AquaBlok® Composite Particle Technology

AquaBlok® is a patented manufactured composite aggregate material that provides a technology platform for the delivery of known materials, such as bentonite, treatment amendments, or seeds, through a water column. The material hydrates in the presence of water and self-compacts to form a low permeability seal.

Although many materials, such as bentonite, have been used for such applications as lining ponds, sealing leaking reservoirs, etc. for decades, the ability to effectively apply bentonite through a significant water column to form an effective seal at the bottom is very difficult. AquaBlok can be applied cost-effectively and efficiently using a variety of standard construction techniques. In addition, because of its expansive properties, durability and demonstrable geotechnical attributes, it can be used as a replacement to anti-seep collars and is a more effective sealant for annular spaces associated with the installation of well casings.

AquaBlok also functions as a geotechnical construction material and can be installed dry in applications such as the construction of a low permeability core in a dam or levee, a lining for canals or as a waterproofing backfill around critical joints on tanks, etc. The material can also be used advantageously as a cap for landfills, as freeze-thaw cycles or desiccation-rehydration cycles will not impact its long-term effectiveness as a low permeability barrier, unlike compacted soil barriers which need to be protected from frost and desiccation, Its geotechnical properties can be determined and anticipated for project-specific design objectives and product formulations can be modified to meet the specified objectives.

The use of this material allows many activities to be conducted “in the wet” and retroactively, can effectively replace current tricky and time-consuming construction activities such as handtamping soil backfill around anti-seep collars. Material placement is accomplished by pouring the aggregated into the void in approximately 8” lifts, spraying with water and placing the next layer. No compactive effort is required and no compaction testing is necessary. The material also does not require “step-cutting” to provide an effective seal. In the case of sediment remediation projects, it can accommodate in-situ remedies that can be used in lieu of much more expensive processes such as dredging, dewatering and disposal of contaminated sediments.

The product was originally developed as a test solution to cap contaminated sediments at a military firing range in Alaska, where it was applied by helicopter drop. It has since been used to cap contaminated sediments at several Superfund sites, and has been used as an effective annular seal to replace recompacted soil and anti-seep collars at several installations associated with landfill improvements. It is currently being evaluated for additional applications by several universities, and is undergoing review under the Superfund Innovative Technologies Evaluation (SITE) program at the U.S. Navy Yard in the Anacostia River in Washington, D.C. Both the Navy and U.S. EPA have recognized this technology in their periodic technical communications such as U.S. EPA Tech Trends and NAVFACs.

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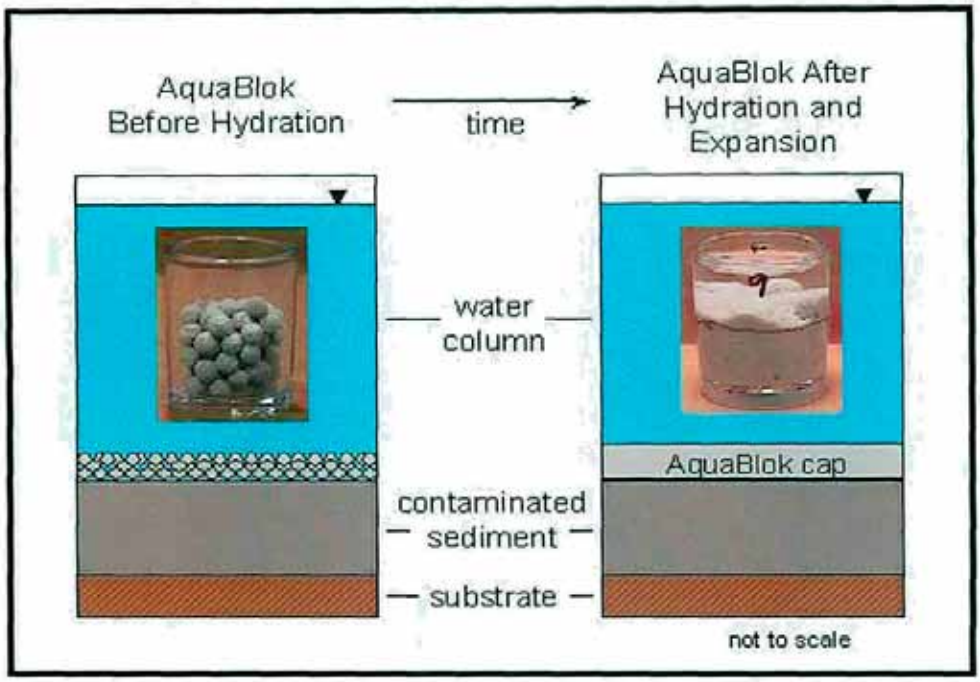

Photo 1 - View of AquaBlok® prior to hydration and after hydration.

Photo 2 - AquaBlok® placement over Geoweb® along a creek in St. Louis, Missouri.

Photo 3 - AquaBlok® placement in Massena, New York using clamshell.

INVESTIGATOR'S SUMMARY`[1]

Nomination 2006-21

Investigator: Hiam M. Khoury[2]

AQUABLOK® COMPOSITE PARTICLE TECHNOLOGY

The Innovation

AquaBlok is a patented, composite-aggregate technology resembling small stones and comprised of a central core (often stone aggregate), clay or clay sized materials (the sealant layer), and polymers (Figure 1).

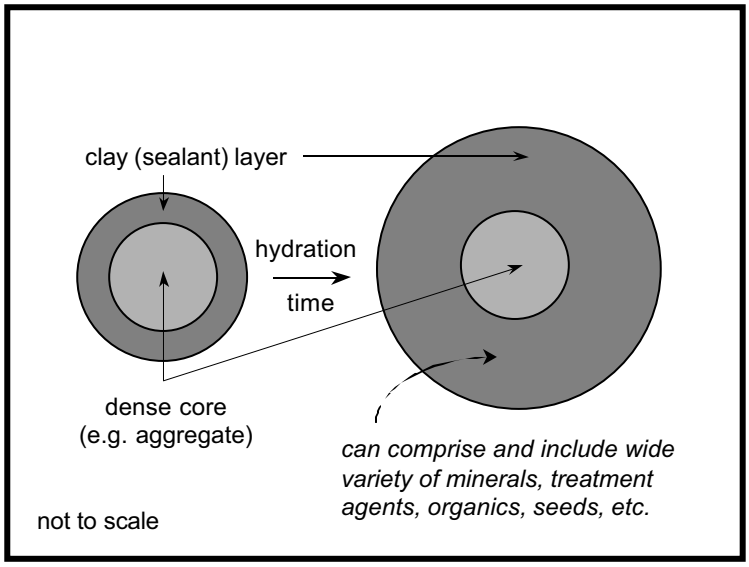

Figure 1. Configuration of a Typical AquaBlok Particle.

