June 27 - August 20, 2011

Civil Engineering at the Grassroots: Management of Water in Mewat Villages

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— Acknowledgements —

I am deeply thankful to everyone who made this internship a reality. First and foremost, thank you to the World Food Prize Foundation, in particular, Ms. Lisa Fleming, Director of Global Education Programs. Thank you to Mr. Jay Seghal, Ms. Pooja Murada, and Mr. Jagdesh Prasad for making the arrangements in preparation for my internship. Thank you to Mr. Lalit Sharma and Mr. Salahuddin Saiphy for your patience as my project mentors. Thank you to Ms. Shavangi Prasad, my Hindi-English translator during my trips to the Mewat villages and to the 16 Mewat village women whom I interviewed. Thank you to Ms. Jane Schouske and Ms. Satoko Okamoto for your guidance, your friendship, and for the dinner table conversations that lasted well into the night. I am grateful to have found such strong female role models. Finally, thank you to everyone in the Institute of Rural Research and Development who made my stay in India such a memorable experience.

—An Introduction —

Personal Foreword

India. Some claim that the name of the country is derived from the Sanskrit word, *Sindhu*, meaning body of water, while others believe the name came from the Latin root, *Indus*, meaning big river. Sprung from the fertile river valleys of the twin Indus and Ganges, India is indeed a country based upon water. How appropriate it was to be welcomed to India in the rain, the beginning of monsoon season. From the subject of my research project, falling sick from the village water, to the changing tides of my life, water continued to be the theme of my two month stay in Gurgaon, Haryana, working at the Institute of Rural Research and Development.

My name is Alice Huang, and I am from Montville, New Jersey. Growing up in a suburban community in northern New Jersey, only an hour away from New York City, I never imagined that I would become involved in agriculture and world development. Until I was 16, the closest contact I had to agriculture was my last name—Huang. In Chinese, it means yellow for the Yellow River, the silt-rich riverbed of Chinese civilization and my agrarian ancestors centuries ago. Something of the distant past—that was all agriculture once meant to me. Although I had often read about global poverty and a world in distress, little did I realize the reality of the subsistence farmer and the concern of food security. It was the World Food Prize that opened my eyes to these issues, and from that point forward, the current of my life was altered.

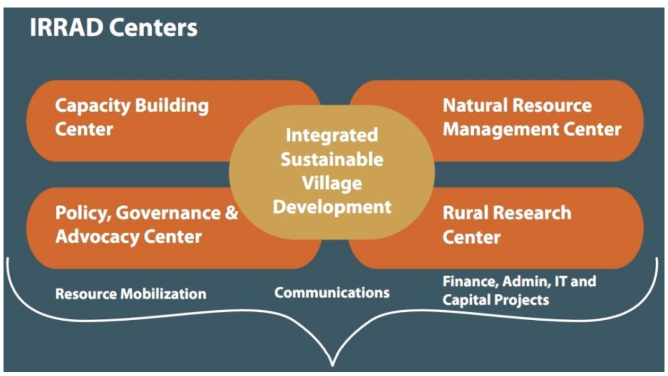
I attended the World Food Prize Global Youth Institute in 2009 and 2010, and it was within those two years that I became committed to the world of development. Today, I am an engineering major at Smith College, and it is my hope to someday help build the infrastructure that will provide subsistence farmers access to the resources they lack. I echo the many students before me when I say that the Global Youth Institute was a humbling experience in the perspective it gave me on global hunger and the potential solutions. Most importantly, through the conference, I became aware of the global community of humanitarians and scientists all trying to achieve the same goal of alleviating global hunger. It was that global community, the strong sense of cooperation, and the shared commitment that inspired me to apply for the Borlaug-Ruan International Internship for two consecutive years, and this past year, I was lucky enough to be selected.

I was going to India, the country that had been most positively affected by the Green Revolution yet still in every sense, a "developing" country. India is a country in movement, a country of such rapid development that buildings seem to sprout up overnight, and in every corner the juxtaposition of the rich and poor is placed vividly before you. It is a country of growing infrastructure with a flooding demand for roads, buildings, public transportation, bridges, and water structures. As a Civil Engineering major, I couldn't have asked for a better internship placement.

My research concentrated on the experimentation upon water structure technologies under IRRAD's Natural Resources Management Center, but over time, as my understanding of my research topic broadened, so did the project itself. Through my internship, I was not only given the opportunity to explore the various technological solutions, I was able to see first-hand, the technologies implemented in the villages and their implications on the grassroots level. The research I have conducted this past summer has undoubtedly provided me depth in perspective to both the problems and the solutions, and I hope to one day become an engineer like my project mentor who is famous in villages as "the water man"—the man who brought them water. Working in IRRAD, I not only found mentors, I found my role models and the real heroes of society. I am forever grateful for this experience that has instilled me with purpose and a deep moral responsibility for improving the world.

The Institute of Rural Research and Development (IRRAD)

Despite India's rising emergence in the global economy, today, nearly 70% of the Indian population still lives in villages, dependent on subsistence farming (Census of India, 2001). Although India's legislation promises a variety of welfare programs in the form of government schemes, there is a clear disconnect between the law and its implementation at the rural grassroots level, an area which suffers from severe poverty, lack of education, and rampant bureaucratic corruption. Established in 1999, the Institute of Rural Research and Development (IRRAD), an initiative of the S. M. Sehgal Foundation, is a nongovernmental organization that works towards empowering rural India—bridging disconnect between the Indian constitution's promised "life of dignity" and the grassroots reality. In order to address the multi-faceted aspects of rural poverty, IRRAD has developed the Integrated Sustainable Village Development (ISVD) model, focused in four areas: Capacity Building Center (CBC), Natural Resource Management (NRM), Policy, Governance & Advocacy (PGA), and Rural Research. The Capacity Building Center is concerned with raising awareness and providing life skills education, particularly to women and children; Natural Resource Management focuses on the improvement of water and agriculture as well as environmental conservation; Policy, Governance & Advocacy seeks to empower villagers with the knowledge to demand their government entitlements; finally, Rural Research conducts research studies in order to examine the context of the issues at hand as well as assess the impact of IRRAD's interventions (Institute of Rural Research and Development [IRRAD], 2008).



IRRAD's Integrated Sustainable Village Development (ISVD)
(photo source: IRRAD Annual Report 2009-10)

IRRAD's ISVD Flagship Programs
(photo source: IRRAD website)

Water Management Program

During my internship, I worked primarily under the Natural Resources Management Center and specifically, under the center's flagship Water Management Program. The Water Management Program seeks to improve the quantity and quality of water through the construction of various water infrastructures for the collection, preservation, and purification of freshwater in intervention villages. These structures include check dams, water harvesting systems, and recharge wells to collect and preserve surface freshwater; constructions also include soak pits that filter wastewater, hand pumps, and water tanks. In conjunction with its construction projects, the Water Management Program rejuvenates old wells and revives traditional ponds to allow villagers to exploit abandoned water infrastructure. In the past decade, close to 800 water structures have been constructed or revived by IRRAD's Water Management Program (IRRAD, 2010). For its work in water management, IRRAD has been named "Best Water NGO 2007-2008 in Water Harvesting," "Best Water NGO 2008-09 for Revival of Rural Water Resources," and "Distinguished Water NGO 'Revival of Rural Water Resources 2009-10'" by Water Digest and UNESCO (IRRAD, 2011).

Expert Profiles

In my time at IRRAD, I found a number of mentors who assisted me through the research process. Their expertise was invaluable to my work and my understanding of the issues at hand.

- ***Mr. Lalit Mohan Sharma***

  My direct project mentor was Mr. Sharma, *Group Leader of the Natural Resource Management Center*. Under his guidance, I developed my focus project of constructing a recharge well model. He also organized trips into the Mewat District villages where I was able to interview women on their water issues, establishing the context to my research. As my project mentor, he spent hours patiently answering my questions, editing my write-ups, and helping me expand the breadth of my research.

