is closed, no statutory or regulatory authority exists for directing further testing by a permit applicant. In the alternative, the Authority contends that the evidence on the hydrogeology issues is conclusive, especially the evidence supporting the principal aquifer determination. The Authority argues that because the results of a pump test will not undermine the conclusion that the buried valley aquifer is confined, such results will not affect the principal aquifer determination by the ALJ and, thus, the testing is not reasonably necessary. Moreover, the Authority points out that Objectors have had ample opportunity to request permission to conduct their own pump test, but have failed to do so.

Staff argues that the Authority's hydrogeological testing was both extensive and complementary and, therefore, provides a high degree of confidence in the Authority's site characterization. Staff contends that the aquifer determination process used in this case -- independent review by two different Department divisions, the Division of Water and the Division of Solid and Hazardous Materials -- also provides for a high degree of reliability. Staff concludes that because the current record provides a reasonable and adequate basis upon which to evaluate the permit application, further testing is neither reasonable nor necessary.

As an initial matter, the Authority's argument that additional testing is not authorized once the hearing record is closed is rejected. ECL 70-0117(2) provides:

> "At any time during the review of an application for a permit * * * the department may request additional information from the applicant * * * with regard to any matter contained in the application * * * when such additional information is necessary for the department to make any findings or determination required by law"

([emphasis added]; see also 6 NYCRR 621.15[b] [similar]; Matter of Peckham Materials Corp., Interim Decision of the Commissioner, Jan. 27, 1992, at 1 [the sources of authority to require additional information from an applicant during the course of the permitting process are ECL 70-0117(2) and 6 NYCRR 621.15(b)]). Nothing in ECL 70-0117(2) or 6 NYCRR 621.15(b) limits the language "at any time" to any time before the hearing record closes. Thus, if additional information is necessary for the Commissioner to make any findings or determinations on the permit application, the Commissioner is authorized to require such testing, even at this stage of the proceedings.

Even though authority exists to require additional testing by an applicant, based upon this record, and in the exercise of discretion, no further testing is required in this case. Whether additional information should be required of an applicant is determined by asking "whether the information is reasonably necessary to make [the necessary legal and factual] determinations or whether the current record would suffice" (Matter of Peckham Materials, at 2). The determination to require such information is discretionary with the Department (see id.). In the later stages of the review process, such as here -- after release of the ALJ's hearing report as a recommended decision -- however, the discretion to require additional information is more circumscribed than earlier in the process, and should be limited to that information that is important to decision making but lacking in the record (see id.). Information is important at this stage "where there is a likelihood that it will change the basic outcome of this proceeding" (id.).

In determining the sufficiency of the current record, particularly in a landfill siting case under 6 NYCRR part 360, a standard of reasonableness is applied to the technical evidence (see Matter of Hyland Facility Assocs., Decision of the Commissioner, April 13, 1995):

> "The regulatory criteria specified in Part 360 are designed to provide environmental protection, as well as certainty to applicants who undertake landfill projects. The level of technical detail required in an application depends upon site conditions, to the extent they are known or can be reasonably inferred from borings, well logs,

> soil sampling and testing, and other data. Professional judgments supplement this information and assess the level of detail submitted to meet the regulatory criteria, the validity of the data and the probable environmental impacts expected.
>
> To ensure regulatory compliance and conformity, the confidence level assigned to technical evidence must consider regulatory criteria, permit conditions and the reliability of the information. While scientific or engineering "certainty" is a laudable goal, it is an unrealistic expectation in complex environmental matters"

(id. at 2). Instead, a "reasonable standard of judgment" is applied when determining the "sufficiency" of the current record (id.). Even "[i]nadequate or incomplete information should be considered in light of existing 'valid' information" (id.).

Objectors' request for a full-scale pump test is relevant to the issue whether the project would violate 6 NYCRR 360-2.12(c)(1)(i). That regulation provides that no new landfill may be constructed over a principal aquifer. A principal aquifer is defined as:

> "a formation or formations known to be highly productive or deposits whose geology suggests abundant potential water supply, but which is not intensively used as a source of water supply by major municipal systems at the present time"

(6 NYCRR 360-1.2[b][10][ii]).

Departmental guidance for determining whether an aquifer should be considered a primary aquifer is provided by Division of Water Technical and Operational Guidance Series

(2.1.3.), Primary and Principal Aquifer Determinations ("TOGS"). According to the TOGS, an aquifer will be deemed a "principal aquifer" and, thus, subject to the "enhanced" regulatory protection afforded by section 360-2.12(c)(1)(i), when it is both (1) highly productive -- has the potential to provide water for large populations -- and (2) highly vulnerable -- highly vulnerable to contamination from activities on the land surface directly over the aquifer (see TOGS, at 2).

With respect to aquifer vulnerability, the TOGS provides that where a highly productive aquifer is overlain by thick, continuous impermeable deposits, and the predominant recharge to the aquifer is from land areas outside the aquifer area, the aquifer does not qualify as a principal aquifer (see id. at 3). With respect to aquifer productivity, the TOGS provides several factors to consider in determining whether an aquifer is sufficiently "highly productive" to qualify as a principal aquifer, including the area of the aquifer, the thickness of the saturated deposits, and obtainable well yields (see id. at 6-7).

The ALJ held that the buried valley aquifer underlying the project site is stratigraphically confined and, thus, not highly vulnerable to activities at the landfill site. The ALJ held that the buried valley aquifer is overlain by continuous impermeable deposits, roughly 40 to 160 feet thick, and that the predominant recharge to the aquifer is from land areas outside of the landfill site. He rejected Objectors' specific criticisms of the Authority's testing data and analyses as unpersuasive and unsupported by the physical evidence.

The ALJ held that due to the variability of the permeable deposits within the deep sand/till unit, the lack of significant groundwater recharge to that unit from the overlying tills and bedrock, and the lack of a hydrologic connection to a large surface water body, the buried valley aquifer was unlikely to provide sufficiently sustainable well yields to be considered "highly productive." Given the likely lack of productivity and the lack of vulnerability to surface activities, the ALJ sustained Department Staff's determination that the buried valley aquifer does not qualify as a "principal aquifer" for purposes of the section 360-2.12 siting prohibition.

By requesting that a full-scale pump test be required, Objectors seek to test the ALJ's conclusions concerning the productivity of the buried valley aquifer underlying the project site. At this late stage of the review process, however, additional testing in the form of a full-scale pump test is not reasonably necessary in order to confirm the ALJ's conclusion that the buried valley aquifer does not require the "enhanced" regulatory protection afforded by the section 360-2.12(c)(1)(i) siting prohibition. Objectors' own comments suggest that, although a pump test might provide relevant information concerning the productivity of the buried valley aquifer, it would provide little or no additional information concerning the permeability of the overlying tills. Thus, the results of such a test, whatever they might be, would not undermine the conclusion that the buried valley aquifer is confined and, therefore, not vulnerable to landfill activities at the surface. Accordingly, because the conclusion on a key factor in the principal aquifer determination -- aquifer vulnerability -- would not change, the pump test would not change the basic outcome of the case.[1]

Moreover, as Staff contends, the technical evidence supporting the principal aquifer determination is reasonably reliable, and the permit conditions requiring, among other things, extensive environmental monitoring, provide reasonable assurance that applicable regulatory standards will be met and maintained. Thus, the current record provides a sufficient basis upon which to base a determination on the permit application. Accordingly, further testing is not reasonably necessary.

SEQRA Findings and Conclusion

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[1] Although Objectors do not specifically make the request in their comments on the hearing report, before the ALJ Objectors requested a variety of tests other than a pump test, some of which would test the permeability of the tills overlying the buried valley aquifer. For the reasons stated in the ALJ's hearing report, which I adopt, those tests also are not reasonably necessary for making any findings or determinations on the permit application.

The ALJ's hearing report, taken in conjunction with the entire hearing record and the Final Environmental Impact Statement ("FEIS"), prepared by the Authority as lead agency, affords an adequate basis for my finding, on behalf of the Department as an involved agency pursuant to ECL 8-0109(8) and 6 NYCRR 617.11(c), that the requirements of the State Environmental Quality Review Act ("SEQRA") contained in ECL 8-0109 and 6 NYCRR part 617 have been met, and that, consistent with social, economic, and other essential considerations, including reasonable available alternatives, the Authority's project is one that avoids or minimizes adverse environmental impacts to the maximum extent practicable, and that adverse environmental impacts will be avoided or minimized to the maximum extent practicable by incorporating as conditions to the permits those mitigative measures that were identified as practicable.

Department Staff is hereby directed to issue the permits requested by the Authority, consistent with the drafts prepared by Department Staff.

For the New York State Department
of Environmental Conservation

By: ________________________________
Erin M. Crotty, Commissioner

Albany, New York
March 19, 2004

STATE OF NEW YORK
DEPARTMENT OF ENVIRONMENTAL CONSERVATION
625 Broadway
Albany, New York 12233-1550

In the Matter

- of -

the Application of the ONEIDA-HERKIMER SOLID WASTE MANAGEMENT AUTHORITY for permits to construct and operate a solid waste landfill in the Town of Ava, Oneida County

DEC Project No. 6-3024-00009/00007

HEARING REPORT

- by -

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Edward Buhrmaster
Administrative Law Judge

ONEIDA-HERKIMER SOLID WASTE MANAGEMENT AUTHORITY
AVA LANDFILL

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PROCEEDINGS

Background and Brief Project Description

The Oneida-Herkimer Solid Waste Management Authority ("the Authority") proposes to construct and operate a full-service sanitary landfill in the Town of Ava, Oneida County. The site, known as WLE-5 East, is four miles west of the Village of Boonville, on the south side of State Route 294 and west of Gleasman (formerly Germanski) Road. The landfill footprint - - the area in which waste would be deposited - - would occupy 150 acres. With a proposed design capacity of 1000 tons per day, the landfill is expected to take in solid waste for 62 years, and to rise to a height of 1625 feet above mean sea level at completion.

To move ahead with this project, the Authority is requesting various permits from the New York State Department of Environmental Conservation ("the Department"), including a permit to construct and operate a solid waste management facility. Issuance of such a permit is governed by Title 7 of Article 27 of the Environmental Conservation Law ("ECL") and Part 360 of Title 6 of the Official Compilation of Codes, Rules and Regulations of the State of New York ("6 NYCRR Part 360").

In conjunction with this permit, the Authority requests variances from 6 NYCRR 360-1.7(a)(2)(iv) concerning construction and operation of a solid waste management facility within the boundary of a DEC-regulated wetland, and from 6 NYCRR 360-2.13(p) regarding the manner of construction of the landfill's gas venting layer. Also, the Authority requests a waiver from the landfill construction requirement of 6 NYCRR 360-2.13(d) that it maintain a minimum separation of five feet between the base of the constructed liner system and the seasonal high groundwater elevation.

The Authority is also requesting the following permits from the Department:

(1) A permit to conduct activities in state-regulated wetlands and their adjacent areas, pursuant to ECL Article 24 and 6 NYCRR Part 663;

(2) A permit regulating disturbance of protected streams, as well as a permit for construction of dams that permanently or temporarily impound water, both pursuant to ECL Article 15 and 6 NYCRR Part 608;

(3) A waste transporter permit to haul leachate from the site, pursuant to ECL Article 27 and 6 NYCRR Part 364;

(4) Stormwater discharge permits, pursuant to Section 122.26 of Title 40 of the Code of Federal Regulations ("CFR");

(5) A water quality certification, pursuant to Section 401 of the federal Clean Water Act; and

(6) A permit for landfill gas emissions, pursuant to ECL Article 19, 6 NYCRR Part 201, Title V of the federal Clean Air Act, and 40 CFR Part 60.750 et seq.

On June 4, 2001, the U.S. Army Corps of Engineers issued a permit to fill on-site wetlands regulated by the federal government under Section 404 of the Clean Water Act. According to the Authority, construction and operation of the landfill would affect 46.6 acres of federally regulated wetlands, 14.34 acres of which are also part of state-regulated freshwater wetland WL-2. The Authority intends to compensate for the loss of federal and state wetland acreage through a combination of on-site wetland creation and off-site land acquisition and preservation.

As lead agency, the Authority performed a coordinated review of the project pursuant to ECL Article 8 (the State Environmental Quality Review Act, or "SEQRA") and 6 NYCRR Part 617. The Authority completed a Draft Environmental Impact Statement ("DEIS") on January 12, 1998, a Final Environmental Impact Statement ("FEIS") on August 24, 1998, and a SEQRA findings statement that was issued on September 16, 1998. The Department is an involved agency in the SEQRA review because the Department has discretion whether to grant certain permits for the project, as noted above. The Authority's application to the Department was deemed complete on November 16, 1998.

Legislative Public Hearing

A joint public hearing of the Department and the U.S. Army Corps of Engineers was held during the afternoon and evening of August 10, 2000, in the Kunsela Auditorium of the SUNY Institute of Technology at Utica/Rome. According to press accounts, about 75 people attended the afternoon session, while 450 people attended the evening session. The evening session drew many more people than the auditorium could handle, so many watched the proceedings from closed-circuit television monitors that had been set up in the outside hallway and an adjacent cafeteria.

Speakers against the project easily outnumbered those in favor, especially at the evening session, which featured an organized protest by project opponents. A caravan of about 90 vehicles bearing anti-dump balloons, including three school buses, traveled to the evening session from Boonville, and people attending the session included a large number of military veterans, some in uniform or carrying American flags. The veterans were particularly concerned about a landfill being constructed near a forest that, a half-century ago, Oneida County dedicated as a veterans memorial. For more than a week prior to the legislative hearing, a group called Veterans Defending Our Memorial Forest camped by the forest monument to protest the landfill siting.

Project opponents who spoke at the legislative hearing included several veterans groups, officials of affected local governments (the Town of Ava, the Town and Village of Boonville, and the Town and County of Lewis), and members of the Adirondack Communities Advisory League, an anti-landfill citizens' organization. The need for the landfill, its siting near the veterans memorial forest, and the environmental, health and safety impacts of the landfill's construction and operation are the main concerns of these and other landfill opponents, as demonstrated by the oral and written comments received as part of the legislative hearing record.

At the request of Oneida and Herkimer County officials, the Authority was established by state law in 1988, and its board is made up of members who are appointed by the two counties' governments. The Authority's duties include providing solid waste management services and developing solid waste management facilities for the benefit of the two counties. The Authority wants to build its own landfill for non-recyclable waste, which would end the current practice of exporting that waste for disposal. For project proponents, which include many local manufacturers, an Authority-operated landfill would provide local residents, businesses and industries with reasonably and reliably priced disposal services, close to where the waste is generated, saving the transportation costs associated with exportation and providing the infrastructure that could bring more jobs and thereby help revive the regional economy.

Claiming that the project is not needed, opponents argued at the legislative hearing that landfills and incinerators within the state have unused capacity that the Authority should negotiate for in the context of a long-term disposal contract. Opponents argued that in the absence of flow control, and given a shrinking local population and expanded recycling efforts, a landfill in Ava might not be able to take in enough waste to pay for itself, leading the Authority to sell or lease its permit to a private entity that would take in waste from outside the region, perhaps from as far away as New York City.

According to project opponents, the Department should not issue a variance to its regulation prohibiting the construction and operation of new solid waste management facilities in state-regulated wetlands. Opponents say the wetlands that would be affected by the project are more extensive and of higher quality than the Authority and Department Staff have acknowledged. They say that landfilling would affect wildlife in the wetlands and in the area adjacent to them, and that, in terms of the mitigation proposed by the Authority, it is difficult to create and maintain wetlands in places where they do not now exist.

Among other arguments against the landfill project, the following dominated in the oral and written comments that were received in response to the hearing notice:

- - The Authority violated its own siting methodology by locating the landfill footprint in a wetland area, and by failing to adequately investigate alternative sites within the two-county region.

- - The Authority settled on the Ava site not because of its environmental merits, but because it is far from population centers, in a rural area whose residents, the Authority presumed, would lack the money, education and political clout to successfully resist the project.

- - Poor road conditions coupled with severe winter weather would create safety hazards for motorists, especially with school buses sharing the roads with waste- and leachate-bearing trucks.

- - The location of the site far from area hospitals would complicate an emergency response to accidents.

- - Escaping landfill leachate would penetrate a buried valley aquifer beneath the landfill footprint, spreading contaminants quickly in the direction of Boonville and its well field.

- - The system designed to suppress groundwater beneath the landfill would lower the water table over a large area outside the footprint, destroying or changing the character of wetlands that are not lost directly by filling.

- - The landfill would draw rats, seagulls and other vectors, create an odor nuisance, and spread blowing papers around the area, a particular concern with regard to the Veterans Memorial Forest.

- - The landfill would pose a health threat to local residents and children at nearby schools, who would be at a greater risk of cancer, leukemia and respiratory illnesses.

- - The landfill would be a visual blight on the surrounding community, blocking scenic views, diminishing tourism and lowering property values.

- - Landfilling would affect threatened bird species who may use the site for activities such as hunting and nesting, as well as brook trout who live in Moose Creek, into which the site's surface waters flow.

Supporters of the landfill were heavily outnumbered by opponents at the legislative hearing, and likewise there were more letters against the landfill than for it. Nevertheless, the project has many proponents, particularly among local manufacturers concerned about the high costs and uncertainties associated with exporting waste to distant landfills. Proponents argue that a landfill constructed according to current regulations (which require double liners and built-in leachate collection systems) are much safer than the unlined, uncovered landfills of years ago. They say that any groundwater contamination would be detected through a network of monitoring wells, allowing for prompt remediation that would avoid off-site impacts. Some commenters congratulated the Authority on the job it had done so far, especially with its recycling center, and said the Authority should be trusted to operate a landfill competently and safely. They said it is preferable to have landfills operated by public entities in the context of an overall plan for solid waste management, rather than by large private outfits more concerned with dominating a market so they can control disposal prices and maximize profits.

Apart from various local businesses, supporters of the landfill project include the New York State Association for Solid Waste Management, the Herkimer County Industrial Development Agency, and the Oneida County Environmental Management and Water Quality Council.

Issues Conference

On August 28, 2000, I started an issues conference at the State Office Building in Utica. The conference was held to determine which issues bearing on DEC's permitting decision would require adjudication, and who, among the petitioners for party status, would participate in an adjudicatory hearing, should one be required. The conference continued on August 29 - 31 and was followed by a visit to the project site and nearby locations, during which I was accompanied by representatives of the conference participants.

Participants at the conference included counsel for the Authority, DEC Staff, and prospective intervenors who filed petitions for party status.

One petition was filed on behalf of a coalition of project opponents (herein referred to as "the Objectors"). This group consists of the Town of Ava, the Town and Village of Boonville, the Town of Lewis, the Adirondack Communities Advisory League, the Harland J. Hennessey Post 553 of the Veterans of Foreign Wars, the Charles J. Love D.S.C. Post 406 of the American Legion, and Veterans Defending Our Memorial Forest. (Since the conference, Lewis County has joined the Objectors.)

A second petition was filed on behalf of Michael Daskiewich, a resident and property owner on the north side of State Route 294 in Ava, across the road from the project site.

Department Staff proposed no issues for adjudication at the issues conference, maintaining the position it took when the hearing was noticed: that the proposed landfill meets all the criteria for the approvals requested by the Authority, provided that the landfill is constructed and operated consistent with the terms and conditions of Staff's draft permit. The Authority had no objection to these terms and conditions, and therefore the only issues considered for adjudication were those proposed by the prospective intervenors. The record of the issues conference, which was augmented by several post-conference submissions, contains the intervenors' offers of proof as well as the responses of the Authority and Department Staff. The Authority and Department Staff both argued that the issues proposed by the prospective intervenors were not substantive and significant and, therefore, that a formal adjudicatory hearing was not necessary.

<u>Rulings on Issues and Party Status</u>

On January 30, 2001, I issued written rulings on party status and issues. These rulings certified four broad issues for adjudication:

(1) Project impacts on wetland resources;

(2) Need for the landfill, especially since its construction would involve the filling of state-regulated wetlands;

(3) Project impacts on several threatened bird species; and

(4) Project impacts on site hydrogeology.

The latter issue, I wrote, concerned the adequacy of the Authority's hydrogeologic investigation, the possibility that the project site overlies a principal aquifer, the characterization of the critical stratigraphic section (which bears on the ability to monitor any contaminants that might escape from the landfill), and the adequacy and potential adverse impacts of the groundwater suppression system.

I granted the Objectors full party status with regard to the adjudication of each of the certified issues, since the issues were identified based on the petition that was filed on their behalf. I denied Mr. Daskiewich party status because I found that his proposed issues did not meet the standards for adjudication, and that he had not shown how he could meaningfully contribute to the record on the issues raised by the Objectors.

Commissioner's Interim Decision

On April 2, 2002, Department Commissioner Erin M. Crotty issued an interim decision addressing appeals of my rulings by the Authority, Department Staff and the Objectors.

Of the four broad issues that I certified for adjudication, two, concerning impacts on threatened bird species and site hydrogeology, survived the appeals and remained joined for adjudication. [Interim Decision, pages 19 and 20 (concerning threatened bird species) and pages 20 to 23 (concerning site hydrogeology).]

A third issue, regarding need for the landfill, was removed from adjudication entirely. [Interim Decision, pages 13 to 19.] The Commissioner reversed my ruling on this point based upon "the clear case of need demonstrated by the Authority and the failure of the Objectors to seriously challenge the Department's determination that the need for the project outweighed the loss of the wetlands to be impacted. Given the thorough analysis of need undertaken by the Authority and the appropriateness to give deference to the decision of the Authority, as a governmental entity, that such a project is necessary to fulfill an essential governmental function, the criticisms set forth in the Objectors' proposed documentary evidence, unsupported by any proposed testimony, fall short of raising a substantive and significant issue requiring adjudication." [Interim Decision, page 17.]

The remaining issue, regarding project impacts on wetland resources, survived the appeal but only in part. [Interim Decision, pages 6 to 19.] One sub-issue, concerning the extent to which the project site should be considered wetlands subject to federal and state regulation, was removed from adjudication after the Commissioner determined that the Objectors' offer of proof was inadequate when weighed against the "convincing" evidence of the Department concerning the wetland boundaries. [Interim Decision, pages 9 and 10.] A second sub-issue, concerning the adequacy of the Authority's wetland impacts mitigation plan, was also removed because the Commissioner accepted Department Staff's view that the plan provides satisfactory compensation for state wetlands that would be lost to filling, and is feasible to the extent that lost wetlands can be re-created successfully elsewhere at the site. [Interim Decision, pages 10 to 12.] Finally, the Commissioner removed a sub-issue concerning the effect of upland habitat destruction on wetland species, finding that the Objectors' offer of proof here was "nothing more than speculation." [Interim Decision, page 12.]

While eliminating these aspects of the wetland impact issue, the Commissioner sustained my ruling to adjudicate other sub-issues bearing on wetland impacts. These sub-issues concern the effect of the groundwater suppression system on the water table, the effect of the leachate collection system on area hydrology, and the effect of the landfill site on area flood flows. [Interim Decision, page 12.] These sub-issues also bear on site hydrogeology and have been adjudicated in the context of the hydrogeology issue.

The Commissioner's interim decision added one issue for adjudication that had been excluded in my issues rulings. That issue concerns air quality impacts associated with the landfill's operation, more particularly those associated with particulate matter 10 microns or less in diameter (PM-10) and certain hazardous air pollutants. [Interim Decision, pages 23 to 25.] The Commissioner concluded that the adjudicatory hearing must consider whether the predicted total maximum concentrations of PM-10 resulting from the landfill's operation would exceed national ambient air quality standards (NAAQS). [Interim Decision, page 25.] Also, she concluded that the hearing must consider whether the maximum predicted emission of the hazardous air pollutants vinyl chloride and acrylonitrile from the landfill's operation would exceed state guidelines. [Interim Decision, page 26.]

<u>Resolution of Threatened Bird Species Issue</u>

The Commissioner's interim decision affirmed my ruling that an issue existed as to whether construction or operation of the proposed landfill would cause or contribute to the adverse modification of the critical habitat of four bird species considered "threatened" according to Department regulation: the least bittern, northern harrier, upland sandpiper and Henslow's sparrow. After this issue was certified in my issues ruling but before the interim decision was issued, a project site bird survey was conducted during the spring and summer of 2001 on behalf of the Objectors.

In the wake of the interim decision, the Objectors proposed that a more limited survey, focused on the northern harrier and upland sandpiper, be conducted on six dates between May 13 and June 6, 2002. By a letter of May 1, 2002, the Authority denied the Objectors' consultants access to the project site, claiming that there had already been a full and fair opportunity for them to evaluate it as bird habitat, and, therefore, further access was unnecessary. This prompted the Objectors to seek my permission for site access pursuant to 6 NYCRR 624.7(c)(4), which in turn prompted the Authority to request a protective order, arguing that another bird survey would cause it unreasonable annoyance and expense in terms of its monitoring of survey dates. Department Staff agreed with the Authority that the Objectors had already been afforded sufficient site access, and that there was ample available information to adjudicate the issue of impacts to the four threatened bird species.

By a written ruling dated May 8, 2002, I granted the Objectors' request that their consultants be allowed access to the site on the six dates they requested, with the understanding that Authority and Department Staff representatives would have the opportunity to monitor site activities and verify any findings that were made. I allowed site access after finding there was no serious doubt that the bird study would provide material and relevant information about the actual use of the site by the identified threatened bird species, which would help determine whether the site is critical habitat for any of them.

The 2002 bird survey went forward as planned by the Objectors. When it was finished, their counsel sent me a letter dated June 10, 2002, withdrawing the issue as to all four of the threatened bird species identified in my issues ruling and the Commissioner's interim decision. With the withdrawal of the issue, the Commissioner may conclude that construction and operation of the proposed landfill would not be in violation of the siting prohibition [at 6 NYCRR 360-1.7(a)(2)(iii)] against the construction and operation of solid waste management facilities in a manner that causes or contributes to the taking of any endangered or threatened species or to the destruction or adverse modification of their critical habitat.

Pre-Hearing Matters

This matter proceeded to adjudication according to a schedule the parties agreed to for
(1) identification of proposed witnesses, (2) submission of discovery demands and motions for protective orders, and (3) production of documents. A conference call involving me and the parties' counsel was held on May 31, 2002, concerning objections that were made to the formal discovery demands that had been circulated. I ruled on some issues, there was agreement on others, and further written submissions were allowed on those issues that remained unresolved, as confirmed in my June 3 memorandum to the parties.

After another conference call on June 20, I released written rulings dated June 27 which resolved the discovery disputes that remained at that time. In response to one of the Objectors' discovery demands, I granted the Authority a protective order confirming that its air quality consultants did not have to review and reveal files of clients other than the Authority for information that was not used, relied on or even reviewed with respect to the issues in this proceeding. Also, in response to another of the Objectors' discovery demands, I reserved a ruling on Department Staff's motion for a protective order, directing instead that the two parties enter discussions to see if a demand Department Staff considered overbroad could be narrowed based on better knowledge of the relevant information the Department maintains concerning air emissions from landfills. (Pursuant to this directive, Department Staff counsel provided additional information to the Objectors, and the discovery dispute was apparently resolved, as it was not brought back to me again.)

The Adjudicatory Hearing

Adjudication of the hearing issues occurred on a schedule of dates that was agreed to in advance by the parties. Adjudication of the issues bearing on site hydrogeology occurred on September 19, 20, 24, 25, 26 and 27, and October 1, 2, 3, 4, 17 and 18, 2002. Adjudication of the air quality issues occurred on October 8, 9 and 10, 2002. A site visit was conducted by me and the parties' counsel on October 16, 2002, allowing an opportunity to see many of the site features that were referenced in the hearing testimony.

The Authority was represented by Louis A. Alexander and H. Dean Heberlig, Esqs., of Bond, Schoeneck & King, PLLC, in Syracuse.

Department Staff was represented by Randall C. Young, Esq., of the Department's Region 6 office in Watertown.

The Objectors were represented by Michael B. Gerrard and Heidi Wendel, Esqs., of Arnold & Porter in New York City.

All hearing sessions were held at the State Office Building in Utica. This was the location proposed by the Authority and Department Staff. The Objectors proposed that the hearing be held at the Ava Town Hall.

In a memorandum dated April 29, 2002, after reviewing the parties' written and oral submissions, I settled on the Utica State Office Building as the place for the hearing. I did this in consideration of factors including proximity to the project site, the availability of suitable facilities, and the convenience of the parties and witnesses, in accordance with 6 NYCRR 624.3(b)(2). Of the two locations proposed by the parties, I found that the Ava Town Hall best met the standard of site proximity, but that its facilities would not be as suitable as those at the State Office Building, or as convenient for the hearing participants, all of whom traveled from out of town.

By letter of August 12, 2002, the Objectors requested permission for Common Cents Media, a videography company in Utica, to film the adjudicatory hearing so residents of Ava and the surrounding communities who could not attend the hearing would be able to view it, and for possible rebroadcasting of the hearing on television. After soliciting responses from the Authority and Department Staff, both of which opposed any filming, I denied the Objectors' request in a memorandum of August 29, 2002. As is more fully explained in the memorandum, my ruling was based on the Department's longstanding policy disallowing filming or videotaping of its adjudicatory hearings. Filming or videotaping these hearings is prohibited by Section 52 of the state's Civil Rights Law and Section 624.6(f) of the Department's permit hearing regulations. Though I allowed local news stations to film the opening of the adjudicatory hearing, filming was prohibited once the first witness took the stand.

Witnesses for the Parties

The following witnesses testified on the hydrogeology issues:

- - For the Authority:

- - Marc W. Sanford, a principal scientist with ARCADIS Geraghty & Miller (G&M), who managed the hydrogeologic site investigation;
- - Michael F. Wolfert, a hydrogeologist with ARCADIS G&M, who directed the hydrogeologic site investigation;
- - Steven M. Feldman, a senior modeler with ARCADIS G&M, who evaluated existing and predicted groundwater flow conditions associated with the site and landfill development;
- - David C. Schafer, a groundwater hydraulics and modeling expert formerly employed by ARCADIS G&M, who reviewed and provided guidance on field test procedures and groundwater flow modeling for this project;
- - William F. Southern, Jr., an engineer with Barton & Loguidice, who addressed environmental protections afforded by the proposed landfill's leachate collection and groundwater suppression systems;
- - Donald L. Coogan, Jr., a scientist with Terrestrial Environmental Specialists, who was involved in the delineation and evaluation of the site's wetlands; and
- - Dr. Donald I. Siegel, an earth sciences professor at Syracuse University and a consultant to the Authority, who reviewed the results of its hydrogeologic investigation.

- - For Department Staff:

- - Lincoln B. Fancher, a hydrogeologist assigned to the Division of Solid & Hazardous Materials in the Department's Region 6 (Watertown) office, who was the main Department reviewer of the Authority's hydrogeologic investigation;
- - Robert James Bazarnick, an engineering geologist with the Department's Division of Solid & Hazardous Materials in Albany, who reviewed the Authority's request for a principal aquifer determination;
- - James D. Garry, a geologist with the Department's Division of Water in Albany, who also reviewed the Authority's request for a principal aquifer determination; and
- - Mark D. Craig, a conservation biologist with the Department's Division of Fish, Wildlife and Marine Resources, who reviewed wetland matters related to the landfill application.

- - For the Objectors:

- - Dr. Andrew Michalski, a consulting hydrogeologist from New Jersey, who reviewed and critiqued the Authority's hydrogeologic investigation;

- - Dr. Ying Fan Reinfelder, a hydrogeology professor at Rutgers University, who reviewed the Authority's groundwater modeling; and

- - Gretchen Stevens, a botanist with Hudsonia Ltd., a non-profit environmental research institute in Annandale, New York, who considered impacts of the landfill's construction on wetland resources.

The following witnesses testified on the air quality issues:

- - For the Authority:

- - William F. Southern, Jr., an engineer with Barton & Loguidice, who described aspects of landfill design and construction bearing on air quality issues and the control of landfill gas;

- - Scott D. Nostrand, a senior managing engineer with Barton & Loguidice, who developed the Title V air permit application for the Authority, and estimated emissions of various pollutants; and

- - Gordon Reusing, an environmental engineer with Conestoga-Rovers & Associates in Ontario, Canada, who evaluated issues of air dispersion modeling, emissions estimates and ambient air concentrations for the pollutants of concern in this hearing.

- - For Department Staff:

- - Thomas R. Christoffel, an environmental engineer employed by the Department's Division of Air Resources in Albany, who reviewed the Authority's air modeling and performed additional modeling for the Department.

- - For the Objectors:

- - Daniel Gutman, an independent consultant from New York City, who reviewed and critiqued the Authority's assessment of air quality impacts related to construction and operation of the landfill.

Each of the above witnesses was cross-examined on the basis of prefiled testimony that is part of the hearing exhibits.

On each of the two issues, the Applicant presented its case first, followed by DEC Staff and then the Objectors. In addition, the Authority, which was directed to prefile its testimony before the other parties, presented a rebuttal case addressing the Towns' arguments on both the hydrogeology and air quality issues. For both of these issues, the rebuttal case involved calling back witnesses who had previously testified.

The Hearing Record

The hearing record includes a transcript of the oral testimony as well as various numbered exhibits. There were 134 numbered exhibits on the hydrogeology issues and 37 numbered exhibits on the air issues. These exhibits include the prefiled direct testimony of hearing witnesses as well as attachments to the prefiled testimony. Exhibits were numbered as they were marked for identification; those exhibits that were received in evidence are so noted. Some exhibits were marked for identification and not offered or received in evidence. Others were withdrawn and returned to the presenting party.

Witnesses were offered the opportunity to make minor corrections to their prefiled testimony as they took the stand, and their corrections were marked in pen on the face of the typewritten testimony before cross-examination began. Also, portions of the prefiled testimony were struck for various reasons. After the Objectors withdrew the hydrogeology sub-issue addressing project-related impacts on flood flows, I struck testimony by Authority witness William Southern and Department Staff witness Mark Craig addressing that sub-issue. Also, I struck portions of the prefiled testimony of Objector witness Gretchen Stevens in response to objections to the testimony by the Authority and Department Staff, as explained in the hearing transcript.

Separate sets of transcripts were developed for the hydrogeology and air issues. The air transcript consists of pages 1 to 573, and the hydrogeology transcript consists of pages 1001 to 3520. After the transcripts were developed and made available to all parties, there was an opportunity for each party to propose corrections, followed by an opportunity to comment on corrections proposed by other parties. Proposed corrections that met no objection were made; where a correction was opposed by another party, I ruled whether the correction would occur. Later, based on my reading of the transcripts, I proposed additional corrections. Again, those corrections which met no objection were made, and to the extent there was an objection I reviewed the record again before deciding whether the correction would occur. The process of correcting the transcript and my rulings about which corrections would be made are confirmed in the file of correspondence among me and the parties' counsel. All corrections have been handwritten into the transcripts themselves.

Because the parties' positions were already clear from the issues conference, no opening statements were taken in this matter. However, the parties were afforded an opportunity to submit briefs at the conclusion of testimony. Two rounds of briefs were solicited from each party. The initial brief was to lay out what the party thought was factually demonstrated at the hearing, as well as what legal conclusions should be drawn from the facts and what action should be taken by the Commissioner. The second brief was to be a reply to the arguments of the other parties. Pursuant to a schedule set by the parties and extensions to that schedule which they negotiated themselves, initial briefs were received on February 4, 2003, and reply briefs were received on February 28, 2003.

On March 13, 2003, I issued a memorandum to the parties' counsel requesting that Department Staff provide draft air permit language that would memorialize the Authority's commitment to a time frame for completing and starting up its landfill gas collection and control system. Department Staff provided that language in a letter of March 20, 2003, and it was discussed during a follow-up conference call I had with attorneys for all three parties. During that call, held on March 25, 2003, the parties all agreed to the language, and it should now be considered part of any air permit that is issued to the Authority.

In my March 13, 2003 memorandum, I also requested that the Authority provide me a copy of the site investigation plan that it had referred to in its evidence and argument on the hydrogeology issue. That plan was provided under a cover letter of Authority counsel on March 19, 2003, and with the parties' agreement during the March 25 conference call, it was received as part of the record without allowance for additional briefing or comment.

A memorandum confirming matters discussed and decided as a result of the March 25 conference call was issued by me to the parties' counsel on April 1, 2003. That memorandum confirmed that with the record of exhibits having been completed, the transcript having been fully corrected, and the initial and reply briefs having been received, the hearing record would be considered officially closed as of that date, April 1, pursuant to 6 NYCRR 624.8(a)(5).

SUMMARY POSITIONS OF THE PARTIES

Position of the Authority and Department Staff

The Authority has met its burden of proof that the proposed landfill will comply with all applicable laws and regulations and, therefore, all necessary approvals should be issued consistent with the terms of Department Staff's draft permits.

Position of the Objectors

The Authority has not met its burden of proof with regard to either the hydrogeology or air quality issues that were certified for adjudication and, therefore, Department permits should be denied. In lieu of denying the landfill permit, the Department should find that additional site work, including a pump test, is reasonably necessary to make determinations on the hydrogeology issues.

ISSUE NO. 1 - - HYDROGEOLOGY

Scope of the Issue

Issues concern the adequacy of the Authority's hydrogeologic investigation, the possibility that the project site overlies a principal aquifer, the characterization of the critical stratigraphic section (which bears on the ability to monitor any contaminants that might escape from the landfill), and the potential of the groundwater suppression system to facilitate leachate migration. Also, with regard to wetland impacts, issues concern the effect of the groundwater suppression system on the water table and the effect of the leachate collection system on area hydrology. (The sub-issue concerning the effect of landfill construction on area flood flows, and the possible loss of flood control values, was not adjudicated after being withdrawn by the Objectors at the start of the hearing.)

Position of the Authority

According to the Authority, the critical stratigraphic section has been properly characterized as including all geologic units at the site, each of which would be adequately monitored under a comprehensive plan if the project is approved. The Authority contends that groundwater modeling undertaken on its behalf was appropriate and reasonably represents site conditions. The Authority argues that bedrock at the site would not provide a rapid migration pathway for contaminant flow, and that streams at the edge of the landfill footprint are gaining (that is, receiving groundwater flow), rather than losing water into their beds.

The Authority claims that evidence presented at the adjudicatory hearing reconfirms Department Staff's initial determinations that site WLE-5 East does not overlie a principal aquifer and that a deep sand/till unit in the footprint subsurface (in which the Objectors claim the aquifer exists) is confined by thick layers of till. Conducting a pump test or any additional testing in this unit or elsewhere at the site is not reasonably necessary or technically justifiable, the Authority asserts.

According to the Authority, the operation of the groundwater suppression system proposed for the site would not facilitate leachate migration and would not negatively impact state-regulated wetlands in the southwest corner of the landfill site, which it says are primarily dependent on precipitation and surface water runoff.

<u>Position of Department Staff</u>

Department Staff's position with regard to the hydrogeology issues is essentially identical to that of the Authority.

Department Staff concur with the Authority's characterization of the critical stratigraphic section and views the Authority's groundwater modeling as a reasonable representation of site conditions. Staff finds that the Authority's modeling results are consistent with reported and observed field conditions and provide a reasonable basis for the Authority's groundwater monitoring plan, which includes upgradient and downgradient wells in each layer of the critical stratigraphic section. Department Staff reject Objectors' claim that contaminants would travel rapidly into and through the deep sand/till unit.

Department Staff reaffirm their prior determination, made early in this project's development, that no principal aquifer exists at the site. According to Department Staff, the low permeability of the glacial tills above the deep sand/till unit precludes that unit from being highly vulnerable to contamination. Staff also maintain that the limited potential for recharge to the deep sand/till unit, and the variability of deposits in the unit, prevent the unit from having sufficient sustainable yield to be a principal aquifer.

Department Staff maintain that the groundwater suppression system provides an additional level of monitoring which would allow a break in the liner to be detected soon after it occurred. Staff rejects the Objectors' claim that excavation for this system would expose macropores and fractures in the underlying tills and thereby facilitate the downward movement of contaminants. In fact, Staff claim that if a leak occurred, the groundwater suppression system would intercept the leachate and conduct it along a path of least resistance to the outlet or discharge point of the system.

Department Staff agree with the Authority that the radius of influence of the groundwater suppression system would not extend significantly beneath wetland areas west and south of the footprint, and that precipitation and other sources of surface water would sustain these wetlands even if the project reduces the amount of groundwater entering them.

<u>Position of the Objectors</u>

According to the Objectors, the Authority has not met its burden of establishing that the proposed landfill would not overlie a principal aquifer. The Objectors claim that data from the Authority's site investigation indicate that there is a high rate of groundwater flow into an aquifer located in a bedrock valley buried beneath the site, and that this aquifer is capable of transmitting large volumes of water. The Objectors assert that the Authority's own data show that the water table in the buried valley aquifer rises strongly and rapidly in response to heavy precipitation and decreases rapidly during drier weather. Furthermore, they claim that the data indicate there are pathways by which contaminants could reach the aquifer through the tills overlying the aquifer and the bedrock surrounding the aquifer. Overall, the Objectors argue, the buried valley aquifer drains groundwater moving through the sediments and bedrock in the site subsurface.