For typical freshwater formulations of AquaBlok, its clay mineral component consists largely of sodium bentonite. Sodium bentonite is a relatively low-cost, mineable geologic material, rich in montmorillonite clay, which has long been used in the remediation, construction, and petroleum industries for various purposes. This clay rich material is widely used because of its well-known physical, hydraulic, and chemical attributes, including its: cohesive, physically resistant nature; low permeability; high surface area and chemical reactivity with dissolved contaminants; and amenability to chemical modification for selective contaminant adsorption. In short, bentonite, the reactive component of typical AquaBlok formulations, has a well-established performance track record in environmental and geotechnical fields.

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[1] September 22, 2006

[2] Ph.D Candidate, Civil & Environmental Engineering, University of Michigan, Ann Arbor, MI 48109.

In addition to, or instead of sodium bentonite, other types of clay materials, including attapulgite (palygorskite) and/or calcium bentonite, can instead be incorporated into the product for applications to saline (brackish to full-strength seawater) environments. A large variety of other reactive minerals or materials can also be used to amend basic product formulations for specific purposes. Such amendments may include, but are not limited to: organoclays, gypsum, carbonates, zeolites, elemental sulfur, oxides, zero-valent iron, organic substrates, plant seeds, nutrients, and microbes. Other technology parameters, such as relative clay content or core density, for example, can also be modified as needed.

AquaBlok can be used to encapsulate a wide variety of sediments and, with appropriate amendments, be used to treat a wide variety of contaminant in-situ through absorption, or by directing pore water contaminants through special porous treatment amended "gates". It can be particularly effective to sequester low flows of dense, non-aqueous phase liquids, such as creosote, DDT, TCE, PCBs and other chlorinated compounds, and can effectively bind up heavy metals such as mercury, lead, arsenic, cadmium, and others. AquaBlok can also be used to deliver materials such as alum to address nutrients in sediments, such as phosphorous, thus addressing algae problems in lakes and ponds. Other additives, such as zero-valent iron, sulfur and various carbon forms, can be added to provide dechlorination of halogenated contaminants, and to bind cap contaminants, such as heavy metals, or enhance microbial degradation of organic components. In addition to its active treatment nature, AquaBlok can be used as a low permeability sealant or isolation layer to permit the injection/extraction of treatment media into the pores of sediment formations without impacting the overlying stream or lake habitat to facilitate active capture and/or in-situ treatment of contaminants co-located with sediments and sediment pore water. Applications can be made in both saline and freshwater by using various blends of clay minerals and polymers. Material can be applied in relatively still water and in moving water, and, once emplaced in especially high-energy environments, can be further protected by the application of an armor layer of stone.

AquaBlok is innovative in that it is actually a technology platform that can be adapted to many environmental, geotechnical, and construction practices. It combines the basic tenants of geotechnology with known or demonstrable (and replicable) qualities such as bearing capacity, shear strength, and expansion ratios and permeabilities to quantify performance of a "soil" that is not found in nature. In addition, its predictability, and ability to reheal itself after freeze/thaw and desiccation/rehydration cycles to maintain a low permeability in freshwater applications is unique in nature. While the properties of bentonite clay minerals are well known, the ability to accurately deliver bentonite and other dry minerals through a water column to form a low-permeability barrier is unique, as fine-grained particles such as clay minerals tend to stay in suspension due to molecular energy (Brownian movement) in very low energy environments such as are found in natural and man-made bodies of water. As noted in various accepted patent claims, the concept of a composite-aggregate particle as a vector for delivery of a variety of materials through a water column is unique and innovative. Other entities have attempted to circumvent our patent by blending clay minerals with sands, organic matter, and other similar

materials for sub-aqueous application. Such applications fail as the materials separate during descent through a water column based on their individual particle size, shape, and density (and the smaller clay-mineral particles typically do not reach to bottom surface intended, but remain resuspended and diffused).The ability to aggregate combinations of amendments with the clay minerals also presents the opportunity to provide in-situ treatment of contaminated sediments to address toxicity or nutrient issues that impact such parameters as residual dissolved oxygen (phosphorous and algae control) or food chain issues presented by chlorinated hydrocarbons and heavy metals.For the application of seeds to restore emergent wetlands, the material delivers multiple seeds to the same location resulting in increased viability of germination as water levels and temperatures fluctuate during the growing season. Also, the combination of seeds with AquaBlok minimizes the movement from the location of "planting" as a result of wind or currents, as happens with seeds broadcast over a water surface. AquaBlok delivered seeds can also be more successful than the use of "plugs" in a wetland restoration activity, as the plugs can be susceptible to shock from moving from a greenhouse setting to the field.

Application of the Innovation

AquaBlok's solid, dense core offers a simple yet effective way of conveying bentonite and other reactive clay components through fresh or saline waters and across the surface of contaminated sediments occurring in environmentally impacted wetland and deepwater ecosystems. The product can also be applied across seasonally water-free wetland areas.

When applied in bulk, AquaBlok particles descend through the water and settle out across the targeted substrate surface. In days, the clay component hydrates and expands, with particles coalescing into a cohesive, relatively physically resistant, and low-permeability barrier cap between the contaminated substrate and the overlying water column (Figure 2), thus protecting aquatic organisms.

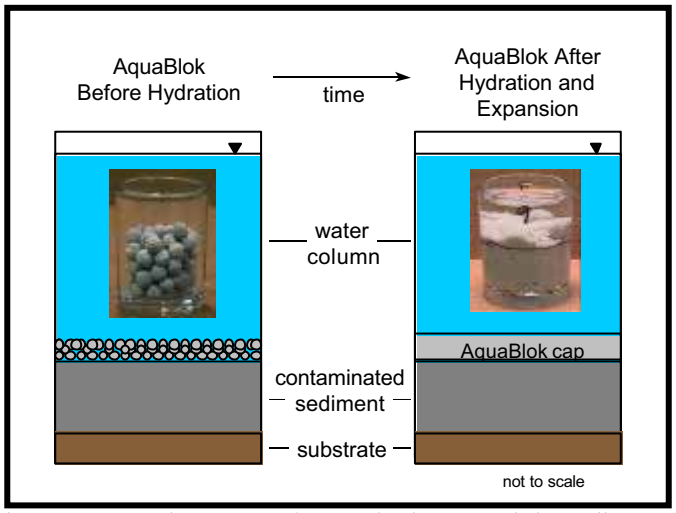


Figure 2. Development of a Typical AquaBlok Sediment Cap.

