January 23, 2010

NEWS RELEASE

Twelfth Annual High School Mathematical Modeling Contest

The Consortium for Mathematics and its Applications (COMAP) is pleased to announce the results of the Twelfth Annual High School Mathematical Contest in Modeling (HiMCM). A total of 277 teams, with up to 4 students each, from 47 schools, competed. All teams worked at their own schools during a designated 36-hour period between November 6th and 23rd, 2009. Each high school team chose from two modeling problems offered and then constructed their solutions.

National Outstanding Teams

Davis Senior High School, Davis, CA
Illinois Mathematics and Science Academy, Aurora, IL (2 Teams)
International School of Duesseldorf, Duesseldorf, Germany
Maggie Walker Governor's School, Richmond, VA
Mills Godwin High School, Richmond, VA
Shanghai Foreign Language School Affiliated to SISU, Shanghai, China
The Ellis School, Pittsburgh, PA

Regional Outstanding Teams

Castilleja School, Palo Alto, CA
Central Academy, Des Moines, IA
Charter School of Wilmington, Wilmington, DE
Dubuque Hempstead High School, Dubuque, IA
Hong Kong International School, Tai Tam, Hong Kong (4 Teams)
Illinois Mathematics and Science Academy, Aurora, IL
Maggie Walker Governor's School, Richmond, VA (2 Teams)
Mills Godwin High School, Richmond, VA (2 Teams)
Shanghai Foreign Language School Affiliated to SISU, Shanghai, China
The Ellis School, Pittsburgh, PA

12TH ANNUAL HIMCM STATISTICS

Problem	National Outstanding	%	Regional Outstanding	%	Meritorious	%	Honorable Mention	%	Successful Participant	%	TOTAL
A	4	3%	5	4%	32	26%	49	39%	35	28%	**125**
B	4	3%	10	7%	28	18%	63	41%	47	31%	**152**
Total	8	3%	15	5%	60	22%	112	40%	82	30%	**277**

All schools are to be commended for their efforts. The judges were impressed with all the teams' creativity and ingenuity in mathematical modeling and in their ability to explain their strategies and problem-solving techniques in clear terms. Each participant is a true winner. A complete Results Report, listing all teams by designation, can be found at www.himcm.org

For additional contest information, contact COMAP at: himcm@comap.com

COMAP

HiMCM is made possible by COMAP, Inc .Additional support is provided by The Institute for Operations Research and the Management Sciences (INFORMS), The Mathematical Association of America (MAA), and The National Council of Teachers of Mathematics (NCTM).

The Contest Director is William P. Fox, Professor at The Naval Postgraduate School.

Project Directors include John A. Dossey, Distinguished University Professor of Mathematics Emeritus, Illinois State University, and Frank Giordano, Professor at The Naval Postgraduate School.

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	

National Outstanding

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2225	B	National Outstanding	International School of Duesseldorf	Phillip Grant	Duesseldorf	NRW
2239	A	National Outstanding	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2332	B	National Outstanding	The Ellis School	Amy Yam	Pittsburgh	Pa
2340	B	National Outstanding	Maggie Walker Governor's School	John Barnes	Richmond	VA
2358	A	National Outstanding	Mills Godwin High School	Todd Phillips	Richmond	VA
2379	B	National Outstanding	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2380	A	National Outstanding	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2461	A	National Outstanding	Davis Senior High School	Gregory Shinault	Davis	CA

Regional Outstanding

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2216	B	Regional Outstanding	Castilleja School	David Lowell	Palo Alto	CA
2248	A	Regional Outstanding	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2287	B	Regional Outstanding	Hong Kong International School	William Stork	Tai Tam	hong
2288	B	Regional Outstanding	Hong Kong International School	William Stork	Tai Tam	hong
2295	A	Regional Outstanding	Hong Kong International School	William Stork	Tai Tam	hong
2303	B	Regional Outstanding	Hong Kong International School	Edgar Fong	Tai Tam	
2311	B	Regional Outstanding	Central Academy	Michael Marcketti	Des Moines	IA
2315	A	Regional Outstanding	Dubuque Hempstead High School	Rita Crotty	Dubuque	IA
2333	B	Regional Outstanding	The Ellis School	Amy Yam	Pittsburgh	Pa
2336	B	Regional Outstanding	Maggie Walker Governor's School	John Barnes	Richmond	VA
2337	B	Regional Outstanding	Maggie Walker Governor's School	John Barnes	Richmond	VA
2356	B	Regional Outstanding	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2359	B	Regional Outstanding	Mills Godwin High School	Todd Phillips	Richmond	VA
2360	A	Regional Outstanding	Mills Godwin High School	Todd Phillips	Richmond	VA
2377	A	Regional Outstanding	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	

Meritorious

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2219	B	Meritorious	The Shipley School	Sarah Mechura	Bryn Mawr	PA
2220	B	Meritorious	Shanghai Foreign Language School	Liqun Pan	Shanghai	Shan
2221	B	Meritorious	Holy Ghost Prep	William Lambert	Bensalem	PA
2222	A	Meritorious	Holy Ghost Prep	William Lambert	Bensalem	PA
2226	A	Meritorious	Shanghai Foreign Language School	sun yue pan li qun	Shanghai	Shan
2235	A	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2236	B	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2237	B	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2240	B	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2241	A	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2242	A	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2243	A	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2244	A	Meritorious	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2253	A	Meritorious	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2258	A	Meritorious	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2262	A	Meritorious	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2263	A	Meritorious	Waterloo Collegiate Institute	Michael Burns	Waterloo	ON
2269	A	Meritorious	Hanover High School	Greta Mills	Hanover	NH
2289	B	Meritorious	Hong Kong International School	William Stork	Tai Tam	hong
2290	B	Meritorious	Hong Kong International School	William Stork	Tai Tam	hong
2291	B	Meritorious	Hong Kong International School	William Stork	Tai Tam	hong
2293	A	Meritorious	Hong Kong International School	William Stork	Tai Tam	hong
2298	B	Meritorious	Hong Kong International School	Edgar Fong	Tai Tam	
2300	B	Meritorious	Hong Kong International School	Edgar Fong	Tai Tam	

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2312	B	Meritorious	Central Academy	Michael Marcketti	Des Moines	IA
2313	B	Meritorious	Central Academy	Michael Marcketti	Des Moines	IA
2326	B	Meritorious	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2328	B	Meritorious	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2338	A	Meritorious	Maggie Walker Governor's School	John Barnes	Richmond	VA
2361	B	Meritorious	Mills Godwin High School	Todd Phillips	Richmond	VA
2362	B	Meritorious	Mills Godwin High School	Todd Phillips	Richmond	VA
2364	B	Meritorious	Maggie Walker Governor's School	John Barnes	Richmond	VA
2373	B	Meritorious	Madrid Waddington Central School	Sandra Ruddy	Madrid	NY
2376	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2378	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2385	A	Meritorious	Evanston Township High School	Peter DeCraene	Evanston	IL
2387	B	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2388	B	Meritorious	Evanston Township High School	Peter DeCraene	Evanston	IL
2389	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2391	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2393	A	Meritorious	Evanston Township High School	Peter DeCraene	Evanston	IL
2400	A	Meritorious	Arkansas School for Math & Science	bruce turkal	hot springs	AR
2412	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2413	A	Meritorious	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2422	B	Meritorious	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2434	B	Meritorious	Madison East High School	Cynthia Chin	Madison	WI
2435	A	Meritorious	Madison East High School	Cynthia Chin	Madison	WI
2453	B	Meritorious	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2455	A	Meritorious	North Cedar Schools	Vicki Hamdorf	Stanwood	IA

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2456	A	Meritorious	North Cedar Schools	Vicki Hamdorf	Stanwood	IA
2480	A	Meritorious	Kent School	Jessica Watkin	Kent	CT
2481	A	Meritorious	Mississippi School for Mathematics and Science	Claudia Carter	Columbus	MS
2483	B	Meritorious	Mississippi School for Mathematics and Science	Claudia Carter	Columbus	MS
2485	A	Meritorious	Mississippi School for Mathematics and Science	Claudia Carter	Columbus	MS
2486	A	Meritorious	Illinois Mathematics and Science Academy	Noah Prince	Aurora	IL
2495	B	Meritorious	John Burroughs High School	Narineh Barzegar	Burbank	CA
2521	B	Meritorious	MARIA CARRILLO HIGH SCHOOL	MARARET BRADYLON	SANTA ROSA	CA
2523	B	Meritorious	Cheshire Academy	Susan Eident	Cheshire	CT
2524	A	Meritorious	Cheshire Academy	Susan Eident	Cheshire	CT
2526	A	Meritorious	Shenandoah CSD	Jenny Stephens	Shenandoah	IA

Honorable Mention

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2217	B	Honorable Mention	Castilleja School	David Lowell	Palo Alto	CA
2218	A	Honorable Mention	MARIA CARRILLO HIGH SCHOOL	MARARET BRADYLON	SANTA ROSA	CA
2227	B	Honorable Mention	Sfls	Yue Sun	Shanghai	Shan
2228	B	Honorable Mention	Collegiate School	David Bannard	Richmond	VA
2229	B	Honorable Mention	Collegiate School	David Bannard	Richmond	VA
2230	B	Honorable Mention	Collegiate School	David Bannard	Richmond	VA
2231	A	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2232	B	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2233	B	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2234	A	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2238	B	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2245	B	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA
2246	B	Honorable Mention	Shanghai Foreign Language School Affiliated to SISU	PAN SUN YUE	SHANGHAI	SHA

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2247	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2249	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2250	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2251	B	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2255	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2257	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2259	B	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2260	A	Honorable Mention	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2261	B	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2265	B	Honorable Mention	Clarkstown South High School	Mary Ann Gavioli	West Nyack	NY
2266	B	Honorable Mention	Lord Byng Secondary School	Dan Kamin	Vancouver	Britis
2267	A	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2268	B	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2270	A	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2271	B	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2272	B	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2273	A	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2274	B	Honorable Mention	Hanover High School	Greta Mills	Hanover	NH
2275	B	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2277	B	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2280	B	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2285	A	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2286	B	Honorable Mention	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2292	B	Honorable Mention	Hong Kong International School	William Stork	Tai Tam	hong
2294	B	Honorable Mention	Hong Kong International School	William Stork	Tai Tam	hong

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2296	B	Honorable Mention	Hong Kong International School	William Stork	Tai Tam	hong
2301	A	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2304	A	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2305	A	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2306	B	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2307	B	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2308	B	Honorable Mention	Hong Kong International School	Edgar Fong	Tai Tam	
2310	B	Honorable Mention	Central Academy	Michael Marcketti	Des Moines	IA
2314	B	Honorable Mention	Central Academy	Michael Marcketti	Des Moines	IA
2320	B	Honorable Mention	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2322	B	Honorable Mention	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2325	B	Honorable Mention	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2335	B	Honorable Mention	NC School of Science and Mathematics	Daniel Teague	Durham	NC
2349	A	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2350	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2352	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2353	A	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2355	A	Honorable Mention	Chang Duk Girls High School	Hak Sup Lee	Seoul	Seoul
2357	A	Honorable Mention	Mills Godwin High School	Todd Phillips	Richmond	VA
2363	B	Honorable Mention	Mills Godwin High School	Todd Phillips	Richmond	VA
2365	A	Honorable Mention	Evanston Township High School	Mark Vondracek	Evanston	IL
2366	B	Honorable Mention	Evanston Township High School	Mark Vondracek	Evanston	IL
2368	B	Honorable Mention	Evanston Township High School	Mark Vondracek	Evanston	IL
2369	A	Honorable Mention	Evanston Township High School	Mark Vondracek	Evanston	IL
2371	A	Honorable Mention	Evanston Township High School	Mark Vondracek	Evanston	IL

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2375	B	Honorable Mention	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2381	B	Honorable Mention	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2383	B	Honorable Mention	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2384	A	Honorable Mention	Evanston Township High School	Peter DeCraene	Evanston	IL
2386	A	Honorable Mention	Evanston Township High School	Peter DeCraene	Evanston	IL
2390	A	Honorable Mention	Evanston Township High School	Peter DeCraene	Evanston	IL
2399	B	Honorable Mention	Arkansas School for Math & Science	bruce turkal	hot springs	AR
2401	A	Honorable Mention	Arkansas School for Math & Science	bruce turkal	hot springs	AR
2414	A	Honorable Mention	Illinois Mathematics and Science Academy	Steven Condie	Aurora	IL
2415	B	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2416	A	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2419	A	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2420	A	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2421	B	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2423	B	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2427	B	Honorable Mention	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2429	A	Honorable Mention	Glenbrook North HS	Brad Benson	Northbrook	IL
2430	B	Honorable Mention	Glenbrook North HS	Brad Benson	Northbrook	IL
2431	B	Honorable Mention	Pinetree Secondary School	George Lin	Coquitlam	BC
2432	A	Honorable Mention	Madison East High School	Cynthia Chin	Madison	WI
2433	A	Honorable Mention	Madison East High School	Cynthia Chin	Madison	WI
2436	A	Honorable Mention	Madison East High School	Cynthia Chin	Madison	WI
2437	B	Honorable Mention	The Hotchkiss School	Marta Eso	Lakeville	CT
2438	A	Honorable Mention	The Hotchkiss School	Marta Eso	Lakeville	CT
2439	A	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2441	A	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2442	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2443	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2444	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2446	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2447	A	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2448	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2452	B	Honorable Mention	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2457	A	Honorable Mention	North Cedar Schools	Vicki Hamdorf	Stanwood	IA
2462	B	Honorable Mention	Davis Senior High School	Gregory Shinault	Davis	CA
2463	B	Honorable Mention	Natomas High School	Gregory Shinault	Davis	CA
2465	B	Honorable Mention	De La Salle Collegiate High School	Michael Kosciuk	Warren	MI
2466	B	Honorable Mention	City Charter High School	Marshall Kohnen	Pittsburgh	PA
2470	A	Honorable Mention	City Charter High School	Marshall Kohnen	Pittsburgh	PA
2472	A	Honorable Mention	Kent School	Jessica Watkin	Kent	CT
2484	A	Honorable Mention	Mississippi School for Mathematics and Science	Claudia Carter	Columbus	MS
2496	A	Honorable Mention	John Burroughs High School	Narineh Barzegar	Burbank	CA
2499	A	Honorable Mention	John Burroughs High School	Narineh Barzegar	Burbank	CA
2503	A	Honorable Mention	Frontier Regional School	Garrett Deane	South Deerfield	MA
2505	A	Honorable Mention	Frontier Regional School	Garrett Deane	South Deerfield	MA
2510	B	Honorable Mention	Frontier Regional School	Garrett Deane	South Deerfield	MA
2515	A	Honorable Mention	American School of Dubai	Jasper Adviento	Dubai	UAE
2520	B	Honorable Mention	American School of Dubai	Jasper Adviento	Dubai	UAE
2527	A	Honorable Mention	Shenandoah CSD	Jenny Stephens	Shenandoah	IA