- ***Mr. Salahuddin Saiphy***
  Mr. Saiphy is the *Program Leader of the Water Management Program* under the Natural Resource Management Center. He provided me guidance in the experimentation with the recharge well model.
- ***Ms. Shavangi Prasad***
  Ms. Prasad is a *consultant to the Capacity Building Center.* She acted as my Hindi-English translator during my field visits to the Mewat villages.

The Mewat District

IRRAD's primary area of intervention is the Mewat District of Haryana state where the Integrated Sustainable Village Development (ISVD) model is implemented in 17 villages (IRRAD, 2011). The objective of these intervention villages is to serve as models for replication by other organizations.

Areas of Intervention *(photo source: IRRAD website)*

Socio-Economic Profile *—Statistics are based on IRRAD's 2009-10 census survey of intervention villages* (Mehta, Socio-Economic Profile of IRRAD's Intervention Villages, 2011).

Although Haryana is considered to be one of the most prosperous states in northern India, the Mewat District is a region marked by rural impoverishment. Currently, over three-fourths of Mewat's population of 1.2 million is employed in the agricultural sector that is characterized by subsistence farming; the per capita income of a Mewat household is ₹78699 INR ($790 USD)— merely one third of the national average. The low household income is only exacerbated by the poor state of education. Although the Indian constitution promises "the right to education" to all Indian children, 69% of Mewat children drop out of school before completing the fifth grade. This lack of education disproportionately affects women—65% of Mewat women are found to be illiterate in comparison to 30% of Mewat men.

In the decades following India's independence, the Mewat District has been bypassed by the Green Revolution and technological advancement experienced by the rest of the state. In fact, merely 30 kilometers away, the city of Gurgaon flourishes in industry, high-tech economic development, and infrastructure growth. Largely ignored by policymakers, Mewat lags behind other districts in nearly all developmental indicators.

The Mewat District and Water

Most of Mewat struggles to obtain freshwater on a daily basis. A semi-arid region with an average annual rainfall of 480 mm over 29 monsoon days, the Mewat District is scarce in water resources. Dependent on rainfall for the irrigation of crops, villagers are only assured one crop a year. In addition, Mewat's fresh groundwater aquifers are limited to the Aravalli foothills where the slopes are so steep, most rainwater never infiltrates the ground to recharge the few freshwater pockets. As a result, of Mewat's 503 villages, only 61 villages have fresh groundwater; the groundwater of the remaining villages is saline. As Mewat's population continues to skyrocket—the average family consisting of seven to eight family members—freshwater resources diminish, leaving aquifers increasingly susceptible to saltwater advancement. Saline groundwater has considerable implications, adversely affecting the health of the village people as well as agricultural productivity. For the past decade, IRRAD's Water Management Program has alleviated Mewat's freshwater shortage through (1) the construction of infrastructure that allows for mass recharging of fresh groundwater aquifers and (2) the construction of alternative fresh surface water resources within saline areas (Sharma, 2011).

Research Abstract - A Borlaug Approach to Science

In working with rural northern Indian farmers, one of the first and foremost concerns to be addressed is securing a freshwater source for agricultural and domestic purposes. In particular, within the Mewat District, saltwater encroaches on the rapidly diminishing fresh groundwater resources. The Institute of Rural Research and Development (IRRAD) is dedicated to providing the tools and expertise to empower impoverished rural Indian villages; one of the key components of IRRAD's Integrated Sustainable Village Development (ISVD) model is the Water Management Program that seeks to improve the quantity and quality of freshwater resources.

In this experiment, a model of a recharge well was constructed and experimented upon. A recharge well is an open catchment, designed to replenish a groundwater aquifer with rainwater, a source of freshwater. Due to the prevalence of saltwater advancement in the groundwater of Mewat District, the Water Management Program has created an innovation on the traditional recharge well design. The well's underground length will be extended to the groundwater aquifer's underlying layer of saltwater. In theory if this innovation is made, due to a number of scientific principles ranging from density and buoyancy force among other reasons enumerated below, a freshwater pocket will be formed separate from the saline water. This will provide villagers freshwater from a source that is contaminated by saltwater.

Therefore, the objectives accomplished in this experiment were (1) constructing a model that would accurately mimic the real conditions of a recharge well (2) measuring the model's recharge rate and (3) confirming the formation of the freshwater pocket given the stated innovation. Experimental objective #2 was determined by attaching a transparent pipe alongside the model to display the water table; experimental objective #3 was determined by measuring the well's discharge water for its total dissolved solids (TDS) content, indicative of salinity.

In the words of the late Dr. Norman Borlaug, "Take it to the farmer." Dr. Borlaug strongly believed in the human dimension of science. The purpose of science was to create the research and technology that would improve humanity; science was worthless if it stayed in the laboratory and did not benefit the people who needed it most. In the effort to understand the grassroots implementation of the technologies I was studying, in addition to my experimentation with a recharge well model, I completed a qualitative study, detailing the various water issues the village women of Mewat experience. For this background survey, the method involved making field visits to villages in the Mewat District and interviewing women in their homes with the assistance of a Hindi-English translator.

— Research —

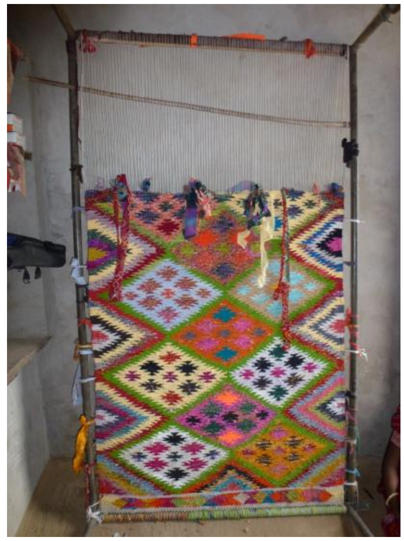
Background Field Survey of Water Situation in Villages

1.1 A Glimpse

In the village of Uletha, I met Vedvati, a beautiful young girl with chocolate skin, smooth dark hair, and gleaming white teeth. The centerpiece of her one-room house was an enormous blanket she had been weaving from scraps of old clothing, a testament to her artistic mastery. Although only 22, four years older than myself, Vedvati already had three children and the responsibility of a household.

While Vedvati's family has a household connection to the government water supply, the water supply is erratic and unpredictable—many times, water is only available in the late hours of the night; other times, there is no water at all for days at a stretch. Vedvati lives in constant fear of water shortage, and she sleeps little at night, waiting for water from the connection. This situation is further exacerbated by the saline nature of the village's groundwater. Although there are a number of common wells throughout the village, most are useless due to the advancement of saltwater. As a result, Vedvati spends her days traveling to neighboring villages to collect freshwater for her family's domestic needs. The trip to the neighboring village takes an hour on foot, and when she finally reaches her destination, she is taunted and bullied by the local villagers who don't want to share their water. She must then carry the heavy container of water back home—another hour. She'll repeat this trip three to four times in a day.

Vedvati's story is hardly an isolated case, and throughout my field visits I would continue to hear stories of hardship experienced by women due to the scarcity of freshwater. The objective of my field visits was to create a background field survey of the water situation in the Mewat District villages to understand the context of IRRAD's Water Management Program. In practicing sustainable engineering, understanding of the local needs, culture, and community is as important as the underlying engineering technology. Without consideration for the people for whom the structures are constructed for, it is impossible for engineering interventions to be successfully implemented in the field. Therefore, this background field survey became an integral portion of my research.



Vedvati from the village of Uletha is one of millions of women in rural India who struggle to obtain freshwater everyday. When she is not collecting water, Vedvati weaves blankets (picture on the right) for her family.