The rate and extent of product hydration, as well as the thickness of the final hydrated cap, depends on a variety of factors such as the product formulation used, salinity of the hydrating water, the thickness of product application, and the nature of the substrate being capped.

The applicability of the AquaBlok technology, and its versatility within the realm of managing impacted sediments would generally include but are not limited to: relatively straightforward encapsulation of contaminated sediments; product integration with other more permeable and "active" treatment media to affect reductions in contaminant mass or mobility (e.g. funnel and gate projects); and integration with relatively simple pore water extraction systems to accomplish effective and accelerated, in situ dewatering of capped sediments, contaminated or not. To date, and as determined mainly by the availability of relatively timely, need- and project-based opportunities that have arisen over time, AquaBlok, Ltd. has identified, initiated and focused efforts on developing markets within several specific areas of product use outside of the sediment capping realm, including:

1. Product use in construction of water, oil, and gas wells;
2. Product use as liners in surface water impoundments; and
3. Product use in mining-related applications.

Product Use in Construction of Water, Oil, and Gas Wells

A low-permeability, hydraulic seal is often required during construction of monitoring and extraction wells related to a variety of industry processes to minimize the potential for vertical transfer of contaminated ground water, oil, or brine along the well's annular space. Such transfers pose a risk in that pollutant migration can contaminate adjacent aquifers.

Current practice for creating a hydraulic seal above a well's screened interval generally involves installation of a low-permeability cap directly over sand or other granular material previously placed into the well's annular space, adjacent to the well screen. The cap is typically created by pouring an adequate quantity of pure, dry bentonite pellets or chips down the annular space and across the surface of the granular component. Water present in the formation hydrates the pellets, thus affecting material expansion and sealing of the annular space. A bentonite or concrete/bentonite slurry, also known as "grout" and typically characterized by a low bearing capacity, is then tremie-piped over the top of the semi-solid clay cap. Well construction is typically completed through application of a surficial concrete cap.

An additional application is to seal penetrations of landfill caps. Upon breaching a previously certified, low-permeability landfill cap for the purpose of installing an extraction well to remove landfill gases, the re-creation of low-permeability conditions around the installed well casing is required, both to maintain low permeability to minimize percolation of precipitation into the

landfill and to provide an air-tight seal around the annular space to minimize air intrusion into the landfill (which can result in combustible conditions).

Current construction practices to re-establish low-permeability conditions lost during gas-well installation, as dictated by existing and relevant regulations, commonly involve the following general procedure: drilling a boring (up to three feet in diameter) through the surficial protective layer, through the low-permeability cap (including the flexible membrane liner [FML] component, if present) and finally down into the landfilled material; placing a 6- to 12-inch diameter perforated well casing into the boring, screened at the appropriate interval; backfilling the screened interval with permeable packing materials like sand or aggregate; then finally backfilling the remainder of the boring area with low permeability soils (e.g. clay) or grout, plus the overlying protective layer, in an effort to re-establish low-permeability conditions around the well casing.

Use of an AquaBlok cap has a number of technical, economic, and regulatory-based advantages over current construction practices, including:

- Formulations of the product are comprised of sodium bentonite clay, and the low-permeability (10^{-9} cm/s) and resiliency, or re-sealing ability, of such material is well known to the environmental community;
- The product self-compacts when wetted and hydrated. Consequently, the material can be placed into a well's annular space as a single three foot-thick dry lift, with water added afterwards. The material's self-compacting ability, in turn, precludes the need for additional and potentially destructive excavation and compaction-driven backfilling of clay and protective material around the well – that is, the gas well can be constructed exclusively within the confines of the existing borehole;
- In its dry form, the product handles easily, like aggregate. Thus, it can be delivered to a well site in packages, varying from 50-lb sacks to two-ton SuperSacks, and either poured or shoveled by hand into a well's annular space, thus precluding the need for equipment rental;
- The amount of water needed to initially hydrate the product, once placed into the annular space, is not critical, thus precluding the need for neutron probe testing during well construction;
- Creation of an air-tight seal around a plastic vent pipe has been demonstrated within the context of some conceptual laboratory tests designed to highlight product use in sediment-related applications. The same air-tight attributes could also be achieved in a landfill application, resulting in minimal air intrusion from above and maintenance of required anaerobic conditions within the well's vicinity; and
- The product's demonstrated abilities to act as a low-permeability, air-tight seal greatly increases the potential for successful re-certification of the landfill cap upon re-inspection.

Product Use as Liners in Surface Water Impoundments

The discharge of process water slurries or wastewater streams containing pollution-control by-products or other solid materials into holding basins or surface impoundments can generally be a viable method for material management. This would include the discharge of suspended coal combustion byproducts into settling ponds or basins for the primary purpose of physically segregating and isolating the settleable solids fraction. Such combustion byproducts are typically comprised of materials (i.e. fly ash, flue gas desulfurization waste, etc.) that, due to their chemical composition and reactivity, require sound environmental management upon their disposal. If discharged to non-lined or inadequately lined basins, contaminants associated with these byproducts can potentially become mobilized, migrate downward, and adversely impact underlying groundwater resources.

Although the byproduct solids being disposed of are non-geologic, or "non-natural", sediments and thus relatively unique in this respect, the management of contaminants associated with such solid-phase materials occurring in surface water bodies is not an issue faced solely by the power-generating industry. Indeed, many business entities are quite familiar with the liability and risks associated with managing contaminants associated with geologically derived or "natural" sediments, as they occur in relatively dynamic riverine, lacustrine, and estuarine environments.

The challenges faced by the power-generating industry and others with respect to disposal of potentially harmful byproduct solids are clearly compounded by the fact that, while air-quality regulations have become more stringent over the past years, so too have regulations governing groundwater quality. As a result of this parallel evolution towards stricter environmental policies, a relatively greater percentage of contaminant mass may end up being transferred to discharged byproduct solids (rather than into the air) while at the same time a greater degree of attenuation, or immobilization, of this increased contaminant mass is being required in order to meet tightening standards for maintaining groundwater quality. This seemingly simple "phase-change" of contaminants - from air to settled solids - requires additional, significant efforts from the industry, not the least of which is the development and management of appropriate disposal facilities.

Constructing new, fully lined and environmentally protective holding basins for the receipt of sediment-bearing discharge waters is costly, and may be impractical due to site constraints. When new basins are impractical, the retrofitting of existing basins could require a cessation of operations, thus making augmentation of existing basins with relatively low-permeability liner systems an attractive and cost-effective option. Allowing for continued use of the basin *during* the retrofitting process is more attractive still.