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	

Successful Participant

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2223	B	Successful Participant	Shanghai Foreign Language School Affliated To SISU	Yue Sun	Shanghai	Shan
2224	B	Successful Participant	Shanghai Foreign Language School	Yue Sun	Shanghai	Shan
2254	A	Successful Participant	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2256	A	Successful Participant	Charter School of Wilmington	L Charles Biehl	Wilmington	DE
2276	B	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2278	B	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2279	B	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2281	A	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2283	B	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2284	B	Successful Participant	Massachusetts Academy of Mathematics and Science at	Jim Barys	Worcester	MA
2297	A	Successful Participant	Hong Kong International School	William Stork	Tai Tam	hong
2302	B	Successful Participant	Hong Kong International School	Edgar Fong	Tai Tam	
2316	B	Successful Participant	Dubuque Hempstead High School	Rita Crotty	Dubuque	IA
2317	A	Successful Participant	Powhatan High School	Diane Leighty	Powhatan	VA
2318	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2319	B	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2321	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2323	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2324	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2327	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2329	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2330	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2331	A	Successful Participant	North Springs Charter School	Scott Hetherington	Atlanta	Ga
2334	A	Successful Participant	NC School of Science and Mathematics	Daniel Teague	Durham	NC

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2339	A	Successful Participant	Maggie Walker Governor's School	John Barnes	Richmond	VA
2341	A	Successful Participant	Maggie Walker Governor's School	John Barnes	Richmond	VA
2342	A	Successful Participant	Montpelier High School	Susan Beem	Montpelier	VT
2343	A	Successful Participant	Montpelier High School	Susan Beem	Montpelier	VT
2344	A	Successful Participant	Montpelier High School	Susan Beem	Montpelier	VT
2345	B	Successful Participant	Montpelier High School	Susan Beem	Montpelier	VT
2346	B	Successful Participant	Montpelier High School	Susan Beem	Montpelier	VT
2348	A	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2351	B	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2367	B	Successful Participant	Evanston Township High School	Mark Vondracek	Evanston	IL
2374	B	Successful Participant	Madrid Waddington Central School	Sandra Ruddy	Madrid	NY
2382	B	Successful Participant	Evanston Township High School	Peter DeCraene	Evanston	IL
2392	A	Successful Participant	Evanston Township High School	Peter DeCraene	Evanston	IL
2407	B	Successful Participant	Winterset Junior High	Danielle Shelley	Winterset	IA
2408	A	Successful Participant	Winterset Junior High	Danielle Shelley	Winterset	IA
2409	A	Successful Participant	Winterset Junior High	Danielle Shelley	Winterset	IA
2410	B	Successful Participant	Winterset Junior High	Danielle Shelley	Winterset	IA
2411	A	Successful Participant	Winterset Junior High	Danielle Shelley	Winterset	IA
2417	B	Successful Participant	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2418	B	Successful Participant	Chesterfield County Mathematics and Science High	Pete Peterson	Midlothian	VA
2428	B	Successful Participant	Hong Kong International School	William Stork	Tai Tam	hong
2440	B	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2445	B	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2449	B	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2450	A	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2451	B	Successful Participant	Hanyoung Foregn Language High School	Hongshick Jang	Seoul	
2458	A	Successful Participant	North Cedar Schools	Vicki Hamdorf	Stanwood	IA
2459	A	Successful Participant	North Cedar Schools	Vicki Hamdorf	Stanwood	IA
2464	B	Successful Participant	Natomas High School	Gregory Shinault	Davis	CA
2467	A	Successful Participant	City Charter High School	Marshall Kohnen	Pittsburgh	PA
2468	A	Successful Participant	City Charter High School	Marshall Kohnen	Pittsburgh	PA
2469	A	Successful Participant	City Charter High School	Marshall Kohnen	Pittsburgh	PA
2473	A	Successful Participant	Kent School	Jessica Watkin	Kent	CT
2479	A	Successful Participant	Kent School	Jessica Watkin	Kent	CT
2482	B	Successful Participant	Mississippi School for Mathematics and Science	Claudia Carter	Columbus	MS
2494	B	Successful Participant	John Burroughs High School	Narineh Barzegar	Burbank	CA
2497	B	Successful Participant	John Burroughs High School	Narineh Barzegar	Burbank	CA
2498	B	Successful Participant	John Burroughs High School	Narineh Barzegar	Burbank	CA
2500	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2501	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2502	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2504	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2506	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2507	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2508	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2509	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2511	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2512	B	Successful Participant	Frontier Regional School	Garrett Deane	South Deerfield	MA
2513	A	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE
2514	B	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE

12th Annual High School Mathematical Contest in Modeling Results

Ctrl #	Prob	Designation	Institution	Advisor	Location	
2516	A	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE
2517	B	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE
2518	B	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE
2519	B	Successful Participant	American School of Dubai	Jasper Adviento	Dubai	UAE
2525	B	Successful Participant	Shenandoah CSD	Jenny Stephens	Shenandoah	IA
2528	A	Successful Participant	Shenandoah CSD	Jenny Stephens	Shenandoah	IA
2529	B	Successful Participant	Shenandoah CSD	Jenny Stephens	Shenandoah	IA
2530	B	Successful Participant	North Cedar Schools	Vicki Hamdorf	Stanwood	IA

Water,

Water Everywhere

Mathematic Models of a US National Water Strategy

2009 HiMCM Problem A

Team 2239

Summary

The ultimate goal of our whole modeling is to devise national water strategies mainly concerned with 6 aspects: conservation, efficiency, markets, collaboration, improved technology and interagency coordination increase. Also, we predict the trend of its development in the future. Thus we build four models totally.

The first model predicts the fresh water withdrawals of the United States at a state level from 2010 to 2025. We basically apply the ***regression analysis*** to the data of state-level fresh water withdrawals. We have taken an ***appropriate level of accuracy*** based on the usage of the data.

The second model is generally committed to the plan of water transfer. We have ***leveled*** each region in terms of its water shortage degree. Also, we have built a model of ***max spanning tree*** to get the shortest route of transfer. We have drawn on the experience of Chinese water transferring project to calculate the capital cost of the project.

The third model estimates the desalination plant construction and the processing cost by establishing a ***sequence.***

The fourth model simulates ***the water price rise*** to find the US water price cap.

We have also researched measures of ***Supervisory Control and Data Acquisition (SCADA) system, water purification, remote sensing techniques and Geographic Information System*** to relieve the water shortage before 2025.

The fifth model is devoted to the economic, physical, cultural and environmental impact of different measures discussed above by using ***Analytic Hierarchy Process (AHP)***.

Finally, we have figured out an ***action plan*** of US National water strategies to achieve our common ultimate goal in WATER 2025.

In a nutshell, we have adopted five models in distinctive thoughts, covering predictions of all times, to the ideal simulations and predictions.

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1. Introduction

The U.S. is facing a shortage of fresh water that the Earth has a finite supply of, stored in aquifers, surface waters and the atmosphere.

Across America, the nation's freshwater supplies can no longer quench its thirst. An epic drought in Georgia has threatened the water supply for millions. Florida doesn't have nearly enough water for its expected population boom. The Great Lakes are shrinking. Upstate New York's reservoirs have dropped to record lows. And in the West, the Sierra Nevada snowpack is melting faster each year. The government projects that at least 36 states will face water shortages by 2012 because of a combination of rising temperatures, drought, and population growth, urban sprawl, waste and excess.

Construction of dams and aqueducts to water arid lands and supply freshwater to population is an effective and historic way. The Croton Aqueduct was a large and complex water distribution system constructed for New York City between 1837 and 1842. It brought water by the force of gravity alone 41 miles (66 km) from the Croton River in Westchester County into reservoirs in Manhattan, where local water resources had become polluted and inadequate for the growing population of the city. A scientific planning of water nationwide infrastructure would help US overcome the shortage of freshwater in the long term.

Waste and inadequate management of water are the main culprits behind growing problems. The state dumps hundreds of billions of gallons a year of treated wastewater into the Atlantic through pipes — water that could otherwise be used for irrigation. Little land is left to store water during wet seasons, and so much of the landscape has been paved over that water can no longer penetrate the ground in some places to recharge aquifers. As a result, the state is forced to flush millions of gallons of excess into the ocean to prevent flooding. As these communities grow, instead of developing new water with new treatment systems, why not better manage the commodity they already have and produce an environmental benefit at the same time. Whatever the use of freshwater (agriculture, industry, domestic use), huge saving of water and improving of water management is possible. Legislative actions should be sought to get municipalities to use water in a rational, planned, orderly way.

In addition to water storage/movement and conservation, desalinization technology that remove excess salt and other minerals from water holds promise to convert salt water into fresh water suitable for human consumption or irrigation. There are more than 1,000 desalinization plants in the U.S., many in the Sunbelt. The largest desalinization plant in the United States is the one at Tampa Bay, Florida, which began desalinizing 25 million gallons of water per day in December 2007. One focus of desalinization is to develop cost-effective ways of providing fresh water for human use in regions where the availability of fresh water is limited. Large-scale desalinization typically uses extremely large amounts of energy as well as specialized, expensive infrastructure, making it very costly compared with the use of fresh water from rivers or groundwater.

2. Regression Models of water use in the United States

2.1 Introduction

Though the current financial crisis has spilt over into areas outside the U.S, the economy of the whole world will undoubtedly develop in the next several decades at a certain pace. Therefore, the aggregate demand for water use in the world will never keep a constant and will surely step up though water use is involved in areas much more than those connected with economy. The United States is not an exception.

2.2 Restatement and Analysis

To “devise an effective, feasible, and cost-efficient national water strategy for 2010 to meet the projected needs of the United States in 2025”, as is stated in the problem, we have to estimate the water needs from 2010 to 2025 in the first place. The information will also be essential to understanding how to meet the future water demands while maintaining water quality and needs of human, ecosystem, culture, and economy.

The U.S. Geological Survey (USGS) publishes a series of reports of “Estimated use of water in the United States” by every 5 years since 1950. These reports include estimated data of water withdrawals by State and County, sources of water, and categories of use. They demonstrate that changes in water use are occurring over time in geographic areas, sources and categories of use.

2.3 Assumptions and Justifications

1. The states we choose for modeling will not experience mass migrations of population.

   The water use at the state level is closely related to the state population. Our water use estimation model does take population change into consideration, while the change follows the current demographic trends.

2. Sweeping reforms will not be implemented in terms of industry, society, economy, policy, culture and environment.

   Our estimation model prefers that the future development in terms of industry, socinety, economy, policy, culture and ecosystem can keep a steady pace through 2010 to 2025.

3. The increase in fresh water storage from the thaw of glaciers caused by climate change and

global warming is not considered.

Climate change and global warming are major obstacles human beings are facing. Many a research has been done on this topic. We expect that effective measures can be taken and the thaw of glaciers will be ceased one day before 2025. And such increase is what we do not hope for.

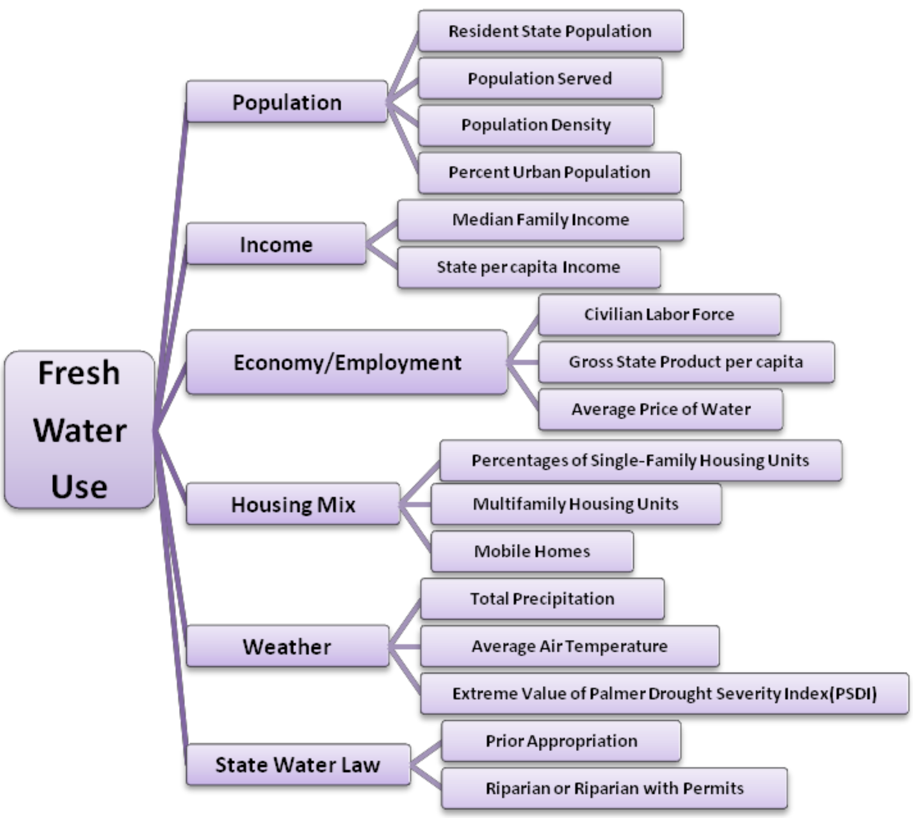
2.4 Variables

Mark	Meaning	Unit
F	Total Fresh Water Withdrawals	Million Gallons per Day
Y	Year	/

2.5 Establishment of the Model

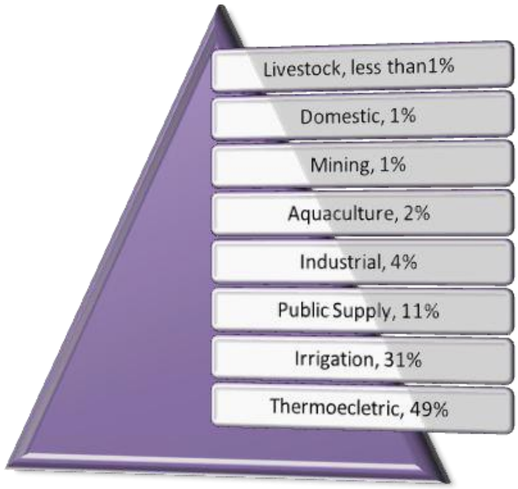
Concerning that "Fresh water is the limiting constraint for development in much of the United States", as is stated in the problem, we mainly focus our research on the fresh water use. Since the United States enjoys a state-independent water management system, we make our estimations on fresh water use at a state level.