1.2 Methodology

To complete this background field survey, between July 8th and August 5th, I traveled to four separate villages in the Mewat District—Karheda, Uletha, Santhawadi, and Nautaki—where I interviewed four women from each village regarding their household water issues. My objective was to understand the problems relating to water and the coping mechanisms of villagers on a household level, particularly in areas where freshwater is scarce. I was assisted by Ms. Shavangi Prasad who acted as my Hindi-English translator.

My study was limited to IRRAD intervention villages in the Mewat District, and as women assume the responsibility of domestic chores relating to water, women were selected as the interviewee subjects. In a few instances, the woman's husband was present and would add his input. Due to the constraints of time of a two month internship, standard statistical procedures were not applied in formulating questions and selecting survey samples. The women interviewed were selected based on their availability during the time of my field visit. Therefore, the data presented is only meant to provide a qualitative overview of the situation in Mewat as opposed to a statistical representation.

Household interviews were conducted in order to hear each woman's personal perspective on water and allow her to speak freely. Although my background survey initially consisted of women from the saline water villages, Karheda and Uletha, as I entered each household, it became increasingly clear that saline groundwater had greater impacts on the lives of the village people than I could have ever anticipated. From my research and background readings in IRRAD's Gurgaon office, I expected to walk into the villages and hear success stories of IRRAD's water interventions. The reality was unsettling. I heard numerous accounts of hardship as the women described the efforts, time, and money spent in order to obtain freshwater for their households. IRRAD had helped in many ways the women all said, but at the end of the day, the groundwater was still saline. In order to fully understand the implications of saltwater advancement, I visited and interviewed women in an additional two villages as a basis for comparison—one village with fresh groundwater, Nautaki, as well as a village where groundwater was partially fresh and partially saline because of saltwater advancement, Santhawadi.

Following my field visits, I typed up the interviews and searched for common themes in the women's responses. The following survey is a synthesis of my analyses, supplemented by secondary data provided by the Rural Research Center.

1.3 Primary Source of Income *(# of households/total households interviewed within village)*

Villages	Agriculture	Non-agricultural
Saline Water Villages		
Karheda	3 / 4	1 / 4
Uletha	3 / 4	1 / 4
Partial Freshwater Villages		
Santhawadi	3 / 4	1 / 4
Freshwater Villages		
Nautaki	3 / 4	1 / 4

Subsistence agriculture was consistently the predominant occupation in the villages. In all four villages, of the interviewed households, 75% cited agriculture as their primary source of income. Although statistical randomization was not used in the selection of the sample, these percentages closely match the 78% reported by IRRAD's 2009-10 census survey of the population engaged in agriculture within the IRRAD intervention villages—an indication that the interview sample was fairly representative of the entire population (Mehta, Socio-Economic Profile of IRRAD's Intervention Villages, 2011). Of the 75% who stated agriculture as their primary source of income, 25% did not own their own fields and labored on other farmers' lands. Non-agricultural occupations included a teacher in a public school, an uncertified doctor, a government employee, and a driver.

1.4 Household Water Utilities Available* *(# of households/total households interviewed within village)*

Villages	Government Pump	Rainwater Harvester	Water Tank	Recharge Well	Bore Well
Saline Water Villages					
Karheda	4 / 4	1 / 4	2 / 4	0 / 4	0 / 4
Uletha	4 / 4	1 / 4	2 / 4	1 / 4	0 / 4
Partial Freshwater Villages					
Santhawadi	4 / 4	0 / 4	0 / 4	0 / 4	4 / 4
Freshwater Villages					
Nautaki	3 / 4	0 / 4	0 / 4	0 / 4	4 / 4

*Some households owned multiple water utilities.

There were a number of household water utilities available in the villages:

1. **Government Pumps**
   The Indian government provides connections to freshwater through common pumps that are shared between 8 to 10 families as well as household pumps. With the exception of one household in Nautaki, in every household visited household pumps were available (93.75%). Despite the connection to freshwater, every household with a household pump interviewed stated the irregularity of the water supply from these connections.
2. **Rainwater Harvesting Systems (IRRAD Water Management Program intervention)**
   Rainwater harvesting systems collect and store rainwater. To reduce the likelihood of contamination, water is directed from the rooftop to filtering tanks. IRRAD builds rainwater harvesting systems for public facilities, but for families interested in a household rainwater harvesting system, IRRAD asks the family for a fee of 500 rupees ($11 USD) and the labor for the project. In return, IRRAD supplies the raw materials and expertise for the construction. In the saline water villages, one in four families interviewed in Karheda (25%) and one in four families interviewed in Uletha (25%) have constructed a household rainwater harvesting system. These structures were not present in the interviewed freshwater village households.
3. **Recharge Wells (IRRAD Water Management Program intervention)**
   A recharge well is a catchment designed to replenish, or "recharge," a groundwater aquifer with rainwater. Recharge wells are effective even in villages where groundwater is saline. Like rainwater harvesting systems, the catchment area is limited to the roof where contamination is less likely to occur; additionally, the water is processed through a filtration pit before it is directed to the aquifer. Despite this, the risk of contamination in recharge wells is greater than rainwater harvesting systems. While rain harvesting structures directly connect rainwater to a storage device,

recharge wells direct rainwater to an underground aquifer, a less contained environment that is subject to surrounding ground contamination.

IRRAD constructs common recharge wells for the entire village, but IRRAD also provides the support for the construction of household recharge wells. As with the rainwater harvesting systems, IRRAD asks the family for a fee of 500 rupees ($11 USD) and the labor for the project in exchange for the raw materials and expertise. In the saline water villages, none of the families interviewed in Karheda (0%) and one of the four families interviewed in Uletha (25%) have constructed a household recharge well. These structures were not present in the interviewed freshwater village households.

4. **Water Tanks (IRRAD Water Management Program intervention)**
   Some families have water tanks constructed for the storage of purchased water. Water tanks are a considerable investment—costing 15,000 rupees ($337 USD) for construction and 350 rupees ($8 USD) to fill the tank each time. The water purchased comes from villages with fresh groundwater. Despite the impressive cost—nearly one half of the average per capita income in Mewat—in the saline water villages, two of the four families interviewed in Karheda (50%) and three of the four families interviewed in Uletha (75%) have constructed a water tank in response to the extreme scarcity of freshwater. Of the five families that owned water tanks, three of the families stated that they filled the tank once a month. One family filled their tank three times a month which they attributed to their large family size. Another family owned a household recharge well and rainwater harvesting system and only purchased water in the months water was not available from these sources. IRRAD also assists in the construction of these tanks.
5. **Submersible Bore Wells**
   Bore wells are pipes inserted into the ground and used with an electric pump to withdraw water. Because bore wells are dependent on electricity that is in short supply, water from this source is limited as well. Bore wells are primarily used to irrigate fields, and while not a household utility, they were included in this category because most of them were privately owned. In addition, all the women interviewed in the freshwater villages, Santhawadi and Nautaki, cited using bore well water for domestic purposes when the government water supply was not available.

Government Pump

Rainwater Harvesting System

Water Tank

Due to the irregular water supply from government connections, many villagers invested in additional water utilities. Despite the high cost, water tanks were the most popular alternative water utility in the saline villages. Although IRRAD offers the construction of household recharge wells and rainwater harvesting systems at a nominal fee—500 rupees in comparison to 15,000 rupees to construct a water tank—these water infrastructures are dependent on rainwater that comes only one month of the year. Ultimately, villagers prefer tanks because the storage of rainwater can last six to eight months but not the entire year due to Mewat's semi-arid climate. In addition, some homes are not supportive of recharge wells and rainwater harvesting systems because water directed from the roof will be insufficient if the roof's surface area is too small. Meanwhile, in the freshwater villages, bore wells were the more favorable alternative because of the availability of fresh groundwater.