The Objectors assert that the Authority's claims that the aquifer receives little groundwater and is protected from contamination by low-permeability sediments are contrary to the bulk of data collected at the site. According to the Objectors, the Authority has placed undue reliance on small-scale permeability tests which are mere snapshots of tiny fractions of soils and rock, and failed to capture the large-scale characteristics of the site hydrogeology. The Objectors point out that the Authority has consistently refused to conduct a pump test which they claim would eliminate any uncertainty as to whether the buried valley aquifer is sufficiently productive to qualify as a principal aquifer and whether it is fully protected from contamination by the overlying sediments. The Objectors claim there is already ample evidence showing that the buried valley aquifer meets standards the Department has developed to define principal aquifers, and that Department Staff's prior determination that it does not meet these standards was based on an inaccurate site portrayal provided by the Authority. The Objectors assert that the Authority's testing seriously underestimated the permeability of site deposits and violated industry standards with regard to sample collection and laboratory procedures as well as data interpretation.

According to the Objectors, the Authority has failed to properly characterize the critical stratigraphic section in light of evidence showing that contamination from the landfill would travel rapidly through the buried valley aquifer toward Boonville. Furthermore, the Objectors assert that, due to various flaws, the Authority's groundwater model does not accurately depict groundwater flow at the site. The Objectors claim that the model results are based on excessively low hydraulic conductivity inputs and an excessively low recharge rate, and depend heavily on the failure to include most of the bedrock beneath the site in the model domain. They state that the model is not reliable because it was not properly calibrated, and is invalid because its results do not match the actual site data. Finally, they assert that the groundwater model is inappropriate for this site because the model does not accommodate unsaturated conditions that exist within parts of the deep sand/till unit.

According to the Objectors, the groundwater suppression system would accelerate the rate at which contaminants would migrate from the landfill to the buried valley aquifer, and would draw down a near-surface water table, thereby removing groundwater that is essential to state-regulated wetlands near the site's southwestern corner. Finally, the Objectors claim that the proposed environmental monitoring system is inadequate to the extent it is based on mistaken assumptions about groundwater flow pathways.

In lieu of denying the landfill permit, the Department should direct that the Authority perform additional site testing, the Objectors argue. On issues involving the buried valley aquifer, they say this testing should include the following:

- - A pump test capable of gauging the productivity of the buried valley aquifer over a large area;

- - Geophysical testing to determine the aquifer's extent and path, particularly downgradient to the east, in the direction of Boonville; and

- - Tritium testing of groundwater in the aquifer and the overlying deep gray till, to assess the alleged confinement of the aquifer.

With regard to the site's bedrock, the Objectors propose that the Authority be required to do borehole geophysical testing to identify water-transmitting fractures, followed by packer testing to quantify the fractures' hydraulic conductivity and transmissivity.

FINDINGS OF FACT

- - Project Description

1. The Authority proposes to construct and operate a long-term, full-service sanitary landfill at Site WLE-5 East, which is located on the south side of State Route 294 and west of Gleasman (formerly Germanski) Road in the Town of Ava, Oneida County. The landfill has a design capacity of 1000 tons of solid waste per day, and a planned life expectancy of 62 years.

2. The proposed landfill site consists of more than 685 acres. The landfill footprint would occupy 150 acres of a 252-acre construction zone. Included in the construction zone would be an access road, leachate storage tanks, stormwater detention basins, a sediment control system, and other support facilities. More than 400 acres of the site would remain in a natural state and serve as a buffer, portions of which would be used for wetland creation and the construction of five small ponds for spotted salamander habitat. (A project site map showing the landfill footprint and other project features, and identifying property owners as of August, 2002, was received as Hydrogeology Exhibit 2.)

3. The highest elevation within the site occurs in a broad, sloping plateau located in the site's western portion. From this area of highest elevation, the land surface across the majority of the proposed development area slopes gradually to the east towards the south branch of Moose Creek. Elevation of the land surface ranges from about 1,480 feet above mean sea level in the western portion of the development area to 1,360 feet above mean sea level along the south branch of Moose Creek.

4. Slopes across the site typically average five to six degrees, with greater slopes associated with drainage swales located in the eastern half of the proposed development area, and a steep-sided ravine (occupied by Tributary No. 14 of the south branch of Moose Creek) in the northern portion of the development area. A number of the small drainage swales and relatively flat low-lying areas throughout the site are occupied by federally regulated wetlands, some of which are also part of the state-regulated wetland WL-2.

- - Leachate Generation, Management and Removal

5. Water percolating down from the surface of the landfill footprint would create leachate as it comes into contact with and passes through the underlying waste mass. Leachate contains contaminants that pose a threat to surface water and groundwater if the leachate is allowed to escape through the liner system at the bottom of the landfill.

6. The Authority plans several measures to minimize the generation of leachate, including:

- - Construction of an earthen berm around the landfill perimeter to minimize surface water runoff into active disposal areas;
- - Phased construction of landfill cells;
- - Minimization of the landfill's working face;
- - Placement of intermediate soil cover, establishment of vegetation on inactive areas of the landfill working face, and diversion of runoff into stormwater detention basins located around the site perimeter;
- - Construction of surface water diversion berms to prevent clean surface water from entering the leachate collection system;
- - Removal of snow from waste disposal areas, to the extent practical; and
- - Capping of closed portions of the landfill with low-permeability soils (or an equivalent cover system approved by the Department).

7. Leachate created within the landfill waste mass would move into a leachate collection and removal system. That system would be an integral part of the double composite liner system which is meant to separate the leachate from the groundwater moving beneath the site. The double composite liner system consists of two separate composite liners, one constructed above the other. Each composite liner would consist of a leachate collection and removal system underlain by a composite of low permeability soil and high-density polyethylene

geomembrane. The leachate collection and removal system would direct the flow of leachate to pump stations from which the leachate would be pumped into storage tanks. The leachate would then be trucked to an off-site wastewater treatment plant for disposal.

8. The performance of the primary composite liner system would be monitored on a daily basis, by measuring the amount of leachate collected in the secondary leachate collection system. Groundwater discharged from the groundwater suppression system would also be tested to ensure that the liner system is functioning properly. Finally, a network of groundwater monitoring wells would be installed at the landfill site. These wells would be sampled and tested quarterly to provide another way to determine whether the landfill's liner and leachate collection systems are working as intended.

9. In an average year, Site WLE-5 East receives about 58 inches of precipitation. The average amount of leachate that would be transported offsite for disposal would be about 9,633,000 gallons per year. That amount represents about 1.15 percent of the 58 inches of precipitation that would fall in an average year over the 532-acre development area. Stated another way, it represents about two-thirds of an inch of precipitation in an average year, and less than .002 inches on an average day. The loss of water resulting from the offsite transportation of leachate would be well within the range of year-to-year precipitation changes normally experienced by the site.

10. Site WLE-5 East is located in the 13,660-acre Moose Creek drainage basin and in the uppermost reach of a 1,697-acre sub-basin of the south branch of Moose Creek. This sub-basin represents the drainage area of the south branch of the Moose Creek defined by the location at which it exits the Authority's site.

11. Assuming average annual precipitation of 58.04 inches, the off-site transportation of an average of 9,633,000 gallons of leachate per year represents, for an average year, about 0.04 percent of the precipitation that would fall on the entire drainage basin and about 0.36 percent of the precipitation that would fall on the sub-basin. Stated another way, the leachate transported offsite would represent less than 0.03 inches of precipitation from the entire drainage basin in an average year (i.e., about 0.00007 inches of precipitation on an average day), and about 0.2 inches of precipitation from the sub-basin in an average year (i.e., less than 0.0006 inches of precipitation on an average day).

12. Operation of the leachate collection and removal system would result in the diversion of less than one and one-half percent of the precipitation falling within the drainage area of the south branch of Moose Creek, defined by and including its confluence with Tributary No. 14 on the north side of the site. This removal of surface runoff from the streams and wetlands on the site perimeter would minimally change the amount of fresh water entering the system, considering that five tributaries and the main channel of the south branch of Moose Creek all enter the WL-2 wetland from the south or west side of the wetland.

- - Drawdown Impacts of Groundwater Suppression System

13. The Authority's project design includes a groundwater suppression system that would be developed under the double composite liner system throughout the landfill footprint to prevent groundwater from contacting and interfering with the liners. There is a groundwater surface that is less than five feet from the base of the proposed liner system in certain areas of the landfill footprint. This is caused by the generally low permeability of underlying deposits in these areas. The Department requires a minimum separation of five feet between the bottom of the liner system and the seasonal high groundwater elevation, but allows for a reduction or waiver of this separation distance if a groundwater suppression system is installed underneath the liner system. [See 6 NYCRR 360-2.13(d).]

14. The groundwater suppression system proposed by the Authority would consist of a six-inch thick Type "C" select fill layer with a minimum permeability of 1×10^{-2} centimeters per second (cm/sec). The system would drain groundwater away from the bottom of the liner system to ensure that groundwater pressure would not damage the liner.

15. At landfills constructed with composite liner and leachate collection systems, if the water table is allowed to rise through the soil component of the landfill system, it can result in "floating" of the geomembrane liner, resulting in a separation of the geomembrane from the liner's soil component. The period of concern is the construction phase of the landfill, before the geomembrane has been adequately weighed down by placement of overlying drainage system materials, additional liner construction materials, and solid waste. The high-permeability of the fill in the groundwater suppression system is intended to promote rapid lateral movement of groundwater from beneath the landfill and prevent contamination that would occur if groundwater were able to mix with the waste mass.

16. In response to comments submitted by Department Staff on the DEIS for this project, the Authority modified the landfill design to reduce the depth of excavation in the southern half of the landfill footprint and to provide for a gravity flow or "daylight" groundwater suppression system which will not require the use of pumps to remove collected water.

17. With exceptions in the northern part of the footprint where the system would be above the water table, the groundwater suppression system would draw down the near-surface water table in the vicinity of the landfill footprint, as groundwater flows into the system in that area. Because of the generally low horizontal permeability of the near-surface soils, the amount of groundwater moving into the system would be limited, as would the area of drawdown.

18. In situations where groundwater now discharges to onsite wetlands, the lowering of the water table by the groundwater suppression system would reduce the rate of groundwater discharge to the wetlands. This could eliminate the flow of groundwater to wetlands in those areas where the water table declines beneath the land surface. When the landfill is fully built there would be a two-foot drawdown of the water table in some portions of state-regulated wetland WL-2 in the western and southwestern portions of the site, closest to the landfill footprint, and a lesser drawdown in other parts of the wetland farther from the footprint in these directions.

19. The modest drawdown of the water table beneath portions of the wetlands in the western and southwestern portions of the site would not have a significant impact on the wetlands in those areas. That is because the wetlands primarily depend upon precipitation and surface runoff from adjacent areas for the water that sustains them. This situation would not change during and after landfill development.

20. Though some groundwater from beneath the landfill footprint does flow westward and then upwell into these wetlands, groundwater recharge to the wetlands is negligible in comparison to the amount of water that sustains the wetlands directly through falling precipitation. (As noted above, the site receives about 58 inches of precipitation in an average year.)

21. The soil composition of the wetlands provides further indication of the wetlands' use of precipitation and surface runoff for its water resources. A very dense clay layer exists within six inches to one foot of the wetland surface. This clay layer effectively traps surface water runoff and direct

precipitation. The soils at the site are very poorly drained and water readily pools on their surface. Precipitation falling on the wetlands during the growing season is retained for a sufficient period of time in the topsoil layer to maintain the area's wetland characteristics.

22. Wetland WL-2 in the western and southwestern portions of the site has developed largely because the underlying soils are so clayey that they drain very poorly. The wetland contains a mixture of vegetation types (all very common to wetlands in upstate New York) including mud flats in what used to be a beaver pond, as well as scrub-shrub, emergent, evergreen and mixed forest wetlands. A stream flows from south to north through the area; later, that stream flows east along the northern part of the landfill site before discharging to the south branch of Moose Creek.

23. To the extent that the groundwater suppression system would lower the water table in wetland areas, the natural process of capillary action would continue to move water upward from the water table to the roots of wetland vegetation. In fine-grained materials like clay and silt which underlie the wetlands, water can move up distances of ten to twenty feet, making a two-foot drop in the water table insignificant.

24. Wetland vegetation depends not only on water but the nutrients that are carried in the water. While groundwater is a source of these nutrients, so is rain falling on the site. Once the rain strikes the clayey soil, it begins to dissolve the soil. Because the soil is fine-grained, the rate of reaction is rather fast, increasing the concentration of dissolved substances fairly quickly.

25. Even for plants associated with calcareous groundwater discharges, such as many identified in these wetlands, the removal of groundwater due to project-related drawdown would not present a problem, since the clayey wetland soils themselves contain calcium carbonate. Rainfall striking and then percolating through these soils, even at shallow depths, would be adequate to dissolve enough calcite to create the environment these plants need.

26. The landfill, including the groundwater suppression system, would be constructed in phases. There would be no construction of the landfill footprint or the groundwater suppression system in the southern and southwestern portions of the site until at least 40 years after the commencement of operations, meaning that any drawdowns outside the footprint in

these areas would be associated only with late stages of the project. Moreover, over the life of the landfill, the Authority, both by permit condition and by commitments made in the Department permit review process, would be monitoring wetlands that are not displaced by construction. Special condition No. 3 in the federal wetland permit requires submission of monitoring reports not later than December 31 for the first five years following construction.

27. In addition, in a formal response four years ago to comments of Department Staff, the Authority indicated that wetlands along the landfill perimeter would be visually inspected on an annual basis in conjunction with other on-site monitoring efforts, to determine if a change in wetland conditions has taken place. The Authority pledged that if it appeared that the wetland status of a particular area was changing as a result of landfill-related activities, a more intensive investigation would be performed. The Authority wrote that it would advise the Department of any apparent changes to state-regulated wetlands and that potential remedial measures would be discussed and, if determined to be appropriate, implemented. For instance, the Authority wrote, additional surface flow could be accomplished by constructing either ditches or low berms, depending on the location of the area and surrounding topography.

28. Consequently, the Authority would have the opportunity to evaluate any potential impacts on the wetlands - - and to undertake appropriate remedial measures - - several decades prior to the construction of the groundwater suppression system near the wetland areas west and southwest of the landfill footprint.

29. Finally, as part of the landfill's stormwater management design features, much of the surface flow at the site would be directed to two stormwater detention basins outside the landfill footprint - - one to the west and one to the southwest - - and these basins would discharge collected water to the wetlands in those areas, thus supplementing the water the wetlands would continue to receive from direct precipitation.

- - Surficial and Subsurface Geology

- - Unconsolidated Deposits

30. The surficial geology of the site is primarily glacial till, with exposed shale bedrock and alluvium (sand, gravel and silt deposited by moving water) which occur in the steep-sided ravine to the north of the proposed footprint. The

surficial till is brown in color and contains both fine-grained and coarse-grained matrix material. The fine-grained material is silty and the coarse-grained material is comprised of various amounts of sand and gravel. The brown till is exposed along the walls of the ravine to the north of the footprint, as well as at various locations along Moose Creek. Shale bedrock is also exposed along the streambed of the unnamed tributary located within the ravine, as well as along the lower 15 feet of the ravine walls above the stream.

31. Overburden deposits at the site, from the land surface downward, are designated as brown till, gray till, and deep sand/till. The overburden deposits occur within and atop a buried bedrock valley that is oriented in a generally northeasterly direction beneath the site. Thickness of the overburden deposits ranges from about 10 feet in the northern part of the site to over 263 feet along the axis of the buried bedrock valley in the southern portion of the site.

32. Till is a poorly sorted, compact to dense assemblage of silt, clay, sand, gravel and cobbles. The matrix, or fine-grained portion of the surficial brown till, is typically composed of clayey or sandy silt. The thickness of the brown till is typically in the range of 5 to 15 feet. In the northwest portion of the site where the depth to bedrock is in the range of 10 to 14 feet, the brown till directly overlies bedrock. In all other areas of the site, the brown till is underlain by and in contact with the gray till. There is a shallow water table in the brown till, reflecting the generally lower permeability of the gray till in comparison to the brown till. Within the northern half of the footprint, this shallow water table slopes towards Moose Creek and its unnamed northern tributary. The color of the brown till reflects the effects of oxidation due to its location near the surface. (The gray till does not show these effects.)

33. In general, the gray till has a silty clay to sandy silt matrix, with varying amounts of sand and fine gravel within the otherwise fine-grained matrix. The gray till is typically more dense and of lower permeability than the brown till, and does not exhibit the effects of weathering because of its depth. The gray till is also generally less variable than the brown till with respect to grain size distribution, moisture content and density. The thickness of the gray till generally increases from north to south across the site, reaching a thickness of 190 feet in the south-central part of the site before thinning again to less than 60 feet in the southern part of the site. The increasing thickness of the gray till in a

north-to-south direction coincides with a pronounced increase in depth to bedrock in the area of the buried bedrock valley.

34. The gray till is stratigraphically underlain either directly by shale bedrock in the northern and southern portions of the site, or by an intervening deposit of sand interlaced with till, which the Authority refers to as the "deep sand/till unit." The deep sand/till occupies the buried valley trough which trends west-southwest to east-northeast beneath the south-central area of the site. The buried valley is up to 260 feet deep along its central axis.

35. Materials that comprise the deep sand/till unit range from over 150 feet thick beneath the south-central portion within the axis of the buried bedrock valley, to much lesser thicknesses both north and south of that axis. The materials of the deep sand/till unit are absent in the northernmost and southernmost area of the site, and thus comprise only the deeper portion of the materials filling the buried bedrock valley. The remainder of the materials filling the buried bedrock valley are comprised of the overlying gray till deposits. The width of the buried valley increases in the east-central portion of the site, and the materials of the deep sand/till unit within the buried bedrock valley extend off-site both east and west of the site, though their extent in both directions has not been conclusively established, particularly to the east.

36. The materials comprising the deep sand/till unit are everywhere onsite overlain directly by the gray till unit. The thickness of the gray till deposits overlying the deep sand/till materials ranges from 11 feet in the northeastern portion of the site (outside the area of the proposed landfill footprint) to greater than 180 feet in the south-central area of the site. The deep sand/till unit is bounded on both sides and underneath by shale bedrock.

37. The materials of the deep sand/till unit vary in terms of their lithology, density, hydraulic conductivity, and degree of saturation. They include damp to wet, loose to compact, brown silty sand, with some gravel (including some areas that have a cemented fine-grained matrix), dry, dense, light brown sand with little silt, and gray-brown, black and gray till.

38. Complete saturation of the unit occurs only at elevations below a water level that fluctuates generally in the range of 1295 to 1297 feet. The area of the deep sand/till unit below this level is referred to by the Objectors (and identified in this report) as the buried valley aquifer. The buried valley

aquifer is bounded by the water level (or, as the Objectors call it, the water table) at its top and has bedrock on its sides and bottom.

39. Horizontal groundwater flow predominates in the buried valley aquifer that is incised into the bedrock surface. The horizontal hydraulic gradient in the buried valley aquifer is extremely flat, the maximum measured value being a one-foot decline in head over a distance of 2,625 feet. The prevailing direction of groundwater flow in the buried valley aquifer is generally northeastward. Hydraulic gradients in adjacent hydrogeologic units (the gray till and bedrock), and a comparison of groundwater levels between the units, indicate that the deep sand/till unit is recharged from above by the gray till and from its sides and below by the bedrock.

- - Bedrock

40. The upper part of the bedrock unit underlying the unconsolidated materials is comprised of dark gray to black shale with thin beds of light gray sandstone and siltstone. However, where the bedrock is exposed in a ravine at the extreme northern area of the site (i.e., where the tributary to Moose Creek is incised into the bedrock), bedrock exposures within the walls of the ravine have been weathered to tan color and consist of fractured thin to medium shale beds with horizontal bedding fractures.

41. The bedrock at the site is either of the Whetstone Gulf Formation or in a transitional zone between the Whetstone Gulf Formation and the Utica Shale, which stratigraphically underlies the Whetstone Gulf Formation. There is a valley incised into the bedrock beneath the project site, as noted above. This buried bedrock valley has no surface expression at or near the landfill site, being entirely filled with glacial sediments. The depth to bedrock varies dramatically across the site, from its exposure at the ground surface in the northern portion of the site, to over 260 feet within the axis of the steep-sided buried valley.

42. Bedrock can vary with depth, with different layers exhibiting different properties. Open, extensive fracturing of the bedrock is more likely where the bedrock is at or close to the surface, than where it is deep under the overburden sediments. Where the bedrock is closest to the surface, it is more likely to be weathered.

- - Monitoring of Critical Stratigraphic Section

43. The Authority has determined that contaminants exiting from the base of the landfill could flow through portions of the four different units discussed above (the brown till, the gray till, the deep/sand till, and the upper portion of the bedrock) during the active life of the landfill (62 years) and 30 years after its closure. Therefore, the Authority has designated these units as the critical stratigraphic section pursuant to 6 NYCRR 360-1.2(b)(47) for the purpose of groundwater monitoring. Monitoring locations for all these units have been fixed downgradient, upgradient and crossgradient of the footprint, based on the Authority's understanding of groundwater flow directions. (The locations of proposed groundwater monitoring wells are shown on Figure 28 of the site investigation report, a large-scale mounted version of which was received as Hydrogeology Exhibit 13.)

44. Based on Part 360 requirements for well spacing, 55 wells are proposed as part of the groundwater monitoring network. This monitoring well network consists of 19 well clusters around the perimeter of the landfill with two to four nested wells at each cluster. There would be 19 wells in the brown till, 24 wells in the gray till, four wells in the deep sand/till unit and eight in the bedrock.

45. In accordance with Part 360, groundwater monitoring to establish existing water quality would be conducted prior to deposition of waste as each new landfill phase is constructed. Over the course of the landfill's life and during the 30-year post-closure period, the monitoring wells would be sampled and the groundwater analyzed for Part 360 baseline and routine parameters in accordance with a schedule described in the Authority's environmental monitoring plan.

46. The proposed monitoring well network would consist of wells spaced 500 feet apart along the northern, eastern and southern perimeter of the footprint. This is consistent with Part 360 requirements for downgradient well spacing, and represents a conservative approach for groundwater monitoring.

47. The only exception to this spacing distance is along the western perimeter of the landfill footprint, where the configuration of the landfill relative to the groundwater flow indicates an upgradient position for the groundwater monitoring wells. Wells in this area would be spaced between 500 and 900 feet apart, still less than the 1,500 feet spacing that is allowed between upgradient wells under Part 360.

48. All monitoring wells would be placed within about 50 feet of the landfill area. In some areas of the landfill, wells would be located within the berm. The placement of monitoring wells as close as practical to the landfill footprint is meant to facilitate early detection of a leachate plume. [See 6 NYCRR 360-2.11(c)(1)(i)(e).]

49. The Authority has designated the brown till as the first water-bearing unit of the critical stratigraphic section. This is appropriate because the brown till is the uppermost geologic material, present at the ground surface over the entire area of the proposed landfill footprint. Although the proposed landfill design involves the removal of the brown till from much of the area of the footprint, portions of the brown till unit would remain in place around the full landfill perimeter. The Authority has proposed monitoring well coverage for the surficial brown till unit for the full footprint perimeter at 19 locations.

50. The saturation of the gray till provides an opportunity for contaminants reaching it to move with and through the groundwater. The Authority has proposed 24 monitoring wells for the gray till unit, at fourteen locations, with two separate depth intervals to be screened at locations where sufficient thickness of the gray till unit warrants a second monitoring well.

51. Fifteen of the gray till monitoring wells have been proposed at nine downgradient locations along the east and south sides of the proposed facility. The spacing between proposed monitoring well locations on the east and south sides of the facility is 500 feet. At six of the locations, on the south and southeast portions of the perimeter, two separate monitoring wells have been proposed, with screening of two separate depth intervals. At the remaining three locations, along the northern portion of the eastern perimeter, one gray till unit well has been proposed due to thinning of the gray till in a south-to-north direction.

52. The remaining nine gray till monitoring wells have been proposed for five upgradient locations on the west side of the facility. Two monitoring wells would be installed at each of four locations along the west side of the southern perimeter of the landfill. At a fifth upgradient location (MW-12G1), a single upgradient monitoring well has been proposed due to thinning of the gray till unit in a south-to-north direction.

53. No gray till unit wells have been proposed for the north side of the landfill due to absence of the gray till there

or because the gray till, where present, lacks sufficient saturated thickness for well placement.

54. One upgradient and three downgradient monitoring wells have been proposed for the deep sand/till unit. The proposed downgradient wells are to be located on the southern portion of the east side of the landfill. Existing monitoring well MW-24DS2, located off the southwest corner of the proposed footprint, would be used as the upgradient monitoring point. This location is on the axis of the buried bedrock valley in which the deep sand/till unit is situated, and is an appropriate location for monitoring upgradient background groundwater quality for the deep sand/till unit.

55. Bedrock monitoring wells have been proposed at six downgradient locations along the northern and northeastern perimeter of the proposed facility, and at two upgradient locations on the west side of the site.

- - Groundwater Monitoring Program

56. The monitoring well system is intended to detect the release of contaminant-bearing leachate which escapes into the subsurface environment. Under the operational groundwater monitoring program, samples would be collected quarterly from the groundwater monitoring network and analyzed three time per year for routine parameters and once per year for Part 360 baseline parameters.

57. If a significant increase above existing groundwater quality values were detected for one or more of the parameters, the Department would be notified within 14 days of the Authority's receipt of the analytical results confirming the increase. If the significant increase were in a routine parameter, the Authority would then sample and analyze the groundwater monitoring network for baseline parameters during the next quarterly sampling round and semiannually thereafter until the significant increase is determined not to be landfill-derived or the Department determines that such monitoring is not needed to protect public health or the environment. If the significant increase is in a baseline parameter, the Authority would initiate a contingency groundwater quality monitoring program within 90 days unless a demonstration could be made that the increase was caused by a source other than the landfill, resulted from a sampling or analytical error, or was due to a natural variation in groundwater quality.

58. Though a monitoring well system is important to groundwater protection, the first line of defense for groundwater protection is the landfill liner system. The liner system would be about five feet thick, containing two separate leachate collection systems and two separate composite low-permeability protective barrier layers. Leachate would be collected by a series of drains and a collection zone placed above the sloped liner surface. Downward migration of leachate into the liner would be minimized by the runoff-inducing slope and high conductivity of the leachate drain materials, which are intended to prevent the buildup of hydrostatic head on the liner. Should the primary leachate collection system fail, the secondary leachate collection system would also serve as a leachate collection and detection system. Both the primary and secondary leachate collection systems would be monitored regularly during the operational and post-closure periods.

59. Monitoring of the leachate collection and removal systems and the groundwater suppression system would be conducted for each of the landfill cells as they are constructed. Monitoring of any particular landfill cell would begin prior to its operation. Leachate samples would be collected on a semiannual basis from the leachate collection and detection systems and analyzed for Part 360 expanded parameters, to characterize the nature of the leachate generated from each phase of the landfill.

60. Additional monitoring would be conducted by collecting groundwater samples from the groundwater suppression system. These samples would be collected on a semiannual basis and analyzed for Part 360 parameters. Monitoring of the groundwater suppression system would begin just prior to the operation of each landfill cell.

61. Surface water samples would be collected from Moose Creek and the unnamed tributary on a quarterly basis and analyzed for routine parameters. On an annual basis, the water samples would be analyzed for baseline parameters.

62. In the event the landfill liners are breached, the groundwater suppression system would offer protection against the subsurface spread of leachate. The system would consist of a granular high-permeability soil layer that would collect groundwater seeping inward toward the landfill footprint except in parts of the far northern portion of the footprint (in cell numbers 1 and 5) where the groundwater suppression system would always be above the high water table. Should leachate migrate through both liner systems, the groundwater suppression system

would collect and remove leachate throughout almost all the footprint area.

DISCUSSION

Introduction

Resolving the hydrogeology issues in this matter requires an understanding of the movement of water over and through the subsurface materials of the landfill site, both as it occurs now and as it would occur in the future should the landfill be built and operated. Rates and directions of groundwater flow must be understood because if leachate were to enter the subsurface environment, the groundwater would carry it. Understanding the patterns of groundwater flow allows one to develop a monitoring plan that would allow for the early detection of a spreading leachate plume, affording time for remediation before there are off-site impacts.

Because hydrogeologic factors are so important to a landfill permitting decision, a complete application for the initial permit to construct and operate a landfill must contain a hydrogeologic report which:

- - Defines the landfill site geology and hydrology and relates these factors to regional and local hydrogeologic patterns;
- - Defines the critical stratigraphic section for the site;
- - Provides an understanding of groundwater and surface water flow at the site sufficient to determine the suitability of the site for a landfill;
- - Establishes an environmental monitoring system capable of readily detecting a contaminant release from the facility and determining whether the site is contaminating surface or subsurface waters; and
- - Forms the basis for the design of the facility and contingency plans relating to ground or surface water contamination. [6 NYCRR 360-2.3(h), 360-2.11.]

This discussion recapitulates the important features of the investigation that resulted in the Authority's hydrogeologic report, the review of that investigation by Department Staff, and the critique of the investigation by the Objectors' chief witness, Dr. Andrew Michalski. (There is also a discussion of the Authority's groundwater modeling, which was done as part of the investigation, and which was critiqued by the Objectors' other hydrogeology witness, Dr. Ying Fan Reinfelder.) The differing conclusions that the parties drew from that investigation - - the Authority and Department Staff on one side, and the Objectors on the other - - are pointed out. As is noted below, the parties disagree on many issues bearing on the proper characterization of the critical stratigraphic section (including the permeability of the various geologic units) and the possibility that the site overlies a principal aquifer (and therefore runs afoul of a Part 360 siting restriction).

Authority's Site Investigation

As explained in Mr. Sanford's testimony for the Authority, hydrogeologic investigations of Site WLE-5 East were conducted over a four-year period beginning in 1993. Initially, a preliminary subsurface investigation was conducted in 1993 and 1994. This was done to evaluate the suitability of geologic conditions relative to the Department's Part 360 regulations and the Authority's siting criteria.

The preliminary subsurface investigation included the drilling and continuous sampling of 20 soil borings and excavation of six test pits throughout the site. The soil boring program also included collection of undisturbed soil samples and determination of soil permeability and other geotechnical properties. The results of the preliminary investigation indicated to the Authority that the subsurface geologic conditions and the permeability of the soil would make the site suitable for the construction and operation of a landfill facility.

A more detailed site investigation was subsequently performed during 1995 and 1996, and included the following components:

- - A literature search to obtain background information on regional and local hydrogeologic conditions in the site vicinity;

- - A survey to locate any municipal, industrial, agricultural, and private water wells within an approximate one-mile radius of the site;

- - A subsurface investigation involving the installation of monitoring wells, the drilling of additional soil borings, the installation of staff gauges and piezometers along Moose Creek and its unnamed tributary, and laboratory geotechnical testing of undisturbed and bulk soil samples collected from monitoring well and soil boring locations;

- - Determination of the elevation and horizontal coordinates of all wells, borings, piezometers and staff gauges;
- - A water quality sampling program consisting of the collection of groundwater and surface water samples from a representative number of locations and analysis of the samples for both expanded and baseline parameters;
- - A groundwater age-dating study involving sampling for tritium;
- - Field testing for horizontal hydraulic conductivity, involving slug tests and pump-out tests;
- - Water level measurements at monitoring well, piezometer and staff gauge locations on a monthly basis from November 1995 to October 1996; and
- - Groundwater flow modeling to evaluate flow patterns as they now exist and as they would change after landfill construction.

The data collected during the investigation were used in preparing tables, cross-sections, and maps that were evaluated, in combination with site observations, to develop an understanding of groundwater movement beneath and around the landfill footprint. According to the Authority, the results of the investigation confirmed that the subsurface conditions were suitable for development of a landfill meeting the requirements of Part 360. The hydrogeologic data, flow modeling, and environmental monitoring plan were presented in a five-volume site investigation report prepared by Geraghty & Miller. (That report, along with other landfill project documents, is incorporated by reference to the hearing record.) Volume I of the site investigation report provides, among other topics, a narrative review of the methodology employed by the Authority (Section 3.0) and the results and findings of the site investigation (Section 6.0).

Data collection methods and protocols were set out in a site investigation plan reviewed by the Department in 1995. The site investigation plan outlined the goals and objectives of the investigation as well as the scope of work to be performed.

According to Mr. Fancher for Department Staff, the methods employed on behalf of the Authority for its site investigation were current, standard, generally accepted procedures, appropriate for the geologic setting in which the site is located. Mr. Fancher also testified that the findings and conclusions of the Authority's investigation were consistent with his understanding of the regional geologic setting.

An elaborate discussion of site hydrogeology is contained in the pre-filed testimony of Mr. Wolfert for the Authority. According to Mr. Wolfert, groundwater flow occurs within both the overburden deposits (both the brown and gray till, and the deep sand/till unit) and the underlying shale bedrock. He says that the movement of groundwater at and in the vicinity of the site is influenced by topography, proximity to Moose Creek and its tributaries, wetland areas, and the "low permeability" of the till setting. Of the 58 inches of average annual precipitation that falls on the site, Mr. Wolfert says that 30 to 35 inches run off to streams due to the low permeability of the soils and the sloping surface topography, another 19 to 21 inches are lost through evapotranspiration, and a relatively small amount, less than one inch up to 2.5 inches per year, recharges the groundwater system. (The Objectors claim that the amount of recharge has been understated.)

According to Mr. Wolfert, there is one water table at the site, and it occurs near the ground surface (generally less than four feet down) within the brown till. He says that the field-observed water level distribution across the site, the results of the tritium age-dating study, and steady-state model simulations of the existing groundwater flow system all indicate that most of the recharge to the groundwater system remains within the brown till and the upper gray till. He adds that groundwater within this shallow system generally moves laterally, discharging to streams and wetlands on-site, though a relatively small portion flows downward to the underlying gray till, deep sand/till, and bedrock.

Mr. Wolfert testified that groundwater movement within the gray till is predominantly downward to the deep sand/till and bedrock, while groundwater flow within the saturated deep sand/till (what the Objectors call the buried valley aquifer) is mainly lateral to the northeast. Mr. Wolfert says that flow within the bedrock moves from areas of higher to lower bedrock elevations mainly toward the axis of the bedrock valley, and that along this axis upward flow from the bedrock to the deep sand/till is suggested by an upward gradient observed at the MW-5 well cluster.

To estimate the speed at which contaminants could move in flowing groundwater beneath the site surface, the Authority calculated the horizontal and vertical permeability of the subsurface deposits. Horizontal permeabilities were determined by in situ slug tests, and vertical permeabilities were determined by laboratory testing of soil samples.

According to Mr. Wolfert, within the brown till, the horizontal permeabilities were deemed to be in the range of 10^{-3} to 10^{-7} cm/sec, with a majority of the slug test results in the 10^{-4} to 10^{-5} range. Horizontal permeabilities within the gray till were calculated as generally one to two orders of magnitude lower than those in the overlying brown till, with a majority of the slug test results in the 10^{-5} to 10^{-6} cm/sec range. (Within the proposed footprint area, the gray till had calculated horizontal permeabilities ranging from 10^{-5} to 10^{-8} cm/sec, with a majority of results in the 10^{-6} to 10^{-7} cm/sec range.)

Slug tests give a rough approximation of horizontal permeability that helps determine whether the tills are tight enough to significantly restrict contaminant migration. Though the Objectors claim that the Authority misinterpreted the slug test data, I find no significant error in the derivation of the Authority's horizontal permeability values, as discussed further below.

The Authority's laboratory testing of soil samples resulted in calculated vertical permeabilities in the range of 10^{-6} to 10^{-8} cm/sec in the brown till, and 10^{-6} to 10^{-9} cm/sec in the gray till (with a majority of the gray till results in the 10^{-7} to 10^{-8} range). These values suggest a high level of impermeability that greatly impedes the downward flow of groundwater. The fact that these values were determined in the laboratory and not in the field may mean that they somewhat overstate the till's impermeability, as discussed below. However, there is no reason to think that any overstatement is significant in terms of the tills' ability to impede the downward flow of water.

Mr. Wolfert testified that the measured values of hydraulic conductivity in the tills conform with literature values in Domenico and Schwartz (1990), which cites values as low as 10^{-10} cm/sec, and Driscoll (1986), which cites values as low as 8×10^{-11} cm/sec. However, as he conceded on cross-examination, typical conductivity values for glacial till vary across eight orders of magnitude, and while the Authority's calculated values are at the "tight" end of the spectrum, other values suggesting much greater permeability would also be typical for such a deposit. This makes accurate testing particularly important.

Mr. Wolfert testified that although the permeability of the deep sand/till unit is higher than that of the overlying gray till, there is very limited recharge to that unit from the overlying gray till and the underlying bedrock. He said that because the hydrologic system always strives to maintain a balance where inflow equals outflow, the very flat gradient in the deep sand/till (what the Objectors refer to as the water table of the buried valley aquifer) is a mechanism to reduce discharge from the unit and thereby balance the limited recharge that the unit receives. According to Mr. Wolfert, the underlying bedrock is less permeable than the deep sand/till and discharges water upward and laterally into the deep sand/till.

Mr. Wolfert claimed that the brown till is saturated below the shallow water table in that unit, the gray till and bedrock are saturated throughout their extent at the site, and the deep sand/till has both saturated and unsaturated portions. Saturated means that all the pore spaces in the unconsolidated sediments (and, for the bedrock, all the pore spaces and fractures) are filled with water, with the water table representing the top of the saturated zone. Conversely, unsaturated means that pore spaces and fractures are not completely filled with water, though they may be partially filled.

Mr. Wolfert testified that the portion of the deep sand/till located along the axis of the bedrock valley is saturated throughout its vertical extent with the exception of the southwestern portion of the site around Well Cluster 24, where the upper portion of the unit is unsaturated while the lower portion is saturated. He said that at Well Cluster 18, where the deep sand/till occurs along the northern wall of the bedrock valley at relatively higher elevations, the unit is unsaturated throughout its vertical extent. Finally, at Well Cluster 3, also located along the northern wall of the bedrock valley, the deep sand/till is unsaturated over at least the upper 26 feet of the unit, Mr. Wolfert claimed.

As noted above in my findings of fact, the Authority designated the brown till, gray till, deep sand/till, and upper portion of the bedrock as the critical stratigraphic section for the purpose of groundwater monitoring. For the upper bedrock, only that portion of it in the northern part of the site was included in the critical stratigraphic section, since it was determined that a hypothetical release from the landfill would not migrate to the bedrock through the thick till in the southern portion of the site, according to Mr. Wolfert.

To determine the critical stratigraphic section, groundwater levels were evaluated and a groundwater model was developed to simulate flow under post-landfill construction conditions. The critical stratigraphic section was determined by considering two scenarios: (1) the projected 62-year active life of the landfill, with the groundwater suppression system operating; and (2) a 30-year post-closure period, with the groundwater suppression system not operating.

The results of the Authority's groundwater modeling exercise are explained in the pre-filed testimony of Mr. Feldman. According to Mr. Feldman, the overall effect of the groundwater suppression system on water levels would be to lower the water table in the brown till by about two to 14 feet at the landfill perimeter, inducing an inward hydraulic gradient and a small amount of groundwater flow toward the groundwater suppression system. Mr. Feldman said that the horizontal component of flow toward Moose Creek and its unnamed tributary would be maintained during the operating life of the landfill. He said a downward component of flow within the gray till to the deep sand/till would also remain; however, most recharge would remain in the shallow groundwater system and discharge to creeks and wetlands.

Authority modeling for the 30-year post-closure monitoring period (with the groundwater suppression system not operating, and the groundwater flow system returning to present-day conditions) indicated that leachate entering the water table in the northwest part of the landfill footprint and around its perimeter would remain in the shallow groundwater system, and move toward Moose Creek, its unnamed tributary, or wetlands to the west of the landfill. Leachate escaping beneath the central part of the footprint generally would move eastward in the gray till toward the axis of the buried valley aquifer. Leachate escaping beneath the southern portion of the footprint would travel only short distances (primarily vertically downward) in the gray till, due to the till's anticipated low vertical permeability. The Authority concludes that some leachate entering beneath the eastern and central portions of the footprint would enter the deep sand/till and move in a northeast direction, but not beyond the footprint boundary. In the northeastern corner of the footprint, escaping leachate would move northeastward, and while some of it would reach the bedrock, it would not migrate past the footprint boundary.

The use of a computer simulation model was proposed by the Authority and accepted by Department Staff in 1996, due to the relative complexity of the groundwater flow regime at the site, involving various units with different hydrogeologic properties. Overall, Mr. Fancher found that the model developed by the Authority to evaluate the groundwater flow conditions was well-supported and employed assumptions appropriate to the conditions present at the site, and produced a reasonable representation of site conditions both as they now exist and as they would be expected to change due to construction of the landfill. Despite the Objectors' critique of the modeling effort, I agree with Mr. Fancher's conclusion.