Fresh water withdrawals at the state level are influenced by the following variables:

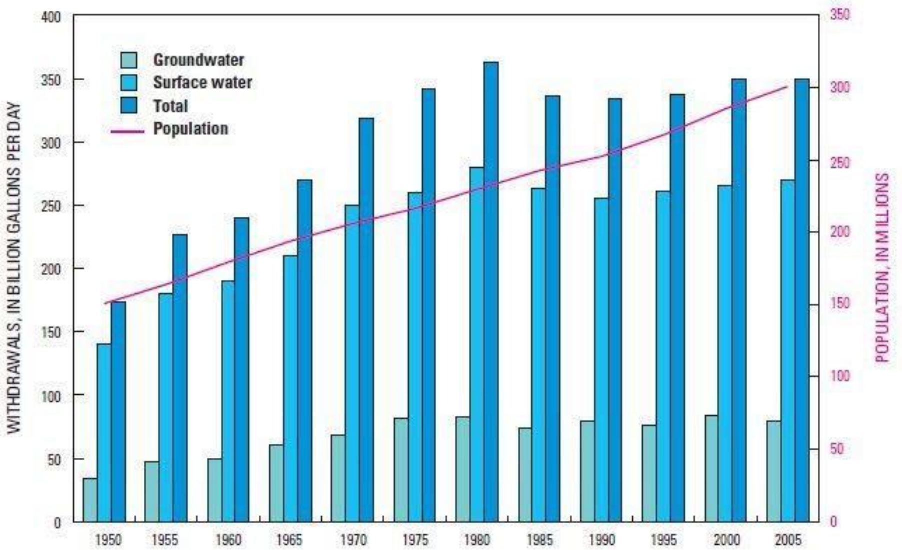


However, less data can be collected in all these aspects illustrated above other than the total fresh water withdrawals in each state from 1955 to 2005. Also, we mainly use the estimated data to choose appropriate measures to be taken to relieve the current fresh water shortage, so we do not have a highly demanded accuracy. Consequently, we choose to estimate the state-level fresh water use as a whole.

Percentages of fresh water withdrawals by categories are shown as follows:



It shows that fresh water use except thermoelectric use is mainly for irrigation, which is closely related to food and population and plays a crucial role in human lives.

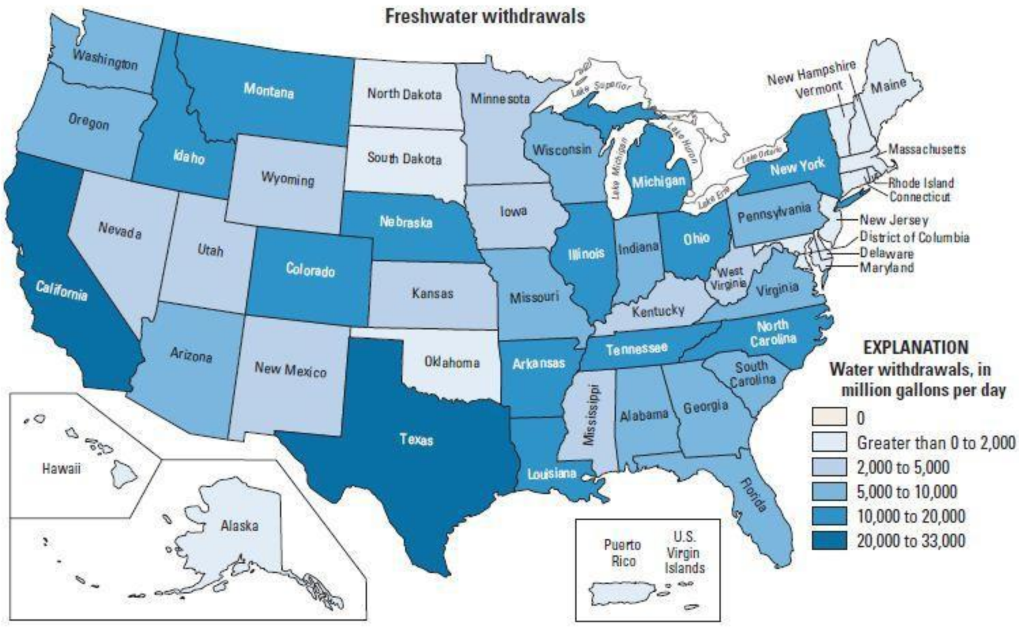


Trends in population and freshwater withdrawals by source, 1950–2005.

It shows that the current US population is growing at a steady pace with the passage of time, and the state-level fresh water use is also roughly increasing steadily.

Thus, we apply regression analysis to the construction of our estimation model, which is a statistical tool for the investigation of relations between variables. It enables us to determine the values of parameters that cause the function to best fit a set of data observations. With the use of regression analysis, the US state-level fresh water use from 2010 to 2025 can be predicted roughly and the whole trend will be unfolded.

The US state-level distribution of fresh water uses is shown by the following map, extracted from **ESTIMATED USE OF WATER IN THE UNITED STATES IN 2005.**

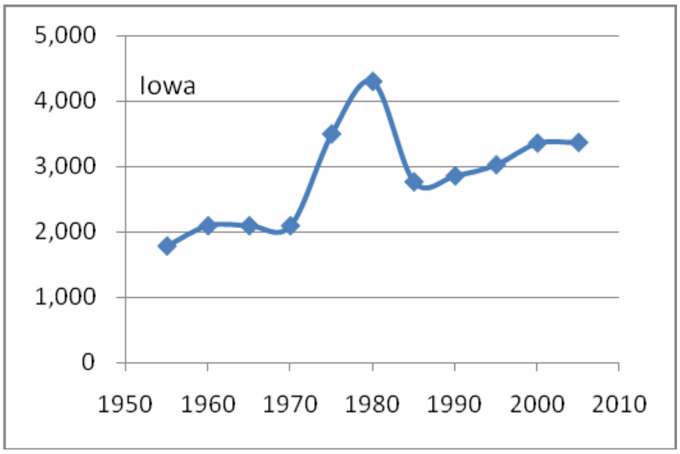


Thus, we have chosen 22 states as representation of fresh water use in each region, including Alabama, Arizona, California, Florida, Georgia, Idaho, Illinois, Iowa, Kansas, Massachusetts, Missouri, Montana, New Hampshire, New York, North Dakota, Oklahoma, Tennessee, Texas, Utah, Virginia, Washington, and Wisconsin.

We obtained the state-level fresh water use data (1955-2005) from **ESTIMATED USE OF WATER IN THE UNITED STATES IN 1955 (1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005)** published by ***U.S. Department of the Interior*** and ***U.S. Geological Survey*** as US GEOLOGICAL SURVEY CIRCULAR 398, 456, 556, 676, 765, 1001, 1004, 1200, 1268, 1344.

We take Iowa as an example of regression analysis.

Year	Total (Fresh) (Million gallons /day)
1955	1,792
1960	2,100
1965	2,100
1970	2,100
1975	3,500
1980	4,300
1985	2,770
1990	2,860
1995	3,030
2000	3,360
2005	3,370



The a scatter plot of the data suggests that higher values of year (the horizontal axis) tend to yield higher values of Fresh Water Withdrawals in Iowa (the vertical axis) in spite that the relationship is not perfect. The values of the year 1975 and 1980 are much greater than is suggested by the whole trend, which can be regarded as abnormal conditions. So we can draw the conclusion that the rising fresh water withdrawals in Iowa do have a certain relationship with the time, most probably a linear one.

To further investigate this speculation, we have constructed an explanatory model with the following variables: Y denotes year (independent variable) and F denotes Fresh Water Withdrawals in Iowa (dependent variable). It seems in the diagram that Y does not suffice for an entirely accurate prediction about F. It is widely acknowledged that factors other than the year affect the withdrawals. Thus, pending discussion below of omitted variables bias, we now hypothesize that the emissions are determined by the year and by an aggregation of omitted factors that we term "noise". In our model, we suppose that the "noise" remains constant and the year affects the withdrawals in a "linear" fashion, that is, each additional year adds the same amount to the withdrawals.

Then, the hypothesized relationship between year and Fresh Water Withdrawals in Iowa may be written as

$$F = \alpha + \beta Y + \varepsilon \quad (1)$$

where

α = a constant amount (what one earns with zero education);

β = the effect in the values of year on the values of withdrawals, hypothesized to be positive;

ε = the "noise" term reflecting other factors that influence the emissions.

Compare the formula (1) with the standard linear regression equation

$$\hat{y} = a + bx \qquad (2)$$

We can find that a = $\alpha + \varepsilon$; b = β; $\hat{y} = C$; $x = Y$.

A. Correlation Coefficient

The correlation coefficient (sometimes also called the product-moment correlation coefficient), which measures the degree of association between two variables in a correlation analysis, is calculated by:

$$r = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2 \sum(y-\bar{y})^2}}$$

x	y	xy	x^2	y^2
1955	1792	3503360	3822025	3211264
1960	2100	4116000	3841600	4410000
1965	2100	4126500	3861225	4410000
1970	2100	4137000	3880900	4410000
1975	3500	6912500	3900625	12250000
1980	4300	8514000	3920400	18490000
1985	2770	5498450	3940225	7672900
1990	2860	5691400	3960100	8179600
1995	3030	6044850	3980025	9180900
2000	3360	6720000	4000000	11289600
2005	3370	6756850	4020025	11356900

$\sum x$=21780

$\sum y$=31282

$\sum xy$=62020910

$\sum x^2$=43127150

$\sum y^2$=94861164

n=11

$\sum(x-\bar{x})^2 = \sum x^2 - \frac{(\sum x)^2}{n}$ $=43127150-21780^2/11=2750$

$\sum(y-\bar{y})^2 = \sum y^2 - \frac{(\sum y)^2}{n}$ $=94861164-31282^2/11=5900844$

$\sum(x-\bar{x})(y-\bar{y}) = \sum xy - \frac{\sum x \times \sum y}{n}$ $=62020910-(21780 \cdot 31282)/11=82550$

$r=\frac{82550}{\sqrt{2750\times5900844}}$=0.6480278399

r^2=0.4199400813

The correlation coefficient is without unit and between +1 and -1. In general, the closer the correlation coefficient is to +1 or -1 the better the association between the two variables x and y. Here r =0.6480278399, so variables Y and C are closely related.

B. Regression Coefficients

Regression coefficients, using the least squares method, are calculated by:

$$b=\frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}=\frac{82550}{2750}=30.01818182$$

$a=y-b\bar{x}$=56592

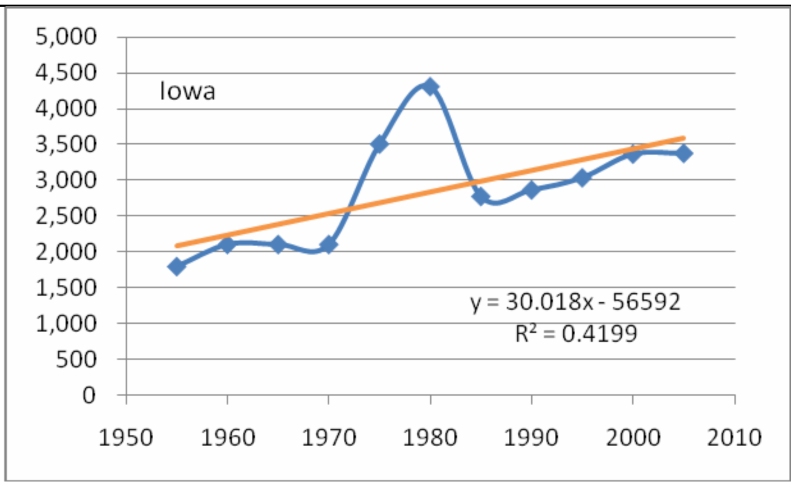
So the linear regression equation for the estimation is

$$y=30.01818182+56592x$$

that is $$F=30.01818182+56592Y$$

Then the estimated fresh water withdrawals in Iowa from 2010 to 2025 are as follows:

Year	2010	2015	2020	2025
Fresh Withdrawals (Mgal/day)	3744	3894	4044	4194

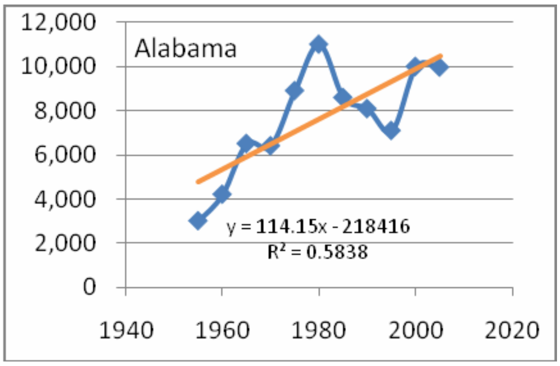

Iowa
y = 30.018x - 56592
R² = 0.4199
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1950
1960
1970
1980
1990
2000
2010

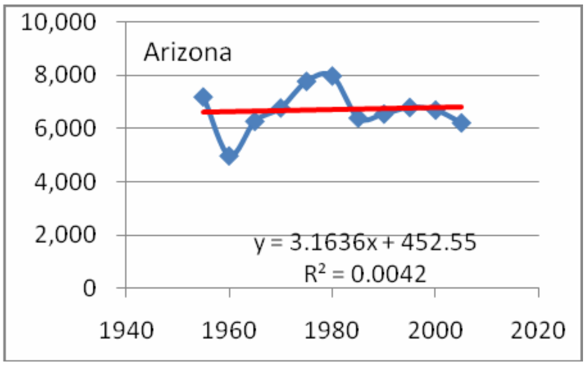
Similarly, we have applied the regression analysis to the other 21 states we have chosen and got the results of the state-level fresh water withdrawals as follows:

Alabama

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	2,999	4,200	6,500	6,400	8,900	11,000	8,590	8,080	7,090	9,990	9,960

Year	2010	2015	2020	2025
Total(Mgal/d)	11,026	11,596	12,167	12,738





Arizona

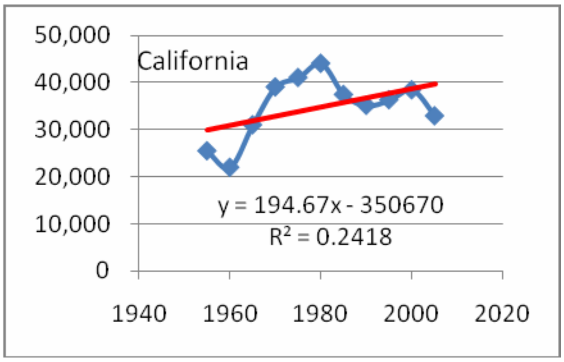
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	7,212	5,000	6,300	6,800	7,800	8,000	6,420	6,570	6,820	6,720	6,240

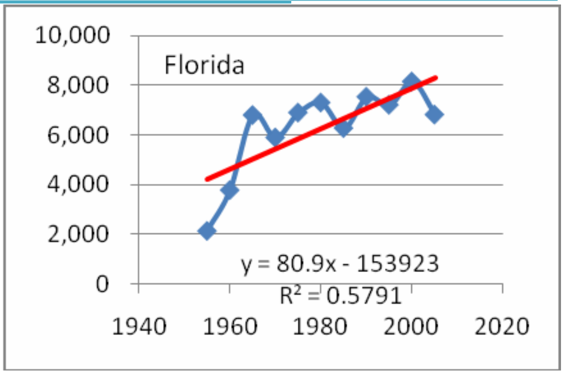
Year	2010	2015	2020	2025
Total(Mgal/d)	6,811	6,827	6,843	6,859