A properly formulated and designed, low-permeability AquaBlok-based liner system placed into existing settling/holding basins can provide for effective protection of underlying groundwater resources. Such a liner system can be formulated and designed to address a

variety of site-specific needs related to meeting groundwater quality objectives. For example, at sites in which the natural processes of groundwater mixing and dilution as well as attenuation by underlying geologic strata can be invoked to assist with meeting target cleanup standards, a non-amended liner material could be used to simply "slow down" the bulk flow of infiltrating waters, thus reducing the flux of dissolved contaminants into the underlying groundwater. At sites in which groundwater mixing, natural attenuation, etc. is not possible or allowable, specially amended formulations of the product can be applied to actively sequester contaminants in order to greatly minimize their diffusive as well as advective flux into underlying groundwater resources in the first place (such that subsequent reliance on mixing, dilution, and/or geologic attenuation is not required).

AquaBlok, Ltd. believes that, in light of the many similar power-generating/impoundment facilities currently in operation across the U.S. – at least a portion of which also likely have associated groundwater impact or related issues – product use as liners in surface water impoundments represents a highly lucrative area for marketing and pursuit. To this end, AquaBlok, Ltd. attended and presented a paper entitled *Augmenting Holding Basins With Relatively Low-Permeability Liner Systems* at the annual International Ash Utilization Symposium (IAUS), held in Lexington, KY in late 2003. More such presentations to IAUS (and to similar symposia and conferences) are planned in the future, as is development and pursuit of the significant owner- and regulatory related contacts that have been, and can continue to be, made while attending these gatherings.

Product Use in Mining-Related Applications

By virtue of AquaBlok's unique composition, demonstrated performance attributes, and flexibility in design, the composite aggregate technology also has direct application to numerous and diverse mining-related environments like pit lakes, tailings impoundments, and surface water lakes and streams impacted by acid rock drainage.

As described in detail in a paper entitled *Potential Uses of Relatively Low-Permeability Liner Systems in Pit Lake Environments*, prepared and presented by AquaBlok, Ltd. at the U.S. EPA's "Pit Lakes 2004" conference in Reno, NV, non-amended or amended formulations of the product can be appropriate for use in various subaerial and subaqueous mining-related applications, including in pit lakes.

Environmental mining-related problems that could be addressed with the AquaBlok technology in this respect could include:

- Minimizing exposure of sulfide-bearing geology in wall rock areas to atmospheric oxygen;
- Minimizing subsequent oxidation of sulfide materials and generation of sulfuric acid, dissolved metals, and sulfate;

- Minimizing translocation of resultant acidic, metal-rich solutions from sulfidic wall-rock areas into impounded surface waters, including mitigating related impacts;
- Minimizing infiltration of acidic, metal-rich surface waters into underlying groundwater resources, and/or into adjacent creeks, streams, etc.; and
- Minimizing resuspension of acidic, sulfidic, and/or metal-rich sediments occurring in lakes and impoundments into overlying water columns as result of seasonal turnover and wind-driven mixing.

It is recognized that issues and challenges associated with these and other mining-related environments are not the same issues and challenges associated with "typical" impacted sediment sites, due in large part to the physical, hydraulic/hydrologic, chemical, and biological characteristics unique to mining environments.

AquaBlock Site Applications

The following sections depict a variety of application techniques and site characteristics. While most of the following applications are pilots, several are actual full deployments at Superfund sites.

1-Fort Richardson/Eagle River Flats Superfund Site, Alaska

Project Status:
Completed in 1994

Environmental Setting:
Wetland (freshwater, with periodic brackish tidal inundation)

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments (demonstration)

Contaminant(s) of Concern:
White Phosphorous (WP)

Approximate Site Area:
4,000 square meters (43,000 square feet)

AquaBlok Cap Design:
AquaBlok placed at hydrated thicknesses ranging from an average of approximately 2.4 inches (~6 cm) on level ground to approximately 6.3 inches (~16 cm) in "cratered" areas of the project site.

Note: Not actual photo of Eagle River Flats (ERF) demonstration. Blackhawk helicopter with same bags used at ERF.

Method of AquaBlok Placement:
Helicopter with specially designed material drop bags

Related References:
- Pochop et al., 2000, Physical Barrier to Reduce WP Mortalities of Foraging Waterfowl, *Journal of Environmental Engineering*, Vol. 126, No. 2, February 2000.
- US EPA's 1998 Record of Decision (ROD) abstract for Operable Unit (OU) 3 in the Eagle River Flats Area of the Fort Richardson, Alaska site, available from the following US EPA website: www.epa.gov/superrods/.

2- Ottawa River, Toledo, Ohio Site

Project Status:
Completed in September 1999

Environmental Setting:
River with estuary characteristics (freshwater)

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments (demonstration)

Contaminant(s) of Concern:
PCBs (polychlorinated biphenyls), various metals

Approximate Site Area:
9,950 square meters (107,000 square feet)

AquaBlok Cap Design:
Three different cap designs of approximately equal area and occurring within three different sections of the site (Section A, Section B, and Section C):
- *Section A cap*: Design comprised of a layer of hydrated AquaBlok (~5-6 inches or ~13-15 cm in target thickness).
- *Section B cap:* Design comprised of a basal geogrid component (Tensar) covered by a layer of hydrated AquaBlok (~5-6 inches or ~13-15 cm in target thickness).
- *Section C cap:* Design comprised of a basal geogrid component (Tensar) covered by a layer of hydrated AquaBlok (~5-6 inches or ~13-15 cm in target thickness) covered by a surficial layer of stone-armor material (~2 inches or ~5 cm in target thickness).

Method of AquaBlok Placement:

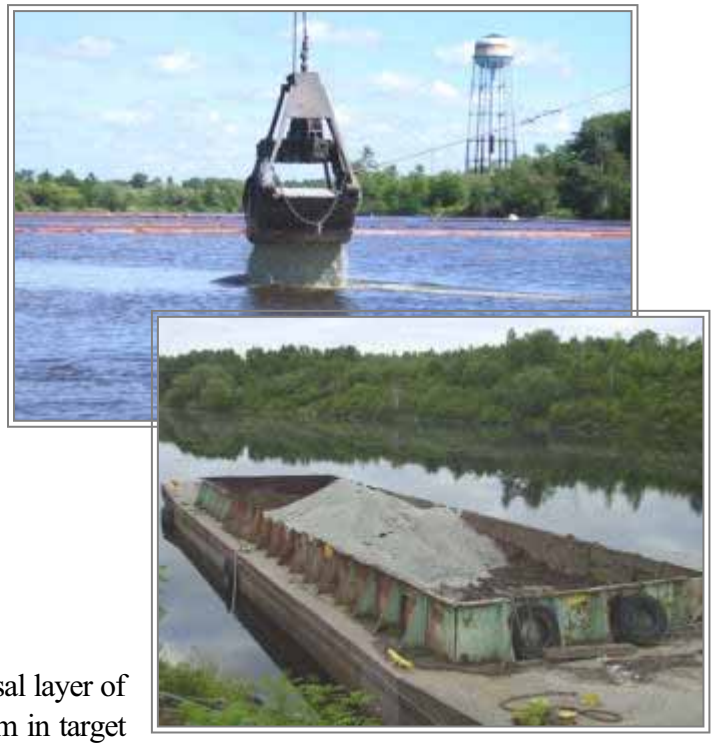
Various methods, including:

