11.0 References

Addy, K., Gold, A., Christianson, L., David, M., Schipper, L., Ratigan, N. (2016). Denitrifying bioreactors for nitrate removal: A meta-analysis. *Journal of Environmental Quality* 45:873-881.

Allen, Y. (2016). Remote sensing of the North Joyce Wetlands from 1952 to 2015. Wetland Assimilation Workshop: October 25-26, 2015. Hammond Louisiana.

Anisfeld, S., Hill, T. (2011). Fertilization effects on elevation change and belowground carbon balance in a Long Island Sound tidal marsh. *Estuaries and Coasts* (2011).

Blahnik, T., Day, J. (2000). The effects of varied hydraulic and nutrient loading rates on water quality and hydrologic distributions in a natural forested treatment wetland. *Wetlands* 20:48-61.

Bodker, J., Turner, R., Tweel, A., Schulz, C., Swarzenksi, C. (2015). Nutrient-enhanced decomposition of plant biomass in a freshwater wetland. *Aquatic Botany* 127(2015) 44-52.

Boscareno, J. (2009). *The Rise and Fall of the Louisiana Muskrat, 1990-1960: An Environmental and Social History*. University of New Orleans, Louisiana, USA.

Brantley, C., Day, J., Lane, R., Hyfield, E., Day, J. (2008). Primary production, nutrient dynamics and accretion of a coastal freshwater forested wetland assimilation in Louisiana. *Ecological Engineering* 31:477-491.

Breaux, A., Day, J (1994). Policy considerations for wetland wastewater treatment in the coastal zone: A case study for Louisiana. *Coastal Management* 22, pp. 285-307.

Brown, S. (1981). A comparison of the structure, primary productivity and transpiration of cypress ecosystems in Florida. *Ecological Monographs* 51(4) 403-427.

Conner, W., Toliver, J., Sklar, F. (1986). Natural regeneration of baldcypress (*Taxodium distichum*) (L.) Rich.) in a Louisiana swamp. *Forest Ecology and Management* 14:305-317.

Conner, W., Day, J. (1988). Rising water levels in coastal Louisiana: Implications for two forested wetlands in Louisiana. *Journal of Coastal Research* 4:589-596.

Conner, W., Day, J. (1991). Variations in vertical accretion in a Louisiana swamp. *Journal of Coastal Research* 7(3):617-622.

Conner, W. (1995). Cypress regeneration in coastal Louisiana and the impact of nutria upon seedling survival. Proceedings of the 13th Annual Conference, Society of Wetland Scientists. New Orleans, Louisiana, pp. 130-136.

Conner, W., Duberstein, J., Day, J. (2014). Impacts of changing hydrology and hurricanes on forest structure and growth along a flooding/elevation gradient in a south Louisiana forested wetland from 1986 to 2009. *Wetlands* (2014) 34:803-814.

Copenheaver, C., Matiuk, J., Nolan, L., Frank, M., Block, P., Reed, W., Kidd, K., Martini, G. (2017). False ring formation in bald cypress (*Taxodium distichum*). *Wetlands* (2017) 37:1037-1044.

CWPPRA (2003). Coastwide nutria control program (LA-30b) fact sheet. Coastal Wetland Planning, Protection and Restoration Act Task Force.

Darby, F., Turner, R. (2008a). Below- and aboveground biomass of *Spartina alternifolia*: Response to nutrient addition in a Louisiana salt marsh. *Estuaries and Coasts*: J CERF (2008) 31:326-334.

Darby, F., Turner, R. (2008b). Effects of eutrophication on salt marsh root and rhizome biomass accumulation. *Marine Ecology Progress Series*. Vol. 363: 63-70.

Darnell, R. (1962). Ecological history of Lake Pontchartrain, an estuarine community. American Midland Naturalist, 68, 434-444.

Day, J., Shaffer, G., Britsch, L., Hawes, S., Reed, D., Cahoon, D. (2000). Pattern and process of land loss in the Mississippi delta: A spatial and temporal analysis of wetland habitat change. Estuaries (2000) 23:425-438.

Day, J., Ko, J-Y., Rybczyk, J., Sabins, D., Bean, R., Berhelot, G., Brantley, C., Cardoch, L., Conner, W., Day, J., Englande, A., Feagley, S., Hyfield, E., Lane, R., Lindsey, J., Mistich, J., Reyes, E., Twilley, R. (2004). The use of wetlands in the Mississippi Delta for wastewater assimilation: A review. Ocean & Coastal Management 47 (2004) 671-691.

Day, J., Boesch, D., Clairain, D., Kemp, G., Laska, S., Mitsch, W., Orth, K., Mashriqui, H., Reed, D., Shabman, L. (2007). Restoration of the Mississippi Delta: Lessons from Hurricanes Katrina and Rita. *Science* (2007) 315:1679-1684.

Day, J., Shaffer, G., Hunter, R., Wood, B., Lane, R., Lundberg, C., Day, J., Hunter, M. (2011). An analysis of the Hammond Assimilation Wetland: System response, nutria herbivory and vegetation recovery. June 2011. https://saveourlake.org/wp-content/uploads/PDF-Documents/our-coast/Hammond-WW-White-Paper-Day-June-2011.pdf

Day, J., Hunter, R., Keim, R., DeLaune, R., Shaffer, G., Evers, E., Reed, D., Brantley, C., Kemp, P., Day, J. (2012). Ecological response of forested wetlands with and without large-scale Mississippi River input: Implications for management. *Ecological Engineering* 2012 46:57-67.

Day, J., Hunter, R., Lane, R., Shaffer, G., Day, J. (2018a). Long-term assimilation wetlands in coastal Louisiana: Review of monitoring data and management. *Ecological Engineering*.

Day, J. DeLaune, R., White, J., Lane, R., Hunter, R., Shaffer, G. (2018b). Can denitrification explain coastal wetland loss: A review of case studies in the Mississippi River Delta and New England. *Estuarine, Coastal and Shelf Science* 213 (2018).

Day, J., Lane, R., Hunter, R., Shaffer, G. (2019). Response to: Turner, R.,E., J.E. Bodker, and C. Schulz. 2018. The belowground intersection of nutrients and buoyancy in a freshwater marsh. *Wetlands Ecology & Management*, 1-9.

DeBell, D., Naylor, A. (1972). Some factors affecting germination of swamp tupelo seeds. *Ecology* 53:504-506.

Effler, R., Goyer, R. (2006). Baldcypress and water tupelo sapling response to multiple stress agents and reforestation implications for Louisiana swamps. *Forest Ecology and Management* 226 (2006) 330-340.

Ewel, K., Parendes, L. (1984). Usefulness of annual growth rings of cypress trees (*Taxodium distichum*) for impact analysis. *Tree-Ring Bulletin*, Vol. 44.

Fisk, H. (1944). Geologic investigation of the alluvial valley of the lower Mississippi River. U.S. War Department, Corps of Engineers. Vicksburg, Mississippi. 78 pages.

Flocks, J., Kulp, M., Smith, J., Williams, S. (2009). Review of the Geologic History of the Pontchartrain Basin, Northern Gulf of Mexico. *Journal of Coastal Research* SI 54, 12-22.

Fritts, H. (1976) *Tree rings and climate*. Academic Press, London.

Geho, E., Campbell D., Keddy, P. (2007). Quantifying ecological filters: the relative impact of herbivory, neighbours and sediment on an oligohaline marsh. *Oikos*

Gibson, W., Gill, S. (1988). Analysis of tidal variations of Lake Pontchartrain and the Mississippi Sound. NOAA Technical Memorandum NOS OMA 36.

Hammond Wetland Wastewater Assimilation Use Attainability Analysis (UAA), Comite Resources Inc., Zachary, Louisiana, April 2005.

Hammond, City of, Louisiana Pollutant Discharge Elimination System (LPDES) Permit No. LA0032328, Louisiana Department of Environmental Quality (LDEQ), Baton Rouge, Louisiana, July 7, 2010.

Hesse, I., Day, J. (1998). Long-term growth enhancement of baldcypress (*Taxodium distichum*) from municipal wastewater application. *Environmental Management* Vo. 22, No. 1, pp. 119-127.

Hester, M., Mendelssohn, I., McKee, K. (1998). Instraspecific variation in salt tolerance and morphology in *Panicum hemitomon* and *Spartina alternifolia* (Poaceae). *Int. J. Plant Sci.* 159(1) 127-138.