California

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	25,506	22,000	31,000	39,000	41,000	44,000	37,400	35,100	36,300	38,400	32,900

				2025
Total(Mgal/d)	40,617	41,590	42,563	43,537





Florida

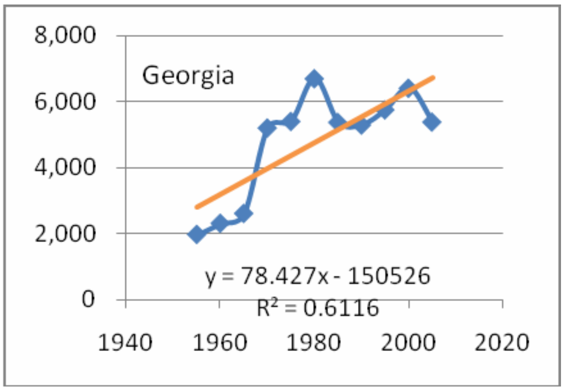
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	2,167	3,800	6,800	5,900	6,900	7,300	6,280	7,530	7,210	8,140	6,820

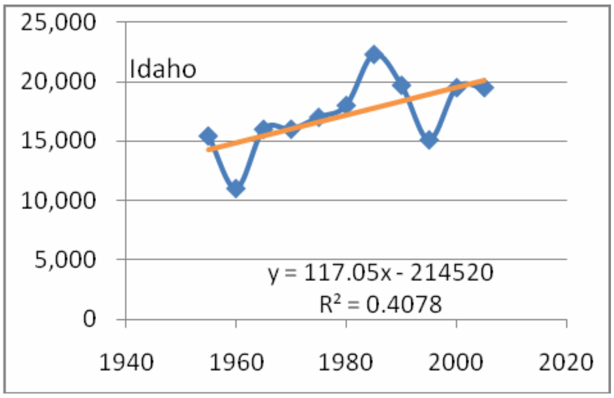
Year	2010	2015	2020	2025
Total(Mgal/d)	8,686	9,091	9,495	9,900

Georgia

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	1,961	2,300	2,600	5,200	5,400	6,700	5,370	5,290	5,750	6,410	5,380

Year	2010	2015	2020	2025
Total(Mgal/d)	7,112	7,504	7,897	8,289





Idaho

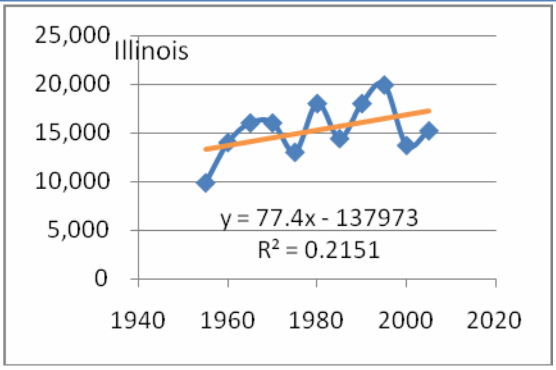
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total	15,425	11,000	16,000	16,000	17,000	18,000	22,300	19,700	15,100	19,500	19,500

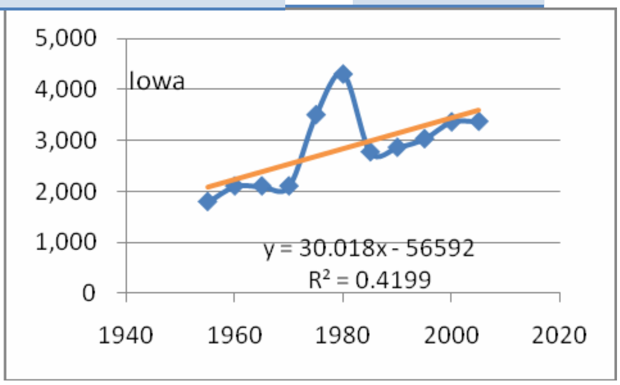
(Mgal/d)				
				2025
Total(Mgal/d)	20,751	21,336	21,921	22,506

Illinois

Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	9,866	14,000	16,000	16,000	13,000	18,000	14,400	18,000	19,900	13,700	15,200

Year	**2010**	**2015**	**2020**	**2025**
Total(Mgal/d)	17,601	17,988	18,375	18,762





Iowa

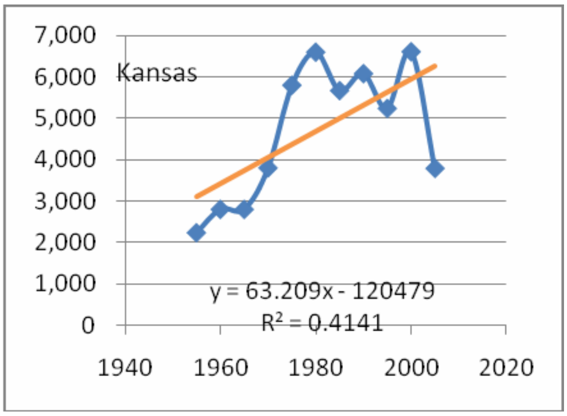
Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	1,792	2,100	2,100	2,100	3,500	4,300	2,770	2,860	3,030	3,360	3,370

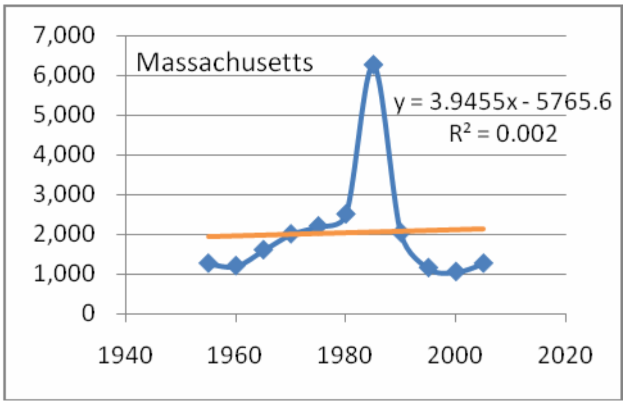
Year	**2010**	**2015**	**2020**	**2025**
Total(Mgal/d)	3,744	3,894	4,044	4,194

Kansas

Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	2,235	2,800	2,800	3,800	5,800	6,600	5,670	6,080	5,240	6,610	3,790

Year	**2010**	**2015**	**2020**	**2025**
Total(Mgal/d)	6,571	6,887	7,203	7,519





Massachusetts

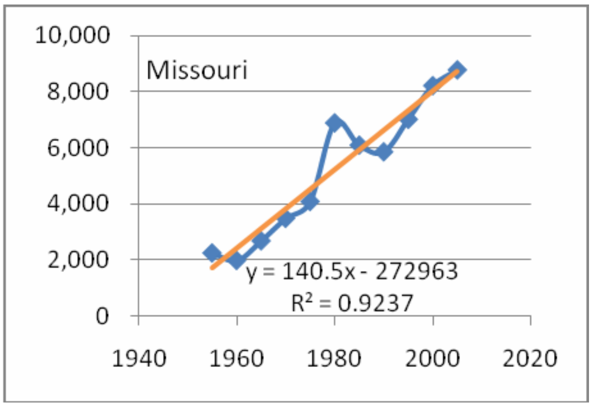
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	1,260	1,200	1,600	2,000	2,200	2,500	6,260	2,030	1,150	1,050	1,260

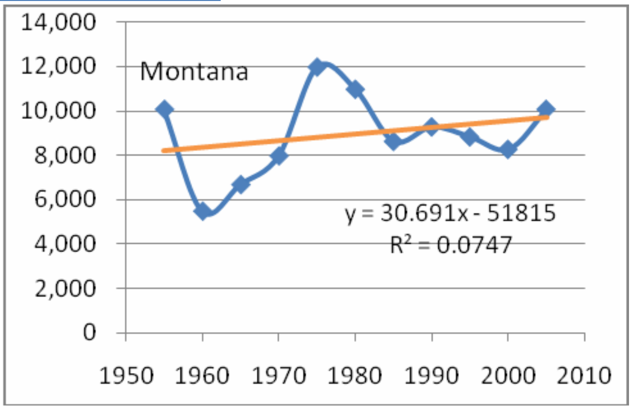
Year	2010	2015	2020	2025
Total(Mgal/d)	2,165	2,185	2,204	2,224

Missouri

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	2,267	2,000	2,700	3,500	4,100	6,900	6,110	5,870	7,030	8,230	8,790

Year	2010	2015	2020	2025
Total(Mgal/d)	9,442	10,145	10,847	11,550





Montana

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	10,096	5,500	6,700	8,000	12,000	11,000	8,650	9,300	8,850	8,290	10,100

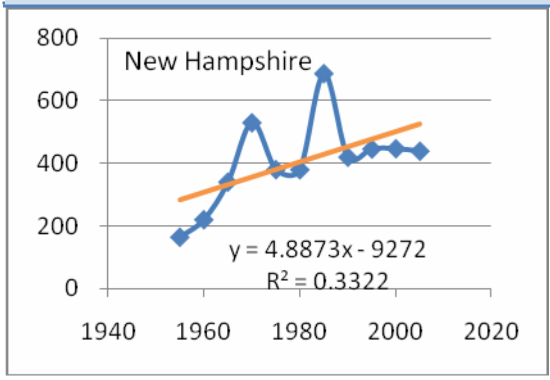
Year	2010	2015	2020	2025

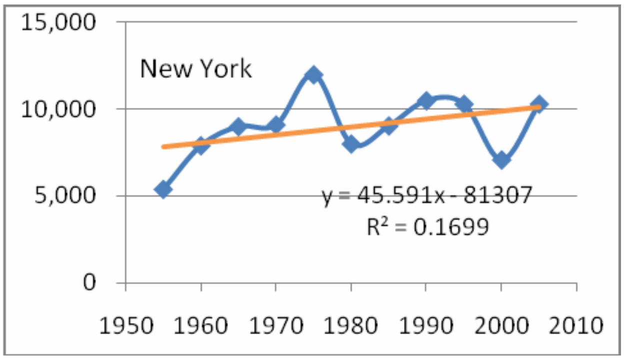
Total(Mgal/d)	9,874	10,027	10,181	10,334

New Hampshire

Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	164	220	340	530	380	380	687	420	446	447	439

Year	**2010**	**2015**	**2020**	**2025**
Total(Mgal/d)	551	576	600	625





New York

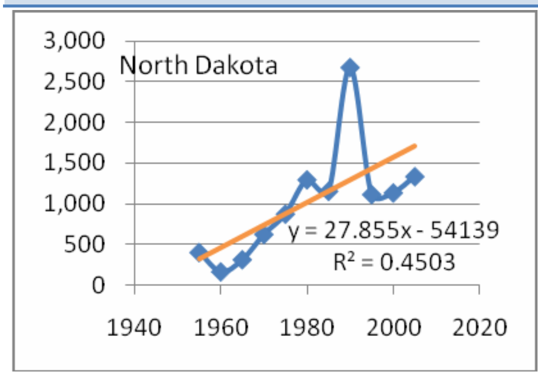
Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	5,377	7,900	9,000	9,100	12,000	8,000	9,040	10,500	10,300	7,080	10,300

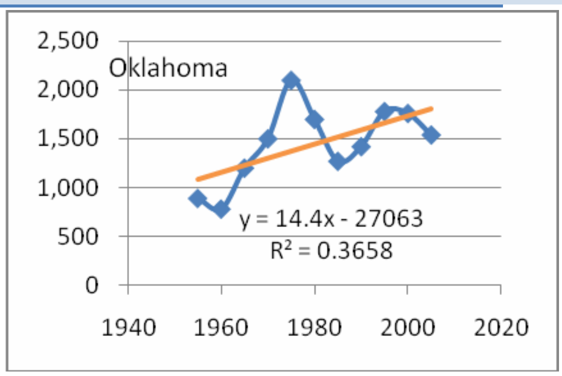
Year	**2010**	**2015**	**2020**	**2025**
Total(Mgal/d)	10,331	10,559	10,787	11,015

North Dakota

Year	**1955**	**1960**	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005**
Total (Mgal/d)	408	170	320	630	880	1,300	1,160	2,680	1,120	1,140	1,340

Year	2010	2015	2020	2025
Total(Mgal/d)	1,850	1,989	2,128	2,267





Oklahoma

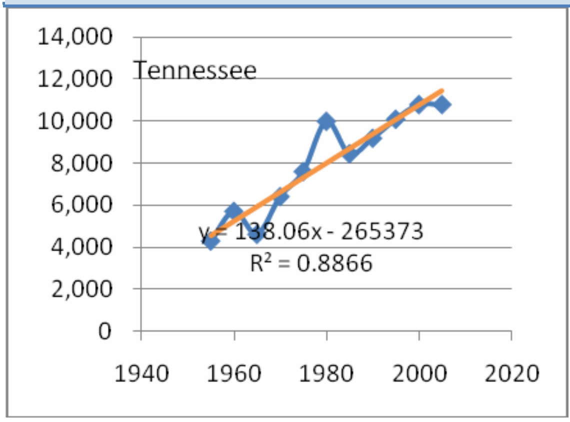
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	890	780	1,200	1,500	2,100	1,700	1,270	1,420	1,780	1,760	1,540

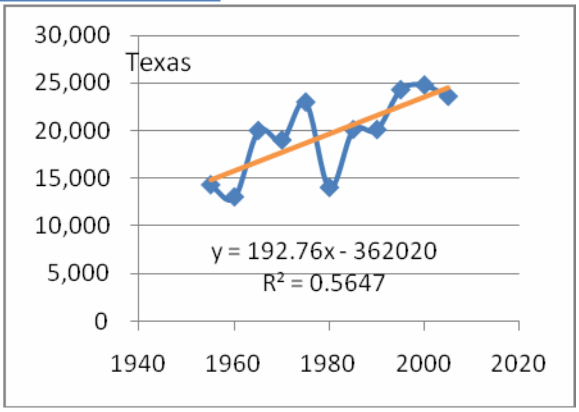
Year	2010	2015	2020	2025
Total(Mgal/d)	1,881	1,953	2,025	2,097

Tennessee

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	4,279	5,700	4,600	6,400	7,600	10,000	8,450	9,190	10,100	10,800	10,800

Year	2010	2015	2020	2025
Total(Mgal/d)	12,128	12,818	13,508	14,199





Texas

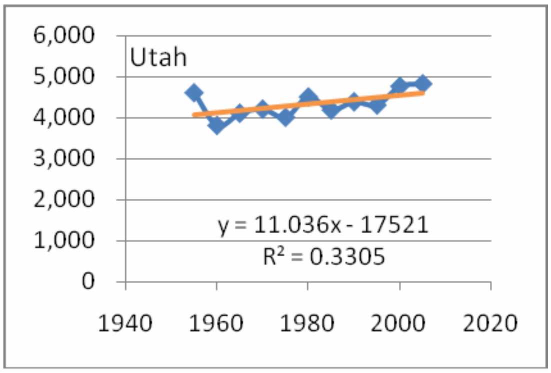
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	14,276	13,000	20,000	19,000	23,000	14,000	20,100	20,100	24,300	24,800	23,600