- Telescoping, articulating conveyor (barge- and shore-based)
- Crane plus clamshell (shore-based)
- Helicopter with specially designed material drop bags

Related References:

- *Interim Report of the Ottawa River AquaBlok™ Application Demonstration*, Prepared for the City of Toledo, October 1999.
- *Summary Report of the Ottawa River AquaBlok™ Application Demonstration*, Prepared for the City of Toledo, December 2000.
- *Ottawa River Restoration Project, Characterization of the Macroinvertebrate Community Two Years After Installation of AquaBlok™-Based Sediment Caps*, Prepared for the City of Toledo, June 2002.
- *Characterization of the Macroinvertebrate Community Five Years After Installation of AquaBlok™-Based Sediment Caps*, Prepared for the City of Toledo, December 2004.

3-Grasse River, Massena, New York Site



Project Status:
Pilot completed in September 2001

Environmental Setting:
River (freshwater)

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments

Contaminant(s) of Concern:
PCBs (polychlorinated biphenyls)

Approximate Site Area:
2,760 square meters (29,700 square feet)

AquaBlok Composite Cap Design:
Multi-layer design. Design comprised of a basal layer of hydrated AquaBlok (~3-4 inches or ~8-10 cm in target thickness) covered by a surficial layer of sand/topsoil mix (~6 inches or ~15 cm in target thickness).

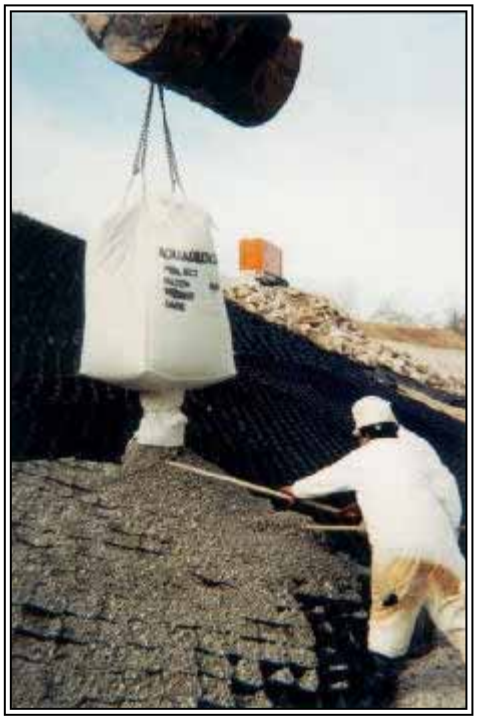
Method of AquaBlok Placement:
Barge-based crane plus clamshell

Related References:

- Refer to project document entitled "Alcoa Grasse River Capping Pilot Study, April 2002". This is available on-line through the opening page of the Sediment Management Work Group (SMWG) website at www.smwg.org under "PRESENTATIONS AND OTHER ITEMS OF GENERAL INTEREST".
- Refer to Grasse River project homepage on-line at www.thegrasseriver.com.

4-Deercreek Superfund Site Project, St. Louis, Missouri

Project Status:
Completed February 2002



Environmental Setting:
River (freshwater)

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments, within the context of a bank stabilization project

Contaminant(s) of Concern:
Hydrocarbon/petroleum-based contaminants originating from an industrial process plant (creosote)

Approximate Site Area:
510 square meters (5,500 square feet)

AquaBlok Composite Cap Design:
The installation comprised tow general, multi-component designs:

- *River-channel area:* Design comprised of a layer of hydrated AquaBlok (~6 inches or ~15 cm in target thickness) covered by a non-woven geotextile covered by a surficial layer of aggregate and riprap stone (~26 inches or ~66 cm in target thickness).
- *Bank-slope area:* Design comprised of a layer of hydrated AquaBlok (~6 inches or ~15 cm in target thickness) placed in Geoweb cells covered by a non-woven geotextile covered by a surficial layer of aggregate and riprap stone (~26 inches or ~66 cm in target thickness).

Method of AquaBlok Placement:
Material typically placed directly from SuperSacks suspended from a shore-based excavator

Related References:
Rick Kottemann
Laclede Gas Company
Email: rkottemann@lacledegas.com

5-Washington, D.C. Site

Project Status:
Cap construction completed April 2004

Environmental Setting:
River, tidally influenced (freshwater)

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments, within the context of an "active caps" designed to accomplish contaminant treatment concurrent with encapsulation (demonstration)

Contaminant(s) of Concern:
PAHs (polynuclear aromatic hydrocarbons); PCBs (polychlorinated biphenyls); and metals

Approximate Site Area:
745 square meters (8,000 square feet)

AquaBlok Composite Cap Design:
Multi-layer design. Design comprised of a basal layer of hydrated AquaBlok (~4 inches or ~10 cm in target thickness) covered by a surficial layer of sand (~8 inches or ~20 cm in target thickness).

Method of AquaBlok Placement:
Barge-based crane plus clamshell

Related References:

- Website established for the project: www.hsrc.org/hsrc/html/ssw/anacostia/
- "Research Brief #23. Comparative Validation of Innovative Capping Technologies: "Active Capping". This document is available from the Hazardous Substance Research Center/South & Southwest website at www.hsrc-ssw.org/pdf/RB23.pdf.

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6-Kearny Marsh Site, Kearny, New Jersey

Project Status:
Part completed in August 2005

Environmental Setting:
Freshwater marsh

Intended Purpose for AquaBlok Use:
Encapsulation of contaminated sediments

Contaminant(s) of Concern:
PAHs, heavy metals

Approximate Site Area:
Six test plots of 3,600 SF each, for a total of 21,600 SF

AquaBlok Composite Cap Design:
Design variations comprised of a layer of hydrated AquaBlok (~6 inches or ~15 cm in target thickness), carbon-amended AquaBlok, and sand.