Hillmann, E. (2011). *The Implications of Nutrient Loading on Deltaic Wetlands*. M.S. Thesis. Southeastern Louisiana University, Hammond Louisiana.

Hillmann, E., Shaffer, G. Wood, W., Day, J., Day, J. Mancuso, J., Lane, R., Hunter, R. (2018). Above- and belowground response of baldcypress and water tupelo seedlings to variable rates of nitrogen loading: Mesocosm and field studes. *Ecological Engineering*.

Hogg, E., Wein, R. (1988). The contribution of *Typha* components to floating mat buoyancy. *Ecology* 69 (4), 1025-1031.

Hollis, L., Turner, R. (2018). The tensile root strength of five emergent coastal macrophytes. *Aquatic Botany* 146 (2018) 39-47.

Hollis, L., Turner, R. (2019). The tensile root strength of *Spartina patens*: Response to Atrazine exposure and nutrient addition. *Wetlands* (2019).

Holm, G., Evers, E., Sasser, C. (2011). *The nutria in Louisiana: A current and historical perspective*. Lake Pontchartrain Basin Foundation.

Hunter, R., Lane, R., Day, J., Lindsey, J., Day, J., Hunter, M. (2009a). Nutrient removal and loading rate analysis of Louisiana forested wetlands assimilating treated municipal effluent. *Environmental Management*.

Hunter R., Day, J., Lane, R., Lindsey, J., Day, J., Hunter, M. (2009b). Impacts of secondarily treated municipal effluent on a freshwater forested wetland after 60 years of discharge. *Wetlands* 29:363-371.

Hunter, R., Day, J., Lane, R., Shaffer, G., Day, J., Conner, W., Rybczyk, J., Mistich, J., Ko, J-Y. (2018). Using natural wetlands for municipal effluent assimilation: A half-century of experience for the Mississippi River Delta and surrounding environs. In: *Multifunctional Wetlands*. (Nagabhatla, N., Metcalfe, C., eds.). Springer International Publishing.

Ialeggio, J., Nyman, J. (2014). Nutria grazing preference as a function of fertilization. *Wetlands* (2014) 34:1039-1045.

International Water Management Institute (IWMI). (2009). *World Water and Climate Atlas*. http://www.iwmi.cgiar.org/resources/world-water-and-climate-atlas/

Izdepski, C., Day, J., Sasser, C., Fry, B. (2009). Early floating marsh establishment and growth dynamics in a nutrient-amended wetland in the lower Mississippi delta. *Wetlands* (2009) 29(3):1004-1013.

Kadlec, R. (1985). Aging phenomena in wastewater wetlands. In: *Ecological Considerations in Wetlands Treatment of Municipal Wastewaters*. (Godfrey, P., Kaynor, E., Pelczarski, S., Benafordo, J. eds). Van Nostrand Reinhold Company, New York.

Kadlec, R. Bevis, F. (1990). Wetlands and wastewater: Kinross, Michigan. *Wetlands* 10 (1), 77-92.

Kadlec R. (1997). An autobiotic wetland phosphorus model. *Ecological Engineering* 8(1997):145-172.

Kadlec, R. (2009a). Wastewater treatment at the Houghton Lake wetland: Hydrology and water quality. Ecological Engineering 35(2009):1287-1311.

Kadlec, R. (2009b). Wastewater treatment at the Houghton Lake wetland: Temperatures and the energy balance. *Ecological Engineering* 35(2009):1349-1356.

Kadlec, R., Bevis, F. (2009). Wastewater treatment at the Houghton Lake wetland: Vegetation response. *Ecological Engineering* 35(2009):1312-1332.

Kadlec, R., Wallace, S. (2009). *Treatment Wetlands, Second Edition*. CRC Press, Boca Raton, Florida USA.

Keddy, P. (2010). *Wetland Ecology: Principles and Conservation, 2nd ed*. Cambridge University Press, Cambridge, UK.

Keim, R., Chambers, J., Hughes, M., Nyman, A., Miller, C., Amos, J., Conner, W., Day, J., Faulkner, S., Gardiner, E., King, S., McLeod, K., Shaffer, G. (2006). Ecological consequences of changing hydrological conditions in wetland forests of coastal Louisiana. *Coastal Environment and Water Quality* (Xu, Y., Sing, V, eds.) Water Resourced Publications LLC, Highlands Ranch, CO, US

Keim, R., Izdepski, C., Day, J. (2012). Growth responses of baldcypress to wastewater nutrient additions and changing hydrologic regime. *Wetlands* (2012) 32:95-103.

Kinler, N., Linscombe, G., Ramsey, P. (1987). Nutria. Wild Furbearer Management and Conservation in North America. M. Novok, J. Baker, M. Obbard and B. Malloch. Toronto, Ontario, Canada, The Ontario Trappers Association: 327-343.

Kleimeier, C., Liu, H., Rezanezhad, F., Lennartz, B. (2018). Nitrate attenuation in degraded peat soil-based constructed wetlands. *Water* (2018) 10, 322.

Ko, J-Y., Day, J., Lane, R., Day, J. (2004). A comparative evaluation of money-based and energy-based cost-benefit analyses of tertiary municipal wastewater treatment using forested wetlands vs. sand filtration in Louisiana. *Ecological Economics* 49 (2004) 331-347.

Ko, J-Y., Day, J., Lane, R., Hunter, R., Sabins, D., Pintado, K., Franklin, J. (2012). Policy adoption of ecosystem services for a sustainable community: A case study of wetland assimilation using natural wetlands in Breaux Bridge, Louisiana. *Ecological Engineering* 38 (2012) 114-118.

Krusi, B., Wein, R. (1988). Experimental studies on the resiliency of floating *Typha* mats in a freshwater marsh. *J. Ecol*. 76, 60-72.

Lane, R. Mashriqui, H., Kemp, G., Day, J., Day, J., Hamilton, A. (2003). Potential nitrate removal from a river diversion into a Mississippi River forested wetland. *Ecological Engineering* 20 (2003) 237-249.

Lane, R., Day, J., Day, J., (2006). Wetland surface elevation, vertical accretion and subsidence at three Louisiana estuaries receiving diverted Mississippi River water. *Wetlands* 26(4), 1130-1142.

Lane, R., Day, J., Shaffer, G., Hunter, R., Day, J., Wood, W., Settoon, P. (2016). Hydrology and water budget analysis of the East Joyce wetlands: Past history and prospects for the future. *Ecological Engineering* 87 (2016) 34-44.

Levin, S., Mooney, H., Field, C. (1989). The dependence of plant root:shoot ratios on internal nitrogen concentration. *American Journal of Botany* 64:71-75.

Lopez, J. (1991). Origin of Lake Pontchartrain and the 1987 Irish Bayou earthquake. In: *Coastal Depositional Systems in the Gulf of Mexico: Quaternary Framework and Environmental Issues*. Gulf Coast Section Society for Sedimentary Geology (GCSSEPM) Twelfth Annual Research Conference, pp. 103-110.

Lopez, J. (2003). *Chronology and Analysis of Environmental Impacts Within the Pontchartrain Basin of the Mississippi Delta Plain*: 1718-2002 (Ph.D. Dissertation). University of New Orleans, Louisiana, USA.

Lopez, J., Boyd, E., Suhayda, J., Needham, H., Hutchison, K. (2016). *The dynamics of storm surge in the Pontchartrain and Maurepas region*. Lake Pontchartrain Basin Foundation Pontchartrain-Maurepas Surge Consortium.

Louisiana Administrative Code (LAC), Title 33, Part IX, Environmental Regulatory Code, specifically LAC 33.IX.1105, LAC 33:IX.1109.J, LAC 33.IX.1111, and LAC 33.IX.1113.B. March 2015.

Louisiana Department of Wildlife and Fisheries (LDWF) (2018). Coastwide nutria control program, 2017-2018. https://www.nutria.com/site13.php

Louisiana Department of Environmental Quality (LDEQ) – Wetland Assimilation: https://deq.louisiana.gov/page/wetland-assimilation (last accessed February 23, 2019).

Louisiana Department of Environmental Quality (LDEQ): *Water Quality Management Plan, Volume 3, Section 10, Permitting Guidance Document for Implementing Louisiana Surface Water Quality Standards*, Version 8. October 26, 2010.

Lundberg, C. (2008). *Using secondarily-treated sewage effluent to restore the baldcypress – water tupelo swamps of the Lake Pontchartrain Basin: A demonstration study*. M.S. Thesis. Southeastern Louisiana University. Hammond, Louisiana.