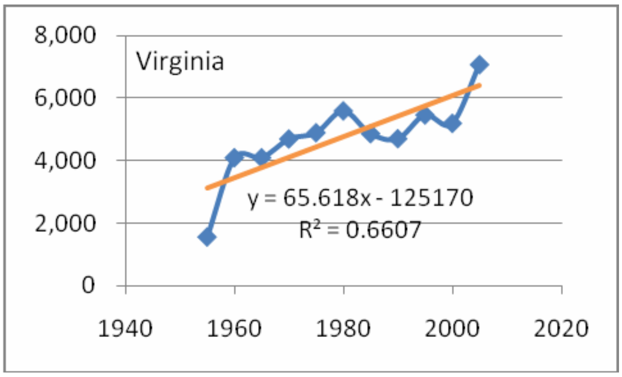
Year	2010	2015	2020	2025
Total(Mgal/d)	25,428	26,391	27,355	28,319

Utah

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	4,602	3,800	4,100	4,200	4,000	4,500	4,180	4,380	4,300	4,760	4,820

Year	2010	2015	2020	2025
Total(Mgal/d)	4,661	4,717	4,772	4,827





Virginia

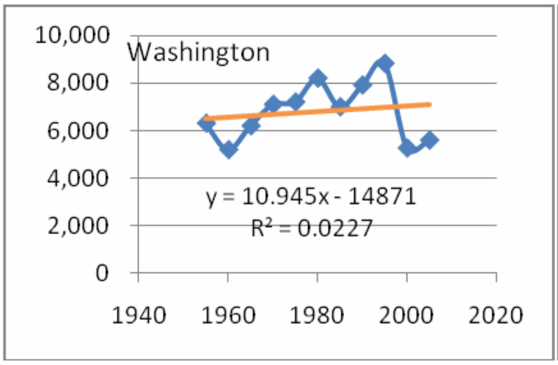
Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	1,562	4,100	4,100	4,700	4,900	5,600	4,870	4,710	5,470	5,200	7,080

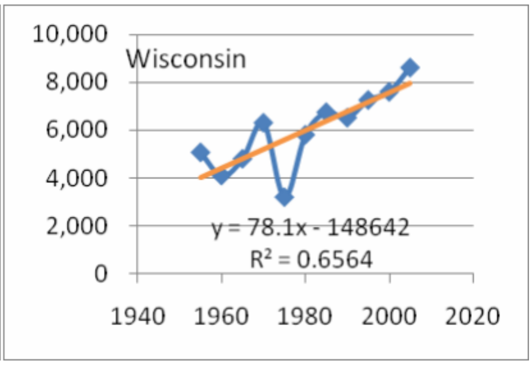
Year	2010	2015	2020	2025
Total(Mgal/d)	6,722	7,050	7,378	7,706

Washington

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	6,308	5,200	6,200	7,100	7,200	8,200	7,000	7,910	8,820	5,270	5,600

Year	2010	2015	2020	2025
Total(Mgal/d)	7,128	7,183	7,238	7,293





Wisconsin

Year	1955	1960	1965	1970	1975	1980	1985	1990	1995	2000	2005
Total (Mgal/d)	5,063	4,100	4,800	6,300	3,200	5,800	6,740	6,510	7,250	7,590	8,600

Year	2010	2015	2020	2025
Total(Mgal/d)	8,339	8,730	9,120	9,511

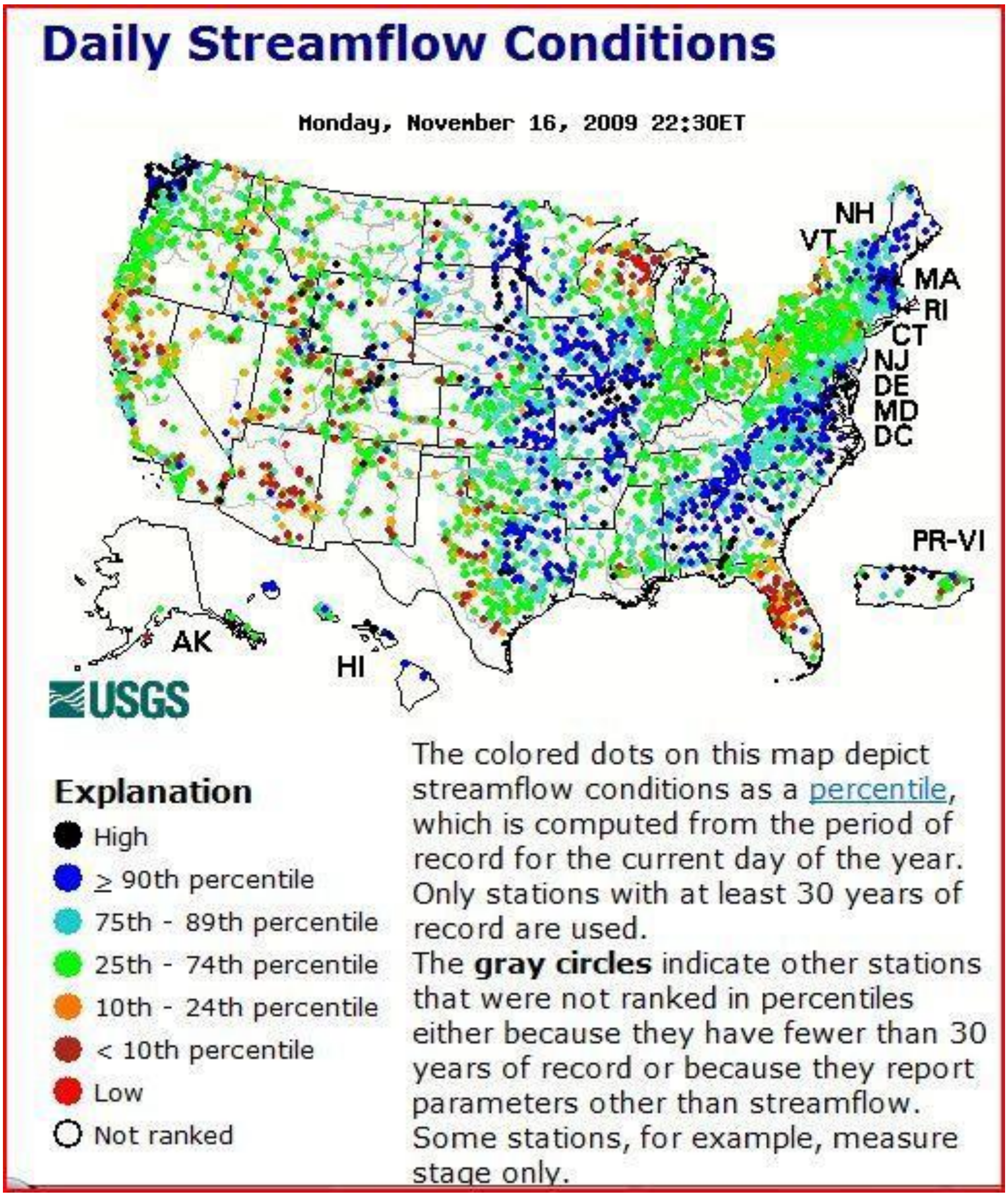
2.6 Evaluation

The regression analysis applied to the US state-level fresh water withdrawals has roughly shown the trend of the values from 2010 to 2025. It lays emphasis on the assumption of the steady development pace in all aspects. However, the results of the regression analysis are used to evaluate the water shortage level of a certain state or region with data accurate enough. Further research will base the regression analysis to a maximum extent.

3. Conservation, Efficiency, and Markets

3.1Water Transfer

3.1.1 Water Shortage and Demand Grading



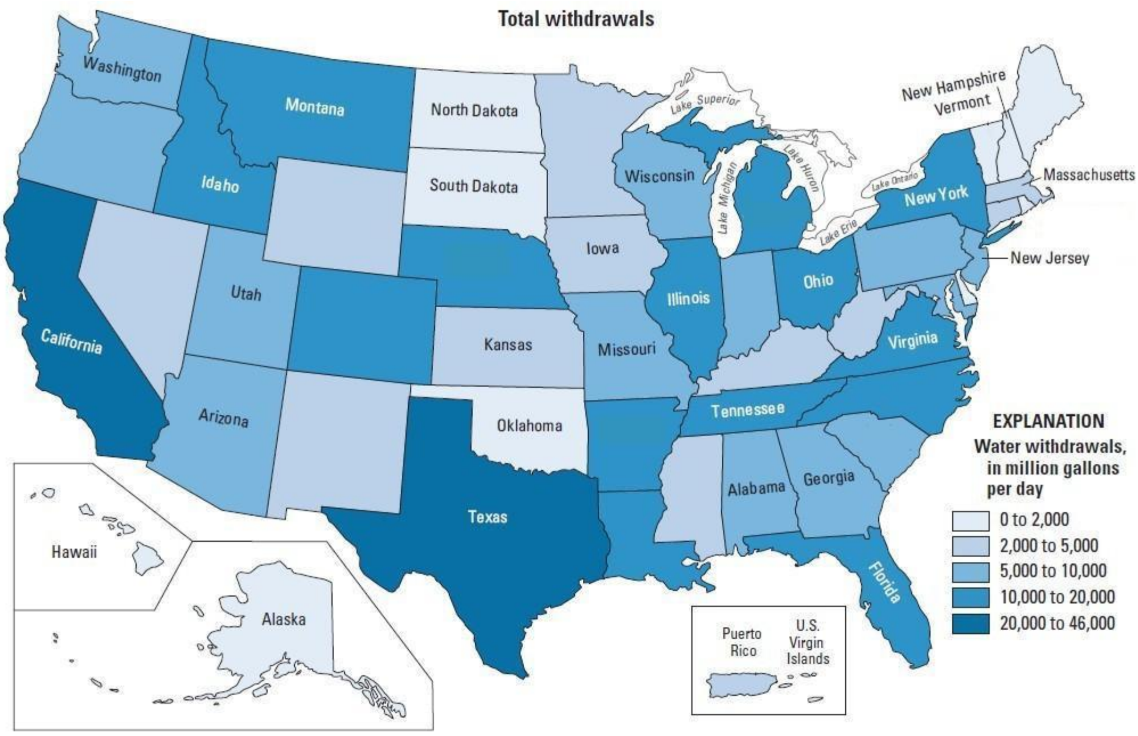
"The colored dots on this map depict stream flow conditions as a percentile, which is computed from the period of record for the current day of the year. Only stations with at least 30 years of record are used.

The gray circles indicate other stations that were not ranked in percentiles either because they have fewer than 30 years of record or because they report parameters other than stream flow. Some stations, for example, measure stage only."

After an overall data processing, we select 25 representative states to make our model penetrating and concise.

Water storage level

1 2 3 4 5



We develop a grading system to illustrate the comparative water storage and water demand.

Since it is hard to unify statistics with different standards, we apply percentage as a standard to the statistics.

Suppose

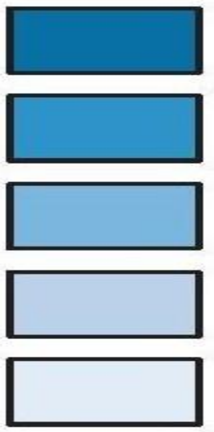
A	an average constant of US water acquisition per day
{N1,N2,N3,.....,Nn}	Water storage of each state (n=50)
P%	percentage of water consumption
H	water use level

P%=Nn/A

A=410000 mGAl/D (from historical water consumption data)

We find that the original ratio of two neighboring grades is 2, which means the coefficient k=2.

H= [log0.25 (Nk/A)]



Water use level

1

2

3

4

5

Total water level=water use level+ water storage level

High water use and low water storage leads to low water storage level. Consequently, Water problems mostly occur in states with low total water level.

	WATER USE LEVEL	WATER STORAGE LEVEL	TOTAL WATER LEVEL
CALIFORNIA	1	1	2
TEXAS(W)	1	1	2
FLORIDA	2	1	3
NEW YORK	2	2	4
MONTANA	2	2	4
IDAHO	2	2	4
ARIZONA	3	1	4
TENNESSEE	2	3	5
UTAH	3	2	5
WISCONSIN	4	1	5

	WATER USE LEVEL	WATER GAINED LEVEL	TOTAL WATER LEVEL
NORTH /SOUTH DAKOTA	5	4	9
NEW HAMPSHIRE	5	4	9
MASSACHUSETTS	4	5	9
IOWA	4	4	8
KANSAS	4	4	8
OKLAHOMA	5	3	8
MISSOURI	3	5	8
ALABAMA	3	5	8
WASHINGTON	3	5	8
ILLINOIS	2	5	7
GEORGIA	3	4	7
VIRGINIA	2	4	6
TEXAS(E)	1	4	5

3.1.2 Modeling-- Max Spanning Tree (MST)

Given that G = (V, E), (u, v) stands for the edge connecting point u and v($(u,v) \in E$), and w(u, v) stands for the weight of the edge.