Method of AquaBlok Placement:
Land-based stone slinger

Related References:

- *Summary Report of Selected Physical Characteristics and Field Observations Related to AquaBlok Use in the Kearny Marsh Capping Project*, Prepared for the New Jersey Meadowlands Commission Environmental Research Institute, September 2005

Generalized cost estimates for 28 ongoing, completed, or planned U.S. sediment removal projects typically range from about $30 to over $3,000/cy according to GLNPO, 1998 and Cushing, 1998 (Appendix B of Volume 2). Specific components included in project cost estimates, such as expenses associated with ex situ treatment, sediment and/or water disposal, project planning and management, engineering design, facility monitoring, and O&M, vary from project to project. A similar generalized cost range – approximately $100 to $1,000/cy – was also provided by a 1997 National Research Council (NRC) document for sediment removal projects, which includes an estimate for ex situ treatment, but not disposal. Assuming a relatively low-end unit cost of $100/cy, remediation of all impacted U.S. sediments using a removal approach could cost on the order of 120 billion dollars, not including natural resource damage claims or mitigation requirements. Fewer cost data are available for in situ remedial capping projects, although capping is generally considered by many experts to be a much more

cost-effective approach for managing contaminated sediments than removal, treatment, and disposal. According to information published by Cushing, 1999 and the Georgia Tech Research Corporation, 1996, unit costs associated with four U.S. capping projects involving the use of sand, fill, stone, and/or geotextile (all of which occurred between 1990 and 1998) range from about $\$4/ft^2$ to about $\$11/ft^2$; it is unclear from the published information if all specific project components are included in these total unit costs, such as permitting, follow-up monitoring and/or contingency planning. In contrast, unit costs associated with completed or recently proposed AquaBlok capping projects (from 2002 to 2004) are typically at the low end of the above range, with most well below the $\$4/ft^2$ mark. Additionally, costs for completed or proposed AquaBlok projects include sub-costs for most key project facets (i.e. materials and placement plus packaging and transport or mobilization, as appropriate to either remote or on-site manufacture scenarios), although costs for other project-related expenses (e.g. planning, management, engineering design, permitting, monitoring, etc.) are not included. Furthermore, clay-based AquaBlok can more effectively meet the isolation, stabilization, and chemical-barrier functions often required of a remedial cap at substantially lesser cap thicknesses than can granular capping materials like sands; most AquaBlok layers are typically placed at thicknesses equal to or less than six inches (initial thickness of dry product) whereas many sand caps are typically on the order of two feet thick or more.

The only other system that the innovators are aware of that can create a low-permeability barrier underwater is a sand-bentonite slurry mixture that was injected by an underwater tremie pipe during the Alcoa Grasse River pilot project. That method was, relative to AquaBlok, much more expensive; the application took about four times as long for a comparable area, the permeability was higher and the application technique caused more re-suspension of contaminated sediments. This technology could also have serious limitations of water depth - being limited to just over twenty feet, while AquaBlok can be applied through a water column of hundreds of feet. With respect to the delivery of treatment materials there are several other techniques that have been used, one being a reactive treatment mat (manufactured by CETCO). The applications of this material require the use of specialty equipment and divers. It is also limited to areas that have limited boat traffic (as anchors could snag it and pull it up). While it could be comparable on a square foot basis, it is relatively highly permeable compared to AquaBlok, and the amount of reactive material capable of being delivered on a square foot basis is quite small (the mat being only several millimeters in thickness). In addition, the set-up and access requirements would make the application scenarios of this material much more restricted than AquaBlok. Finally, it does not approximate a natural habitat for re-colonization of benthic communities, nor does it re-heal itself if it is torn of punctured.

Consequently, using AquaBlok for sediment capping is often more cost effective than using sand because less material need be purchased and applied to achieve an effective sediment cap and the lower cap thickness will have less impact on the hydrology of the body of water, thus minimizing changes to the area from an ecological/habitat standpoint and also from a floodway capacity standpoint.

Background of the Innovation

The product was developed and successfully applied in 1994 at a site in Alaska (the Eagle River Flats area of the Fort Richardson Superfund Site, or ERF). The initial field-scale demonstration test at ERF was monitored for several years and the technology ultimately included in the remedial approach to the site as per the final 1998 Record of Decision (ROD). In addition to the ERF project, additional field-scale demonstration projects have been or are presently being conducted across the Eastern U.S. and Japan by regulatory, private, and/or academic entities. Included among them is the high-profile, Anacostia River demonstration capping project in Washington D.C., which is being conducted by the HSRC/S&SW with direct involvement by the U.S. EPA SITE program, and MERI's Kearny Marsh demonstration project, which is being conducted in the Meadowlands of New Jersey. Various attributes of the technology are being demonstrated in these field-scale tests, ranging from the product's ability to serve as a hydraulic barrier in redirecting groundwater flow to the use of organic- and seed-amended formulations to help restore faunal and floral communities. Significant laboratory based research related to physical, hydraulic, chemical, and biological aspects of freshwater and saline formulations of the technology has been conducted and disseminated over the last several years by AquaBlok, Ltd. and third-party entities, which both supports and lends credibility to these field-scale demonstrations.

In addition to the field-scale demonstrations, full-scale remedial applications (not demonstrations) of various sizes have been or are presently being conducted or planned at sites in the U.S. and Canada by various responsible parties, pursuant to and with oversight from a number of state, federal, and/or provincial regulatory agencies. Among these remedial applications is the upcoming Cold Creek Swamp project for which, based on U.S. EPA Region 4's favorable assessment of the technology, negotiations are currently underway for re-opening the site's ROD to accommodate use of the AquaBlok technology. Product use resulting from such ROD re-openings represents a significant additional market for the technology.

The product and its field-scale uses have received significant regulatory interest and encouragement from agencies including the U.S. EPA, USFWS, and USACE. AquaBlok, Ltd. has developed and maintained contacts with numerous representatives from these agencies, either within the context of specific projects or through attendance at sediment-related workshops, conferences, etc. Continued contact with agency representatives, as well as with Superfund site PRPs, researchers, and consultants typically involved with sediment remediation projects is critical to entrenching user confidence in the product, as is continued publishing, presentations at workshops and conferences, and maintaining the technology website. Increased user confidence will result in securing future opportunities for field-scale demonstrations which will, in turn, promote accelerated product consideration and use in full-scale remedial applications.