Lundberg, C., Shaffer, G., Wood, W., Day, J. (2011). Growth rates of baldcypress (*Taxodium distichum*) seedlings in a treated effluent assimilation marsh. *Ecological Engineering* 37 (2011) 549-553.

Mancil, E. (1972). An Historical Geograpjy of Industrial Cypress Lumbering in Louisiana (Volumes I and II). (Ph.D. Dissertation). Louisiana State University, Baton Rouge, Louisiana.

Marschner, H. (2012). *Mineral Nutrition of Higher Plants*, 3rd Edition. Academic Press, London.

McFalls, T. (2004). Effects of disturbance and fertility upon the vegetation of a Louisiana coastal marsh. (M.Sc. Thesis). Southeastern Louisiana University, Hammond, Louisiana.

McIlheny, E. (1935). The alligator's life history. Christopher Publishing House, Boston. Republished (1976) by the Society for the Study of Amphibians and Reptiles.

McKee, K., Mendelssohn, I. (1989). Response of a freshwater marsh plant community to increased salinity and increased water level. *Aquatic Botany* 34 (1989) 301-316.

Mitsch, W., Gosselink, J. (2007). *Wetlands, Fourth Edition*. John Wiley & Sons, Inc.

Morris, J., Bowden, W. (1986). A mechanistic, numerical model of sedimentation, mineralization and decomposition for marsh sediments. *Soil Sci. Soc. Am. J.* 50:96-105.

Morris, J., Bradley, P. (1999). Effects of nutrient loading on the carbon balance of coastal wetland sediments. *Limnol. Oceanogr*. 44(3), 1999, 699-702.

Morris, J., Nyman, J., Shaffer, G. (2014). The influence of nutrients on the coastal wetlands of the Mississippi delta. In: *Perspectives on the restoration of the Mississippi Delta* (Day, J., Demp, G., Freemen, A., Muth, D., eds)). Springer, Dordrecht, pp. 111-123.

Myers, R., Shaffer, G., Llewellyn, D. (1995). Baldcypress (*Taxodium distichum*) restoration in southeastern Louisiana: the relative effects of herbivory, flooding, competition and macronutrients. *Wetlands* 15:141-148.

Nessel, J., Ewel, K., Burnett, M. (1982). Wastewater enrichment increases mature pondcypress growth rates. *Forest Science* 28:400-403.

Nichols, D. (1983). Capacity of natural wetlands to remove nutrients from wastewater. *Journal WPCF*, Vol. 55, No. 5, pp. 495-505.

Norgress, R. (1947). The history of the cypress lumber industry in Louisiana. The Louisiana Historical Quarterly, 30: 979-1059.

Odum, W., (1988). Predicting ecosystem development following creation and restoration of wetlands. In: Wetlands: Increasing our wetland resources. (Zelazny, J., Feierabend, J., eds.). National Wildlife Federation, Washington DC.

O'Neill, T. (1949). *The Muskrat in Louisiana Coastal Marshes*. Louisiana Wildlife and Fisheries Commission, New Orleans, Louisiana, USA.

Otvos, E. (1978). New Orleans – South Hancock Holocene barrier trends and origins of Lake Pontchartrain. Gulf Coast Association of Geological Societies Transactions 28, 337-355.

Penland, S., Ramsey, K. (1990). Relative sea level rise in Louisiana and the Gulf of Mexico: 1908-1988. *J. Coastal Res*. 6, 323-342.

Perrin, J. (2000). *Home Town Ponchatoula. A Community History of Ponchatoula, Louisiana*. (Self-published). Ponchatoula, Louisiana, USA.

Reddy, K., DeLaune, R. (2008). *Biogeochemistry of Wetlands: Science and Applications, 1st ed*. CRC Press, Boca Raton, Florida USA.

Rezanezhad, F., Price, J., Quinton, W., Lennartz, B., Milojevic, T., Van Cappellen, P. (2016). Structure of peat soils and implications for water storage, flow and solute transport: A review update for geochemists. *Chemical Geology* 429 (2016) 75-84.

Richardson, C., Nichols, D. (1985). Ecological analysis of wastewater management criteria in wetland ecosystems. In: *Ecological Considerations in Wetlands Treatment of Municipal Wastewaters*. (Godfrey, P., Kaynor, E., Pelczarski, S., Benafordo, J. eds). Van Nostrand Reinhold Company, New York.

Rybcyzk, J., Callaway, J., Day, J. (1998). A relative elevation model for a subsiding coastal forested wetland receiving wastewater effluent. *Ecological Modeling* 112 (1998) 23-44.

Rybczyk, J., Day, J., Conner, W. (2002). The impact of wastewater effluent on accretion and decomposition in a subsiding forested wetland. *Wetlands* 22, 18-32.

Sasser, C., Gosselink, J., Swenson, E., Swarzenski, C., Leibowitz, N. (1996). Vegetation, substrate and hydrology in floating marshes in the Mississippi River delta plain wetlands, USA. *Vegetatio* 122:129-142.

Sasser, C., Holm, G., Visser, J., Swenson, E. (2005). *Thin-Mat Floating Marsh Enhancement Demonstration Project TE-36*. Louisiana State University, Baton Rouge Louisiana USA.

Sterner, R., Elser, J. (2002). *Ecological Stoichiometry*. Princeton University Press.

Saucier, R. (1963). *Recent Geomorphic History of the Pontchartrain Basin*. Louisiana State University Press, Baton Rouge, Louisiana, 1963.

Saucier, R. (1994). Geomorphology and Quaternary Geologic History of the Lower Mississippi River Valley. Vicksburg, Mississippi. U.S. Army Corps of Engineers, Waterways Experiment Station, 1, 361p.

Shaffer, G., Wood, W., Hoeppner, S., Perkins, T., Zoller, J., Kandalepas, D. (2009a). Degradation of Baldcypress-Water Tupelo swamp to marsh and open water in Southeastern Louisiana, U.S.A.: An irreversible trajectory? *Journal of Coastal Research*, 54 (2009).

Shaffer, G., Day, J., Mack, S., Kemp, G., van Heerden, I., Poirrier, M., Westpahl, K., FitzGerald, D. Milanes, A., Morris, C. (2009b). The MRGO navigation project: A massive human-induced environmental, economic and storm disaster. *Journal of Coastal Research*, (2009) 54:152-165.

Shaffer, G., Day, J., Hunter, R., Lane, R., Lundberg, C., Wood, W., Hillmann, E., Day, J., Strickland, E., Kandalepas, D. (2015). System response, nutria herbivory, and vegetation recovery of a wetland receiving secondarily-treated effluent in coastal Louisiana. *Ecological Engineering* 79 (2015) 120-131.

Shaffer, G., Day, J., Kandalepass, D., Wood, W., Hunter, R., Lane, R., Hillmann, E. (2016). Decline of the Maurepas Swamp, Pontchartrain Basin, Louisiana and approaches to restoration. *Water* (2016) 8, 101.

Sharpe, P., Baldwin, A. (2012). Tidal marsh plant community response to sea-level rise: A mesocosm study. *Aquatic Botany* 101 (2012) 34-40.

Stokes, M., Smiley, T. (1968). *An introduction to tree-ring dating*. University of Chicago Press. Chicago Illinois.

Turner, R., Howes, B., Teal, J., Milan, C., Swenson, E., Goehringer-Toner, D. (2009). Salt marshes and eutrophication: An unsustainable outcome. *Limnol. Oceanogr*. 54(5) 2009, 1643-1642.

Turner, R. (2011). Beneath the salt marsh canopy: Loss of soil strength with increasing nutrient loads. *Estuaries and Coasts* (2011) 34:1084-1093.

Turner R. (2017). *On the ground observations of sewage disposal into wetlands: What is happening to the marsh/swamp?* Handout presented at a public hearing for the renewal of the discharge permit for the City of Mandeville, Louisiana, October 19, 2017.

Turner, R., Bodker E. (2016). The effects of N, P and crude oil on the decomposition of *Spartina alterniflora* belowground biomass.

Turner, R., Bodker, J., Schulz, C. (2018). The belowground intersection of nutrients and buoyancy in a freshwater marsh. *Wetlands Ecol. Manage* (2018) 26:151-159.

Turner R. (2019). Personal communication (via letter) to Scott Wallace, January 26, 2019.

Thomson, D., Shaffer, G., McCorquodale, J. (2002). A potential interaction between sea-level rise and global warming: Implications for coastal stability on the Mississippi River deltaic plan. *Global Planetary Change* 32:49-59.