1.5 Functioning Common Water Utilities

Villages	*Check Dams*	*Ponds*	*Rainwater Harvesters*	*Recharge Wells*	*Soak Pits*	*Water Tank*
Saline Water Villages						
Karheda	—	✓	✓	✓	✓	—
Uletha	—	✓	✓	✓	✓	—
Partial Freshwater Villages						
Santhawadi	✓	✓	✓	—	✓	✓
Freshwater Villages						
Nautaki	✓	✓	✓	—	✓	—

Key: (✓) indicates presence of functioning water structure, (—) indicates structure is not present

Due to the irregular water supply from government connections, the villages had a number of water utilities for each village's use:

1. **Check Dams (IRRAD Water Management Program intervention)**
   IRRAD constructs check dams that trap rainwater at the Aravalli foothills, forcing rainwater to infiltrate the ground and recharge nearby aquifers.
2. **Ponds**
   Ponds provide villagers with a source of water for domestic purposes. IRRAD expands ponds in village to store surface rainwater and increase recharge of aquifers.
3. **Rainwater Harvesting Structures (IRRAD Water Management Program intervention)**
   IRRAD constructs rainwater harvesters in schools and public facilities for drinking and domestic purposes.
4. **Recharge Wells (IRRAD Water Management Program intervention)**
   IRRAD constructs recharge wells for domestic purposes, but not drinking due to risk of contamination. This structure is especially useful in saline water villages because it allows the collection of fresh surface water in aquifers which are saline.
5. **Soak Pits (IRRAD Water Management Program intervention)**
   A soak pit is a covered underground chamber that filters wastewater of its impurities, so the discharge water is safe to infiltrate the surrounding soil. In intervention villages, IRRAD constructs household pipes that connect to soak pits as a means of sanitation management.
6. **Water Tanks (IRRAD Water Management Program intervention)**
   IRRAD constructs community water tanks for drinking water and domestic purposes.


Common Recharge Well in Karheda Village
There are a total of 52 common wells in Karheda, but most of them are saline.

1.6 Explanations for Why the Government Water Supply is Irregular**

(# of households/total households interviewed within village with household government pump)

Villages	Government Neglect	Electrical Supply	Intra-village disputes	Poor Maintenance
Saline Water Villages				
Karheda	3 / 4	2 / 4	1 / 4	0 / 4
Uletha	2 / 4	2 / 4	0 / 4	0 / 4
Partial Freshwater Villages				
Santhawadi	1 / 4	4 / 4	0 / 4	4 / 4
Freshwater Villages				
Nautaki	0 / 3	2 / 3	0 / 3	2 / 3

*Most households provided multiple explanations.

**One household in Nautaki provided no explanation.

Every household interviewed that owned a household government pump cited the irregularity of water supply from the government connections. The most cited explanations in the saline water villages were government neglect (62.5%), followed by electricity supply (50%); in Karheda, there was one household explanation of intra-village disputes. In comparison, in the freshwater villages, the most cited explanations were poor maintenance (85.7%) and electricity supply (85.7%); there was one household complaint of government neglect in Santhawadi. Ultimately, one realizes the issues of government neglect, poor maintenance, and faulty distribution system are interconnected, and the differences in explanation are only a reflection of perspective and circumstance. The majority of women interviewed in the saline villages expressed particular resentment towards the government, a blame that reflected the helplessness and anger over the extreme water shortage. This was an attitude that was not present in the more water-secure freshwater villages where the villagers mainly blamed technical malfunction for the irregularity of the water supply.

1. ***Government Neglect***
   Government functionaries and, in particular, the Panchayat—the elected leader of the village—lack incentives and the capabilities to maintain the water supply systems. In addition, limited mechanisms exist for citizens to hold government officials accountable.

"Most of us are illiterate; we don't know what to do and where to ask when water isn't available. Because people are unaware, they don't know how to make an effort to improve their situation. The government won't listen to an individual, but if we approach them as a group, they will pay attention to us. We need to mobilize as a community. The government will never know there's a problem if we never come to them. "

— Laxmi, Karheda Village

2. ***Electrical Supply***
   Water supply from the government pumps is dependent on electricity which is distributed between rural and urban regions. Due to industry, the electricity demands of cities outweigh rural demands during the day, and electricity is relegated to villages only at night when the demand of industry is less. Water supply from the connections is only readily available during crop seasons.

"Water is the most problematic concern in the village. The water supply from the government pumps is always irregular because of the electricity, and often water is only available at night. We'll stay up late at night to wait for the water."

— Rekha, Uletha Village

3. ***Intra-Village Disputes***
   When a new connection is established, there are differences in a opinion over how water should be distributed.

"Our village has two main chambers of freshwater that the pumps draw water from. There has been a new freshwater pipeline directed to our village but there are arguments amongst the village over which of the two chambers the pipeline should direct into, so although more water is available, the operation is currently at a standstill."

— Abdul and Hussnini Rehman, Karheda Village

4. ***Poor Maintenance***
   The rural distribution network is characterized by leaky, poorly maintained pipes and motor break-downs, resulting in the reduction of water supply. In addition, villages lack spare parts, tools, and mechanical expertise.

"Water may only come for three days in a week—and even then the water may not be clean. Maintenance of the water supply is inadequate. The electricity motor frequently breaks down, and someone may not come to fix it until ten to fifteen days later."

— Parmeena, Santhawadi Village

Although not cited by the interview subjects, there are number of additional factors affecting the water supply:

5. ***Limited Resources***
   In the Mewat District, fresh groundwater pockets are limited to villages at the foothills of Aravalli Valleys. Even when electricity is available, the amount of water may not be sufficient to travel through connections.
6. ***Illegal Pipelines***
   Some farmers will purchase land in freshwater zones and install bore wells that steal water from a pipeline delivering freshwater to a village. Often times, this water is sold to villagers through tankers. Although these waters are intended for domestic purposes, the water from this black market source is often misused as irrigation water. In addition, punctures created by these illegal connections weaken the water pressure, reducing the water supply to the villages.
7. ***Over-Exploitation & Saltwater Advancement***
   As freshwater resources are depleted by Mewat's growing population, advancement of saltwater into freshwater pockets is more likely to occur, rendering aquifers ineffective. When freshwater is withdrawn faster than it can be replenished, the pressure of the freshwater column in the aquifer decreases; the resulting hydrostatic pressure difference between the freshwater aquifer and surrounding saltwater causes the saltwater to enter the aquifer.
8. ***Awareness of Water Conservation***
   Awareness of water conservation is low among the Mewat community due to lack of education. IRRAD's Water Management Program promotes water literacy through training sessions and an annual Jal Chentna Yatra, a three day water awareness march that covers over 60 villages in Mewat. Although water conservation is a topic in the secondary school syllabus, most children in Mewat drop out of school before graduating primary school. In order to address this issue, the Water Management Program is beginning a new initiative to bring water conservation education into the primary school syllabus.

1.7 How Households Respond to Lack of Drinking Water *(# of households/total households interviewed within village)*

Villages	Borrow from a neighbor	Travel to neighboring village	Purchase tanker water
Saline Water Villages			
Karheda	2 / 4	4 / 4	2 / 4
Uletha	2 / 4	4 / 4	2 / 4
Partial Freshwater Villages			
Santhawadi	1 / 4	2 / 4	4 / 4
Freshwater Villages			
Nautaki	1 / 4	0 / 4	0 / 4

*Some households provided more than one answer.
**Three households in Nautaki did not find the question applicable.

Every household interviewed in the saline villages cited traveling to neighboring villages for drinking (100%). Half of the households interviewed in Karheda and Uletha stated that after the construction of a household water tank, they did not have to travel to other villages anymore and borrowed water from a neighbor when drinking water was not available (50%). For households that cannot afford the cost of additional water utilities, it is necessary to travel to other villages for water.

In Santhawadi, a partial freshwater village, half the households interviewed stated that they still needed to travel to other villages for water because of the gradual saltwater advancement in their fresh groundwater (50%). All the households interviewed stated that the purchase of tanker water was necessary to respond to lack of drinking water. Tankers are purchased for 350 rupees ($8 USD) by giving a call to the company that then delivers the water to their homes. This is the same system saline water villages use to purchase water for household water tanks. Because water scarcity is not as dire in Santhawadi, none of the households visited had invested in a household water tank.