Responsibility for the Innovation

John Hull and Thomas Nachtman were the original inventors of AquaBlok. Hull and Nachtman, along with a business partner, started a company, New Waste Concepts (NWC), to develop and market a sanitary landfill product (ConCover®). At the request of researchers at U.S. Fish and Wildlife (USFW) and U.S. Department of Agriculture (USDA), Hull and Nachtman subsequently developed bird and bear repellents for incorporation into the landfill product. Through this successful collaboration, the same USFW researchers enlisted their assistance to try to incorporate a bird repellent for use at a Superfund site to address duck mortality from contaminated sediments; a condition was that the material had to be able to be applied by air broadcast, as the presence of unexploded ordinance precluded standard construction technologies for removal. The initial thought was to deliver a bird repellent in palletized form, but upon learning that ducks dabble, the concept of a self-compacting contaminant barrier that could be applied in particle form was born. Consequently, after bench-scale lab work was completed by Hull and Nachtman, the concept was realized with full-scale on-site production in Alaska for a pilot application. As an engineer practicing in the geotech and environmental remedial areas, Hull realized the potential for applications to address contaminated sediments where removal by dredging, or diversion of waterways for removal and/or capping by conventional construction technologies would be very expensive and/or highly disruptive to recreational/wildlife habitat, navigation or water supply. The original patent was granted in 1998. After a second successful pilot demonstration on the Ottawa River in 1999, AquaBlok, Ltd. was formed to advance the technology. Hull is currently the President of AquaBlok, Ltd., and Thomas Nachtman (President of a second NWC spin-off, Instacote, Inc.) has periodically served as a consultant during additional product advancement.

Therefore, based on the available background of the AquaBlok solution, the following persons are found to be responsible for the innovation and must be recognized by CIF as such, should this innovation receive a NOVA award:

- John Hull
- Thomas Nachtman

Opinions of Persons Contacted

A list of people interviewed, along with a short summary, is provided ahead in this report in the section titled “Selected Interview Summaries”.

Investigator’s Comments

The function of AquaBlok as a system is two-fold to form a uniform low-permeability barrier underwater and to act as a vector or delivery system to place treatment amendments at the sediment/water column interface.

AquaBlok, Ltd. claims that their clientele is vast and that many of them have drew great and tangible benefits from the use of this technology. AquaBlok, Ltd. is asserting that, based on several pilots and full deployment applications, the material quality is very consistent, the properties are consistent and predictable, and the ability to meet design objectives with reasonable tolerances has been demonstrated under a variety of application conditions.

The investigator interviewed a couple of people (see selected interview summaries). One of the people that I was able to establish contact with for information had positive remarks about the innovation and was enthusiastic in providing information on how the innovation improved many operations in several different areas. Other users of the technology with whom the investigator communicated have recently adopted tools from the solution, have used it and are using it on "pilot" projects.

The investigator was able to conclude that the AquaBlok material has **unique** physical characteristics and its attributes has been identified as an **effective** physical, hydraulic, chemical, and biological barrier in many applications. Additionally, AquaBlok's composite aggregate structure allows for its use as a vector for **efficiently and accurately** delivering or conveying treatment chemicals or other environmental media to targeted locations in a **cost-effective** manner.

SELECTED INTERVIEW SUMMARIES

John Hull, P.E.
President
AquaBlok, Ltd.
Toledo, Ohio
Interview by Hiam M. Khoury, August 25, 2006

Mr. John Hull is the primary contact person identified on the original nomination for AquaBlok. Mr. Hull was very enthusiastic and cooperative in providing comments and detailed information on the project, which the investigator has used in most of the parts of this report.

Jim Mueller, Ph.D.
Director of Remedial Solutions
Adventus Americas, Inc.
Freeport, Illinois
Interview by Hiam M. Khoury, September 18, 2006

Jim Mueller was very helpful in providing information about the innovation. He stated that AquaBlok composite particle technology has proven to be extremely diverse in its applications, and it has been enthusiastically accepted throughout the world as a means of managing some of the more complicated, challenging and significant environmental contamination issues we currently face. Additionally, he mentioned that the AquaBlok remedial technologies have been selected by regulators, consultants and site owners as the preferred means of managing very large, complex sites where sediment contamination is a significant issue. Superfund sites in TN and AL are examples; multiple sites in Europe and Israel exemplify international interest.

He also confidently mentioned that the core AquaBlok composite particles will serve as the foundation for revolutionary technologies in the remedial construction and environmental engineering sectors, yielding safe, effective and cost-efficient remedial strategies. He stated as well that there are similar benefits to the civil engineering construction sectors and that AquaBlok would have been an excellent choice to bridge the levee gaps in New Orleans following the flooding caused by hurricane Katrina and could likely have prevented much of the subsequent damage.

He concluded by saying that he supports unreservedly AquaBlok technology selection as a recipient of the NOVA award and recognition under the Construction Innovation Forum.

Francisco Artigas
Director, MERI Group
New Jersey Meadowlands Commission
Lyndhurst, New Jersey
Interview by Hiam M. Khoury, September 19, 2006

MERI Group is conducting an AquaBlok experimental study at Kearny Marsh, New Jersey Meadowlands. Kearny Marsh in the NJ Meadowlands was chosen as the site for the pilot field study. The study is still ongoing so I was provided with some facts.

The study design involved five treatments done in duplicate. They included 1) AquaBlok (AB) alone, 2) AB with SubmerSeed, 3) AB amended with 2% peat moss and SubmerSeed, 4) uncapped control and 5) uncapped control with SubmerSeed. SubmerSeed is AB amended with seeds from aquatic plants. It was used to evaluate the ability of aquatic plants to germinate and grow in AB as well as to take up contaminants from their surroundings and/or the cap.

Each of the 10 plots was approximately 60 by 60 feet. AB was placed in the marsh by a "stone-flinger" between July 25th and August 3rd of 2005. The study site proved too deep for optimal germination of aquatic plants, so SubmerSeed was placed on sunken Biologs covered with AB. The Biologs and SubmerSeed were put in the marsh between November 2005 and January 2006.

Overall, results showed that the marsh is contaminated with heavy metals such as Cd, Pb, DDT and PCBs. After the first year of post-capping monitoring activities, deposition of AB did not greatly increase suspended solids in the marsh and was associated with a reduction of organic contaminants in surface water. The modest increase in surface water pH indicated that AquaBlok was probably binding cations as in laboratory studies but this did not correspond with lower heavy metal concentrations in the post capping monitoring results. Benthic Macroinvertebrate (BMI) did not thrive in AquaBlok in the lab; however, AquaBlok in the marsh enhanced colonization of Hester-Dendy by some species and was associated with higher dissolved oxygen (DO). In time, BMI may come to colonize the AB substrate itself. This may be seen after further ongoing monitoring activities are concluded next year.