United States Code (USC) 33 1251. Federal Water Pollution Control Act. United States Congress, November 27, 2002.

United States Army Corps of Engineers (USCOE). (2012). *Mississippi River Gulf Outlet (MRGO) Ecosystem Restoration Plan, Final Feasibility Report*. (Supplemental Report of the Chief of Engineers in Response to the Water Resources Development Act of 2007). U.S. Army Corps of Engineers, New Orleans District. New Orleans, Louisiana.

United States Department of Agriculture (USDA), Bureau of Soils, Louisiana Agricultural Experiment Station (1905). *Soil Map of Tangipahoa Parish, Louisiana*.

United States Department of Agriculture (USDA). (2007). Aerial photo of Hammond, Louisiana area (10-12-2007).

United States Department of Agriculture (USDA). (2009). Aerial photo of Hammond, Louisiana area (8-25-2009).

United States Department of Agriculture (USDA). (2010). Aerial photo of Hammond, Louisiana area (8-15-2010).

United States Department of Agriculture (USDA). (2013). Aerial photo of Hammond, Louisiana area (10-17-2013).

United States Department of Agriculture (USDA). (2013). Aerial photo of Hammond, Louisiana area (10-17-2013).

United States Geological Survey (USGS). (1965). Aerial photo of Hammond, Louisiana area. (Composite of images taken 2-25-1965 and 10-27-1965).

United States Geological Survey (USGS). (1972). Aerial photo of Hammond, Louisiana area. (11-17-1972).

United States Geological Survey (USGS). (1998). Aerial photo of Hammond, Louisiana area. (8-2-1998).

United States Geological Survey (USGS). (2005). Aerial photo of Hammond, Louisiana area. (11-18-2005).

United States Geological Survey (USGS) (2015). *Ponchatoula, Louisiana Quadrangle topographic map*, 7.5-minute series

Valiela, I., Teal, J., Persson, N. (1976). Production and dynamics of experimentally enriched salt marsh vegetation: Belowground biomass. Limnology and Oceanography, March 1975 V. 21(2): 245-252.

Visser, J., Sasser, C., Chabreck, R., Linscombe, R. (1999). Long-term vegetation changes in Louisiana tidal marshes, 1968-1992. *Wetlands* 19(1):168-175.

Wallace, S., Knight, R. (2006). *Small-scale constructed wetland treatment systems: Feasibility, design criteria and O&M requirements*. Final Report, Project 01-CTS-5, Water Environment Research Foundation (WERF), Alexandria, Virginia.

Weller, M., Bossart, J. (2017). Insect community diversity tracks degradation and recovery of a wastewater assimilation marsh in southeast Louisiana. *Wetlands* (2017) 37(4):661-673.

Wigand, C., Brennan, M., Stolt, M., Ryba, S. (2009). Soil respiration rates in coastal marshes subject to increasing watershed nitrogen loads in southern New England, USA. *Wetlands* 29: 952-963.

Winters, R., Ward, G., Eldredge, I. (1943). *Louisiana Forest Resources and Industries*. United States Department of Agriculture (USDA), Miscellaneous Publication No. 519, Washington DC, USA.

Young, P., Megonigal, P., Sharitz, R., Day, F. (1993). False ring formation in baldcypress (*Taxodium distichum*) saplings under two flooding regimes. *Wetlands* 13:293-298.

Zhang, X., Feagley, S., Day, J., Conner, W., Hesse, I., Rybcyzk, J., Hudnall, W. (2000). A water chemistry assessment of wastewater remediation in a natural swamp. *Journal of Environmental Quality* 29:1960-1968.

APPENDIX A – SITE VISIT SUMMARY REPORT, NOVEMBER 2018

SITE VISIT SUMMARY REPORT

To:	Amanda Vincent, LDEQ Project Manager
From:	Scott Wallace, NWC Project Manager
Copy:	Rhonda Bright Doiron, NWC
Project :	South Slough Wetland Study LaGov No. 2000359113
Report Date:	November 26, 2018
Re:	Site Visit, November 13-14, 2018

Site Visit Meetings

LDEQ Meeting

A Site Visit kick-off meeting was held on the morning of November 13, 2018 at DEQ's offices in Baton Rouge. Amanda Vincent (LDEQ), Jonathan McFarland (LDEQ), Chuck Brown (LDEQ), Todd Franklin (LDEQ), Lorna Putnam-Duhon (LDEQ) and Scott Wallace (NWC) were in attendance to briefly discuss the project goals and objectives

City of Hammond Meeting

A Site Visit meeting was also held with the City of Hammond on the morning of November 12, 2018 at the wastewater treatment plant. Amanda Vincent (LDEQ), Jonathan McFarland (LDEQ), Scott Wallace (NWC), Guy Palermo (City of Hammond), Wanda Brumfield (City of Hammond) and Vernon Banks (City of Hammond) were in attendance to discuss operations at the treatment plant and how flow is delivered and distributed to the South Slough wetland assimilation area.

Wastewater from the City of Hammond enters the treatment facility through multiple lift stations. Flow through the aerated lagoons is by gravity to the effluent lift station. Due to infiltration and inflow (I/I), flows increase from 2-4 million gallons per day (MGD) up to around 8-9 MGD during precipitation events. This flow entering the treatment facility exceeds the pumping capacity of the effluent lift station, and water levels in the treatment lagoons will rise, providing some flow equalization capacity.

There are three pumps at the effluent lift station, although the City has found that running all three pumps simultaneously provides no benefit vs. running two pumps during peak flow events and retaining the third pump as a standby. The effluent pumps operate on demand and rotate through a lead/lag/standby sequence. When in operation, the pumps provide pressure head all the way through the 6-mile long pipeline to the distribution pipes at the South Slough Wetland, but when the pumps are off flow can continue through the wetland distribution pipes via gravity drainage of the force main. The

City has experienced some problems with air entrainment/relief with the force main, but those problems appear to have been resolved through recent improvement to the air relief valves

Treated effluent is disinfected by chlorine (hypochlorite with chlorine gas backup), with the disinfection dosing rate being manually set based on operating experience. Effluent is dechlorinated via bisulfite addition (again, manually adjusted based on operating experience) south of the treatment facility with the effluent transfer pipeline serving as the chlorine contact chamber. The effluent pumping, disinfection and dechlorination systems appear to be adequate and no operational problems were noted by the operators.

South Slough Wetland Walk-Through

Immediately following the meeting at the wastewater treatment plant, the attendees visited the South Slough site and walked the length of the first 3,000 feet of the effluent distribution pipe (Figure 1). After walking the effluent distribution pipe, the meeting participants visited the Joyce Wetlands boardwalk (Figure 2), which allows access near the MID monitoring point of the wetlands.

Figure 1 – South Slough Distribution Pipe and Boardwalk

Figure 2 – Joyce Wetland Boardwalk (access to MID monitoring point)

South Slough Wetlands Site Evaluation

Field studies were conducted at the South Slough site on November 13 and 14, 2018.

Site Description

The South Slough Wetlands are located on the northern edge of the Lake Pontchartrain basin between Lake Maurepas and Lake Pontchartrain (Flocks *et al*., 2009). Over the last 150 years a number of construction projects have largely cut off tributary watershed drainage on the north side (due to construction of the South Slough canal) and to the west (due to construction of the railroad, U.S. 51 and I-55). The area is hydrologically connected to Lake Pontchartrain to the south and the discharge of the Tangipahoa River to the east. While water levels in Lake Pontchartrain can (and do) affect water levels in the South Slough wetlands, stem drag due to vegetation creates considerable barriers to water movement. As a result, application of treated effluent is the primary water input in the Hammond Assimilation Wetland area, resulting in water levels that are higher in elevation and more stable than surrounding reference wetlands. Movement of effluent through the wetland assimilation area is generally to the south and east, and hydrology of the area has been described in detail (Lane *et al*., 2016).

Effluent is applied to an area of wetland dominated by emergent wetland vegetation which is surrounded by forest swamp (Figure 3).

Figure 3 – Aerial View of the South Slough Wetlands (including the wetland assimilation area), looking southeast. Red arrows indicate the primary direction of effluent movement.