In Nautaki, a freshwater village, none of the households interviewed stated the need to travel to other villages or purchase tankers for drinking water. In fact, one of the women told us that the village discouraged traveling to other villages to collect water. This regular access to freshwater is in part due to check dams in the village, an IRRAD intervention, that provide the mass recharging of aquifers.

Because the fetching of drinking water is a chore designated to women, the scarcity of water is directly related to the issue of women's drudgery. According to data obtained from the Rural Research Center, in 2010, the total average time expended on fetching drinking water in the saline intervention villages was 949 hours, an average of 156 minutes a day. In comparison, the total average time spent on fetching water in freshwater intervention villages was 432 hours, an average of 71 minutes a day—less than half the time spent by the women in saline villages.

"The biggest problem relating to water is the scarcity of freshwater. My mother travels to Ghaghas nearly every day to collect water. Each trip takes one hour to get there, one hour to return, and she'll make four visits in a day. I go with my mother to help collect water in the evenings after I'm finished with school. We have not fallen sick from drinking the water from these sources so far, although we have skin problems when we use the village's saline groundwater." — Jyoti, Karheda Village

1.8 Irrigation of Crops* *(# of households/total households interviewed with agriculture as the primary source of income)*

Villages	Rainfall	Purchase Water	Bore Wells
Saline Water Villages			
Karheda	3 / 3	1 / 3	0 / 4
Uletha	3 / 3	0 / 3	0 / 4
Partial Freshwater Villages			
Santhawadi	3 / 3	1 / 3	3 / 3
Freshwater Villages	-	-	
Nautaki	3 / 3	0 / 3	3 / 3

*Some households provided more than one response.

In the saline water villages, of the six households interviewed with agriculture as the primary source of income, five households stated that they relied solely on rainfall for irrigation (83.3%); one household from Karheda stated they purchased water from illegal connections to irrigate their crops. To irrigate the crop once from an illegal connection costs about 1000 rupees, and the household will irrigate the crop four to five times a season. This is an instance where bias may have occurred. It is possible that other households also purchased water from the black water market, but did not disclose this information during the interview. In the freshwater villages, all households interviewed with agriculture as the primary source of income stated that, in addition to rainfall, they pumped water from bore wells irrigate their crops.

" We are completely dependent on the rains for our crops which are very erratic. Those who can afford it buy illegal pipeline connections that steal water from neighboring villages. The lack of water is an enormous hindrance to our agriculture. Our livestock eat dry fodder, and we don't have enough water to grow bajra and vegetables—only less water-intensive crops such as wheat." — Laxmi, Karheda Village

1.9 Perception of Health Issues Related to Water**

Villages	*Poor Personal Hygiene*	*Skin Irritation & Rashes*	*Diarrhea*	*Eye Allergies*	*Fever*
Saline Water Villages					
Karheda	1 / 4	4 / 4	1 / 4	0 / 4	0 / 4
Uletha	0 / 4	3 / 4	2 / 4	1 / 4	0 / 4
Partial Freshwater Villages					
Santhawadi	0 / 4	2 / 4	2 / 4	1 / 4	2 / 4
Freshwater Villages					
Nautaki	0 / 4	0 / 4	1 / 4	0 / 4	0 / 4

*Some households provided more than one response.
**Three households in Nautaki stated that there were no health issues related to water.

The majority of perceived health issues related to water—diarrhea, eye allergies, fever—were mainly due to biological contaminants such as viruses and bacteria. Otherwise, skin irritation and rashes were due to washing with saline water, and as could be expected, this was a health issue primarily cited by the saline water village households. In addition, this was health problem cited by half the interviewed households in the partial freshwater village (50%). Lastly, poor personal hygiene can be attributed to the scarcity of freshwater.

Scarcity of freshwater is also directly related to other health problems. In the village of Uletha, we were told that a diarrhea epidemic occurred in the village a month ago because villagers had resorted to drinking water from the village's common recharge wells. Although not cited in the interviews, more severe water-related diseases such as malaria, typhoid, cholera, and gastroenteritis are also an issue. In fact, in some regions of Mewat, the incidence of malaria is high as 8% at any given time (Mehta, Harnessing Natural Resources and Optimizing Water Usage: An Assessment, 2011).

"There are skin problems associated with using the village's saline groundwater, and although I've never experienced this, I've heard that even if you wear clothes washed in the saline water, you will develop rashes and itching."
— Gulshin, Karheda Village

1.10 Perception of How IRRAD has Helped in the Area of Water Management*

Villages	Household Infrastructure	Village Infrastructure	Awareness	No Help
Saline Water Villages				
Karheda	4 / 4	4 / 4	1 / 4	N / A
Uletha	2 / 4	3 / 4	3 / 4	N / A
Partial Freshwater Villages				
Santhawadi	0 / 4	1 / 4	3 / 4	1 / 4
Freshwater Villages				
Nautaki	0 / 4	3 / 4	3 / 4	N / A

*Most households provided more than one response.

In the saline water villages, a significant number of households interviewed perceived that IRRAD had intervened in the areas of household infrastructure (75%) and village infrastructure (87.5%) as well as raising awareness (50%). In comparison, in Santhawadi, the partial freshwater village, the households interviewed cited awareness (75%) as IRRAD's main contribution in regards to water management. Likewise, in Nautaki, the freshwater village, awareness was perceived to be a key contribution in water management (75%). Village infrastructure was also cited as a major contribution in Nautaki (75%). These varied perceptions are a reflection of IRRAD's localized target approach in water management. In the saline villages where freshwater is especially scarce, IRRAD concentrates on the construction of household utilities and water infrastructure in the village. Meanwhile, in villages where freshwater is available, IRRAD focuses more on the improvement of water literacy and water conservation.

Engineering Solutions: Experimentation on a Recharge Well Model

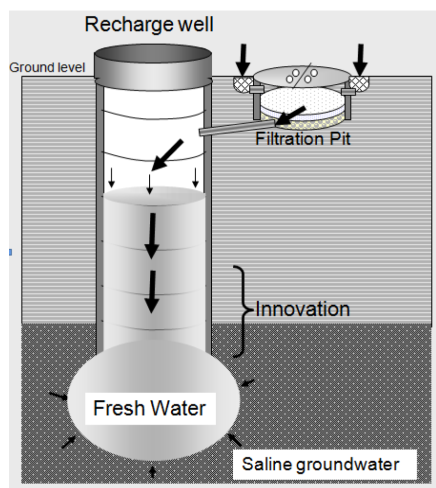
2.1 The Underlying Scientific Principles of a Recharge Well

As established by the background field survey, the issue of saltwater advancement in groundwater is one of dire concern. Not only does the saltwater advancement adversely affect the daily health and quality of life of the Mewat village people, saltwater inhibits agricultural productivity which threatens food security in the long term. One of the solutions is recharge wells.

Objective: Access to freshwater from wells despite the advancement of saltwater in groundwater

The Innovation: The well's underground length is extended to the groundwater aquifer's underlying layer of saltwater. In theory, if this innovation is made, a freshwater pocket will be formed due to:

1. **Density -** Freshwater is less dense so it will float above saline water.
2. **Overburden Pressure -** The pressure of the imposing layers of freshwater pushes the saline water down to form a surrounding freshwater pocket.
3. **Laminar Flow -** The flow of the rainwater percolating through the well is laminar, meaning the flow is streamlined with little turbulence and stirring. This prevents the mixing of the fresh and salt water.
4. **Buoyant Force -** Buoyancy is the force that is exerted by a liquid (saltwater) in opposition to the weight or gravitational force of an object (the freshwater pocket). This also prevents the fresh and salt water from mixing, keeping the freshwater pocket intact.
5. **Porosity/Void Ratio -** Low porosity (space between soil particles) and low void ratio (ratio of the volume of voids to volume of solids) limit the diffusion of fresh and salt water.