Buried Valley Aquifer

The Authority's findings regarding surficial geology and the identification of four distinct geologic units within the subsurface (brown till, gray till, bedrock, and deep sand/till) were adopted by Department Staff and went largely unchallenged by the Objectors, allowing my own findings to basically track the testimony of Mr. Sanford and Mr. Fancher. The major difference between their testimony and Dr. Michalski's in this regard relates to Michalski's subdivision of the deep sand/till unit to include what he calls the "buried valley aquifer," with a water table at its top separating the aquifer from dry (or unsaturated) deposits above it over large portions of the unit.

Under cross-examination, Authority witness Mr. Wolfert acknowledged the presence of a valley (or "depression," as he called it) which runs across the bedrock surface beneath the site. He also acknowledged that it may have been created by an ancient river or, at the least, that a river may have flowed through it at some point. Finally, he acknowledged that while the feature's orientation can be determined, at least under the site, its lateral extent is unknown. As part of its preliminary subsurface investigation, the Authority did several borings that located the bedrock surface west of the site, but no borings have been done beyond the site's eastern boundary at Gleasman (formerly Germanski) Road.

Though the existence of the buried bedrock valley is acknowledged by all parties, neither the Authority nor Department Staff accept Dr. Michalski's characterization of a buried valley aquifer. Such a feature does not appear in the Authority's drawings, nor is it described in its hydrogeologic report.

Generally speaking, an aquifer is defined as a saturated permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients. To be considered an aquifer, the unit should be permeable enough to yield economic quantities of water to wells.

The extensive saturation of the deep sand/till unit, particularly at depth, is acknowledged by all the parties. However, the unit's permeability and transmissivity are in dispute, which means there is no agreement about the long-term productivity of wells that could be placed in the unit, and therefore whether an aquifer, properly speaking, exists.

As the Objectors argue in their closing brief, water levels measured in monitoring wells within the deep sand/till (at MW-5DS2, MW-6DS2, MW-7DS2, and MW-24DS2) are all at virtually identical elevations just below 1300 feet above sea level, suggesting the presence of a water table and a saturated deposit beneath it in the same way that the surface of an above-ground river evidences the presence of a water body beneath it. On cross-examination, Mr. Fancher for Department Staff acknowledged that, in portions of the deep sand/till unit that are not completely saturated, there is a water level in the area of about 1300 feet, and that the top of the water could be described as a water table.

The Department's solid waste management facility regulations define an aquifer as "a consolidated or unconsolidated geologic formation, group of formations or part of a formation capable of yielding a significant amount of groundwater to wells or springs." [6 NYCRR 360-1.2(b)(10)]. Though the regulations do not define "significant" in this context, monitoring wells screened in the buried valley aquifer (at MW-6DS2 and MW-24DS2) did produce some appreciable amount of water during development, and the Objectors argue that well developed production wells screened over the entire saturated portion of the aquifer could produce much more. That water was produced, at least on a short-term basis, from monitoring wells screened below the water table in the deep sand/till unit tends to indicate the presence of an aquifer, at least as that term is commonly applied. However, the parties disagree about what type of long-term yield the aquifer could produce, which depends in large part on the amount of recharge it receives.
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According to Mr. Wolfert, the very flat slope of the water surface of the deep sand/till appears attributable to very limited recharge to that unit from the overlying gray till and the surrounding bedrock. To the contrary, Dr. Michalski claims there is plentiful recharge to the buried valley aquifer, and that its almost flat water table indicates the aquifer is highly transmissive, meaning it can move large quantities of water off-site in a relatively short time.

The key conclusions reached by Dr. Michalski in his pre-filed testimony are as follows:

(1) The buried valley aquifer beneath the landfill site is prolific and laterally extensive, fully satisfying Department criteria for classification as a principal aquifer.

(2) Owing to its high transmissivity and water level deep beneath the site surface, the buried valley aquifer has an overwhelming influence on the site hydrogeology, acting as an underground river that drains the bulk of groundwater flowing through the overlying unconsolidated materials and the adjacent bedrock, not only within the landfill site but over large areas along the sides of the buried valley.

(3) The buried valley aquifer is the main water-table aquifer at the site and is vulnerable to contamination due to its lack of confinement.

(4) Downward leakage of water through the brown and gray till to the buried valley aquifer is very non-uniform in character, with water moving along preferential pathways created by sandy zones, macropores and possibly fractures.

(5) Precipitation can reach the buried valley aquifer in weeks or months, and contaminants entering the aquifer could travel at least two to three miles east from the site during the projected life of the landfill and its post-closure period, reaching the western edge of a well protection district area.

(6) The proposed groundwater suppression system, rather than safeguarding against the escape of contamination, would virtually assure that landfill contaminants reach the buried valley aquifer.

In their closing brief, Department Staff argues that the buried valley aquifer is an artificial construct of the Objectors intended to create the impression that there is a principal aquifer beneath the site. Whatever the Objectors' intent, certainly there is a distinction between an ordinary aquifer, or water-bearing unit, and a principal aquifer that, by definition, can produce an abundant water supply on a sustained basis.

Department Staff also argues that the Objectors provide no lithological distinction between what they call the buried valley aquifer and the larger deep sand/till unit. However, as the Objectors respond, the area above the water table, by definition, could not be part of the aquifer; the water table defines the aquifer, not a distinction between the deposits above and below the water table. For the Objectors, the buried valley aquifer is the saturated portion of the deep sand/till which is below the level of the water table, acknowledging that in parts of the deep sand/till, the unit is saturated from top to bottom.

The Authority argues that, properly speaking, the only water table at the site is in the brown till, not, as Dr. Michalski claims, in the deep sand/till unit. This is correct. As Dr. Siegel explained, the water table is the surface and subsurface where all the pore space is saturated with water, and where the pore pressure at the surface is equal to atmospheric pressure. With respect to the upper portions of the deep sand/till unit that are unsaturated, Dr. Siegel explained that there is insufficient recharge in those areas to fill the pore spaces with groundwater. As a result, he said, overpressured air fills part of the confined unit, instead of overpressured water, which explains air blowing from a deep sand/till unit monitoring well (MW-24DS1) in the southwestern part of the site.

Mr. Wolfert acknowledged there is a water level (not properly a water table) in areas where the deep sand/till is not entirely saturated. As he explained in his prefiled testimony, at numerous locations in the deep sand/till unit, the water level surface of the deep sand/till rises into the overlying gray till, creating in those areas conditions of hydraulic confinement. However, he adds, in other locations where the water-level surface is in the deep sand/till, below the contact between that unit and the gray till, the unit exhibits unconfined hydraulic characteristics. In these latter locations, Mr. Wolfert testified, the upper portion of the deep sand/till is unsaturated because the low permeability of the overlying gray till restricts the rate of downward groundwater movement.

In its closing brief, the Authority argues that the it is a "complete fiction" to consider the buried valley aquifer an underground river, as Dr. Michalski has described it. The Authority argues that the deep sand/till unit is more like a tapered finite trough, filled with a "mishmash" of various sediments that, as described by Dr. Siegel, include silty deposits, chunks of till and possibly reworked lake clays. Dr. Siegel argues that to move a lot water as a river does, the deep sand/till unit would have to demonstrate a lateral continuity of high-permeability materials, which it does not. On the other hand, as the Objectors counter, grain size analyses indicate that the buried valley aquifer appears to consist mostly of sand and gravel, which have the capacity to effectively transmit water.

Finally, the Authority argues that the Objectors' claims about the off-site areal extent of the buried valley aquifer are unsupported by factual evidence. In fact, all the parties' arguments on the areal extent of the aquifer are based on inferences, given the paucity of borings west of the site and the absence of borings and other investigation of the subsurface east of the site.

Principal Aquifer Issue

Whether the buried valley aquifer qualifies as a principal aquifer, and the role that aquifer could play in contaminant transport, are key issues in this proceeding. In fact, the first of these issues is a threshold issue affecting whether the project can go forward at all, given a siting restriction at 6 NYCRR 360-2.12(c)(1)(i) which would prohibit this landfill's construction over a principal aquifer. A principal aquifer is defined by regulation as "a formation or formations known to be highly productive or deposits whose geology suggests abundant potential water supply, but which is not intensively used as a source of water supply by major municipal systems at the present time." [6 NYCRR 360-1.2(b)(10)(ii).]

- - Application of TOGS Memorandum

The Department's Division of Water has issued a Technical and Operational Guidance Series (TOGS) memorandum 2.1.3, which is intended to clarify the meaning of the term "principal aquifer" and to establish guidance for determining whether an aquifer may meet that definition. A copy of the memorandum (dated December 23, 1990, and received as Hydrogeology Exhibit 116-C) points out that "highly productive" unconsolidated aquifers which provide, or which have the potential to provide water for large populations and which are "highly vulnerable" to contamination from activities over the land surface directly over the aquifer, underlie only a small portion - - roughly ten percent - - of the state's land area. Such aquifers that are presently being used as sources of water supply by major municipal water supply systems are known as "primary water supply aquifers." Those that are not intensively used for such a purpose are known as "principal aquifers." In the absence of a variance granted pursuant to 6 NYCRR 360-1.7(c), a new landfill cannot be built over either a primary water supply aquifer or a principal aquifer, except in Nassau and Suffolk counties, according to 6 NYCRR 360-2.12(c)(1)(i).

The TOGS memorandum states that, to be "highly productive," a primary water supply aquifer or principal aquifer must have "capability to provide water for public water supply of a quantity and natural background quality which is of regional significance." According to page 6 of the TOGS memorandum, the

Department's Division of Water uses the following guidelines related specifically to the question of aquifer productivity:

- - Area of the aquifer: It should be five to ten square miles of contiguous area at a minimum;

- - Thickness of saturated deposits: Saturated deposits of highly permeable materials should average at least 20 feet through much of the area, with some locations at least 50 feet thick; and

- - Obtainable Well Yields: Saturated yields to individual wells should be 50 gallons per minute or more from sizable areas (two square miles or greater) throughout the aquifer.

The TOGS memorandum states (at page 6) that these are general guidelines that should not be applied rigidly, and that there may be instances where all three need not be met simultaneously. For example, the memorandum continues, there may be situations where the thickness of highly permeable deposits and the ability to produce high yields (e.g., through interconnection with a major surface stream) lead to the conclusion that a particular aquifer is a principal aquifer, even though its areal extent is smaller than the suggested minimum range.

To qualify as a principal aquifer, the overall aquifer yield should be comparable to those of the smaller known primary water supply aquifers. In other words, the aquifer should be able to supply a population of 5,000 to 10,000 people, or a yield of 500,000 to 1,000,000 gallons of water per day. (TOGS memorandum, pages 5 and 6.)

The TOGS memorandum states that, to be "highly vulnerable," a primary water supply aquifer or principal aquifer must be highly susceptible to contamination from human activities at the land surface over the aquifer. Additionally, so that the special policies designed to protect them can be applied fairly and equitably, such aquifers must be generally identifiable based on available mapping if they are to be considered primary water supply aquifers or principal aquifers, according to the TOGS memorandum.

The TOGS memorandum provides further that:

"Unconfined (water table) aquifers consisting of unconsolidated geologic deposits (a) are the most common type of high-yielding aquifer system in upstate New York, (b) are generally mapped, so that regulated entities and the general public can be provided with at least reasonably accurate comprehensive mapping showing where they exist, and (c) are vulnerable to contamination from the land surface over the aquifer. These aquifers, where they are sufficiently productive, fall within the meaning of "Primary Water Supply Aquifer" and "Principal Aquifer."

"Where a highly productive aquifer is overlain by thick, continuous impermeable deposits and the predominant recharge to the aquifer is from land areas outside of the aquifer area, the aquifer does not fall within the meaning of the terms "Primary" and "Principal".

"Some high yielding aquifer areas are underlain by patterns of geologic deposits which include unconfined permeable deposits in some portions of the area, and less permeable confining layers over the highly permeable deposits in other portions. Often, however, the confining layers are not so extensive, thick, and continuous as to assure that there are not pathways for contaminants to reach the aquifer from the overlying land surface. Where a high-yielding aquifer system exhibits this type of condition and it cannot be shown that major potential contaminant pathways from the land surface do not exist, the Division of Water will treat the system as being an unconfined system (i.e., it falls within the meaning of "Primary" and "Principal")." (TOGS memorandum, pages 3 and 4.)

According to the TOGS memorandum, existing aquifer maps and reports are the basis for preliminary identification of primary water supply aquifer areas and principal aquifer areas. Permit applicants may request that the Department make a determination whether a site for proposed development overlies one of these areas. The request, with supporting hydrogeologic information, should be submitted through the regulatory program having jurisdiction in a particular situation (e.g., for a landfill site, to the Division of Solid Waste). The Department's Division of Water is ultimately responsible for making the formal determination whether a location is within a primary water supply aquifer area or a principal aquifer area. (TOGS memorandum, page 7.)

At the time the Authority was searching for a landfill site and, later, when it was conducting its environmental review and assembling the landfill permit application for WLE-5 East, the site was not mapped or reported by the Department to be within a protected aquifer area. Nevertheless, viewing the principal aquifer question as a threshold issue to considering whether to site the landfill at this location, the Authority, in the early stages of its SEQRA process, consulted with Department

Staff as to onsite work that would be necessary for the Department to determine officially whether there is a principal aquifer within the site's deep sand/till unit. Then, in 1996, the Authority made a formal request for an aquifer determination, using pertinent data collected during Geraghty & Miller's subsurface site investigations.

In this two-volume request (Issues Conference Exhibits 9-Q-1 and 9-Q-2), Geraghty & Miller wrote that the deep/sand till unit found beneath a portion of the site would not meet the above-referenced standards of vulnerability and productivity for a principal aquifer even if the TOGS memorandum were given the most liberal interpretation. Geraghty & Miller reasoned that the "significant thickness" of "extremely low permeability till" that would overlie the sand/till unit after landfill excavation would continue to confine the unit, and that the "very poor" water-yielding capabilities of the sand/till itself preclude it from being classified as highly productive "or anything close to it." (Exhibit 9-Q-1, page 12.)

The Authority's request for aquifer determination was reviewed concurrently by two members of Department Staff, both of whom testified at the hearing: James D. Garry of the Division of Water, and Robert J. Bazarnick of the Division of Solid and Hazardous Materials. In an internal Department memorandum dated November 26, 1996, Mr. Garry agreed with the Authority that the deep sand/till unit "does not meet TOGS 2.1.3 requirements for status as a Principal Aquifer in that it is of variably low permeability, would not be capable of sustaining the high yield typical of a Principal Aquifer, and is, in any case, confined by the overlying low permeability tills. The mapped extent of this unit on-site is less than 1/4 square mile. While it is possible that the unit could extend off-site, it is unlikely to be of five to ten square miles of contiguous area. Regardless, even if a significant areal extent existed, its hydrogeologic characteristics would preclude it from Principal Aquifer status." (Hydrogeology Exhibit 116-B, page 3.)

Mr. Garry defended these conclusions during the adjudicatory hearing, noting also that he was unaware of any instance in which the Department had designated an area as a principal aquifer where the water-bearing unit is overlain by glacial till. As Mr. Garry pointed out, the TOGS memorandum includes a table that provides relevant data for the upstate primary water supply aquifers and several aquifers considered to be principal aquifers. Each of these aquifers, he said, has permeable deposits at the surface, as well as a hydrologic connection to a large surface water body which serves as a huge, ready source of recharge. Each one is unconfined, with “a river or very large stream or something that flows over the aquifer,” according to Mr. Garry. In contrast, he added, the buried valley aquifer at the landfill site is confined by low-permeability till deposits, and has no apparent connection to large recharge source that would allow it to produce an abundant water supply.

Apart from the examples cited by Mr. Garry, the Southern Wallkill Valley aquifer is a good example of a principal aquifer identified by the Department. Covering an area of 14 square miles, this aquifer extends in a southwest-northeast orientation parallel to the Wallkill River from the New Jersey state line northeast to Phillipsburg, New York. Its water-bearing formation consists of glacio-fluvial sand and gravel deposits that are at the surface or semi-confined by overlying silt and clay. An application to site a landfill over the principal aquifer was denied by the Commissioner in 1988, because the Applicant had not adequately considered whether there were reasonable alternatives pursuant to SEQRA. [See In the Matter of the Application of Orange County Department of Public Works, Decision of the Commissioner, July 20, 1988, and attached hearing report of ALJ Andrew S. Pearlstein, particularly page 19 of the report, which contains the aquifer description.] The hearing report in that matter illustrates features of the Southern Wallkill Valley aquifer that differentiate it from the one at the Ava site: large areas in which the aquifer is not confined, and contact between the aquifer and the bed and banks of the Wallkill River, which flows over the aquifer area. Pump tests at the site of Orange County’s proposed landfill indicated that the sustained yields of wells in the aquifer would far exceed 50 gallons per minute, which is not surprising given the aquifer’s direct hydrologic connection with the river.

Mr. Garry was not the only Department witness who testified about the confinement of the buried valley aquifer at the Ava site. On this issue he was joined by Mr. Bazarnick, who testified that the brown and gray till sequences act as a stratigraphically confining layer to the deep sand/till unit and would provide protection to that unit from landfilling directly above it. Therefore, he reasoned, the aquifer in the deep sand/till unit is not “highly vulnerable” pursuant to TOGS 2.1.3, and further consideration of the other TOGS factors (pertaining to productivity) is not necessary to determine that the landfill would not be constructed over a principal aquifer. Mr. Bazarnick acknowledged that there is a water table in portions of the deep sand/till at about 1297 to 1300 feet, above which the deep sand/till is unsaturated. He said this water table is due to the equilibrium of recharge to discharge in deep sand/till unit.

In its closing brief, the Authority argues that the technical determination that Site WLE-5 East does not overlie a principal aquifer was an independent determination of the Department, within the agency's expertise, and involves an issue which, by the wording of the TOGS memorandum, has been reserved ultimately to the Department's Division of Water. To the extent the Authority continues to maintain that Department Staff's aquifer determination cannot be reconsidered in this hearing, its arguments were considered and rejected in my earlier ruling identifying the principal aquifer issue for adjudication. (See pages 24 to 27 of the issues ruling.) This ruling was affirmed by the Commissioner after the Authority appealed from it, which indicates that, from her perspective, Staff's aquifer determination can be reconsidered in light of the evidence presented by the Objectors, who had no avenue for intervention when Staff's determination was made. (Indeed, the Objectors claim in their closing brief that Staff's aquifer determination was based on an inaccurate portrayal of the site by the Authority.)

The issue at this point is whether a principal aquifer exists beneath the site, not, as the Authority argues, whether Staff was arbitrary or capricious in its earlier determination that there is no principal aquifer. The Authority's reliance on Seaview Association of Fire Island v. DEC, et al., 123 A.D.2d 619, 506 N.Y.S.2d 775 (2d Dep't, 1986) for the appropriate standard of review here is misplaced. In that case, the court held that the Commissioner's issuance of a tidal wetlands permit after an administrative hearing, allowing the subdivision of property without requiring an environmental impact statement, was not arbitrary and capricious, absent evidence establishing the subdivision of property alone might have a significant effect on the environment. There, a court was reviewing the final decision of the agency commissioner; whereas here, the agency commissioner is reviewing a determination of her own staff. The Commissioner can and should draw her own conclusion on the principal aquifer issue and not be limited to a review of whether her staff's prior determination was arbitrary or capricious. The issue is not whether Department Staff's determination was arbitrary or capricious, or had a rational basis, but instead whether the determination is correct.

The Authority emphasizes that Staff's aquifer determination was a fundamental and foundational determination in the landfill siting process, and critical to advancing its permit application to completion and finalizing its environmental impact statement. However, as I said in my issues ruling, while I appreciate the Authority's concern for decision-making finality, the principal aquifer issue could have been laid to rest prior to completion of the entire application had the Authority availed itself of the option of conceptual review under 6 NYCRR 621.11. Conceptual review allows project sponsors to receive binding decisions of the Department on particular compliance issues prior to the development of detailed plans, specifications and applications, so that these issues cannot arise later to defeat a project after development expenses have been incurred. (Issues ruling, page 26.) In the Matter of Integrated Waste Systems, Inc., a May 15, 1996 decision of the Commissioner, illustrates conceptual review of a principal aquifer issue in the context of a landfill application. In that case, the Commissioner determined after an adjudicatory hearing, and applying the criteria in the TOGS memorandum, that an aquifer in Cattaraugus County had no reasonable potential to be categorized as a principal aquifer, removing that issue as a possible barrier to permit issuance before any permit application was completed.

As noted above, the Department's TOGS memorandum identifies two criteria, both of which must be met, that qualify an aquifer as a principal aquifer deserving of special protection. Those criteria are (1) high productivity and (2) high vulnerability. I find that the record as a whole demonstrates that, due to its stratigraphic confinement, the buried valley aquifer is not highly vulnerable to groundwater contamination that could result from the landfill project. Also, I find that it is unlikely that the aquifer would satisfy the Department's standard for productivity, noting particularly that the aquifer has no apparent connection to a large source of recharge and therefore would be unlikely to produce an abundant water supply. I make these findings while acknowledging that the overall area of the buried valley aquifer is unknown, due especially to the lack of investigation of the deep sand/till unit as it extends east of the project site. Whatever the unit's size and direction east of the site, I find no reliable evidence that the unit connects with the Boonville municipal well field. The well field, which has been described as a series of interconnected wells which provide the locality's water supply, is of special concern to the Objectors, though it does not draw from a primary water supply or principal aquifer identified by the Department.

- - Aquifer Productivity

As noted above, to be "highly productive," a principal aquifer must be able to provide water for public water supply of a quantity and natural background quality which is of regional significance. (TOGS memorandum, page 3.) Productivity is considered in terms of area of the aquifer, thickness of saturated deposits, and obtainable well yields.

- - Area of Aquifer

The TOGS memorandum states that, to be sufficiently productive to qualify as a principal aquifer, an aquifer should be five to ten square miles in area at a minimum. In the request for an aquifer determination, Geraghty & Miller pointed out that the mapped extent of the deep sand/till unit on-site is about one-quarter of a square mile, meaning that an aquifer in that unit would have to extend for a considerable distance off-site to meet the Department's area guideline. Mr. Garry said it would have extend for a total length of 25 to 30 miles, assuming it maintained the width that it is shown at the landfill site.

Evaluating the Authority's request, Mr. Garry reviewed various regional mapping reports (attached to his pre-filed testimony) and did a drive-through of the area between Ava and Boonville, where the Objectors have argued that the buried valley aquifer extends in a downgradient direction. Mr. Garry acknowledged that the maps he reviewed are of low detail, lacking the quality and quantity of information gathered during the Authority's hydrogeologic investigation, and that the maps provide only general information about the region. Even so, on a 1987 regional surficial geology map (Hydrogeology Exhibit 116-E), the area of the proposed landfill site is shown as till, and there are no contiguous bodies of permeable surface deposits east from the site toward Boonville. Mr. Garry also reviewed a 1988 map (Hydrogeology Exhibit 116-D) indicating potential yields of wells in unconsolidated aquifers in New York State. On this map, by Bugliosi and others, unconsolidated water table aquifers from which yields of more than 100 gallons per minute can be obtained are shown in blue, while similar aquifers from which 10 to 100 gallons per minute can be obtained are shown in green. Also, aquifers of unknown but lower potential and aquifers that are present but are too small to plot are shown by uncolored areas with letter designations. As Mr. Garry points out, the proposed landfill site is not indicated under any of these possible categories, nor is any of the area between the site and the Boonville well field, though the well field itself is part of an area that is highlighted in green.

Mr. Garry said that on his drive-through of the area between Ava and Boonville, he found mostly till hills and no surface expressions indicative of a large continuous aquifer. Even though the aquifer in this case is buried under till, Mr. Garry said it would be "virtually impossible" that it extends from the landfill site to the Boonville area, given an understanding of the geomorphology between those two locations (in other words, by studying the physical features of the land surface to determine their relation to its geological structures). Mr. Garry said that if there were some type of buried permeable material between those two locations, one would certainly see something of it at the surface, because buried valley aquifers (alternatively called buried channels) occur within standard river valleys with walls and stratified materials at their base.

Asked by me what surface expressions would signal a possible connection or extension between the landfill site and the Boonville area, Mr. Garry responded:

"There would be river valley deposits and parallel contour lines showing some feature trending between the two locations... You would see something on the contours of a topographic map indicating that something was going on there." [T: 3242-3243.]

According to Mr. Garry, one "would have to come to some kind of contrivance" to say, as Dr. Michalski has claimed, that there is some type of buried permeable material between Ava and Boonville. [T: 3241-3242.] That, he said, is because the bedrock is extremely close to the surface, if not at the surface in some areas of Boonville, according to a top of bedrock elevation map for the village (Hydrogeology Exhibit 118).

Mr. Garry defined a buried valley aquifer as a bedrock depression created during glacial times that has since been filled with permeable materials and covered over by normally impermeable materials. He said two such aquifers are shown on the Bugliosi map (Exhibit 116-D). They are identified on the map as buried channels, which the map key defines as "stratified drift of unknown saturated thickness and yield potential and overlain by other unconsolidated deposits." One of the channels extends generally from Albany northwest to the Schenectady area, and the other extends generally from Albany north to Saratoga Springs and then Glens Falls. No buried channels are illustrated in the area of the project site.

An excerpt from Fetter's book, <u>Applied Hydrogeology</u>, provides some explanation of how buried valley aquifers were created. According to Fetter, the pre-Pleistocene landscape of the midcontinent was a bedrock erosional surface in which deeply incised rivers drained the land with a well-developed drainage network. During the Pleistocene epoch, meltwaters from continental glaciers flowed across much of the North American landscape, carrying large volumes of sediments. The glacial sculpting of the landscape caused many changes in the pre-glacial drainage patterns. Many of the deep bedrock valleys were filled with sediment including layers of till, lacustrine silts, and clays alternating with well-sorted glaciofluvial deposits which can provide excellent supplies of groundwater. Modern rivers follow the courses of some of the buried channels, whereas other former channels lie inconspicuously beneath the farmland of the Midwest. [Fetter excerpt, Hydrogeology Exhibit 131, page 287.]

The Fetter excerpt provides some support for Mr. Garry's explanation of how buried valley aquifers were created, but tends to undermine his conclusions based on the lack of river valley features at the surface. It appears that, at least in some cases, a buried valley aquifer is undetectable from study of the overlying land surface, and would only be discovered by subsurface investigation, such as the placement of borings. Under cross-examination, Mr. Garry acknowledged that, on the Bugliosi map, there is a mapped aquifer extending from Boonville to the southeast, and another aquifer to the east of Boonville, with a gap between them. He said he did not know how much subsurface investigation had occurred in that gap or between the proposed landfill and these aquifers. While he said it was geologically unlikely that there is an underground connection between the landfill site and these aquifers, he added that one could not know for sure in the absence of further testing (T: 3200).

Mr. Garry said the rolling nature of the till hills suggested to him that the bedrock must also be rising and falling between Ava and Boonville, though, under cross-examination, he conceded that the hills could have been formed by glacial forces that do not depend on the bedrock surface below, meaning that a hill would not always correspond to an elevated bedrock level. In fact, even at the landfill site, the depth of the till varies widely, and the bedrock surface does not mimic the land surface.

Dr. Michalski maintains that, in the downgradient (or eastward) direction, there is no question that the buried valley aquifer extends for several miles before joining another buried valley to form a contiguous system, in the same way that rivers connect with each other on the land surface. According to his pre-filed testimony, the continuous character of the buried valley aquifer system is evidenced by the valley's origin through incision into the bedrock and by the low elevation of the water table in the deep sand/till unit, which he said necessitates a distant point of recharge. Dr. Michalski said that the buried valley must widen and deepen in the downgradient direction, as indicated by the bedrock surface elevations shown on the Authority's own maps, including Figure 22 of the site investigation report (received as Hydrogeology Exhibit 9). Though he added it is "virtually certain" that further exploration of the buried valley aquifer would prove that it is at least five square miles in area, such a claim is more in the realm of speculation than certainty.

Whether or not the aquifer meets the minimum area guideline for classification as a principal aquifer, it appears that it does continue for some distance to the east of the landfill site. Based on its orientation beneath the site, the Objectors conclude that it continues toward or to the north of the village of Boonville. Dr. Michalski testified that if the aquifer did not have a distant outflow to the east, the level of the water table would have risen in the buried valley, possibly even overflowing the valley and rising into the overlying till. Also, Mr. Fancher explained that the dry areas between the bottom of the gray till and the top of the water-bearing layer in the deep sand/till unit are due not only to limited recharge to that unit (something the Objectors dispute), but to the fact that water flows from the saturated portion of the deep sand/till to some undefined off-site location to the east. Mr. Fancher agreed with the Objectors' assessment that if there were no outlet from the site to the east, the deep sand/till unit would fill up like a bathtub and become fully saturated.

Mr. Garry testified that to the north, south and west, the deep sand/till unit terminates against shale bedrock of low permeability. The Authority's mapping of the site subsurface indicates where the unit terminates to the north and the south. To the west, there is some dispute about where the unit ends, though evidence from borings of a generally rising bedrock surface, accompanied by an apparent pinching out of the deep sand deposits, indicate that the deep sand/till unit and the buried valley aquifer may terminate not far from the western site perimeter. For instance, Boring B-22 indicates a bedrock surface elevation of 1295.4 feet, a few feet below the elevation of the water table beneath the landfill site. The deep sand/till unit is only six feet deep at this location, indicating it is thinning out. Though B-22 is the first boring west of the site, and generally in the area where one would expect the deep sand/till unit to extend off-site, the Objectors argue that the axis of the buried bedrock valley likely trends south of the boring, and therefore has not yet been gauged. As Mr. Garry conceded, the contours of the Authority's bedrock surface map (Hydrogeology Exhibit 9) are only inferences based on data points where the subsurface has actually been probed, and therefore are not conclusive about the depth to bedrock at all locations.

Dr. Michalski testified that west of the landfill, the axis of the buried bedrock valley is known to turn due west and extend for a distance of at least 4,000 feet, crossing the topographic divide between the Black River and Mohawk River basins and draining the entire bedrock within the 1.6-mile reach between Route 294 and East Ava Road. Some evidence of an extensive westward continuation of the bedrock valley to the west is provided by the Authority's own bedrock surface contour map (Plate 10) developed as part of the preliminary subsurface investigation of site WLE-5. (See Issues Conference Exhibit 9-N, the preliminary subsurface investigation report.) The contours on this map are roughly inferred from borings that extend west from B-22.

- - Thickness of Saturated Deposits

The TOGS memorandum states that, to satisfy the productivity guideline, saturated deposits of highly permeable materials should average at least 20 feet in thickness through much of the aquifer area, with some locations at least 50 feet thick. In its request for aquifer determination, the Authority conceded that while the deep sand/till unit is sufficiently thick to meet these standards, the unit contains both high and low permeability deposits, meaning that all the materials are not highly permeable, as the TOGS memorandum requires if the feature is to be properly designated as a principal aquifer.

Reviewing the aquifer determination for Department Staff, Mr. Garry wrote that the saturated thickness of the deep sand/till unit ranges from zero to 120 feet. This is consistent with Dr. Michalski's prefiled testimony that the saturated aquifer thickness reaches 120 feet along the axis of the buried bedrock valley. Pointing out that these saturated deposits are primarily sand and gravel, as evidenced by the Authority's soil borings, Dr. Michalski claims that the aquifer has good productivity potential.

Without knowing the overall area of the buried valley aquifer, one cannot discern the average saturated thickness of the aquifer as a whole. However, one can use existing information to infer whether its deposits are highly permeable, at least beneath the landfill site. As the Objectors argue, the saturated deposits consist primarily of sand and gravel, both of which suggest high permeability. But as noted by Department Staff, the deposits also include areas of till and silt, which are low permeability materials. Mr. Garry testified that, based on a grain size analysis of materials in the deep sand/till unit, there are permeable materials in some locations and highly impermeable materials, at least from a water supply standpoint, in other locations, but that in almost all locations the amount of fine-grained materials is large enough to limit the ability of a well to yield significant quantities of water. Likewise, Dr. Siegel testified that materials found in the buried valley are a "mishmash" of highly variable sediment types, some with clay and silt that would tend to clog pore spaces, reduce permeability, and inhibit groundwater flow.

On balance, the Objectors are correct that, within the deep sand/till unit, there are significant areas of deposits suggesting high permeability, in sharp contrast to the confining tills closer to the site surface. For locations within the buried valley aquifer, the Authority's own investigation indicates deposits that are “brown sand and gravel” (MW-5DS1), “tan sand” (MW-5DS2, MW-6DS1 and MW-6 DS2), “gray fine sand to light gray sandy silt” (MW-7DS), and “dense brown silty sand and gravel” (MW-24DS2). A grain size analysis of materials at MW-6DS1 indicates that the great bulk of the material is gravel or sand, with only very small amounts of silt or clay. Likewise, the grain size analysis for MW-6DS2 indicates poorly sorted sand and gravel, with almost no silt or clay. Finally, the grain size analysis for MW-5DS2 indicates sediments that are mostly sand and gravel with very little silt or clay.

Dr. Michalski claims that the materials in the buried valley aquifer are glacial outwash deposited from fast-moving streams that started out beneath melting glaciers. Glacial outwash consists of clean and well-sorted sand and gravel, since the silt and clay, being finer-grained, are swept away for eventual deposition in lakes or an ocean. Dr. Siegel, on the other hand, considers the materials in the buried valley aquifer to be more in the nature of ice contact deposits which he said are laid down in bulldozer fashion in front of stagnant glaciers. Dr. Siegel said that the variety of sediment types within the deep sand/till unit - - including dense silty sand, pockets of clean sand, and chunks of till entrained within silty sand - - suggests that the materials are ice contact deposits. However, he conceded that samples from the area of the buried valley aquifer did not exhibit two characteristics typical of such deposits: extreme range and abrupt changes in grain size, and marked deformation. Dr. Siegel also acknowledged that the bedrock valley in which the deep sand/till is located likely existed before the glaciers came through, and that this valley would have formed a natural channel for glacial outwash to be carried.

Though the source of the aquifer deposits is open to question, what matters with regard to potential water supply is their permeability. In its request for aquifer determination, the Authority wrote that slug tests carried out in wells in the deep sand/till unit resulted in horizontal hydraulic conductivity values ranging from 6.9×10^{-2} cm/sec to 3.92×10^{-6} cm/sec. However, the latter value is from MW-17DS, which was screened above the water table of the buried valley aquifer. Removing that value from consideration and looking solely at the area within the aquifer, the values suggesting lowest permeability are in the range of 5×10^{-4} cm/sec. At the other end of the range, three of seven slug tests produced values greater than 10^{-2} cm/sec, according to the Authority’s reports. This indicates the occurrence within the buried valley aquifer of both high permeability deposits, from which water can be drawn readily, as well as less permeable deposits that would tend to impede water flow.

Dr. Michalski said the Authority, through its interpretation of slug test data, biased the highest-permeability values by about 100 to 200 percent to suggest a lower conductivity than actually exists. However, asked under cross-examination whether he had prepared any calculations which support that conclusion, he said he had not, which makes his claim impossible to verify. Dr. Michalski also said that for the wells showing the highest hydraulic conductivity, slug tends to provide inaccurate results because it takes less than two to three seconds to dissipate a change in water level in the well created at the start of testing, while creating such a change, which is supposed to be instantaneous, takes a comparable length of time. Dr. Michalski says it is a standard professional practice to use pump tests to determine hydraulic conductivity in such permeable deposits, but no pump tests have were performed in the buried valley aquifer.

- - Obtainable Well Yields

Finally, on the issue of productivity, one must consider whether individual wells within the aquifer are capable of yielding water at a rate of 50 gallons per minute or more from sizable areas. In the request for aquifer determination, Geraghty & Miller concluded that 50 gallons or more per well (or anything even close to it) is not obtainable throughout the deep sand/till unit on-site. The request reported that during development of wells screened in the deep sand/till unit (at MW-6DS2 and MW-24DS2, both in the buried valley aquifer), maximum attainable pumping rates were no greater than 6 gallons per minute, using a pump with a capacity of 7 to 8 gallons per minute over 100 feet of head.

The request stated that although the monitoring wells were only two inches in diameter and not designed as production wells, the wells should have yielded up to 7 to 8 gallons per minute if the formation could produce that much water. Geraghty & Miller concluded that the very limited well yields were not related to well construction, but rather reflected the "extremely poor" water-yielding capacities of the deep sand/till unit. Finally, Geraghty & Miller reported that several "dry" wells screened within the deep sand/till unit (above the water table of the buried valley aquifer, at MW-24DS1, MW-18DS, and MW-3DS) reflected low water-yielding capability and unsaturated or partially saturated conditions at those locations.

In his prefiled testimony, Mr. Garry agreed with the Authority that the deep sand/till unit could not sustain the high yield typical of a principal aquifer. Mr. Garry said the failure to detect any water in wells above the water table of the buried valley aquifer reflects a very low rate of recharge from the overlying gray till, though Dr. Michalski said the dry wells instead indicate very rapid drainage through the unsaturated portion of the deep sand/till and the unconfined nature of the underlying aquifer.

In its closing brief, the Authority argues that the "limited" rate of recharge to the deep sand/till unit (estimated on the basis of its modeling as 8.2 gallons per minute), as well as that unit's variable permeability and confinement, all severely inhibit the yield that could be sustained from wells in that unit. Mr. Wolfert testified that the long-term sustainable yield to a production well in the deep sand/till would be only tens of gallons per minute, based on the very low recharge rate to the unit, its low conductivity, and the tightness of the surrounding bedrock. Department Staff argued that a yield of less than 8.2 gallons per minute is most likely, given that the amount of water available for pumping must account for the difference between the amount of recharge received from above and the amount that is discharged naturally through the unit to the northeast.

Contrary to the other parties' assertions, the Objectors argue in closing that the potential yield of the buried valley aquifer greatly exceeds 50 gallons per minute, based on calculations that are part of Dr. Michalski's testimony, and which are based on the Authority's own well development data. As the Applicant acknowledged, when well MW-6DS2 was being developed in the buried valley aquifer, water was pumped from the well for an hour at a rate of 6 gallons per minute while the drawdown in the well was about 0.5 feet. Based on the standard formula in which specific capacity is calculated as the pumping rate divided by drawdown, Dr. Michalski calculated a specific capacity of about 12 gallons per minute per foot of drawdown. Multiplying that specific capacity by the total available drawdown at the well of 85 feet, which is the depth from the water table to the top of the screen, Dr. Michalski arrived at a potential yield of 1,020 gallons per minute, which is more than 20 times the minimum level set forth in the TOGS memorandum.

Dr. Michalski also points to MW-24DS2, which is 2,300 feet from well MW-6DS2. That well was pumped during development for a little more than an hour at a rate of 6 gallons per minute at a drawdown of 1.6 feet. This produces a specific capacity of 3.75 gallons per minute per foot, which indicates that a yield of at least 130 gallons per minute could be obtained from a properly constructed supply well over the 35 feet of drawdown available at this location, according to Dr. Michalski.

Dr. Michalski said in his prefiled testimony that the specific capacity of MW-6DS2 would likely be far greater from a properly constructed and developed larger-diameter supply well. Mr. Garry cautioned that by using a small-diameter well and developing it for a shorter time period than one would for a water supply well, one could understate how much water could be drawn from the well on a per minute basis. However, he added that by pumping the well for only an hour or so, one could at the same time be overstating the yield, because at some point the supply of available water could be exhausted.

The purpose of monitoring wells is to determine water quality and water levels. Monitoring wells are not nearly as wide as production wells, nor are they developed like production wells to get rid of fine materials and thereby achieve the maximum pumping capacity of a formation. As Dr. Michalski testified, monitoring wells have small screen openings and small open areas which may offer greater resistance to flow than the formation itself, though Mr. Schafer said the resistance through the screens is very small. Also, as Mr. Wolfert acknowledged, the submersible Redi-Flo 2 pump that was used in MW-6DS2 was pumping close to its limit of 8 to 8.5 gallons per minute during well development.

Mr. Wolfert said that the Objectors' estimated yield of 1,020 gallons per minute from MW-6DS2 has very little significance because it would be unreasonable to think that one could actually pump anywhere near that much water from the formation. He said it merely represents the short-term yield of a deep sand/till unit that is very heterogeneous, with highly variable lithology including dense and silty sand as well as till. He said that while the well is screened in tan sand, there is a lot of silt nearby, and the specific capacity would have dropped dramatically if the well had been pumped longer and the effect of different, less permeable deposits had been felt. Mr. Garry agreed that specific capacity is not a viable tool to look at in monitoring wells because of their construction and because of the short length of time that they are pumped. He said that the problem with monitoring wells is that one does not know how big the reservoir is that one is pumping. As he explained:

"I think a good way to look at this is, if I filled my bathtub up at home and put a pump in and starting pumping it at one gallon a minute, after 15 minutes I have gotten a foot out...