$\exists T \subseteq E$ in a non-cyclic graph, and

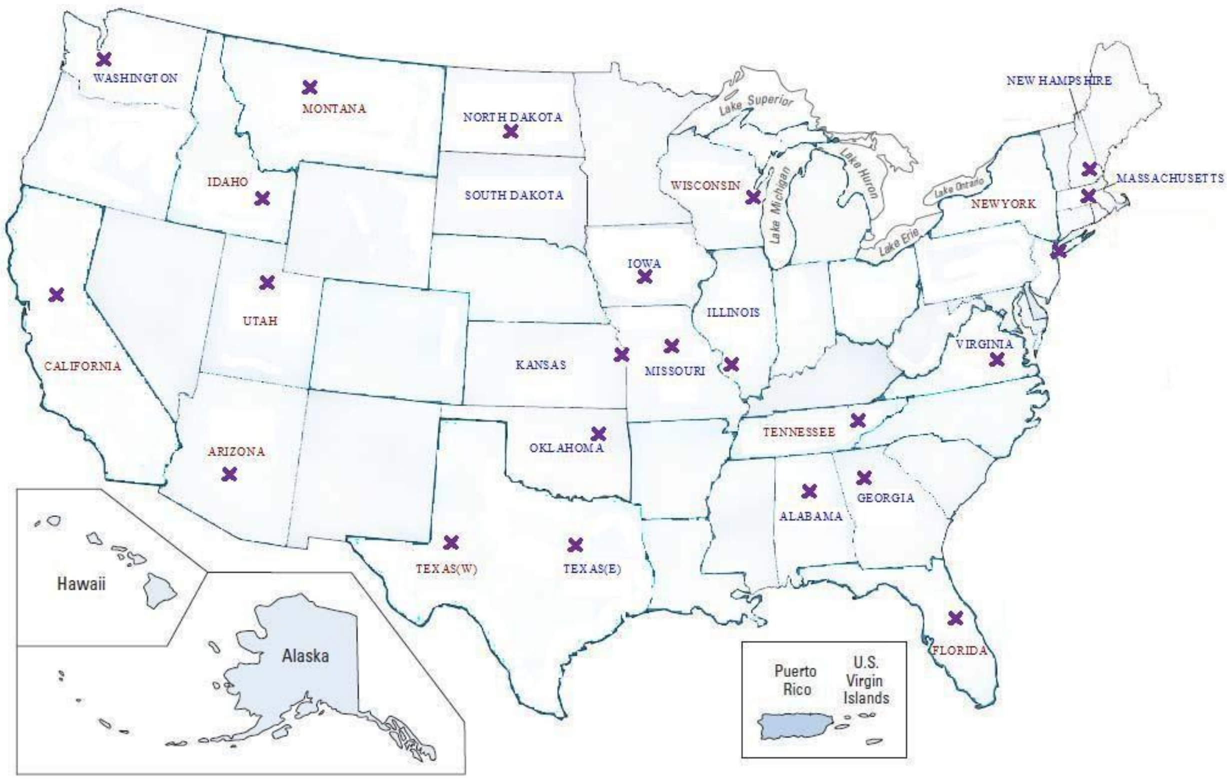
$$w(T) = \sum_{(u,v)\in T} w(u,v)$$

Both Prim's and Kruskal's algorithms are classic methods for MST models.
To regard states as particles, we choose from the above states major cities with high water supply or demand. We realize that these cities should maintain economic growth so as to distribute the transferred water to the rest area. As for water transfer within the states, the existing pipeline system within each state may serve the need.

We list the states and their core cities as follows:

CALIFORNIA	SACRENMANTO
TEXAS(W)	MIDLAND
FLORIDA	ORLANDO
NEW YORK	NEW YORK
MONTANA	GREAT FALLS
IDAHO	IDAHO FALLS
ARIZONA	PHOENIX
TENNESSEE	KNOXVILLE
UTAH	SALT LAKE CITY
WISCONSIN	GREEN BAY
NORTH /SOUTH DAKOTA	BISMARCK
NEW HAMPSHIRE	CONCORD
MASSACHUSETTS	WORCESTER
IOWA	DES MOINES
KANSAS	KANSAS CITY
OKLAHOMA	TULSA
MISSOURI	COLUMBIA
ALABAMA	BIRMINGHAM
WASHINGTON	SEATTLE
ILLINOIS	BELLEVILLE
GEORGIA	ATLANTA
VIRGINIA	RICHMOND
TEXAS(E)	DALLAS

Here is their location.



From our grading result and Figure, we can infer that western US faces serious water challenge while the central US have surplus water storage.

The Eastern states, though confronted with water shortage to some degree, are generally self-sufficient without large-scale water transfer.

1) North-eastern US (chiefly NEW HAMPSHIRE，MASSACHUSETTS, NEW YORK)

2)South-eastern US（chiefly ALABAMA, GEORGIA, FLORIDA ）

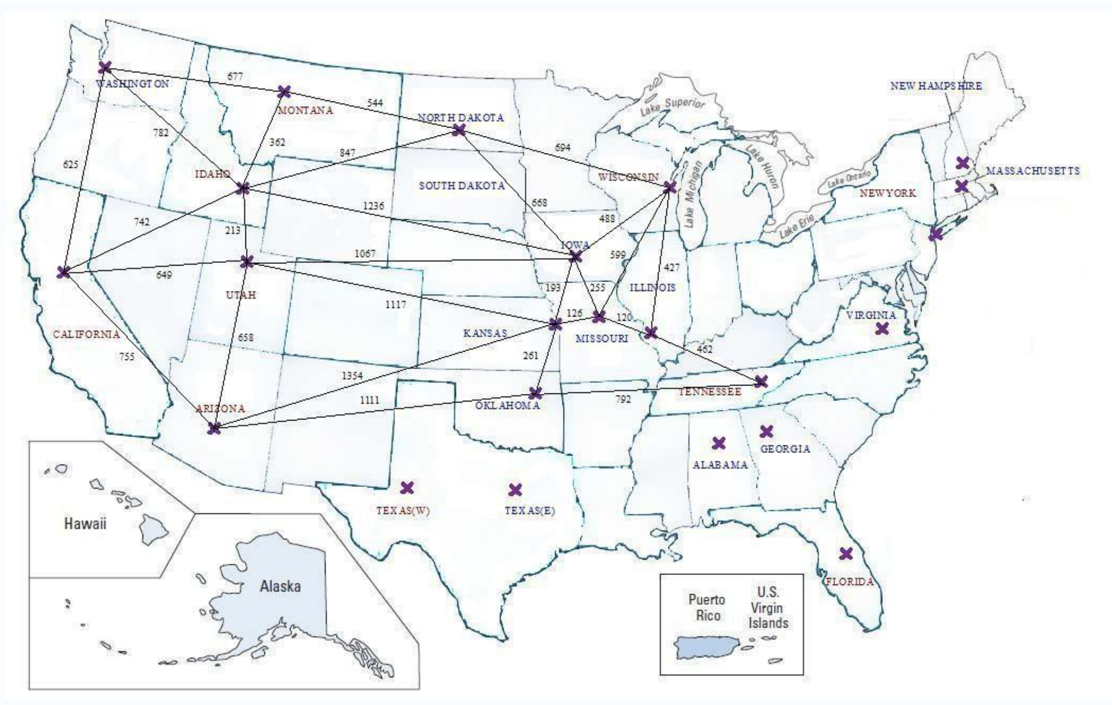
3) Southern US(chiefly TEXAS(E) TEXAS(W))

What is worth noting is that Texas has distinct water storage in its eastern and western region and thus is able to redress the balance by itself.

Blue letters are for water-surplus states and Red ones for water-deficient states.

According to the MST model, we draft a cyclic graph and mark the weight of each edge on the graph.

To simplify the problem, we connect the cities with straight lines. However, The statistics of distances between cities are the shortest transfer route in which twists and turns inevitably appear.

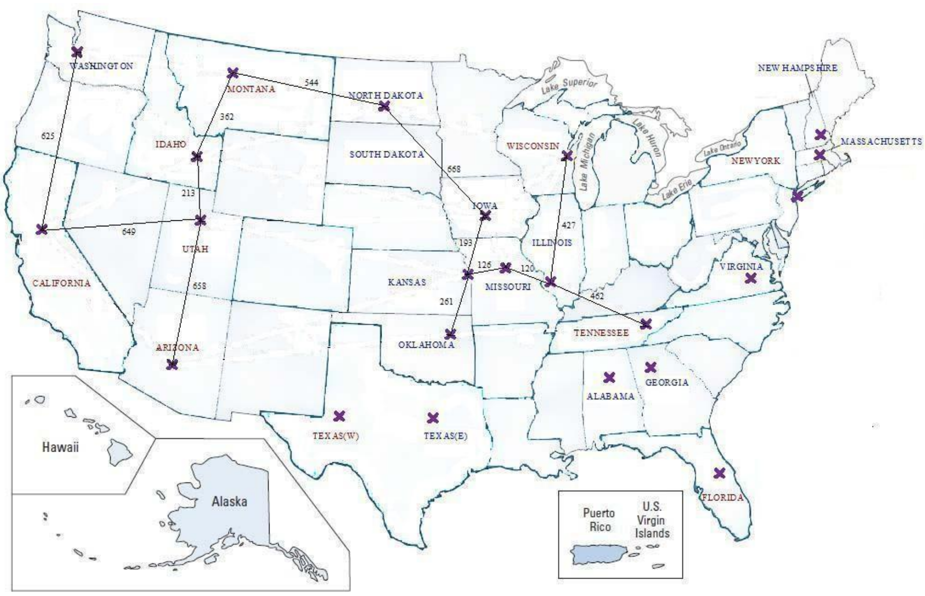


Distance statistics are taken from Google Map.

The 'safe edge' theory

```
GENERIC-MST-FUNCTION (G,w)
    T := Φ
    while T is not yet a 'tree'
    do look for a 'safe edge' (u, v) for T
    T := T U {(u, v)}
     return T
```

A 'safe edge' is generated each time.



We obtain a max spanning tree through calculation. The whole pipeline system is approximately 5308 miles. Deviation might be between （0,200） miles.

3.1.3 Transfer Cost

The South-to-North water diversion in China provides an expedient example for our water transfer model. In a 50-year period, the Chinese pipeline , measuring 3884 kilometers , requires an investment of 486 billion RMB.

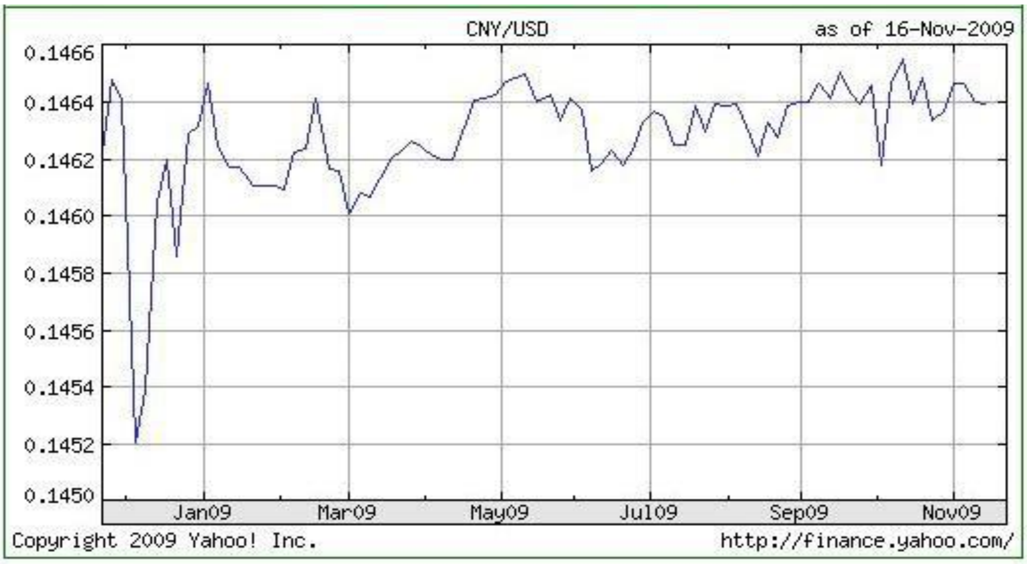
km.	mile
1	0.621382
1	0.621382

3884km≈2413.4477 miles

Estimated cost per year

∑=(5308/2413.4477*4860)/50=213.7761213.77617 billion RMB

Currency exchange chart in a year (CNY/USD)



Year	Exchange rate
1981	1.705
1982	1.8925
1983	1.9757
1984	2.327
1985	2.9366
1986	3.4528
1987	3.7221
1988	3.7221
1989	3.7651
1990	4.7832

1991	5.3233
1992	5.5146
1993	5.762
1994	8.6187
1995	8.351
1996	8.3142
1997	8.2898
1998	8.2791
1999	8.2783
2000	8.2784
2001	8.277
2002	8.277
2003	8.277
2004	8.2768
2005	8.1917
2006	7.9718
2007	7.604

The exchange rate of CYN to USD is expected to decline to 5.8 in 2015 and 2.8 in 2025. We are fully aware that financial problems can hardly be modeled, so we modestly regard it as 5.7.
Estimated cost per year is 213.7761/5.7=$37.505 billion.

3.1.4 Evaluation

Strengths:
The MST Modeling allows us to transfer between two places with the shortest route. If we calculate the costs by the whole route of 17824 miles, the costs will be
17824/2413.4477*37.505*0.1=27.6985 (billion USD)
In other words, our plan has lowered the capital cost to the maximum extent. We can spend 23.948 billion USD less than usual.
Weaknesses:
We lack considerations in the factors of roads, climate and so on. We have not adopted energy-efficiency methods. However, it does not affect our ultimate result.

3.2 Water Desalination

3.2.1 Assumptions and Justifications

1. The narrow regions planned for construction of desalination plants are able to rely totally

on desalinated water to meet water demand by 2025.

2. Barely any desalination plants of large scale have been put into use in the specific region by 2010.

3. The rise in water price caused by water desalination project is counted in the economic expenditure as it inevitably triggers equivalent economic impact on either consumers or the government.

3.2.2 Price, Sites and Methods

Variables

n	**the year n+2009**
Xn	treatment cost of desalination per thousand gallons in the year n

Treatment cost for water from current-generation advanced desalination in the U S is between $3 per thousand gallons (or up to 5-6 times more than 'conventionally treated' fresh water).

Prices

Cost structure of reverse-osmosis desalination

Electric power	44%	#
Fixed charges	37%	#
Maintenance and parts	7%	
Labor	4%	
Consumables	3%	

Among the treatment cost, electric power and fixed charges take the most significant percentage. Therefore, technological evolution/revolution in these two fields is most likely to result in a decline in treatment cost.

Marked change in cost can be seen after technological revolution takes place. According to historical data, water desalination cost has declined over time, albeit at a rate of only approximately 4% per year. In the short term (2010-2025), a constant 4% cut down on treatment cost is realistic.

year	sequence(n)	Xn
2010	1	3$ per thousand gallons
2011	2	
……		
2025	15	

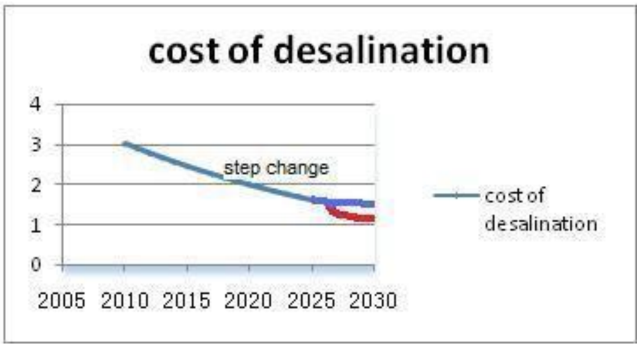
X1=3

X2=x1*(1-4%)
X3=x1*(1-4%)^2 ……

We can easily conclude that $\{x_n\}$ is a monotonically decreasing geometric sequence.

x_n=x_1*(1-4%)^(n-1)

Year	Xn
2010	3
2011	2.88
2012	2.7648
2013	2.654208
2014	2.54804
2015	2.446118
2016	2.348273
2017	2.254342
2018	2.164169
2019	2.077602
2020	1.994498
2021	1.914718
2022	1.838129
2023	1.764604
2024	1.69402
2025	1.626259



A step change in price is expected to occur in the long term.

Sites

1) Coastal regions with power plants

As High transportation cost adds to the cost of desalinated water, coastal regions with high economic growth are the priority of our choice.