Recharge Well Innovation
(photo source: Lalit Sharma)

As a result of this recharge well, freshwater can be stored and withdrawn from a saline aquifer in a cost-effective manner. In an effort to contribute to the understanding of how a recharge well functions and how its design may be further improved, in this experiment, the objectives were (1) construct a model that will accurately mimic the conditions of a recharge well, (2) measure the model's rate of recharge, and (3) confirm the formation of the freshwater pocket given the stated innovation.

2.2 Building the Recharge Well Model

Objective (1): Construct a model that will accurately mimic the conditions of a recharge well.

Because there was no precedent to this experiment, building a functional model was a continual trial and error process. In six weeks, we constructed three separate models before producing a satisfactory prototype that could be used for experimentation.

2.2.1 Securing the Necessary Materials

There were several elements essential to the model:

- To represent *an appropriate environment*, we acquired a tank 1 m by 1.5 m which we calculated to be sufficiently large for a freshwater pocket to form in relation to the size of the recharge well pipe (experiment objective #3). Bricks were lined underneath the tank to prevent the model from sinking into the ground once loaded.
- To represent *the soil* in an aquifer system, we obtained gravel and sand from the neighboring construction site.
- To represent *the water* in a saline village aquifer, we collected saltwater from the saline wells during my field visits to the saline water villages.
- To represent *the recharge well* itself, we used a PVC pipe with a diameter of 85 mm; holes were drilled along the last ten inches to allow for the formation of a freshwater pocket (experiment objective #3).

In addition, a number of elements were required for the planned experimentation of the model:

- In order to add an underlying layer of saline water into the aquifer system, a PVC pipe with a diameter of 25 mm was inserted in the system. It was important that this pipe was smaller so the water pressure to the main recharge well pipe was not disturbed.
- A steel frame, 1 m by 1.75 m was placed next to the tank, and a container of saline water was put on top of the structure. Afterwards, a siphon was attached from the container to the 25 mm diameter pipe. Gravitational force due to the taller height of the steel frame in relation to the tank and the air pressure pushing down on the liquid in the container (like how air pressure pushes down on mercury in a barometer) forces the saline water through the siphon without application of external forces.
- In order to measure rate of recharge (experiment objective #2), an adjoining transparent tube was attached to observe the water table in the tank.

2.2.2 First Attempt (July 1 - July 15)

Methodology:

1. A transparent tube was attached in connection to the tank as a water table indicator.
2. Using a crane from the neighboring construction site, the tank was first filled with a layer of gravel.
3. The remainder of tank was filled with buckets of sand lifted by the crane. With each layer of sand poured into the tank, construction workers climbed into the tank and stomped on the sand with their feet to compact the soil. Compaction in the soil is important to equalize the porosity, or empty spaces in the soil, so that the flow of water is consistent throughout the soil.
4. Afterwards, the two PVC pipes were inserted in the model. The 85 mm diameter pipe that represented the recharge well was inserted halfway into the soil at the center of the tank. The 25 mm diameter pipe to be used for the addition of saline water was inserted to the bottom at the side of the tank.
5. Once in place, about 70 liters of saline water was poured into the 25 mm diameter pipe through a siphon. A day was reserved to wait for the water table to settle evenly throughout the tank.
6. The next day we tested if the water table was level in the tank by inserting an open electric circuit into the PVC pipes. An open electric circuit lacks a complete path between its positive and negative terminals. Due to the ions in the saline water, once the electric circuit touches the saline water, its circuit path is completed and the adjoining conductivity meter signals a beep. Therefore, if the water table is level in the water tank, the circuit should be completed at the same depth in the 25 mm diameter pipe as the 85 mm diameter pipe.

With the help of a crane and some construction workers, sand is poured into the tank.

I pose for a picture, pointing to the tank's water table.

Result: The problem with our first attempt model arose in the final step. The open electric circuit was not completed at the same depth in the two pipes—the water table was not level in the tank. Even as water was withdrawn or added, the water in the smaller pipe was consistently higher than the center pipe. We hypothesized that this problem occurred because the compaction of the soil was not sufficient and the flow of water was not consistent in the tank. In addition, the water table indicator frequently fluctuated without the addition or withdrawal of water. We hypothesized that this problem occurred because of the accumulation of water along the sides of the tank.

2.2.3 Second Attempt (July 15 - August 2)

Methodology: The same methodology was applied in the second attempt with a few modifications. In consideration of the time constraints, the second model was constructed in a smaller tank 90 cm tall and 55 cm in circumference. To address the hypothesized issue of inadequate compaction, a damper device was used to compact the soil. To replace the inaccurate water table indicator, a smaller transparent tube was installed next to the section of recharge well pipe that was above-ground. The water table indicator connection to the above-ground portion of the pipe was important so the indicator would not read the accumulation of water at the sides of the tank. Although an overall water level indicator for the entire tank would be ideal, for our experimentation we only needed an indicator for the measurement of the well's rate of recharge (experiment objective #2).

Result: The water table in the two pipes was still not matching. We hypothesized that again this was due to improper compaction of the soil. Because it was monsoon season, the sand was wet on the day it was put into the tank. During compaction, the sand particles may have been weathered by the water, breaking into smaller pieces. When these smaller pieces are compacted the result is reduced porosity and reduced free flow of water in the tank.

2.2.4 Third Attempt (August 2 - August 12)

Methodology: The same methodology in the second attempt was applied in the third attempt. On this third attempt, we made certain the sand was dry and compacted by a damper.

Result: The water table in the two pipes were at the same level. We monitored this the water levels throughout the day, and the levels did not fluctuate. We determined a water table had been established, and the model to be ready for experimentation.

The tank used for the second and third attempt

2.3 The Recharge Well's Recharge Rate

Objective (2): Measure the model's rate of recharge.

Hypothesis: A well's rate of recharge is the volume of water that infiltrates the ground per unit of time. This is significant to know because if the model is functioning properly, the well's rate of recharge should decrease as time progresses. As the aquifer becomes saturated with water, porosity is reduced, and it should take more time for water to infiltrate the ground. Therefore, measuring the model's rate of recharge is a key aspect in determining if the model accurately mimics the real conditions of a recharge well (experiment objective #1).

Methodology: First, three liters of freshwater representative of rainwater were poured into the recharge well pipe. Every five to eight minute interval, I recorded the water level by drawing marks on the recharge well pipe until water was not visible in the water table indicator.

The entire recording lasted for three and half hours into the night, and as it became dark, the likelihood for an error to occur in measurement increased. In the following tables, the small time intervals were combined and averaged together to curtail error in measurement and prevent a misrepresentation of the data.

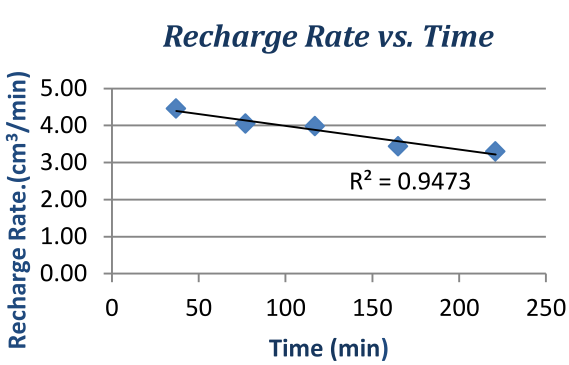
The water table indicator

2.3.1 Recharge Rate and Time

Time (min)	Water Level (cm)	Volume of Recharge (cm^3)	Time Interval (min)	Rate of Recharge (cm^3/min)
0	10.00	N/A	N/A	N/A
37	12.90	164.63	37	4.45
77	15.75	161.79	40	4.04
117	18.55	158.95	40	3.97
165	21.45	164.63	48	3.43
221	24.70	184.50	56	3.29

Table Columns Explained:

- Water Level (cm) - This was the height difference between the top of the recharge well pipe and the aboveground water height as displayed by the water table indicator tube.
- Volume of Recharge (cm^3) - This was the amount of water that had infiltrated the ground within a certain time period. It was calculated using the formula for the volume of a cylinder, $\pi r^2 h$. We derived radius (r) from the pipe's diameter of 85 mm; the height (h) was calculated by subtracting the previous water level from the current water level. [Formula: π x $(85/2)^2$ x (water level - previous water level)]
- Time Interval (min) - This was calculated by subtracting the previous time from the current time.
- Rate of Recharge (cm^3/min) - This is the rate at which water infiltrates the ground. It was calculated by dividing the volume of recharge by the corresponding time interval.