And then I pump for another 15 minutes, I get another foot out, so I have a specific capacity in my bathtub of four gallons per minute per foot. But then I keep pumping, and there is no more water left. Now, my specific capacity has gone to zero." [T: 3182.]

The Objectors claim that, until a large-scale pump test is conducted, one cannot definitively resolve the question of whether the buried valley aquifer can produce large quantities of water. Mr. Wolfert responds that the Authority considered doing such a test, but concluded it was not necessary in light of the extensive hydrogeologic investigation it did conduct and the perceived variability of the deposits in the deep sand/till unit, based on continuous sampling of soil borings. Mr. Wolfert said that the Authority set well screens in the deep sand/till at what appeared from the soil profile to be the most permeable parts of that unit, and even then the slug tests indicated horizontal permeabilities that varied over four orders of magnitude, suggesting that the unit has highly variable lithology, with not only sand but also appreciable amounts of till and zones where pore spaces have been cemented shut.

The Objectors point out that a buried valley aquifer in Dayton, Ohio, discussed by C.W. Fetter in his book Applied Hydrogeology (excerpted as Hydrogeology Exhibit 131) produces large quantities of water even though it contains interspersed layers of sand and gravel and till. However, as Dr. Siegel pointed out, the Dayton aquifer differs from the one at this site because its materials are highly stratified (unlike those at the Ava site, which are poorly sorted) and have a direct connection to a river system. According to Fetter's book, the Dayton aquifer, described by Fetter as a "classic buried valley aquifer" running beneath the city, consists of permeable layers of glacial drift in a bedrock valley, which are recharged by the infiltration of precipitation, as well as by water from the Miami River and its tributaries. Though the aquifer materials alternate with confining till sheets, the aquifer layers beneath the till sheets are recharged where the till is missing because of either nondeposition or river-channel erosion. Because the till is discontinuous, it does not confine the Dayton aquifer in the same way that the buried valley aquifer at the Ava site is confined. Finally, the Miami River is incised into the sand and gravel aquifer deposits, allowing a good hydraulic connection between the river and the aquifer. Such a connection with a large surface water body, which would afford the recharge necessary to sustain long-term aquifer productivity, is absent at the Ava landfill site.

- - Aquifer Vulnerability

As noted above, to be considered highly vulnerable, a principal aquifer must be highly susceptible to contamination from human activities at the land surface over the aquifer. On the one hand, an aquifer that is overlain by thick, continuous impermeable deposits, and which is recharged mostly from land areas outside of the aquifer area, is deemed not to meet this standard, according to the TOGS memorandum. On the other hand, where confining layers are not well defined and not so extensive, thick, and continuous as to assure that contaminants cannot reach a high-yielding aquifer from the overlying land surface, the Department will treat the system as unconfined, meaning that aquifer may be classified as a primary water supply or principal aquifer. The vulnerability of the buried valley aquifer to landfilling is a key consideration in this case, with the Authority and Department Staff asserting that the aquifer area is confined and the Objectors arguing that there are high-permeability pathways between the land surface and the aquifer.

- - The Case for Confinement

In the request for an aquifer determination, Geraghty & Miller claimed that the deep sand/till unit is overlain everywhere on-site by till ranging from 25 to 180 feet deep. According to Mr. Wolfert's prefiled testimony, the till ranges from 80 to 146 feet deep along the axis of the buried bedrock valley, where the deep sand/till unit is thickest, decreasing to about 40 feet in the central part of the site. Consistent with Part 360, the till's vertical permeability was tested by laboratory analyses of samples, and the till's horizontal permeability was assessed by slug tests in monitoring wells. On the basis of its testing, Geraghty & Miller determined that the till was highly impermeable to water penetration, particularly in a vertical direction.

According to the request for aquifer determination, the thickness and "extremely low" vertical hydraulic conductivity of the gray till, combined with the fact that it completely covers the deep sand/till unit on-site and would continue to completely cover that unit after the landfill is constructed, rule out the possibility that the site contains an aquifer deserving of special protection. Mr. Wolfert confirmed the Authority's position in his pre-filed testimony, stating that the deep sand/till is not vulnerable to contamination because it is overlain by a thick, saturated, tight gray till which geologically confines that unit throughout the landfill site.

The issue of the aquifer's confinement was considered on behalf of Department Staff both by Mr. Garry and Mr. Bazarnick. Mr. Garry testified that he considered the deep sand/till unit "confined by the overlying low permeability tills that exist on site." Mr. Bazarnick agreed. Asked whether the site data indicated whether the deep sand/till unit is confined or unconfined, he replied that all of the data which he reviewed indicated that the unit - - which he placed in a southwest to northeast trending bedrock valley in the central to eastern part of the site - - is confined stratigraphically by low-permeability brown and gray tills. He then elaborated as follows:

"The permeability testing conducted on the on-site tills, as found in Appendix C of the 1996 Request for Aquifer Determination report, indicates that the vertical permeability ranges from 4.97 x 10^{-6} cm/sec to 5.73 x 10^{-9} cm/sec with most data lying within the 10^{-7} to 10^{-8} cm/sec range while horizontal permeabilities range from approximately 10^{-3} cm/sec to approximately
10^{-8} cm./sec. The thickness and low vertical permeability of the overlying tills provides stratigraphic confinement to the more permeable sandy deposits found in the center of this buried bedrock valley. The borings show that the sequences of low permeability till are continuous across the site and that the major sources of recharge to the sandy material in the middle of the buried valley could not come through the overlying tills within the proposed landfill footprint.

"The well and boring logs at the WLE-5 site indicate that the recharge to the permeable deposits is limited in volume and the equilibrium of recharge to discharge causes a water level in the buried sand deposits to be positioned at an elevation below the bottom of the till sequences. This partially saturated condition in the buried sand deposits does not pre-empt the till units from being "confining layers". It means that there is a very limited recharge to the buried sand material in the center of the bedrock valley that is stratigraphically confined." [Bazarnick prefiled testimony, Hydrogeology Exhibit 70, Answer 7, pages 2 and 3.]

Mr. Bazarnick acknowledged on cross-examination that in the center of the bedrock valley, there are permeable sand and gravel deposits, but added that where they are found the overlying till sequences are thickest. He conceded that some small amount of water could reach these deposits as recharge from the surface of the landfill site, but said this only confirmed that the deposits are not "highly" vulnerable from surface activities. Finally, he said that because of unsaturated conditions within the deep sand/till, the unit is not hydraulically confined; if it were, he said, a pressure head would rise up into the confining layer. He then contrasted hydraulic confinement from stratigraphic confinement, adding that while the unit is not hydraulically confined, it is stratigraphically confined, and on that basis he found that it was not highly vulnerable to landfilling.

Part 360 offers two different definitions for a "confined aquifer," one being "an aquifer bound above and below by impermeable beds or by beds of distinctly lower permeability than that of the aquifer itself" (which I interpret as stratigraphic confinement, also referred to as geologic confinement), and the other being "an aquifer containing groundwater whose potentiometric head lies above the top of the aquifer itself" (which I interpret as hydraulic confinement). [See 6 NYCRR 360-12.(b)(35).] An aquifer meeting one definition or the other can be called "confined" according to this subsection; it need not meet both definitions. At any rate, as Department Staff argues in its brief, this subsection is not directly applicable to aquifer determinations under the TOGS memorandum; it merely highlights the distinction between two different types of aquifer confinement. In the portion of the TOGS memorandum discussing aquifer vulnerability, stratigraphic confinement is what matters, as is apparent from the document's emphasis on the permeability of the overlying deposits.

In their closing brief, the Objectors challenge a claim by Dr. Siegel, offered in the Authority's rebuttal case, that the deep sand/till unit is geologically confined everywhere by between 40 to 160 feet of silty and clayey till. According to Dr. Michalski, water leaks through the till and recharges the buried valley aquifer along preferential pathways in the till that are caused by what he describes as hydrogeologic heterogeneities, including sandy zones, high-permeability macropores, and possibly fractures. Based on its permeability testing and groundwater modeling, the Authority claims that it would take centuries for surface water to pass downward through the till. However, Dr. Michalski says that along so-called preferential pathways, precipitation takes only weeks or months to reach the buried valley aquifer beneath the southern portion of the landfill footprint, despite the extensive thickness of the overlying till. Therefore, he says it is an "illusion" that the till is a uniformly low-permeability deposit.

Dr. Michalski's claim of preferential flow pathways that cut downward through the tills was unconvincing. Of the various heterogeneities to which he alluded, only the sandy zones (or sand bodies) could be traced to information in the site investigation report, and there was no evidence that these are extensive or interconnected. Dr. Michalski said there were indications of sandy zones in the Authority's boring logs. In fact, Dr. Siegel acknowledged that the logs do show that the till contains sand stringers, but added that such stringers are lateral in extent (not vertical) and appear only over short distances, since they are encased in the till. Dr. Michalski infers that the sandy zones observed in the boring logs must have some kind of vertical continuity that cannot be discerned from the boring logs, based on various lines of evidence that he says show water moves rapidly from the surface through the tills and into the buried valley aquifer. However, based on my review of this evidence, as discussed below, I find such an inference cannot be supported.

As for so-called macropores and fractures in the brown and gray till, none were observed by Dr. Michalski, though he said that fractures would be difficult to see in the till cores, and he said the macropores, opened by the root systems of long-dead plants, cannot be observed directly but must be inferred from other data.

Dr. Siegel persuasively refuted Dr. Michalski's speculation about macropores and fractures providing preferential pathways through the till. Macropores, Dr. Siegel explained, are generally limited to the upper five feet or so of the soil column. Fractures in glacial till, he added, are limited to the upper ten to twenty feet, and seal off quickly beyond those depths. Based on his review of literature and his own experience, Dr. Siegel testified on rebuttal that fractures in till can be seen as thin lines where the till outcrops at the surface. Where the fractures extend fairly deep, Dr. Siegel explained, they appear as inverted narrow funnels that are open at the top and pinch off at depth. Dr. Siegel said that if there were near-surface fractures in the till, they could be seen in test pits and occasionally in cores, but there was nothing in the test pit or coring information to suggest their existence. If there were any fractures in the gray till, he said they would be appear as linear red features due to the oxidization of iron by recharge water. He added that any fractures that could serve as preferential downward pathways would also have to be wide enough that water could move through them by force of gravity. Again, the site investigation provides no evidence of such fracturing.

Dr. Michalski claimed that high-porosity loess deposits were indicated at certain onsite locations including tills at the MW-3 and MW-17 clusters. According to Dr. Michalski, loess is known to have both vertical fractures and macropores, and the combination of the two gives it greater vertical than horizontal permeability. His claims about loess were convincingly rebutted by Dr. Siegel, who testified that loess is a feature found generally in the Midwest and the Great Plains; in New York, he said, the only place where loess has been clearly defined is the extreme southwestern corner of the state, and perhaps in the Niagara Falls area. Dr. Siegel explained that loess is atmospherically deposited silt, fine-grained material blown by the wind from the front of glaciers during periods of arid climate. Siegel said he could not believe there would be a loess deposit at this site, because the glacial front was there, at the foot of the Adirondacks. What Dr. Michalski described as loess Dr. Siegel said was more likely to be varved glacial lake clays made up of clay and silt layers.

Dr. Michalski's various lines of evidence that the buried valley aquifer is highly vulnerable to contamination from land surface activities, and therefore may be considered a principal aquifer, are evaluated below, along with the responses of witnesses for the Authority and Department Staff.

- - Hydrograph Data

Dr. Michalski said in his prefiled testimony that the response of wells in the buried valley aquifer to precipitation events indicates that the bulk of recharge to the buried valley aquifer occurs within weeks to months, much faster than the Authority or Department Staff acknowledge. Using groundwater elevation and precipitation data from the Authority's own site investigation, Dr. Michalski prepared a hydrograph to illustrate an alleged correlation between monthly precipitation and water levels in wells screened in the buried valley aquifer. [See the first page of Exhibit 7 to Dr. Michalski's prefiled testimony, which is Hydrogeology Exhibit 74.]

As argued by the Objectors in their closing brief, it is apparent that a decline in precipitation from about mid-November 1995 to mid-December 1995 was followed by a decline in water levels from December 1995 to January 1996, and likewise an increase in precipitation in December 1995 was followed by an increase in water levels in February 1996. Finally, the hydrograph illustrates that a pronounced upward trend in precipitation from March through June 1996 was followed by an increase in water levels from late May 1996 through September 1996, and a downward trend in precipitation in August 1996 was followed by a decline in water levels from September 1996 to October 1996.

Dr. Michalski testified that, as seen in the hydrograph, water levels in the wells in the buried valley aquifer respond very well to changes in precipitation, in that the spring rains increased water levels and the drier months in the fall caused a decline in the water table of the buried valley aquifer. This response, he said, means there is an effective hydraulic connection between the shallow groundwater in the till and the buried valley aquifer, and that the Authority has vastly underestimated the percentage of precipitation that winds up recharging the groundwater, which bears on the potential of the buried valley aquifer to produce significant well yields.

The correlation between monthly precipitation totals and the water level in the deep sand/till beneath the landfill site was acknowledged by witnesses for the other parties, though they offered different explanations of it. Mr. Fancher for Department Staff said that water levels in the deep sand/till unit rise with the spring snow melt, which makes more water available for recharge, and subsequently decline in the drier months of summer. However, he said this did not suggest to him that the deep sand/till unit is not hydraulically confined, because it could be receiving water from a source other than the overlying tills. Mr. Fancher said that the change in groundwater elevation beneath the site could be explained by a fluctuation in groundwater levels east of the site. As he explained, if there is a rise in the base level (meaning the level to which water will locally drain), then upgradient water levels (in this case, those to the west) will rise in response. Therefore, he said, it is possible that as water levels to the east go up and down with the weather, water levels beneath the site are affected too.

Dr. Siegel also confirmed that water levels in the deep sand/till unit go up seasonally with snow melts and rain events in the spring, which he said in itself is not remarkable, since groundwater levels in general go up at that time of year throughout the Northeast. Dr. Siegel said that what happens at the site is due to either a rise in the potentiometric surface of the underlying bedrock, or a rise in water levels in the overlying glacial till and the increased pressure it imposes on the deep sand/till unit.

This idea of a so-called “pressure response” was elaborated on by Mr. Schafer, who compared it to the response one gets from a garden hose when the faucet is turned on and water shoots out of the other end. Mr. Schafer said that when precipitation infiltrates the shallow subsurface, heads there build up, increasing pressure that is then delivered through the sediments to the deeper units relatively quickly (within weeks or months) even though the physical flow of water downward through the tills takes "an eternity."

According to Mr. Schafer, responses to precipitation in the form of water level changes in the deep sand/till represent pressure response, not the physical movement of water all the way to that unit from the surface. To further illustrate this concept, he offered the example of a municipal well being pumped. As the pump starts up, an observation well a mile away shows a response within the first minute of pumping, which reflects the pressure being transmitted, not the physical flow of water between the two wells, which takes years to accomplish.

Similarly, Mr. Schafer said it takes centuries for water to pass through the tills from the surface to the deep sand/till unit, while the pressure transmittals occur much faster. Mr. Schafer said there is always flow into the deep sand/till from the adjacent sediments, but it occurs at a slow rate which changes in magnitude in response to pressure differences generated within the hydrologic system.

As was pointed out during his cross-examination, Mr. Schafer's theory of pressure response depends on the confinement of the deep sand/till unit, or, as Mr. Schafer described it, on the unit "being totally clad in tight gray till and brown till and bedrock." If the unit is not so confined (in other words, if the till is leaky, as Dr. Michalski contends), then precipitation would infiltrate the unit directly from above, following the so-called preferential flow pathways described by Dr. Michalski.

The problem with Dr. Michalski's theory is that these preferential flow pathways have not been identified, nor can they be inferred from the hydrograph data, because the data can be readily explained consistent with the Authority's position (which is the same as Department Staff's) that the deep sand/till unit is stratigraphically confined from above. As Department Staff argues in its closing brief, given the number of different possible explanations for water level changes in the deep sand/till unit, it is impossible to conclude that these changes must be due to precipitation moving rapidly through the till.

Dr. Michalski claimed that a two-foot rise in the water table of the buried valley aquifer during the spring of 1996, coupled with a temporary "mounding" of that water table in the southeastern part of the site, can be explained only by heavy spring rains leaking into the unit from above. Dr. Michalski used the hydrograph data to estimate the amount of annual recharge to the buried valley aquifer. According to his prefiled testimony, his estimate of 61 million gallons during a typical year is 14 times greater than the recharge predicted by the Authority's modeling.

Dr. Michalski argued that water table fluctuation is a well-established technique for estimating the rate of recharge to an aquifer. However, as Dr. Siegel cautioned, this technique only works for unconfined aquifers (this aquifer is confined stratigraphically by overlying low-permeability deposits) and near-surface aquifers (this one is deep below the surface). The technique also works best in relation to particular storm events (which are not broken out in the hydrograph data), and to sharp water table fluctuations that occur over, at most, a few days, rather than changes that occur over a period of months.

On the basis of the hydrograph data, Dr. Michalski calculated that between February 28 and May 28, 1996, 20 million gallons of water recharged the buried valley aquifer. However, as Mr. Schafer testified, there were two large errors in this estimate. First, Dr. Michalski used an approximate area of 4.8 million square feet (1,200 feet wide by 4,000 feet long) for the water table of the buried valley aquifer within the project area, neglecting the fact that the water table does not occur continuously across this area, and that instead, over large parts of the area, the interface between the gray till and the deep sand/till unit plunges below the water table level. To account for this, Dr. Michalski should have used a value of 1.7 million square feet, reflecting that portion of the deep sand/till unit where the water table indicates the upper extent of saturation, Mr. Schafer testified.

As Mr. Schafer explained, a second error involved Dr. Michalski's use of a .25 value reflecting the total porosity (or amount of void space) in the sediments, rather than a value of about .05 reflecting their specific yield. Dr. Michalski said the porosity and specific yield of very coarse material (such as clean sand and gravel) are nearly identical, but the deep sand/till unit includes signficant amounts of silt, and its unsaturated areas are not entirely devoid of water. As Mr. Schafer testified, because as the water table rises the sediments into which the water moves already have some water clinging to them, the volume of space available for new water to enter is just a fraction of the materials' total porosity.

Correcting for these two errors, Mr. Schafer said a "ballpark estimate" of the amount of water entering the buried valley aquifer between February 28 and May 28, 1996, would be about 1.4 million gallons, rather than the 20 million gallons calculated by Dr. Michalski.

Dr. Michalski testified that high recharge to the buried valley aquifer beneath the southeastern part of the landfill footprint is indicated by a temporary mounding of the aquifer's water table there during the late spring of 1996. However, Dr. Siegel dismissed the significance of this so-called mounding, pointing out that it reflected only a tenth of a foot difference in head over about 800 feet or so in either direction along the axis of the buried valley. The Objectors argue that mounding is an extremely transient phenomenon in highly transmissive materials such as those found in the buried valley aquifer. However, as Dr. Siegel responds, the mounding indicates nothing about transmissivity, as the variety of sedimentary types in the deep sand/till unit does not indicate any lateral continuity of materials of high permeability.

- - Temperature Data

The Objectors claim that the Authority's water temperature data for the buried valley aquifer also indicate that there are preferential flow pathways from the surface to the aquifer. The Authority performed two rounds of subsurface temperature measurements in 1996 as part of its baseline environmental monitoring. Three of its monitoring wells were completed in the buried valley aquifer (MW-6DS1, MW-6DS2, and MW-24DS2).

Dr. Michalski testified that since the effective perturbation depth of seasonal temperature variations in the subsurface is on the order of 30 feet, generally only very shallow groundwater exhibits appreciable temperature changes in response to such variations. He said that below this depth, at 145 feet and beyond in the three wells screened in the buried valley aquifer, groundwater temperatures should be close to the local mean annual temperature of 42.32 ° F (or 5.7 ° C) unless the recharge and groundwater flow at depth are large enough to produce anomalous groundwater temperatures.

Dr. Michalski notes that on February 7, 1996, the recorded water temperature in well MW-24DS2 (195 feet below the surface) was 5 ° C, lower than the mean annual temperature, which suggests to him that the aquifer was then being recharged by cold winter water. He also notes that on June 6, 1996, the water temperature in this well was recorded as 11.7 ° C, which he said indicates the aquifer was being recharged by warmer water from late-spring storms.

Likewise, between January and May of 1996 the temperature in MW-6DS1 (145 feet below the surface, where Dr. Michalski detected the groundwater mound) increased by two degrees (from 9 ° C to 11 ° C) which Dr. Michalski said was due to the inflow of warm spring water into an aquifer apparently still under the influence of warm-weather recharge from the preceding year. Meanwhile, at MW-6DS2, 210 feet below the surface, the temperature was reported to have dropped during this same period from 9 to 8 ° C. This fluctuation in the deep part of the aquifer confirmed to Dr. Michalski that water was recharging quickly from the land surface, but that its impact was most pronounced near the top of the aquifer, where the inflow occurred.

Responding to Dr. Michalski, Mr. Wolfert said arguments based on temperature readings had to consider how those readings were taken. At this site, Mr. Wolfert said, Geraghty & Miller's general procedure was to purge a well of all standing water with either a pump or a bailer, and then, as soon as the well had recovered enough for sampling, to collect samples with a bailer, bring them to the surface, and carry them to an onsite trailer where temperatures were taken. Mr. Wolfert said that when water is bailed from depths of about 150 feet and more, the temperature of the bailed water will change in response to the bailer being raised through the air column in the well and then in response to the air temperatures at the land surface and in the trailer. He added that due to the way the temperature measurements were collected, they should not be used to make any determinations regarding groundwater recharge.

Under cross-examination, Mr. Wolfert said that because the Authority could not get a steady flow of water from most of the wells at the site (the wells were pumped or bailed dry), in-hole water temperature measurements (which would be taken with a down-hole probe) were not necessary to determine that the wells were being sampled properly. Because of this, he said, water temperatures were not taken right away, and, due to cold weather when sampling was done, samples were taken to a heated van where they would warm before temperatures were measured. My own review of the groundwater temperature data for the period of May and June, 1996, indicates that, in all cases for samples below 30 feet from the ground surface, measured temperatures were significantly higher than the 5.7 ° C local mean annual temperature. Most likely, this merely reflects the warming of water after it was removed from the wells.

The Objectors claim that, despite the Authority's denials, a down-hole probe was used to take at least some of water temperature measurements. For example, an entry in a "water level/pumping test record" prepared for the Authority (and attached to Dr. Michalski's prefiled testimony) indicates that the water temperature for MW-24DS2 was listed in December 1995 as "NR" (which Dr. Michalski interprets to mean "not recorded" or "not registered"), and in the "remarks" column "NR" appears again, along with the notation "150' maximum." Dr. Michalski interprets these entries to mean that a down-hole probe was used for temperature measurements, but because the probe could not go deeper than 150 feet, it could not reach the deeper well screen at this location. Likewise, Dr. Michalski attributes the recorded failure to get a temperature reading at MW-3G to an indication in the record that there was only three-tenths of a foot of water in the well, suggesting that the water was not deep enough for a probe to be useful.

Dr. Michalski was not onsite to observe the taking of temperatures or, for that matter, to observe any other part of the hydrogeologic investigation, and has worked entirely from a review of the documentation growing out of that investigation. Though Mr. Sanford, for the Authority, could not explain the meaning of the entry "150' maximum," he said he did not think it referred to a sampling device that could go down only 150 feet, because the same document records a depth-to-water measurement of 161 feet at MW-24DS2, despite the absence of a recorded temperature. The "water level/pumping test record" form indicates that measurements were done with an "m-scope," which Mr. Sanford called a water level meter. The recorded temperature measurements apparently related to conductivity determinations; where no temperature is recorded, no conductivity is recorded either. As part of the Authority's rebuttal case, Mr. Sanford reasserted that, to his knowledge, a downhole probe was never used to measure temperatures during the site investigation. Because he led that investigation, I see no reason to doubt him on this.

Mr. Fancher, for Department Staff, also testified that temperature readings were taken with a meter at the land surface, but said he did not know how long it was between when the groundwater was sampled in the wells and when the temperatures were taken. In its closing brief, Department Staff emphasizes that it did not rely on the temperature data to determine hydraulic conductivity. The Authority's work plan did not call for collecting the data for that purpose, and Staff argues that to be useful in determining groundwater flow, the data would have to reflect temperatures measured below the surface. Because the temperature data is tainted, I find that it cannot be used reliably to infer the fast flow of water from the surface to the buried valley aquifer.

Dr. Michalski testified that ever since water was recognized as a principal agent of heat transfer in the subsurface, temperature measurements in boreholes and wells have been used to obtain information on groundwater flow and recharge. In fact, pursuant to 6 NYCRR 360-2.11(a)(11), "thermal detection" is one of many methods recognized by the Department as suitable for determining hydraulic conductivity.

In their closing brief, the Objectors argue that, if the existing temperature data are found to be unusable, the Authority should be required to take new temperature readings using in situ recording devices. According to Dr. Michalski, it would not be difficult to take new measurements by lowering relatively inexpensive temperature-recording probes, which could provide more or less continuous data, into the monitoring wells.

Such probes would certainly be useful in getting accurate readings of water temperatures within the landfill subsurface, as the Objectors argue. However, I do not find that additional temperature testing would be useful in this case, which involves the movement of water to the deep subsurface over a period even the Objectors describe as weeks or months. As Dr. Siegel testified, it is implausible to think that water, even water that is moving through fractures or macropores, will maintain the same temperature over such long periods. In fact, as he explained, thermal equilibrium of water with its surroundings occurs rather quickly, so that water moving through the subsurface would fairly quickly pick up the temperature of the surrounding deposits.

Dr. Siegel analogized what happens in the subsurface to what happens when a six-pack of Coke is set outside during a winter party. As he explained:

"I get a six-pack of Coke at room temperature, and in the winter I put it on my back porch when the temperature is cold, 40 degrees or so Fahrenheit, about what you would normally find a constant temperature, say, 40 feet down in the subsurface. . . Now, how long I asked myself does it take to get cold enough to start drinking. Now, a bottle of Coke is a heck of a lot wider than a tiny little fracture in the subsurface. If it takes an hour, two hours, I could even put a hot pie outside and maybe in a matter of six hours this cools down to ambient temperature. . . So the idea that if you have a fracture, a thin little fracture, a millimeter across, maybe even fractures so small you can't see them, that transports water down 160 feet, and it stays in that fracture zone for weeks to months, within that zone where the temperature remains constant, and not to pick up that temperature, is wrong." (T: 3317-3318.)

- - Tritium Data

The Objectors argue that the Authority's tritium testing also indicates there are preferential pathways from the surface of the landfill site to the buried valley aquifer. As explained by Mr. Sanford in his prefiled testimony, tritium is a radioactive isotope of hydrogen with a half-life of 12.3 years, which is present in the earth's atmosphere through both man-made and natural sources. Tritium is produced naturally by the interaction of cosmic-ray produced neutrons and nitrogen. Elevated levels of tritium and many other radioisotopes entered the atmosphere beginning in about 1953 as a result of nuclear weapons testing, which reached peak levels in 1963 and 1964. The resulting atmospheric tritium became part of the hydrologic cycle by precipitation. The parties all agree, and the scientific literature confirms, that tritium which has entered the groundwater system through infiltration of precipitation can be used as a kind of time clock to estimate the groundwater's age.

The scope of the Authority's tritium testing was approved by Department Staff and outlined in the Authority's site investigation plan. As explained in the site investigation report, tritium activity is measured in tritium units. Elevated levels of tritium in groundwater (typically referred to as bomb tritium or modern water) vary locally but generally are in the range of 20 tritium units. Background or pre-bomb levels of tritium in groundwater, where the water has not mixed with post-1953 water, are typically less than one or two tritium units. Consequently, groundwater that contains low amounts of tritium can be inferred to have entered the subsurface prior to 1953, and analytical testing of groundwater samples for tritium can be used to identify groundwater that is older or younger than 1953, and as a check on groundwater velocity calculations.

Two rounds of groundwater samples were collected from monitoring well clusters 18 and 22 in March and June of 1996 for analysis of tritium. (Cluster 18 is in the east-central portion of the landfill footprint, and cluster 22 is in the southwestern portion of the footprint.) Borings for wells installed within the overburden at these two clusters were drilled without adding water or any drilling fluids to prevent the introduction of relatively "younger" tritiated water to the formation, though water had to be added when coring bedrock at well MW-18BR.

Screened intervals of wells in clusters 18 and 22 were reduced to two or five foot lengths to obtain a more discrete groundwater sample. Groundwater samples were analyzed at the University of Waterloo, Ontario, environmental isotope laboratory for tritium content using a technique that has a detection limit of about 0.8 tritium units.

According to Mr. Sanford's prefiled testimony, tritium levels were not detected within the till below a depth of 10 feet at the MW-22 well cluster and below a depth of 20 feet at the MW-18 well cluster. As a result, Mr. Sanford concluded, groundwater below those depths would have entered the groundwater system prior to 1953. The results of the tritium testing, Mr. Sanford said, were consistent with the Authority's characterization of shallow groundwater flow at the site based on its potentiometric surface maps, water level data, vertical hydraulic gradients and hydraulic conductivity data, as well as the Authority's model simulations for the shallow flow system at the site. Dr. Siegel said the tritium results confirm the Authority's assertions about the slow rate of recharge through the brown and gray till to the deep sand/till unit, adding that since that unit is buried by a substantial thickness of low permeability till, it is implausible that the deep sand/till is recharged actively from above in any meaningful way.

According to Dr. Michalski, the testing result for the MW-22 well cluster illustrates a slow-flow regime that he acknowledges to exist in portions of the gray till, and which he said restricts direct downward water flow, particularly at that well cluster where the till is very thick. However, he said the testing result at the MW-18 well cluster illustrates a faster flow regime that he says exists in the northern and eastern portions of the site. At MW-18, tritium levels reflective of post-1953 water were found during testing in both March and June of 1996 at screened depths of two to four feet (MW-18B1) and five to seven feet (MW-18B2) in the brown till, and at screened depths of 10 to 15 feet (MW-18G1) and 16 to 21 feet (MW-18G2) in the gray till. However, at a screened depth of 30 to 35 feet (MW-18G3) in the gray till, tritium was below the detection limit.

Below the gray till at the MW-18 cluster, there was a dry well screened in the deep/sand till unit and then one well, the deepest of the cluster, in the bedrock at a screened depth of 70 to 80 feet from the surface. At this bedrock well (MW-18BR), tritium was recorded at levels of 3.4 units in March 1996 and 1.2 units in June 1996. Dr. Michalski says these results indicate the presence of post-1953 water in the bedrock formation and show that water can travel downward through the site in a relatively short time frame. He testified that the young, post-1953 water in well MW-18BR must have leaked from an overlying perched zone while bypassing low-permeability lenses such as one at MW-18G3, where hydraulic conductivity data indicate the till is very tight.

Dr. Michalski concedes that his view of two different flow regimes in the till - - a slow-flow regime in the gray till of the central and western parts of the site, and a faster flow regime in the northern and eastern portions of the site - - is not shared by the Authority. In fact, the Authority argues that the limited downward movement of tritiated water in the low permeability till at locations where high downward vertical gradients are present, affirms the Authority’s conclusion that these gradients are due to restricted vertical movement throughout the till deposits.

The Authority points out that the tritium levels detected in the bedrock well are well below the 20 tritium unit range that is characteristic of modern water, and attributes them to water that was added during the drilling of MW-18BR. I agree with this conclusion. As Mr. Wolfert explained, water from the surface was added to the well during drilling and coring and some of this water may have seeped into the bedrock formation. Mr. Wolfert points out that the higher value of 3.4 tritium units came from the first round of testing and argues that the second, lower value of 1.2 tritium units is much more representative of groundwater conditions. The fact that no tritium was detected in the deepest gray till well at the MW-18 cluster tends to support the idea that tritiated water was added during drilling and coring, and did not seep down from above.

Dr. Siegel confirmed Mr. Wolfert’s claims during the Authority’s rebuttal case. He said the tritium.data are consistent with tight clay tills, that tritium values in the upper 20 feet or so of the soil column reflect water that may be 40 years old, but that below that depth the water tests below tritium detection limits. According to Dr. Siegel, the tritium values in the bedrock were surely attributable to the inability to fully remove the water that was introduced when the bedrock was cored. Dr. Siegel said it is difficult to purge coring waters to get pure non-impacted tritium readings, since once tritium gets into bedrock fractures, it will diffuse into dead pore space. Even Dr. Michalski, during cross-examination, acknowledged that the fact MW-18BR was drilled with water from the surface could account for the 3.2 tritium unit reading recorded in March of 1996.

In a 1995 memorandum addressing the draft site investigation plan, Mr. Fancher wrote that for the tritium groundwater age-dating, it is essential to remove all fluids introduced during drilling and construction of monitoring well boreholes. (Hydrogeology Exhibit 42, page 9.) Doing so is important, he said, because water introduced to the formation during drilling for lubrication of the drill bit and removal of cuttings from the borehole is modern water, and it can bias the tritium result upward, above what would be representative of the condition within the deposit. Mr. Fancher said that if all the drilling water is not accounted for, a question can arise, as it has in this case, whether the tritium found in the groundwater was introduced during drilling.

Mr. Fancher said that if fresh water gets into a borehole- - in which case he said it can be fairly difficult to get it out - - you can either discard the tritium result or do a second round of sampling later to see if the result changes with time. Here, a second round of sampling was performed, and in fact the tritium value declined significantly, to roughly a background level. This indicates to me that the initial result was attributable to water introduced through drilling. Therefore, I reject Dr. Michalski's arguments that the tritium testing provides any evidence of a fast-flow regime of downward groundwater movement. To the contrary, the tritium testing tends to confirm the relative tightness of the till deposits, and the protection they provide against contamination of the buried valley aquifer.

- - Nitrate Data

The Objectors claim that nitrate levels found in wells MW-6DS1 and MW-24DS2, which are screened in the upper part of the buried valley aquifer, also show that there are pathways through which contaminants could reach the aquifer. In water quality analyses for leachate indicators, the Authority's data indicate nitrate concentrations in MW-6DS1 of 0.6 and 0.64 mg/l (milligrams per liter) in January of 1996 and 0.76 mg/l in June of 1996. Nitrate concentrations in MW-24DS2 were 0.11 mg/l in February of 1996 and 0.1 mg/l in June of 1996. As the Objectors point out, nitrate was detected in only a few wells at the site, including these two and both the brown and gray till wells in the MW-6 cluster. (Nitrate was not detected in MW-6DS2, which is screened in the bottom part of the buried valley aquifer.)

The MW-6 well cluster is located in an area where Dr. Michalski detected a temporary mounding of the water table in the buried valley aquifer during the spring of 1996, which indicated to him there was a particularly high rate of recharge from the land surface. He claims that the detection of nitrate in the buried valley aquifer wells at MW-6 and MW-24 confirm that there are extensive pathways to the aquifer from the land surface, where nitrates can be attributed to agricultural activities. (MW-6DS1 is screened at 140 to 150 feet below the ground surface.) I do not agree with this conclusion.

As Dr. Siegel explained, nitrate at low concentrations (such as those detected here) can occur naturally in uncontaminated aquifers, because all aquifers contain a small portion of organic material within their mineral matrix, and this material contains nitrogen which reacts with the water and is released into it. According to Dr. Siegel, soils developing with organic matter between periods of glaciation became part of the tills at the landfill site, which would explain the detection of small amounts of nitrate in some of the wells screened in the till deposits. While Dr. Michalski finds some significance in the nitrate detection at two wells in the buried valley aquifer, the fact is that the levels are very small, in the parts per billion range, according to Dr. Siegel. Dr. Siegel's opinion was echoed by Mr. Wolfert, who cited documentation of the US Geological Survey (Hydrogeology Exhibit 18) that concentrations of 2 mg/l or less are considered natural background levels for nitrate in groundwater.

Dr. Siegel has been evaluating nitrates in groundwater for the last 30 years - - previously when he was a hydrogeologist with the US Geological Survey and currently in his research programs at Syracuse University. His testimony on the nitrate issue convincingly rebutted Dr. Michalski's claims. Dr. Siegel acknowledged that nitrate is a potential tracer for subsurface water migration, but questioned what conclusions one could draw from the nitrate data here, where concentrations are so negligible.

The Authority points out that nitrates were detected not only in scattered groundwater locations, they were also detected in stream water samples, which would be expected given the site's past agricultural use. What the Authority emphasizes is that at the MW-1 cluster, where the Objectors claim the northern tributary of Moose Creek is a losing stream, no nitrates were found whatsoever, which, using the theory advanced by Mr. Michalski, would suggest there is no influx of water from the streambed to the underlying till.

- - Moose Creek Water Elevation Data

The Objectors claim that Moose Creek and its unnamed tributary are losing water through their streambeds in the northeastern part of the site and that this indicates the "very leaky" nature of the till in this area. Dr. Michalski used a yellow highlighter on Hydrogeology Exhibit 5 (a mounted site map) to indicate the portions of the streams he said were losing water as determined from water level data in Table 6 of the site investigation report.

As shown in the monthly data covering the period between November 1995 and October 1996, in nearly every month in which measurements were taken, the stream water levels at surface water staff gauges MS-3 and MS-4 along Moose Creek were higher than the water levels measured by piezometers in the brown and gray tills at those locations. For example, in January 1996, the water level in the creek at MS-3 was 1363.30 feet above sea level, while the water level in the brown till in that location was 1359.30 feet, and the water level in the gray till was 1359.50 feet In every month for which data are available except December 1995 (in other words, for all data covering January through October 1996), the water level of the creek at MS-3 was higher than the water levels in the brown and gray till at that location. Likewise, at MS-4, further north along Moose Creek, the water level in the creek was higher than the water level in the brown and gray till in most months in which measurements were taken (including all measurements between April and October 1996). Where the water level in the creek was higher than the water level in the brown till, the difference between the two generally was greater at MS-3 than at MS-4; at MS-3, a four-foot difference, the greatest measured, was recorded in January 1996, while at MS-4 the difference was never more than about one and a half feet, recorded in September 1996. (At MS-3, the piezometer in the brown till was dry between June and October 1996.)

During cross-examination, Mr. Schafer for the Authority acknowledged the data showing the comparatively high water levels in Moose Creek in relation to the water levels of the piezometers in the brown and gray till at MS-3 and MS-4. So did Mr. Wolfert in his prefiled testimony. He said that at these two clusters, although monitoring well data indicate that water-table elevations in the laterally adjacent brown till are above the stream stage, the water level of the piezometer in the brown till was slightly lower than the stream stage. He added that this possible localized gradient reversal is most likely due to the increase in stream stage caused by nearby beaver dams.

Mr. Wolfert also addressed a location (US-2) along the unnamed tributary to Moose Creek north of the landfill footprint, where Dr. Michalski also said the stream was losing water into the till. At this location, he said, there was a consistent upward gradient from the gray till to the brown till, but due to the influence of nearby beaver dams, the stream stage elevation was above the water level measurement in the brown till. Mr. Wolfert said that because groundwater cannot converge on a point that is not functioning as a groundwater system discharge boundary (i.e., stream stage above brown till water level), upward groundwater flowpaths (i.e., upward gradient from the gray till to the brown till) would indicate discharge to a nearby reach of the stream that exists at a lower elevation.

Mr. Wolfert pointed to other data and evidence supporting his conclusion that the vast majority of groundwater recharge discharges to Moose Creek and its unnamed tributary (and not through the till to the deep sand/till unit):

- - Visual field observations of groundwater seeps along the channels of Moose Creek and the unnamed tributary;
- - The perennial nature of these streams, which maintain flow during prolonged dry periods due to groundwater discharge, since surface runoff alone could not sustain them; and
- - The limitation on groundwater flow through the brown till and into the gray till by virtue of the gray till's low hydraulic conductivity.

Mr. Fancher's prefiled testimony supports the Authority's view that the unnamed tributary to Moose Creek, on the north side of the site, is gaining flow from groundwater rather than losing flow through the stream bed. He says that the tributary is a predominantly gaining stream, in light of a comparison of groundwater elevations measured in monitoring wells and water levels in the piezometers located next to the stream. Such a comparison, he said, shows that laterally in the direction of the stream, groundwater elevations decrease. In addition, he said, flow within the stream persists during dry periods, and seepage can be observed on the side-walls of the shallow bedrock gorge through which the stream runs.

According to Mr. Fancher, exchange of water between a stream and its bed and bank materials is a normal part of groundwater/surface water interaction, and changes in the relative direction of water movement, both with time and distance along stream reaches, can be expected. There was testimony at the hearing regarding the "step" nature of streams which allows water to move out of a creek and into its bank only to return a short distance downstream. Mr. Fancher said it is simplistic to characterize a stream as being always gaining water or always losing water.