Definition: Coastal regions------regions less than 20 kilometers from the coast where transportation cost can be neglected.

2) Arid Southwest areas where water demand is high

Esp. areas with fossil energy production

Large volumes of saline or brackish water are commonly co-produced in oil and gas production. Using desalination technologies to treat this water may offer oil-producing areas a beneficial use for this water.

Considering all the factors above, we demonstrate desalination plant sites in the following map.

Desalination Methods:

Multiple-effect evaporation

Vapor-compression distillation

Flash evaporation

Freezing

Reverse osmosis

Electro dialysis

From the data we consulted, we find the above desalination methods share the most favorable characteristics:

Comparatively widely used

Acceptable in cost

Moderately efficient

3.2.3 Modeling

Cf	Average construction fee of a desalination plant	\$300*million*
Wp	Water production by a desalination plant per day	50million *gallons per day*
Nn	number of plants to be constructed in the year n	

P	average water price in the current US	*$1.5 per thousand gallons*

In the year n,

Economic expenditure
= Cf*Nn+(Xn-P)/1000 *Wp*365*Nn (dollars)

=300m*Nn+$((3*(1-4\%))^{\wedge}(n-1)-1.5)/1000*50m*365*Nn$

=min

Water shortage resolved= Wp*365*Nn=50m*365*Nn (gallons)

Water demand in related regions in 2025=Wp*365* $\sum_{k=1}^{n} Nk$=5,000m*365

By consulting our prediction of 2025 water demand, we roughly estimate the 2025 water demand in the chosen regions at 20,000 million gallons per day.(almost 1/8 of California's water demand)

$\sum_{k=1}^{n} Nk$=100

$\sum$ economic expenditure=

$\sum_{k=1}^{n} N_n$*300m+$\sum_{k=1}^{n}((3*(1-4\%))^{\wedge}(n-1)-1.5)/1000*50m*365*Nn$

=min

Obviously minimum economic expenditure is achieved when

Nn=$\sum_{k=1}^{n} N_n$ N_{16}=$\sum_{k=1}^{n} N_n$=100

Ee=30354 million
Economic expenditure per yr=30354/16=$18.97 billion

As the economic expenditure is undertaken by markets, government and consumers, it can also be viewed as the quantitative economic impact of water desalination.

3.2.4 Impact

1. economic impact--$18.97 billion per yr
2. Cultural and environmental impact

Desalinated water mainly targets domestic water use and has very little environmental impact on related regions. Yet the construction of desalination plants might bring about pollution if not well managed.

3. physical impact

In this model, the major physical impact on water consumers is the water demand resolved via desalination.

2025--1,825,000 million gallons

3.3 **Water Price Rise of Domestic Water**

3.3.1 Introduction

The average price of water in the United States is about $1.50 for 1,000 gallons.

The supply-demand theory indicates that prices change with the fluctuations of supply and demand. It is common for the government to raise water price for domestic water conservation. Yet there exists a water price cap, which to some extent restricts the macro regulation.

We build a blurred water price model to calculate the cap.

The model consists of two parts: estimation and calculation----estimation evaluates the accuracy of water resources; calculation indicates the value of water resources.

3.3.2 Water Value Modeling

Suppose the vector X={X1, *X*2 ,...... *Xn* } represents evaluation factors, the vector W=(HH, H, M, L, LL) represents evaluation degree(to be specific, extremely high, high, medium, low, extremely low)

V=A○R

V---evaluation value of water A---

weight of each factor

○---operation of a blurred matrix, usually“^”

R---evaluation matrix formed by matrixes $_1X$, $_2X$,...... $_nX$

$$R=\begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ \cdots\cdots \\ R_n \end{bmatrix}=\begin{bmatrix} R_{11} & R_{12} & R_{13} & R_{14} & R_{15} \\ R_{21} & R_{22} & R_{23} & R_{24} & R_{25} \\ R_{31} & R_{32} & R_{33} & R_{34} & R_{35} \\ \cdots\cdots & \cdots\cdots & \cdots\cdots & \cdots\cdots & \cdots\cdots \\ R_{n1} & R_{n2} & R_{n3} & R_{n4} & R_{n5} \end{bmatrix}$$

K_{ij}---evaluation value of factor i in the grade j （i=1，2，……n；j=1，2，……n

We set a vector L=（1，2，3，4，5）
And I=V·L
I---blurred index of water value V---
evaluation value
L---vector of evaluation grades

The higher I is, the more abundant water resources a region possess and the lower V is. Vice versa.

3.3.3 Water Price Modeling

W---water cost
S---the vector of water cost
W =V · S

S=（P ，P1， P2 ，P3 ，0）
P---the highest water price affordable
Arithmetic progression of P, P1, P2, P3 composes S.

P=B×E/C－D

B---endurance index(of P) =max{water expenditure/income}

When a situation with endurance index>B occurs , people's mental conditions and behaviors will be unusually interfered. Typical symptoms include discredibility towards government and protests. Normally B includes both physical and mental aspects. We revise the economic endurance index in some other models and propose a water price endurance index for our research.

E---average income
C---water consumption
D---cost for water supply

3.3.4 Water Price Calculation

To determine factors and parameters of the model, we insist efficiency and typification as our principle.
Here we use water quality, storage, GDP and population density as factors for evaluation and water cost as a parameter.

3.3.5 Comprehensive Evaluation of Water Value

1 Evaluation of water quality

After combining the matrix with weight, we evaluate the water quality as
（0.53，0.014，0.075，0.25，0.25）
We use MATLAB to normalize the result and get
R_1 ＝（0.0825，0.0218，0.1168，0.389，0.389）

2 Evaluation of water storage

Consulting the evaluation level of average water storage in the US, we get
R_2 ＝（0.082，0.918，0，0，0）

3 Evaluation of population density and GDP per capita

Likewise, The blurred relation between population density and GDP can be expressed as follows:
R_3 ＝（0，0.47，0.53，0，0）
R_4 ＝（0.948，0.052，0，0，0）

Then we get the evaluation matrix:

$$R = \begin{bmatrix} R_1 \\ R_2 \\ R_3 \\ R_4 \end{bmatrix} = \begin{bmatrix} 0.0825 & 0.0218 & 0.1168 & 0.389 & 0.389 \\ 0.082 & 0.918 & 0 & 0 & 0 \\ 0 & 0.47 & 0.53 & 0 & 0 \\ 0.948 & 0.052 & 0 & 0 & 0 \end{bmatrix}$$

Through research and data collection, we decide A=（0.30，0.40，0.15，0.15）
S
$$V = A \circ R = (0.30\ 0.40\ 0.15\ 0.15) \circ \begin{Bmatrix} 0.0825 & 0.0218 & 0.1168 & 0.389 & 0.389 \\ 0.082 & 0.918 & 0 & 0 & 0 \\ 0 & 0.47 & 0.53 & 0 & 0 \\ 0.948 & 0.052 & 0 & 0 & 0 \end{Bmatrix}$$
＝（0.15，0.40，0.15，0.30，0.30）
The normalized result is （0.115，0.308，0.115，0.231，0.231）
So I＝V·L=(0.115，0.308，0.115，0.231，0.231)·(1，2，3，4，5)＝3.155

3.3.6 US Water Price Cap Calculation

E---Average income of US citizens $24,000 per yr
C---Average domestic water use(cubic metre)

1gallon = 0.00378541178 m^3

36500gallon per capita=138cubic meters per capita per yr

D---Cost for water supply
$0.75 per thousand gallons=$2.8 per cubic meter
Endurance index B=0.06
P=B×E/C—D=0.06×24000/138—2.8=7.63

We introduce an arithmetic sequence of P to depict S. The difference is P/4=1.9075

S=（P ， P1 ， P2 ， P3 ， 0）=（7.63，5.7225，3.815，1.9075，0）

W =(0.115，0.308，0.115，0.231，0.231)·（2.42，1.815，1.21，0.605，0）
=$3.5 per cubic meter

Water price (3.5+2.8)/3.7854=$1.67
（http://www.cenet.org.cn/userfiles/2008-11-9/20081109223820362.pdf）

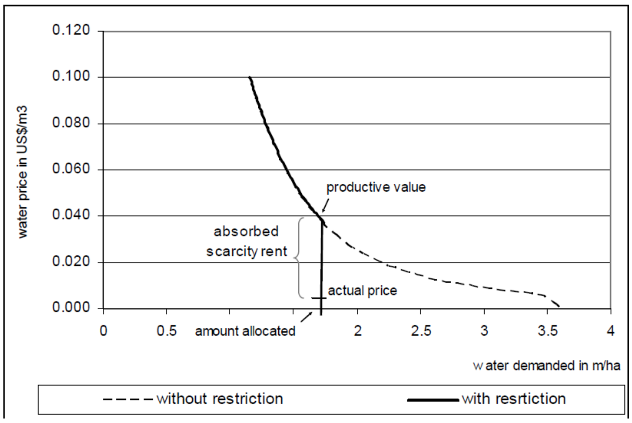
3.3.7 Conclusions and Suggestions

$$\frac{1.67-1.5}{1.5}*100\%=11.3\%$$

The current average water price for domestic use in the US is $1.5 per thousand gallons. Yet from analysis above, the highest water price affordable can reach $ 1.67, which suggests certain potential for a rise in water price is feasible.

3.3.8 Impacts

Water price reduction → **Water conservation**



4. Improved Technology

4.1 Remote Sensing Techniques (RST)

Not only can remote sensing technique help observe the characteristics and changes in water body itself, but also provide comprehensive information of the surrounding geographic conditions and the impacts of human activities. It assists the researches on the relationship of natural environment and water to further acknowledge the changing laws of water in nature.

Also, remote sensing technique offers much more comprehensive, detailed and accurate information than is obtained by other measures of natural environment dynamic supervision, which plays a vital role in water management and researches of global water cycle and water balance.

Distribution, size, capacity and water quality of the surface water, along with those of ground water, can be measured by remote sensing technique. It can also show perfect water distribution map to control the total available sea water content to optimize water use structure.

4.2 Geographic Information System (GIS)

Geographic Information process system has regional, multi-latitude and dynamic characteristics. Global information can be divided into 5 levels: super-short term (typhoon and earthquake), short term (river, flood and low temperature in fall), medium term (ground utilization and agricultural products estimation), long term (urbanization and soil and water loss) and super-long term(crust movement and climate change). To control floods and soil and water loss will increase the adjustment space of the United States to optimize the US water use plan.

4.3 Supervisory Control and Data Acquisition (SCADA) System

Concerning that irrigation water use accounts for 31% of the total fresh water withdrawals in 2005, ranking only after thermoelectric water use, we find it extremely vital to improve water management for irrigation. The major loss in water for irrigation occurs when the projected region is fully irrigated and extra water is still coming down. This loss is mainly caused by defects in water measuring devices, which includes inaccuracy and lack of timeliness.

Nowadays supervisory control and data acquisition system is very popular in electricity management system, which boasts open platforms with multi-windows technology, access to GIS geographic graphs and data, topological analysis and distributed network. Similarly, SCADA system will bring great improvement to water management system.

In addition to working for irrigation delivery systems, SCADA system can also help supervise regional water conditions and determine water conservation and movement.

We prefer the SCADA system to function as follows to meet the needs of water management.

A. Data Acquisition(DA)
SCADA system collects timely data and information of water current, irrigation process, water level and weather conditions and color the screen dynamically to show the facilities' operational state. SCADA system for irrigation is preferred to connect all the local measuring stations together with GPS, GIS, meteorological observatories and hydrological research agencies.

B. Alarm
SCADA system sends alarms out when water level is about to exceed a certain height or when some accidents are happening. Alarms are divided into two levels: I represents omen, II shows accident. The bounds are set based on regional conditions specifically.
Ways of warning include flashing warnings, showing on alarming charts and printing out the condition and sound warning to catch manager's attention.

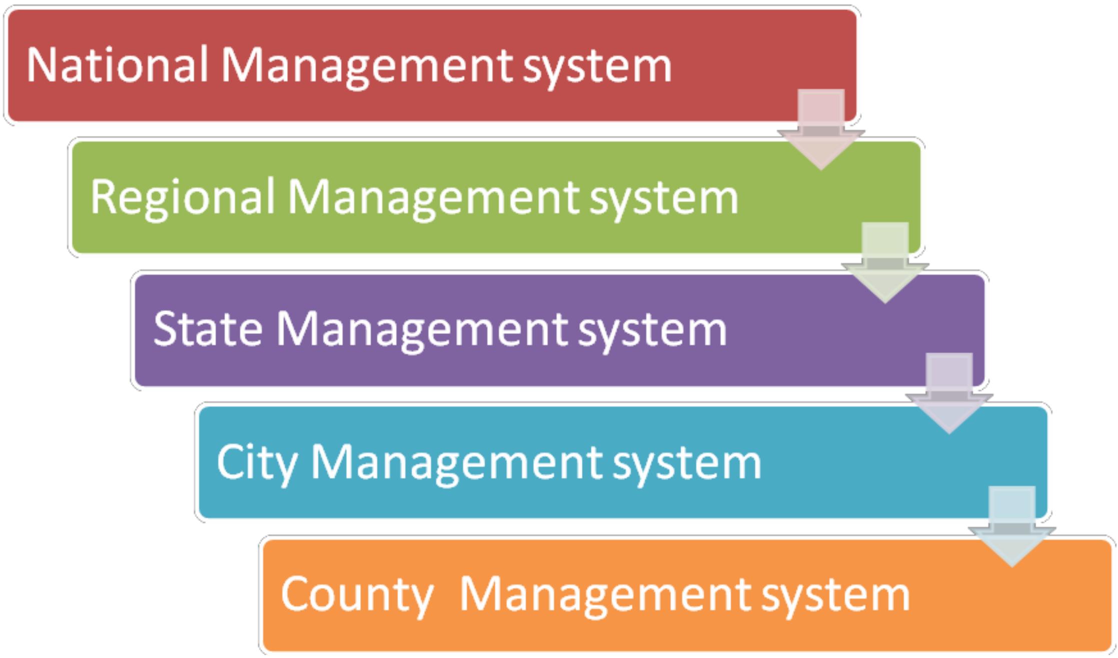
C. Control
Remote controls are operated by the following two ways: Check Back Before Execute and Direct Execute. The former one is used to deal with accidents, while the latter one is set for the immediate reaction of full irrigation.

D. Calculation
Calculation of SCADA system functions to estimate the irrigation process. If the alarm system does not work properly, the system ought to caution the control system or the manager when the projected time is up.

E. History and Report
The data of water current, irrigation process, water level and weather conditions are often collected once a minute, which requires that the water measuring devices should collect the water level data once a minute 10 seconds prior to the SCADA system collection node. It calculates the mean of the respective data and graphs the data once 10 minutes. The system lumps the data together once a day. It not only helps collect the timely data, but also provides exact history data for system of dispatch and decision maker for future use.