Result: As demonstrated by the downward slope of the plotted data, as time progresses, the rate of recharge decreases. In addition, the correlation between the two variables is strong as demonstrated by the high linear regression R^2 value of 0.9473. The results support the initial hypothesis and further validate the model's accuracy in imitating the conditions of a recharge well.

2.3.2 Recharge Rate and Hydraulic Head

One of the fundamental formulas in the study of hydrogeology is **Darcy's Law [Q = KIA]** which characterizes groundwater movement by relating the fluid's discharge through a porous medium to change in pressure. If the model is an accurate portrayal of the conditions of a recharge well, the data and measurements obtained from the model—in particular, the rate of recharge should follow this formula. The breakdown of Darcy's Law is as follows:

1. **Q** is the total discharge, the volume of water flowing through an aquifer per unit of time. [Note that total discharge represents recharge rate in this experiment.]
2. **K** is hydraulic conductivity or permeability, the ability of a particular material to allow water to pass through it.
3. **I (dh/dl)** is hydraulic gradient—hydraulic head (dh) or height of the water table divided by the length of the water column (dl). This can be thought of as the slope of the water table.
4. **A** is the water's area of flow.

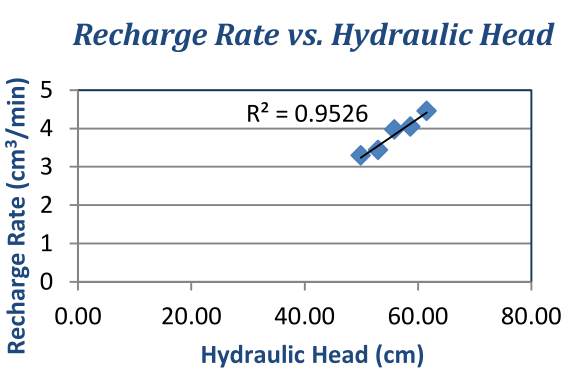
<u>*Hypothesis:*</u> Although it is important to understand the entire system, for our purposes we concentrated on the variables Q and I, total discharge and hydraulic gradient. According to the Darcy's Law relationship, hydraulic gradient and discharge, or in our case recharge rate, are directly proportional—as hydraulic head increases so should rate of recharge. From the measurements of the water levels, we were able to calculate the hydraulic head (dh), a component of hydraulic gradient. The relationship of direct proportionality with rate of recharge continues to hold, and therefore, if hydraulic head increases, the corresponding rate of recharge should increase as well.

Water Table and Hydraulic Head

Time (min)	*Datum (cm)*	*Water Level (cm)*	*Water Table (cm)*	*Hydraulic Head (cm)*
0	73	10.00	63.00	N/A
37	73	12.90	60.10	61.55
77	73	15.75	57.25	58.68
117	73	18.55	54.45	55.85
165	73	21.45	51.55	53.00
221	73	24.70	48.30	49.93

Table Columns Explained:

- <u>*Datum (cm)*</u> - A datum is a reference point from which measurements are made. The length of the recharge well pipe was our datum.
- <u>*Water Level (cm)*</u> - This was the height difference between the top of the recharge well pipe and the above-ground water level as displayed by the water table indicator tube.
- <u>*Water Table (cm)*</u> - The water table is the height of the water's position in the tank in relation to the designated datum. It was calculated by subtracting the water level from the datum.
- <u>*Hydraulic Head (cm)*</u> - In reality, the hydraulic head (the height of the water column) is the same as the water table. The hydraulic head represented in this table is an average the previous and current water table. This was done to reduce error that may have occurred during measurement and to create values to correspond to the recharge rate calculations.



<u>*Result:*</u> The plotted data indicates a directly proportional relationship between hydraulic head and recharge rate; as hydraulic head increases, recharge rate increases. In addition, the correlation between the two variables is strong as demonstrated by the high linear regression R^2 value of 0.9526. The results follow Darcy's Law and further validate the model's accuracy in imitating the conditions of a recharge well.

2.4 Confirming the Theory - Formation of a Freshwater Pocket

Objective (3): Confirm the formation of the freshwater pocket given the stated innovation.

Hypothesis: If a freshwater pocket is formed in the recharge well prototype, as depth increases, the water gradually becomes more saline.

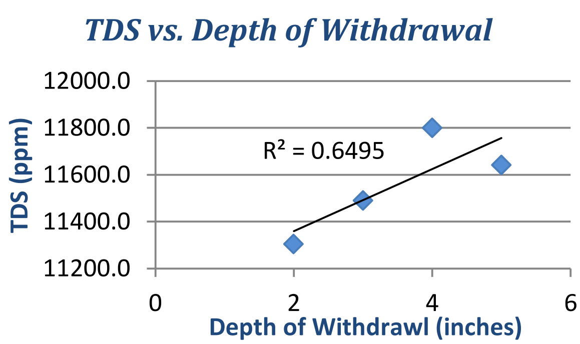
Methodology: A siphon was inserted into the recharge well pipe at different depths, and samples of water at each depth were withdrawn by sucking the end of the siphon like a straw. Each sample of water was then tested for its total dissolved solids (TDS) which represents the total amount of salts in the water. The higher the water sample's TDS, the higher the water sample's salinity; therefore, if a freshwater pocket is formed in the recharge well prototype, with increasing depth, the TDS of the water withdrawn from the prototype should also increase.

2.4.1 Data Set #1: TDS and Depth of Withdrawal

Depth of Withdrawal (in)	*V_1 (ml)*	*C_1 (ppm)*	*V_2 (ml)*	*C_2 = TDS (ppm)*
2	1000	1639	145	11303.4
3	1000	1666	145	11489.7
4	1000	1711	145	11800.0
5	1000	1688	145	11641.4

In this data set, the water withdrawn from the model was too saline for the TDS reader. In order to obtain the TDS reading of the samples, the samples were diluted with freshwater and the TDS was calculated using the dilution equation $\mathbf{C_1V_1=C_2V_2}$. The breakdown of the equation as shown in the table is as follows:

1. $\mathbf{V_1}$ is the volume of the solution after dilution
2. $\mathbf{C_1}$ is the concentration of the solution after dilution
3. $\mathbf{V_2}$ is the volume of the solution before dilution
4. $\mathbf{C_2}$ is the original concentration of the solution



Result: The plotted data indicates a directly proportional relationship between depth of withdrawal; as depth of withdrawal increases, TDS increases. The correlation between the two variables is moderately strong as demonstrated by the linear regression R^2 value of 0.6495. The results support our hypothesis, but to prove the formation of the freshwater pocket, an additional data collection was completed where the samples withdrawn were fresh.