Throughout the various studies and reports done on the project, different areas and terminologies have been used to describe the wetland system. For the sake of clarity, this report uses the following definitions:

- South Slough Wetlands: The total area of wetlands considered for effluent utilization under LPDES Permit LA0032328, including approximately 10,000 acres of the East Joyce Wetlands (EJW) and the effluent distribution area owned by the City of Hammond (UAA, 2005)
- Effluent distribution area: Land owned by the City of Hammond and utilized for purposes of effluent distribution. This area is approximately 130 acres.
- Four Mile Marsh: The area of naturally-occurring emergent wetland vegetation (including the effluent distribution area) that existed prior to the effluent application project. The boundaries of Four Mile Marsh appear unchanged from historical aerial photographs dating back as far as 1965 (USGS 1965). This area is approximately 750 acres (Lundberg *et al*, 2011)
- Hammond Assimilation Wetland area (HAW): Area of the Four Mile Marsh where changes in the vegetative community have occurred after effluent application began in 2006. While this area has not been field delineated, it is estimated at 321 acres (Shaffer *et al*, 2015).
- East Joyce Wetlands (EJW): The state wildlife area managed by the Louisiana Department of Wildlife & Fisheries south and east of the effluent distribution area. This is approximately 34,600 acres (Lane *et al*, 2016) and includes all of Four Mile Marsh not owned by the City of Hammond. Other than two emergent marsh areas (Four Mile Marsh and Seven Mile Marsh), the majority of the EJW is forested swamp.

Observations in the Wetland Assimilation Area

Water Movement

Effluent pumped from the City of Hammond is distributed along a 3,600-foot elevated pipeline that runs east-west along the north side of the distribution area (Figure 1). The spoil bank created by the construction of South Slough does not (under normal circumstances) allow water to flow north and enter the South Slough canal. Berms created by the construction of the railroad, U.S. 51, and I-55 largely cut off flows to the west (with the exception of a few culverts). As a result, effluent moves south and east towards Lake Pontchartrain. However, regional water levels are dominated by Lake Pontchartrain and the entire site can be underwater after major hurricane events.

The effluent distribution pipeline has 900 hand-operated distribution valves, divided into six zones of 150 valves apiece (Figure 4). Flow is normally rotated to different application zones on a quarterly basis by the operations staff to allow loading and resting of different parts of the assimilation area. During the period of field observations, the westernmost zone (closest to the railroad, U.S. 51 and I-55) was being utilized. Due to recent rainfall (the City of Hammond received 11.4 inches of precipitation on November 10-11, 2018), the effluent pumps were operating continuously. Water levels west of I-55 were lower than on the east side, and flow velocity in South Slough was >1 foot per second (ft/s) towards the west.

Flow was visualized using fluorescent dye (Figure 5 inset) along the zone of effluent application (Zone 1) and along the first wetland boardwalk (Figure 4). Flow velocity decreased as effluent moved away from the distribution point(s). Based on dye movement, flow was towards the south-southwest (SSW) at velocities of ~0.3 ft/s thirty feet from the distribution pipeline, ~0.1 ft/s one hundred feet from the distribution pipeline, and not detectable at the end of the boardwalk.

Figure 4 – Effluent application zones within the Hammond Assimilation Wetland (HAW) area and observed flow movement on November 13-14, 2018. Image is from Google Maps (2018).

Some channelization of flow and movement to the culverts under the railroad and U.S. 51 was observed (Figure 5). While this was estimated to be a small percentage of the overall effluent application, it demonstrates that flow to the west is possible under favorable conditions.

Figure 5 – Visualization of flow in the effluent application zone (Zone 1) using fluorescent dye.

There are two "water level control" structures located adjacent to the effluent distribution pipeline in the northeast and northwest corners of the HAW. Under favorable water level conditions, excess water in the HAW could be drained into South Slough to facilitate drawdown and promote vegetation growth. These control structures have a flap arrangement that can be open or closed. Both of these structures were leaking and in poor repair (Figure 6) and dye tracing showed that flow was entering South Slough (Figure 4). It is recommended that these be replaced with new, water-tight structures that can be opened and closed to give operators positive control over water levels.

Figure 6 – Water level control structure with missing flap gate at northeast corner of the effluent distribution area

Vegetation

The area immediately adjacent to the effluent distribution pipeline supports the growth of trees (Figure 1), on the South Slough spoil bank. Additional Bald Cypress trees (*Taxodium distichum*) were planted in 2008 consisting of 11 groupings of 8 seedlings per group in four experimental subunits (Annual Report, 2010). Studies by Lundberg *et al.*, (2011) showed higher rates of seedling survival and greater tree growth in closer proximity to the effluent distribution pipeline. Those cypress trees are continuing to thrive and have in many cases, split the original 4-inch plastic guards placed to deter nutria grazing (Figure 7).

Figure 7 - Growth of Bald Cypress (*Taxodium distichum*) trees adjacent to the effluent distribution pipeline

Further to the south, trees give way to emergent vegetation (Figure 8). Along accessible areas (extending from existing boardwalks, the emergent vegetation was a diverse community consisting of Maidencane (*Panicum hemitomon*), Broadleaf Arrowhead (*Sagittaria lancifolia*), Willow Primrose (*Ludwegia leptocarpa*), and Giant Cutgrass (*Zizaniopsis miliacea*) (Figure 9). Some isolated stands of Cattail (*Typha domingensis*) were observed, these could have possibly expanded from nutria-exclusion pens as described by Shaffer *et al.* (2015).

It was apparent that most of the emergent wetland vegetation was occurring on top of floating mats of detritus; areas were not wadable even with special equipment, and probes could push through the vegetation mats to a depth of 3 to >6 feet. Some areas of open water were visible (Figure 10), and some areas supported floating mats of Marsh Pennywort (*Hydrocotyle ranunculoides*), Giant Salvinia (*Salvinia molesta*), and Duckweed (*Lemna minor*).

Figure 8 – Transition from trees to emergent marsh (looking south from effluent distribution pipe)

Figure 9 – Typical view of emergent marsh area (looking south from effluent distribution pipe)

Figure 10 – One of the smaller open-water areas in the emergent marsh area (looking south from westernmost observation boardwalk).

Observations made at the MID Monitoring Location

The MID monitoring location is located at the transition back to forested swamp along the southern edge of the emergent marsh area (Figure 2). This is the southern edge of Four Mile Marsh, and the transition point from emergent marsh to forested swamp appears unchanged from historical photos dating back as far as 1965 (USGS, 1965). The MID monitoring point was established as part of the Use Attainability Analysis (UAA, 2005), and is monitored annually under LPDES Permit LA0032228.

The site is accessible by walking to the end of the Joyce Swamp Walk Nature Trail boardwalk (Figure 11) and then wading north through the cypress swamp. This area was selected to represent an intermediate location beyond the immediate zone of effluent distribution, but still be in an area where the effects of effluent assimilation would be apparent.

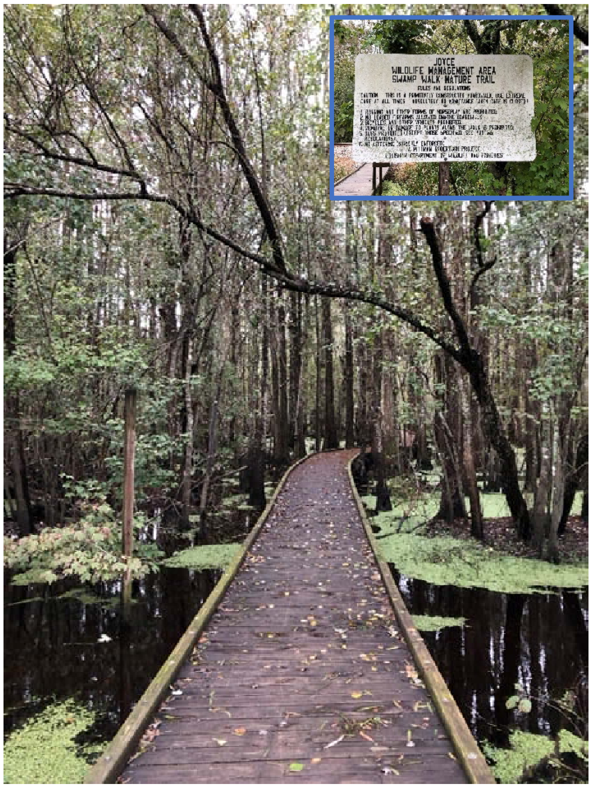


Figure 11 – Access to the MID monitoring location

Water Movement
No discernable current or flow could be observed with the naked eye using fluorescent dye drops. Dye dispersed uniformly in all directions until no longer visible.