F. Clock
The system requires great accuracy in time. Thus an extra clock is needed.

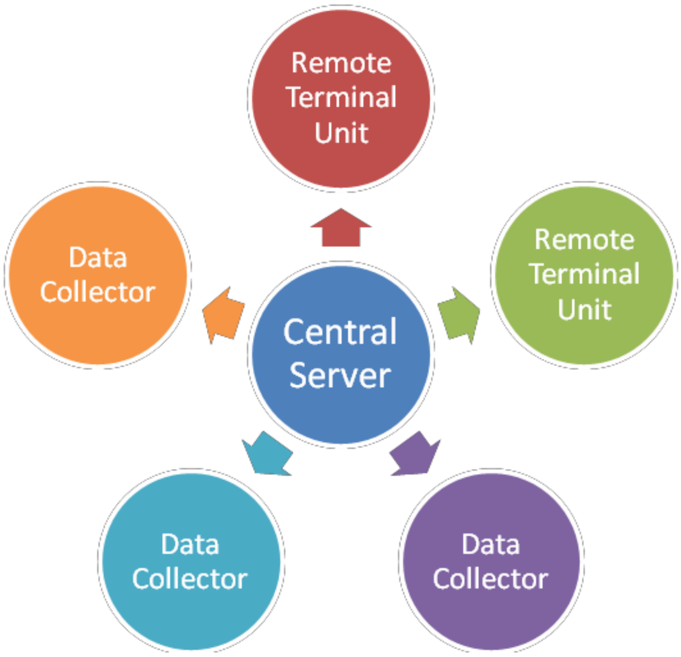
For further application of the SCADA system to fresh water conservation and movement process, we prefer graded control and management and unified dispatch, as is shown roughly in the following graph:



Unified dispatch and graded control and management represents a whole fresh water management system while unified dispatch is based on graded control and management. And graded control and management is for more efficient and effective unified dispatch, which improves the reliability and reaction time of the whole system, the decision-making system in particular.

As for the United State, we can install a rudimentary SCADA system in each water-rich or water-poor region, as is shown in the graph above, and central severs in both Utah and Texas in the West and New York in the East, where transportation is very busy. We may establish a central supervisory department in the pivot of the US water transportation to maintain the perfect operation of the whole SCADA system.

The communication pattern of SCADA system is shown as follows:



It currently boasts the advantage of unmanned operation and the optimization of water resource.

The connection of SCADA system and MIS, Geographic Information System, Automatic Water Dispatch System, Automatic System of Dispatch and Production, and Automatic Office System has become a major trend of the SCADA system's development.

4.4 Water Purification

We prefer the way of generating electric power from the marsh gas, which integrates environmental protection and energy economizing. It makes use of the marsh gas from the industrial waste water fermentation. Its generating efficiency can reach approximately 80%, which is also a great way of industrial water purification.

To transfer the urban waste water caused by human living for purification it by the suburban large ground is a great way of water purification.

Take a medium-sized city which supplies 1 million cubic meters of water daily as an example:

Normal waste water purification facilities cost 150 USD per cubic meter. The capital cost of the establishment is 0.15 billion USD. The operation cost per year is 1 million/day ×365days×0.07USD/cubic meter=25.55 million USD

The establishment of ground purification costs 150 USD/cubic meter. The operation cost per year is 1 million/day ×365days×0.015USD/cubic meter=547.5 million USD.

Thus we consume 0.36 billion cubic meter agricultural water less per year, 10 thousand tons of fertilizer less per year and 5 tons of pesticides less per year. The overall benefits are considerable.

5 Analytical Hierarchy Process of Impacts Evaluation

5.1 Introduction and Restatement

Analytic Hierarchy Process (AHP) is an approach to decision making that involves structuring multiple choice criteria into a hierarchy, assessing the relative importance of these criteria, comparing alternatives for each criterion, and determining an overall ranking of the alternatives.

By organizing and assessing alternatives against a hierarchy of multifaceted objectives, AHP provides a proven, effective means to deal with complex decision making. In this model, we use AHP to allow a better, easier, and more efficient identification of factor criteria, their weighing and analysis.

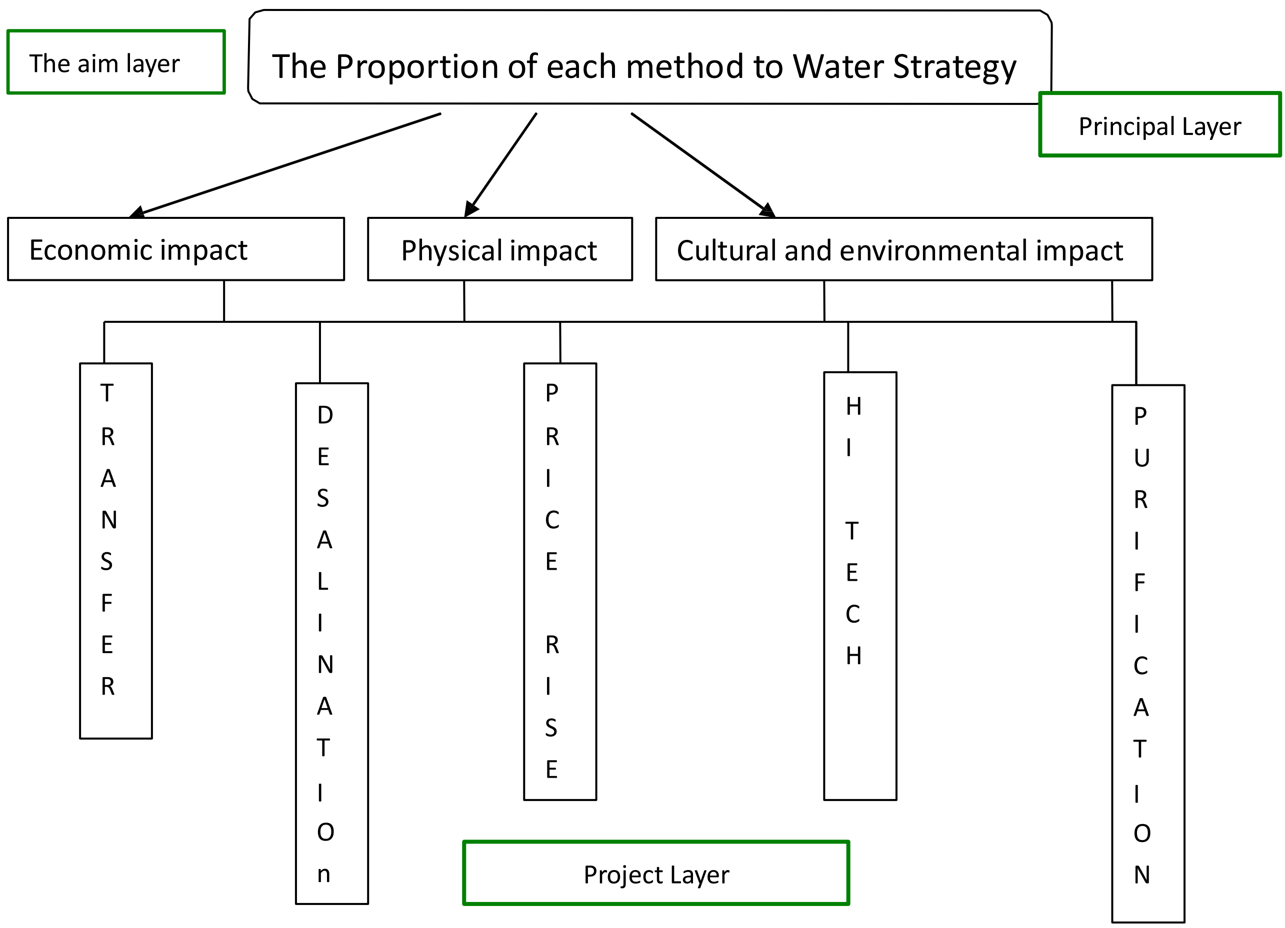
5.2 Variables

Variables	
A，B1，B2，B3	The Comparison Matrix
n，m	The Exponent Number of A，B
Aw	The Vector of Weighing
Bw1	Weighting of Economic Impact
Bw2	Weighting of Physical Impact
Bw3	Weighting of Cultural and Environmental Impact
CR	Coherent Ratio

5.3 Procedure I: Draw the Hierarchy Image

This is the partial application of AHP, where we aim at determining the weighing of each factor.

The Hiberarchy Image



5.4 Procedure II: Construct a Comparison Matrix

Principal:

Relative importance	Grade
Equally Important	1
Generally more Important	3
Far more Important	5
More Important at the second highest degree	7
More Important at the highest	9

degree	

Note:

1) 2， 4， 6， 8 represents the importance level is in between according to the chart.

2) The reciprocal value is used to express ‘Less important’

A. Principle layer

Explanation for importance grade:

Factors include: economic, physical, cultural and environmental impacts.

1) Economic impact is namely the economic expenditure of the project.($)

2) Physical impact refers to the water shortage solved or conservation reserved by the project. (gallons)

3) Cultural and environmental impact can hardly be measured by precise data, yet they do play a role in decision-making.

The weighing result is as follow:

	Economic impact	Physical impact	Cultural and environmenta impact
Economic impact	1	9/7	9/4
Physical impact	7/9	1	7/4
Cultural and environmental impact	4/9	4/7	1

B. Project layer

Due to the complexity of calculation in this layer, we basically grade the value in the matrixes as:

Factors	Economic impact	Physical impact	Cultural and environmental impact
Transfer	10	10	6
Desalination	6.5	8.5	4
Price rise	1.5	1	3
Hi-Tech	5	3	5
Purification	3	1.5	6

*Note: Though we omit units of all the data, the grades we provide are all acquired from the above models. To make program processing easier, we use grades to depict the comparative amount of impact.

5.5 Procedure III: Calculation of The Vector of Weighing and Coherence Check

A. Calculation of The Vector of Weighing

A=

$$\begin{pmatrix} 1 & 9/7 & 9/4 \\ 7/9 & 1 & 7/4 \\ 4/9 & 4/7 & 1 \end{pmatrix}$$

n=3

After the standardization of eigenvector,

The Vector of Weighing is acquired.

B. Coherence Check

Calculated by Matlab,

$$CR = \frac{CI}{RI}$$

Table of the RI V

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.901	[illegible]	1.24	1.32	1.41	1.45

Through calculation by MATLAB

CR< 0.1

So the coherence of the matrix is qualified.

5.6 Procedure IV: Hierarchy total taxis and coherence check

A. Hierarchy total taxis

After the standardization of eigenvector, apply the algorithm to generate Bw1, Bw2, Bw3, in each of the project; the proportion of each project in the whole 2025Water Strategy:

$$Bws=\begin{Bmatrix} Bw1 \\ Bw2 \\ Bw3 \end{Bmatrix}$$

Importance=Aw*Bws

B. Coherence Check

Hierarchy	A_1 $A_2 \ldots A_m$ a_1 $a_2 \ldots a_m$				Hierarchy total taxis
B_1	$b^{(1)}{}_1$	$b^{(2)}{}_1$		$b^{(n)}{}_1$	$\sum_{i=1}^{m} a_i b_1^{(i)}$
B_2	$b^{(1)}{}_2$	$b^{(2)}{}_2$		$b^{(n)}{}_2$	$\sum_{i=1}^{m} a_i b_1^{(i)}$
⋮	⋮	⋮	⋮	⋮	⋮
B_n	$b^{(1)}{}_n$	$b^{(2)}{}_n$		$b^{(n)}{}_n$	$\sum_{i=1}^{m} a_1 b_n^{(i)}$

$$CR=\frac{a_1CI_1+a_2CI_2+\cdots+a_mCI_m}{a_1RI_1+a_2RI_2+\cdots+a_mRI_m}$$

Through calculation by MATLAB

CR <0.1

So the coherence of the matrix is qualified.

5.7 Results

method	Importance sequence (High to Low)
Water transfer	1
Water desalination	2
Water price rise	5
Hi-tech Method (SCADA)	3
Water Purification	4

5.8 Evaluation

Strengths

1. Uses of scientifically methods as simulation, AHP that enables the outcome to be relatively objective and reasonable.
2. Factors of impacts are taken into consideration to make the problem fully discussed and can ensure the result to be reasonable.
3. By AHP, we decide importance of each method and might be able to adjust the distribution and implement timeline with regard to the result.

Weaknesses

1. The precision of AHP is relatively low
2. Due to time limit, we introduce the concept of grading to vaguely model the data of impacts.

6 Appendix

6.1Reference

1. *ESTIMATED USE OF WATER IN THE UNITED STATES IN 1955 (1960, 1965, 1970, 1975, 1980, 1985, 1990, 1995, 2000, 2005) published by* ***U.S. Department of the Interior*** and ***U.S. Geological Survey*** as US GEOLOGICAL SURVEY CIRCULAR 398, 456, 556, 676, 765, 1001, 1004, 1200, 1268, 1344
2. http://www.cenet.org.cn/userfiles/2008-11-9/20081109223820362.pdf）
3. *WATER 2025: PREVENTING CRISES AND CONFLICT IN THE WEST* published by ***U.S. Department of the Interior and Bureau of Reclamation***
4. ***ESTIMATING WATER USE IN THE UNITED STATES: A NEW PARADIGM FOR THE NATIONAL WATER-USE INFORMATION PROGRAM*** published by ***Committee on USGS Water Resources Research, National Research Council***
5. ***WATER.USGS.GOV***
6. ***WIKIPEDIA***

6.2Program

Program for AHP

```
n=3;
A=[1,9/7,9/4;5/9,1,7/4;4/9,4/7,1];
[x,y]=eig(A);
p=max(y);
Amax=max(p);
CI=(Amax-n)/(n-1);
RI=0.901;
CRA=CI/RI;
if CRA>=0.1
    disp('wrong')
    return
end
disp('right')
wa1=sum(A);
for i=1:n
    for j=1:n
        wa2(i,j)=A(i,j)/wa1(j);
    end
end
```

6.3 Position Paper for the United States Congress

To whom it may concern:

The 2025 Water Strategy may include the following five aspects:

A water transfer system that transport water from water-sufficient regions (mainly the Midlands) to the arid Southwestern regions, especially during the predicted 2018 and 2025 droughts;

A water desalination program to encourage desalination plants to be constructed in favorable coastal area and therefore to resolve water shortage;

Hi-tech methods such as SCADA system applied to macro structuring and supervision of water use;

Water purification sites ensured to redress the balance of nature and meanwhile to advance the efficiency of water use;

Water price moderately rose to realize water conservation of domestic water use through price leverage.

Why choose our model?

Our model takes insightful look into the most technological and feasible methods. We base our decision on precise calculation and analysis of every single listed method. Mathematical model is applied in the detailed implement plan whilst economic, physical, cultural and environmental impacts are all foreseen. Experience from other countries and past measures is also taken into consideration.

The future of US lies in your hand. You won’t regret.

Yours sincerely,
Team 2239
2009-11-22