SUPPORTING EXHIBITS

1. **AquaBlok Experimental Applications Images (including sediment capping images)**
2. **AquaBlok technical sheets**


Eagle River Flats before and after AquaBlok treatment


Equipment and cap placement techniques

Placing Aggregate Capping Material
Using a Helicopter

Placing Aggregate Capping Material
from Shore Using a Dragline

Adventus Americas
Engineering Brief
Number 5 in a Series
Subject: *In Situ*
Hydraulic Sealing
and Treatment

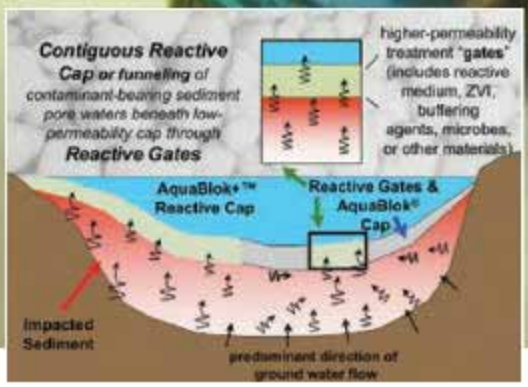
5

Looking for Solutions to Contaminated Sediments?

AquaBlok® is a patented composite aggregate technology that solves many of the traditional problems associated with either impermeable sealing or *in situ* treatment of contaminated sediments. To meet site-specific needs, a variety of minerals or materials can be incorporated into the AquaBlok delivery vector (such as ZVI, organics, seeds, etc.). This enhanced product, AquaBlok+™ – from Adventus Americas and the inventors of AquaBlok – provides an engineered "reactive" barrier that both isolates and ameliorates contaminated sediments. This option permanently addresses sediment concerns driven by body burden and water contamination issues. This non-invasive approach promptly meets regulatory obligations such as the Clean Water Act, National Resources Damages, and others.

KEY BENEFITS:

- Substantial savings over traditional invasive approaches
- Allows either effective isolation or *in situ* treatment of contaminants
- Ease of placement with standard material handling equipment
- Versatile technical platform as a vector delivery system



AquaBlok® Composite Particle System

www.aquablokinfo.com

Adventus Americas is the exclusive global distributor of customized AquaBlok® remediation products.

ADVENTUS

Proven Soil, Sediment, and Groundwater Remediation Biotechnologies

Contact Adventus Americas for a free site evaluation. Call toll free at 888-295-8661 or visit us online at www.adventus.us

AquaBlok+ Use In Water and Oil Well Construction

AquaBlok+™

Reactive Hole Plug and Sealant Aids in Pollution Prevention

By adding reactive media or catalysts to the AquaBlok® delivery vector, the hydratable composite particles quickly form subsurface seals around targeted objects such as well casings, caissons, pillars, piping, or other engineered structures when introduced into the environment. The reactive nature of the improved sealant is such that organic compounds which partition into the sealant will be destroyed. Inorganic compounds that tend to migrate along the preferred path of the boreholes or engineered structures will be effectively sequestered, thereby preventing extended or cross-contamination of sub-aqueous environments.
PATENTS PENDING.

Technology Overview

AquaBlok is a patented, composite-aggregate technology resembling small stones and typically comprised of a dense aggregate core, clay or clay sized materials, and polymers (**Figure 1**).

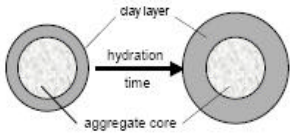


Figure 1. Configuration of Typical AquaBlok Particle (not to scale)

AquaBlok's clay (sealant) component consists largely of bentonite clay. However, other clay minerals can be incorporated to meet project-specific needs. Other technology parameters (particle size, relative clay content, etc.) can also be modified, as appropriate. As AquaBlok particles expand when hydrated, the mass coalesces into a contiguous, impermeable ($5x10^{-9}$ cm/sec) and relatively soft body of material. Once developed, hydrated AquaBlok can act as an effective physical, hydraulic, and chemical barrier by virtue of its relatively cohesive and homogeneous character, low permeability to water, and chemically active (sorptive) nature.

Problem Statement

A low-permeability, hydraulic seal is often required during construction of monitoring, remedial action, and extraction wells related to a variety of industry processes to minimize the potential for vertical transfer of contaminated ground water, oil, or brine along the well's annular space. Such transfers pose a risk in that pollutant migration can contaminate adjacent aquifers.

Solution – Reactive Sealant

The use of AquaBlok+ (AB+) reactive hole plug helps ensure that cross contamination of aquifers does not occur during site investigation, delineation and remedial actions. In addition, rebound of contaminants, which may be attributed to the sorptive nature of conventional sealants, can be avoided.

Creating a reactive hydraulic seal above a well's screened interval generally involves installation of a low-permeability reactive cap directly over sand or other granular material previously placed into the well's annular space, adjacent to the well screen (**Figure 2**).

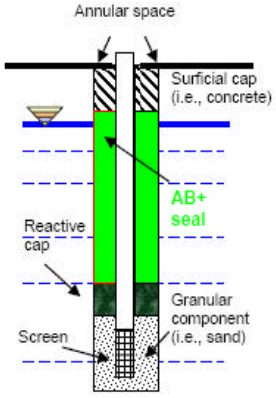


Figure 2. Schematic of well constructed with AB+ Hole Plug.

The reactive cap and remainder of the hole plug for the annular space can be comprised of AB+ rather than conventional grouting materials. It provides comparable performance to bentonite pellets, and superior performance to bentonite flakes or chips in placement and elimination of "bridging" within the annular space.

Bridging results in the formation of an ineffective bentonite cap positioned above, rather than contiguous with, the underlying granular surface. Such a hydraulic gap could create pathways for the release or uncontrolled transfer of contaminated ground waters from one aquifer to another.

AquaBlok+ Improvements over Conventional Approaches:

- Easy application and fast settling = reduced field time
- Uniform distribution minimizes bridging
- Contiguous and effective reactive well seal
- Reactive matrix = no rebound of contaminants
- Improved remedial performance
- Cost effective

AquaBlok+ Hole Plug pellets are easy to handle and place. No mixing or special equipment is required.

Cost: Quantity pricing available based on packaging requirements. Volume discounts apply.

ADVENTUS

An AquaBlok® Remediation Technology Representative

For more information please call us on **(888) 295-8661**, or send an email to:
info@adventus.us

We are online on:
www.adventusgroup.com
www.aquablokinfo.com

Capping Experiment at the Kearny Marsh

Participants: MERI, Seton Hall University, Fairleigh Dickinson University & AquaBlok Ltd.

AquaBlok is a patented material designed to create a physical and chemical barrier between pollutants in sediment and the aquatic food chain. Scientists from MERI, Seton Hall University, and Farleigh Dickinson University will test AquaBlok's effectiveness using ten small submerged plots established throughout the Kearny Marsh study area. Six of these plots will be capped with AquaBlok, a dry-composite material. The capping material will immobilize contaminants and promote regrowth of wetland vegetation. Test plots will be monitored through long-term sampling of vegetation and macroinvertebrate diversity.