Vegetation
The MID location is a region of forested swamp dominated by Bald Cypress (*Taxodium dystichum*) with the minor presence of Tupelo (*Nyssa aquatica*), Red Maple (*Acer rubrum*), Sandbar Willow (*Salix interior*) and Green Ash (*Fraxinus pennsylvanica*) (Figure 12). Understory vegetation consisted of floating aquatic plants such as duckweeds (*Lemna minor*, *Spirodela polyrhiza*).

Figure 12 – MID monitoring point looking west (November 14, 2018)

Trees at the MID monitoring point appeared healthy and growing. Core samples from 10 cypress trees were collected using a hand-held increment borer (Figure 13) and retained for future analysis.

Figure 13 – Collection of tree core samples using increment borer

References Cited

Annual Wetland Monitoring Report (2010). City of Hammond Wetland Assimilation Project. Comite Resources Inc., Zachary, Louisiana, United States.

Flocks, J., Kulp, M., Smith, J., Williams, S. (2009). Review of the geologic history of the Pontchartrain Basin, northern Gulf of Mexico. *Journal of Coastal Research*. Special Issue 54, pp. 12-22.

Lane, R., Day, J., Shaffer, G., Hunter, R., Day, J., Wood, W., Settoon, P. (2016), Hydrology and water budget analysis of the East Joyce wetlands: Past history and prospects for the future. *Ecological Engineering* 87 (2016) 34-44.

Louisiana Department of Environmental Quality (LDEQ). LPDES Permit LA0032328 (September 1, 2016).

Lundberg, C., Shaffer, G., Wood, W., Day, J. (2011). Growth rates of baldcypress (Taxodium distichum) seedlings in a treated effluent assimilation marsh. *Ecological Engineering* 37 (2011) 549-553.

Shaffer, G., Day, J., Hunter, R., Lane, R., Lundberg, C., Wood, W., Hillmann, E., Day, J., Strickland, E., Kandalepass, D. (2015). System response, nutria herbivory, and vegetation recovery of a wetland receiving secondarily-treated effluent in coastal Louisiana. *Ecological Engineering* 79 (2015) 120-131.

UAA, 2005: Hammond Wetland Wastewater Use Attainability Analysis (April 2005), Comite Resources Inc., Zachary, Louisiana, United States.

USGS, 1965: United States Geologic Survey. (1965). Aerial photo of Hammond, Louisiana area. (Composite of images taken 2-25-1965 and 10-27-1965).

APPENDIX B – HISTORICAL AERIAL PHOTOS

1965

USGS
2-25-1965
10-27-1965

1972

USGS
11-17-1972

1998

USGS
8-2-1998

2005

USGS
11-18-2005

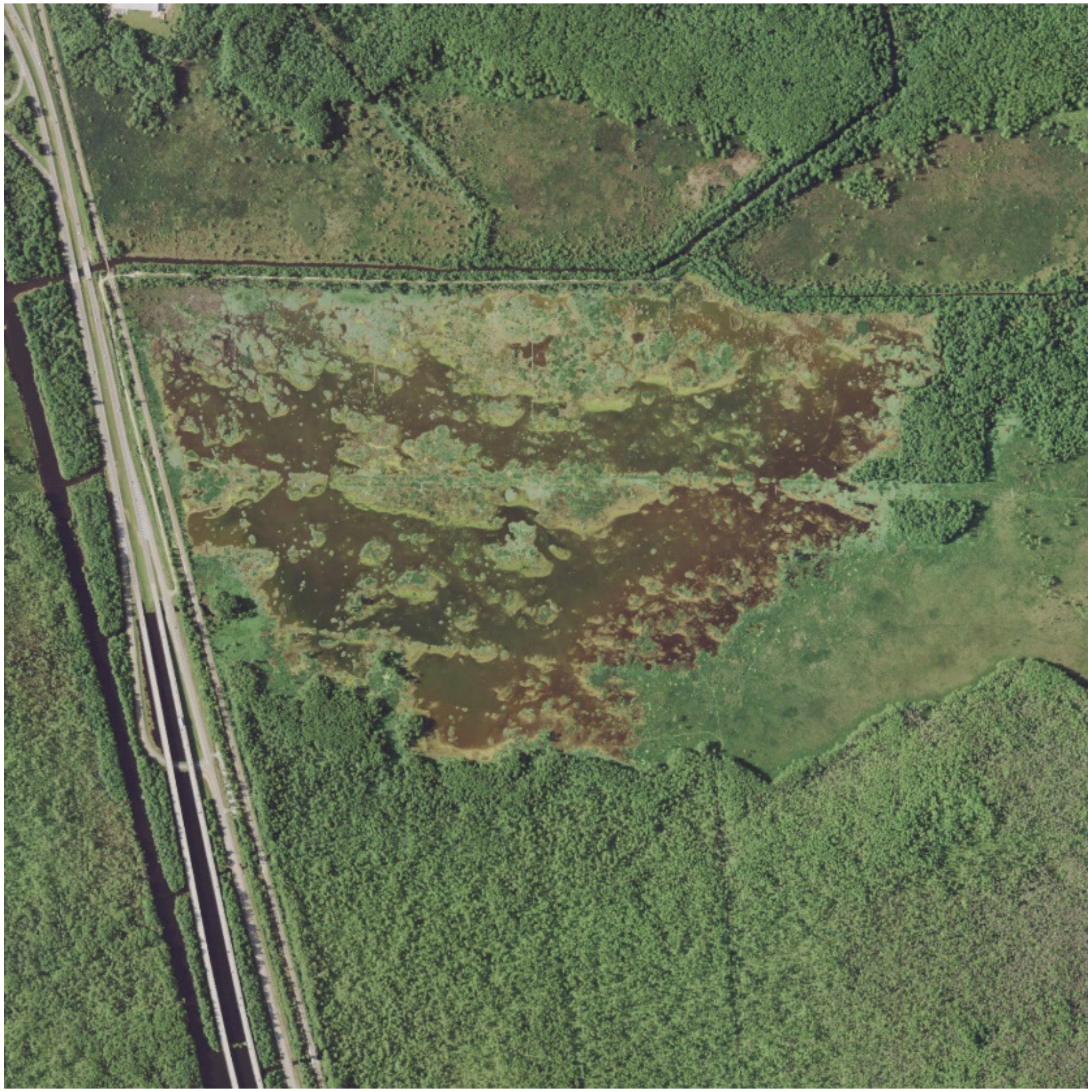
2007

USDA
10-12-2007

2009

USDA
8-25-2009

2010



USDA
8-15-2010

2013

USDA
10-17-2013

2018 (Google Maps)

APPENDIX C – DRAWBACKS AND LIMITATIONS OF THE "LOADING CHART" APPROACH

Historically, planning of wastewater assimilation wetland projects in Louisiana has been based on a "loading chart" approach (Breaux & Day, 1994, Hunter *et al*. 2009a, Hunter *et al*. 2018). This same approach was used to plan the City of Hammond project (UAA, 2005).

The "loading chart" approach is based on the observation that when nutrients are spread over a sufficiently large area, they are incorporated into the plant biomass cycle of the wetland such that the resulting exit concentrations are at (or close to) ecosystem background concentrations.

A review of wetland systems receiving municipal wastewater effluent was presented by Nichols (1983) and Richardson & Nichols (1985). This review was based on nine different wetland systems in Michigan, Ireland, Florida, Wisconsin, Massachusetts, and Ontario comprising a variety of wetland types that had been receiving wastewater effluent between 1 – 69 years. None of these systems were in Louisiana and only one was a cypress swamp.