In fairness to the Objectors, they do not assert that Moose Creek or its unnamed tributary are intermittent or predominantly losing streams. Dr. Michalski admits that they flow throughout the year and asserts that they are losing water only in the northeastern part of the site, arguing that this means there are effective flow pathways through the tills in this area through which water can drain into the buried valley aquifer. He admits that there is a shallow perched water table in the brown till and that the water table slopes toward Moose Creek in the northern half of the site, but adds that the water level measurements at Moose Creek at MS-3 and MS-4 and near Moose Creek at well cluster MW-3 show that the groundwater flowing laterally northward toward the creek does not reach it. (The well in the brown till at MW-3 was consistently dry, according to the water level data in the site investigation report, which indicates to the Objectors that water there is draining rapidly through the till to the buried valley aquifer.)

Though the Authority has offered a reasonable explanation of the stream level data, its arguments about the effect of beaver dams on surface water levels would be more effective if the beaver dams had been located with any precision, and if it were known how long they existed. Instead, the hearing record contains only generalized references to these features. Dr. Siegel said the unnamed tributary to Moose Creek proceeds in a step-wise fashion along the northern border of the site, and that beaver dams would have created ponding basins behind them, which would give the appearance of a flow component downward into the streambed. As the Objectors point out, Dr. Siegel could not place the steps or the beaver dams with any precision in relation to the monitoring points for which data were collected; in fact, he was not at the site in 1996, but became involved in this matter only within the last year or so, as a peer reviewer of the Authority's work. On cross-examination, Mr. Schafer said he could not locate where any stream steps actually occur and said he did not know where any beaver dam was in relation to the segment of Moose Creek that Dr. Michalski said is losing water. Yet he admitted that in order to determine whether beaver dams were causing the stream levels in Moose Creek to be higher than in the tills one would have to look at the locations of the dams and the topography over every piece of the creek.

Dr. Michalski testified that without seeing the site at the time the hydrogeologic investigation was conducted, it would be difficult for him to comment on the possibility of beaver dams along the northern tributary to Moose Creek. But he adds that from the Authority's own mapping, shown on Hydrogeology Exhibit 5, the nearest pond on Moose Creek that could arguably indicate the presence of a beaver dam was 400 feet downstream of MS-3 and about 150 feet upstream of MS-4. Though not referenced by the parties, a figure in the general ecology report prepared as part of the application also indicates patches of open water in the northeast corner of the site, some of which are attributed to stream channels expanded by the activity of beavers observed in that environment.

In the absence of better identification of beaver dams and stream steps, the Authority's claims about impacts attributed to these features cannot be verified to a level of certainty. Even so, these features would obviously have a bearing on stream levels. However, while the possibility remains, at least theoretically, that Moose Creek and its unnamed tributary are losing streams at least in some stretches north and east of the landfill footprint, that by itself does not prove there are effective flow pathways by which water can drain all the way through the tills to the buried valley aquifer. For one thing, the areas where Dr. Michalski says the streams are losing water are almost entirely outside the area he has identified as the buried valley aquifer, the one exception being near the MW-3 monitoring cluster. Dr. Michalski claims that there is an extensive unsaturated zone throughout this cluster, which is about 250 feet west of MS-3, where the Objectors claim there is a rapid drainage conduit from the creek to the aquifer.

Addressing the MW-3 cluster, the Authority effectively rebutted the Objectors' claim in their closing brief that wells there are dry for 70 feet through the brown and gray tills. As the Authority argues, the brown till well MW-3B, which is screened from 3 to 11 feet below the surface, is dry because it is completed above the water table at that location. The gray till well MW-3G1, which is screened from 17 to 27 feet below the surface, does contain water, as is indicated in Table 6 of the site investigation report. This well was initially recorded as "dry" immediately after its completion (in November 1995) because the fairly tight soils in which it was located did not readily yield water which took days or weeks to seep into the well and reach equilibrium, Mr. Schafer explained. The next well down, MW-3DS, which is screened from 41 to 51 feet below the surface, is dry because the deep/sand till is unsaturated at that location, according to Mr. Wolfert's prefiled testimony.

The Objectors claim in their closing brief that unsaturated conditions in the gray till in portions of the proposed landfill footprint are indicative of areas of high permeability. However, as the Authority responds, the site investigation shows that the gray till is saturated throughout its extent at the site. As Mr. Wolfert testified, wells completed at all depths within the gray till contain water and produce water when pumped or bailed. If the till were only partially saturated, he added, the pore pressure would be insufficient to make water flow into the well screens.

Asked if he was aware of any well screened in the gray till that failed to produce water, Dr. Michalski referred to MW-9G2 (in the southwestern part of the site) and MW-3G1 (in the northeastern part of the site). In Table 6 of the site investigation report, both wells are listed as "dry" when initial readings were taken (at the end of November, 1995), but have recorded water levels on all subsequent testing dates (from three weeks later through the end of the monitoring period in October, 1996). Also, as the Authority points out, both wells are outside the landfill footprint, outside any vertical pathway contaminants could follow from the landfill bottom to the deep sand/till unit.

- - Coliform In Well Water

The Objectors claim that "excessive" levels of coliform bacteria in a domestic well east of the project site, which the Objectors say receives water from the buried valley aquifer, confirm that there are pathways for contaminants from the land surface to the aquifer. As part of its hydrogeologic investigation, the Authority performed a water well survey to locate any municipal, industrial, agricultural, and private water wells within an approximate one-mile radius of the project site. A survey questionnaire completed by Samuel Deschamps said that his drinking water and residential use well, installed in 1991, had a coliform level "just above limit" and was treated with a chlorinator. Dr. Michalski placed the well one-half mile east of Gleasman Road, east of the project site, downgradient and possibly on the northern side of the buried valley aquifer. According to the questionnaire, the well is 123 feet deep and has a submersible pump about 115 feet from the top of the well.

Dr. Michalski claims that the survey response indicates that contaminants can penetrate more than 100 feet beneath the land surface and enter the buried valley aquifer. However, because the aquifer is not mapped off-site, it is by no means certain that the well taps into the aquifer. Assuming it does, the Authority points out that the coliform level could be attributed to any number of possibilities, including a defective well casing allowing septic system contaminants to enter the well. Department Staff also argues that because most people sample their water at the tap, the possibility of contamination related to the home's plumbing cannot be excluded. Dr. Michalski admitted that he did not visit the Deschamps property or do any testing of his own to verify the property owner's claims or the source of the alleged contamination. In light of all these factors, the finding of coliform in an off-site well demonstrates nothing about soil permeability at and around the proposed landfill footprint.

- - Conductivity Data

According to the Objectors, low electrical conductivity measurements for groundwater in the wells screened in the tills and the buried valley aquifer indicate low mineralization of the groundwater and, therefore, a high, relatively rapid rate of recharge through the site subsurface. Dr. Michalski explains that the "few exceptions" of very high electrical conductivity during measurements made in December 1995 (which were done concurrently with temperature measurements) are based on wells in which grout was used to cement the boring below the screen and therefore are not reliable.

Arguing in their closing brief from data in the site investigation report, the Objectors point out that in the winter of 1996 the electrical conductivity (also known as specific conductance) of the groundwater in well MW-6DS1 in the upper part of the buried valley aquifer was 152 microohms per centimeter (uhmos/cm), which was as low as the electrical conductivity of some of the wells in the brown till and quite low for wells at that depth. Moreover, they claim, it was much lower than the electrical conductivity of water in MW-6DS2 (382 uhmos/cm), which is located in the lower part of the buried valley aquifer and therefore, the Objectors claim, receives more mineralized water from the bedrock.

Overall, the Objectors claim that the electrical conductivity of water increases as it flows underground and picks up minerals from the sediments and rock. Applying a general rule that the lower the electrical conductivity, the more recently water fell on the surface as rain, they say the relatively low electrical conductivity of the water in well MW-6DS1 indicates that it traveled relatively rapidly through the tills into the buried valley aquifer.

Specific conductance is one of many routine field parameters that the Authority collected information on pursuant to Part 360-2.11(c)(5)(i), to establish an existing water quality data base for comparison with data collected once the landfill begins operation. The Authority and Department Staff contend that specific conductance data do not provide a basis to evaluate flow rates or patterns, and I find nothing in the Department's regulations that suggests the data were collected for or should be used for these purposes. For that reason alone, I give no weight to the Objectors' claims.

Also, the Objectors' arguments about electrical conductivity in the MW-6 well cluster were not developed at the hearing, but only afterward in the Objectors' closing brief, so the other parties were not able to respond to them on the record. Even so, Department Staff point out in their reply brief that while the 152 uhmos/cm reading at MW-6DS1 was as low as some of the readings in the brown till, a reading as low as 55 uhmos/cm was recorded at MW-6B, one of the brown till wells tested in the same sampling round. Also, a reading of 91 uhmos/cm was recorded at another brown till well, MW-28B, during that round. These readings tend to undermine the Objectors' arguments.

- - Piper Diagrams

The Objectors claim that data regarding the chemical composition of water in the site's different geologic units show that the bedrock affords groundwater flow pathways from the surface to the buried valley aquifer. The data were illustrated on Piper diagrams prepared by Mr. Fancher to see if there were any differences between the site's geologic units in terms of the ions common to groundwater. A comparison of diagrams developed before and after the placement of waste can be helpful in looking for contamination that could be attributed to a leachate breakout, Mr. Fancher explained. Mr. Fancher developed diagrams for the surface water, the brown till, the gray till, the deep sand/till and the bedrock, and found slight differences in their plots.

As Mr. Fancher explained during cross-examination, the diagram presenting data from the Authority's first round of water quality testing showed that the chemical composition of water in the wells tested in the upper part of the buried valley aquifer, MW-6DS1 and MW-24DS2, is similar to the chemical composition of the water tested in the wells in the brown till. He said the diagrams also show that the chemical composition of the water in those wells is slightly different from the chemical composition of the water in well MW-6DS2, which lies in the deeper part of the buried valley aquifer. According to Mr. Fancher, the chemical composition of the water in well MW-6DS2 is similar to the chemical composition of the water in three of the four bedrock water samples.

The Objectors say this data shows that groundwater can travel through the site from the brown till into the upper part of the buried valley aquifer and through the bedrock into the lower part of the buried valley aquifer. Mr. Fancher conceded that the diagrams do provide some information about flow between geologic units, but cautioned that the diagrams should not be looked at in isolation but must be viewed in relation to the positioning of the various units and other data about flow patterns between them.

I agree that the record demonstrates some level of flow through the tills to the buried valley aquifer, and also some flow to the aquifer through the surrounding bedrock. However, the diagrams do not indicate that the buried valley aquifer is rapidly recharged from the tills above or from the bedrock on its sides. The Authority and Department Staff point out that the Piper diagrams were not received in evidence. However, Mr. Fancher's testimony is part of the record. I do not read this testimony as suggesting that the aquifer is not fundamentally confined. The Authority concedes that some small amount of recharge gets to the deep sand/till unit, which explains the unit's partial saturation.

- - Conclusions

In summary, I find that the buried valley aquifer does not meet the definition of a principal aquifer. Applying the definition in the Department's regulations, the aquifer does not have the ability to produce an abundant water supply. Though the aquifer contains some high-permeability deposits, as evidenced by slug testing, it also contains an appreciable amount of fine material that prevents it from yielding significant amounts of water. More important, the aquifer is confined by low-permeability till, which means that it receives very little recharge. As Mr. Garry points out, the state's primary water supply aquifers and the principal aquifers listed in the TOGS memorandum are unconfined aquifers, with permeable surface deposits and a hydrologic connection to a major source of recharge. Though the Objectors argue that the buried valley aquifer is recharged quickly and substantially by Moose Creek and precipitation that moves through the overlying tills, their evidence is not convincing. Rather than an indication of high transmissivity, the lack of a meaningful gradient in the potentiometric surface of the deep sand/till indicates that there is insufficient recharge for the aquifer to produce an abundant water supply on a sustained basis, as Dr. Siegel points out in his prefiled testimony.

Even if the buried valley aquifer were found to be highly productive, the TOGS memorandum provides that it would still not qualify as a principal aquifer if it is overlain by thick, continuous impermeable deposits and the predominant recharge to the aquifer is from land areas outside of the aquifer area. The buried valley aquifer is blanketed by roughly 40 to 160 feet of low-permeability till, based on the Authority's hydraulic conductivity testing. While the till allows some water through to the buried valley aquifer, it is not much. As Dr. Siegel explained, the bulk of the recharge to the deep sand/till probably is slow leakage from the underlying bedrock.

In summary, the confinement of the buried valley aquifer, combined with the minimal recharge it receives from the land surface overlying it, effectively eliminate the possibility that the aquifer could be considered a principal aquifer warranting the special protection that accompanies such a designation. While additional testing, as proposed by the Objectors, would provide relevant information bearing on factors affecting a principal aquifer determination, such testing is not reasonably necessary to determine that no principal aquifer exists, and therefore should not be required of the Authority.

- - Additional Testing

The Objectors assert that before granting any landfill permit, the Department should require the Authority to perform additional testing that would better determine whether the buried valley aquifer qualifies for designation as a principal aquifer. I do not recommend such testing given that the record already adequately demonstrates the aquifer is confined and would not be highly vulnerable to landfilling activities. Due to the time and expense that would be involved in further site investigation, the Department could require additional testing by the Authority only if such testing would provide information "which is reasonably necessary to make any findings or determinations required by law." [6 NYCRR 621.15(b); see also ECL Section 70-0117(2).] Additional testing is not reasonably necessary to determine that there is no principal aquifer beneath the landfill site, or to decide the other issues that have been identified for adjudication. Therefore, a decision in this matter should not be deferred so that more testing may occur.

The tests proposed by Dr. Michalski in prior comments to the Authority (which were appended to his prefiled testimony) include a pump test in the buried valley aquifer, geophysical testing to determine the aquifer's extent, and additional tritium testing. The need to perform pump tests and geophysical testing in relation to the principal aquifer question was explicitly identified in my issues ruling as a matter for adjudication. [See issues ruling, page 26.]

- - Pump Test

The Objectors propose that the Authority be required to perform a full-scale pump test in a large-diameter production well penetrating the buried valley aquifer in the southeastern corner of the landfill footprint. The Objectors claim that a pump test should be done to test the aquifer's productivity, hydraulic conductivity and transmissivity. The aquifer's productivity is relevant to whether it meets the criteria for classification as a principal aquifer. The aquifer's hydraulic conductivity and transmissivity bear on its ability to spread contaminants should the aquifer be impacted by a leachate breakout.

On behalf of the Objectors, Dr. Michalski requested a pump test in comments he submitted in 1998 on the DEIS for this project. He maintained the request at the Department's issues conference in 2000 and again at the adjudicatory hearing last year.

Dr. Michalski estimated that a pump test would cost the Authority between $25,000 and $50,000, with most of the money being spent on installing a production well that would have to be 10 to 12 inches wide so it could accommodate a pump capable of removing up to 1000 gallons per minute. Dr. Michalski said that the well would have to be installed in a manner allowing it to screen the entire saturated thickness of the aquifer, acknowledging that it is difficult to install a well in what he described as a gravelly formation containing cobble.

According to Dr. Michalski, it would take a couple of months, including the time spent on well installation, to conduct a proper pump test. First, he said, a step drawdown test would be required to evaluate the hydraulic efficiency of the well and to select a proper pumping rate. Then, he said, the main or full-scale pump test could be performed, which would involve pumping the well at a constant rate and measuring water level drawdown in preselected monitoring wells in the buried valley aquifer and in the bedrock which Dr. Michalski said contributes to the aquifer's recharge. According to Dr. Michalski, as a cost-saving measure, these wells could include existing monitoring wells that were constructed as part of the Authority's site investigation. However, he said that it would be desirable to install more observation wells particularly in the aquifer downgradient from the MW-5 cluster, because he contends that this is where the aquifer would be most productive. Dr. Michalski said the main pump test should continue for a week, and at least for a period of three days. He conceded that if the test could not be sustained for the requisite time (due, for example, to the well running dry), it would suggest that the aquifer materials are much less permeable than he contends. In other words, even the failure of the pump test would provide useful information about the aquifer.

The Authority opposes a large-scale pump test as expensive and unnecessary. Mr. Schafer testified that the total cost of such a test would be at least $300,000, far more than Dr. Michalski estimates. He said that to do the test would require installation of a high-capacity production well, probably 12 inches in diameter, at a cost of between $50,000 and $60,000. Also, he said existing piezometers are not properly located or screened at the right levels for a pump test, so additional ones, perhaps six, would have to be installed at a cost of about $15,000 apiece because of the great depth required. According to Mr. Schafer, because the deep sand/till unit is bounded on the north and south by tight bedrock, one could not do a short-term test; instead, one would want to do a 30-day test with the understanding that pumping could be curtailed sooner if the unit was being dewatered, or could run longer if required to collect sufficient information. Mr. Schafer said that running a 30-day test would require bringing power to the site along with electronic equipment to measure heads and a constant personnel presence to run the pump and oversee the monitoring. Finally, Mr. Schafer said there would be costs for a geologist during drilling as well as costs for analysis of pump test data. Even if one limited the number of new piezometers and reduced the pumping time to cut costs, Mr. Schafer said a pump test would still cost in the range of $150,000 to $200,000.

Pump tests are useful for determining hydraulic conductivity in highly permeable deposits and, in the context of water supply exploration, to determine the long-term yields of aquifers that receive large amounts of recharge. Such tests are performed by pumping water from a well and monitoring the impacts at nearby observation wells as a cone of depression develops. As the Objectors argue, if the test runs long enough to be successful, it can provide permeability information over an area much larger than that affected by a slug test. On the other hand, if the deposit lacks the requisite permeability, the pumping well can be drawn down quickly, the pumping rate cannot be sustained, and the test essentially fails because it cannot produce the necessary data.

Witnesses for the Authority and Department Staff questioned the utility of a pump test in the deep sand/till unit. Mr. Wolfert said in his prefiled testimony that there is no technical justification for conducting a pump test since the test would only demonstrate the unit's short-term yield potential which, in this case, would be much higher than the long-term yield due to hydraulic boundary conditions involving the bedrock and gray till. Also, he said the hypothetical migration of landfill releases would be independent of the permeability of the deep sand/till unit, as confirmed by sensitivity analyses which were performed as part of the Authority's groundwater modeling. According to Mr. Wolfert, the flow of water through the deep sand/till is limited by the unit's confinement by the gray till and bedrock, and a greater conductivity value in the model for the deep sand/till (in other words, assuming it to be more permeable) would not result in greater computer-calculated groundwater flow velocities through the unit but rather would result only in correspondingly flatter hydraulic gradients, because the velocity of the groundwater flow results from the total volume of water entering the deep sand/till which in turn is constrained by the low conductivities of the bedrock and gray till.

Mr. Wolfert said a pump test would need to continue at a set pumping rate for three to five days to get the data one would need to analyze, adding that he did not think a test in the deep sand/till could last that long. Dr. Siegel agreed. He compared the buried bedrock valley to a gutter with tight sides on it, containing not only sand but also till and some reworked clay. He said if one did a pump test, water levels would quickly drop as the water was drained from the clean sand, then drawdown would increase around the production well as the expanding cone of influence hit zones of much lower permeability, and finally one would hit the shale bedrock wall of the valley, at which point the test would fail due to inability to sustain the pre-set pumping rate.

Mr. Garry also expressed doubt about the utility of a pump test at this site. Asked under cross-examination whether a pump test would not be the most definitive method of determining the obtainable yield of a well in the buried valley aquifer, he responded:

"That is not necessarily so. It depends on the area involved. If you are talking about a high-yielding aquifer with a lot of recharge, then that certainly is the absolute way to go. . . But at this site, to me, that was clearly not a viable option . . because the recharge was limited and the aquifer, itself, was limited. And in my opinion, if a well . . . constructed to yield a reasonable amount of water necessary for a pump test was installed, the aquifer would be very quickly dewatered." [T: 3177.]

Had the Objectors requested permission for site access to conduct their own pump test, I would have evaluated the request in terms of whether the test would provide information that is relevant to the adjudication of an identified issue, in a manner similar to my consideration of the requests that were made to access the site for bird surveys, which I authorized. However, where the Objectors seek to shift the obligation of doing the test (and its attendant costs) onto the Authority, I must evaluate the proposal in terms of whether the additional information it would provide is "reasonably necessary to make any findings or determinations required by law," pursuant to 6 NYCRR 621.15(b). Also, I must do this in light of the information that is already part of the Authority's permit application and the adjudicatory hearing record that has already been developed.

In light of the existing information, I do not consider a pump test to be reasonably necessary, and on that basis I do not recommend that the Authority be required to perform one. I agree with the Authority and Department Staff that, based on the composition of the materials in the buried valley aquifer, there is a high likelihood that the test would fail. The nature of the deposits in the buried valley aquifer have already been explored, and their permeability has been reasonably determined using appropriate methods such as slug tests and laboratory tests. Given reliable evidence about the confinement of the buried valley aquifer and the lack of any apparent connection between the aquifer and a large source of recharge, a pump test would in all likelihood provide information only about the short-term yield of the aquifer, rather than the long-term yield necessary to consider the aquifer an abundant potential water supply.

While I do not consider a pump test to be reasonably necessary at this point, I acknowledge that, if one were conducted, it would provide information that could be used to verify certain conclusions that were drawn from the Authority's site investigation and accepted by Department Staff in its review of the permit application. Therefore, depending on the level of confidence the Commissioner has in these conclusions, she would have the discretion to order additional testing as a way of confirming or substantiating them.

Though a pump test could provide relevant information about the permeability and transmissivity of the deep sand/till unit, it would not likely determine whether the unit is confined from above. The Objectors did not request the pump test for this purpose, and Dr. Siegel said that, on the confinement issue, pump test information would be equivocal.

- - Geophysical Testing

The Objectors propose that the Authority be required to use surface geophysics such as seismic surveys to determine the full course and extent of the buried valley aquifer, particularly east of the site. The Objectors say that exploring the aquifer east of the site for a distance of at least three miles is especially important because, according to Dr. Michalski, contaminants could travel in that direction for at least two to three miles during a period of 92 years encompassing the 62-year life of the facility and the 30-year post-closure period that is fixed by regulation. The Objectors are concerned that, while traveling off-site through the aquifer, contaminants from the landfill could affect domestic supply wells and pass into the area of a well protection district that is located 2.6 miles east of the landfill.

As noted above, the extension of the aquifer to the east of the site has not been confirmed, though the likelihood of such an extension can be inferred from existing information suggesting that, to the extent water is moving in the aquifer, it is going east to a downgradient point of discharge.

Dr. Michalski testified that, in terms of surface geophysical testing, he favors seismic refraction or reflection over an area roughly perpendicular to the buried valley aquifer. Though he offered no cost estimate of this testing at the adjudicatory hearing, he said during the issues conference that such testing could be done for about $10,000.

Mr. Garry said that a refractive method of seismic testing involves creating sound waves at the surface and then bouncing them off the underlying deposits. He said the sound waves bounce off different deposits at different speeds, and based on the amount of time it takes the sound waves to come back to the surface one can determine the density of the deposits. However, he cautioned that this testing works best when one is going from less dense materials at the surface to more dense materials below, whereas the tills at the surface are denser than the materials in the deep sand/till unit. Also, he cautioned that there might not be enough difference between the densities of the till and the deep sand/till to get a good interpretation of the boundary between these units.

Mr. Garry said that seismic reflection would not provide useful information in this case, because it is used when one wants to get information for depths below 500 feet. Given the problems associated with geophysical testing, Mr. Garry said that he would be most comfortable with borings as a means of mapping the buried bedrock valley off-site. Needless to say, continuing the hydrogeologic investigation outside the landfill site, particularly with intrusive testing like the drilling of borings, would raise issues of securing access to property not now controlled by the Authority.

Any need to perform mapping of the buried valley aquifer east of the site would have to be associated with a possibility that contaminants could move off-site in that direction. The Authority's modeling, which is discussed below, indicates that this would not happen. The almost flat water surface in the buried valley aquifer indicates that to the extent water is moving through it offsite to the east, it is doing so at a trickle. The Authority's ability to detect contaminants as they exit the facility and also below the water level in the buried valley aquifer assures adequate time to remediate a leachate breakout before it impacts local groundwater resources. For that reason, off-site geophysical testing is not reasonably necessary.

- - Additional Tritium Testing

The Objectors have proposed that additional tritium testing be done in wells located in the southern portion of the landfill to determine the age of groundwater in the lower gray till and the buried valley aquifer. Dr. Michalski said in prior comments that monitoring wells completed in the buried valley aquifer (MW-6DS1, MW-8DS, MW-24DS) and selected till wells (MW-8G2, MW-24G2) should be included in such sampling. As noted above, the Authority has already done testing in two well clusters (MW-18 and MW-22) indicating that so-called modern, tritiated water is not present below a depth of about 10 to 20 feet.

I agree with the Authority that in light of this testing and other evidence, including hydraulic conductivity measurements, indicating the confinement of the buried valley aquifer, further tritium testing is not reasonably necessary. However, should the Commissioner want further assurance about the aquifer’s confinement, expanding tritium testing to other well clusters would provide useful information in that regard.

Characterization of the Critical Stratigraphic Section

Apart from the issue of whether the deep sand/till unit contains a principal aquifer, issues exist as to the characterization of the critical stratigraphic section. (Issues ruling, page 27.) According to 6 NYCRR 360-1.2(b)(47), the critical stratigraphic section is defined as all stratigraphic units into which escaping facility-derived contaminants might reasonably be expected to enter and cause contamination during the active life of the landfill or within 30 years following the facility's closure. The hydrogeologic report must, among other things, define the critical stratigraphic section and provide an understanding of groundwater and surface water flow at the site sufficient to determine the suitability of the site for a landfill. [6 NYCRR 360-2.11] Also, groundwater monitoring wells must capable of detecting landfill-derived groundwater contamination within the critical stratigraphic section. [6 NYCRR 360-2.11(c)(1)]

As noted above, this issue generally concerns the characterization of the critical stratigraphic section, not merely identification of the units that make it up. The Authority's hydrogeologic report identifies four units as constituting the critical stratigraphic section: the brown till, the gray till, the deep sand/till and the bedrock. Monitoring wells are intended for each of these units. The Objectors have identified no additional units for inclusion in the critical stratigraphic section; the buried valley aquifer, their main area of concern, is part of the deep sand/till. They also concede that the Authority's monitoring well network encompasses all the units that have been identified. If the issue were only the identification of units making up the critical stratigraphic section, the issue would not have been certified for adjudication. Instead, the issue is the characterization of the critical stratigraphic section, which involves considerations of speed and direction of groundwater flow, and the identification of any preferential pathways that contaminants could take in moving from one unit to another.

- - Reliability of Authority's Hydraulic Conductivity Measurements

The Objectors argue that the hydraulic conductivity tests performed on behalf of the Authority seriously underestimate the hydraulic conductivity (or permeability) of the till materials and violate the standards of the industry.

The Authority determined hydraulic conductivity in two different ways: field tests, which were used to determine horizontal conductivity, and laboratory tests, which were used to determine vertical conductivity. It used standard and accepted laboratory and field methods, and performed its testing in accordance with a Department-approved site investigation plan. Samples of till collected during the drilling of boreholes were submitted for laboratory analysis to determine their vertical permeability. Field testing consisted of performing slug tests in wells, which primarily reflects hydraulic conductivity in a horizontal direction.

As Mr. Wolfert explained, to determine the horizontal hydraulic conductivity of each geologic unit, rising head and falling head slug tests were performed in each of the monitoring wells. The slug tests involved the instantaneous lowering or raising of the water level within the well. Water level readings were collected by using an electronic water level indicator or data logger and transducer. The resulting data were analyzed by using a computer program, AQTESOLV, which applies the Bouwer and Rice method of analysis to determine permeability. Permeability is determined by fitting a line to data plotting the displacement of the water level over time. AQTESOLV allows the user the options of having the computer automatically fit a line to the curve, or allowing the user to do it manually. The Authority exercised the latter option.

As Mr. Wolfert explained, the small-scale permeability testing performed by the Authority was appropriate for this site given the tightness of the soils. The Department's landfill regulations require that, as part of the hydrogeologic investigation, in situ hydraulic conductivity testing be done in all monitoring wells and piezometers, unless other methods approved by the Department are used. Among the suitable methods explicitly recognized by the Department for determining hydraulic conductivity are slug tests and pump tests. [6 NYCRR 360-2.11(a)(11).]

Slug tests are most appropriate for relatively tight soils, like the till deposits. Pump tests are useful in more permeable soils, and can determine hydraulic conductivity over a wider area than a slug test. But as discussed above with regard to the buried valley aquifer, the success of a pump test depends on sustaining a set pumping rate for a relatively long period of time, which depends on the ability to pull water from the deposit. Mr. Wolfert pointed out that one would do slug tests to determine horizontal conductivity in a formation that yields very little water, but a slug test cannot determine vertical conductivity, which is why vertical conductivity was measured in the laboratory on samples extracted from the different units.

Mr. Schafer made the same point that, in tight soils, slug tests are really the only method that will work to determine horizontal conductivity. He said that the soils are so tight that one could not produce enough water to run a meaningful pump test, so slug testing or pump out testing (also known as specific capacity testing, which the Authority also did) are the only options for getting horizontal conductivity values. As for vertical conductivity, Schafer said it must be calculated on the basis of laboratory tests because one cannot devise a field test that would produce reliable values.

As the peer reviewer of the Authority's site investigation, Dr. Siegel confirmed that the methods used to determine hydraulic conductivity were appropriate. He said the "variable head" tests to determine in-situ hydraulic conductivity are "proven, very well-established engineering tests" documented widely in the peer-reviewed scientific literature and textbooks and used routinely by himself to determine the hydraulic conductivity of organic and clayey sediments. Mr. Fancher, Department Staff's reviewer of the site investigation, agreed that in terms of his knowledge of the Authority's laboratory and field testing of hydraulic conductivity, the tests were conducted in accordance with proper testing practice, and that there was nothing in his review that suggested the tests dramatically understated permeability values, one of Dr. Michalski's main contentions. The U.S. Environmental Protection Agency considers both in-situ slug testing to determine horizontal hydraulic conductivity - - and permeameter testing of undisturbed core samples to determine vertical hydraulic conductivity - - to be standard tests with good reliability.
[See Hydrogeology Exhibit 69, a table from an EPA guidance manual for identifying areas of vulnerable hydrogeology under the Resource Conservation and Recovery Act.]

- - Field Testing for Horizontal Conductivity

Dr. Michalski was critical of the Authority's hydraulic conductivity values determined from the slug testing, saying they were erroneously calculated with a consistent bias toward obtaining values that are too low. In some cases, for example at MW-27G2, Dr. Michalski said corrected values would be greater by more than two orders of magnitude, meaning that contaminants could travel more than 100 times faster than the Authority contends. Dr. Michalski testified that due to the Authority's errors, both the average and the range of horizontal hydraulic conductivity values for the various units are underestimated by as much as an order of magnitude, particularly for the gray till.

According to Dr. Michalski, the most common and consequential error was the use of very late slug test data for analysis, sometimes after 80 to 90 percent of the initial head change had dissipated. He said the very small and slow head changes during the very late period should generally be ignored in favor of data from earlier in the test. However, on cross-examination, he conceded that early test data can be affected by filter pack drainage (this impact occurs when the water level in the well is below the top of the well screen) and the heterogeneity of materials in the immediate vicinity of the borehole.

The site investigation report (Section 6.3.2.1, page 44) states that for most of the slug tests, the time-displacement data plotted as a straight line on a semi-log graph. The report states that slug test data for some wells, however, showed a curved data plot where a more rapid change in water level was observed during the early part of the test and was followed by a decrease in the rate of water level change later in the test. Slug tests in those wells were interpreted as having been affected by conditions in which either the water level was within the screen during the slug test, or there were zones of varying permeability within the screened interval.

As to the first condition, the report explains that wells which are screened across the water table or where the water level is in the screen present a special problem in slug test interpretation because water standing in the filter pack drains rapidly into the well following the slug’s removal. Therefore, the water level in the well recovers rapidly during the early portion of the slug test due to drainage of water from the filter pack and not from the surrounding formation. This initial rapid refilling results in erroneously high values of hydraulic conductivity when using the early-time data to calculate conductivity. When filter pack drainage occurs, the report cautions, the hydraulic conductivity must be computed from the late data.

Likewise, the report states, middle-to-late data provide a better integrated average of hydraulic conductivity over a broader area around a well than do the early time data. The report cites the example of a well penetrating an isolated pocket of gravel that is not hydraulically connected to other permeable materials. During slug testing the cone of depression expands rapidly through the permeable gravel and may result in a rapid initial water level response inside the well. But as the cone continues to expand into the matrix material (clay or silt, for example) the rate of water level change will decrease in accordance with the reduced hydraulic conductivity of the matrix material. Thus, the initial water level response reflects the hydraulic conductivity of the pocket of gravel while the later data reflect the hydraulic conductivity of the formation as a whole.

Mr. Schafer, as part of the Authority's rebuttal case, elaborated on these points in relation to the criticisms in Dr. Michalski's prefiled testimony, effectively refuting those criticisms. Mr. Schafer has been involved in the groundwater industry for more than 30 years. As a groundwater hydraulics expert with Geraghty and Miller, he reviewed and offered guidance on slug test procedures and the analysis of slug test data. Mr. Schafer testified persuasively that the slug tests were analyzed correctly by Geraghty & Miller and that the resulting values of horizontal hydraulic conductivity were reliable.

With regard to the slug test at MW-27G2, a particular focus of Dr. Michalski, Mr. Schafer presented a mounted blow-up (Hydrogeology Exhibit 105) of the time-displacement semi-log data plot depicting the shallow line fitted through late-time data by Geraghty & Miller and the much steeper, "corrected" line drawn by Dr. Michalski through earlier-time data. As Mr. Schafer explained, the plotted data show a very steep initial curve in the early data (highlighted in pink on the exhibit), followed by a flat response in the later data (which is highlighted in yellow). The early, steep response reflects a permeable pocket of material (a sand stringer) that the well screen penetrated so that the water drained rapidly into the well. However, as time went on, the flatter response reflected the true character of the surrounding matrix material in which the more permeable zone is set. Because the soil is reasonably tight, the initial water level is not regained except over a very long period of time, and the horizontal permeability is calculated from the shallow line reflecting the long passage of time during which the well returns to that initial level, Mr. Schafer explained. The fact that the well intersected a permeable pocket of material is confirmed by the boring log of MW-27G2, which shows that the well, screened at a depth of 40 to 50 feet, intersected a permeable pocket of material in the depth interval between 43 and 45 feet, such interval indicating "fine to coarse sand, little fine to medium sand," with less permeable silty zones immediately above and below.

In their closing brief, the Objectors have also criticized the Authority for ignoring early slug test data and thereby greatly underestimating the hydraulic conductivity of sediments screened in other gray till wells (MW-24G2, MW-8G2, and MW-25G2). Relative to these wells, the Objectors ignored the limitations and errors associated with using early time data, and the double straight line effect, as the Authority argues in response. The double straight line effect is explained by Fetter on page 199 of his book Applied Hydrogeology, excerpted by Dr. Michalski as Exhibit 15 to his pre-filed testimony (Hydrogeology Exhibit 74). Fetter explains that in some cases the plot of head versus time will yield a curve with two straight-line segments. This, he said, occurs when the gravel pack drains rapidly into the well. Once the water level in the gravel pack equals the water level in the well, the second straight-line segment forms, representing the hydraulic conductivity of the undisturbed formation. Where a double straight line forms, the second segment should be used, Fetter explains.

To illustrate this point, Mr. Schafer presented a blow-up of the time-displacement semi-log data plot for the slug test at MW-8G2 (Exhibit 104) showing a red-highlighted shallow line drawn by Geraghty & Miller through late-time data and a blue-highlighted steep line drawn by Dr. Michalski through early-time data. Mr. Schafer explained that the red-highlighted line reflects the correct analysis of the data accounting for the permeability of the formation, while the blue-highlighted line reflects the drainage of the well filter pack. Using the blue line results in a calculated permeability that is an order of magnitude greater than the actual permeability, which is a major error, as Mr. Schafer pointed out.

Finally, in their closing brief, the Objectors have criticized the Authority for underestimating the hydraulic conductivity at wells screened in the deep sand/till unit (MW5-DS1, MW-5DS2, MW-6DS1, and MW-7DS), arguing that the Authority fitted its lines to only late-time data, after 90 percent of displacement had occurred, and bunched early-time data to the far left part of the graph, effectively ignoring it. The bulk of the data for each of these wells plot generally in a single-slope fashion, with little room for varying the fit of a straight line through the data. However, with regard to the slug testing more generally, whether Geraghty & Miller's lines best fit the data can be a subject of legitimate scientific disagreement. In fact, the Authority admitted so in the FEIS, in response to a comment by Department Staff that for several wells (including MW-5DS1), there was a poor fit between the data and the fitted curve on slug test data plots.

Responding to this comment, the Authority said that of the 100 or more hydraulic tests conducted at the site, it is likely that a few of them could have been interpreted somewhat differently. The Authority said that given the subjective nature of the interpretation, several scientists analyzing the same slug test independently would likely produce different results. However, for the wells identified by Department Staff, the Authority said that other reasonable interpretations would not alter the calculated conductivity values by more than about a 2 to 1 ratio (i.e., a doubling or halving of the calculated value). Also, the Authority pointed out that the conductivity values obtained from the hydraulic testing were used for determining initial estimates of formation properties for input into a computer model for the site. The Authority said that because model calibration was performed to adjust the formation properties until the model simulations faithfully reproduced water levels observed at the site, minor adjustments in slug test interpretation would not alter the conclusions regarding formation properties or the results of the groundwater flow modeling analysis. [See FEIS, pages C-106 to C-108.] Department Staff found this response by the Authority to be acceptable, as noted in its subsequent correspondence to the Authority. [Hydrogeology Exhibit 65, page 21.]

Dr. Michalski testifed that his analysis of slug test results for wells MW-5DS1, MW-5DS2, MW-6DS2, MW-8DS, and MW-24DS2 showed that the hydraulic conductivity values reported in the site investigation report were biased toward lower values than appropriate by about 100 percent to 200 percent. However, asked on cross-examination if he prepared any calculations which support this conclusion, he said he did not. Dr. Michalski said he did "mental calculations" to come to his conclusion, but in the absence of written work product, his claim could not be verified by the other parties or by me.

Dr. Michalski also testified that the Authority's use of the Bouwer and Rice method of slug test analysis was questionable in light of an "oscillatory" response observed in the buried valley aquifer wells, which he said is typical of a highly transmissive aquifer. However, Mr. Schafer denied there was any such response, only an early-time "blip" reflecting a rise and fall of water levels that would occur in the first few seconds after the slug is inserted or removed. Schafer said this occurred in virtually all the wells in all the units, not just those in the deep sand/till, though he said it is not apparent in the graphs due to their scale. Dr. Michalski said he favored the Hvorslev method over the Bouwer and Rice method of slug test analysis, but acknowledged that Fetter considers the Bouwer and

Rice slug test method “very useful” in open boreholes or screened wells.

Dr. Michalski challenged the Authority’s use of the Bouwer and Rice method, saying it contributed to the underestimation of conductivity values for the lower portion of the gray till. However, Mr. Schafer defended use of the Bouwer and Rice method as an incremental improvement over the Hvorslev method, because it is uses actual well and formation geometry. Dr. Michalski said use of the Bouwer and Rice method depends on accepting a “fiction” that the gray till is saturated throughout its extent. But the gray till actually is saturated everywhere on the site, so there is no fiction involved. As Mr. Schafer explained, all the wells completed in the gray till contain water, and water levels fluctuate in all the wells, signifying saturated conditions. If the gray till was not saturated, groundwater could not move out of the formation and into the well. If the till was only partially saturated, the water would be held to the till by capillary forces and the well would remain dry. Dr. Michalski claims that the partially filled well screens in some of the gray till wells in the southwestern portion of the site indicate the till is not saturated in those locations. However, Mr. Schafer explained that this phenomenon is due to the tightness of the soils and the steep downward gradients where water is moving more or less straight downward with only slight pressure head.

Dr. Michalski said the Authority erred in using an inappropriate value for the full screen length of 10 feet in the Bouwer and Rice formula for wells in which water fills only the lower portion of the screen. In the case of MW-8G2, he said the Authority used a thickness of 10 feet to calculate the hydraulic conductivity value for the well, when the saturated screen thickness in the well was only 3.9 feet, thereby underestimating the hydraulic conductivity in the well by about 60 percent. Mr. Schafer countered effectively that the entire screen length should be used to do the permeability calculation because the entire screen is engaged in the flow, with water continuously entering the upper portion of the screen and discharging through the bottom portion of the screen.

Dr. Michalski testified that the small size of the #10 screen openings and the very small open area of the screens installed in wells in the buried valley aquifer may have offered a greater resistance to flow than the formation itself. This claim was refuted by Mr. Wolfert, who said the same screen is used to pump aquifers on Long Island, and that it no way impedes the flow of water into wells. Also, Mr. Schafer performed a rough calculation on the stand demonstrating that the resistance of the well screen would be responsible for a negligible amount of head loss. (Dr. Michalski performed no such calculation himself, and conceded that his theory of screen resistance was only a possibility.)