2.4.2 Data Set #2: TDS and Depth of Withdrawal

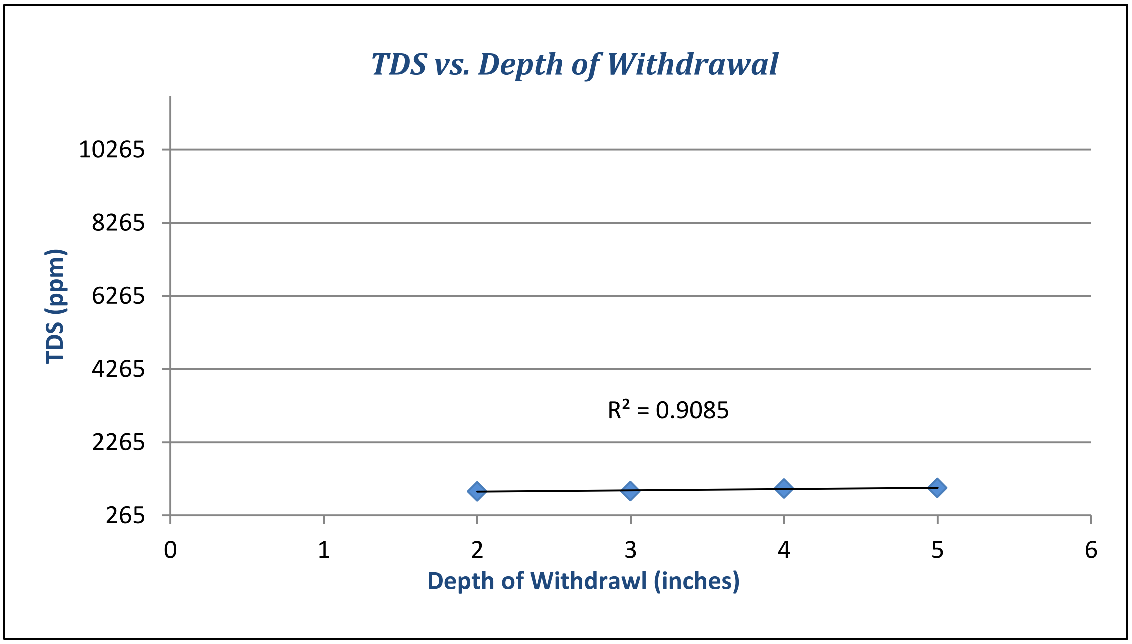
Depth of Withdrawal (in)	TDS (ppm)
2	917
3	932
4	1001
5	1012

Before this second set of data was collected, 2.5 L of freshwater was added to the recharge well pipe and allowed to recharge into the model overnight. The water withdrawn the next day was mostly fresh and did not need to be diluted to obtain a TDS reading. Because of the recent addition of freshwater, this data collection was more accurate than the previous data collection.

Result: The TDS of the saltwater layer loaded into the tank was 11,730 ppm. Meanwhile, the freshwater added to the recharge well was 265 ppm. In comparison, the TDS of the extracted water ranged from 917 ppm to 1012 ppm. Although the TDS of the extracted water does not match the TDS of the loaded freshwater, it is significantly lower than the TDS of the loaded saltwater. In fact, the difference between the TDS of the extracted water and loaded freshwater (652 to 747 ppm) is significantly lower than the difference between the TDS of the extracted water and loaded saltwater (10718 to 10813 ppm). Because of this, despite the discrepancy between the TDS of the loaded freshwater and extracted water, we may conclude the formation of a freshwater pocket.

Explanations for the rise in TDS level of the extracted water include:

- During loading of the freshwater (265 ppm), the recharge well pipe contained some stagnated saltwater (11730 ppm) between the datum level and the water table level. Because of this, some saltwater mixed with the freshwater before the model was recharged.
- The quantity of freshwater loaded into the tank was too small to flush the salinity in the soil voids. In a real-life scenario, the quantity of rainwater would recharge the aquifer on a massive scale, effectively flushing the salinity from the soil voids.



Result: As shown on the graph, the data points are significantly closer to the 265 ppm TDS of the loaded freshwater than 11,730 ppm TDS of the loaded saltwater. Furthermore, the plotted data indicates a directly proportional relationship between depth of withdrawal; as depth of withdrawal increases, TDS increases. The correlation between the two variables is strong as demonstrated by the high linear regression R^2 value of 0.9085. These results validate our hypothesis of the formation of a freshwater pocket.

Comprehensive Results and Discussion: Water and Food Security

All three experimental objectives were satisfied: (1) construction of a model that accurately mimics the conditions of a recharge well, (2) measurement of the model's rate of recharge, and (3) confirmation of the formation of a freshwater pocket given the recharge well innovation. This research will contribute to further IRRAD's understanding of using technological innovations to maximize clean freshwater resources, and by extension, improvement of food security. The availability of water impacts food security on a number of levels. Firstly, access to clean freshwater is essential to health and intake of nutrition. Sickness resulting from waterborne illnesses cost subsistence farmers money, time, and energy that can be contributed towards income enhancement. In addition, in walking far distances for collection of freshwater, women sacrifice time, education, and health—resources that can additionally contribute towards income enhancement. Finally, scarcity of water results in lower agricultural productivity and lower purchasing power for subsistence farmers. Water is related to nearly every aspect of human livelihood—domestic and agricultural—and further research on technologies that increase freshwater availability is a key step to the improvement of food security.

—Reflections —

Everything you've ever heard about India is true, but the opposite is also true. This was one of the first observations I was told about India upon arrival. I would continue to hear variations of this statement throughout my trip, and indeed, the India I saw was a country of extremes. One day, I was in conservative Muslim villages of the Mewat District; the next I was floored by the opulent wealth of a New Delhi mall. On the streets of Gurgaon, trash littered the roads, but within the IRRAD compound, I was living in a sustainable green building of the future. It was as if I was continually entering a time machine, zooming into the past and then into the future. Sometimes my time machine was an air-conditioned van, sometimes the metro, other times a rickshaw, but most times, I found that my two legs were able to transport me between the different worlds.

Even while I was traveling through time on a regular basis, at the end of two months, I felt as if I was left with not enough time—not enough time to experience everything there was to offer, not enough time to pursue my research, not enough time to truly immerse myself and make a more tangible contribution. In another sense, it was just enough time—enough time to give me a glimpse of the work of IRRAD, of Vedvati and the other village women, enough time to grasp the meaning of having to survive without access to the most basic of human necessities. My time in India was short, but it was enough.

If the villages of Mewat were a snapshot of the past, my time in IRRAD has granted me the ability to envision a future of an empowered rural India. I entered the villages, believing that I knew what poverty would look like, only to arrive and realize how wrong my preconceptions were. I saw first-hand how the stereotypes I had of poverty were only a small facet of a bigger picture—a picture that is messier and more complex than I could ever have imagined. Poverty is not merely a matter of food security; it is one that is intertwined with all other issues: government, market infrastructure, education, healthcare, environment. All of this, I have come to understand, but what never ceases to surprise me is despite the overwhelming issues at hand, everyone in the villages shares the conviction that things *will* get better—despite it all, the presence of hope is *strong*. There is something to be said for the resilience of the human spirit.

Before I embarked on this journey, I was repeatedly told that I would not be the same person when I returned home. Is this true? Absolutely. I remember how frightened I was of leaving the IRRAD compound when I first arrived. As soon as I walked onto the street, I was overwhelmed by the roads filled with dust—cars, cows, rickshaws, and motorcycles all traveling along at different speeds. I remember in the beginning how self-conscious I felt to eat with my hands and wear Indian clothing. After living independently for two months though—after all of this, I cannot say that I am afraid anymore. I am not afraid to cross a road, to seek understanding in the unfamiliar; I am not afraid to speak my mind. This experience had changed me for the better, and I am confident that in the years ahead of me, I will recall the lessons and skills that I have developed in India.

I am honored to have played a small part in continuing Dr. Borlaug's legacy this past summer. Wherever my future of hunger fighting may take me, I hope to live by Dr. Borlaug's five principles: give your best; believe you can succeed; face adversity squarely; be confident you will find the answers when problems arise; then go out and win some bouts. May his vision live on, and may his life continue to inspire the world. His life has certainly inspired mine.

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