The authors observed that when the mass load of nutrients was introduced to a wetland of sufficiently large area, the effluent concentrations of nutrients were low (close to background concentrations). Nichols (1983) and Richardson & Nichols (1985) calculated a "loading rate" and "percent removal" as follows:

$$\text{"Loading Rate"} = \frac{mass\ of\ nutrient\ applied}{total\ wetland\ area}$$

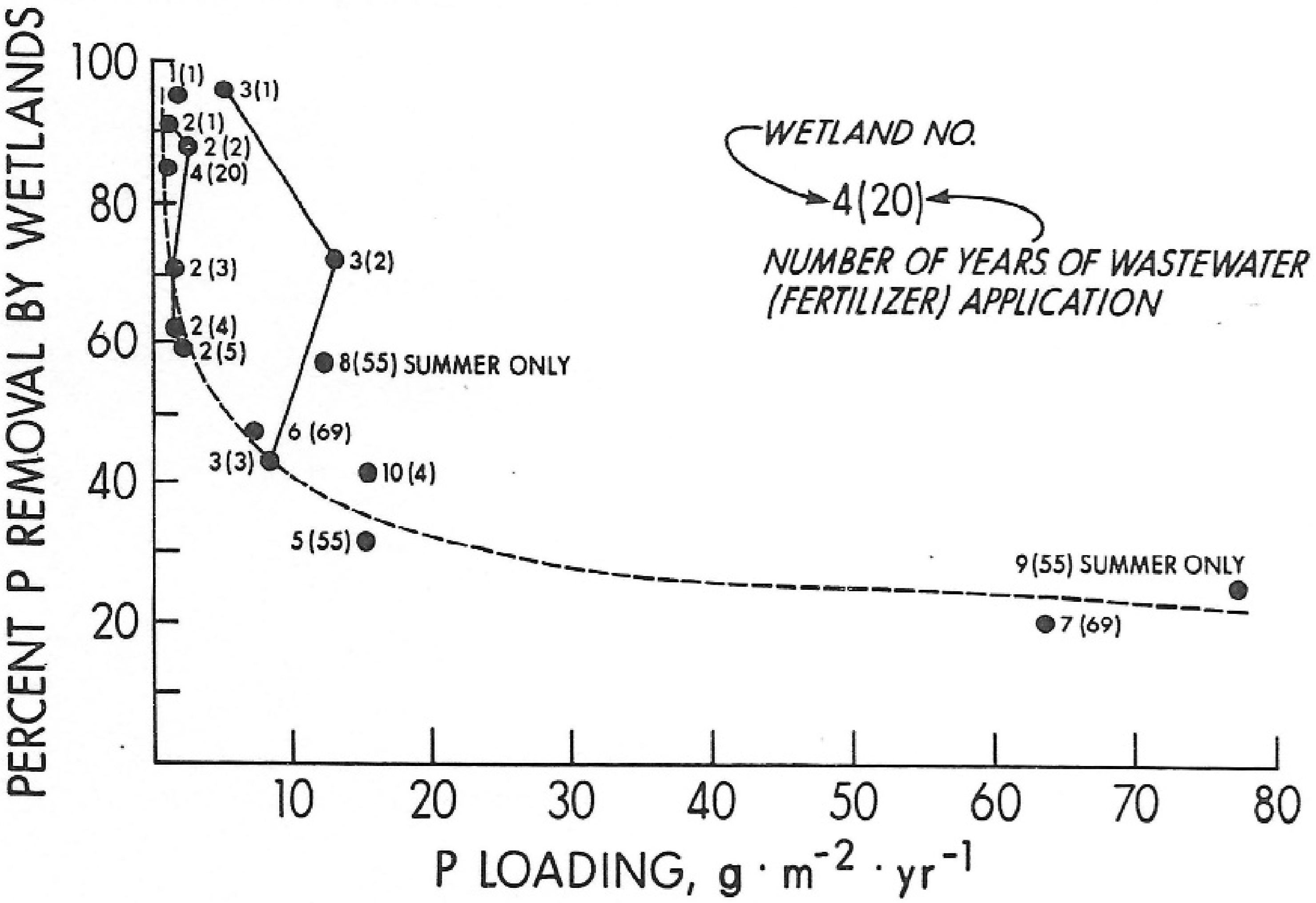
$$"Percent\ Removal" = \left(1 - \frac{outlet\ concentration}{inlet\ concentration}\right) \times 100$$

These numbers were published in a table and plotted on a X-Y graphs to produce "loading charts" (see Figure C.1 for example).

The "loading chart" approach presented in Nichols (1983) and Richardson & Nichols (1985) has two key limitations if used for predictive purposes:

1. The wastewater was not actually distributed over the entire area of the wetlands studied. Dividing the mass load by the overall wetland area mistakenly assumes that the effluent is evenly distributed over that entire wetland area. In reality, this uniformity of application has never been achieved for full-scale assimilation systems, all of which use pipes to distribute effluent over a small fraction of the wetland area.
    a. Consequently, the nutrient loading is non-uniform (highest in the inlet region), and the wetland plant community will adapt to this gradient in nutrient availability as predicted by Kadlec (1985).
2. Percent removal is calculated as the difference between the inlet concentration and the outlet concentrations. However, wetlands have non-zero background concentrations for nitrogen and phosphorus (Kadlec & Wallace 2009). If the inlet concentration was very close to the wetland background concentration, there would be low percent removal, regardless of the loading. The "loading chart" approach does not incorporate the concept of non-zero background concentrations into predicted percent removals.

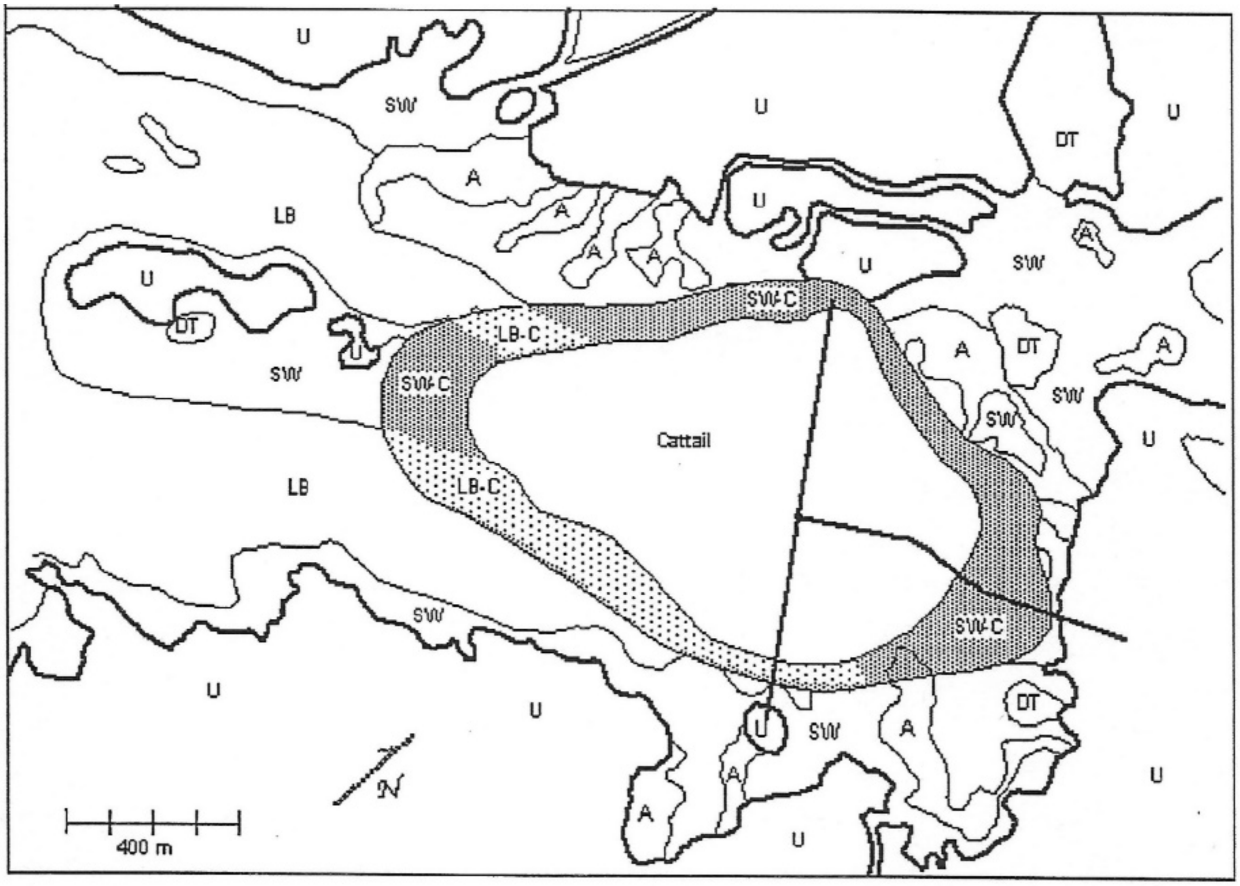
Figure C.1 – **Phosphorus “loading chart” from Nichols (1983) and Richardson & Nichols (1985).**



As a case in point, the extensively-studied Houghton Lake, Michigan assimilation wetland was approximately 700 ha in area. Dividing the influent mass load over the entire wetland area yields a "loading rate" of approximately 0.3 g/m^2-yr for phosphorus, which the chart (Figure C.1) of Nichols (1983) and Richardson & Nichols (1985) would predict almost complete (100%) phosphorus removal, regardless of the influent concentration.