Dr. Michalski said that falling-head slug tests in MW-18G3 and MW-18BR were impacted by a heavy rainfall event on July 16, 1996, the date on the semi-log plot sheets prepared by the Authority. He said the ambient rise of groundwater levels after the rain event countered the falling head in the tested wells, causing the wells to appear much slower. However, the Authority notes in its reply brief that the dates on the plot sheets are the dates of the slug test data review and printout, not the dates of the tests themselves, which effectively nullifies Dr. Michalski’s argument.

Dr. Michalski said slug test results from MW-23G3 should be disregarded because the well was clogged and undeveloped, and therefore produced an unrealistically low horizontal hydraulic conductivity value of 1×10^{-7} cm/sec. However, even if these results are set aside, there are other locations in the gray till with comparably low values. No other examples of inadequate well development are provided in Dr. Michalski’s testimony, so it is impossible to ascertain the extent of the problem.

Apart from slug tests, pump out tests (also known as specific capacity tests) were performed at wells MW-13G1, MW-15G1 and MW-30B to estimate horizontal hydraulic conductivity. As explained in the site investigation report (page 22), in pump out testing, the well is pumped for a set time period and then the pump is shut off. As water continues to enter the well, the rate of recharge (water level rise) is observed by recording time and water level measurements. Measurements of drawdown in relation to the time after pumping stops can then be entered into an equation used to calculate the formation’s transmissivity, which is then converted to a hydraulic conductivity value.

Dr. Michalski characterized the pump out tests as “non-standard” tests that, by the Authority’s own admission in the site investigation report, produced hydraulic conductivity values in the gray till that were orders of magnitude lower than the slug-test-derived values for the same locations. However, Mr. Schafer countered that the results merely confirm the low horizontal permeability of the formation, and the conservatism of the slug test analyses. Mr. Schafer said the pump out tests are innovative because they allow one to derive information from wells that are so low-yielding that they cannot be pumped continuously. As the site investigation report indicates, pump out tests generally yield values of permeability that are more representative than those derived from slug tests. The pumping of the wells during these tests results in a significant drawdown and pulls water out of isolated pockets of sand and gravel within the screened till interval, thereby minimizing the influence of those more permeable zones on the rate of water level recovery.

After adjusting for the Authority's alleged testing errors, Dr. Michalski said the actual horizontal hydraulic conductivity of the more permeable zones of the buried valley aquifer is on the order of at least 1×10^{-1} cm/sec. This value is outside the range of those the Authority derived from its slug tests throughout the deep sand/till unit, and I do not deem it reliable. Furthermore, the Objectors have assumed an average horizontal conductivity of 1×10^{-1} cm/sec for the buried valley aquifer as part of their calculation determining that contaminants could travel through the aquifer at a rate of 160 feet per year, or about three miles during 92 years. By itself, the assumption of such high conductivity - - unverified by the Authority's testing - - casts doubt on this travel time estimate, even assuming the aquifer's continuation to the east.

- - Laboratory Testing for Vertical Conductivity

The Authority, in accordance with its Department-approved site investigation plan, conducted an extensive number of vertical hydraulic conductivity tests. These tests were done by collecting undisturbed and bulk soil samples from monitoring well and soil boring locations throughout the site and sending them to a recognized and approved laboratory for vertical permeability testing in accordance with ASTM 5084, as well as a variety of other geotechnical tests. The testing was done pursuant to 6 NYCRR 360-2.11(a)(9)(ii), which requires that a representative number of undisturbed samples be collected from test pits and soil borings and analyzed in the laboratory for various soil characteristics including undisturbed permeability.

Dr. Michalski challenged the reliability of the Authority's laboratory testing for vertical hydraulic conductivity, arguing that the testing was done on small soil samples that are not representative of large-scale features of the till units. Dr. Michalski said in his prefiled testimony that the bulk of downward groundwater flow and contaminant transport occurs along more permeable, large-scale heterogeneities, including macropores and fractures, and therefore bypasses zones of lower permeability. He said hydraulic conductivity values typical of such more permeable zones should have been included in the Authority's vertical flow and velocity calculations.

Had such values been included, the flow system would exhibit faster movement, as Dr. Michalski argues. But it would be a mistake to include values typical of features that were not actually located and measured. Though the samples that were tested were small, they were taken from a variety of different depths and locations throughout the site. Nearly 60 undisturbed soil samples were tested for vertical permeability, and nothing suggests that they were not representative of site conditions. Dr. Michalski infers a fast rate of downward flow through the tills on the basis of hydrograph, temperature, electrical conductivity, and other data in the hydrogeologic report. These inferences are not reliable, as noted above in my discussion of the vulnerability of the buried valley aquifer.

The Objectors claim that most of the vertical hydraulic conductivity values obtained from the laboratory testing underestimated actual values of the samples by one or two orders of magnitude, due to alleged testing errors outlined in Dr. Michalski's testimony.

Dr. Michalski said that prior to the laboratory testing, each soil sample, including samples from shallow depth, was subjected to a very high ambient pressure (reported by the Authority as between 64 to 71 pounds per square inch, much greater than atmospheric pressure, which is 14.7 pounds per square inch). He said this caused the samples to consolidate, which changed their porosity and permeability. Dr. Michalski said the consolidation of samples is evidenced by a reduction in sample diameters and heights after testing. I see no evidence of this from my own review of the laboratory reports (see Appendix E of the site investigation report); a comparison of initial and final heights and diameters, as measured by the laboratory, indicates that testing-related changes were negligible or non-existent.

As the Authority argues, this may be due to the fact that, in their natural state, site soils were previously buried by glaciers more than a mile thick. Dr. Michalski himself acknowledged that, like the pressure applied during testing, the pressure applied by glaciers to the deep gray till would have been substantially higher than atmospheric pressure. Therefore, one could expect that if any consolidation had occurred, it happened well before the samples were taken, and not after the samples reached the laboratory. One of the Authority's witnesses, Mr. Sanford, was cross-examined extensively about the pressure that a shallow brown till sample, MW-12B, was exposed to in the laboratory, and whether that pressure might have contributed to the lab result indicating low vertical permeability. On redirect, the relevance of the lab result dissolved when Mr. Sanford testified that the brown till near that location, at the western edge of the landfill footprint, would be removed during the landfill's construction.

Dr. Michalski also said that soil samples were subjected to testing under an excessively high vertical hydraulic gradient that could mobilize and move silt and clay particles within the sample, clogging pore spaces. However, the ASTM standard under which the conductivity testing was performed states that if the hydraulic conductivity of the specimen is less than about 1 x 10^{-8} cm/sec, standard hydraulic environments will typically not suffice and various strategies may be considered for such impervious materials, including use of higher gradients. [ASTM D 5084, Hydrogeology Exhibit 4, Section 1.2.2, page 1.]

The current version of the ASTM notes that when possible, the hydraulic gradient used for hydraulic conductivity measurements should be similar to that expected to occur in the field, but that the use of small hydraulic gradients (such as those found at this site) can lead to very long testing times for materials having low hydraulic conductivity. The ASTM states that somewhat larger hydraulic gradients are usually used in the laboratory to accelerate testing, but excessive gradients must be avoided because high seepage pressures may consolidate the material, material may be washed from the specimen, or fine particles may be washed downstream and plug the effluent end of the test specimen. These effects, according to the ASTM, could increase or decrease hydraulic conductivity [ASTM D 5084, Hydrogeology Exhibit 4, Section 9.5.1, page 10.] As Dr. Siegel explained, laboratory testing results often results in conservative permeability values due to water leakage between the sample and the wall of its container. In this case, Dr. Siegel said, flexible walls were used to hug the samples and assure tight fits. However, he added that while this is done to prevent leakage, sometimes that effect is not achieved, particularly with dense materials like these. With such materials, he explained, there can be some trickling of water along the edge of a tube where the soil is not neatly attached.

Mr. Sanford acknowledged that, in the case of a sample from MW-12B, the downward vertical gradient of 0.02 that exists in the ground was increased to 26.9 (in other words, by hundreds of times) by using a piston to ram water through the sample. However, this did not compress the sample at all; according to the lab report, the sample's initial and final heights were the same.

The current ASTM also warns that seepage pressures associated with large hydraulic gradients can consolidate soft, compressible specimens and reduce their hydraulic conductivity, making it necessary to use smaller hydraulic gradients for such specimens. [ASTM D 5084, Hydrogeology Exhibit 4, Note 13 under Section 9.5.1, page 10.] However, as the Authority responds, its specimens were not soft, as evidenced by their high bulk densities; therefore, this caution is not applicable.

Finally, the ASTM cautions that the correlation between results obtained in the laboratory using the test methods described in the ASTM and the hydraulic conductivities of in-place field materials has not been fully investigated. According to the ASTM, experience has sometimes shown that hydraulic conductivities measured on small-scale specimens are not necessarily the same as larger-scale values, and therefore the results derived in the laboratory should be applied to field situations with caution and by qualified personnel. [ASTM D 5084, Hydrogeology Exhibit 4, Section 4.5, page 2.] In a similar vein, Fetter writes in Applied Hydrogeology that in most cases, if both laboratory and field tests are conducted in the same till, the field test indicates one to three orders of magnitude more permeability, because the field test measures properties of a larger sample of material, which may have fractures or sand and silt seams with higher conductivity values than the clay matrix. [Hydrogeology Exhibit 8, an excerpt from the book, on page 286.]

Dr. Siegel testified that field testing for vertical permeability would have been very difficult to perform due to the clay and silt content of the tills. He said that for low-permeability materials, laboratory testing of vertical permeability is routine practice, and about the only thing that can be done on a practical level. Department Staff agreed that for determining vertical conductivity, laboratory permeameter testing, as performed by the Authority, is the standard method. An EPA table comparing test procedures for vertical hydraulic conductivity says that permeameter testing of undisturbed core samples is a standard test with good reliability, provided one secures a minimum of ten samples per strata to account for spatial variability. (Hydrogeology Exhibit 69.) Dr. Michalski said that at one point in his career, during the late 1960's and early 1970's, he himself had done hundreds or thousands of laboratory hydraulic conductivity tests similar to those discussed in this hearing.

Dr. Siegel said that among other laboratory methods not used by the Authority, vertical permeability could have been tested by a falling head method in which water is allowed to drain through a soil-filled tube. However, he added that in soils with a permeability of less than about 10^{-5} cm/sec it can take a week or so to get a viable number, and the test is not cost-efficient either. On the other hand, the falling head method allows for testing at lower hydraulic gradients than were used in this case.

The Objectors highlight the discrepancy between the Authority's calculated values of horizontal and vertical permeability of the tills, using MW-12B (in the shallow brown till) as an example. At that location, the slug-tested value of horizontal permeability (2.39×10^{-5} cm/sec) is 240 times greater than the lab-tested value of vertical permeability (1×10^{-7} cm/sec). Glacial till was deposited directly from the glacial ice without significant sorting by running water. Therefore, from a geologic standpoint, there is little reason why its horizontal and vertical permeabilities should be so different, Dr. Michalski testified.

Mr. Sanford said that, at the MW-12B location, the much higher horizontal conductivity could be due to a lateral sand or silt seam. However, he also conceded it could be due to the different testing methods that were used to determine horizontal and vertical permeability.

As noted above, there is a possibility that field measurements of the till's vertical permeability would have generated values greater than those that were determined in the laboratory. But an appreciably higher value of vertical permeability would depend on there being some kind of large-scale fracturing of the till that was not captured in the small-scale lab samples, and there is no evidence of such fracturing, as Mr. Sanford argued. Also, other evidence, including the tritium test results, suggests that while water moves downward through the tills, it does so very slowly, consistent with the Authority's lab test results. Therefore, if the lab testing overstates the tightness of the till, there is nothing to suggest that the overstatement is significant.

The Objectors have suggested that, if the same samples were tested for both vertical and horizontal permeability in the laboratory, one could have eliminated any error inherent to the fact that vertical permeability was tested in the laboratory while horizontal permeability was tested in the field. However, as Mr. Sanford explained, this would have presented practical difficulties, in terms of trimming samples to fit the testing cylinder. Turning lab samples on their sides to test for horizontal permeability, as proposed by the Objectors, is not commonly done, nor is it recommended by ASTM guidance, Mr. Sanford said. The EPA table (Hydrogeology Exhibit 69) also indicates it would not have been a good idea. According to the table, permeameter testing of undisturbed core samples provides only "fair to poor" reliability for determining horizontal permeability, and if the samples have already been disturbed, the reliability of such testing is "very poor." In its closing brief, Department Staff argues that even if the same soil sample could be trimmed in the lab for both horizontal and vertical permeability testing, the testing of both in sequence would result in charges that the first test compressed the sample or otherwise altered it, thereby throwing the second test result into question. Another possible alternative, not proposed by any party, would be slug testing for both horizontal and vertical permeability. This too is frowned upon, according to the EPA table, which says slug testing has "good" reliability for determining horizontal permeability, but only "fair to poor" reliability for determining vertical permeability in soils that are not coarse-textured.

Dr. Siegel agreed that the test methods for determining vertical and horizontal permeability, respectively, should not be considered interchangeable. This is underscored by the EPA table. For measuring horizontal conductivity, EPA says in-situ slug testing provides the greatest reliability among different identified alternatives. However, for measuring vertical conductivity, EPA says the greatest reliability is provided by permeameter testing of undisturbed core samples.

- - Bedrock as a Conduit for Contaminants

The Objectors argue that there is evidence of pathways in the bedrock through which contamination could travel rapidly into the buried valley aquifer. This evidence, they say, consists of slug test results indicative of bedrock fractures.

Based on the Authority's analysis of the slug test results, one of the 12 bedrock wells tested, MW-1BR1, had a hydraulic conductivity of about 10^{-3} cm/sec, and MW-13BR and MW-30BR had hydraulic conductivities in the range of 10^{-4} cm/sec. Other wells tested in the range of 10^{-7} cm/sec. Dr. Michalski says that while the lowest permeability values are typical of practically unfractured bedrock matrix, the highest values in the range of 10^{-3} to 10^{-4} cm/sec are likely associated with the presence of one or more large-aperture fractures within the screened interval.

Dr. Michalski claims that because water in the bedrock flows toward the buried valley aquifer, bedrock fractures could open pathways allowing contaminants to reach the aquifer and then spread eastward. According to Dr. Michalski, the bedrock would be an underdrain for the till in the northwestern part of the landfill footprint, and any leachate released in that area could migrate quickly to the aquifer. In fact, he says the bedrock and the buried valley aquifer are the only two units that require contaminant monitoring, since the groundwater suppression system would check contaminant spread through the tills, at least over large areas in the southern and western parts of the landfill footprint.

According to Dr. Michalski, bedrock fractures decrease with depth, but only after about 300 feet. Therefore, he says, contaminants could reach the buried valley aquifer along a combination of vertical bedrock fractures under the northern portion of the landfill footprint (where the gray till is absent) and horizontal bedding fractures to which they may be connected. Dr. Michalski testified that these horizontal fractures would have expanded due to stress release caused by the melting glaciers. These fractures need to be identified, he said, to establish a reliable monitoring system.

Dr. Michalski said that geophysical testing, also known as packer testing, should be done for the purpose of isolating fractures so their conductivity and transmissivity can be measured. He said these fractures could be identified by various means including temperature conductivity logging and flow meter testing in exploratory bedrock boreholes.

As noted in my findings of fact, the Authority has designated the uppermost portion of the bedrock as part of its critical stratigraphic section, which means it would be monitored for escaping contaminants. According to rock cores obtained during drilling and observation of bedrock exposures, the underlying bedrock is dark gray to black shale with thin beds of light gray sandstone and siltstone, indicative of the Whetstone Gulf Formation, which Mr. Sanford explained is of low permeability.

Depth to bedrock reaches a maximum of 263 feet below the land surface at the MW-7 well cluster location and decreases to about 10 feet along the northern perimeter of the proposed footprint (MW-28 cluster). Within the ravine to the north of the proposed footprint, the bedrock is exposed in the streambed.

The deeper bedrock wells at the MW-1 and MW-28 clusters show lower hydraulic conductivities consistent with a reduced number of fractures at depth, as noted in the site investigation report. This reduction in the fracture network occurs relatively quickly as one goes deeper at these locations, over distances of 20 feet and less. Mr. Feldman confirmed that the fracture network in the first 20 to 40 feet of the bedrock closes up significantly as one goes deeper, something he said he has seen at numerous sites. Mr. Fancher agreed, noting that the upper bedrock unit (to a depth of 10 to 15 feet) is more weathered and transmissive than the tighter bedrock below it. According to Mr. Fancher, the measured horizontal conductivity of the bedrock also decreases from the north (where overburden is thin or absent) to the south (where the overburden is thickest) because where the bedrock is deepest under the site, there are less open, continuous fractures.

Testifying on rebuttal for the Authority, Dr. Siegel acknowledged that there is a hydraulic gradient moving water through the bedrock toward its buried valley. However, consistent with the Authority's groundwater modeling results, he said it would take hundreds of year for flow from the northwest part of the landfill footprint (the Objectors' principal area of concern) to reach the valley via the brown till and the bedrock. He said it was "not plausible" that there is a continuous horizontal bedrock fracture network connecting the northwest part of the landfill footprint to the buried valley aquifer to the south. He acknowledged there are fractures in the bedrock that allow water into the monitoring wells, but said that overall the bedrock is "pretty darn tight," based on the results of the Authority's permeability testing. He said the site is typical of others he has observed in upstate New York, where the top of the bedrock is partly fractured due to glacial action and unloading. These fractures, he emphasized, are discontinuous. Dr. Siegel said that he saw no evidence geologically that there should be significant faults or other structures that would create what Dr. Michalski described as pathways for preferential flow of groundwater.

Mr. Fancher agreed that it is not likely that the bedrock would act as a conduit for the migration of contaminants to the deep sand/till unit. He said that because of its makeup, the site's bedrock is of low to moderate permeability and not the type associated with the development of large, open, highly transmissive fractures. Such fractures, he said, are more typical of karst limestone, which is of special concern in landfill siting due to the potential it creates for rapid or unpredictable groundwater flow. Bedrock subject to rapid or unpredictable groundwater flow must be avoided unless it can be demonstrated that a containment failure would not result in contamination entering the bedrock system resulting in a contravention of groundwater standards. [See 6 NYCRR 360-2.12(b)(2)(i)(b)(2).] According to Mr. Fancher, the bedrock at this site is not subject to rapid or unpredictable groundwater flow. To the contrary, he said, it is of a type most likely to impede groundwater flow.

Mr. Fancher’s testimony is consistent with findings I made in another landfill case involving the same restriction against siting landfills over bedrock that is subject to rapid or unpredictable groundwater flow. In that matter, involving Waste Management of New York’s application to construct a landfill in Albion, Orleans County, I found compliance with the same siting restriction that is at issue here. My hearing report, which was adopted by the Commissioner, cites favorably the testimony of the applicant’s hydrogeologist, Timothy Roeper, to the effect that rapid or unpredictable groundwater flow is generally caused by large voids or fractures in the bedrock that form open flow pathways. Such flow, my report said, is generally associated with carbonate rocks such as limestone and dolomite where groundwater can dissolve the rock to form open subterranean drainage and sinkholes. At the Albion site, the bedrock was sandstone and shale, not unlike the bedrock here. Neither sandstone nor shale are susceptible to dissolution by groundwater, my hearing report states. [See In the Matter of Waste Management of New York, an application for permits to construct the Towpath Environmental and Recycling Center, pages 55 and 62 of my hearing report attached to the February 10, 2003 Decision of the Commissioner.]

Mr. Fancher stressed that groundwater elevations within the upper portion of the bedrock exhibit a relative consistency which the Authority has satisfactorily mapped, meaning that groundwater flow within the bedrock can be effectively monitored. Also, he said the proposed locations for bedrock monitoring wells are consistent with the mapped groundwater flow patterns, and with the relative movement of groundwater which has been documented between the bedrock and the other units of the critical stratigraphic section.

Mr. Fancher said that construction of the landfill would not alter the configuration of the bedrock surface and is not expected to alter groundwater elevations in the bedrock unit. Landfill construction would maintain the required 10-foot separation distance to bedrock required by 6 NYCRR 360-2.13(e). Thus, groundwater flow patterns within the upper bedrock are expected to remain similar to their current configuration.

In his prefiled testimony, Dr. Michalski cited an article by Novakowski and Lapcevic (Hydrogeology Exhibit 126) as an example of bedding plane fractures with large apertures transmitting the bulk of groundwater flow in bedrock. The article addresses groundwater flow in an uppermost regime consisting of fracture zones in the Guelph and Lockport Formations underlying Niagara Falls. As Dr. Siegel explained, these formations are in no way comparable to Whetstone shale. The reason, he said, is that they consist of two minerals, dolomite and calcite, which dissolve quickly. The Guelph and Lockport formations were set down in thick layers with weaker zones between them which allowed water in and caused the minerals to dissolve, opening wide bedding plane fractures and even some caves, Dr. Siegel testified. In contrast, he said, the bedrock at the landfill site was set down in very thin layers, it is not subject to dissolution, and therefore, bedding plane fractures cannot be discerned.

Under cross-examination, Dr. Michalski acknowledged the differences between the Lockport and Guelph dolostone formations underlying Niagara Falls, and the Utica Whetstone shales beneath the landfill site. This undercut the relevance of the article he had cited. He said that the hydraulic conductivity of dolomite is primarily controlled by bedding plane fractures, adding, however, that from a lithological standpoint, dolomite and shale are different rock types.

Dr. Siegel established that, in this instance, packer tests are not necessary, given the nature of the bedrock present. As he explained, such tests would be more appropriate in crystalline rock like granite, which has open fractures, or in dolomite to isolate bedding plane fractures. According to Dr. Siegel, shales are inherently softer than these other rock types. Fractures in shale, he added, tend to pinch off at depth or become clogged with mineral precipitates.

That the shale becomes tighter, even at shallow depths, was confirmed by the Authority’s permeability testing. Contrary to the Objectors’ representation, that testing does not suggest there are fast-flow pathways through the bedrock to the buried valley aquifer. Overall, the testing indicates that the bedrock is tight. The testing also suggests nothing about the continuity of fractures over large distances, or the interconnection of fractures at depth. In fact, all the evidence suggests that the bedrock is of a type that is not conducive to the development of large, open, highly transmissive fractures. Such was the testimony of Mr. Fancher, which went unchallenged during his cross-examination. One may safely conclude that should the landfill leak, contaminants would not move rapidly through the bedrock.

The Effect of the Leachate Collection System on Area Hydrology

At the issues conference, the Objectors claimed that the leachate collection system would substantially alter the hydrology of the site and its surrounding wetlands by diverting millions of gallons of precipitation annually from its accustomed paths. The Authority claimed in the FEIS that 91.4 percent of the precipitation which falls on the site would be handled by a stormwater management and drainage system, from which it would flow into the south branch of Moose Creek, and that the remaining 8.6 percent would go into the leachate collection system, and from there into trucks for off-site treatment and removal. (See page 12 of my issues ruling.)

These estimates were apparently the product of a previously undetected mathematical conversion error, according to Mr. Fancher's prefiled testimony. Mr. Fancher (for Department Staff) and Mr. Southern (for the Authority) both now calculate that only 1.15 percent of the precipitation that falls over the 532-acre development area would be diverted into the leachate collection system. The calculations of these two witnesses were laid out in their prefiled testimony. The Objectors did not challenge the calculations or offer different ones of their own.

The Authority has maintained throughout this proceeding that the diversion of precipitation into the leachate collection system (and the disposal of the leachate offsite) would have no significant environmental impact. In particular, the Authority foresees no impact in terms of water quality, base flow to the creek, or biological resources such as wetlands that are associated with the creek. At the hearing, Mark Craig, a Department biologist, agreed with the Authority's assessment, pointing out that most of the surface water entering the on-site wetlands comes from off-site sources. Mr. Craig testified that the supply of water entering the WL-2 wetland would see minimal change resulting from landfill construction because five tributaries and the main channel of the south branch of Moose Creek all enter the wetland system from south or west of the site. As claimed by the Authority in its closing brief, the

Objectors effectively conceded the issue of impacts stemming from the leachate collection system by presenting no evidence on the issue during the adjudicatory hearing and by failing to cross-examine Mr. Fancher and Mr. Southern on their calculations.

<u>The Effect of the Groundwater Suppression System on the Water Table</u>

At the issues conference, the Objectors claimed that the planned groundwater suppression system would lower the water table substantially in the area south of the landfill footprint, draining beaver ponds and at least 20 acres of wetlands, and lowering the base flow of the south branch of Moose Creek. (Issues rulings, page 12.) Although the Authority claimed that the area's wetlands were predominantly dependent on precipitation and surface water runoff, Dr. Michalski said the wetlands also depend on groundwater to a significant degree.

Dr. Michalski's pre-filed testimony did not address, let alone back up, this assertion. When asked in his pre-filed testimony to predict the effect of the groundwater suppression system, Dr. Michalski addressed only the alleged impact it would have in facilitating the rate of downward groundwater flow from the near-surface to the buried valley aquifer, making no reference to the alleged wetland impacts that were key to my identifying this issue in the first place. The Objectors' only testimony on wetland impacts allegedly associated with the groundwater suppression system came from Gretchen Stevens, a botanist. Ms. Stevens did not present her case from a hydrogeologic standpoint, but instead from her observation that plants ordinarily associated with groundwater discharge occur along the edge of wetlands in the southwest corner of the site. This suggested to her that the wetlands are supported in part by groundwater originating from within the landfill site.

There is no question that some groundwater from the area of the landfill footprint flows toward and upwells in the adjacent wetlands. However, the Authority's modeling indicates that the contribution of groundwater to wetlands on the site is minimal, in the range of 0.09 to 0.445 inches annually, compared to the 58 inches of precipitation that falls directly on the wetlands in an average year, and the other water the wetlands receive due to surface runoff. Dr. Michalski offered no testimony challenging the Authority's projections of the area and extent of drawdown attributable to the groundwater suppression system. Nothing was offered to support the Objectors' claims that drawdown would be more severe and widespread than the Authority has predicted.

Dr. Siegel testified that the hydraulic conductivity of the soils is so low that it is implausible that water could be induced to drain into the groundwater suppression system from very away. He said it is implausible that the system would create a cone of depression that would lead to a loss of wetlands for a distance of up to 1,500 feet along the southern edge of the landfill, as Dr. Michalski had claimed in comments on the DEIS.

The evidence indicated there is a clay layer within six inches to one foot of the wetland surface which effectively traps surface water runoff and precipitation. The layer was apparent from soil auger testing and soil sampling done during an August 2002 walkover in the southwestern part of the site involving Dr. Siegel and Mr. Coogan (for the Authority) and Ms. Stevens (for the Objectors). Ms. Stevens acknowledged the existence of a clay layer in her prefiled testimony, stating that even if the water table is drawn down by the groundwater suppression system, the wetland is likely to remain in some form due to its location in a local basin and the underlying clayey soils which will continue to perch rainwater and surface runoff to some degree.

The Authority concedes that when the landfill is fully built, there will be a two-foot drawdown of the water table in some portion of the wetlands west of the site. In the area Ms. Stevens focused on during her August 2002 visit, the drawdown would be even less, if there is any at all. Despite the possible drawdown of the water table, capillary action would continue to move water upward through the soil column to make it available to the roots of wetland plants. The capillary action phenomenon was explained in detail by Dr. Siegel and was acknowledged by Ms. Stevens as well.

Ms. Stevens testified that the plants observed in the wetland confirmed that the wetland is partly fed by groundwater. However, these plants are not associated with groundwater in all instances, as the Authority pointed out during her cross-examination. For instance, Ms. Stevens cited a reference that the moss Rhizomnium appalachianum is strongly associated with groundwater seepage habitats in the southern part of its range. However, she then conceded that the southern part of its range is in Georgia and the southern areas of the Piedmont, while in the northern part of its range (which extends to Labrador and Nova Scotia) it occurs in seepage areas but also in other kinds of wooded and shrubby wetlands. The Authority made a similar point with golden saxifrage, another of Ms. Stevens' indicator species. While golden saxifrage is often found in shaded groundwater springs and seeps, it also occurs in the headwaters of streams, muddy soils, swamps, and wooded shrubby wetlands. Ms. Stevens testified that lowering the water table by one to two feet would transform a wetland fed substantially by groundwater into non-wetland, and that along transition zones at the wetland margin, a drop in the water table of as little as a few inches could effect the same transformation. Again, however, there is no evidence that these wetlands are fed substantially by groundwater. In fact, it appears they are fed primarily by precipitation and surface water runoff.

Ms. Stevens expressed concern about water quality as well as water quantity. She testified that groundwater is rich in minerals, more so than precipitation, and where it emerges from calcareous deposits, groundwater also tends to be alkaline, so it can buffer acidity attributable to rainwater and the decay of organic matter. The wetlands do contain calcicoles, which are plants normally associated with calcareous soils. Therefore, maintaining a calcareous environment is important to these species' preservation, as the Authority acknowledges.

Ms. Stevens suggested that the requisite environment is now maintained by calcareous groundwater flow which could be reduced or eliminated due to impacts of the groundwater suppression system. However, as Dr. Siegel explained, such flow is not essential, given different ways that nutrients can reach wetland plants. Dr. Siegel said that even if groundwater flow stopped totally on the landfill side of the wetlands, the soils would still contain enough calcite to sustain plant growth. Rainfall striking the soil would dissolve the calcite and release it to the plants in the shallow subsurface, and in the deeper subsurface, calcium would still be pulled up along the capillary fringe, the zone from the water table up through the unsaturated clay.

In summary, because wetland plants receive nutrients in different ways, they should not be affected by the small water table drawdown that is projected by the Authority. The record demonstrates that groundwater makes a minimal contribution to the wetlands, and that precipitation and surface water runoff are much more important to the wetlands' viability. The Authority intends to build surface water collection basins from which water would be discharged to the wetlands, supplementing other sources of recharge. Finally, in the western and southwestern portions of the site, drawdown impacts are associated only with late stages of this 62-year project, given the sequencing of cell construction. If drawdowns due to the groundwater suppression system are greater than anticipated, that will be apparent well before the wetlands of greatest concern to the Objectors could possibly be affected.

The Effect of the Groundwater Suppression System on Contaminant Transport

The Objectors claim that the groundwater suppression system would facilitate the downward flow of contaminants from the near-surface soils to the buried valley aquifer, accelerating the rate of contaminant migration. As noted in my findings of fact, the groundwater suppression system would be developed under the double composite liners throughout the landfill footprint to prevent groundwater from contacting and interfering with the liners. The system would consist of six inches of fill with a minimum permeability of 1×10^{-2} cm/sec. This high-permeability fill is intended to promote rapid lateral movement of groundwater from beneath the landfill and prevent contamination that would occur if groundwater were able to mix with the waste mass. The groundwater suppression system is now designed to be free-draining under gravity flow, meaning that it would not require the use of pumps to remove collected water.

At the issues conference, Dr. Michalski argued that the creation of a continuous high-permeability drainage layer under the footprint would intensify the downward flow of contaminants through high-permeability features in the till. I found that this offer of proof raised an issue under 6 NYCRR 360-2.17(g), which requires, among other things, that the landfill be constructed and operated to prevent the migration of leachate into surface water and groundwater. (See page 28 of my issues ruling.)

Dr. Michalski's claim was addressed by Mr. Fancher in his prefiled testimony. According to Mr. Fancher, the groundwater suppression system would not facilitate leachate migration because it could not increase the gradient away from the landfill in the geologic subsurface. Therefore, said Mr. Fancher, it could not increase the speed of a release traveling through the groundwater. Mr. Fancher said that inclusion of the groundwater suppression system is consistent with Section 360-2.17(g), not contrary to it, because separating the base of the landfill from the groundwater is fundamental to minimizing the potential for groundwater contamination.

Mr. Fancher observed that, with groundwater entering the suppression system, the water table would be lowered in the immediate vicinity of the landfill. This lowering is intended and necessary to achieve the desired separation between the groundwater and the base of the landfill liners. Mr. Fancher said that should these liners leak, a release entering the groundwater suppression system would tend to move along the system, due to its high permeability, rather than through the system and downward.

Mr. Fancher explained that there would be a decrease in hydraulic head wherever the water table intersects the proposed groundwater suppression system. Because groundwater flows only in response to a gradient in hydraulic head, a lowering in head at the base of the landfill would have the overall effect of reducing the gradients away from the facility. Furthermore, he said that if the reduction in head is sufficient, a localized reversal in hydraulic gradients is possible as well, such that groundwater flow would be directed inward. Such a scenario, he said, is most likely to occur in low-permeability formations such as those at this landfill site. Mr. Fancher added that any reversal in gradients would reduce the potential for migration of contaminants away from the landfill. In fact, such a reversal has been predicted by the Authority's groundwater simulation model for much of the proposed footprint.

Mr. Fancher said he agreed with the Authority's prediction that the water table in the surficial brown till would be drawn down by between 2 and 14 feet over a relatively limited area in the immediate vicinity of the landfill perimeter. While he said this would affect groundwater flow patterns particularly in the surficial brown till, he added that it would have a negligible effect on the upper bedrock unit. Mr. Wolfert agreed. He pointed out that the groundwater suppression system would be constructed above the bedrock, and in much of the footprint would be well above the bedrock. Because the suppression system can only affect groundwater movement and water levels above and around it, he said it would be impossible for the system to affect the gradient in the bedrock.

Dr. Michalski claimed that a groundwater suppression system would be appropriate for settings involving a groundwater discharge area (with a vertical flow component directed upward) or in a setting with horizontal groundwater flow that the system could then capture. However, he said such a system is not well-suited for a recharge area with a strong downward gradient, particularly with a water table he describes as perched in the near-surface tills.

According to Dr. Michalski, excavation into the gray till for construction of the groundwater suppression system would compromise the integrity of the till in areas where it is already weakened due to thinness and the presence of high-permeability sand bodies, fractures or other heterogeneities that provide preferential downward migration pathways in the till. Also, he said, the system, once in place, would create a fast horizontal pathway between the liner bottom and these pathways, having the unintended effect of speeding releases to the buried valley aquifer much faster than they would travel if there were no such system installed.

Dr. Michalski's assertions were convincingly rebutted by Mr. Wolfert for the Authority. Like Mr. Fancher, Mr. Wolfert testified that if leachate were able to penetrate the double composite liners, it would tend to move horizontally through the high-permeability gravel drainage layer that constitutes the groundwater suppression system. Ultimately, the leachate would go to the down-slope end of that system, from which it would be pumped, stored onsite, then taken offsite for disposal. The slope of the drainage layer, its very high permeability, and the low permeability of the underlying till all promote the movement of liquid laterally through the drainage layer rather than downward through the till, under both saturated and unsaturated conditions, Mr. Wolfert explained.

Dr. Michalski's stated concern depends on the existence of large-scale high-permeability features that could carry contaminants through the tills to the buried valley aquifer. As discussed above in relation to the confinement of the buried valley aquifer, there is no convincing evidence that such features exist. They are not reflected in, and cannot be inferred from data collected during the site investigation, as noted earlier in this discussion. Also, there is no basis to think that such features would be created during the landfill's construction.

Dr. Michalski points out that in large portions of the northernmost part of the landfill footprint, the bottom of the groundwater suppression system would always be above the high water table. In these portions, he says, it is virtually certain that a release would percolate through the system and into the brown till where it is unsaturated. According to Dr. Michalski, the reported permeability of the brown till in this part of the footprint is in the range of 10^{-3} to 10^{-4} cm/sec. However, as the Authority points out, that is a horizontal permeability value; the vertical permeability is in 10^{-6} to 10^{-8} range, reflecting very little potential for downward contaminant movement. The permeability of the groundwater suppression system would 1 x 10^{-2} cm/sec at a minimum, so even in the area where the suppression system would be above the water table, leachate exiting the landfill would still tend to move along the system rather than through it. As an additional safeguard against leachate escape, Dr. Siegel explained that in the northern portion of the landfill, the topsoil would be removed during the landfill's construction and the brown till would be rolled and compacted before the liner system is constructed.

The construction of the groundwater suppression system above the water table in the northern portion of the landfill was acknowledged by Mr. Wolfert in his prefiled testimony. The reason for it, he said, is to maintain design slopes for the landfill liner and leachate collection system as well as the underlying groundwater suppression system. In this portion of the landfill, the groundwater suppression system would not be removing groundwater because the system would be above the water table. Instead, it would act as a third collection and removal layer for leachate in the event that the primary and secondary liner and leachate collection systems fail.

In summary, the groundwater suppression system would not facilitate the migration of leachate to the buried valley aquifer. To the contrary, it would help assure that contaminants do not spread within the subsurface.

<u>Modeling of Groundwater Flow in the Critical Stratigraphic Section</u>

- - Identification of Issue

Using data generated during the hydrogeologic site investigation, the Authority's consulting firm, Geraghty & Miller, modeled groundwater flow patterns as they now exist and as they would change during and after the landfill's operation. At the issues conference, the Objectors argued that the modeling is inadequate and, therefore, the Authority's groundwater monitoring plan is unreliable. Based on the Objectors' offer of proof, I found an adjudicable issue under 6 NYCRR 360-2.11(c)(1), which states that groundwater monitoring wells must be capable of detecting landfill-derived groundwater contamination within the critical stratigraphic section. The concern is not simply that the units making up the critical stratigraphic section be defined, but that there be a proper understanding of potential contaminant pathways over the life of the landfill and its post-closure period. Items for consideration included the conductivity of the bedrock and till units, the components of lateral and vertical groundwater flow within those units, the relationship of the unnamed Moose Creek tributary to the local water table, and the possibility that bedrock could provide a rapid migration pathway allowing contaminants to move into the buried valley aquifer. (Issues ruling, pages 27 and 28.)

In affirming my issues ruling, the Commissioner said that further inquiry was warranted due to competing information presented by the Authority and the Objectors with respect to groundwater flow, as well as the import of the accuracy of models used to predict groundwater flow for accurately developing a monitoring well plan to detect landfill-derived contamination within the critical stratigraphic section. (Interim Decision, page 22.)

- - Modeling Overview

As discussed above in my findings of fact, the Authority has subdivided the critical stratigraphic section into four units: the surficial brown till, the underlying gray till, the deep sand/till unit (which includes the buried valley aquifer), and the upper portion of the bedrock. Furthermore, it has developed a monitoring well network based on its understanding of site hydrogeology, three-dimensional flow modeling, particle tracking of hypothetical releases, and groundwater flow maps.

The Authority argues in its closing brief that groundwater moves slowly in the till units, that the bedrock will not act as a conduit for the fast migration of potential contaminants to the deep sand/till unit, that Moose Creek is a gaining stream, and that the predominant flow of groundwater at the site is horizontal, within the shallow subsurface, discharging to local streams and wetlands. I agree with these assessments, and they are confirmed by the groundwater flow modeling.

The Authority presented two witnesses solely on the issue of groundwater flow modeling: Steven Feldman and David Schafer, both from Geraghty & Miller. In March 1996, Mr. Feldman became the senior modeler responsible for the quantitative evaluation of groundwater flow conditions and the simulation of the groundwater system response to the hydrologic stress that would be induced by the groundwater suppression system. Mr. Schafer provided technical review of the groundwater flow modeling effort.

The Objectors presented as their witness Dr. Ying Fan Reinfelder, a hydrogeology professor at Rutgers University in New Jersey. Dr. Reinfelder was retained by the Objectors to review and analyze Geraghty & Miller’s groundwater modeling. She concluded that there were several problems with the construction, calibration and reporting of the Authority’s model, and that the modeling program it used was the wrong one for this site. Dr.

Reinfelder also performed additional runs of the Authority's model using modified parameters. These additional runs were done as part of a critique of the Authority's modeling, to show that when certain parameters are changed, the model results are strongly affected. As the Objectors argue in their reply brief, Dr. Reinfelder did not adopt these runs as her own version of how groundwater flows at the site. In fact, the Objectors have not done any groundwater flow modeling of their own.

During the issues conference, Department Staff opined that the Authority's groundwater flow model does reasonably represent what happens at the site and adequately supports the Authority's environmental monitoring plan. Given the sophistication of the issues presented and Staff's duty to independently and dispassionately review permit applications, I wrote in my issues ruling that testimony supporting these opinions would be especially welcome at the adjudicatory hearing. Such testimony was provided by Lincoln Fancher, an engineering geologist with Region 6 Staff.

Mr. Fancher's prefiled testimony explains the purpose of groundwater computer simulation models in the evaluation of proposed landfill sites. Mr. Fancher said that where site hydrogeologic conditions are relatively simple, and can be characterized as a single water-bearing formation having relatively uniform properties, groundwater flow relationships can generally be characterized using a combination of relatively simple algebraic equations, analytical solutions, and graphical techniques. However, he added, where several geologic units with contrasting hydrogeologic properties are present at a site, or where the hydrogeologic properties of a single unit vary spatially or directionally, consideration of flow patterns within and between the various geologic materials becomes more difficult. According to Mr. Fancher, in these instances, a groundwater computer simulation may be appropriate to allow simultaneous consideration of the interaction between many spatially-varying or time-varying parameters which would make evaluation of groundwater flow relationships tenuous by other means. In addition, he said, such a simulation enables the modeler to make predictions concerning the probable routes of groundwater flow under the changed conditions which would be expected to result from the landfill's construction, and to make predictions on the potential rates of contaminant transport under those changed conditions.

The Part 360 landfill regulations state that the Department may require an applicant to develop acceptable computer models of contaminant plume behavior from hypothetical leaks in the liner system, if necessary to determine optimum monitoring well spacing. [6 NYCRR 360-2.11(c)(1)(i)(c).] In the case of the Authority's investigation of site WLE-5 East, the use of a computer simulation model was an evaluation method which was proposed by the Authority and accepted by Department Staff in 1996. The Authority was advised by Department Staff to employ generally accepted modeling protocols, as specific criteria are not set out in the regulations.

The Authority's groundwater flow modeling is embodied in a report that is Appendix "L" to the site investigation report. (A copy of the report is Exhibit "B" to Mr. Feldman's prefiled testimony, which is Hydrogeology Exhibit 23.) The model used by Geraghty & Miller at this site was the USGS Modular Three-Dimensional Finite Difference Groundwater Flow Model (MODFLOW). Its model code is well-documented and publicly available, and Mr. Schafer described MODFLOW as the most universally accepted, tested and verified modeling program in the groundwater industry.

The process of defining the groundwater flow system and then constructing the model to represent actual site conditions is detailed in Mr. Feldman's and Mr. Schafer's prefiled testimony. Mr. Feldman explained that, to define the external geometry of the model, it was necessary to set outer limits. Here, the lateral and bottom limits of the flow system were specified as no-flow boundaries. Mr. Feldman explained that beyond these boundaries, which were set in the bedrock, flow is considered insignificant to the overall hydrologic budget, so the model shows no movement of water at the boundaries. The upper limit of the flow system (the landfill site surface) is not a no-flow boundary, because that is where precipitation enters the system.

Once the area of study was defined, it was necessary to understand how water moves through the groundwater system from recharge to discharge areas. The Authority's site investigation report was relied on for data about the thickness of different units, the distribution of horizontal and vertical conductivity, and the distribution of water levels across the site. In the Authority's conceptual model, the greater component of groundwater flow eventually goes to Moose Creek and, from there, out of the flow system. A lesser component moves through the gray till and bedrock into the deep sand/till unit, but in terms of the overall water balance, it is a small component of flow.

MODFLOW allowed the Authority to convert its conceptual model into a numeric model incorporating the Authority's hydrogeologic data. As Mr. Schafer explained, the model domain is divided into a series of horizontal layers and each layer is then subdivided into a large number of rectangular cells, resulting in a three-dimensional array of rectangular grid blocks. Here, the model consisted of a rectangular grid with 103 rows, 100 columns, and six layers. The grid was electronically overlain on a site map to provide an areal orientation. Areas of the grid that were outside the conceptual site model were specified as inactive model cells. Those cells were not part of the model domain and therefore not part of the study area.

As Mr. Feldman explained, Model Layer 1 represents the brown till over a majority of the site. (Along the unnamed Moose Creek tributary it is transitional to bedrock.) Model Layer 2 primarily represents the upper part of the gray till unit, but also transitions to bedrock toward the northwest portion of the site. Model Layers 3 and 4 represent the gray till, which is bounded laterally with active cells that represent the transition to bedrock. Model Layer 5 represents the deep sand/till unit bounded laterally by active cells that represent bedrock. Model Layer 6 represents bedrock. The model was constructed with six layers in order to represent the transition between units and to accurately simulate the steep vertical hydraulic gradients in the gray till and the hydraulic response to the groundwater suppression system.

In MODFLOW, after the model domain is subdivided, appropriate physical attributes are assigned to each grid block, including such things as hydraulic conductivity, water level and applied flow rate. According to Mr. Feldman, hydraulic conductivity values were assigned to the model based on data obtained from slug testing and laboratory testing. Since every model cell was assigned a hydraulic conductivity value, the next step in model construction involved areal mapping of the relative trends in hydraulic conductivity values so that zones of hydraulic conductivity could be assigned to groups of model cells.

MODFLOW uses known groundwater flow principles to set up equations calculating the movement of groundwater, both horizontally and vertically, between all pairs of adjacent grid blocks. The equations are then solved simultaneously on a computer, while satisfying the applied boundary conditions, to determine the resulting water levels for each grid block and the movement of groundwater from one grid block to another. After the model is fully constructed, its simulation of the flow system is then compared to what is known about the system, and an attempt is made to conform the simulation to reality.

As Mr. Feldman explained, this model calibration process is an iterative procedure in which the properties of the hydrogeologic units (hydraulic conductivity, anisotropy ratio, creek bed conductance, and recharge rate) are adjusted within a reasonable range of values to obtain an acceptable match between observed (field-measured) water level elevations (or heads) and model-calculated heads. The process here used 75 calibration targets which were well-distributed, both areally and vertically, throughout the model domain.

As Mr. Schafer explained, the calibrated model reproduces all the significant characteristics of the groundwater flow regime, including the groundwater divide near the western portion of the model domain, the steep downward gradients in the brown and gray tills, and the very flat gradient in the deep sand/till unit. The majority of simulated heads show close agreement with observed water level measurements, and the model reproduces the overall magnitude and distribution of heads throughout the site.

The calibrated model was put through a sensitivity analysis to determine which input parameters have the most impact on the model's calibration accuracy and conclusions. According to Mr. Schafer, a sensitivity analysis involves varying selected parameters over a specified range and running the model simulation again to see what changes are produced.

As Mr. Feldman explained, of the various sensitivity analyses performed, the model was found to be most sensitive to changes within a range of values for recharge and hydraulic conductivity. Under cross-examination, Mr. Feldman explained that as part of the sensitivity analysis, he ran the model with higher values for recharge and again with higher values for hydraulic conductivity, but not at the same time with higher values for both. Had he run the model with higher values for both recharge and hydraulic conductivity, the Objectors argue, it is possible that he could have maintained the same heads, indicating a "non-uniqueness" problem with the model, as discussed further below.

As the reviewer of the modeling effort, Mr. Schafer testified that the calibrated groundwater flow model provides a reliable, scientific integration of the abundant field data collected from the site and is a reliable predictor of groundwater flow patterns and flow rates, as well as future hydraulic responses. He said that available geologic and hydraulic data had been incorporated into the model in an appropriate manner, using accepted, industry-standard modeling protocols. He added that the calibrated model successfully replicates key site observations including:

- - Horizontal groundwater gradients toward surface water features;
- - Steep gradients in the till units;
- - The groundwater divide in the western portion of the site;
- - The unsaturated portion of the deep sand/till unit;
- - The extremely flat gradient in the deep sand/till, which he says illustrates that very little groundwater migrates to that unit through the gray till and shale bedrock; and
- - The extremely low vertical velocities through the brown and gray tills, consistent with the tritium age-dating of shallow groundwater.

To simulate the advective transport of particles within the flow field generated by MODFLOW, Geraghty & Miller used the USGS three-dimensional particle tracking technique called MODPATH. In general terms, advective transport is the process by which a water particle is transported by the overall motion of groundwater flow. MODPATH computes flow paths, travel times, discharge locations, and the position of particles at specified points in time. As with MODFLOW, the model code is well-documented, publicly available, and widely used in the scientific community, according to Mr. Feldman.

MODPATH allows for a traceable particle to be depicted as it moves from cell to cell in the model domain, which can be interpreted as the path that a water particle will take within the flow field described by MODFLOW. As applied to this project, it allows the modeler to determine how potential landfill releases would move within the groundwater flow system, both where they move and the associated travel time, as Mr. Schafer explained.

Mr. Schafer testified that the model calculations and particle tracking demonstrate that, under present conditions, most of the site recharge moves through the shallow portions of the brown and gray till and bedrock, discharging to surface water features including wetlands, Moose Creek and its unnamed tributary. These discharges, the modeling determined, account for about 92 percent of the site recharge, primarily that portion that infiltrates in the northern, central and eastern areas of the site. The remaining eight percent of site recharge, primarily from western portions of the site, migrates through the gray till and/or bedrock, eventually reaching the deep sand/till unit and discharging to the east through that unit, the modeling determined. According to the modeling, groundwater migration rates are very low and residence times are very long, which the Authority argues is consistent with the tritium age dating analysis of groundwater samples.

The modeling showed that operation of the groundwater suppression system would have only a minor effect on flow conditions, drawing in a relatively minor volume of groundwater. During the active operating period, the modeling indicated, the only groundwater exiting from the area of the landfill footprint would be in the northern part of the site, where groundwater migrates horizontally to the unnamed tributary to Moose Creek.

The Authority modeled a hypothetical worst-case condition in which the groundwater suppression system is not working and the groundwater flow system returns to present-day conditions. In that simulation, particles that enter the deep sand/till unit do not travel beyond the landfill footprint. Therefore, if the simulation is correct, offsite groundwater contamination would not occur.

Department Staff reviewed the Authority’s groundwater computer simulation model report and concluded that the modeling provided a reasonable representation of site conditions as they exist now and as they would change with operation of the groundwater suppression system during the landfill’s operation. Mr. Fancher testified that the Authority’s modeling incorporated assumptions which are appropriate for the geologic and physical setting of the site, and that model node assignments were reported to be within the range of variation of the reported field data. He said the variation of hydraulic conductivity values during the Authority’s model calibration was within the range of reported field values, and the model’s anisotropy ratio (the ratio between horizontal and vertical hydraulic conductivity) was within the range of variation determined by slug tests (for horizontal conductivity) and laboratory testing of soil samples (for vertical conductivity).

Among the key conclusions outlined in his prefiled testimony, Mr. Fancher found that:

- - The Authority’s computer simulation of existing site conditions reproduced hydraulic gradients which are generally consistent with overall gradients and groundwater flow patterns which have been reported for the site, with no prevailing positive or negative bias in residual head levels.

- - During the predictive simulation of groundwater flow patterns which are likely to prevail following full construction of the landfill, the Authority employed assumptions which were appropriate for the representation of a groundwater suppression system beneath the landfill footprint.

- - During the Authority’s consideration of post-landfill conditions, the assumption of an inoperative groundwater suppression system is appropriate, and consistent with the Department’s view that the prediction of groundwater flow patterns and travel times for purposes of determining the critical stratigraphic section for the site should make the conservative assumption of an absence of engineering controls.

- - Objectors’ Criticisms of Authority Modeling

The Objectors argue in their closing brief that contaminants from the proposed landfill would travel much faster and farther than the Authority has estimated on the basis of its modeling effort. The Authority claims that it would take centuries for contaminants to escape the site through the subsurface deposits. However, Dr. Michalski claims that contaminants carried by groundwater in the buried valley aquifer could reasonably be expected to travel a distance of at least 2 to 3 miles along the buried valley aquifer during the 92 years that encompass the 62-year life of the landfill and the 30-year post-closure period. With this understanding, the Objectors claim that the full downgradient extent of the buried valley aquifer must be considered part of the critical stratigraphic section and that the groundwater monitoring system must be adjusted to account for the speed at which contaminants could travel through the aquifer.

As noted above, the critical stratigraphic section includes the deep sand/till unit in which the buried valley aquifer is located. Three of the Authority’s deep sand/till monitoring wells would be screened below an elevation of 1297 feet, in the aquifer itself. Two of these wells are in downgradient locations: MW-38DS (at a screened interval of 1270 to 1280 feet) and MW-40DS (at a screened interval of 1250 to 1260 feet). Another well (MW-24DS2) provides upgradient monitoring of the aquifer.

In cross-examination of Mr. Schafer, the Objectors pointed out that contamination between the bottom of the well screens of MW-38DS and MW-40DS and the top of bedrock in these locations (a distance of 30 feet at MW-38DS, and 70 feet at MW-40DS) would not be detected by the environmental monitoring system. However, to reach these locations, the contamination would have to pass through the liner and groundwater suppression systems and then through the deposits overlying the aquifer.

Monitoring of leachate in the secondary leachate collection system and groundwater in the groundwater suppression system should allow for the early detection of a tear in the liner system, allowing ample time for investigation and remediation before contaminants could reach the buried valley aquifer, given the slow travel times predicted by the Authority's modeling. Should a leachate breakout occur, the Department retains the authority to require more rigorous and frequent groundwater monitoring, including the addition of monitoring wells as needed in the buried valley aquifer or anywhere else on the landfill site. Also, though modeling tracks contaminants as particles, leachate tends to move through the landfill subsurface in spreading plumes, particularly in high-permeability formations. Therefore, it is difficult to imagine that contaminants could reach the bottom of the buried valley aquifer while escaping detection all along the way.

The Department's regulations require that each unit of the critical stratigraphic section be monitored, but not that each unit be monitored throughout its entire depth. In fact, as Department Staff argue, the intent of the Department's monitoring requirements is to catch contamination at the earliest point possible, so that remediation may be instituted immediately. All downgradient monitoring wells must be located as close as practical to but not more than 50 feet from the waste boundary, unless otherwise approved by the Department due to site-specific conditions, to ensure early detection of any contaminant plume. [6 NYCRR 360-2.11(c)(1)(i)(e).] If contamination is detected, the landfill operator may then be required to install additional monitoring wells at the facility boundary in the direction of contaminant migration. [6 NYCRR 360-2.11(c)(5)(iii)(e)(1) and (2)]. However, the overall intent of the regulations is that monitoring be restricted to the site itself, with the idea that a leachate breakout be detected at the earliest opportunity.

The Authority's modeling considered a worst-case condition involving simultaneous failure of the primary and secondary liners, a non-operating groundwater suppression system, and no on-site remediation. Even in such a situation, it found that none of the particles entering the deep sand/till unit would travel beyond the boundary of the landfill footprint. Nonetheless, the Objectors say the modeling is deeply flawed for various reasons discussed below. According to the Objectors:

- - The hydraulic conductivities assigned in the model are inaccurate, which causes the model's predicted contaminant travel times to be unrealistically slow.

- - The model relies on an artificially low recharge rate.

- - The model has not been properly calibrated and its results are not consistent with observed data from the site.

- - The model fails to include the bulk of the bedrock at the site, which reduces the number of pathways to the buried valley aquifer.

- - The program used by the Authority (MODFLOW) is the wrong model to use because of unsaturated conditions in the deep sand/till unit.

- - Assignment of Hydraulic Conductivity Values

The Objectors claim that the hydraulic conductivity values used by the Authority in its modeling were assigned in an arbitrary manner inconsistent with the data obtained in the field tests, the soil types known to be present at the site, and reported literature values.

In his pre-filed testimony, Mr. Feldman described the process of assigning hydraulic conductivity values to the model. As he explained, the starting point was to incorporate the slug test data into the model; after that, relative trends in hydraulic conductivity values were mapped so that zones of hydraulic conductivity could be assigned to groups of model cells. Mr. Feldman said that adjustments to both horizontal and vertical pemeabilities during model calibration were limited to the range of values as defined by the field data, and that based on the slug test values, laboratory geotechnical testing, and supporting literature, the values assigned to the model were reasonable and reliable data for the model calibration process.

Dr. Michalski testified that the horizontal hydraulic conductivity values assigned to the gray till unit in the model range from 2.4×10^{-8} cm/sec to 3.5×10^{-6} cm/sec, whereas the Authority reported horizontal conductivities of more than 1×10^{-4} in three wells and 1×10^{-5} cm/sec in an additional 14 wells based on slug test data. However, as Mr. Feldman testified, the value of 2.4×10^{-8} cm/sec was a "fringe" value assigned to only five of the 62,000 model cells, and has no impact on the model results. Also, 3.5×10^{-6} cm/sec did not actually represent the high end of the permeability range used in the Authority's model. Higher permeability values were used in the model, as the Authority counters, citing Hydrogeology Exhibit 99, a table that identifies the hydraulic conductivity zones. In Model Layer 2, nearly the entire areal extent of the gray till (Zone No. 38) was assigned a permeability value of 1.06×10^{-5} cm/sec. In Model Layer 3, a large portion of the gray till (Zone No. 18) was assigned a permeability value of 1.06 x 10^{-5} cm/sec, and in the smaller Zone 19 an ever higher permeability value of 1.06 x 10^{-4} was assigned. According to scientific references cited in the record, the hydraulic conductivity of till varies over a very wide range, as much as eight orders of magnitude, and the values determined by the Authority fall within that range, as Dr. Michalski himself conceded on cross-examination. In fact, they fall toward the middle of that range, which tends to discredit Dr. Michalski's claim in his prefiled testimony that the horizontal conductivity values the Authority used for the gray till were "grossly unrepresentative and unrealistic."

Mr. Schafer testified that most of the horizontal permeability values assigned to the gray till were probably in the 10^{-5} to 10^{-6} cm/sec range, though the model also used "outliers" as appropriate (as high as 10^{-4} and as low as 10^{-8} cm/sec). Contrary to the Objectors' characterization of his testimony in their closing brief, Mr. Schafer did not say that the assigned horizontal conductivity values simply reflected mean values determined from slug tests, nor did he suggest that "outliers" should not be used.

The Objectors claim that the vertical conductivity values assumed in the model are even more unrealistic than those for horizontal conductivity. They say there is no justification for a horizontal-to-vertical anisotropy ratio of 400:1 in the gray till, and that the Authority's assumption of such a high level of anisotropy suppressed the downward flow of groundwater through the gray till into the buried valley aquifer and forced virtually all of the groundwater to flow horizontally, at an unrealistically slow rate, into Moose Creek. However, as the Authority points out, an anisotropy ratio as great as 400:1 was used for only a few cells, and those were in the brown till, in Model Layer 1. In the gray till, the anisotropy ratio assigned to the model varied from 60:1 to 125:1, based on the field and laboratory data, Mr. Feldman explained. The Objectors argue that an anisotropy ratio of 400:1 implies that the vertical hydraulic conductivity values for the gray till ranged from 10^{-10} to 10^{-8} cm/sec. In fact, the vertical conductivity modeled for the gray till ranges from 1.76 x 10^{-6} cm/sec (in Zone 39) to 2.47 x 10^{-10} cm/sec (in zone 15, which is only five model cells).

Mr. Schafer explained that, in general terms, the horizontal conductivity values for the gray till range from 10^{-5} to 10^{-8} cm/sec, while the vertical conductivity values for the gray till range from 10^{-7} to 10^{-10} cm/sec. In other words, the vertical conductivity values are roughly two orders of magnitude lower than the horizontal conductivity values. Of the values employed in the model, Mr. Schafer said that those in the range of 10^{-5} to 10^{-6} cm/sec for the horizontal conductivity, and those in the range of 10^{-7} to 10^{-8} for the vertical conductivity, "drive" the model, while the values suggesting less permeability (10^{-7} to 10^{-8} cm/sec for horizontal conductivity, and 10^{-9} to 10^{-10} cm/sec for vertical conductivity) are "fringe" values that have no effect on flux through the system.

The conformance of the anisotropy ratios to literature values is presented in Mr. Feldman's prefiled testimony. According to that testimony, studies in geologic terrain characterized by an upper brown weathered till and a lower gray non-weathered till, which is common in the glaciated areas of North America, provide supporting evidence of the horizontal-to-vertical anisotropy derived from the Authority's testing. Mr. Feldman cites an article by Hendry addressing till in the prairie region of Canada, indicating that horizontal to vertical anisotropy is likely to be between 10:1 and 100:1 in unweathered gray till. (See Exhibit "C" to Feldman's prefiled testimony, Hydrogeology Exhibit 23.) Of the 43 wells for which the Authority had both slug test data and laboratory vertical permeability results, 25 wells had horizontal to vertical anisotropy ratios greater than 100:1. Of these 25 wells, all but one had ratios greater than the model's upper limit of 125:1, which indicates an effort by the Authority to better conform its test values to literature values as part of the model's calibration.

Dr. Michalski testified that by virtue of its mode of origin, typical till is an unstratified, chaotic mixture of heterogeneous material without any consistent anisotropy typically associated with stratified or laminated deposits; therefore, he said, there is little geologic justification for any large difference between its horizontal and vertical conductivities. Dr. Siegel, however, testified that where you have clay sediment of any kind, or where sediments are layered, one finds a pronounced anisotropy, up to or even higher than 100:1.

The Objectors point out that the Authority's model is very sensitive to changes in hydraulic conductivity, and that if the values of hydraulic conductivity are "off," that can have a real effect on what the model produces, as Mr. Feldman himself acknowledged under cross-examination. However, as the Authority points out, Mr. Feldman did not make assumptions about hydraulic conductivity values. Mr. Feldman testified that adjustments he made to the horizontal and vertical conductivities during the model calibration process were limited to the range of values as defined by the field data, which were derived from slug tests and laboratory testing of soil samples. To the extent these adjustments relied on his judgment, the Authority points to Mr. Feldman's extensive experience, which over the course of 19 years as a groundwater hydrologist includes numerous groundwater flow and contaminant transport modeling projects in a variety of hydrogeologic settings.

- - Identification of Recharge Rate

Dr. Reinfelder testified that anisotropy ratios above 10:1 are somewhat unique or unusual. In the first of her model runs, she re-ran the Authority's model by reducing the anisotropy ratio to 10:1 in all zones, without altering the horizontal conductivity values. However, to roughly approximate the measured heads, she also increased the modeled recharge rate to 2.5 inches per year over the entire model domain. (The Authority had used a range of rates from less than one inch up to 2.5 inches per year, depending on the location.) As Dr. Reinfelder explained, reducing the anisotropy ratio causes water to drain more rapidly through the model site, the head levels drop and recharge must increase in order to bring the head levels up to the measured levels.

The Objectors state that by using anisotropy ratios up to 400:1, the Authority "predicted" its recharge rate. However, as the Authority responds, it undertook a literature and statistical review before estimating a recharge rate for the site and assigning recharge values to the model. That process is explained in Mr. Feldman's prefiled testimony. In order to estimate the amount of recharge to the groundwater system in the site area, a hydrologic budget was created to quantify the amount of precipitation that becomes surface water runoff and the amount that is lost through evapotranspiration. The presence of low-permeability surficial till and moderately sloping land surface result in a relatively high percentage of runoff to streams, Mr. Feldman explained. Regional data indicated that the average annual runoff in the site vicinity is on the order of 30 to 35 inches a year. Annual evapotranspiration, determined using the range of mean annual temperatures for the period from 1950 to 1996, was estimated to be 19 to 21 inches. These estimates of runoff and evapotranspiration indicated to Mr. Feldman that the amount of recharge to the groundwater system is a small percentage of precipitation. A reference to a state groundwater study by Heath, cited by Mr. Feldman and attached to his prefiled testimony, reported that, on till-covered hills, recharge ranges from 0.2 to 2.0 inches per year.

With respect to the recharge rate to groundwater used in the model, Mr. Feldman said the brown till has a low permeability and would accept relatively low rates of recharge. A lack of seasonal variation in the water table configuration also provided evidence that seasonal variation in recharge rates (due to snowfall and variability in recharge) does not significantly affect recharge rates or water levels.

Based upon an evaluation of this information, Mr. Feldman’s final calibrated recharge rate to the groundwater system ranged from about 1.0 to 2.5 inches per year, though in topographic areas with a steep slope and areas such as the ravines along creek channels, the recharge rate was fixed at less than one inch per year. He determined that the remainder of the 58 inches of precipitation that fall on the site during an average year either moves laterally to nearby streams and wetlands as overland runoff, or is lost through evapotranspiration.

The Objectors claim that Mr. Feldman used an excessively low recharge rate. Dr. Michalski said that Heath’s estimate of recharge on till-covered hills should not be applied to this site given that much of the landfill site is underlain by high-permeability sand and gravel deposits. Dr. Michalski’s evidence on this point is a USGS map that was included in a report prepared by the Authority in 1994. The map and the report predate the Authority’s extensive site investigation which concluded that the site is in fact covered by low-permeability till deposits. As such, the map and the report are outdated and any information they provide should be disregarded in favor of the data compiled as part of the more recent site investigation report which is part of the permit application.

The Objectors also point out that Mr. Feldman’s recharge rate is at the low end of potential rates calculated by subtracting runoff (30 to 35 inches per year) and evapotranspiration (19 to 21 inches per year) from the average annual precipitation of 58 inches. The Objectors are correct on this point, but as the Authority responds, the runoff and evapotranspiration figures were used only as an indication that the amount of recharge to the groundwater system is quite small. In determining the recharge rate, the Authority evaluated relevant literature and incorporated information from on-site testing which confirmed the low permeability of the soils at the site.

The Objectors claim that the Authority should have considered not the average annual precipitation of 58 inches per year for the period between 1950 and 1996, but the actual annual precipitation of 64.36 inches for the year 1996, given that it used 1996 water level data. However, even if this higher value had been used, the resulting increase in recharge would be very modest, given the small percentage of precipitation that enters the groundwater system.

The Objectors assert that the total amount of recharge must account for near-surface runoff that moves toward Moose Creek before flowing downward to recharge the buried valley aquifer. However, as discussed above, the evidence does not demonstrate that this pattern of recharge exists. As the Authority and Department Staff both argue, the evidence indicates that, where they run through the project site, Moose Creek and its northern tributary are gaining streams. The only doubt exists with regard to the area near their confluence in the northeastern part of the site, where beaver dams and the step nature of the topography may have created some localized, temporary outflow from the streams into their banks. Even in this area, there are upward groundwater gradients in the till, which suggest that groundwater is moving up and into the stream, rather than out of the stream and downward. Despite the Objectors' claims, there is no reliable evidence that, in the vicinity of Moose Creek or elsewhere, the tills contain effective flow pathways through which water would quickly drain, as if through a sieve, all the way down to the buried valley aquifer.

Dr. Reinfelder testified that the Authority should have determined recharge by calibration of its model to stream flows, because recharge is extremely difficult to estimate. The method proposed by Dr. Reinfelder involves calculating the recharge needed to produce observed heads and flows after the proper values for hydraulic conductivity and flow are input into the model. The Authority had data for heads but not for stream flows. Mr. Schafer responded that calibration of the model to stream flows was not necessary because if one has data on conductivity and heads, flows can be computed using Darcy's Law. He added that at a site like this with such steep grades and such a large amount of runoff, conductivity can be measured more accurately than stream flows, which can only be roughly estimated.

Mr. Feldman agreed, saying that he calibrated the model to potentiometric surface data in the wells, and to test data for hydaulic conductivity, because of the confidence he had in that data. Mr. Feldman said the base flow of streams is much more difficult to determine accurately, a representation that is confirmed by ASTM standard D 5981 (Hydrogeology Exhibit 25-C, an attachment to Mr. Schafer's prefiled testimony), which is a guide for calibrating a groundwater flow model application. The standard states that errors in the estimates of groundwater flow rates will usually be larger than those in heads, and that base flow estimates, for example, are generally accurate only to within an order of magnitude.

As the Authority argues, its recharge values were calibrated to actual head measurements and hydraulic conductivity measurements from the site. The recharge rate was adjusted within a reasonable range of values to obtain an acceptable match between field-measured and simulated heads. The 75 calibration targets (or observed water levels) used in the site model were well-distributed both areally and vertically throughout the model domain. The Authority convincingly explained that, in this way, it was able to achieve a reasonably precise determination of recharge rates, while the approach suggested by Dr. Reinfelder would have been error-prone and far less exact.

- - Model Calibration

The Objectors argue that the Authority's model is unreliable because it was not properly calibrated. As Dr. Reinfelder explained in her prefiled testimony, calibration to measured heads only assures that water entering the system is properly drained out of the system, or that the ratio of recharge to hydraulic conductivity is correct. By itself, it does not assure that the values of recharge or hydraulic conductivity are correct, because any combination of the two, as long as their ratio stays the same, can produce the desired head.

To explain this concept, Dr. Reinfelder offered an analogy to a kitchen sink. One can adjust the inflow (the faucet) and the outflow (the drain) to maintain a certain water level in the sink. If one turns up the faucet, the water will rise, but then one can open the drain a little more to get the water back to the earlier level. In other words, the same water level can be maintained through an infinite number of pairings of inflow and drainage. This so-called "non-uniqueness" problem, Dr. Reinfelder explained, is well known in groundwater modeling. In the case of groundwater flow through the site, she said, there are likewise an infinite number of possible combinations of recharge (inflow) and hydraulic conductivity (drainage or outflow) that can give the correct heads. However, she added, the recharge rate and the amount of flow into streams and deep aquifers may not reflect the actual site conditions. According to the Objectors, this "non-uniqueness" problem must be solved by ensuring that the model is able to reproduce the correct flows at the site, such as the flow into streams or the flow into or out of the buried valley aquifer (which Mr. Feldman said could not be measured in a realistic sense, because the aquifer is below the ground surface).

As the Authority points out, the flaw in the kitchen sink analogy is that by allowing the openness of the drain to vary, thereby simulating varying and arbitrary conductivities, Dr. Reinfelder ignores the fact that the conductivities for this site are well-established. At WLE-5 East, data for head and hydraulic conductivity were developed through the site investigation. From this base of information, model calibration could accurately produce the flows. As Mr. Feldman explained, if one adds more water or adjusts the drain in the sink analogy, all types of solutions are possible. But in this case he was constrained by all kinds of real-world data, including head measurements at specific observation points, slug-tested conductivity values in the different hydrogeologic units, and various gradients in the different units. In other words, Mr. Feldman testified, the Authority's model is the unique solution to the flow domain, in that one can change things around "a little bit," but cannot make a "wholesale change" to the model and reproduce the groundwater flow regime.

Dr. Reinfelder testified that by running the Authority's model with a recharge rate of 2.5 inches per year throughout the model (an increase in overall recharge) and reducing the anisotropy ratio to 10:1 for all zones (to allow more flow through the system) she was able to produce the same observed heads (with a mean error of 0.23 feet and a relative error of 6.25 percent) while increasing leakage to the streams by 11.91 times and flow to the deep sand/till unit by 4.54 times. However, as Mr. Feldman responded in rebuttal, there were serious flaws in this model run:

- - It caused the dewatering of Model Layer 1 in the area over the buried valley, due to unrealistically high vertical permeabilities;

- - The model created heads in the northwest corner of Model Layer 1 that were as much as 100 feet and more above the land surface; and

- - The model created unrealistic changes in head levels for what the Objectors call the buried valley aquifer, steepening the measured horizontal gradient beyond anything measured by the Authority in the many tests of water levels done during the site investigation.

Dr. Reinfelder said this run of the model had a relative error rate of only 6.25 percent, but that rate was about three times greater than the Authority's error rate of about 2 percent, Mr. Feldman testified.

Mr. Schafer conceded under cross-examination that it is possible to use stream gauges to measure flows in a creek, but added that it would have resulted in large errors that would have rendered the effort futile. Also, he said that the gauges would only measure total flow, not the groundwater component of the flow, which is the part that would need to be analyzed. The Objectors contend that, by using stream flow data indicating the flow of groundwater into or out of the streams, the Authority could have assured that its modeled recharge rate represented a unique and accurate solution to the problem of modeling site conditions. However, the Authority properly points out that given the significant errors and unmeasurable inputs that are inherent to this approach, it was not advisable to use stream flows for calibration purposes.

Mr. Feldman pointed out that the model was calibrated to data in which there was much more confidence - - water level measurements in wells, which are usually accurate within a few tenths of a foot, and slug-tested and laboratory-determined permeability measurements.

The Objectors note that language in ASTM D5981 indicates that flow rate data can be used with head data to establish calibration targets for a medium- to high-fidelity model application, and that if multiple different hydrologic conditions are not available for a site (which is the case here), another way to address the uniqueness problem is to include groundwater flows with heads as calibration targets. The ASTM contemplates that flow rates may be used appropriately in certain situations, but as the Authority points out, it also cautions about the likelihood of large errors in the estimation of groundwater flow rates and the problems that ensue from such errors.

The Objectors claim that the lack of proper calibration of the Authority's model is particularly problematic because the model could not be verified by comparing the model calculations to another set of field observations representing a different set of boundary conditions or stresses. In fact, as Mr. Schafer conceded, such verification was not possible in this case, because there was no hydrologic stress during the period of the Authority's investigation, such as several wet years followed by a severe drought, that would have produced a distinctively different set of field measurements. ASTM 5447 (Hydrogeology Exhibit 25-B) states that successful verification of a groundwater flow model results in a higher degree of confidence in model predictions, but adds that a calibrated but unverified model may still be used to perform predictive simulations when coupled with a careful sensitivity analysis, which is a quantitative method of determining the effect of parameter variation on model results. As noted above, in this case the Authority did perform a sensitivity analysis which found that the model was most sensitive to changes in recharge and hydraulic conductivity, in that changes to these parameters caused the largest responses in calculated heads.

The Objectors assert that the Authority violated ASTM D 5447 by not developing a water budget as part of its conceptual model, deferring this task instead until the model was calibrated. However, as Mr. Schafer testified, it was not necessary to develop the water budget at an early stage since it was already well understood that a portion of the precipitation recharges the formations, and that water discharges through the creeks and wetlands and the deep sand/till unit. As he explained, the water budget was well thought out early on, but the numbers were not identified until the model was calibrated. (The water budget that was developed appears in Table L-2 of the groundwater flow model report.)

The Objectors assert that the Authority violated ASTM D 5447 by not specifically stating the assumptions of its model in the modeling report. The ASTM provides an example for a table of contents in which model assumptions and limitations are reported under a specific subheading in the section for summary and conclusions. However, this is just an example, not a binding requirement for how assumptions are to be stated. As Mr. Schafer pointed out, the Authority's assumptions are scattered throughout the report, but they are there nonetheless. For example, assumptions were made regarding the recharge to the till, the deeper portion of the bedrock was assumed to be no-flow, and the vertical conductivity of the bedrock was assumed in the absence of reported data.

Finally, the Objectors assert that the Authority violated ASTM D 5611 (Hydrogeology Exhibit 25-D) by failing to test the sensitivity of its model to coordinated changes in model inputs. The Authority points out that this was done as part of the model calibration process, though not as a formal sensitivity analysis. According to Mr. Feldman, as part of the model's calibration, Geraghty & Miller went through a very methodical process where values were changed within a reasonable range, rather than on a large-scale basis, with the objective of minimizing residuals representing differences between modeled and measured heads. Mr. Feldman said he was "pretty confident" that he attempted to increase conductivity and recharge in a coordinated fashion to yield about the same heads, but admitted that such efforts were not reflected in any of the reports that are part of this application. The modeling report indicates that, in each of the simulations that were part of the sensitivity analysis, only one input parameter was changed while the others were held constant. ASTM D 5611 states that if a model has not been calibrated to multiple hydrologic conditions, sensitivity analysis of coordinated changes can identify potential non-uniqueness of the calibrated input data sets. But such an analysis of coordinated changes is not an absolute requirement of the ASTM.

The Objectors state that the Authority's model is invalid because the potentiometric heads it predicts correspond poorly with the heads that were actually measured in the monitoring wells. Dr. Michalski testified that in the brown till unit, the model-predicted water table is positioned above the ground surface for most wells, in one case by 7.6 feet. In reality, Dr. Michalski points out, the water table in the brown till is four feet below the ground surface.

The Authority considers Dr. Michalski's criticisms to be "nit-picking" and points out that they focus on the brown till without mentioning the other units. Dr. Michalski conceded that, for the deep sand/till unit and the bedrock under the buried valley aquifer, the modeled heads achieve a reasonable degree of accuracy in relation to the measured heads. The Authority's modeling report indicates that of the 75 calibration targets for the entire site, 52 of the Authority's residuals were within five feet of the target, including those in 22 of 28 brown till wells. In fact, as noted in the site investigation report, spatial analysis of residuals shows that simulated heads in the model provide an acceptable match with field measurements in terms of reproducing the magnitude and distribution of head throughout the site.

Mr. Feldman explained why, in modeling, comparing simulated head values to the land surface is not meaningful. A groundwater flow model, he explained, only simulates groundwater flow from the water table, which is a free surface that can rise or fall with changes in hydrologic conditions, down to the base of the model area. The area from the ground surface down to the top of the water table is not part of the model domain. Therefore, to compare simulated head values to the land surface is not meaningful, especially in light of the fact that the depth to water at most wells screened in the brown till is between two and five feet below land surface, and has no bearing on whether the model is calibrated.

As Mr. Feldman explained, what is relevant is that most of the simulated heads show close agreement with observed water level measurements, and that the model reproduces the overall magnitude and distribution of heads throughout the site. Feldman said that except in the most simplified model domain, one rarely has a match between observed and simulated heads, though he did concede that underestimating conductivity could explain simulated heads that are higher than observed heads, which is what happened in the brown till.

Dr. Michalski also points out that the simulated heads for the gray till are generally much higher than the actually measured heads, in several wells by more than 10 feet. However, as the Authority points out in the FEIS, 12 simulated heads in the gray till are less than the observed heads, and 19 simulated heads in that unit are more than the observed heads. According to the Authority, the significant feature of the model calibration is that the highest heads are in the brown till and the lowest heads are in the deep sand/till unit. The simulated heads in the gray till reflect the observed vertical head loss through the gray till, resulting in a simulated component of flow through the gray till to the deep sand/till unit.

Dr. Michalski contends that most of the groundwater from the gray till discharges to the buried valley aquifer, either directly or via the bedrock in areas where the deep sand/till unit is absent. He also says that the discharge to the deep sand/till is 14 times greater than what the Authority has modeled (116 gallons per minute vs. 8.2 gallons per minute). However, Mr. Schafer says Dr. Michalski's estimate is unrealistic in light of the nature of the materials in the deep sand/till and its flat gradient.

- - Modeling of Bedrock

The Objectors claim that the Authority's modeling results depend heavily on the failure to include most of the bedrock in the model domain. They claim that only a "thin shell" of the thick and extensive bedrock on the sides of the buried valley was assumed to be capable of transmitting groundwater, and that the rest of the bedrock was represented in the model as inactive cells.

In his prefiled testimony, Mr. Feldman explained how the bedrock was incorporated into the model, and how this fits in with his conceptual understanding of the hydrologic role of the bedrock unit. According to Mr. Feldman, the portion of the bedrock that transmits water, derived from precipitation to the Moose Creek watershed, to the glacial deposits is incorporated in the model. Accordingly, he said, the model incorporates downward movement through the bedrock and lateral leakage from the bedrock into the gray till and the deep sand/till unit. This is done by encompassing the simulated area of glacial deposits with an area of active model cells which allow the model to represent the exchange of water between the glacial deposits and the bedrock. According to Mr. Feldman, this is the most commonly used and scientifically accepted method of representing such an exchange.

Mr. Feldman explained that the model domain is bounded by active model cells that represent groundwater movement in the bedrock that transmits water both vertically and horizontally into the glacial deposits within the deep sand/till unit. The bedrock components of the model domain are Model Layers 2 - 6.

- - In Model Layer 2, bedrock extends throughout the northwest part of the model, including the northwest corner of the landfill boundary. The width of this bedrock area is about 2,600 feet.
- - In Model Layer 3, bedrock extends laterally (from between 100 and 500 feet) beyond the extent of the gray till.
- - In Model Layer 4, bedrock extends laterally (from between 400 and 1000 feet) beyond the extent of the gray till.
- - In Model Layer 5, bedrock extends laterally (from between 100 and 400 feet) beyond the extent of the gray till.
- - In Model Layer 6, bedrock underlies the deep sand/till unit.

As a practical matter, a lateral and bottom boundary surface must be chosen in order to define the external geometry of the groundwater flow system. As Mr. Feldman explained, for this model, that boundary is the interface between the active model cells representing the bedrock and the inactive model part of the model. This interface represents a no-flow boundary which assumes that no flow components exist normal (or perpendicular) to the boundary and that no flow crosses the boundary. Mr. Feldman explained that use of a no-flow boundary does not imply that there is no exchange of water between the bedrock and the glacial deposits. Instead, the volume or rate of exchange is incorporated into the model to ensure accurate representation of the groundwater system water budget. Mr. Feldman said this is a reasonable assumption because (1) groundwater flow in the deeper portions of the bedrock (outside of the model domain) would most likely be derived from recharge outside of the Moose Creek watershed, and (2) groundwater movement outside of the model area would most likely be part of a more regional inter-basin flow regime that would not be influenced by localized events within the Moose Creek watershed. (In other words, the groundwater flux moving across the defined no-flow boundary would be an insignificant percentage of the overall water balance for the watershed.)

Mr. Feldman said that in constructing his model, he accounted for the most significant aspects of the interrelation between the bedrock and the unconsolidated deposits. He also notes that his approach allowed the model to simulate the bedrock unit in terms of matching 10 bedrock well calibration targets (see Table L-1 of the modeling report) and the seepage of groundwater from the bedrock into the unconsolidated deposits.

Dr. Reinfelder contends that only a "thin shell" of bedrock is represented in model layers 3, 4 and 5, which she says has the effect of reducing the flow pathway to the deep sand/till unit. To illustrate this point, she re-ran the Authority's model after extending the bedrock in layers 3 through 6 to the same area as in layers 1 and 2, while maintaining the same hydraulic conductivities for the extended areas as those shown in the outermost cells of the Authority's model. Dr. Reinfelder kept the recharge rate the same as in the Authority's model, meaning that the total amount of flow through the system did not change. However, the resulting flow to the deep sand/unit increased by 2.41 times over that shown in the Authority's model.