The Houghton Lake system did indeed remove high levels of phosphorus (94% over 30 years of operation) as summarized in Kadlec (2009a). However, the "loading chart" approach ignores the non-uniformity of the nutrient application, and thus misses the development of the 83 ha active assimilation zone, which underwent a major shift in vegetation type (sedge-willow → *Typha* spp.), biomass production (3X), nutrient content of plant tissue (2-3X) and wetland structure (fixed marsh → floating mats). The nutrient "assimilation zone" predicted by Kadlec (1985, 1997) did develop at Houghton Lake, as shown in Figure C.2 (also Figure 6.3). The entire 700 ha of the Houghton Lake wetland was not involved in nutrient assimilation, only the 83 ha of the active assimilation zone.

Figure C.2 (also Figure 6.3) – Assimilation zone occupying 83 ha within a 700-ha assimilation wetland, Houghton Lake, Michigan (Kadlec, 2009b). The assimilation zone took approximately 9 years to develop, and then was stable for the remainder of the 30-year period of operation.



The active assimilation zone model developed by Kadlec (1997) was applied to the Houghton Lake Michigan project (Kadlec & Bevis, 2009). These results indicate that the removal rates of nitrogen and phosphorus are far higher in the active assimilation zone (approximately 100 g/m^2-yr for N and 5 g/m^2-yr for P) than in the surrounding wetland area.

Regulatory guidance in Louisiana lists threshold "loading rates" (mass of nutrient applied divided by total wetland area) of 15 g/m^2-yr for N and 4 g/m^2-yr for P (see Section 2.0). These "loading rates" are very conservative for nitrogen; less so for phosphorus. If the calculated "loading rate" is below these thresholds, it is an indication that the wetland is likely large enough to contain the active assimilation zone.

A recent summary of wastewater assimilation wetlands in Louisiana was completed by Hunter *et al*. 2018, which lists estimated "loading rates" for each assimilation wetland based on the approach of Nichols (1983) and Richardson & Nichols (1985).

Another way of looking at this data is to estimate the percentage of the total wetland area involved in the active assimilation zone using the methods of Kadlec (1997) and Kadlec & Bevis, 2009. These results are summarized in Table C.1.

Operating performance of these assimilation wetlands generally indicates they are all successful in reducing N and P concentrations to background levels (Hunter *et al*. 2018), which is not surprising considering that most of the assimilation wetland projects were far larger than the active assimilation zone (Table C.1). The exception is Mandeville Bayou Chinchuba, where essentially half the wetland is involved in nitrogen assimilation and all of the wetland is involved in phosphorus assimilation. Not surprisingly, Hunter *et al.* 2018 notes that it takes about half of the Bayou Chinchuba wetland to remove nitrogen (BC MID site), and phosphorus is only reduced to ≈1 mg/L at the BC OUT site. This is considerably higher than background P concentration in other nearby wetlands, but consistent with calculations indicating that Bayou Chinchuba is too small to contain the active assimilation zone.

Table C.1 - Summary of Louisiana wastewater assimilation wetlands and estimated percentage of wetland in the active assimilation zone. Data adapted from Hunter *et al*. 2009a and Hunter *et al*. 2018. Estimated percentages of the wetland within the active assimilation zone were calculated by the author.

				Mean "Loading Rate" (7) g/m^2-yr		Estimated Percent of Wetland in Active Assimilation Area (1)	
City	**Period of Record**	**Flow, MGD**	**Size, ha (5)**	**Nitrogen**	**Phosphorus**	**Nitrogen**	**Phosphorus**
Breaux Bridge (6)	2001-2013	0.96	1,490	1.89	0.24	2%	5%
Broussard	2007-2013	0.59	136	14.75	2.62	15%	52%
Hammond	2007-2013	3.90	4,047	2.39	0.48	2%	10%
Luling	2006-2013	1.58	608	2.52	0.84	3%	17%
Mandeville BC (2)	2006-2013	1.19	98	56.50	13.90	57%	>100% (4)
Mandeville TM (3)	2009-2013	1.44	413	7.48	1.46	7%	29%
St. Martinville	2011-2013	0.74	63	8.70	3.00	9%	60%
Thibodaux	2001-2008	3.10	300	20.18 ± 1.74	2.17 ± 0.33	20%	43%

Notes:

1. Based in assimilation rates estimated at 100 gN/m^2-yr and 5 gP/m^2-yr in the active assimilation zone.
2. Mandeville Bayou Chinchuba
3. Mandeville Tchefuncte Marsh
4. Area required for active assimilation exceeds the available wetland area.
5. Size calculated based on "loading rates" from Hunter *et al*. 2009a and Hunter *et al*. 2018; may be different than total project area.
6. Due to uncertainties as to how much of the Breaux Bridge wetlands are actually involved in nutrient assimilation, Hunter *et al*. 2009b has previously used 10%, 55% and 100% of the total wetland area to calculate estimated "loading rates".
7. The "loading rate" is the mass of nutrients applied divided by the total project area. This follows the approach of Nichols (1983) and Richardson & Nichols (1985).

Application to the City of Hammond

As seen in Table C.1, a very small percentage of the 4,047 ha (10,000 acres) defined as the "South Slough Wetland" (UAA, 2005) is actually involved in the active assimilation zone. This is entirely consistent with conclusions drawn from Figures 5.8, 5.9, 5.10 and 5.11 of this study, all of which indicate that monitoring locations outside of the active assimilation zone report background concentrations.

The risk of using the "loading chart" approach is made apparent when one uses the "loading rates" of Nichols (1983) and Richardson & Nichols (1985) for predictive purposes. The data presented by Hunter *et al*. 2018 indicates the N and P "loading rates" for Hammond are 2.39 gN/m^2-yr and 0.48 gP/m^2-yr, respectively.

These numbers are only 6-10% of the internal loadings within the active assimilation zone estimated using the method of Kadlec, 1997 and Kadlec & Bevis, 2009. If the actual loading rates in the assimilation zone were as low as those estimated by Hunter *et al*. 2018, the assimilation zone within Four Mile Marsh should have only been running at 68% of biomass maximum. This would have been only a moderate "fertilizer effect" and appears inconsistent with the observations of Lundberg (2008), Figure 6.4, and the marsh conversion described by Day *et al*. 2011, Lundberg *et al*. 2011, Bodker *et al*. 2015, Shaffer *et al*. 2015, Turner *et al*. 2018, and Day *et al*. 2019.

Another way to look to examine the situation is to compare the area of Four Mile Marsh immediately downstream of the effluent distribution pipe (approximately 122 ha, Bodker *et al*. 2015) with the estimated size of the active assimilation zone (Table C.2):

Table C.2 – Estimated active assimilation zone areas compared to receiving wetlands

	Estimated Active Assimilation Zone, ha		Percentage of Four-Mile Marsh (122) ha		Percentage of remaining South Slough Wetlands (3,925 ha)	
Year	**N**	**P**	**N**	**P**	**N**	**P**
2006	52	204	43%	100%	0%	2%
2007	76	281	62%	100%	0%	4%
2008	76	281	62%	100%	0%	4%
2009	94	273	77%	100%	0%	4%
2010	96	298	79%	100%	0%	5%
2011	92	238	75%	100%	0%	3%
2012	98	324	80%	100%	0%	5%
2013	128	359	100%	100%	<1%	6%
2014	132	357	100%	100%	<1%	6%
2015	146	392	100%	100%	1%	7%
2016	143	413	100%	100%	1%	7%
2017	262	619	100%	100%	4%	13%
2018	294	660	100%	100%	4%	14%

As seen in Table C.2, the percentage of the overall South Slough Wetlands (4,047 ha) involved in N assimilation increased from 1% in 2006 to 7% in 2018. For phosphorus, the assimilation area increased from 5% in 2006 to 16% in 2018.

Monitoring locations were established in the UAA based on the assumption that the project area was 10,000 acres (4,047 ha) (UAA, 2005). Consequently, the monitoring locations were spread out to cover that area, and the baseline review done in the UAA was done in the context of that total area.

Review of Table C.2 makes clear that the most important region of the receiving wetland is the section of Four Mile Marsh immediately downstream of the effluent distribution pipe. With the benefit of hindsight, focusing the UAA study in this area, and establishing monitoring locations within the expected bounds of the active assimilation zone, would have been more beneficial to the project.