Dr. Reinfelder explained that, by adding more bedrock to the Authority's model, she opened up additional pathways for downward flow. This, she said, implies an increased chance for any potential release from the landfill to enter the deep sand/till unit not just through the overlying tills, but also through the more permeable fractured bedrock. Indeed, she said, her particle tracking analysis showed that more particles from the northern and western portion of the footprint would migrate downward, through the added bedrock, and enter the deep sand/till where the buried valley aquifer is located.

Mr. Schafer defended the Authority's modeling of bedrock, noting that in model layer 2, the bedrock extends through the full watershed domain, but in the deeper model layers, the amount of depicted bedrock is reduced given the understanding that the bedrock gets tighter (and, therefore, less transmissive) with depth. In the deeper model layers, the bedrock flow is insignificant, and the bedrock that is shown - -

the so-called “thin shell” referred to by the Objectors - - is meant to simulate the exchange of flow between the bedrock and the glacial till. The deepest layer, layer 6, consists entirely of bedrock beneath the deep sand/till, and is meant to reflect the upward movement of water from the bedrock to that unit, Mr. Schafer explained.

The Objectors claim there is no merit or justification for the Authority’s reducing the depiction of bedrock in the deeper portions of its model domain. However, as the Authority responds, the evidence does suggest a tightening of the bedrock with depth. According to the bedrock conductivity measurements reported in the site investigation report, the average horizontal conductivity of the shallower bedrock wells (less than 50 feet deep) is 3×10^{-4} cm/sec, while the average conductivity of the deeper bedrock wells (50 feet or deeper) is 1.7×10^{-5} cm/sec. The Authority did no testing to determine the vertical conductivity of the bedrock, as the Objectors argue. Instead, Mr. Schafer explained, the Authority assumed an anisotropy ratio that was in a similar range to the measured anisotropy of the other units, working from the understanding (not challenged by the Objectors) that since the bedrock was laid down in layers, it would be less conductive vertically than horizontally.

Though the Authority inferred the vertical permeability of the bedrock in the absence of measured values, witnesses for the Authority and Department Staff explained why bedrock becomes tighter and less transmissive with depth. For instance, Mr. Fancher explained that the upper bedrock exhibits the effects of weathering that does not impact the deeper part of the formation. Dr. Siegel explained how shale fractures pinch off at depth, and Mr. Feldman said that as one moves deeper into a bedrock system, the fracture network typically closes up.

The flaws in Dr. Reinfelder’s run adding bedrock to the Authority’s model were explained by Mr. Feldman. He said that by creating a much greater area of active bedrock in the model domain, and greatly overestimating the vertical fracture network, Dr. Reinfelder had generated a run that dewatered the northwest portion of the site in the top model layer, and created a steep head distribution in the deep sand/till unit that is not reflective of actual conditions. Mr. Schafer explained that the effect of “stretching” the bedrock was to divert some flow from Moose Creek to the deep sand/till unit, but added that the increase, from 8.2 to 19.8 gallons per minute, was “rather trivial” in the context of the total flux of 103 gallons per minute.

The Objectors question how the Authority fixed the limits of its model domain, though, as the Authority responds, some lateral and bottom boundary surface must be chosen to define the external geometry of the groundwater flow system. Modeling is intended to replicate the significant components of groundwater flow that affect the project site, and the Authority's modeling succeeds in this regard.

Dr. Reinfelder argues that a much larger model domain should be used to minimize the uncertainty of setting hydraulic boundary conditions and to include regional, inter-basin flow through the fractured bedrock. However, as Mr. Feldman correctly points out, that goes beyond the scope of what is necessary at this site. As he testified, it was enough for the modeling to account for the flow from the bedrock to the deep sand/till unit, as the water that flows on a regional, inter-basin level moves beneath the area of study and is not relevant to the modeling effort.

Dr. Reinfelder also says that there should be more layers in the model to adequately represent the large vertical gradient and to ensure that the observation depths are close to the center of the model layers. However, I agree with Mr. Schafer that six layers were enough to properly represent the hydrologic units and their vertical flow components.

- - Adequacy of MODFLOW

The Objectors claim that MODFLOW was inappropriate for use at this site because it cannot properly accommodate unsaturated flows, and that a different computer code that is designed for simulating flow through unsaturated media, such as FEMWATER or FEFLOW, should have been selected instead.

Dr. Reinfelder testified that a key advantage of FEMWATER (a U.S. Department of Defense model) and FEFLOW (by Waterloo Hydrogeologic Inc.) is that they can explicitly simulate the flow through the unsaturated zone between the bottom of the gray till and the saturated portion of the deep sand/till unit. However, as Mr. Feldman points out, simulating that flow requires an additional subset of parameters which adds a new level of complexity and uncertainty to the modeling effort. Also, assuming the Authority is correct that water takes more than a century to pass through the gray till, it becomes almost irrelevant to understand the subtle nuances of unsaturated flow through the deeper deposits, as Mr. Schafer argues.

The Objectors quote Mr. Feldman's assertion that MODFLOW would have difficulty dealing with completely dry layers, but omit his response that, in this case, no layer was completely dry. The Objectors also quote Mr. Feldman saying that MODFLOW treats a dry cell as an inactive cell which basically drops out of the mathematical formulation. Again, however, they omit his response that there were no fully dry cells in the calibrated model, and that MODFLOW calculated that the materials below the gray till all had some water in them.

Mr. Feldman explained how the partial saturation of the deep sand/till unit is addressed by MODFLOW. In any given location in that unit, there is one vertical cell that, by means of a calculated head measurement, reflects both the saturated and unsaturated conditions within the unit, he said. Water moving through the dry (or unsaturated) portion of the unit moves vertically downward by force of gravity, while water moving through the saturated portion of the unit moves from areas of high head to areas of low head. Mr. Feldman said that where the deep sand/till is unsaturated, it acts like a sponge, slowing particle flow. But because MODFLOW does not portray any cell as fully dry, it allows flow between the base of the gray till to the saturated portion of the deep sand/till unit to occur faster than it would in reality. In that sense, Mr. Feldman pointed out, MODFLOW is conservative in its depiction of the time it would take contaminants to reach the so-called buried valley aquifer.

- - Other Claims

Apart from alleged problems with the construction, calibration and reporting of the Authority's groundwater flow model, Dr. Reinfelder's prefiled testimony lays out certain other problems which she says illustrate carelessness on the part of the modelers. Because she acknowledged that these problems did not significantly affect the modeling results, only a brief discussion of her claims is necessary.

Among her claims, Dr. Reinfelder asserts that the model input file contains numerous negative transmissivity values which would have the effect of locally reversing flow directions and, in a small way, lengthening particle travel times. Though such values are apparently reflected in the data array, they were not used in the model, according to Mr. Feldman. Mr. Feldman also said that a preprocessor, MODELCAD, which was used in the model runs automatically corrected for such values in the active model area.

Dr. Reinfelder said that reported hydraulic conductivity values were incorrect, including a value of 0.00625 foot per day for model layer 1. That value represents a typographical error in the modeling report when in fact a correct value of 0.0625, one order of magnitude different, was actually used in the model, according to Mr. Feldman.

A reported range of conductivity values spanning three different layers was misread by Dr. Reinfelder as applying to only layer 2. Dr. Reinfelder questioned the bedrock conductivity value for layer 6 as being outside the range of reported values, though the Authority defended it as consistent with its understanding of conductivity decreasing with depth. Dr. Reinfelder also questioned an anisotropy ratio of 400:1 in a small part of the brown till in layer 1, which Mr. Feldman conceded was an error that was likely caused during the model calibration, but one that has little bearing on the model results. Dr. Reinfelder said there was an anisotropy ratio of 200:1, outside the reported range of 60:1 to 125:1, in model layers 2, 3 and 4, under the southern portion of the landfill footprint. But Mr. Feldman, rechecking the layers himself, said there was no such ratio, and said he had no idea how Dr. Reinfelder came to her conclusion.

Dr. Reinfelder said that the Authority had neglected the fact that MODFLOW has been significantly improved to allow dry (or inactive) cells to be rewetted (and thereby re-activated) from bottom or neighboring cells. However, Mr. Feldman said rewetting was unnecessary because there were no dry cells in his model.

Finally, Dr.Reinfelder said that the Authority's observation wells were not adequately distributed spatially, in that they were clustered near the landfill footprint, occupying less than half of the model domain. Mr. Feldman replied that the wells were in fact well distributed both areally (over the landfill site) and vertically (over various horizons in the till, deep sand/till and bedrock units).

- - Conclusions

Overall, I conclude that the Authority's modeling was appropriate and reasonably represents site conditions. The modeling was adequately sophisticated and relied on reasonable data inputs collected from the site investigation and background literature. The model was appropriately calibrated and satisfactorily replicates measured heads.

CONCLUSIONS - - HYDROGEOLOGY ISSUES

1. The deep sand/till unit contains a buried aquifer that exists within a valley or depression in the bedrock surface. The aquifer's confinement by low-permeability till, combined with the limited recharge it receives from the overlying land surface, effectively eliminate the possibility that the aquifer could be considered a principal aquifer warranting the special protection that accompanies such a designation. While additional testing, as proposed by the Objectors, would provide relevant information bearing on factors affecting a principal aquifer determination, such testing is not reasonably necessary to determine that no principal aquifer exists. For that reason, no further testing should be required of the Authority.

2. The Authority has properly and adequately characterized the critical stratigraphic section, including existing and projected flow patterns. Its calculated conductivity values were reasonably determined using appropriate methods. There is no reliable evidence of preferential flow pathways through which contaminants could quickly reach the buried valley aquifer either through the tills or the bedrock. The landfill's design allows for the early detection of a leachate breakout, and the planned network of monitoring wells complies with Department regulations governing site coverage. The Authority developed a groundwater model that reasonably represents site conditions and adequately supports the Authority's environmental monitoring plan.

3. The diversion of precipitation into a leachate collection system would have no significant impact on surface water resources such as wetlands and streams.

4. The operation of the groundwater suppression system would not facilitate leachate migration; in fact, it would impede it. Drawdown of the near-surface water table due to the system's operation should not significantly affect wetlands on the site south and west of the footprint area.

5. The identified issue regarding the project's impact on area flood flows was withdrawn by the Objectors. Therefore, the Commissioner may conclude that existing flood control values would be maintained, and that the Authority has adequately addressed impacts that would be caused by the destruction of wetlands during project construction.

ISSUE NO. 2 - - AIR QUALITY IMPACTS

Issues identified by the Commissioner for adjudication concern air quality impacts associated with the landfill's operation, and more particularly those associated with particulate matter 10 microns or less in diameter (PM-10) and certain hazardous air pollutants. Issues are whether the predicted total maximum concentrations of PM-10 resulting from the landfill's operation would exceed the national ambient air quality standard (NAAQS), and whether the maximum predicted emission of the hazardous air pollutants vinyl chloride and acrylonitrile would exceed state guidelines. [See Commissioner's interim decision, pages 23 - 26.]

The Authority and Department Staff submitted prefiled testimony on both issues; however, the Objectors submitted prefiled testimony only on the hazardous air pollutant issue, choosing not to contest on the PM-10 issue. Because the PM-10 issue was not pursued by the Objectors, I said that my hearing report would make findings on that issue based on the prefiled and unchallenged testimony of witnesses for the Authority and Department Staff.

VINYL CHLORIDE AND ACRYLONITRILE

Issue: Would emissions of the hazardous air pollutants vinyl chloride and acrylonitrile exceed state guidelines during the life of the landfill?

Position of the Authority

Based on documented high gas collection efficiencies and low gas emission rates at modern landfills, there would be no exceedances of state guidance values for vinyl chloride and acrylonitrile. The landfill's design would effectively limit emissions of these hazardous air pollutants. Significant protections are provided by the draft permit prepared by Department Staff and the Authority's own waste control system. The conservative nature of the Authority's air modeling demonstrates that emissions of vinyl chloride and acrylonitrile would not create a public health concern.

Position of Department Staff

Department Staff agree with the Authority that, under terms of its draft permits, facility emissions would not violate state guidelines. Staff says its own conservative modeling indicates that uncontrolled emissions would not create an exceedance of state guidelines for at least 18 years into the life of the landfill. It adds that once the facility's gas collection and control system begins operating (54 months from the first deposition of waste) actual emissions data would be collected, allowing for better forecasting of air quality impacts over the 62-year life of the facility. According to Department Staff, denying permits on projections of impacts that might occur toward the end of the project's life would be inappropriate, particularly given the possibility that guideline values would change over time. Department Staff is confident that, under terms of its draft permit, the Authority would achieve the 80 percent gas capture efficiency the Authority used in its own modeling of air quality impacts. If monitoring indicates this is not the case, Department Staff argues that steps can be taken to increase the capture rate, including increasing the vacuum that would draw gas from the waste, adding additional gas collection wells, and improving the landfill cap.

Position of the Objectors

The Objectors contend that the Authority's application for an air permit should be denied because off-site concentrations of vinyl chloride and acrylonitrile would substantially exceed state guidelines. According to the Objectors, the Authority's claim that its estimates of vinyl chloride and acrylonitrile are conservative is not supported by the evidence, and the conditions in the draft permit are not sufficient to ensure that state guidelines would be met.

FINDINGS OF FACT

1. Landfill gas is a naturally occurring byproduct of all municipal solid waste landfills. It results from the anaerobic decomposition of organic material contained in wastes placed in landfills. During initial placement of waste, there is generally enough available oxygen for aerobic decomposition to take place. However, once the available oxygen supply is consumed, the anaerobic decomposition process takes over, and landfill gas is produced.

2. Approximately 55 percent of landfill gas is methane, and the remaining gas is primarily carbon dioxide. In addition, the gas contains non-methane organic compounds, some of which are hazardous air pollutants like vinyl chloride and acrylonitrile. Vinyl chloride is a known carcinogen, and acrylonitrile is a suspected carcinogen. Both are highly toxic.

3. The Department has issued guidelines with respect to vinyl chloride and acrylonitrile. For vinyl chloride, the annual guideline concentration is 0.020 micrograms per cubic meter (ug/m^3). For acrylonitrile, the annual guideline concentration is 0.015 ug/m^3. These values appear in the Department's DAR-1 (Air Guide-1) list of annual and short-term guideline concentrations dated July 12, 2000.

4. Annual guideline concentrations are those concentrations that represent a one-in-a-million excess cancer risk over a lifetime exposure to the compound in question. Concentration levels are developed by the U.S. Environmental Protection Agency, but for any particular pollutant the Department's value may be more conservative than the one used by EPA. For instance, the EPA raised its annual guideline concentration for vinyl chloride to 0.11 ug/m^3 in August 2000, but the Department still maintains the more conservative value of 0.020 ug/m^3.

5. Compliance with annual guideline concentrations is determined on the basis of an ambient air quality impact analysis that is performed for a new source. This analysis, performed using Air Guide 1, uses estimated emission rates of compounds to determine the expected ambient concentration of those compounds in the area around the location of the source. These expected concentrations are compared to the annual guideline concentration for the compound to determine if the ambient concentration will be harmful to human health or the environment. If the model predicts that the annual guideline concentration will be exceeded, the source owner must take steps to reduce or eliminate emissions of the compound in question.

6. To prevent emissions of volatile organic compounds from exceeding the major source threshold of 50 tons per year, condition 38 of the proposed Title V air permit establishes a 178,880 ton per year limit on waste disposal until a landfill gas collection and control system is operating at the landfill. Running the Air Guide 1 model using this waste disposal limit, Department Staff determined that the predicted uncontrolled emissions of acrylonitrile would exceed the Department's annual guideline concentration in the 18^{th} year of operations. Uncontrolled emissions are emissions directly from the landfill, with no collection of the landfill gas and no control devices installed to destroy the landfill gas.

7. The Authority's project design includes an active landfill gas management system that is proven and reflects standard engineering practice for modern landfills. Under this

system, horizontal gas collection trenches would be installed at periodic intervals during the landfill's development. These trenches would lead to riser pipes on the side slopes of the landfill. When gas controls are installed, the riser pipes at the ends of the horizontal gas collection trenches would be tied to a vacuum extraction system which would actively collect the gas. The gas would then be conveyed to a flare for final combustion. Vacuum extraction is highly effective in pulling gas from the landfill mass and allows for a high collection efficiency that minimizes off-site gas migration.

8. Condition 36 of the Department's air permit would require that construction of the initial phase of the gas collection and control system be completed within 54 months from the date of the first waste placement. Start-up of the system would occur immediately following completion of that initial phase, and the Authority would be unable to request an extension of this time frame.

9. In support of its Title V air permit application, the Authority prepared an inventory of the expected air emissions from landfill operations. The emissions inventory included estimation of expected emissions of landfill gas and its components, including hazardous air pollutants.

10. Because the landfill does not exist and site-specific landfill emissions data are not available, the Authority's emissions inventory relies on EPA's Landfill Air Emissions Estimation Model (LAEEM) and Compilation of Air Pollutant Emissions Factors (AP-42). AP-42 provides air emissions factors and equations used to estimate emissions of landfill gas, non-methane organic compounds, and hazardous air pollutants.

11. The Authority's use of AP-42 default values, derived from analyses made on average 15 years ago, reflects the conservative nature of its emissions inventory, since these values were developed from older facilities with higher emissions than those one would expect from a modern landfill operation. For example, the EPA default concentration for non-methane organic compounds is 2420 parts per million, though data obtained from nine comparable landfills operating in New York indicate that actual measured non-methane organic compounds are all less than 500 parts per million, and on average 262 parts per million, which is nearly 90 percent below the default value. Also, data from three comparable landfills operating in New York State indicate that measured values of vinyl chloride are less than 30

percent of the AP-42 default values, and acrylonitrile is below detectable levels in two data sets where it was tested.

12. Ongoing monitoring data from five comparable landfills in Ontario also suggest that the Authority's use of AP-42 values was conservative. The Ontario data indicate a representative average concentration of 3.6 parts per million for the concentration of vinyl chloride in landfill gas, with a maximum expected concentration of 4.7 parts per million. Acrylonitrile was not detected in any of the samples analyzed from these landfills, the highest detection limit being 0.91 parts per million and the mean value being 0.73 parts per million. All of these referenced values are considerably lower than the AP-42 defaults used to model landfill gas emissions at the proposed landfill, which are 7.34 parts per million (for vinyl chloride) and 6.33 parts per million (for acrylonitrile).

13. Finally, recent data from landfills across the United States indicate an average vinyl chloride concentration of 1.077 parts per million for 46 sites surveyed, and acrylonitrile at less than the detection limit of 0.036 parts per million at each of three sites surveyed. Another national landfill study found the average concentration of acrylonitrile to be 0.332 parts per million, and the average concentration of vinyl chloride to be 1.682 parts per million, again dramatically below the AP-42 values.

14. The emissions inventory prepared using AP-42 values was an input to an ambient air quality impact screening model the Authority developed to predict emissions in the 62nd (or final) year of operation for the landfill, when emissions would reach their peak. After that year, with the landfill closed and no more waste being added, gas generation would decline.

15. In its modeling effort, the Authority assumed an 80 percent collection efficiency. This assumption was also conservative given the high collection efficiencies achieved at sites which are engineered to control gas emissions.

16. Ambient air quality modeling was performed in 1998 and included as part of the FEIS for this project, and also as part of the Authority's air permit application that was submitted to the Department. Based on this modeling, which assumed an 80 percent gas collection efficiency, the Authority concluded that emissions of hazardous air pollutants would not exceed Department guideline concentrations. However, the modeling did not involve placing receptors along the project boundaries, so there was no

modeling for the area in which the highest off-site concentrations of pollutants would occur.

17. Supplemental runs of the same air quality model were performed in December 2000, with 65 additional receptors placed along the potential site boundary. These runs were submitted to the Department as part of a supplemental ambient air quality impact screening study. The supplemental study, using the same assumptions as before, showed an exceedance of the state annual guidance concentration for vinyl chloride at five receptors and an exceedance of the state annual guidance concentration for acrylonitrile at four locations. Adjusting the assumed landfill gas collection efficiency from 80 to 85 percent, only one receptor showed a modeled exceedance for the two pollutants, and adjusting the collection efficiency to 90 percent, no exceedances at all were projected.

18. In order to assure an 80 percent gas capture efficiency, Condition 38 of Department Staff's draft air permit requires that the landfill be constructed with a geomembrane liner, horizontal gas collection trenches with a disposable plastic cover while the landfill is active and a gas-impermeable geomembrane final cover, or an equivalent system approved by the Department, at closure.

19. Additional ambient air quality modeling was performed by the Authority in 2002, in preparation for the adjudicatory hearing. This modeling was run to take into account newer landfill site boundaries. Since the issues conference in 2000, the Authority has purchased the Moonan property in the buffer zone extending along Route 294 and has extended the southwestern boundary of the landfill site to include a small portion of property owned by Warren and Marie Backer, which will be acquired by the Authority. [Exhibit M to Mr. Nostrand's prefiled testimony (Air Exhibit 8) indicates the current boundary lines for the proposed landfill and property ownership information.]

20. With the new boundaries, and at a landfill gas collection efficiency of 80 percent, the 2002 modeling indicates that all the modeled concentrations for hazardous air pollutants do not exceed their respective guideline concentrations except for two receptors, S-28 and DR-22, along Gleasman Road on the southeastern property boundary, where there is a slight exceedance of the annual guideline concentration for vinyl chloride. At these receptors, vinyl chloride was modeled at 0.021 ug/m^3, just above the Department's annual guideline concentration of 0.020 ug/m^3, but well below EPA's guidance value

of 0.11ug/m^3. Also at these receptors, acrylonitrile was modeled at 0.015 ug/m^3, equal to the Department's annual guideline concentration.

21. Adjusting the landfill gas capture efficiency to 85 percent for the 2002 modeling, all modeled concentrations of hazardous air pollutants do not exceed their respective guidelines.
The maximum off-property concentration for vinyl chloride drops to 0.016 ug/m^3, and the maximum off-property concentration for acrylonitrile drops to 0.011 ug/m^3.

22. Several conditions in Department Staff's draft air permit are relevant to the evaluation and control of emissions from the landfill. The most important is Condition 97, which requires testing for all hazardous air pollutants identified in AP-42, section 2.4 (which includes vinyl chloride and acrylonitrile) every two years. If actual emissions exceed predicted emissions, additional modeling is required, and the Authority is required to perform a risk assessment for possible health impacts if an exceedance of a guideline value is anticipated. As a result of the risk assessment, the Department can move to modify the permit so as to mitigate any emissions of concern.

23. Other conditions relevant to emissions evaluation and control include the following:

- - Condition 50, which requires the planning, design and construction of the landfill gas collection and control system, and the commencement of operation of that system within 54 months of receipt of the first waste at the landfill. This condition accelerates the schedule by which the landfill gas collection system would be required to be installed under federal regulation, to address the estimated production of landfill gas presented in the emission inventory.

- - Condition 73, which requires monthly monitoring of both the gauge pressure in the gas collection header, as well as the temperature and nitrogen or oxygen concentration of landfill gas. This condition requires monitoring of parameters that relate to the landfill gas system's collection efficiency.

- - Condition 64, which requires testing for non-methane organic compounds every two years (rather than every five years as allowed by federal regulations).

24. The types of waste that are disposed of at a landfill affect landfill gas emissions. In 1991, Subtitle D of the federal Resource Conservation and Recovery Act (RCRA) excluded the disposal of nearly all types of hazardous waste in municipal solid waste landfills. The prohibition against disposing of hazardous waste in landfills has led to a reduction in certain types of landfill gas emissions. Because much of the information and data used in AP-42 is derived from the period prior to the implementation of RCRA Subtitle D, the AP-42 values tend to overestimate projected emissions from landfills that have not yet been developed.

25. The Authority has implemented programs that, as one of their incidental benefits, would tend to reduce the production of hazardous air pollutants in landfill gas. For instance, the Authority has implemented a program that helps remove household hazardous waste from the landfill waste stream. Diverting this waste to a hazardous waste landfill or recycling facility would lead to a reduction in organic compounds in the landfill, and consequently would reduce the emissions of hazardous air pollutants, other volatile organic compounds, and anything else that would volatilize from the waste.

26. Also, the Authority has implemented an industrial and commercial waste audit program whereby it conducts a review of the waste stream at industrial and commercial facilities, determines whether there is any waste that needs to be tested as potentially hazardous, and assists in the development of facility recycling programs to reduce the amount of waste that needs to be landfilled.

27. Finally, the Authority accepts hazardous waste from conditionally exempt small quantity generators within Oneida and Herkimer counties for proper environmental disposal and recycling, which also helps it maintain proper control over the two-county waste stream.

28. The removal of hazardous compounds from the waste stream that would go to the landfill is important because the hazardous air pollutants that a landfill emits come primarily from the volatilization of hazardous waste chemicals or their degradation to create other elements such as tetrachloroethylene which then degrades to vinyl chloride.

DISCUSSION

With the Objectors not contesting on the PM-10 issue identified by the Commissioner, the only air quality issue still under debate concerns whether emissions of vinyl chloride and acrylonitrile would exceed state guidelines at and beyond the site boundary. Based on modeling results and the so-called conservative assumptions that were used in the modeling, the Authority and Department Staff maintain that there would be no exceedances over the life of the landfill. On the other hand, the Objectors claim that emissions of these two hazardous air pollutants would substantially exceed the state guidelines.

- - Overview of Testimony

The Authority's case involved testimony from three witnesses. The first, William Southern, explained the landfill design and construction features that bear on landfill gas control. The second, Scott Nostrand, is an engineer with Barton & Loguidice, which, in support of the Title V air permit application, developed an inventory of anticipated air emissions. Mr. Nostrand testified about how the emissions inventory was developed and also explained the successive rounds of ambient air quality modeling that have been done for this project. Finally, Gordon Reusing, an engineer with Conestoga-Rovers & Associates, explained the most recent air pollutant dispersion modeling, which he performed in 2002 shortly before the adjudicatory hearing. He testified to the conservatism of the emission rate inputs which were used in the model, as well as the reasonableness of the gas collection efficiency that is assumed for this landfill.

Department Staff presented one witness, Thomas Christoffel of the Department's Division of Air Resources, who did his own emissions modeling and confirmed that the modeling done on behalf of the Authority was acceptable. Though Mr. Christoffel said that predicted uncontrolled emissions of acrylonitrile would begin to exceed the Department's annual guideline concentration 18 years into the landfill's operation, a gas collection and control system would start up 54 months after the first waste placement. Since the adjudicatory hearing, the Authority's commitment to launch the system within this time frame has been turned into a permit condition acceptable to all parties. [See letter of Randall Young, dated March 20, 2003, and my memorandum to the parties, dated April 1, 2003.]

With the gas collection and control system in place and operating, fugitive emissions from the landfill would drop very rapidly, and any potential exceedances of the annual guideline concentration for vinyl chloride and acrylonitrile would not occur until the very end of the project's 62-year life, when the waste mass is largest, according to the Authority. Even then, based on its air modeling, and assuming an 80 percent gas collection efficiency, acrylonitrile would not exceed the Department's existing annual guideline concentration, while the exceedance for vinyl chloride would be minimal and isolated to a stretch of road along the southeastern property boundary. (There would be no exceedance of guideline values for vinyl chloride or acrylonitrile for any of the remaining residences proximate to the landfill site.)

The Objectors' witness, Daniel Gutman, is a private consultant who, over the course of his career, has analyzed air quality impacts of various projects for both government agencies and private environmental and citizens' groups. He became involved with the groups opposing this project in 1998, and has reviewed all of the Authority's air quality modeling. Mr. Gutman's prefiled testimony sets forth two main conclusions based on his work on this project:

- -The Authority has underestimated emissions of vinyl chloride and acrylonitrile because it underestimated the total amount of gas that would be generated and because it failed to use EPA's recommended collection efficiency for a landfill gas collection system.

- - The proposed permit conditions are not sufficient to prevent off-site concentrations of vinyl chloride and acrylonitrile from exceeding Department guideline concentrations.

I have reviewed Mr. Gutman's contentions and find them unpersuasive, for the reasons discussed below.

- - Estimation of Emissions

The Authority contends that emissions from its landfill would be substantially less than those indicated by EPA's AP-42 default values that were used in its modeling, since those values were developed from older landfills with higher emissions than those from more modern landfills. Though Mr. Gutman sought to raise doubts about this contention, the Authority presented extensive evidence that the default values for non-methane organic compounds generally or for vinyl chloride and acrylonitrile in particular are much higher than the concentrations actually being measured at comparable co-disposal landfills in New York State and Ontario. The Authority also presented two studies supporting its conclusion that, on a national basis, average landfill gas concentrations for acrylonitrile and vinyl chloride are significantly lower than their respective AP-42 levels. As the Authority argues, if this recent data had been used in its screening model (rather than the older and more conservative AP-42 values), there would be no exceedances of Department guideline values for any hazardous air pollutant at the property boundaries, assuming a landfill gas collection efficiency of 80 percent.

The Authority was able to demonstrate not only that AP-42 defaults substantially overstate current landfill gas constituent levels, but why landfill gas constituent levels have been declining over time. In a January 2001 report of the Waste Industry Air Coalition comparing recent landfill gas analyses with AP-42 values (Air Exhibit 14-E), the authors write that this may be due to a variety of factors including:

- - Improvement of analytical methodologies that better identify and quantify trace constituents;
- - Federal introduction of waste management regulations that strictly regulate hazardous waste disposal;
- - Federal introduction of municipal solid waste landfill regulations that detect and prevent disposal of unacceptable hazardous wastes; and
- - Industry transition to processes and products requiring less or no hazardous materials.

- - Methane Estimation

The Objectors are concerned that the Authority may have underestimated projected methane emissions, and therefore may have underestimated the emissions of hazardous air pollutants. Mr. Nostrand testified that modeled methane volumes are used to generate the mass emissions of hazardous air pollutants based on the AP-42 default concentrations for each of these pollutants.

Methane is the primary constituent of landfill gas, and as Mr. Gutman testified, methane emissions are influenced by a number of factors. As Mr. Gutman explained, EPA's LAEEM model, which estimates methane generation over time, accounts for these factors through three parameters: (1) the refuse acceptance rate, which includes only biodegradable refuse, (2) the methane generation potential, which is understood to depend on the moisture and organic content of the refuse, and (3) a decay constant, which is thought to depend on moisture, pH, temperature, and other environmental factors, as well as operating conditions. Mr. Gutman said that moisture is clearly important since it is thought to influence both the methane generation potential and the decay constant. In general, he added, more moisture in a landfill means both faster and more complete conversion of refuse to methane, and the higher the methane emissions, the higher the emissions of vinyl chloride and acrylonitrile, because methane acts as a mechanism to transport hazardous air pollutants out of a landfill.

For the purpose of compiling an emissions inventory, EPA sets out two different recommended values for the decay constant, 0.02 for landfills in a relatively arid area, and 0.04 for landfills located in a relatively moist area, the dividing line between the two being an annual precipitation of 25 inches. The Authority used the higher value of 0.04, though Mr. Gutman said this value is insufficient given that the annual precipitation in the vicinity of the project site is 58 inches per year. Mr. Gutman said that industry experts EPA consulted while developing its model recommended even higher values for the decay constant in high-moisture areas, and he said a minimum value of 0.1, consistent with these recommendations, should have been applied in this case, which would have meant higher methane emissions and consequently higher emissions of vinyl chloride and acrylonitrile.

The Authority responds simply that its modeling incorporates the higher of the two decay constant values that EPA recommends, and that this value, 0.04, is the one that would apply because the annual precipitation is above 25 inches. The Authority cannot be faulted for complying with EPA's recommendation, though the Objectors would prefer that an adjustment be made in this instance. Mr. Gutman conceded that EPA did not adopt and incorporate into AP-42 the value that he is arguing should apply, despite its consultants' comments he refers to in his testimony. He also acknowledged that, in estimating off-site vinyl chloride and acrylonitrile concentrations, the Authority followed all of EPA's recommendations except with regard to collection efficiency, which is discussed below.

Mr. Nostrand acknowledged that, all else remaining the same, if methane emissions are double what the Authority has predicted, vinyl chloride emissions should also be double what the Authority has predicted, because methane emissions are the transport vehicle for vinyl chloride emissions. However, he added that the Authority still expects that the gas concentration of vinyl chloride to be substantially less than the value used in its modeling, so a higher rate of gas generation "doesn't change necessarily where we are at in terms of the AGC (annual guideline values) values." In other words, more gas with a concentration of vinyl chloride less than that factored into the modeling does not automatically create or worsen an exceedance of the annual guideline value for vinyl chloride at and beyond the facility boundary.

Mr. Nostrand explained that pursuant to Condition 97 of the draft air permit, the Authority would be measuring concentrations of vinyl chloride in the landfill gas. Though the concentration data would not indicate how much vinyl chloride is being emitted, at the same time it is being generated the Authority would be measuring the flow of gas into its collection system, giving it a good idea of the amount of gas being generated, Mr. Nostrand explained.

As the Objectors argue, some gas may escape the collection system. However, Condition 70 of the draft permit also requires monitoring for surface concentrations of methane after the gas collection system is installed. If methane concentrations exceed a certain level, the Authority would have to perform cover maintenance or adjustments to the vacuum of adjacent wells to increase gas collection in the vicinity of the exceedance, and for repeated exceedances, it could also have to install new wells or collection devices, or upgrade the blower, the header pipes or the control devices on the gas collection system. As the Authority argues, the permit must be viewed in totality with regard to safeguards against exceedances in state guideline values for hazardous air pollutants. In this regard, the permit includes requirements to detect pollutant concentrations, measure collected gas, and minimize uncollected gas.

The Objectors are concerned about possible exceedances of the state guidelines for hazardous air pollutants in the period before active gas collection and control begins. Mr. Gutman said that the value the Authority used for vinyl chloride emissions in the 62nd and final year of landfill operations is virtually identical to the emissions that would occur after five years. However, the Authority has committed to begin operating its gas collection and control system 54 months after the first placement of waste, before five years have passed.

Mr. Gutman said that if, as he expects, methane emissions are double what the Authority has projected, emission levels forecasted for year five could occur in year two or three. However, Mr. Nostrand states that in this regard the modeling is conservative because it assumes that methane gas is produced immediately, whereas in actuality there would be a delay in the production of methane. (Methane is produced anaerobically, in the absence of oxygen, so the oxygen in the waste mass must be consumed before methane is generated.)

Mr. Gutman said that EPA's model which was used by the Authority underpredicts methane emissions by as much as a factor of two or more. His prefiled testimony includes a table indicating that at a number of landfills in "moist" areas that were studied by EPA in developing its LAEEM model, the amount of methane actually collected ranged from 1.6 to 2.4 times the amount of methane the model predicted. However, this table omits data Mr. Gutman had for other moist-climate landfills which indicated that collected and predicted amounts of methane were more closely matched. As the Authority argues, Mr. Gutman purposely omitted this data (including data for landfills where collected methane was less than the amount predicted) on the speculation that landfills at which less methane was collected than predicted might have ineefficient collection systems. (EPA only had data on methane collected, not methane emitted.)

Authority witness Mr. Nostrand, using all the available data for moist-climate landfills, found that the ratio of actual to predicted methane had a mean value of 1.23. (Exhibit 34) This tends to undermine Mr. Gutman's claim that a doubling of predicted methane emissions can be expected.

- - Collection Efficiency

To assure the 80 percent gas collection efficiency used in the Authority's modeling, Department Staff's permit requires that the landfill be constructed with a geomembrane liner, horizontal gas collection trenches with a disposable plastic cover while the landfill is active, and a gas-impermeable geomembrane final cover, or an equivalent system approved by the Department, at closure. In its engineering report, the Authority said that 80 percent collection efficiency is greater than the average reported efficiency of landfills, but lower than reported collection efficiencies of newly designed landfills, which the report says exceed 90 percent.

EPA's AP-42 document notes that reported collection efficiencies typically range from 60 to 85 percent, with an average of 75 percent most commonly assumed. However, it adds that higher collection efficiencies may be achieved at some sites (i.e., those engineered to control emissions). Mr. Gutman says that the Authority's modeling should have employed the most commonly assumed average value of 75 percent. He adds that with a change in the collection efficiency from 80 percent to 75 percent, the off-site concentration of vinyl chloride would reach 0.026 ug/m^3 for vinyl chloride and 0.019 ug/m^3 for acrylonitrile, both in excess of the Department's annual guideline values of 0.020 and 0.015 ug/m^3, respectively.

Though a collection efficiency of 75 percent would add conservatism to the modeling, I find that the Authority was reasonable to assume a collection efficiency of 80 percent in this case, given the modern gas collection and control system it would use. With this system, one would expect a collection efficiency at the high end of the range reported in the AP-42 document.

Mr. Reusing explained that his firm, Conestoga-Rovers & Associates, has experience with modern landfill gas collection systems, similar to the one designed for this landfill, that achieve efficiencies greater than 80 percent. For instance, he said the firm was the design engineer of the Keele Valley Landfill, a landfill operating in Ontario that is approximately twice the size of the proposed Ava landfill. He said that based on 2000 data, the Keele Valley Landfill is operating at a collection efficiency of over 90 percent of estimated landfill gas production. According to Mr. Reusing, the Keele Valley Landfill gas collection system is very similar to the one for the propoed Ava landfill, because it also uses horizontal trenches combined with supplemental vertical collection wells. Also, he said the two landfills would be comparable in terms of their waste acceptance profiles and the climate of the areas in which they are located.

Mr. Reusing and Mr. Nostrand both said they considered the collection efficiency assumed by the Authority to be reasonable. Mr. Nostrand noted that when considering the landfill design, which would use horizontal gas collection trenches installed as each landfill cell is developed, AP-42 suggests that the system's gas collection efficiency is likely to exceed the document's average value of 75 percent. As he explained, this average value is based on older-generation landfills, and should not be applied to newly constructed facilities with state-of-the-art gas collection and control systems. The active nature of the system to be used at this landfill - - creating a vacuum to draw gas from the waste - - would help achieve a high collection rate, and regular monitoring of the system would assure that the collection rate is maintained. As Mr. Southern explained, monitoring of the system's performance would include taking quarterly measurements of surface concentrations of methane (as required by Condition 70), and monthly monitoring of landfill gas temperature, concentrations of nitrogen or oxygen in the gas, and gauge pressure in the landfill gas collection header (as required by Condition 73).

PM-10

Issue: Would the concentrations of particulate matter that is 10 microns in size or smaller (PM-10) resulting from the operation of the landfill exceed the applicable national ambient air quality standards (NAAQS)?

FINDINGS OF FACT

1. PM-10 would be generated by trucks driving over dirt roads during construction and operation of the landfill. It would also be generated as a by-product of combustion of the landfill gas in a flare.

2. The federal Clean Air Act requires the U.S. Environmental Protection Agency (EPA) to set national ambient air quality standards (NAAQS) for pollutants considered harmful to public health and the environment.

3. The 24-hour NAAQS for PM-10 is 150 micrograms per cubic meter, and the annual NAAQS for PM-10 is 50 micrograms per cubic meter.

4. The landfill project would not cause an exceedance of these standards, according to modeling that accounts for both project impacts and background PM-10 concentrations. Modeling performed by the Authority indicates that the highest concentrations of PM-10 along the site boundaries would be 79.6 micrograms per cubic meter (24-hour impact) and 6.73 micrograms per cubic meter (annual impact).

5. PM-10 generated by truck traffic can be controlled with dust control measures such as wetting or applying calcium chloride to roadways. PM-10 generated as a combustion by-product in a flare cannot be controlled.

6. Department Staff's draft landfill permit contains provisions designed to control PM-10 generation. For instance, dust generated by mining activities and on haul roads must be controlled by water spray, and all paved surfaces must be swept as often as necessary to control dust. Also, soil stockpiled for future use must be seeded to prevent erosion.

7. In addition to the controls established by the landfill permit and the Department's regulations, the Authority has committed to implement dust control strategies in the construction and operation of the proposed landfill. The Authority would use various best management practices to minimize dust generation including minimizing the areas of earthworking

activities, quickly vegetating soil borrow areas, and paving the road surfaces with asphalt or surfacing them with gravel.

DISCUSSION

As noted above, the Objectors presented no evidence on the PM-10 issue. Because their testimony was not contradicted, my findings merely restate the contentions of Mr. Nostrand (for the Authority) and Mr. Christoffel (for Department Staff).

CONCLUSIONS - - AIR QUALITY ISSUES

1. Emissions of the hazardous air pollutants vinyl chloride and acrylonitrile would not exceed state guidelines during the life of the landfill.

2. Concentrations of PM-10 resulting from the landfill's operation would not exceed national ambient air quality standards during the life of the landfill.

RECOMMENDATION

Because the Authority has met its burden of proof on all the issues that were identified by the Commissioner for adjudication, the Commissioner should grant the permits requested by the Authority, consistent with the drafts prepared by Department Staff.